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Adoption of improved citrus orchard management practices: a micro study from Drujegang growers, Dagana, Bhutan

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Abstract

Background: Citrus ranks top among the agricultural export commodities of Bhutan both in terms of volume and value. However, citrus cultivation practices still remain traditional with very low yield and inferior fruit quality. This study adopted community approach to identify basic components of citrus orchard management. Citrus growers of Drujegang were trained on citrus orchard management and assessed the impact of training on the adoption of management technology and subsequent effect on the yield and household (HH) income for 40 randomly selected individuals.

Results: Statistical results showed significant difference both in terms of adoption of improved orchard management practices ($p = 0.04$) and HH income generation ($p = 0.01$). Adoption of improved management practices increased from 4.54 % (in 2012) to over 16 % (in 2014) with a mean yield increase of 27.5 % (212 kg acre^{-1}) over previous year. Similarly, mean production increased from 5376 (2012) to 11,993 (2014) kg HH^{-1}. Thus, average annual HH income from the sale of citrus increased from Nu. 82,641 (in 2012) to 164,307 (in 2014).

Conclusions: Hands-on training on basic orchard management increased the rate of adoption and resulted in increased yield and production. Huge potential exists in enhancing the livelihood of citrus growers by taking forward the available orchard management technology to growers through appropriate research and extension intervention. Therefore, replication of similar participatory approach at community level is recommended in other parts of the country.

Keywords: Citrus, Orchard management, Drujegang, Bhutan, Technology adoption

Background

"Citrus" is a generic term that refers to wide range of plants under Rutaceae family. In Bhutan, citrus refers exclusively to mandarin (*Citrus reticulata* Blanco), which constitutes more than 95 % of total citrus production in the country [1]. Citrus is a major horticultural crop of Bhutan cultivated over 5048.6 hectares in 17 of the 20 districts. Currently, citrus ranks first both in terms of export volume and value [2]. It is also the main agricultural commodity that earns foreign exchange and provides livelihood to 60 % of rural population [1]. However, the national yield (3.9 tons acre^{-1}) is far below the average yield of Thailand and Taiwan (6 tons acre^{-1}) (http://www.agnet.org/index.php) mainly because of poor technology adoption and traditional system of management [3]. In fact, citrus orchard management remains almost primitive [4] though the market demand for Bhutanese mandarin across the border is almost consistent over the years [5]. Almost all the existing citrus trees are raised from seedlings, which are mostly grown in their own home yard. Citrus trees in the field remain under water stress for almost 8 months in a year besides poor nutrient management [4].

Technology is an important force to increase yield and production in agriculture. The adoption of technology depends on several factors—economic, social, institutional, and policy [6, 7]. The adoption of new

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technology also depends on farmers' need, and any new technology must fit in the complex pattern of agriculture dynamism in which all participate [8]. Assessment of technology and its adoption has become an essential component of research and extension intervention to justify the investments on technology generation and adoption to the funding agencies. Even more attention is currently paid to the assessment of research-extension technology and its transfer process to enhance the transparency, accountability, and effectiveness of the project [9–12].

Several international organizations and researchers adopt different areas of focus for assessing the research technology and its adoption. For example, a CIMMYT method of assessment focuses on study of agricultural change with little attention being paid to process of technology development [12]. On the contrary, ICARDA approach insists on the process of technology generation as adoption where long-term impact depends on the nature of technology [13]. Both methods mentioned above are based on results of sound socio-economic analysis (adaptability, adoptability, and potential impact analysis). Further, evaluation process depends on the stages of implementation of technology adoption studies (ex-post and ex-ante evaluation). The adoption of technology also depends on its perceived characteristics (i.e., subjective preferences toward technology) and relevant past information providing better idea on the speed and rate of adoption [14].

In Bhutan, adaptive research on agriculture started almost six decades back (1962) with the establishment of Center for Agriculture Research and Development in west-central region of Bhutan. Unlike in the past, there is a fair amount of technology and information on citrus orchard management being generated by the research and other development agencies which are based on field problems and opportunities [15, 16]. However, when compared with other cash crops, farmers' practice in citrus orchard management lags behind [4] probably because not much attention is paid to the need and appropriateness of technology and subsequent transfer.

On the other hand, due to poor linkages between research and extension, inappropriate extension approaches have resulted in low adoption of technology. Conventional technology transfer model is a one-way (top-down) approach where growers remain simply a passive recipient of the technology. Farming system research/extension (FRS/E) approach proved advantageous as the process involves growers/end user in whole process of technology generation and transfer. FRS/E is described as an approach that generates technologies for studying existing farming systems and involving technology users. Farmers, especially small growers, are actively involved in planning and evaluation process (http://www.fao.org). Citrus orchard management requires sound understanding of physiology and crop phenological stages that differ with environmental conditions [17, 18]. Appropriate and timely implementation of management activities enhances plant physiological functions with the final outcome of economic efficiency, i.e., in terms of resource use.

Citrus in Bhutan is grown from as low as 300 m above sea level to about 1800 m in diverse agro-ecological conditions, resulting in a huge variation in phenological stages even across a small location. Poor orchard management (esp. pests and diseases) is of the greatest concerns in Bhutanese citrus industry [19]. Chinese fruit fly (*Bactrocera minax* Enderlein) alone cause fruit drop ranging from 35 to 70 % followed by shied bug (*Rhynochocoris poseidon* Kirkaldy) [19]. Other pests such as trunk borer (*Anoplophora versteegi*) and citrus leaf miner (*Phyllonictis citrella*) are also a problem in some areas (Chukha and Dagana). Currently, most orchards are believed to have declined due to citrus greening disease, which is officially known as huanglongbing (HLB) [20]. In Bhutan, citrus HLB disease was first reported in 2003 [21]. The disease is caused by *Candidatus liberibacter asiaticus* which is vectored by Asian citrus psylla (*Diaphorina citri* Kuwayama) [22]. Currently, HLB is presumed to be one of the major causes of citrus decline especially in low lying areas (<1000 masl) [23]. While HLB's role in declining orchards cannot be denied, poor orchard management further made it worse by reducing tree vigor and productive bearing period. Therefore, supply of high health status seedlings is a major focus both for policy makers and researchers.

Appropriate nutrient management is crucial to optimize yield and production. Nutrition programming requires in-depth understanding of plant physiology and phenology [24]. Sound fertilizer recommendation follows scientific studies on the form of fertilizers, fertilization rate, nutrient content, and timing of the application and its placement [25]. Different methods of nutrient application (soil application, foliar application, fertigation) are practiced only in research fields. High-yield, better-quality fruits are obtained only through correct application of appropriate fertilizers in right form and time [26]. Moreover, fertilizer rate depends on soil types [26] and other climatic conditions [27]. Currently, integrated nutrient management [the use of farm yard manure (FYM) and fertilizers to optimize yield and sustain soil health] is recommended in many developing countries including Bhutan [28, 29]. Therefore, this paper evaluates the effectiveness of the research and extension interventions in transferring of technology and assesses gain in yield and household (HH) income using farming system extension approach at community level.

Fig. 1 Map of Bhutan showing study site—Drujegang geog and three Chiwogs (Thangna, Pangna and Pangserpo) under Dagana district

Methods

Site selection

A total of 320 citrus growers from Drujegang geog (26°58′57″ N to 26°59′23″ N and 90°01′53″ E to 90°02′42″ E) comprising three Chiwogs[1] (Pangna, Thangna and Pangserpo) were selected as it represents one of the major citrus growing areas with minimal orchard management technology being adopted (Fig. 1). Most of the citrus orchards are located within the altitude range of 750–1200 masl.

Methodology

Farming system research and extension approach was recommended during annual regional review and planning workshop (2011) held at Research and Development Center, Bajo. Approval was obtained from Council for Renewable Natural Resource Research Bhutan (CoRRB) under Ministry of Agriculture and Forests. Informed consent was obtained from all individual participants, and the letter of undertaking was obtained from Drujegang geog (sub-district) administration. Assessment of farmers' level of knowledge and the yield was conducted initially through semi-structured interview and focus group discussion method. Key management components were identified and appropriate extension interventions were formulated. Growers were imparted with hands-on training on key management components: canopy management, basin preparation, mulching, integrated nutrient management (FYM and fertilizer application), integrated pest management (plant protection chemical application, mechanical control, biological control, etc.), and irrigation and water management.

Fertilizer application was based on soil analysis report published by the Soil Fertility Unit of the National Soil Service Center [26], while fertilizer rate was based on its guide to fertilizer recommendation for citrus (110–220 g Urea, 126–315 g SSP, 170–225 g MoP) tree^{-1}year^{-1} for non-bearing trees and (330–550 g Urea, 315–630 g SSP, 425–595 g MoP) tree^{-1}year^{-1} for bearing trees [28]. Similarly, the use of biopesticide (Azadirachtin 0.15 % ww^{-1}—0.15 ml L^{-1} of water) and chemical pesticides (Dimethoate 30 EC—2 ml liter^{-1} of water and cypermethrin 10 EC—0.5 ml liter^{-1} of water) was recommended as per the citrus production manual (Department of Agriculture, Bhutan).

Data collection

A total of 40 households were randomly sampled and interviewed using semi-structured questionnaire. Each respondents represented a HH and they were segregated into three typologies (small, medium, and large) based on the number of trees in their orchard. The characteristics of the respondents as obtained from interview data were reported in Table 1.

Each component of orchard management practices was initially assigned with appropriate score. Data on the level of adoption before (2012) and after (2014) for each component were collected in the month of August. Corresponding operating cost for each

[1] Administrative unit under geog; usually comprise of few villages.

Table 1 Respondents (citrus growers) with their categories and general description

Characteristics	Small growers ($n = 20$)	Medium growers ($n = 10$)	Large growers ($n = 10$)
Household size (person)	6.3	5.7	5.6
Gender	$m = 9, f = 11$	$m = 7, f = 3$	$m = 8, f = 2$
Labor force (person)	1.3	1.2	1.3
Farm size (acres)	1.8	2.1	2.4
Orchard size (acres)	0.45	1.13	6.3
No. of trees	63 (<100)	(141) 101–200	210 (>201)
Level of technology adoption	Negligible	Low	Low

component was determined, and cost of production was calculated in ngultrum[2] (Nu). Similarly, data on mean yield and annual income were also collected for three consecutive years (2012–2014) during the month of December.

Data analysis

The adoption data before (2012) and after (2014) were compared and presented using descriptive statistics. The effect of management training on technology adoption was calculated as adoption quotient (AQ) as per the following formula and statistically analyzed using Student's t tests assuming equal variance:

$$\mathrm{AQ} = \frac{\text{Sum of the adoption score obtained}}{\text{Maximum possible adoption score}} \times 100.$$

The effect of technology adoption on mean yield (kg acre^{-1}) per HH was determined by gap analysis approach [30]:

$$\mathrm{GY} = \sum_{n=1}^{n} \left(\frac{Y_2 - Y_1}{n} \right),$$

where Y_2 is average yield of the new technology, Y_1 is the yield of the farmers' practice in ith farm, and 'n' is the number of farms. Similarly, the changes in HH income (GI) accrued from increased yield was assessed using the equation

$$\mathrm{GI} = \sum_{n=1}^{n} \left(\frac{I_2 - I_1}{n} \right),$$

where I_2 is the average income of the new technology, I_1 is the income of the farmers' practice in ith farm, and 'n' is the number of farms. The interview data were validated through independent field visits and random crop cuts (yield assessment). Similarly, differences in income before (2012) and after (2014) interventions were tested for statistical significance using repeated-measure t test: two-sample—assuming equal variances USING R [31].

Results and discussion

Farming system extension approach at community level as research and extension intervention on citrus orchard management is first of its kind adopted in Drujegang. After intervention, the adoption of improved management practices increased from 4.54 % (in 2012) to 16.56 % (2014). The total adoption score increased from 296 (in 2012) to 737 (in 2014), and the rate of adoption increased by almost two-and-a-half-fold (2.49) which accounts to more than 12 % rise over base year (2012). This increased rate of adoption has increased the yield and HH income. Adoption rate for 2012 and 2014 differed significantly with $t(14) = 1.7$, $p = 0.04$. The difference in AQ for 2012 (before) and 2014 (after) research-extension intervention for different management components is shown in Table 2.

Different management components received varying levels of adoption rates among the groups. Out of seven improved management practices imparted to the groups, majority of the growers in the groups adopted basin making (total score = 294), and the rate of adoption increased by 38 % followed by FYM application (17 %) and fertilizer application (12 %). On the other hand, application of plant protection chemicals received very poor attention with only 3 % increase followed by tree mulching (3.07 %) and irrigation (7.7 %). The mean yield increased by almost 27.5 % accounting to almost 212 kg acre^{-1}. The highest increase in yield (429.51 kg acre^{-1}) was observed for medium grower category, while large and small growers' category realized similar raise in yield which is 100.79 and 104.9 kg acre^{-1}, respectively.

Similarly, mean HH income also increased by more than double—from Nu. 110.7 thousand in 2012 to 237.15 thousand in 2014. The increase in HH income showed statistically significant difference, $t(73) = 1.66$, $p = 0.03$). Almost all the growers received increased HH income by little over 114 % after research and extension interventions irrespective of their categories (Table 3). Mean

[2] Bhutan currency roughly equivalent to 0.016 US Dollar.

Table 2 Comparison of adoption quotient (AQ) before (2012) and after (2014) research-extension intervention for different management components

Management component	AQ (2012)			AQ (2014)			Rank
	Small	Medium	Large	Small	Medium	Large	
Basin preparation	24	32	45	98	98	98	I
FYM application	18	27	42	51	53	53	II
Fertilizer application	6	42	17	29	27	21	III
Plant protection chemicals	7	5	5	13	8	17	VII
Irrigation	4	3	3	19	22	21	IV
Tree canopy management	0	0	8	7	12	8	V
Mulching	3	2	3	15	18	55	VI

Table 3 Effect of technology adoption on yield and household income

Typology	Mean yield (kg acre^{-1})				Mean HH income (Nu.)			
	Before (2012)	After (2014)	YG	% Increase	Before (2012)	After (2014)	IG	% Increase
Small	802.51	907.41	104.90	13.07	14,800.00	37,306.22	22,506.00	150.07
Medium	891.00	1320.52	429.51	48.21	69,892.10	181,471.34	111,579.00	159.65
Large	612.24	713.03	100.79	16.46	247,504.00	492,669.03	245,165.00	99.05
Mean	768.58	980.32	211.73	27.54	110,732.00	237,148.86	126,417.00	114.17

'YG' and 'IG' refer to yield gap and income gap, respectively

HH production also increased as a result of the increased technology adoption (Fig. 2).

Agriculture research and extension intervention can be crucial in increasing yield and production in mandarin in Bhutan. Training of citrus growers had positive impact on adoption of improved orchard management practices which in turn helped increasing yield and HH income. Different management components received different levels of attention and subsequent adoption. In addition, other factors such as credit facility and established irrigation infrastructure are found precursors to help increased adoption of technology [32] .

Basin preparation is one of the most laborious and daunting tasks among the seven management components identified and implemented. Basin preparation had the highest adoption rate after the training

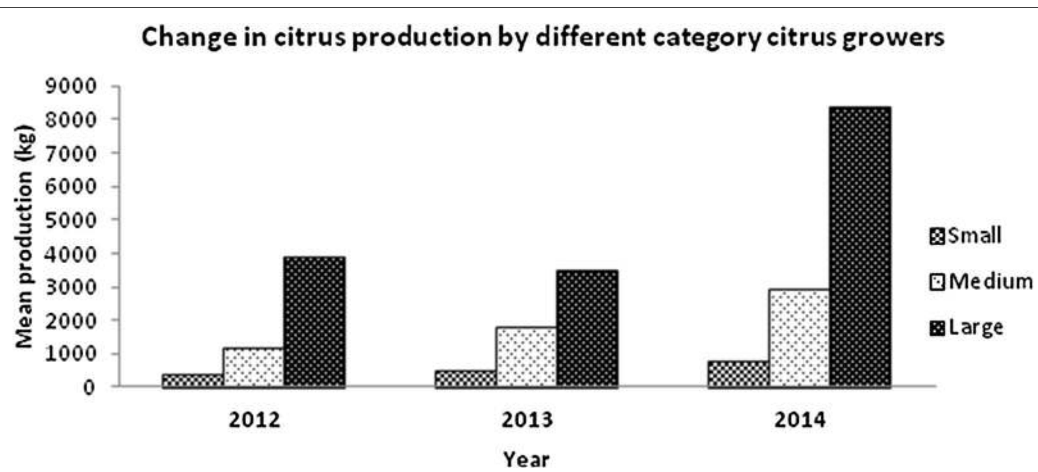

Fig. 2 Production in three consecutive years by grower category

program. This was evident from our independent random field visits. However, the quality of the basin prepared differed from orchard to orchard. This was clearly due to the differences in the farm gradient. The most common basins on the slopes were prepared, raising stone walls on which the soil was leveled. This basin preparation has not only loosened the surface soils but also provided better platform for fertilizer application and irrigation. The hands-on training provided on key orchard management components might have had positive impact on growers' knowledge base, while community mobilization helped resolve the issue of labor constraints.

FYM application is one of the traditional systems of management practiced in other crops from very early days. However, only about 17 % of the growers applied FYM in citrus orchards. Tethering of cattle to the trees is widely practiced to supplement nutrients such as FYM [4]. The incidence of tethering cattle is said to have declined, and application of FYM has increased. This is because tethering cattle around the trees is found to damage basin and compact the soil.

Mulching is another management component adopted by the growers. Prior to the training, mulching was simply default placement of plant debris during weeding. Proper mulching began only after our intervention. Considering the limitation of irrigation in citrus orchard in Bhutan, mulching is perceived as one of the important components to be implemented to conserve soil moisture. Timely removal of the mulch (early May) before the onset of monsoon is found crucial in preventing pest such as trunk borer.

Canopy management is quite new to citrus management in Bhutan although it is being promoted sporadically in other districts (Tsirang and Sarpang). Baseline information collected showed not even a single respondent managed canopy. After the program, 3.6 % of the growers implemented canopy management practices. Further, canopy management practices are complicated by alternate bearing nature as orchards consists of trees (i.e., heterogeneous population) expressing irregular bearing habit and thus adversely affecting the crop yield. In addition, not many growers are confident with this technology as it initially requires identification of individual trees expressing alternate bearing habit.

Other components such as spraying of plant protection chemicals and application of fertilizers are on the rise following the training in 2012 although chemical application is affected by the religious sentiments. Only few sections of the growers picked up the use of chemicals. The application of chemical fertilizers and fungicides faced resistance as farmers opined that it kills insects besides deteriorating soil health.

Irrigation is an issue to many citrus growers. Adoption would be difficult in the absence of irrigation water source and infrastructure. Moreover, most of the orchards are not only located in slopes of varying gradient but also away from water source. Water stress in citrus reduces the yield considerably (30 %) [33]. Under Drujegang condition, the driest months of the year (January, February and March) coincides with flowering stage while delay in onset of monsoon (dry period—April through May) and rising temperature (28–36 °C) coincide with fruit cell division stage. Physiological fruit drop (June drop) is severe in citrus orchards in Drujegang areas especially when untimely rainfall occurs. The growers were imparted with the training on the importance of water in tree physiological process and their critical requirement during certain phonological stages. Many small and medium category growers use drinking water for hand irrigating their orchards during critical stages (flower initiation, fruit cell division, and cell development) as deficit affects the yield and quality adversely to greater extent. Mulching is another technology that farmers adopted to retain soil moisture in situ. Majority of large growers also used hand watering due to lack of proper irrigation infrastructure.

The training conducted on orchard management had positive impact on the overall rate of adoption, increasing yield, and HH income although the rate of adoption was influenced by many independent factors (like nature of technology, belief, and availability of infrastructure). Average annual HH income increased almost two-fold (Nu. 82,641 in 2012 to Nu. 164,308 in 2014). In 2013, the average HH income increased by 12 % only. This is because of canopy management and alternate bearing habit of the mandarin, which usually reduces the yield and production in the corresponding year. Further, the year also coincided with lean year of bearing. Alternate bearing is one of the constraints with local and many other commercial citrus varieties [34]. Studies have shown that management operations (canopy, fertilizer, and irrigation) can address this problem to a great extent although the presence of fruit alters genes expression (floral promoter) that affects flushing and flowering [35]. Still, there is an opportunity for Bhutanese citrus growers to stabilize yield through better management practices.

Although the categories of growers were based on the number of trees, some of the small growers group received higher income than medium group because they had more number of bearing trees. The medium group who received lower income had younger trees (10–15 years old) with low yield or trees that have just fruited. Similar observation was made in large category growers where they received lesser income than medium category growers. Replacement of declined trees with un-grafted poor quality seedlings with long juvenile period is one of the main reasons. Few individuals in medium and large categories who received lower income had their orchards in decline. Most of the orchards in severe decline that were below altitudes of 1000 masl are suspected with HLB infection as trees at Pangserpo showed characteristic HLB symptoms, while the presence of Asian Citrus Psyllids (*Diaphorina citri*) was reported in adjoining district of Sarpang. Nevertheless, almost all the declining orchards were poorly managed—heavily infested with trunk borer and parasitic weeds (*Loranthus* sp.).

Conclusions

Hands-on training on orchard management at Drujegang had positive impact on adoption of management practices, yield, and HH income. Majority of growers irrespective of their categories received higher yield and income after they started orchard management practices. One of the constraints in citrus orchards management was lack of know-how among growers besides shortage of farm labor. Lack of irrigation and erratic rainfall affect yield and production. Religious sentiments also limit spraying of plant protection chemicals and fertilizer application except for a small section of the community. Although increase in adoption of management practices and impact on HH income cannot be denied, constant monitoring and follow-up by research and extension personnel may be necessary for a few more years. There is a huge potential to increase yield and production in Bhutan, by improving few components of orchard management. Therefore, replication of similar community level, participatory approach of research-extension intervention (farming system extension approach) may be beneficial to take the technology at shelf to farmers' field and to enhance the livelihood of rural people.

Abbreviations

AQ: adoption quotient; FYM: farm yard manure; GI: gap in income; GY: gap in yield; HH: household; HLB: huanglongbing; I_1: initial income (before intervention); I_2: final income (after intervention); Masl: meters above sea level; MoP: muriate of potash; Nu: ngultrum; SSP: single superphosphate; Y_1: initial yield (before intervention); Y_2: final yield (after intervention).

Authors' contributions

KD conceptualized, analyzed, and interpreted data and drafted the manuscript. SC, SDD, and BBT have been involved in conducting field works, training of growers, data collection, supervision, field verification and constant monitoring. L revised the manuscript critically for intellectual content. All the authors agree to be accountable for accuracy and content of the work. All the authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests to declare (both financial and non-financial).

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