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Does empowerment influence women's willingness to pay for integrated pest management practices? A case study of mango growers in Zambia

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ABSTRACT

Mango is an important fruit crop in sub-Saharan Africa (SSA), including Zambia, due to its nutritional value and contribution to food security. However, the invasive and mango-infesting fruit fly is a significant constraint in mango production. Therefore, *icipe* and partners developed and disseminated the integrated pest management package to curb this menace. The current study uses household-level data from 325 smallholder mango-growing households from selected regions in Zambia to evaluate how empowerment affects women's willingness to pay (WTP) for an Integrated Pest Management (IPM) package for the suppression of mango-infesting fruit flies. We used a double-bounded contingent valuation model to determine the association between Project-Level Women's Empowerment in Agriculture Index (pro-WEAI), other social-economics factors, and WTP. The results show that women's empowerment status positively and significantly increased the likelihood of considering a higher bid for the IPM package. Other factors affecting women's WTP for the IPM package were women's education level, access to extension services, non-farm occupation, and household income from mangoes, with a positive and significant influence on their WTP. However, distance to the input market, perception of the effectiveness of current fruit fly management methods, and level of mango loss due to fruit flies negatively influenced WTP for the IPM package. Empowering women, especially increasing their access to extension services, and providing livelihood alternatives would increase their uptake of pest management technologies. Efforts to lower women's domestic workloads, boost their finances, and sensitize others in the community to promote women's freedom of movement would be vital to empowering women hence increasing their uptake of new agricultural innovations.

Introduction

Mango (*Mangifera indica L*) (Anacardiaceae) is an important fruit crop in sub-Saharan Africa (SSA). In Zambia, mango is the most common fruit in terms of production and consumption (Siafunda, 2019). Mango is particularly important to women and children due to their nutritional value and contribution to food security (Chipili, 2015). Despite the critical role played by mangoes in SSA, potential mango productivity is yet to be achieved (Siafunda, 2019). The most significant productivity gap is attributed to pests, particularly the oriental fruit flies, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae) (Vayssières et al., 2005). Most farmers depend on synthetic chemical insecticides as a primary means of controlling the fruit flies, which is neither sustainable nor effective as the pest has developed resistance to most used classes of insecticides (Van Timmeren et al., 2019; Wang et al., 2013). Thus, smallholder farmers risk substantial economic losses when using those pesticides. Furthermore, pesticides are associated with high hidden and external costs, affecting human health and causing environmental pollution (Bourguet & Guillemaud, 2016).

To conquer the challenges associated with synthetic pesticides, researchers recommend adopting environmentally friendly techniques for pests, such as Integrated Pest Management (IPM) technologies (Chowdhury et al., 2019; Wyckhuys et al., 2022). IPM involves a coordinated integration of multiple complementary methods to suppress pests safely, cost-effectively, and eco-friendly manner (Ehler, 2006; Kogan, 1998). The International Centre of Insect Physiology and Ecology (*icipe)* and its partners have, in the last two decades, developed, disseminated, and validated an IPM package for the management of native and invasive mango-infesting fruit flies. The package was successfully tested and piloted among horticultural-producing households, including mango growers in sub-Saharan Africa (Midingoyi et al., 2019; Wangithi et al., 2021).

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The IPM package consists of different tactics that target different stages of fruit flies. These include; (1) the male annihilation technique (MAT) which uses female pheromones (methyl eugenol) mixed with insecticides to attract and kill adult male fruit flies (Abbas et al., 2021), (2) the protein bait spray technique which mixes proteinaceous food baits with a toxic dose of insecticide that attracts and kill the female adult fruit flies (Ekesi & Tanga, 2016), (3) fungus-based bio-pesticide which attracts and contaminates the adult fruit fly with a pathogen and then the infected individual escapes to potentially transmit the fungus to other fruit flies before being killed by the fungus (Marri et al., 2018), (4) the release of exotic efficient parasitoids which feed on the fruit fly eggs and larvae thus reducing their population (Birke et al., 2013), and (5) orchard sanitation using *augmentoria* which sequester fruit flies while conserving and augmenting parasitoids population (Ekesi et al., 2007). The Orchard sanitation involves the farmer collecting infected mangoes and safely disposing of them in the *augmentoria,* which traps the fruit flies, thus reducing their population.

Previous socioeconomics studies following the implementation of the fruit fly IPM strategy in East and West Africa have proved that this approach is effective and eco-friendly (Kibira et al., 2015; Midingoyi et al., 2019; Muriithi et al., 2020). The IPM strategy has helped smallholder mango growers maximize profits by improving the yield and quality of produced mango while at the same time reducing or eliminating the use of synthetic insecticides. By reducing the use of insecticides, implementing the IPM strategies also confers a health benefit to the mango growers, farmworkers, consumers, and the environment at large (Kibira et al., 2015; Muriithi et al., 2016).

The outstanding success in East Africa motivated the expansion of the IPM strategy to other African regions. *Icipe,* jointly with partners in Zambia, Malawi, Mozambique, and Zimbabwe, aims to promote the wide-scale adoption of IPM strategies to benefit smallholder mango growers through the second phase of the Cultivate Africa's Future Fund (CultiAF-2) program in the Southern African region. The four-year program (2019–2022) endeavors to create awareness of the use of the IPM strategies in the major mango-growing regions in Southern Africa and also train farmers to enhance the uptake of the strategies.

The CultiAF-2 program focuses on improving food security, resilience, and gender equality across Eastern and Southern Africa. Women have been reported to benefit less from agricultural interventions than men and sometimes become worse off due to the interventions in developing countries (Quisumbing & Pandolfelli, 2010). For instance, Fischer and Qaim (2012) in investigating the gender implications of farmer groups that increased the commercialization of bananas in Kenya found that men took control over bananas which had been in the past regarded as a woman's crop. Gichungi et al. (2021) in assessing the effect of the adoption of IPM strategies intended to increase farmers' income from mangoes in Kenya on gender roles, found that women lost control over production and marketing decision-making to men. The negative impact on women is due to gender gaps caused by unequal access to and control over productive resources (Fletschner & Kenney, 2014). The unequal access could be attributed to societal norms that hinder women's rights over resources, among other constraints (Meinzen-Dick et al., 2011; Quisumbing et al., 2015). Moreover, women in developing countries have generally lower levels of education than men (Roudi-Fahimi & Moghadam, 2006; Shabaya & Konadu-Agyemang, 2004) and rarely attend training programs that aim to improve their knowledge of agricultural innovations (Bergman Lodin et al., 2019). Hence, IPM interventions risk benefiting men and women farmers unequally if project partners and implementing institutions need to be made aware of the need to develop gender-responsive interventions targeting both men and women.

Gender researchers consider enhancing women's empowerment a critical pathway for increasing women's access to vital agricultural resources, which they can use to access and pay for agricultural technologies (Ashby et al., 2009; Quisumbing et al., 2014). Gender gaps in resource ownership are significant in households where women are not empowered (United Nations (UN), 2009). Indeed, disempowered women have less participation in marketing agricultural products and control over income from agricultural produce (Fischer & Qaim, 2012a) thus lacking income that can be used to pay for agricultural innovations. In addition to their involvement in agricultural production, women are burdened with domestic duties and caregiving activities and less involved in off-farm income-generating activities, contributing to disempowerment (Farnworth & Colverson, 2016). The constrained freedom of movement due to domestic chores and cultural norms may also limit their access to agricultural information. Yet, they need proper knowledge to inform their decisions on whether and how much to pay for improved agricultural technologies (Bergman Lodin et al., 2019).

Despite women's empowerment being considered vital in ensuring women's access to and benefits from agricultural interventions, there is a gap in research analyzing how women's empowerment affects their access to and willingness to pay for agricultural interventions to support mango production in Zambia. This study aims to fill the gap with data from selected smallholder rural mango farmers from Zambia to examine how women's empowerment influences their willingness to pay for the eco-friendly IPM package to manage mango-infesting fruit flies. The findings will inform project interventions (and potential sellers of the IPM components) that aim to ensure that both men and women have access to and benefit from the IPM package for wide-scale adoption and impact.

Measurement of women's empowerment and its effects on the adoption of agricultural technology

Empowerment is commonly defined as the process of acquiring the power to make strategic life choices in a context in which power was previously denied (Johnson et al., 2017; Kabeer, 1999, 2005; Malapit et al., 2019). Past studies (e.g., Banerjee et al., 2020; Chowdhury & Chowdhury, 2011; Jeckoniah & Mdoe, 2012) have used diverse measurements or proxies for women's empowerment, such as household decision-making, asset control and ownership, education, and labour force participation. These varieties of methods contribute to difficulty in understanding and tracking changes in women's empowerment (Doss et al., 2020) and ignore the multidimensional nature of empowerment by considering only one or two aspects of women's empowerment (Johnson et al., 2017). The need to measure empowerment and to track changes in empowerment over time with a validated and standardized tool that allows researchers to compare results across different contexts more accurately became evident (Doss et al., 2020).

In 2012, the International Food Policy Research Institute (IFPRI), Oxford Poverty and Human Development Initiative (OPHDI), and the United States Agency for International Development (USAID) developed the Women's Empowerment in Agriculture Index (WEAI) (Alkire et al., 2013). The index is an aggregate made up of two components, the five domains of empowerment (5DE) and the gender parity index (GPI) (Alkire et al., 2013; Malapit et al., 2015). The 5DE summarizes women's empowerment in five domains: production, resources, income, leadership, and time, measured by ten indicators and has a 90 % weight in the index calculation. The GPI, on the other hand, is the relative empowerment between men and women as primary decision-makers within a household and carries a 10 % weight. The initial index was calculated for the country or regional level and is less suitable for tracking short-time and project-specific changes in empowerment.

In the recent past, subsequent variants of the WEAI have been developed. In 2015, IFPRI and the OPHI WEAI teams developed the Abbreviated Women's Empowerment in Agriculture Index (A-WEAI) in response to concerns raised on the length of interviews and difficulty in implementing some modules of the WEAI in household interviews (Malapit et al., 2015; Quisumbing et al., 2022). The A-WEAI condenses the WEAI into six indicators but retains the five domains. The WEAI and AWEAI are designed for population-based surveys, not for monitoring and evaluating a project's impact on women's empowerment

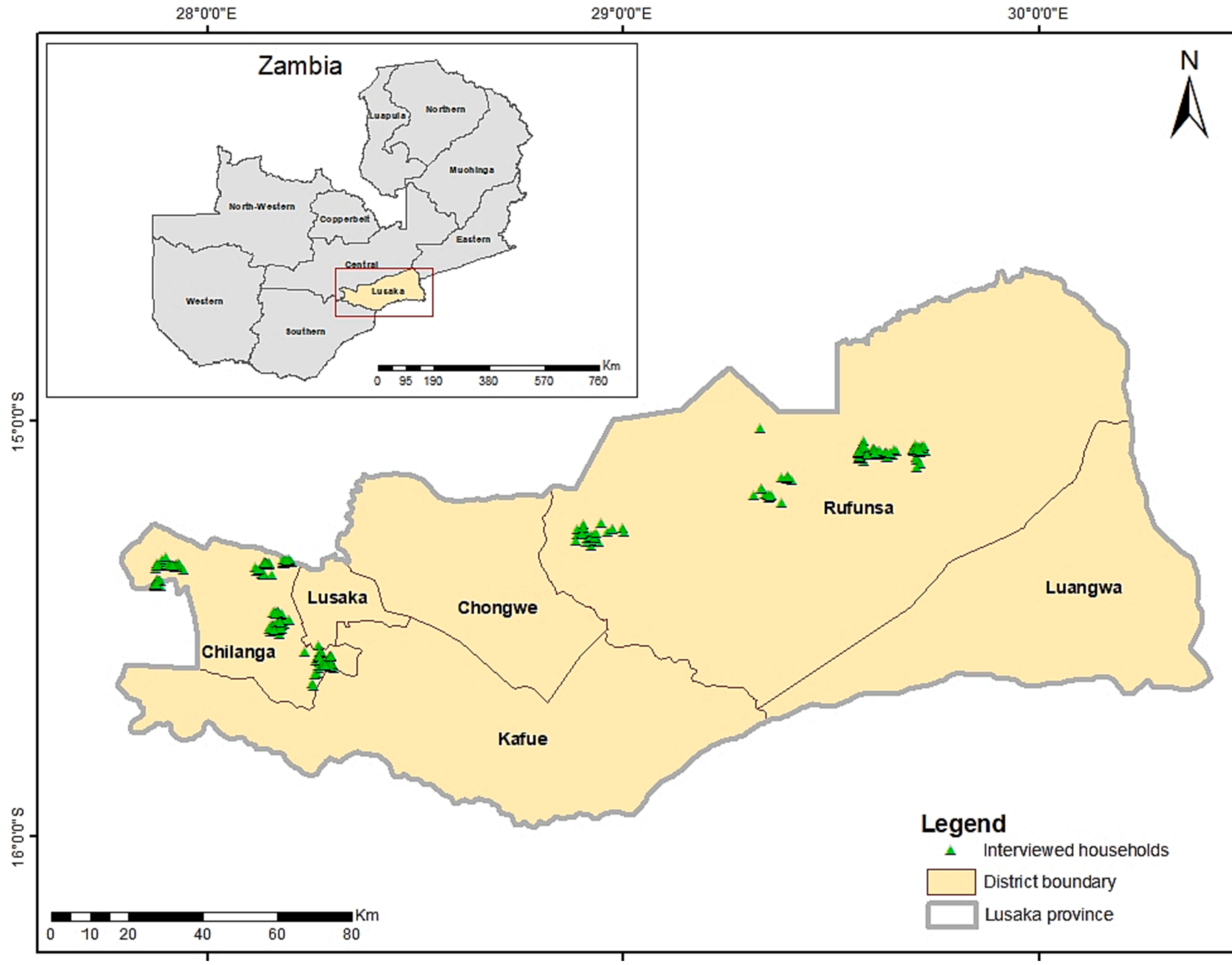

Fig. 1. Study area in Lusaka Province, Zambia.

(Quisumbing et al., 2022). To meet the need for monitoring projects and assessing their impact, the WEAI was modified to the project-level women empowerment in agriculture index (pro-WEAI). The pro-WEAI consists of 12 indicators grouped into three domains and the GPI (Malapit et al., 2019). The pro-WEAI indicators are refined to be more sensitive and responsive to project effects within a typical time frame of project implementation (Malapit et al., 2019; Quisumbing et al., 2022). The pro-WEAI also includes additional indicators which measure freedom of movement, relations within a household, attitudes toward domestic violence, and self-efficacy, which are important indicators of empowerment (Martinez et al., 2018; Malapit et al., 2019; Yount et al., 2019; Quisumbing et al., 2022). According to Doss et al. (2020), 232 organizations across 58 countries had used some versions of the WEAI tool by April 2022. This study employs the proWEAI to measure women's empowerment. Annex 1 provides detailed descriptions of the pro-WEAI.

Past studies using different versions of WEAI tools in assessing the effect of women's empowerment on the adoption of agricultural technology have found that women farmers are less empowered than their male counterparts and are less likely to adopt improved agricultural technology. For instance, Oyawole et al. (2020) employed the A-WEAI to measure women's empowerment and assessed its effect on the adoption of climate-smart agriculture (CSA) practices in Nigeria. The results showed that compared to women, men plot managers are significantly more empowered in four of the five domains of the A-WEAI: production, resources, income, and leadership. Though the multivariate probit model showed no evidence of a relationship between the empowerment score and the adoption of other CSA practices, the empowerment gap between men and women negatively influenced the adoption of agroforestry. Ragasa (2012), in reviewing empirical studies and case studies from 35 organizations, consistently found that women have much slower observed adoption rates of a wide range of technologies than men due to differentiated access to inputs and services. Mponela et al. (2021) found that an increase in the WEAI score led to increased adoption of integrated soil fertility management in Malawi.

This study contributes to the existing literature in four main ways. Firstly, to our knowledge, this is the first study to assess how women's empowerment influences their willingness to pay for agricultural innovations such as fruit fly IPM in Zambia. Secondly, this study contributes to the ongoing discussion regarding using standardized tools such as the pro-WEAI to inform the implementation of sustainable agricultural innovations. Thirdly, the study contributes to the gap in the literature on gender and mango production. Finally, the study also provides insights to policymakers on reducing the gender gap for enhanced adoption and sustainable impact of agricultural technologies, in this case, fruit flies IPM.

Methods

Study area and data collection

The data utilized in this study was collected from smallholder mango growers from Lusaka province in Zambia (Fig. 1). The study area and the sample of mango-growing households were selected using a two-stage sampling technique. First, two districts (Rufunsa and Chilanga) in the leading mango production areas in Lusaka province were purposefully selected as the study and project benchmark sites, where a census of mango-growing households was carried out with the help of the national project partners. In the second stage, a sample within the targeted beneficiaries' sampling frame was randomly selected for the interviews.

This study relies on two questionnaires administered in two rounds of data collection. During the first round, in November 2019, a questionnaire was administered which included general questions that focused on household demographic characteristics, mango production, and marketing, knowledge, attitude, and management of mango pests, including fruit flies, awareness, and willingness to pay for fruit fly IPM, institutional factors, and other contextual variables. The interviews in the first round targeted the household head or spouse. During the second round, the standard pro-WEAI questionnaire developed by Malapit et al. (2019) was utilized. The survey was conducted among the same households interviewed during the first round but targeted primary male and female household members. The pro-WEAI survey was conducted in February and March 2021. Extensive training of enumerators was conducted before commencing the surveys, and questionnaires were pre-tested to ensure accuracy of the collected data. Three hundred and twenty-five (325) households were interviewed during the first round. In the second round, 513 respondents from the 325 households (185 men and 206 women from male-headed (dual) households, and 122 women from female-headed households) were interviewed using the pro-WEAI individual questionnaire. In 185 dual households, the primary male and female decision-makers were interviewed, while in 21 similar households, only the primary female decision-maker was interviewed. Household heads and their spouses were interviewed concurrently, where applicable, by a male and female enumerator, respectively. The data collection exercise was conducted by enumerators who could speak the local language and used the CSPro entry android application to record the responses. This study utilizes data from the two rounds of surveys.

Ethical consideration

Approvals and research permits were obtained from the *icipe* and the Zambian government before the data collection. The household survey participants consented before being allowed to participate in the study voluntarily. We promised to keep the anonymity of the responses and personal details of the participants. Due to the risk posed by the COVID-19 pandemic, we followed the COVID-19 control measures/protocols set by the Zambian government, such as maintaining distance, washing/sanitizing hands, and wearing masks.

Data analysis

Measurement of women empowerment

We employed pro-WEAI to measure women empowerment, which is a weighted mean of two sub-indices; the three dimensions score (3DE) which carries the weight of 0.9, and the gender parity index (GPI) which carries the weight of 0.1 (Malapit et al., 2019). The 3DE score has 12 indicators fitted in the three dimensions (1) Intrinsic agency's indicators are; autonomy in income, self-efficacy, attitudes about domestic violence, and respect among household members, (2) instrumental agency's indicators are; input into productive decisions, ownership of land and other assets, access to and decisions on financial services, control over income, work balance and visiting important locations (3) collective agency's indicators are; group membership and membership in influential groups. Respondents were categorized as adequate (=1) or inadequate (=0) for each indicator based on predetermined thresholds. To develop the pro-WEAI score, we calculated (1) Each respondent's 3DE score by summing the score in all the 12 indicators (2) Each respondent's empowerment status categorized as empowered (=1) if a respondent achieved adequacy at least 9 of the 12 indicators and as unempowered (=0) otherwise, (3) the gender parity status of the DHHs classified as "achieved gender parity (=1)" if the woman in the respective housed is empowered or their 3DE score is at least as high as their male partner and "0" otherwise. The table in Annex 1 gives a detailed description of the indicators used and the predetermined threshold of achieving adequacy in each indicator as adopted by Malapit et al. (2019).

Empirical analysis

We employed a double-bounded dichotomous choice contingent valuation method (CVM) (Hanemann et al., 1991) to determine the effect of women's empowerment on their willingness to pay (WTP) for the fruit fly IPM strategies. In this approach, an individual is presented with two price offers/bids, where the second one is conditional on the response of the first bid or offer. If an individual agrees to pay for the first bid, the second offer is increased by a premium. On the other hand, if they decline the first bid, the second bid is lowered by a discount. The follow-up questions (or second bid) provide more information about an individual's WTP (Hanemann et al., 1991), increasing this approach's effectiveness in determining the WTP estimates of the IPM strategies. Past studies underscore this advantage for the double-bounded CV over the single- and multiple-bounded approaches. The single-bounded CV approach lacks follow-up questions, leading to less efficient WTP estimates (Hanemann et al., 1991; Koss & Khawaja, 2001), while multiple-bounded estimates are inclined to potential bias that may occur in design and response influenced by the multiple bids (Whitehead, 2002).

Following the above approach to elicit the WTP, pictures containing *icipe*'s IPM strategies for controlling mango fruit flies were shown to the respondents. The importance of IPM compared to other fruit fly management strategies was carefully explained. The first question asked respondents if they were WTP for the IPM strategies without quoting any cost; if the respondent declined, the subsequent questions were not asked. Respondents who said yes to the first question were asked if they were willing to pay for the IPM strategies at ZWM 40 (~$2.85) per mango tree per year; this is a price for a standard IPM package computed based on previous studies conducted in East Africa (Muriithi et al., 2016). If the respondent said "no" to the first bid, the second bid was randomly decreased by either 15 %, 30 %, 45 %, or 60 %. For those who said "yes," the initial bid was increased by either 15 %, 30 %, 45 %, or 60 %, and asked if the respondent was still willing to pay for it. The enumerator picked the premium or discount randomly after an individual agreed or declined to pay for the first bid respectively.

Therefore, the responses for the second bid took the form of "yes" or "no," meaning that the respondents agreed with the first bid but rejected the second higher bid, "yes," "yes," implying that the respondents agreed with both the first and second higher bid, "no" "yes" where the respondent declined the first bid but accepted the second lower bid, and "no" "no" where the respondent declined both the first and the second lower bid. The probabilities of these outcomes are denoted as π^{yn}, π^{yy}, π^{ny}, and π^{nn}, respectively, which are functions of the initial bid 1 and a higher or lower bid 2.

These probabilities suggest four possible outcomes: the first is to reject both bids if an individual WTP for the IPM is lower than the two offers. The second is to reject the first offer if an individual WTP for IPM is lower than the first offer but higher or equal to the second offer. The third outcome is to accept the first bid if the individual WTP for the IPM strategies falls between the bids. The fourth outcome is to accept both bids implying that the individual WTP for the IPM strategies falls above the highest bid.

The outcome can be expressed empirically as shown in Equations (1)-(4) below:

$$\pi^{nn}\left(\beta_i^1;\beta_i^2\right) = p(\beta_i^1 \geq maxWTP \; and \; \beta_i^2 \geq maxWTP) = G(\beta_i^2;\theta) \tag{1}$$

Table 1
Descriptive statistics for mango-growing households.

Variables	Women (DHHs + FHHs)		Women in DHHs		Women in FHHs		Men in DHHs	
	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
Household characteristics								
Women Empowerment (1 = Empowered, 0 = Not Empowered)	0.61	0.04	0.59	0.06	0.61	0.04	0.56	0.04
Household type (DHHs = 1, FHHs = 0)	0.37	0.03						
income from mango production (ZMW)	5576.30	982.48	3939.18	1469.56	6555.88	1297.52	6386.79	1532.88
Tropical livestock unit (TLU)	1.34	0.19	1.86	0.38	1.03	0.19	1.64	0.25
Household size (number)	5.08	0.16	5.66	0.24	4.73	0.20	5.28	0.20
Land cultivated (Ha)	2.86	0.26	3.49	0.56	2.49	0.23	3.21	0.35
Improved mango variety (1 = Yes, 0 = Otherwise)	0.06	0.02	0.07	0.03	0.06	0.02	0.05	0.02
Respondent characteristics								
Perceived damage by mango fruit fly								
No damage (1 = Yes, 0 = otherwise)	0.37	0.03	0.37	0.06	0.38	0.04	0.45	0.04
Low (1 = Yes, 0 = Otherwise)	0.26	0.03	0.30	0.05	0.23	0.04	0.26	0.04
High (1 = Yes, 0 = Otherwise)	0.30	0.03	0.26	0.05	0.32	0.04	0.22	0.04
Perceived effectiveness of current fruit fly control method (1 = effective, 0 = otherwise)	0.22	0.03	0.16	0.04	0.25	0.04	0.18	0.03
Respondent education (years)	7.02	0.29	7.55	0.43	6.70	0.39	7.36	0.35
Respondent age (years)	57.42	1.03	53.34	1.65	59.85	1.27	47.15	1.28
Respondent Occupation (1 = non-farm income, 0 = Otherwise)	0.17	0.03	0.10	0.03	0.22	0.04	0.16	0.03
Institutional factors								
Extension services (1 = accessed, 0 = otherwise)	0.75	0.03	0.79	0.05	0.73	0.04	0.82	0.03
Distance to the source of input (walking minutes)	127.18	13.16	126.07	23.47	127.84	15.73	144.11	17.97
Number of observations	195		73		122		130	

Note: HH represents household. *Source:* Baseline survey data; Exchange rate during the survey was 1 US$=ZMW 18.

$$\pi^{ny}(\beta_i^1, \beta_i^2) = P(\beta_i^1 \geq maxWTP \geq \beta_i^2) = G(\beta_i^1;\theta) - G(\beta_i^2;\theta) \quad (2)$$

$$\pi^{yn}(\beta_i^1;\beta_i^2) = P(\beta_i^1 \leq maxWTP \leq \beta_i^2) = G(\beta_I^2;\theta) - G(\beta_I^1;\theta) \quad (3)$$

$$\pi^{yy}(\beta_i^1, \beta_i^2) = P(\beta_i^1 \leq maxWTP\, and\, \beta_i^2 \leq maxWTP) = 1 - G(\beta_i^2;\theta) \quad (4)$$

where max *WTP* is the maximum offer an individual is willing to pay for fruit fly IPM, while β_i are the bids used for the i^{th} respondent, and *N* denotes the number of respondents. From the four equations above, we estimated a log-likelihood function for the double dichotomous model as illustrated in Eqn. (5) below.

$$\ln L(\theta) = \sum_{I=1}^{N}\{d_i^{nn} ln\pi^{nn}(\beta_i^1,\beta_i^2) + d_i^{ny} ln\pi^{ny}(\beta_i^1,\beta_i^2) + d_i^{yn} ln\pi^{yn}(\beta_i^1,\beta_i^2) + d_i^{yy} ln\pi^{yy}(\beta_i^1,\beta_i^2)\} \quad (5)$$

where d_i^{nn}, d_i^{ny}, d_i^{yn}, and d_i^{yy} denote binary-valued indicator variables and the formulas for the corresponding response probabilities in Eqs. (1)–(4).

Statistical modeling of the effect of women's empowerment on WTP for IPM package for suppression of mango fruit flies

The dichotomous choice CVM is based on the premises of utility maximization theory, where an individual will be willing to pay more if the expected utility is commensurate with the amount paid on the condition of other constraints. Therefore, the probability that the respondent will pay for the IPM package at the bid offered (β_i) is expressed as a function of women's empowerment and other social-economic characteristics, as illustrated in Eqn. (6). We included both dual-headed and female-headed households in the analysis.

$$\pi^y(B_i, \chi_i) = \pi^y(v) \quad (6)$$

where *v* is a linear function showing how women's empowerment and other social-economic characteristics influence the probability that the respondent will say "yes" to the bid offered, as shown in Eqn (7).

$$v = \alpha - \sigma B_i + \rho 3DE_i + \lambda \chi_i + \varepsilon_i \quad (7)$$

where $3DE_i$ denotes the three domains of empowerment score for household *i*, while ρ is the coefficient showing the effect of the $3DE_i$ the score has on the respondent's WTP for the IPM package. χ_i denotes households and individual characteristics that are likely to influence WTP. These include demographic characteristics (respondent's age, education, occupation, type of household, and household size), resources (income from mango production, livestock ownership in tropical livestock units (TLU), size of land cultivated, mango varieties produced by a household), mango production management (perceived level of fruit fly damage, perceived effectiveness of current mango fruit fly management practices), and access to extension services and mango production inputs. λ is a matrix of the coefficient showing the correlation of the households and individual characteristics to the respondent's WTP, while ε_i represents the unobservable factors influencing WTP.

Equation (8) shows how each of the 12 pro-WEAI indicators affects WTP, denoted by $ProWEAI_{j_i}$ showing indicator *j* for household *i*. We estimated 12 equations for each indicator and other independent variables as pro-WEAI indicators are likely to be correlated with each other.

$$v = \alpha - \sigma B_i + \rho ProWEAI_{j_i} + \lambda \chi_i + \varepsilon_i \quad (8)$$

Results and discussion

Descriptive statistics

A total of 328 respondents from mango-growing households were interviewed using the semi-structured household questionnaire in the first round of interviews. However, three households could not be matched with the second round of interviews therefore they were dropped from the analysis. Among those interviewed, 60 % were female respondents, of which 37 % were from dual households while the rest were from female-headed households. Table 1 presents summary statistics of selected farmers and farm characteristics of the sampled respondents that are expected to influence willingness to pay for a fruit fly suppressing IPM package. The selection of the variables is guided by past literature on the adoption of agricultural technologies (e.g. Fadare et al., 2014; Fadeyi et al., 2022; Gebrezgabher et al., 2015; Kinyangi, 2014;

Table 2
Pro-WEAI estimates.

Indicator	Women in Dual HHs	Men in Dual HHs	Women in FHHs
Number of observations	206	185	122
3DE score	0.81	0.89	0.85
Disempowerment score (1 – 3DE)	0.19	0.11	0.15
% Achieving empowerment	0.57	0.74	0.61
% Not achieving empowerment	0.43	0.26	0.39
Mean 3DE score for not yet empowered	0.56	0.60	0.61
Mean disempowerment score (1 – 3DE)	0.44	0.4	0.39
Gender Parity Index (GPI)	0.90		
Number of dual-adult households	185		
% Achieving gender parity	0.63		
% Not achieving gender parity	0.37		
Average empowerment gap	0.27		
Pro-WEAI score	0.82		

Source: Pro-WEAI survey data.

Shita et al., 2018) as well as the study context. These are broadly classified into respondents' characteristics, farm characteristics, and institutional and financial variables.

On average, farmers generated ZMW 5891(~US$331) per annum from mango farming which was estimated by the respondents to be 22 % of the household's annual income. The total land size cultivated each year was about 3 ha. Less than 10 % of the surveyed households grew improved mango varieties such as Apple, Kent, Ngowe, Tommy Atkins, and Van dyke. More women (30 %) than men (22 %) felt that the level of damage caused by mango fruit flies was high, with only about 20 % of respondents perceiving the current fruit fly management strategies to be effective. Both male and female respondents had an average of 7 years of education. Slightly more women than men had off-farm income-generating activities. About 78 % of respondents had access to extension services, with more men accessing extension services compared to women.

Three-dimension empowerment score (3DE) and Gender parity index (GPI)

A total of 513 individual respondents were interviewed, out of which 40 % were women in dual households, 36 % were men in dual households (DHHs), and the rest were women in female-headed households (FHHs). The pro-WEAI analysis results are presented in Table 2. The aggregate pro-WEAI score for women in dual households is 0.82. The score was calculated by weighting the GPI score, 0.90, and women's 3DE score 0.81, at 0.1 and 0.9 weights, respectively.

The results further indicate that 43 % of women in dual households are disempowered, in comparison to only 26 % of men in the same households. A person is considered disempowered if they have not achieved adequacy in 9 or more indicators or have a pro-WEAI score below 0.75. Among the disempowered women, the average adequacy score is 0.56 which was slightly lower than the disempowered men's score (0.60). These results align with most studies comparing women and men empowerment using pro-WEAI (e.g see, Crookston et al., 2021; Kumar et al., 2021; Malapit et al., 2019) which found that more women than men are disempowered in rural households and the score for disempowered women is lower than their male counterparts.

In households where both the primary male and female decision-makers were interviewed (n = 185), only 63 % achieved gender parity. The average empowerment gap between men and women in dual households was 0.27. Tankari (2018) in assessing how gender parity affects the adoption of organic fertilizer technology in Niger farm households using the WEAI approach, found that a high GPI had a negative impact on technology adoption.

Women in female-headed households' adequacy score are 0.85 which is higher than women in dual households' score but lower than the men's score. About 40 % of women in female-headed households are disempowered with an average adequacy score of 0.61. These findings are similar to Malapit et al. (2019) who measured pro-WEAI across five projects and found that women in FHHs are more empowered than women in DHHs. This could be explained by the fact that women are the primary decision-makers in female-headed households.

Fig. 2 shows a comparison of the number of inadequacies among men and women. About 25 % of female respondents in female-headed households were inadequate in three indicators, 26 % of men in dual households were inadequate in two indicators, and 21 % of women in female-headed households were inadequate in three indicators. Overall, women in dual households had the highest number of inadequacies compared to men in dual households and women in female-headed households. Similarly, more women than men are disempowered and have more inadequacies than men on average.

Table 3 shows the uncensored and censored headcount ratio for the 12 indicators. The uncensored head-count ratio represents the percentage of respondents who are disempowered in a given indicator regardless of their empowerment status. On the other hand, the censored headcount represents the percentage of disempowered respondents who are disempowered in a particular indicator (Malapit et al., 2019). In dual

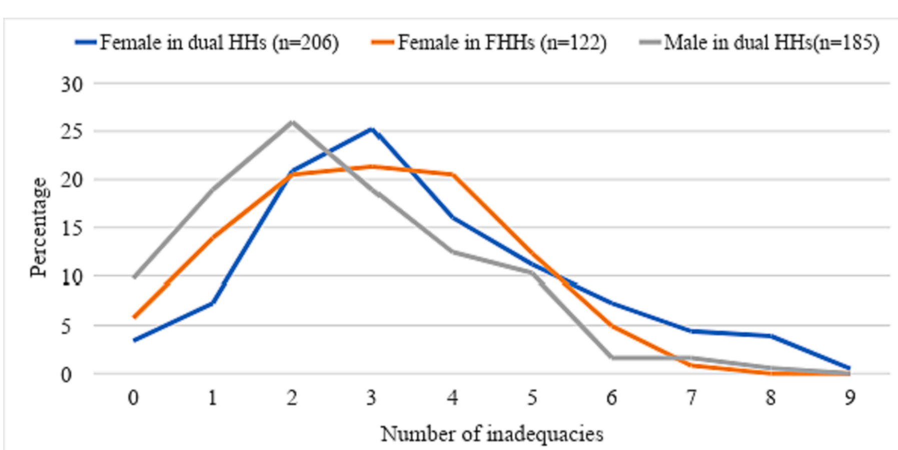

Fig. 2. Distribution of inadequacies; *Source*: Pro-WEAI survey data.

Table 3
Uncensored and censored headcount ratios and contribution of each indicator to disempowerment.

Indicator	Uncensored Headcount Ratio (%)			Censored Headcount Ratio (%)			Proportional contribution to disempowerment (%)		
	Women in DHHs	Men in DHHs	Women in FHHs	Women in DHHs	Men in DHHs	Women in FHHs	Women in DHHs	Men in DHHs	Women in FHHs
Intrinsic agency									
Autonomy in income	61.65	44.32	50.81	33.00	18.9	28.7	14.38	14.96	16.05
Self-efficacy	51.94	46.49	56.55	32.03	21.08	28.69	13.95	16.67	16.06
Attitudes about intimate partner violence against women	18.45	12.43	13.93	13.59	6.49	8.2	5.92	5.13	4.59
Respect among household members	27.18	9.19		16.99	4.86		7.4	3.42	
Instrumental agency									
Input in productive decisions	12.14	5.95	0.82	10.68	4.32	0.82	4.65	3.85	0.46
Ownership of land and other assets	0.97	0.54	0.16	0.97	0.54	1.64	0.427	0.423	0.917
Access to and decisions on financial services	17.48	11.89	27.05	12.62	7.57	18.85	5.49	5.98	10.55
Control over use of income	33.98	31.89	30.33	23.79	13.51	15.57	10.68	10.36	8.72
Work balance	47.09	15.14	31.97	24.76	4.32	17.21	10.78	3.42	9.63
Ability to visit important locations	34.95	31.35	42.62	20.39	15.68	23.77	8.87	12.39	13.3
Collective agency									
Group membership	21.84	16.76	15.57	18.45	12.43	14.75	8.03	9.83	8.26
Membership in influential groups	26.7	28.11	26.23	22.33	16.76	20.49	9.73	13.25	11.47

Source: Authors' Pro-WEAI survey data

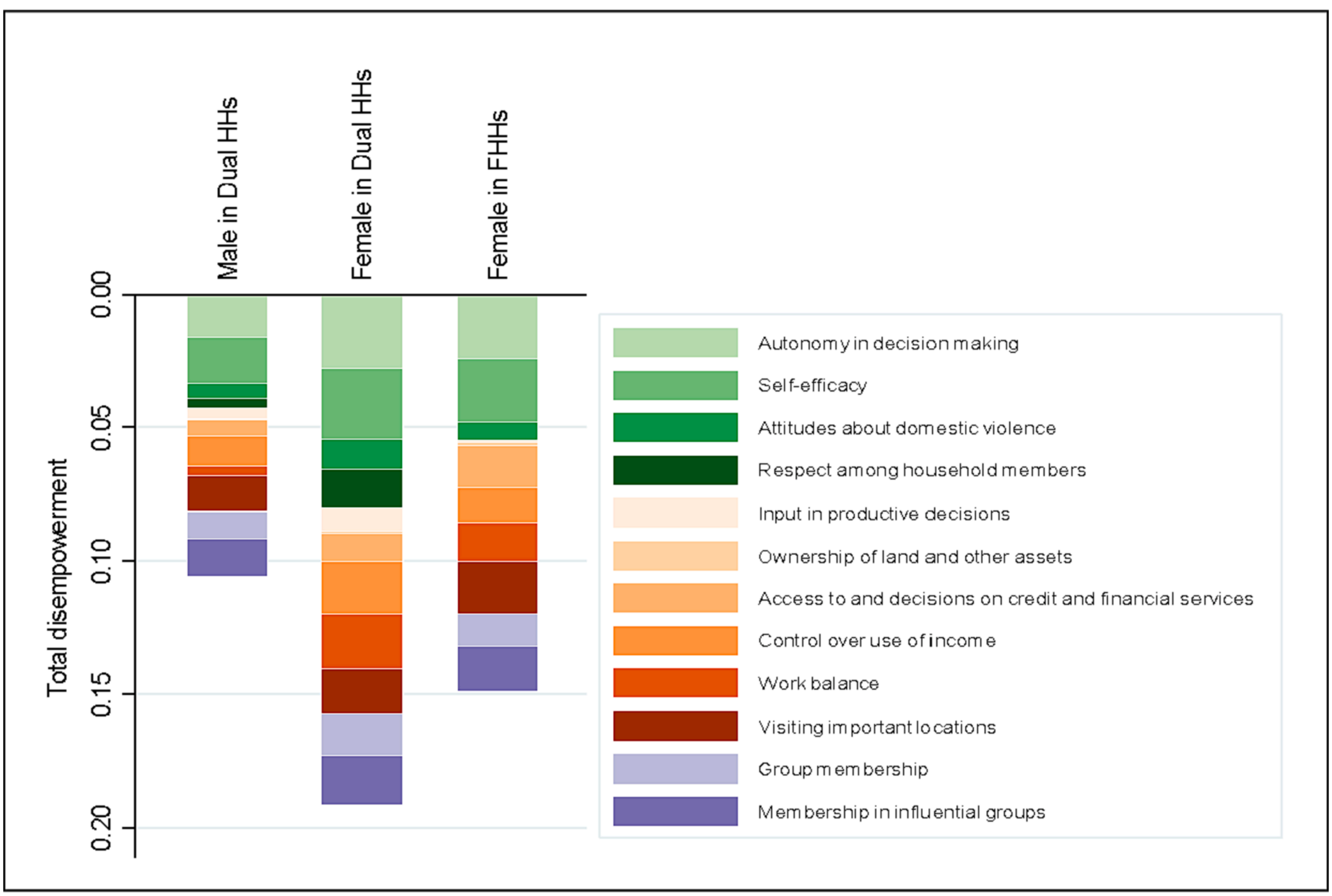

Fig. 3. Contribution to disempowerment by category of respondent.

households, a higher percentage of women are disempowered compared to men for all indicators as shown by both the uncensored and censored headcount ratio.

Intrinsic agency indicators, autonomy in income, and self-efficacy had the highest censored and uncensored headcount ratios with a higher proportion of women being disadvantaged compared to men. In the instrumental agency indicators, work balance had the highest censored headcount ratio of 25 % for women in dual households, while ownership of land and other assets had the lowest headcount ratio. Women who have ownership and control of land and other assets are

Table 4
Double-bounded contingent valuation model estimates without control variables.

Variable	Female respondents (DHHs + FHHs)		Female respondents in DHHs		Female respondents in FHHs		Male respondents	
	Coefficient (Std. err)	z	Coefficient (Std. err)	z	Coefficient (Std. err)	z	Coefficient (Std. err)	z
Mean WTP	46.911*** (1.106)	42.41	46.635***(2.15)	21.73	47.051*** (1.25)	37.76	48.637*** (1.310)	37.12
Sigma	13.774***	14.09	16.372	8.31	12.220	1.09	13.160***	1.17
No. of observations	186		69		117		127	

***, **, * Significant at 1 %, 5 %, and 10 %. Standard errors in parenthesis.

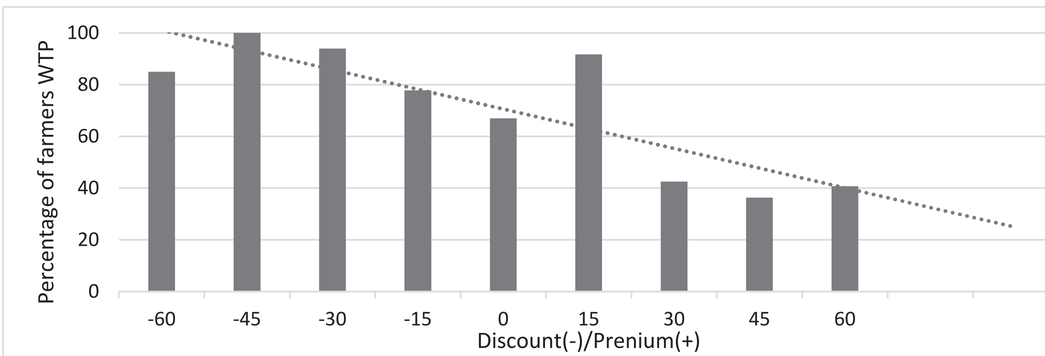

Fig. 4. Percentage of farmer's WTP for IPM package according to the bid price.

Table 5
Effect of pro-WEAI indicators on respondents' willingness to pay for the IPM package.

	Women (DHHs + FHHs)			Women in DHHs			Women in FHHs			Men in DHHs		
Variables	Coeff.	SE	z	Coeff.	SE	z	Coeff.	SE	z	Coeff.	SE	z
Dependent variable: willingness to pay												
Mean WTP	43.314***	10.45	4.14	41.079**	20.40	2.01	46.930***	1.32	4.15	55.568***	14.24	3.90
Household characteristics												
Women Empowerment (1 = Empowered, 0 = Not Empowered)	7.727***	1.90	4.06	7.840**	3.89	2.01	6.991***	2.18	3.21	8.533***	2.11	4.04
Household type (DHHs = 1, FHHs = 0)	1.254	1.95	0.64									
Log income from mango production	0.522*	0.28	1.89	0.063	0.52	0.12	0.657**	0.31	2.09	0.022	0.30	0.07
Tropical livestock unit (TLU)	0.314	0.37	0.84	0.250	0.58	0.43	0.241	0.53	0.46	0.787**	0.37	2.11
Household size (number)	0.934**	0.44	2.13	0.277	0.84	0.33	1.216**	0.49	2.48	−0.123	0.47	−0.26
Land cultivated (Ha)	0.071	0.27	0.26	1.017*	0.55	1.85	−0.571	0.43	−1.34	0.715**	0.32	2.21
Improved mango variety (1 = Yes, 0 = Otherwise)	7.427*	4.36	1.70	2.583	7.74	0.33	8.862*	5.08	1.74	21.143**	8.37	2.53
Respondent characteristics												
Perceived damage by mango fruit fly												
No damage (1 = Yes, 0 = otherwise)	−6.429	4.13	−1.56	−10.891	7.26	−1.50	−3.012	4.78	−0.63	−16.283***	5.22	−3.12
Low (1 = Yes, 0 = Otherwise)	−1.270	3.80	−0.33	−0.050	7.19	−0.01	−2.249	4.36	−0.52	−9.787**	4.95	−1.98
High (1 = Yes, 0 = Otherwise)	4.976	4.00	1.24	8.434	7.36	1.15	5.197	4.48	1.16	−2.730	5.42	−0.5
Perceived effectiveness of current fruit fly control method (1 = effective, 0 = otherwise)	−7.364***	2.78	−2.65	−8.342	5.81	−1.44	−4.353	2.98	−1.46	−6.592**	3.25	−2.03
Respondent education (years)	0.553**	0.24	2.34	0.370	0.52	0.71	0.679***	0.26	2.6	0.375	0.26	1.42
Respondent age (years)	0.061	0.07	0.91	0.103	0.11	0.90	0.037	0.08	0.46	−0.084	0.07	−1.22
Respondent Occupation (1 = non-farm income, 0 = Otherwise)	5.712**	2.57	2.22	3.950	6.23	0.63	4.882*	2.63	1.86	5.608*	3.26	1.72
Institutional factors												
Extension services (1 = accessed, 0 = otherwise)	4.821**	2.16	2.23	7.801**	4.05	1.93	3.454	2.51	1.37	7.077**	2.82	2.51
Distance to the source of input (walking minutes)	−0.013***	0.00	−2.64	−0.026***	0.01	−3.10	−0.003	0.01	−0.57	−0.002	0.00	−0.35
Constant	24.017***	7.82	3.07	27.703**	12.37	2.24	24.901***	9.23	2.7	46.910***	7.19	6.52
Number of observations	186			69			122			126		

Table 1
Pro-WEAI indicators and definition of adequacy.

Indicator	Definition of adequacy
Intrinsic agency	
Autonomy in income	Individuals are motivated more by their own values rather than coercion or fear of what others might think. *Relative autonomy index* (RAI) =>1.RAI score is calculated by summing up vignettes about a person's motivation for how they use income generated from the following weighting schemes: - i. 0 for vignette 1 - no alternative *("There is no alternative to how Mary/John uses his/her income. How she/he uses her/his income is determined by necessity"),* ii. -2 for vignette 2 - external motivation *("Mary/John uses her/his income how her/his spouse, or another person or group in her/his community tell her/him she/he must use it. She/he does what they tell her/him to do")* iii. -1 for vignette 3 - introjected motivation *("Mary/John uses her income in the way her family or community expect. She wants them to approve of her"),* iv. +3 for vignette 4 - autonomous motivation. *("Mary/John chooses to use her income how she personally wants to, and thinks is best for herself and her family. She values using her income this way. If she changed her mind, she could act differently".)*
Self-efficacy	"Agree" or greater on average with self-efficacy questions. New general self-efficacy scale (NGSE) =>32. It is an 8-item measure that assesses how much people believe they can achieve their goals, despite difficulties. The scale uses a 5-point rating scale *(1= strongly disagree; 3 = neither agree nor disagree; 5 = strongly agree),*
Attitudes about intimate partner violence (IPV)	Believes husband is NOT justified in hitting or beating his wife in all 5 scenarios: -(1). She goes out without telling him.(2). She neglects the children.(3). She argues with him.(4). She refuses to have sex with him.(5). She burns the food.
Respects among household's members	Meets ALL the following conditions related to their spouse, the other respondent, or another household member: - Respondents respect relations (Most of the time) AND. Relationships respect the respondent (Most of the time) AND. Respondent trusts relation (Most of the time) AND. Respondents are comfortable with disagreeing with relations (Most of the time).
Instrumental agency	
Input into productive decisions	Meets at least ONE of the following conditions for all the agricultural activities they participate in: - Make the related decision solely. Makes the decisions jointly and has at least some input in all the decisions made. Feels they could make a decision if they wanted to (to at least some medium extent).
Ownership of land and other assets	Owns either solely or jointly at least ONE of the following. At least THREE small assets (poultry, non-mechanized assets, or small consumer durables) At least TWO large assets Land.
Access to and decisions on financial services	Meets at least one of the following conditions- Belongs to a household that used a source of credit in the past year and participated in at least ONE sole or joint decision about it. Belongs to a household that did not use credit in the past year but would have if they wanted to from at least ONE source. Has access either solely or jointly to a financial account.
Control over use of income	Has input in decisions related to how to use BOTH income and output from all agricultural activities they participate in AND has input in decisions related to income from all non-agricultural activities they participate in unless no decision was made.
Work balance	Works less than 10.5 hours per day.Workload= Time spent on primary activity + (1/2) time spent on childcare as a secondary activity.
Visiting important locations	Meets at least one of the following conditions: - Visits at least two locations at least once per week of (City, market, family/relative). Visits at least one location at least once per month of (public meeting, health facility)
Collective agency	
Group membership	Active member of at least one group
Membership in influential groups	Membership in at least one group that can influence the community to at least a medium extent.

Source: Malapit et al. (2019).

more likely to adopt agricultural technologies (Doss et al., 2018; Doss, 2001; Rola-Rubzen et al., 2020). This could be attributed to the vulnerability women have in losing land they have invested in if men want to take over or in case of their husband's death or divorce.

Approximately 35 % of women in DHHs and 42 % of women in FHHs, did not achieve adequacy in the visiting important places indicator compared to 31 % of men. Research has shown that in the context of agricultural transformation such as moving from subsistence to commercial agriculture or uptake of improved technology, freedom of movement is an important aspect of women's empowerment (Heckert et al., 2020; Bergman Lodin et al., 2019).

Contribution to disempowerment

Fig. 3 indicates the total contribution of each indicator to disempowerment among the disempowered men and women in the sample. The total disempowerment score (1-3DE) among the disempowered is depicted by the total length of the bar and the different colored bars within, showing the total contribution of each indicator to disempowerment. The length of the female respondents in the dual household's bar implies that women had higher, and more inadequacies compared to men and women in female-headed households. Table 4 in the previous section shows the proportion of distribution of each indicator to disempowerment.

The largest contributors to disempowerment for all respondents are self-efficacy and autonomy in income. In dual households, self-efficacy contributes 14 % and 17 % to disempowerment among men and women, respectively. The least contributors to disempowerment among women in dual households are attitudes about domestic violence, input into productive decisions, and ownership of land and other assets. While among the women in female-headed households' attitudes towards domestic violence and input in productivity are the least contributors to disempowerment. The indicators with large variations between men and women in dual households (work balance, respect among household members, autonomy in income, and membership in influential groups) should be the areas of focus for interventions aimed at bridging the disempowerment gap.

Willingness to pay for the mango fruit fly IPM package

About 67 % of the survey respondents were WTP for the fruit fly IPM at the initial offer (ZMW 40 per tree). Out of those who accepted the initial offer, only 45 % were WTP for the package at a premium (+15 %, +30 %, +45 %, or + 60 % of the initial bid). On the other hand, 91 % of farmers who did not accept the initial bid were WTP when the discount

(-15 %, −30 %, −45 %, or −60 % of the initial price), was offered (Fig. 4). These results implied that the higher the price, the lower the number of farmers who are WTP for mango fruit fly control IPM package. The liner projection in Fig. 4 shows that as the bid price premium increased, fewer farmers were WTP for the IPM package.

Factors influencing women's willingness to pay for the mango fruit fly IPM package and the mean WTP price

We estimated the unconditional and conditional mean WTP using the logistic model (Eq. (8)) for the three groups of respondents (women in DHHs, women in FHHs, and men in DHHs). First, we estimated the double-bonded contingent valuation model without either the women's empowerment status or other independent variables to show the unconditional mean WTP for the IPM package. The results indicate that female respondents' mean WTP was slightly lower compared to male respondents. This finding implies that the uptake of new agricultural technology by women farmers is slightly slower compared to men, which collaborates with the findings of earlier studies (e.g. Rola-Rubzen et al., 2020). On average female and male respondents were willing to pay ZMW 47 (~USD 2.4) and ZMW 49 (~USD 2.5) respectively for the fruit fly IPM package. There was no significant difference in the unconditional mean WTP between women in FHHs and DHHs (Table 4). The mean WTP was higher than the initial bid of ZMW 40 indicating potential demand for the fruit fly IPM package among smallholder mango farmers in Zambia.

We then estimated the conditional double-bounded contingent valuation using two models, first with women's empowerment status and second with each of the pro-WEAI indicators. The first model includes the women's empowerment status as well as other social-economic factors that are likely to influence women's willingness to pay for the IPM package (Table 5). Men had a higher conditional mean WTP of ZWM 56, compared to women, ZWM 43 further emphasizing a lower uptake of the IPM strategies by female farmers in comparison to men. Women in FHHs had a higher mean WTP of ZWM 47 than women in DHHs with a mean WTP of ZMW 41. This difference could be attributed to the higher percentage of women in FHHs achieving adequacy in most of the pro-WEAI indicators than women in DHHs. For instance, more women in FHHs had control over use of income and had input over productive decisions compared to women in DHHs.

Women's empowerment status had a significant and positive effect on the willingness to pay for IPM strategies for all the groups of respondents. This implies that empowered women were more likely to make a higher bid on the IPM package than women who are not empowered. This could be attributed to an empowered woman's ability to access resources that she can use to pay for new agricultural technology. For instance, the censored headcount ratio in the previous section shows that 87 % and 81 % of empowered women in DHHs and FHHs, respectively, had achieved adequacy in access to and decisions on financial services indicators. Moreover, when empowered women have achieved adequacy in input in production decisions and control over income indicators, they may be more likely to be able to make decisions regarding purchasing the IPM package. These findings were in line with that of Ragasa (2012) in reviewing the gender and institutional dimension of agricultural technology across 35 case studies, in which the author established that empowering women increased their uptake of agricultural technology.

In the second model, we estimated 12 equations showing the effect of each pro-WEAI indicator and other independent variables on the different categories of respondents' willingness to pay (Table 5). The results show that autonomy in income, self-efficacy, attitudes about intimate partner violence against women (IPV), input in productive decisions, control over use of income, work balance and ability to visit important locations positively and significantly influenced women's WTP for IPM. However, for women in DHHs only autonomy income, input in productive decisions, and ability to visit important locations had a significant influence on WTP, while for women in FHHs, self-efficacy, control over use of income, work balance, and ability to visit important location had a significant influence on WTP.

These results suggest that women who have achieved adequacy regarding mobility and workload may have been able to more easily attend training aiming to improve their knowledge about agricultural innovations, in this case, fruit fly which motivated them to be more willing to pay for the IPM package. Alem et al. (2020) in assessing decision-making within the households and the role of autonomy in Tigray, Ethiopia, found that women who have higher autonomy in decision-making are willing to pay substantially more for new technology than those with lower decision-making autonomy.

Household size had a positive and significant association with women's willingness to pay for the IPM package. This suggests that a larger household size increases the likelihood of paying a higher bid; this could be attributed to more household income generated by other household members that can be used to pay for IPM. These results were similar to the case of vaccination against East Coast fever, where women from households with larger adult children were more likely to pay for the vaccine (Jumba et al., 2020).

The respondent's years of education had a positive and significant influence on the women's WTP for the fruit fly IPM package. This could be attributed to the ability of an individual to access and comprehend information regarding the IPM package. However, in some cases, education has been shown to influence the WTP for agricultural innovations negatively. This was demonstrated by the case of index-based livestock insurance in South Africa; where educated farmers were skeptical and consequently were not WTP for this innovation because farmers had no information or were unaware of the details of the programme (Oduniyi et al., 2020).

Respondent's occupation had a significant positive and significant influence on WTP, implying that women who have a non-farm occupation, were more likely to pay a higher bid for IPM packages than those without. This may be because women earning their income have the freedom to make decisions in acquiring improved technologies that will benefit them as demonstrated in previous similar studies (Alem et al., 2020; Doss, 2001).

Distance to the source of agricultural inputs returned a negative and significant coefficient. This implies that mango farmers who were far away from markets where they could source pesticides were less likely to pay for the IPM strategy. Similar findings were reported by Chia et al. (2020), where farmers who reside far away from input markets were less likely to pay for insect feed as a replacement for conventional animal feed. Perception of the effectiveness of the current fruit fly control method also positively influenced women's willingness to pay for the IPM package. If a farmer perceived the current method they are using to control mango fruit flies was effective they are less likely to purchase an innovation for controlling the same, therefore the lower bid.

Access to extension services positively and significantly influenced women's ability to pay for the IPM package. Extension services equip women with proper knowledge and information regarding IPM packages, hence increasing their WTP. According to Diiro et al. (2020), training activities increase public health awareness and may induce behavioral change in more participants hence increasing their WTP for technologies that aim to curb malaria infection. Research has shown that agricultural extension plays a vital role in enhancing technology adoption, however, women frequently have less access to extension services than their male counterparts (Peterman et al., 2011; Rola-Rubzen et al., 2020).

Conclusion

This study explored the implications of women's empowerment on the willingness to pay for *icipe*'s IPM package for the management of mango-infesting fruit flies in Lusaka province, Zambia using a double-bounded contingent valuation model. The study contributes to the literature on the effect of integrating women's empowerment during project implementation on the uptake of agricultural interventions. In addition to this, the study applied the pro-WEAI tool which is a standardized tool under development for monitoring and assessing a project's impact on women's empowerment. The paper contributes to the ongoing discussion regarding the tool's development and implementation and the opportunities of using the index to explain or evaluate women's economic behavior like the WTP for IPM measurements. In detail, we analyze the effect of each 12 pro-WEAI indicators on women mango farmers' willingness to pay for the technology.

The IPM package for controlling mango fruit fly and its benefit was carefully explained to respondents who were not aware of its use and importance before the willingness to pay questions were administered. Currently, most mango farmers in Zambia are willing to pay for the IPM package, however, a linear projection indicated that as the price went up, fewer farmers were willing to pay. A comparison of the mean willingness to pay prices between men and women indicates that men are willing to pay at higher prices compared to women thus implying women are more price-sensitive hence the need to assure a lower price for the IPM package.

The pro-WEAI results show that men are more empowered than women in dual and female-headed households, however, women in female-headed households are more empowered than women in dual households. Uncensored and censored headcount ratios on the disempowered showed that most women did not achieve adequacy in autonomy in income and self-efficacy indicators. A high percentage of women were also inadequate in their work balance, control over income, and ability to visit important locations. The regression analysis highlights that the women's empowerment status strongly influenced women's willingness to pay for the IPM package. Moreover, pro-WEAI individual indicators; autonomy in income, self-efficacy, attitudes about domestic violence, work balance, ability to visit important locations, and group membership had a positive and significant effect on women's willingness to pay for the package. These indicators were also the highest contributors to women's disempowerment, therefore achieving adequacy in them would greatly influence the uptake of the IPM package.

This study concludes that there is clear evidence that empowering women through intentional inclusion in training, encouragement to join groups, and awareness creation on negative gender norms will increase agricultural technology uptake for which the WTP can be seen as a proxy. Therefore, projects aiming to introduce new technology in rural households should integrate women's empowerment during implementation. Policy implications of the findings are that encouraging women's participation in agricultural production and marketing groups will not only increase their empowerment but also the uptake of innovation that increases agricultural productivity. Engaging a gender expert at the onset of agricultural projects aimed at introducing new technologies and integrating a gender analysis will contribute to ensuring women are not negatively affected by intervention strategies or intended project outcomes. The training on agricultural technology should be informed by gender analysis and aim at changing existing norms on intra-household and community relationships to where both male and female primary decision-makers should attend. Due to pre-existing constraints such as heavy domestic workload, lack of finances, and lack of freedom of movement, all of which prevent women's attendance of agricultural training, sponsoring women to attend the training is vital to increasing the participation of women and the potential benefits they will receive from increased education and technical training. Also, efforts to lower women's domestic workloads, boost their finances, and sensitize others in the community to promote women's freedom of movement would be key to empowering women, hence increasing their uptake of new agricultural innovations.

CRediT authorship contribution statement

Hannah M. Gichungi: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision. **Beatrice W. Muriithi:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition. **Holger Kirscht:** Conceptualization, Methodology, Software, Validation, Investigation, Resources, Writing – original draft, Writing – review & editing, Visualization, Supervision, Funding acquisition. **Samira A. Mohamed:** Conceptualization, Resources, Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition. **Shepard Ndlela:** Conceptualization, Resources, Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition. **Kassie Menale:** Conceptualization, Methodology, Validation, Investigation, Resources, Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Annex

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