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The Impact of Information and Treatment of Jumping Worms on Consumer Willingness to Buy Potted Plants

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Abstract. **Jumping worms [*Amynthas* (Kinberg) spp.], an emergent invasive species group native to East-Central Asia, threaten the health of temperate ecosystems and the livelihood of the plant production industry in the United States. Aptly named because of their characteristic and distinctive ability to thrash, these invasive annelids contribute substantial alterations to soil structure and nutrient dynamics in temperate forests and potted plants. Their impact on the physical and chemical properties of native soils results in plant health decline and leads to biodiversity loss of flora and fauna. An unintentional, yet predominant, vector of the spread of jumping worms throughout the United States is through horticultural materials such as mulch, potting media, compost, and potted plants. Although controlling the spread of these invasive worms is a forefront goal of producers and regulatory authorities in the green industry, there is surprisingly little knowledge about consumer awareness of the worms and their willingness to purchase horticultural products infested with, or treated for, jumping worms, which may help inform management of plant production and sales in the green industry. The objectives of our study were to examine how purchasing decisions are affected by consumer awareness and jumping worm treatment information. To achieve this, an online survey was conducted with a diverse sample of 925 of 1000 consumers in the United States to gauge their awareness and knowledge of jumping worms, gardening habits, and demographic profile. Participants were asked questions about worm knowledge and their willingness to buy treated potted plants before and again after being provided with jumping worm information. The study revealed a significant decrease in willingness to buy untreated potted plants after participants were informed about the detrimental effects of jumping worms. Furthermore, consumer willingness to buy treated potted plants increased when participants were informed about potential jumping worm treatment options. The findings of our study underscore the pivotal role of awareness and information in shaping consumer decisions regarding potted plants amid jumping worm infestations. These insights are essential for formulating effective communication and treatment strategies to mitigate the impact on ecosystems and the green industry.**

Jumping worm damage and spread across the United States (Ziter et al. 2021) through horticultural products (Bellitürk et al. 2015; Redmond et al. 2016) is a cause for concern among practitioners in the green industry and home gardeners. Jumping worms are ecosystem engineers. They alter the soil structure and subsequent temperature, deplete soil nutrients, and contribute to excessive erosion in managed and natural landscapes (Görres et al. 2019). These effects lead to decreases in plant health and appearance. Where they have invaded natural settings, jumping worms disturb ecosystems, leading to biodiversity loss in animals, including birds, frogs, and salamanders (Bethke and Midgley 2020; Loss and Blair 2011; Loss et al. 2012; Ziemba et al. 2015, 2016). Jumping worms have been known to consume fresh and decaying leaves, roots, underground stems, turf, soil, mulch, and soilless potting media (Bellitürk et al. 2015; Chang et al. 2021; Frelich et al. 2019; Redmond et al. 2016). Their wide-ranging diet enables them to cause extensive damage. With the ability to survive by consuming soilless potting media, jumping worms can likely reside in potted plants for long periods of time. It can be challenging to detect these pests because they exhibit an annual life cycle and are resistant to harsh climatic conditions during their cocoon life phase (Schult et al. 2016). Jumping worms are hermaphroditic and reproduce primarily through parthenogenesis—meaning, that new populations have the potential to arise from a single undetected individual (Shen et al. 2011).

The wholesale plant trade is a leading vector of spread for jumping worms, in which potted plants are traded and transferred from one site to another, especially with interstate commerce (Brown 1878; Chang et al. 2021; Houchins 1995; Nelson 1917). Potted plants are ideal for jumping worm spread because they are maintained at moisture levels and temperatures conducive to worm survival and reproduction. In plant containers, jumping worms have the potential to consume organic material (including roots), modify substrate texture and nutrient chemistry, and contribute to excessive nutrient leaching from container nursery stock (Chang et al. 2021; Resner et al. 2015). There are many ways jumping worms can be introduced into potted plants. Infested horticultural materials and poor biosecurity measures are the leading causes of jumping worm introduction and spread (Brown 1878; Chang et al. 2021; Houchins 1995; Nelson 1917). Jumping worms and their extremely small cocoons can survive in piles of mulch, compost, or potting media as long as temperatures and moisture content requirements are met (Bellitürk et al. 2015). In many cases, the worms remain undetected because adults can move away from disturbances within the media and because the cocoons are challenging to see with the naked eye (Bellitürk et al. 2015). Observations of worms by gardeners typically do not elicit concerns, because their presence is often associated, perhaps mistakenly, with beneficial roles in horticultural settings (Darwin 1881; Moore et al. 2018). However, in certain locations and conditions, worms may act as agents of disruption, altering soil composition, nutrient cycling, and plant diversity, and detracting from horticultural values. It is believed that adult jumping worms cannot survive temperatures $< 5\,^{\circ}C$ or $> 38\,^{\circ}C$, whereas their cocoons may be able to endure more extreme temperatures (Görres et al. 2019; Johnston and Herrick 2019). Therefore, heat treatments may be a potential option for controlling jumping worms, but may not result in complete eradication, especially with large quantities of substrate such as mulch.

American gardeners have long been interested in new and exotic plants (Wilson 1929). For the past few hundred years, plants and soils from foreign countries where jumping worms are endemic have been moved to North America, serving as initial sources of infestation and fueling their spread in the United States (Brown 1878; Houchins 1995; Nelson 1917). Today, gardeners and consumers who purchase plants, mulch, or compost from nurseries may unknowingly introduce jumping worm cocoons into their landscapes. These cocoons, which are small and difficult to detect, can hitch a ride in the soil surrounding potted plants or within organic mulch and compost materials (Bellitürk et al. 2015; Brown 1878; Chang et al. 2021; Houchins 1995; Nelson 1917). In addition, equipment, tools, and footwear contaminated with worm-infested soil can serve as vectors for their spread (Görres et al. 2019).

The presence of jumping worms and their unique effect on potting media may affect consumer preferences for plant materials negatively. The purchasing behaviors and willingness of consumers to adopt preventive measures, such as purchasing plants treated for jumping worms, play a crucial role in mitigating the spread of infestation. Understanding consumer responses to jumping worm treatment is essential for developing effective management strategies. However, very few studies have examined the public's perceptions or preferences regarding jumping worms. To our knowledge, the only study of this topic was conducted by Johnson et al. (2021), which found that homeowners view jumping worms unfavorably, after learning about their negative ecological impacts on gardens and natural ecosystems. Public perception of invasive species management varies, and resistance to interventions resulting from cost, inconvenience, or lack of awareness may hinder widespread adoption. Studying consumer attitudes and preferences regarding jumping worm treatments will help policymakers, researchers, and industry professionals develop targeted outreach programs and incentives that encourage responsible gardening practices and slow the spread of jumping worms. In particular, knowledge of jumping worms and nursery treatments might mitigate their impact, and may influence consumer purchasing decisions for potted plants. Therefore, the aim of our study was to investigate these dynamics by examining the willingness to buy (WTB) potted plants under different treatment scenarios and by providing information about jumping worms to consumers. To achieve this objective, we designed and distributed an online survey targeting a diverse sample of consumers across the United States. The objective of the study was to gather insights into participant awareness and knowledge of jumping worms, their gardening habits, and demographic characteristics, as well as to explore how, or whether, perspectives change when participants are educated about jumping worm treatment to determine impacts on purchasing decisions.

Materials and Methods

To investigate how the willingness of consumers to buy a potted plant is influenced by the information and treatment of jumping worms, and their awareness of the harmfulness of jumping worms, we designed an online survey. The survey was distributed across the United States by Qualtrics, a professional online survey company. Qualtrics panelists are invited through a variety of methods, such as e-mail lists, ads and promotions across various digital networks, word of mouth and membership referrals, online and mobile games, TV and radio ads, and so on, to achieve a broad reach of participants of different demographics (Barnes et al. 2021; Miller et al. 2020). The survey was distributed to selected panelists online. In total, 1000 people answered the survey and 925 participants completed all the questions used in our analysis.

In the survey, a series of questions were asked regarding the knowledge of the participants, their awareness of jumping worms, demographics, gardening habits, and willingness to purchase potted plants that had been treated or untreated for jumping worms. At first, without providing any information about jumping worms, we used two questions to elicit the likelihood of participants to purchase a potted plant that has not been treated and one that has been treated for jumping worms. For each question, participants were asked to indicate their likelihood of purchase based on a 7-point Likert scale, where 1 point = very unlikely and 7 points = very likely. Their

Table 1. Summary statistics of the variables used in the ordered probit model.

Variable	Mean	Standard deviation
Willingness to buy[i]		
Treated = 0, informed = 0	3.961	1.896
Treated = 0, informed = 1	3.303	2.014
Treated = 1, informed = 0	4.888	1.663
Treated = 1, informed = 1	5.289	1.644
Age (years)	59.499	14.749
Female[ii]	0.576	0.494
Education[iii]	3.075	1.151
Income (in $1000)	63.441	50.119
Renting[iv]	0.195	0.396
No. of potted plant purchases	5.914	4.623
Compost[v]	0.320	0.467
Time spent gardening per week (h)	3.412	2.714
Familiarity with worms[vi]	0.986	0.118
Participants' knowledge score about jumping worms	1.935	0.95
Ability to distinguish jumping worms from European nightcrawlers[vii]	0.488	0.500
Participant location by region		
Northeast[viii]	0.213	0.410
Midwest[ix]	0.238	0.426
South[x]	0.398	0.490
West[xi]	0.151	0.359

[i] Scored as 1 point = very unwilling to buy, 5 points = very willing to buy.
[ii] Scored as 1 point = female, 0 point = otherwise.
[iii] Scored as 1 point = had some high school, 2 points = completed high school, 3 points = acquired associate's degree or higher, 4 points = acquired bachelor's degree or higher, 5 points = master's degree or higher.
[iv] Scored as 1 point = rents a home, 0 point = otherwise.
[v] Scored as 1 point = owns a compost bin, 0 point = otherwise.
[vi] Scored as 1 point = familiar with worms, 0 point = otherwise.
[vii] Scored as 1 point = able to distinguish jumping worms, 0 point = otherwise.
[viii] Scored as 1 point = lives in the northeastern United States, 0 point = otherwise. In this survey, states in the Northeast include Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, New Jersey, New York, and Pennsylvania.
[ix] Scored as 1 point = lives in the midwestern United States, 0 point = otherwise. In this survey, states in the Midwest include Illinois, Indiana, Michigan, Ohio, Wisconsin, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota.
[x] Scored as 1 point = lives in the southern United States, 0 point = otherwise. In this survey, states in the South include Florida, Georgia, North Carolina, South Carolina, Virginia, District of Columbia, Maryland, Delaware, West Virginia, Alabama, Kentucky, Mississippi, Tennessee, Arkansas, Louisiana, Oklahoma, Texas.
[xi] Scored as 1 point = lives in the western United States, 0 point = otherwise. In this survey, states in the West include Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Alaska, California, Hawaii, Oregon, and Washington.

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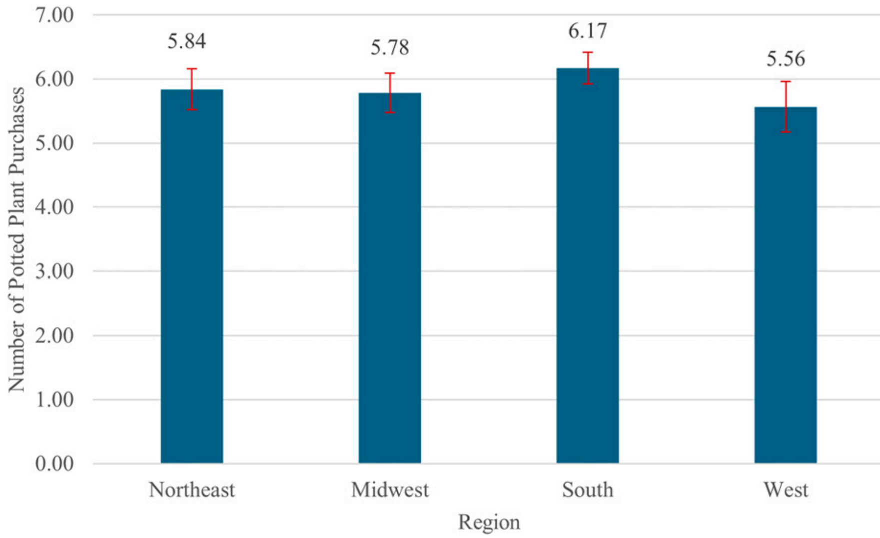

Fig. 1. Number of potted plant purchases by region based on a national survey of 925 US consumers.

responses were used to measure their WTB a potted plant both with and without the jumping worm treatment. Subsequently, subjects were presented with a paragraph of information detailing the harmfulness of jumping worms. After that, participants were asked to answer the two questions again. The answers of participants to these four questions were then used to assess their WTB a potted plant with and without the jumping worm treatment, and before and after being informed about the harmfulness of jumping worms.

The ordered Probit model was used to examine participants' WTB potted plants under the two conditions: 1) with or without treatment and 2) with or without the detailed information about jumping worms. These four measures were pooled into one ordered Probit model as the dependent variable called WTB, which formed panel data with 3700 observations (925 subjects × 4 WTBs). To distinguish these measures, two dummy variables were introduced: treated and informed. The treated variable was given a value of 1 if WTB was measured for a potted plant with jumping worm treatment, and was valued at 0 otherwise. The informed variable was assigned a value of 1 if the WTB was measured after a participant had been informed about the detrimental effects of jumping worms, and was given a value of 0 otherwise.

In the ordered Probit model, the treated dummy was used as an independent variable to capture the main effect of the jumping worm treatment on the WTB of consumers. In addition, an interaction term was included between treated and informed to investigate how information regarding the harmfulness of jumping worms influenced WTB for potted plants with and without treatment. To explore further the varying reactions of different consumer groups to the treatment and information, background characteristics of participants (such as demographics, gardening experience, knowledge of jumping worms, and geographic location) were included as independent variables through three-way interaction terms. This meant that, for every background characteristic, its three-way interaction term with the treated and informed dummy variables was added, which enabled a comparison of the effects of each background characteristic on WTB across four scenarios: untreated and uninformed, untreated and informed, treated and uninformed, and treated and informed.

Demographics in the model included age, gender (an indicator of female), education level, income level, and whether the participant was a renter. Gardening experience included the average number of annual potted plant purchases, an indicator of owning a compost bin, and per-week gardening time. Knowledge of jumping worms included an indicator of being familiar with what a worm is (as self-reported by participants), a knowledge score based on judgments made by participants of three statements regarding jumping worms (from 0 to 3 points, adding 1 point if a participant made a correct judgment), and an indicator of whether a participant could distinguish a jumping worm from a European nightcrawler [*Lumbricus terrestris* L. (1758)] correctly. Geographic location included the indicators of living in the Northeast, Midwest, and South United States (the indicator of the West region was dropped because of collinearity).

To explain the ordered Probit model, let WTB_{ij} denote the WTB of consumer i ($i = 1, 2, \dots, 925$) under scenario j ($j = 1, 2, 3, 4$). Scenarios are defined based on whether the potted plant has or has not been treated for jumping worms and before or after reading the information about the harmfulness of jumping worms. Let $Treated_j$ and $Informed_j$ be the treated and informed dummies under scenario j. Then, we have

$$Treated_1 = 0 \text{ and } Informed_1 = 0,$$

$$Treated_2 = 0 \text{ and } Informed_2 = 1,$$

$$Treated_3 = 1 \text{ and } Informed_3 = 0, \text{ and}$$

$$Treated_4 = 1 \text{ and } Informed_4 = 1.$$

Let $\mathbf{Independent\_Variable_{ij}}$ represent the vector of all independent variables, including the treated dummy, the interaction term between treated and informed, and all three-way interaction terms of background characteristic variables. Assume that the value of WTB_{ij} is determined by consumer i's evaluation V_{ij}^* of the potted plant under scenario j. The evaluation is affected by all independent variables ($\mathbf{Independent\_Variable_{ij}}$) and a standard normal distributed error term e_{ij}. Hence, the evaluation V_{ij}^* can be defined for any i and j as

$$V_{ij}^* = \boldsymbol{\alpha}'\mathbf{Independent\_Variable_{ij}} + e_{ij}.$$

Then, assume that, for any i and j,

$WTB_{ij} = 1$ (very unlikely), if $V_{ij}^* \leq v_1$,

$WTB_{ij} = 2$ (somewhat unlikely), if

$$v_1 < V_{ij}^* \leq v_2,$$

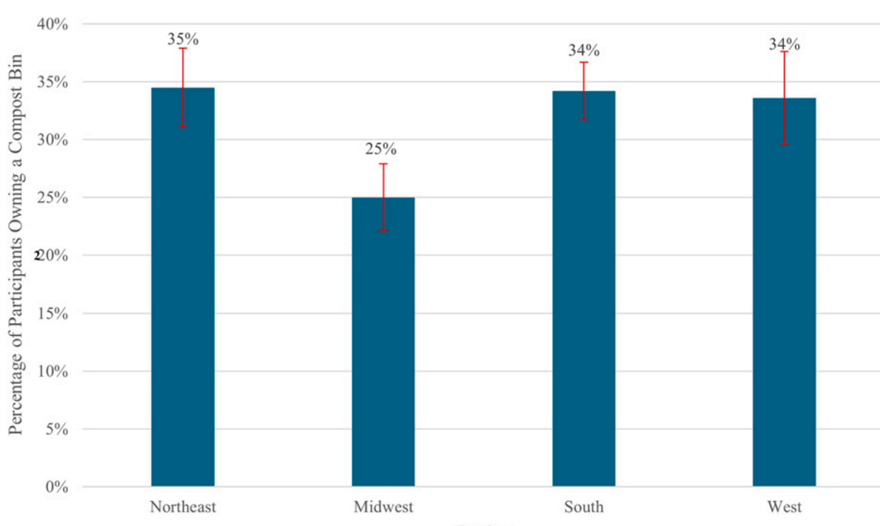

Fig. 2. Percentage of participants owning a compost bin by region based on a national survey of 925 US consumers.

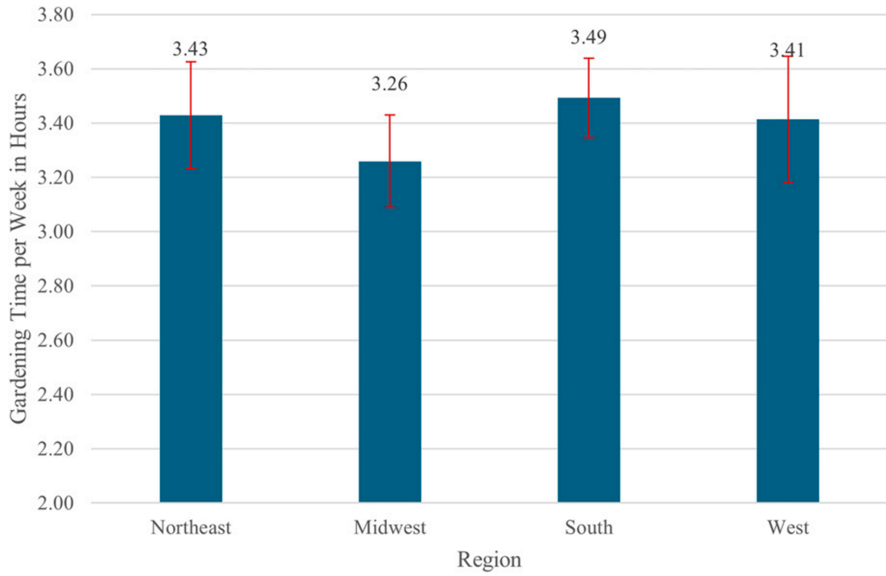

Fig. 3. Gardening time per week by region based on a national survey of 925 US consumers.

$\text{WTB}_{ij} = 3$ (slightly unlikely), if

$$v_2 < V^*_{ij} \le v_3,$$

$\text{WTB}_{ij} = 4$ (neutral), if

$$v_3 < V^*_{ij} \le v_4,$$

$\text{WTB}_{ij} = 5$ (slightly likely), if

$$v_4 < V^*_{ij} \le v_5,$$

$\text{WTB}_{ij} = 6$ (somewhat likely), if

$$v_5 < V^*_{ij} \le v_6, \text{ and}$$

$\text{WTB}_{ij} = 7$ (very likely), if $v_6 < V^*_{ij}$, where v_1 to v_6 are the thresholds for the ordered Probit model where participants change their WTB levels.

Equations [1] through [4] define the probabilities of participant i's WTB $= x$, $x = 1, 2, \ldots, 7$:

$$\begin{aligned}&\Pr(\text{WTB}_{ij} = 1|\textbf{Independent\_Variable}_{ij})\\&= \Pr(V^*_{ij} \le v_1|\textbf{Independent\_Variable}_{ij})\\&= \Pr(e_{ij} \le v_1 - (\alpha'\textbf{Independent\_Variable}_{ij})\\&\quad|\textbf{Independent\_Variable}_{ij}) = \Phi[v_1\\&\quad-(\boldsymbol{\alpha}'\textbf{Independent\_Variable}_{ij})],\end{aligned} \quad [1]$$

$$\begin{aligned}&\Pr(\text{WTB}_{ij} = x|\textbf{Independent\_Variable}_{ij})\\&= \Pr(v_{x-1}\langle V^*_{ij} \le v_x|\textbf{Independent\_Variable}_{ij})\\&= \Phi[v_x - (\boldsymbol{\alpha}'\textbf{Independent\_Variable}_{ij})]\\&- \Phi[v_{x-1} - (\boldsymbol{\alpha}'\textbf{Independent\_Variable}_{ij})],\\&x = 2, 3, 4, 5, 6,\end{aligned} \quad [2]$$

$$\begin{aligned}&\Pr(\text{WTB}_{ij} = 7|\textbf{Independent\_Variable}_{ij})\\&= \Pr(v_6\langle V^*_{ij}|\textbf{Independent\_Variable}_{ij})\\&= 1 - \Phi[v_6 - (\boldsymbol{\alpha}'\textbf{Independent\_Variable}_{ij})].\end{aligned} \quad [3]$$

In the equations, $\Phi(.)$ denotes the cumulative distribution function for standard normal distribution. With Eqs. [1] through [3], the log-likelihood function [denoted as $\log L(.)$] of the ordered Probit model can be written as Eq. [4]:

$$\log L(\boldsymbol{\alpha}) = \sum_{i=1}^{925}\sum_{j=1}^{4}\sum_{x=1}^{7} 1\{\text{WTB}_{ij} = x\} \log[\Pr(\text{WTB}_{ij} = x|\textbf{Independent\_Variable}_{ij})]. \quad [4]$$

In Eq. [4], $1\{\text{WTB}_{ij} = x\} = 1$ when $\text{WTB}_{ij} = x$; otherwise, it equals 0. $\boldsymbol{\alpha}$ is the vector of coefficients to be estimated for the independent variables.

By the maximum likelihood estimation, we can get the ordered Probit estimates $\hat{\alpha}$ satisfying

$$\hat{\boldsymbol{\alpha}} = \text{argmax}[\log L(\boldsymbol{\alpha})], \quad [5]$$

where $\hat{\alpha}$ is the vector of the estimated coefficients of the independent variables.

Results

Table 1 summarizes the descriptive statistics of the variables. The average age of the participants was ∼59 years old, indicating a significant representation of middle-aged and older individuals in our sample. Among the participants, 57.6% were female. The average education level in our sample was an associate's degree or higher. The average annual household income of our sample was ∼$63,441. In the sample, 19.5% of participants rented their home. On average, participants made six potted plant purchases per year. In addition, 32% of participants owned a compost bin. On average, participants spent about 3.41 h per week on gardening activities. Nearly all participants (98.6%) reported they were familiar with worms. The average knowledge score (based on the response of participants to three statements regarding jumping worms) was 1.94 of 3 points. Almost half (48.8%) of the participants could distinguish correctly between a jumping worm and a European nightcrawler. Geographically, 21.3% of participants resided in the Northeast, 23.8% in the Midwest, 39.8% in the South, and the remaining 15.1% in the West.

Figures 1 through 6 show how the experiences of participants with potted plants and their familiarity with and knowledge of jumping worms differ across different regions. On average, participants in the South purchased ∼6.166 potted plants annually, which was significantly more than the average annual purchases in the other regions. In the Midwest, only 25% of participants owned a compost bin, which is much less compared with the other three regions. Similarly, participants in the Midwest had the shortest average weekly gardening time (3.259 h). Across all four regions, nearly all participants believed they were familiar with worms; notably, all participants in the West reported being familiar with worms. Participants from the Northeast have the lowest knowledge score about jumping worms, with an average of 1.812 of 3 points. Only 45.4% of participants in the South could differentiate between a jumping

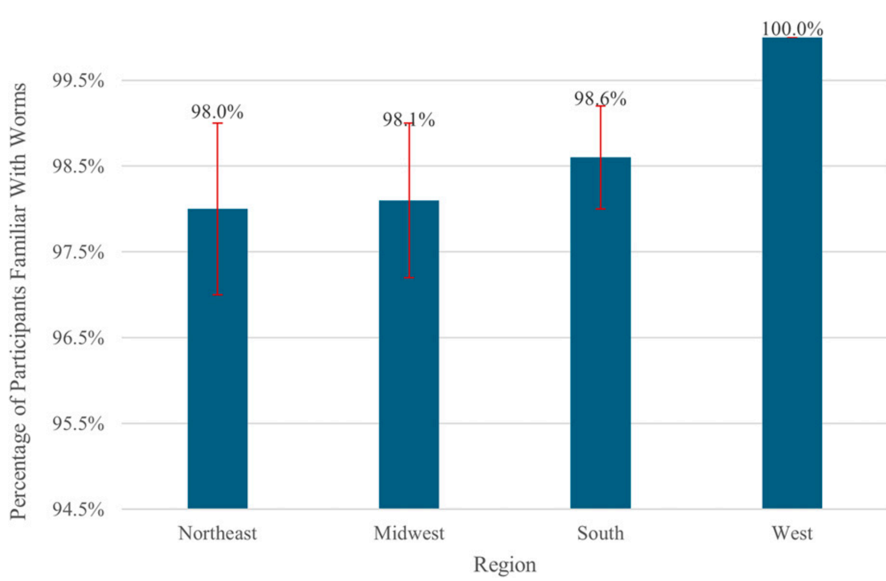

Fig. 4. Percentage of participants who are familiar with worms by region based on a national survey of 925 US consumers.

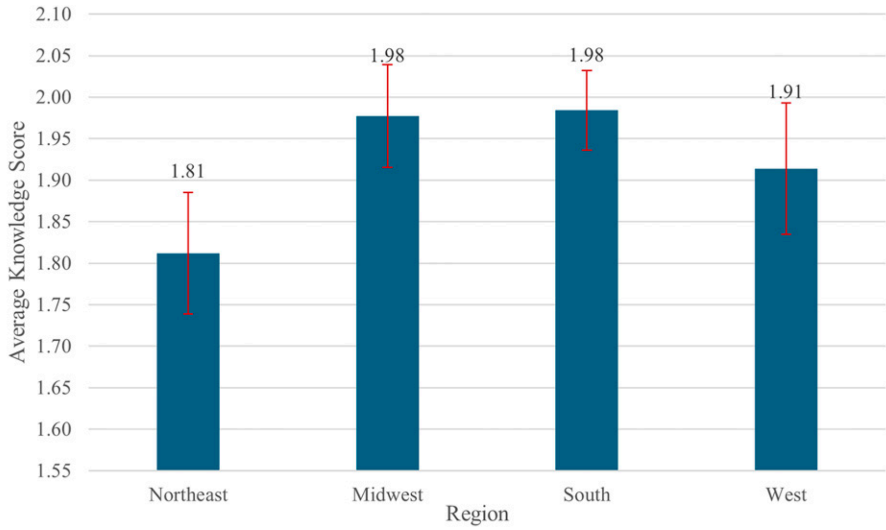

Fig. 5. Participants' average knowledge score about jumping worms by region based on a national survey of 925 US consumers. Total score = 3 points.

worm and a European nightcrawler, whereas this percentage exceeded 50% in the other three regions. For each question, participants were asked to indicate their likelihood of purchase on a 7-point Likert scale with 1 point = very unlikely and 7 points = very likely. The average WTB for a potted plant not treated for jumping worms was 3.96 before participants were informed of the harmfulness of jumping worms. This value decreased to 3.30 after participants were informed. This result suggests that, in general, participants were less inclined to purchase a untreated potted plant after they learned about the detrimental effects of jumping worms. Conversely, the average WTB for a treated potted plant increased from 4.89 to 5.29 after providing information on the harmfulness of jumping worms. In other words, awareness of the harmfulness of jumping worms increased the WTB potted plants with the jumping worm treatment. The maximum WTB was 7 points (Fig. 7).

Table 2 shows the results of the ordered Probit model. The coefficients of the three-way interaction of age indicate how the willingness of older consumers to buy a potted plant varies with the treatment and information. Consider the scenario in which the potted plant has not been treated for jumping worms (treated = 0). Before being informed about the harmfulness of jumping worms (informed = 0), the significantly negative coefficient of age suggests that older participants are less willing to purchase untreated plants compared with younger participants. After being informed about the harmfulness of jumping worms (informed = 1), the coefficient becomes even more significantly negative, indicating that the information further reduces the WTB of older participants. This result suggests that the information makes older participants more aware of the harmful effects of jumping worms, thereby decreasing their WTB even more. Similarly, when the potted plant had been treated (treated = 1), the information, at least in part, mitigated the reluctance to buy of older participants, as the previously negative and significant coefficient of age became insignificantly positive after they were informed about the harmfulness of jumping worms (informed = 1). This result implies that the information may help older participants recognize that treatment makes potted plants safer.

The coefficients of the three-way interaction of the female indicator exhibit a pattern similar to that of the age coefficients (i.e., the information makes females more unwilling to buy an untreated potted plant). This result indicates that females may refer to the information when reassessing their WTB and may have recognized the potential risks associated with jumping worms. However, the information did not present a significant impact on females' WTB a treated potted plant.

According to the coefficients, the information did not affect how education level influenced participants' WTB. Education level did not change participants' WTB a treated potted plant. This result might be because a higher education level enhances participants' confidence in their own judgment, and they choose to adhere to their judgment, despite the information indicating that jumping worms are detrimental.

The coefficients of the three-way interaction of income suggested that, after being informed of the detrimental effects of jumping worms, participants with higher incomes exhibited a greater WTB treated potted plants.

Although only one coefficient is significant, three of four coefficients of the three-way interaction of renting a home were negative, implying that participants who rented a home were more unwilling to buy a potted plant. Participants who rented a home had less motivation to decorate it with potted plants compared with those who owned a home. This result is consistent with previous research (Behe 2006) that showed homeowners were more likely to participate in gardening-related activities and make gardening-related purchases compared with renters. In addition, after learning about the harmfulness of jumping worms, their WTB an untreated potted plant was significantly reduced.

All coefficients of the three-way interaction of the average annual potted plant purchase amount were positive. Participants who purchased more potted plants tended to have a stronger preference for them, making them more likely to purchase a new potted plant. Similar to the pattern of education level, participants who made higher average annual potted plant purchases were more willing to buy an untreated potted plant, which is affected significantly by the jumping worm harmfulness information. They might be more confident in their own experience and prefer to adhere to their judgment.

Both the knowledge score and the indicator of whether participants can distinguish correctly a jumping worm from a European nightcrawler measured their familiarity with jumping worms. The coefficients of the

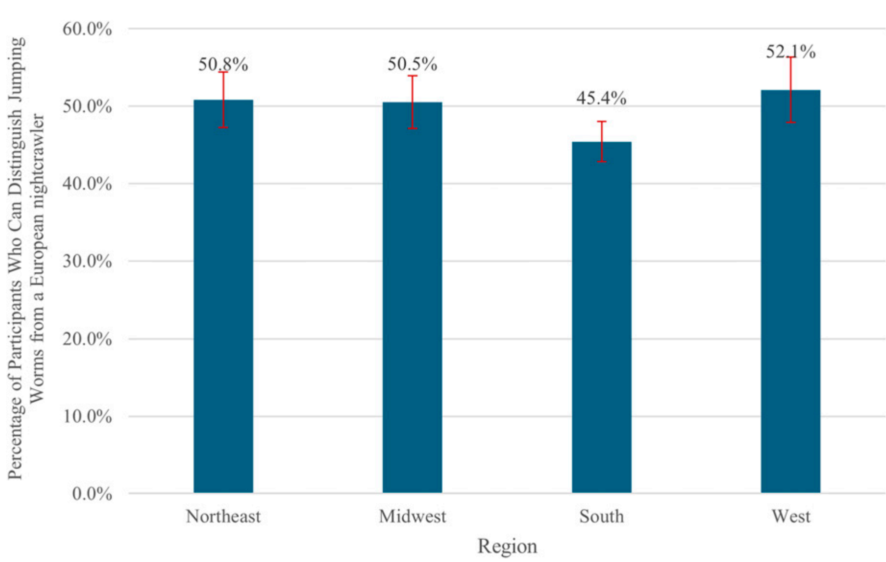

Fig. 6. Percentage of participants by region that can distinguish jumping worms from a European nightcrawler based on a national survey of 925 US consumers.

Table 2. Ordered probit model estimation results on how the willingness of participants to buy a potted plant is influenced by jumping worm treatment, their awareness of the harmfulness of jumping worms, gardening habits, and demographics.

Variable	Coefficient (standard error)
Treated	0.487 (0.508)
Treated × informed	
Treated = 0	0.090 (0.518)
Treated = 1	–0.246 (0.509)
Treated × informed × age	
Treated = 0, informed = 0	–0.005 (0.003)**
Treated = 0, informed = 1	–0.014 (0.003)***
Treated = 1, informed = 0	–0.006 (0.003)**
Treated = 1, informed = 1	0.002 (0.003)
Treated × informed × female	
Treated = 0, informed = 0	–0.125 (0.073)*
Treated = 0, informed = 1	–0.303 (0.074)***
Treated = 1, informed = 0	–0.034
Treated = 1, informed = 1	0.096
Treated × informed × education	
Treated = 0, informed = 0	0.120 (0.035)***
Treated = 0, informed = 1	0.113 (0.034)***
Treated = 1, informed = 0	0.022 (0.035)
Treated = 1, informed = 1	0.025 (0.036)
Treated × informed × income	
Treated = 0, informed = 0	0.0004 (0.008)
Treated = 0, informed = 1	0.006 (0.008)
Treated = 1, informed = 0	0.008 (0.008)
Treated = 1, informed = 1	0.02 (0.008)**
Treated × informed × renting	
Treated = 0, informed = 0	–0.031 (0.092)
Treated = 0, informed = 1	–0.177 (0.094)*
Treated = 1, informed = 0	–0.044 (0.02)
Treated = 1, informed = 1	0.003 (0.092)
Treated × informed × purchase	
Treated = 0, informed = 0	0.029 (0.009)***
Treated = 0, informed = 1	0.024 (0.009)***
Treated = 1, informed = 0	0.008 (0.009)
Treated = 1, informed = 1	0.0003 (0.009)
Treated × informed × compost	
Treated = 0, informed = 0	0.083 (0.086)
Treated = 0, informed = 1	–0.034 (0.088)
Treated = 1, informed = 0	–0.126 (0.087)
Treated = 1, informed = 1	–0.072 (0.088)
Treated × informed × gardening	
Treated = 0, informed = 0	0.001 (0.015)
Treated = 0, informed = 1	–0.006 (0.015)
Treated = 1, informed = 0	0.020 (0.015)
Treated = 1, informed = 1	0.011 (0.015)
Treated × informed × familiar	
Treated = 0, informed = 0	0.159 (0.292)
Treated = 0, informed = 1	0.379 (0.305)
Treated = 1, informed = 0	0.364 (0.292)
Treated = 1, informed = 1	0.223 (0.292)
Treated × informed × knowledge	
Treated = 0, informed = 0	–0.085 (0.037)**
Treated = 0, informed = 1	–0.020 (0.038)
Treated = 1, informed = 0	–0.011 (0.037)
Treated = 1, informed = 1	–0.033 (0.038)
Treated × informed × distinguishing	
Treated = 0, informed = 0	–0.195 (0.069)***
Treated = 0, informed = 1	–0.038 (0.070)
Treated = 1, informed = 0	0.024 (0.069)
Treated = 1, informed = 1	–0.037 (0.070)
Treated × informed × Northeast	
Treated = 0, informed = 0	–0.029 (0.116)
Treated = 0, informed = 1	–0.184 (0.118)
Treated = 1, informed = 0	–0.010 (0.116)
Treated = 1, informed = 1	0.144 (0.118)
Treated × informed × Midwest	
Treated = 0, informed = 0	0.003 (0.114)
Treated = 0, informed = 1	–0.285 (0.115)**
Treated = 1, informed = 0	–0.132 (0.114)
Treated = 1, informed = 1	0.0280 (0.115)
Treated × informed × South	
Treated = 0, informed = 0	–0.061 (0.105)

(Continued on next page)

three-way interaction presented the same pattern, where the only significant negative coefficient was for an untreated potted plant and before being informed of the harmfulness of jumping worms. This result is consistent with the literature, which shows that consumers with prior knowledge have greater support for invasive non-native species management projects (Bremner and Park 2007). Before being informed, participants with higher knowledge scores or those who could distinguish a jumping worm from a European nightcrawler were less likely to buy an untreated potted plant. Because these individuals know more about jumping worms, their knowledge can help them avoid the risks associated with untreated potted plants, resulting in their lower WTB. However, after everybody had learned about the detrimental effects of jumping worms, the familiarity impact disappeared.

Based on the coefficients of the three-way interaction involving the indicator of living in the Midwest, participants living in that region were less likely to purchase an untreated potted plant after they were made aware of the detrimental effects of jumping worms. Given that the Midwest is heavily infested with jumping worms, participants in that area were more likely to have encountered them. The higher likelihood of exposure fostered a heightened awareness and level of caution after learning about the harmful effects of jumping worms, thereby reducing their likelihood of buying an untreated potted plant. Other variables did not have a significant effect on participants' WTB a potted plant.

Discussion

Jumping worms are an invasive species that pose a significant threat to soil health and ecosystem stability. The spread of jumping worms has, historically, been facilitated by human activities, particularly through the transportation of horticultural products (Bellitürk et al. 2015; Brown 1878; Chang et al. 2021; Houchins 1995; Nelson 1917). Unlike other earthworms, jumping worms consume organic matter rapidly, depleting soil nutrients and disrupting plant growth. Their unique feeding behavior makes the soil structure more granular and less capable of retaining water, which affects plant roots negatively and increases erosion risks. Given these environmental concerns, it is crucial to study consumer knowledge and WTB plants treated to mitigate jumping worm infestations. Understanding consumer attitudes toward these treatments can inform the development of effective market and public education strategies.

We conducted a survey of 1000 US consumers to evaluate their knowledge about jumping worms and to investigate how jumping worm treatment and information about jumping worms affect their WTB potted plants.

We found consumer awareness of jumping worms significantly influenced their WTB potted plants. Treatments for jumping worms increased the likelihood of purchase, especially after consumers were informed about the

Table 2. (*Continued*)

Variable	Coefficient (standard error)
Treated = 0, informed = 1	–0.117 (0.106)
Treated = 1, informed = 0	–0.036 (0.105)
Treated = 1, informed = 1	0.078 (0.105)
v_1	−0.906 (0.360)**
v_2	−0.597 (0.360)*
v_3	−0.369 (0.360)
v_4	0.429 (0.360)
v_5	0.817 (0.360)**
v_6	1.310 (0.360)***
No. of observations	3700

*, **, *** Significant at $P < 0.1$, $P < 0.05$, and $P < 0.01$, respectively.

Treated × Informed × West was not included in the estimation due to perfect collinearity and it was used as the base for estimation.

harmful effects of these worms. Knowing more about the harmful effects of jumping worms made consumers more risk-averse, and fewer planter were bought. Conversely, the WTB treated plants increased significantly after being informed, indicating that consumer education is crucial in influencing purchasing decisions, making them more aware and cautious.

Older participants showed a significant decline in WTB untreated plants upon receiving information, indicating a higher risk perception in this age group. However, the WTB treated plants among older participants increased, suggesting they appreciate mitigation efforts when adequately informed. Female participants also exhibited a reduced WTB untreated plants after being informed, highlighting their greater sensitivity to environmental risks compared with others. Higher education and income levels correlated with a greater WTB treated plants. This might be result of a better comprehension and appreciation for preventive measures against invasive species among those with higher education levels and incomes. This finding aligns with earlier research (McClendon et al. 2024; Tangeland et al. 2013) that demonstrated people with higher incomes showed more concern about invasive species and tended to participate in nature-based activities more than those with lower incomes.

Participants in the South display the greatest purchase frequency for potted plants, which could be influenced by regional gardening trends and climate. Because of the warmer climate, the South has a significantly extended growing season compared with other regions in the United States (Albert 2020). Moreover, in comparison with the Northeast and West, residents in the South typically own larger properties, which is primarily a result of the greater prevalence of outer suburban and rural areas in the South, where home lots tend to be larger (Freedonia Group 2024). This fact enables people in the southern United States to have more space for home gardening. Because of the longer growing season and more gardening space, people in the South can plant more species and garden longer every year, which might lead to a greater chance of them being exposed to, and thus more familiar with, jumping worms. Despite their familiarity with worms, their knowledge about worms was relatively low, suggesting a need for targeted educational outreach. Given the greater infestation rates, participants in the Midwest show heightened caution toward untreated plants once informed. This result indicates that direct experience with jumping worms significantly influences consumer response to jumping worms. Participants with higher worm knowledge scores, or those who can distinguish between a jumping worm and a European nightcrawler, are less likely to buy untreated plants initially. This result demonstrates that prior knowledge equips consumers with better risk assessment capabilities. However, after being supplied with information, this distinction becomes less significant, because all participants receive the same information.

It is important for consumers to be able to identify jumping worms from other earthworms. In our study, only 50% of respondents were able to identify these invasive worms correctly, highlighting a significant gap in public awareness and education. These errors can lead to misdirected control measures, wasted resources, invasive species spread, incorrect tracking, and unnecessary concern. Misidentification of jumping worms can have significant ecological and management consequences. If nonjumping worm species are removed mistakenly, beneficial earthworms may be eliminated unnecessarily, disrupting soil health and nutrient cycles. On the other hand, failing to recognize jumping worm infestations can allow their populations to spread unchecked, leading to soil degradation, reduced plant growth, and altered forest ecosystems. To address this issue, targeted educational initiatives, improved field identification guides, and enhanced outreach efforts should be prioritized. Strengthening public knowledge will not only improve reporting accuracy, but also will contribute to more effective management strategies for these invasive species.

Research has shown that providing consumers with relevant environmental information can significantly affect their purchasing behavior and willingness to adopt sustainable practices (Fu et al. 2023). For example, Kim and Lee (2023) suggested that informed individuals are more likely to make choices that mitigate ecological harm. Others, including Palani (2023), found that when consumers are given clear, science-based information about the environmental impact of their choices, they are more inclined to select ecofriendly products. Yang and Yu (2024) demonstrated the importance of accessibility to information in achieving environmental sustainability. Our study also indicates that increased awareness of the harmfulness of jumping worms decreases consumers' WTB untreated plants, while increasing their WTB treated plants, which is consistent with a previous study (Roberts 1996) that showed environmental awareness was important to bridge the gap between environmental issues and sustainable behavior. Therefore, we recommend the dissemination of information to consumers on jumping worms to enhance knowledge and awareness of jumping worms and their adverse environmental effects. Recommendations for information dissemination include educational campaigns, in-store information, and collaborative efforts. Targeted educational initiatives focusing on the harmful

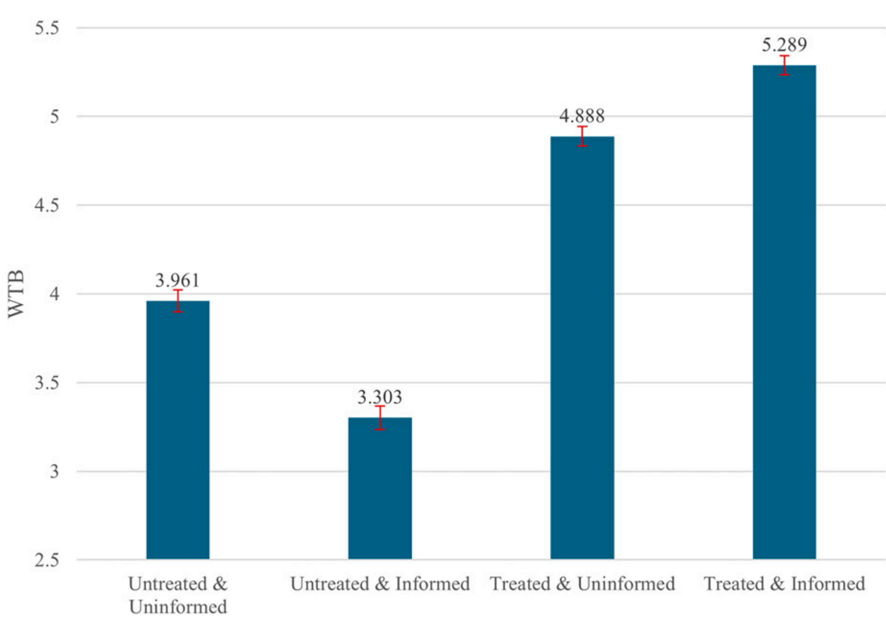

Fig. 7. Willingness to buy (WTB) potted plants that were treated or untreated for jumping worms by participants who read or did not read the information about jumping worms based on a national survey of 925 US consumers.

effects of jumping worms and the benefits of treatments could influence consumer behavior significantly and reduce the spread of the invasive species. Garden stores could display information about jumping worms and the importance of treated plants to inform consumers at the point of purchase.

A limitation of our study was the reliance on self-reported data, which might be subject to bias, such as social desirability. Experimental validations could strengthen the findings. Although the knowledge score provides insight into the awareness of participants in our study, a more comprehensive assessment could offer a deeper understanding. Another limitation was the overrepresentation of middle-aged and older females, which may limit the generalizability of our results. Future studies could explore behavior changes over time to understand the long-term effectiveness of information dissemination and consumer behavior.

Conclusion

Addressing the jumping worm invasion requires a collaborative effort from consumers, horticulturists, and policymakers to ensure the protection of our ecosystems. By understanding and influencing consumer behavior, significant steps toward mitigating the impact of invasive species and preserving our natural habitats can take place. The greater WTB treated plants among informed participants suggests that consumers are willing to invest in preventive measures when they understand the risks of jumping worms. Nurseries and garden centers could use this information to educate customers on the effects of jumping worms, thereby increasing sales of treated plants while mitigating invasive species. Educational campaigns focused on the dangers of jumping worms could reduce their spread significantly by altering consumer behavior.

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