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Agriculture communities' perception and willingness to pay for eradicating *Xanthium strumarium* L: A step towards the progressive decrease of economic and biodiversity loss

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ABSTRACT: *Xanthium strumarium* L. is native to North America and rapidly spreading in Khyber Pakhtunkhwa (KP) Pakistan as an alien invasive plant species (AIPs) and possess a severe threat to crops. Hence this study was conducted to assess socioeconomic impacts on agriculture, livestock, and biodiversity along with the mode of invasion, spread, and willingness to pay for its eradication in selected areas of KP Pakistan. **Methods:** Three divisions of Khyber Pakhtunkhwa province , i.e. Malakand, Peshawar, and Hazara, were selected for the study. The respondents were divided into two categories, i.e., agricultural and non-agricultural. The respondent's information was collected using a closed-ended questionnaire and semi-structured interview. The data were analyzed and interpreted by tabulation in excel 2010, and variation was tested using online chi-square tests. **Results:** Most respondents believed that the plant preferred to grow on the roadside and wasteland, affecting crops, especially maize, and infesting the areas for more than 20 years with regular and timely increased infestation. Livestock animals are affected severely in health and products. The chi-square test results indicated that the agricultural communities were affected more than non-agricultural communities. The invasion of the species has affected people's livelihood to the extent that they would spend money on its eradication/control. Biodiversity effects were severe in all the areas, as revealed by decreased species richness index in invaded sites. **Conclusions:** We concluded that cash crops and communities' economic value suffered severely from the invasion of *X. strumarium*, and therefore integrated management is needed for its control and eradication.

KEY WORDS: Agriculture, Live-stock, Invasive alien species, *Xanthium strumarium*, respondents.

INTRODUCTION

Alien invasive plants (AIPs) biophysical aspects have been considered for scientific studies for a long time (Martin and Genovesi, 2013). However, the socioeconomic aspect of AIPs invasion has rarely been focused on and is therefore merely studied (Charles and Dukes, 2007). The reasons for not considered focusing on AIPs socioeconomic aspect may be attributed to a number of reasons, which may include 1) the inability of the markets to capture the economic value of the damage caused by AIPs on many ecosystem services, 2) limited knowledge and experience with AIPs impacts on ecosystems and 3) conflicts of interest often associated with AIPs control (Pejchar and Money, 2009) that affect massive scale conservation and management policies designed for their control. These challenges are critical, and constructive considerations are generally required for ecosystem conservation to prevent biodiversity loss and native communities' conservation, especially in protected areas. In contrast, certain special cases may also harbour difficulties evaluating the strategies, including human-induced pressures, lack of financial resources, and competition for conservation projects (Emerton *et al*., 2006).

Recently several methods have been evaluated to study the impacts of AIPs on social and economic livelihood (Pejchar and Money, 2009). These include cost-based methods like production function, replacement cost and avoided damage cost, and preference-based methods like travel cost method, contingent valuation, and choice of the experiment. Amongst the preference-based techniques, Contingent Valuation (CV) has commonly been used to assess the public's perception of the impacts of AIPs and their willingness to pay (WTP) for control programs. CV method is survey-based, where responses are directly recorded beside their preferences for quantitative or qualitative deviations in ecosystem goods or services (Alberini and Kahn, 2006). Even though CV has its limitations (Venkatachalam, 2004), it is still a useful way to provide input into the decision-making process, especially when dealing with effects not expressed through market signals (Bräuer, 2003). The method was employed to assess the economic value of potentially eradicating a single AIP, such as *Eichhornia crassipes* (Law, 2008) and *Acacia saligna* (Lehrer *et al*., 2013) or a set of AIPs (Bardsley and Jones, 2006). Still, few studies have examined agricultural communities' perception of WTP for AIP control, especially in PAs that are directly dependent on the economy and social livelihood of people in the area.

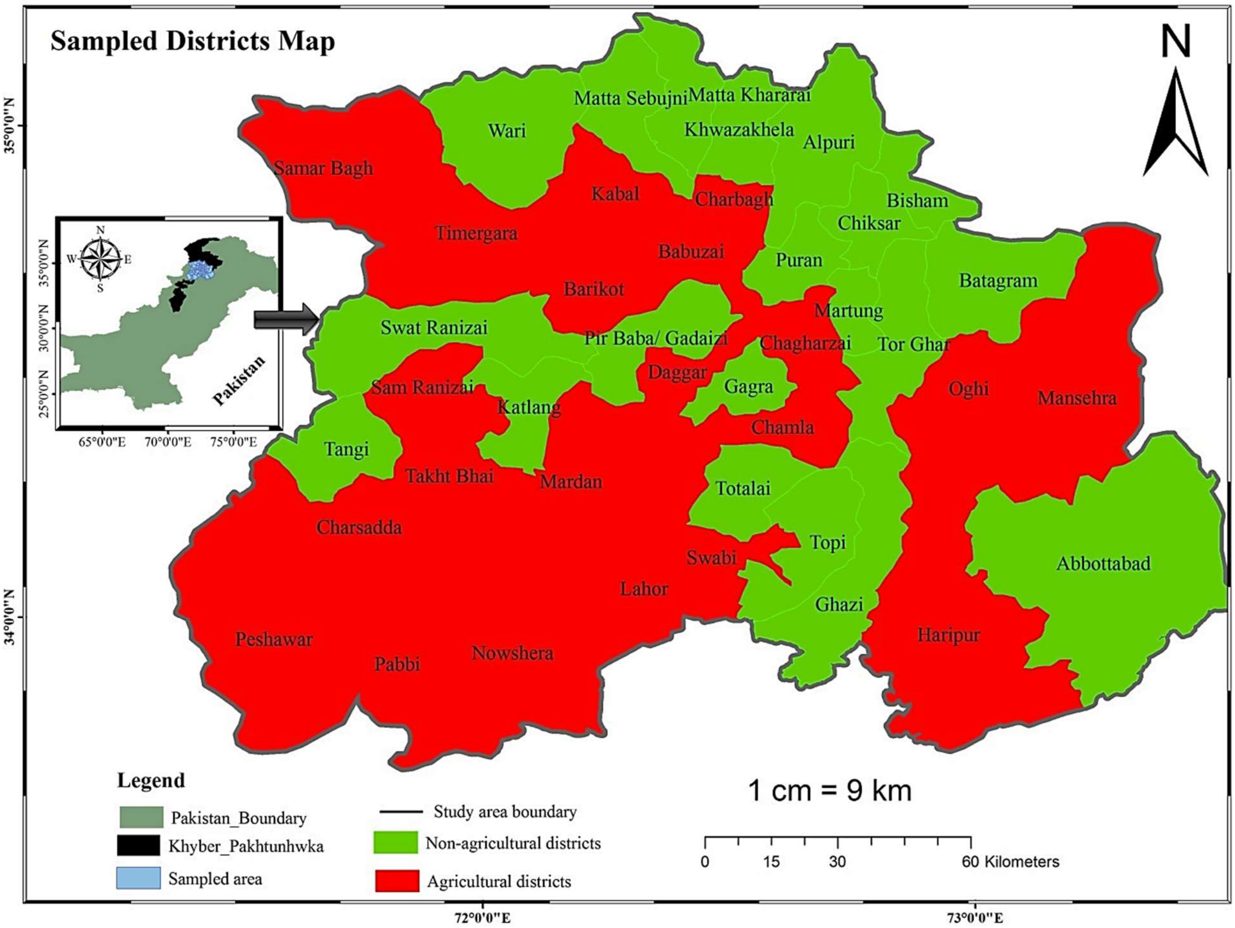

Fig. 1. Map of the study area showing agriculture districts in red and non-agriculture in green.

This research project investigates the agricultural communities' perceptions of selected AIPs present in Khyber Pakhtunkhwa (KP) and assesses farmers WTP to control *Xanthium strumarium* L. (hereafter *X. strumarium*) in KP, using combined CV and visual aids surveys. *X. strumarium* was selected for its severe impacts on agricultural communities concerning crop and livestock yield reduction. The plant also causes diseases without any critical potential benefits for local communities in or around conservation areas, as the plant is not used for animal forage or human consumption. *X. strumarium* is an invasive, herbaceous, annual, monoecious plant species of the Asteraceae (Dekker, 2011). The native range of the species is supposed to be North and Central America, from where it invades and is distributed throughout the world (Dekker, 2011). There was found variation in a morphological characteristic of fruits, an essential structure for its reproduction and propagation with agreement on the number of chromosomes, i.e., 2n=36, and is tetraploid (Kaur *et al*., 2014; Dekker, 2011). The plant species has the enormous ability for invasion tolerating wide ranges of temperatures, and is usually found in wetlands of ruderal areas affecting different crops, i.e., maize, cotton, soybeans, and groundnuts in different parts of the world (Sartorato *et al*., 1996; Amini *et al*., 2014). The plant invades grazing pastures reducing the biomass of forage species, consequently decreasing the production of dairy products and grazing animals (Kamboj and Saluja, 2010; Weaver and Lechowicz, 1983). The sticky fruit causes reasonable disturbance to animals and human hairs with skin irritation, and its phytochemical can cause liver disorders, muscular spasms, vomiting, and death in rare cases (Weaver and Lechowicz, 1983). In KP, the plant was distributed throughout the plains covering the fields and gradually invaded the hills up to 8000 ft. in northern regions with no competitors (Marwat, 1993). Afghan refugees introduced the plant during the war in 1979 through the transportation of their domestic sheep and goats (Hashim and Marwat, 2002).

METHODS

Study area

The study was conducted in Khyber Pakhtunkhwa Province of Pakistan with three sampled divisions, i.e., Peshawar, Malakand, and Hazara, based on the intensity of invasion and its effects. The latitude and longitude are

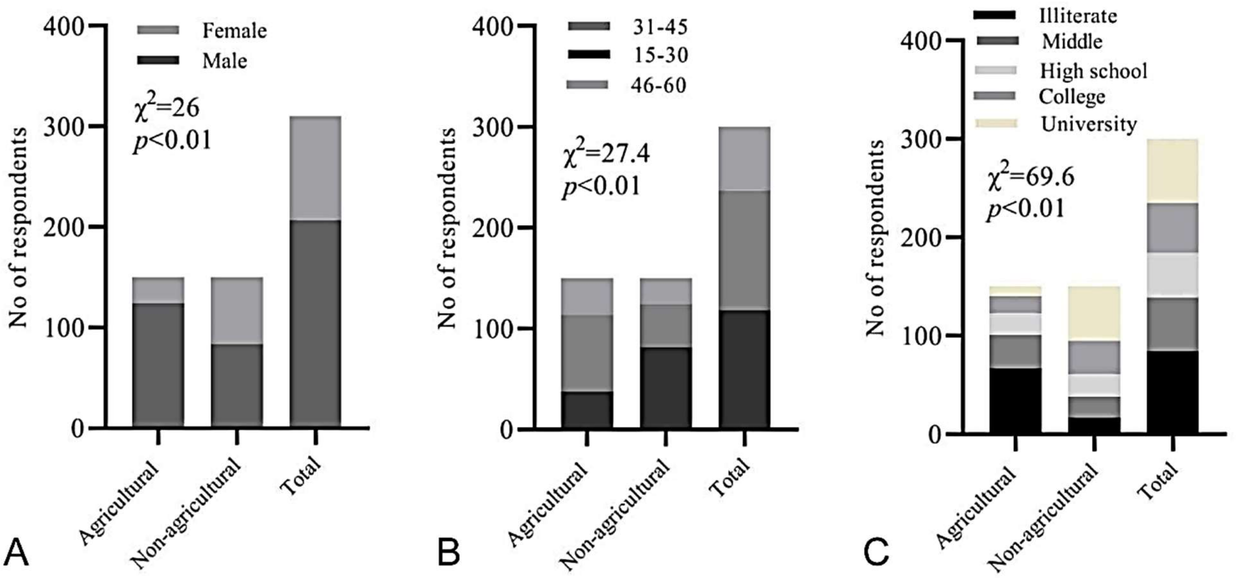

Fig. 2. Demography of the respondent according to (**A**) gender, (**B**) age, and (**C**) education in agricultural and non-agricultural categories.

34°02' and 71°56′ for Peshawar, 34°44′ and 72°21′ for Hazara, and 34°11′ and 73°15′ for the Malakand division (Figure 1). The provincial capital is Peshawar and is considered the province's largest city, while Malakand and Hazara division lies in the northern parts. The climate is arid in plain areas while humid sub-tropical passes from plains to hills (Wasim, 2018). The climate of the area is variable, where June is the hottest month with a mean maximum and minimum temperature of 34.96±1.36 °C and 19.10±1.50 °C, respectively. January is the coldest month, with a mean maximum and minimum temperature of 13.72±1.39 °C and 0.67±0.97 °C indicating that winters are more severe where the temperature generally falls below the freezing point (Rahman and Khan, 2013). The average annual precipitation ranges (Khan, 2013) from 384 mm to 639 mm, whereas the relative humidity varies between 54.81±2.18% to 77.35±3.12% (Ali *et al*., 2018). The area's climate plays a pivotal role in the economic, social, hydrological, and agricultural activities and is thus necessary for vegetation structure analysis (Deo and Sahin, 2015). The plant under investigation was widely spread in the study area ranging from plains to 8,000ft across the northern areas. The plant damages crops in areas like Nowshera, Abbottabad, Mardan, and Mansehra districts and abundantly grows along the roadside and ruderal areas (Marwat *et al*., 2010).

Data Acquisition

The CV and WTP surveys were conducted to evaluate the agricultural communities' perception of *X. strumaium* invasion following Alberini and Kahn (2006). The CV survey questionnaire was pre-tested by agriculture officers in the respective districts for external clarity and validity and for collecting sufficient information and time duration needed from the respondents. After properly screening the comments, modifications were incorporated and randomly distributed to three hundred respondents, including agricultural and non-agricultural communities, in equal numbers. In the survey, non-agricultural communities' were included to compare the responses and severity of the problem regarding the agricultural community following Arrow *et al*. (1993) by distributing a close-ended questionnaire. The questionnaire has seven parts that focus on different features, i.e., Part I focuses on the respondents' demographic information (Age, Sex, Education, profession, Address).

In contrast, Part II focuses on the information related to *X. strumarium* period of prevalence, area of infestation, rate of invasion, and mode of spread. Part III, IV and V of the questionnaire focus on their impacts on agricultural, livestock, and human health, whereas Part VI reveals the eradication method used to control its spread. The agriculture communities' WTP for eradicating the plant was evaluated in Part VII of the questionnaire. Semi-structured interviews were conducted for gathering additional data and verifying the information collected from the respondents in the survey. *X. strumarium* invasion impacts on biodiversity were assessed in 18 different sites in three divisions by counting the number of species in invaded and non-invaded plots, as Gotelli and Chao (2013) described.

Statistical analysis

The data were arranged in contingency tables using Excel 2010 and were subjected to various descriptive statistical analyses, i.e., percentages, frequencies, and arithmetic mean. The data were analyzed using a chi-square (χ^2) test to evaluate the difference in responses between the agricultural and non-agricultural communities.

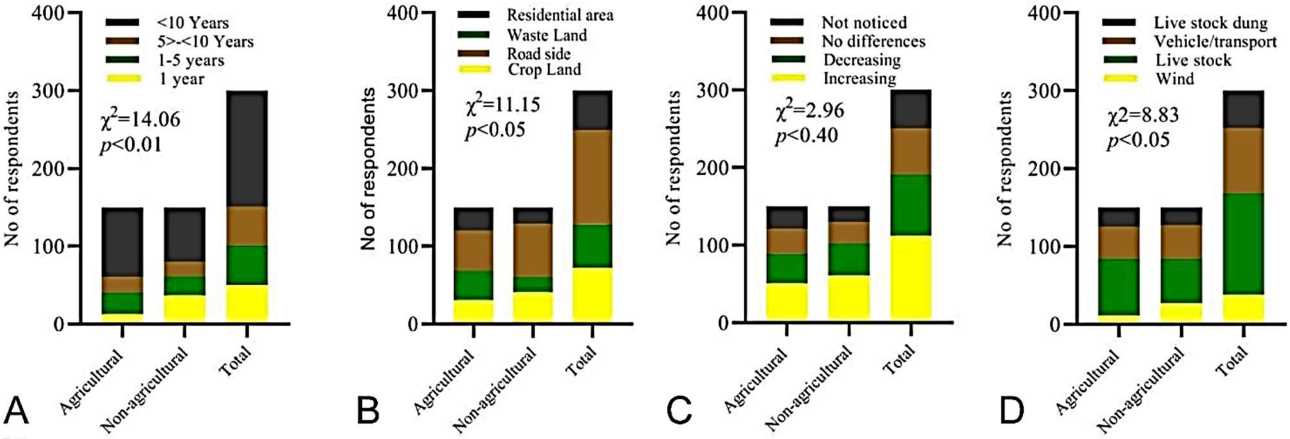

Fig. 3. Shows the response of respondents regarding information about ***Xanthium strumarium*** L. **A**. Period of prevalence. **B**. Infestation area. **C**. Rate of invasion. **D**. Mode of spread.

RESULTS

Impacts of *Xanthium strumarium*

Figure 2 shows the gender, age, and education of the respondents. The proportion of males was more than females ($p < 0.05$) because agriculture is gender-oriented, demanding more males than females. In age distribution, agricultural and non-agricultural communities exhibited a significant chi-square difference ($p < 0.01$). The average age of the respondent engaged in agriculture was between 30-45 years of age, as agriculture is a laborious profession and needs energetic people. Education-wise, most of the respondents in agricultural families were illiterate using old agriculture practices. In non-agricultural communities, most of the respondents were university-level, indicating that agriculture is not an attractive profession for the area's people. Therefore the agricultural communities do not use useful tools for eradicating invasive weeds. The agricultural system got defaults from time to time with the increase of invasive species and reduces crop yield. According to chi-square statistics, the education difference among the communities was significant ($p<0.01$).

The respondents were interviewed regarding *X. strumarium* L. invasion (Figure 3). Most respondents (49.66%) thought that the species was introduced <10 years before, while an equal number of respondents has the view that the plant may invade the area from 1 to 5 or 10 years. The area frequently invaded by the plant species is the roadside (40.34%), followed by the cropland (24%), while the differences in infestations are significant ($\chi^2=11.15$, $p<0.01$). The rate of invasion tends to increase and is viewed by 37.34% of the respondents indicating the plant will further enhance its propagation and affect the roadside and cropland areas. According to the respondents (43.33%), the plant spread through livestock, while 28% replied about its spread through automobiles transport. The difference among the respondents' views was significant ($\chi^2=8.8$, $p<0.03$).

Respondents were interviewed regarding the impacts of the invasive plant species on agriculture (Table 1). It is one of the most listed weeds found in crops; 72.34% of the respondents agreed on its nuisance. The most affected crops include maize, wheat, rice, sugar cane, and vegetables. The most affected crop, according to the respondents, was maize (30.67%), followed by vegetables (24.66%), while the less affected crop was wheat (10%). Some non-agricultural respondents were unaware of the most affected crop by *X. strumarium* L. In addition, agricultural and non-agricultural respondents elaborated the weed effects of the plant species in the maize field. The lowest number of agricultural respondents responded not knowing about the crop affected by the plant species in their vicinity. The respondents' responses varied significantly with chi-square statistics ($p<0.05$), indicating respondents' differences in opinion regarding the crop most affected. The results show significant variations ($\chi^2=16$, $p<0.01$), indicating that the species are nuisance weeds.

Livestock is one of the important resources for the agricultural community as many of the forage plants act as food for livestock animals. The agricultural community provides forage for grazing animals. Palatability of the plants is less, i.e., 37% agree on using by grazing while 64% of the respondents agreed on seldom used by livestock animals (Table 2). According to 40% of the respondents, the species affected animal health, while 32% believed it decreased milk quantity. The chi-square test variation was significant in all the parameters regarding the impact on livestock, with the highest variation in its effects on livestock and its product ($\chi^2= 30.762$, $p< 0.01$). Agricultural and non-agricultural communities agreed that this plant had pronounced effects on dermal health, causing skin allergies and irritations (Table 3). According to some respondents, the plant species may cause respiratory disorders, which might be due to allergies or other unknown reasons. The differences in chi-square statistics was significant for all

Table 1. Shows the impacts of ***Xanthium strumarium*** as a weed on different staple crops.

Nuisance weed					
Variables	Agriculture (150)	Non-Agriculture (150)	Total (300)	χ^2-Value	Sig Level
Yes	124 (82.66)	93 (62)	217 (72.34)	16.00	$p<0.01$
No	26 (17.34)	57 (38)	83 (27.66)		
Crop most effected					
Maize	53 (35.34)	39 (26)	92 (30.67)	11.57	$p<0.05$
Wheat	17 (11.33)	13 (8.67)	30 (10)		
Rice	13 (8.66)	19 (12.66)	32 (10.66)		
Sugarcane	27 (18)	17 (11.33)	44 (14.66)		
Vegetables	31 (20.66)	43 (28.66)	74 (24.66)		
Not known	9 (6)	19 (12.66)	28 (9.33)		

Table 2. Shows the impacts of ***Xanthium strumarium*** on livestock and its products.

Palatability					
Variables	Agriculture (150)	Non-Agriculture (150)	Total (300)	χ^2-Value	Sig Level
Yes	38 (25.33)	73 (48.67)	111 (37)	17.51	$p<0.01$
No	112 (74.67)	77 (51.33)	189 (63)		
How often eaten					
Frequent	13 (8.66)	35 (23.33)	48 (16)	13.68	$p<0.01$
Moderate	37 (24.66)	23 (15.33)	60 (20)		
Seldom	100 (66.67)	92 (61.34)	192 (64)		
Effects Livestock/product					
Animal Health	83 (55.33)	37 (24.66)	120 (40)	30.76	$p<0.01$
Milk Quality	13 (8.67)	31 (20.66)	44 (14.66)		
Milk Quantity	38 (25.33)	58 (38.67)	96 (32)		
Bodyweight	16 (10.66)	24 (16)	40 (13.34)		

Table 3. Shows respondent's view regarding impacts of ***Xanthium strumarium*** on Human health.

Health problems					
Variables	Agriculture (150)	Non-Agriculture (150)	Total (300)	χ^2-value	Sig-level
Skin Allergies	131(87.34)	129(86)	260 (86.66)	0.11	Not Significant
Respiratory disorders	19 (12.66)	21(14)	40 (13.34)		
Beneficial Use					
Yes	23 (15.34)	12 (8)	35 (11.66)	3.91	$p<0.05$
No	127 (84.66)	138(92)	265 (88.34)		

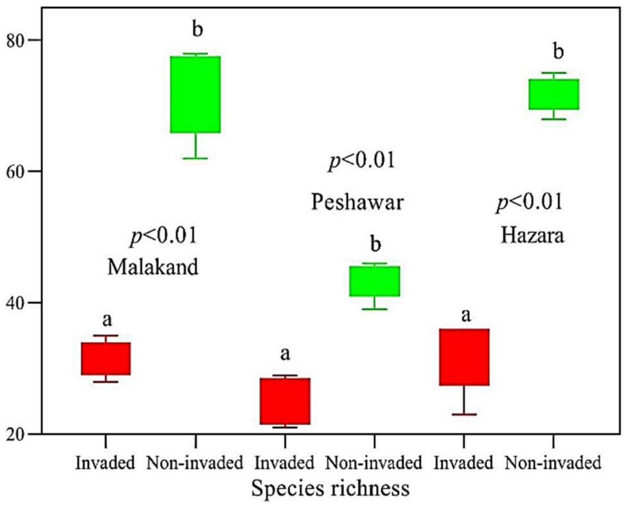

Fig. 4. Comparison of species richness between ***Xanthium strumarium*** invaded and Native areas.

the parameters, i.e., palatability, how often eaten, and effects of livestock/product ($p<0.01$). A few of the respondents (11.66%) believed that this plant has a beneficial effect and will probably clean wasteland, while most respondents (88.34%) suggested that this plant has no beneficial effects.

The effects of *X. strumarium* on species richness was pronounced and presented in Figure 3. The species richness in invaded areas was lower than in non-invaded or native areas in all the three major divisions of the study areas, indicating the species can reduce biodiversity and disturb the native plant communities. The effect was pronounced in the Hazara division, followed by Swat and Peshawar, indicating the plant species grow well in Hazara (Figure 4).

Eradication and willingness to pay

The respondents agreed that the species is a nuisance weed in agriculture fields and must be eradicated. In this

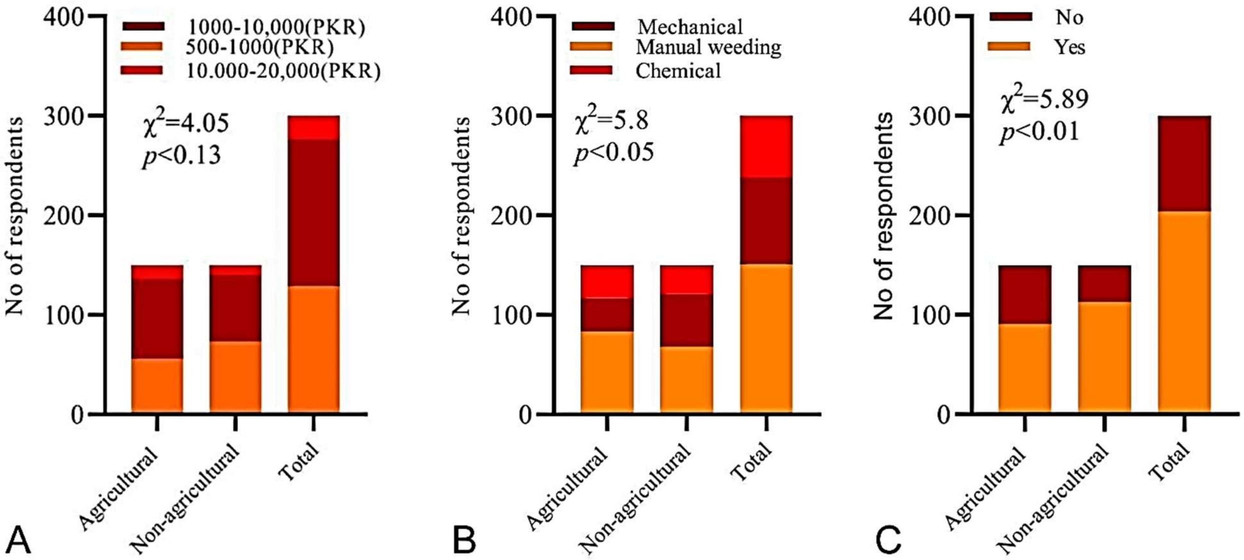

Fig. 5. Showing respondent's view about **A**. WTP (per annum), **B**. eradication method and **C**. Labor for weeding for ***Xanthium strumarium***.

Table 4 Willingness to pay frequency and %age for the eradication of ***Xanthium strumarium*** during the year 2018-2019.

WTP(PKR)	500	750	1000	5000	10,000	15,000	20,000
F	23	49	57	66	81	16	8
CF	23	72	129	195	276	292	300
%age	7.7	16.3	19.0	22.0	27.0	5.3	2.7

WTP (Willingness to Pay); PKR (Pakistani rupees); F (Frequency); CF (Cumulative frequency); %age (Percentage)

regard, 50.34% of the respondents viewed removing the plant by manual weeding. In weeding, 68% responded “yes” to labor for its weeding. The use of chemicals for its eradication was 20.66% of respondents, which is the least of all the three methods. According to most respondents, the cost for its eradication ranges mostly from 500-PKR-10,000-PKR per annum. At the same time, the chi-square statistics were found to be significant for the eradication method ($p<0.05$) and labour for weeding ($p<0.01$) and is non-significant for eradication cost per annum (Figure 5). The agricultural community mostly prefers manual weeding and labour for its eradication because of its harmful effects on crop plants and economic loss. In terms of eradication cost, the agricultural community, i.e., 53.33%, viewed spending 1000-PKR-10,000-PKR per annum for its eradication. The smallest spending group was 10,000-PKR-20,000-PKR per annum for its eradication in the agricultural and non-agricultural communities with 9.33% and 6.66%, respectively.

The WTP results (Table 4) indicated that the highest percentage of respondents, i.e., 27% and 22%, were ready to pay the amount of PKR-10,000 and 5,000PKR per annum, respectively, for eradication of the plant, indicating that the plant has highly affected the local crops in the area. One protest response stated his refusal to pay a higher price due to already high prices utilized in payment of fertilizers and insecticide. Of the respondents willing to pay higher fees, two did not quantify the amount they were willing to pay and responded with 'not sure' and 'reasonable amount.' One respondent did not provide his WTP, and also, in this survey, “I don't know”-type answers were excluded from the WTP analysis.

DISCUSSION

In this research, 300 respondents were interviewed to investigate the invasive behaviour, spread, and propagation effects on plants, animals, and diversity of invaded and non-invaded areas of *X. strumarium* dominated vegetation in Khyber Pakhtunkhwa, Pakistan. Age and education-wise, mostly male and agricultural citizens were focused; non-agricultural respondents were also interviewed for comparison. The people most concerned with agriculture were males; fewer females were involved in agricultural activities. Such findings were also reported by Kitula (2006) while studying the socioeconomic importance of mining activities in the Geita District of Tanzania.

There are many reasons for the efficient propagation and development of *X. strumarium* in which certain reproductive efforts play a key role, including the woody burs that insulate and protect the seed inside from fire and heat, thus enabling it to resist tough conditions (Love and Dansereau, 1959; Saeed *et al*., 2020). The plant has produced large quantities of seeds that fall near the mother plant forming a dense population in nearby areas

Fig. 6. Goats and sheep having sticky burs (**A**, **B**, and **C**) of ***Xanthium strumarium***, and the species' dense population (**D**).

that seriously affect the native plant communities (Weaver *et al*., 1983; Alfarhan, 2002). The sticky burs of the fruits help in physical dispersal by live stocks of animals and even human beings. These livestock animals were found to graze the plant up to some extent. The sticky nature fruits of *X. strumarium* with hook-like structures effectively dispersal (Chikuruwo *et al*., 2017). The respondents in our survey noted similar observations and added many other sources (transportation of seeds, grazing animals, pet animals of shepherds) that probably aid in the dispersion of fruit and its propagation which ultimately led to its invasive nature (Figure 6A-D).

X. strumarium is one of the alien noxious weeds that has invaded from its native North America (Dekker, 2011) progressively propagate and magnify its invasion after the Afghan refugee movement, thus causing enormous damage to the crop and local native populations. Many authors from different parts of the world reported the same finding from other countries of tropical and temperate distribution. Its propagation causes disturbance in agricultural fields, livestock, and many industrial products (Sartorato *et al*., 1996; Kaur *et al*., 2014). During field studies, the plant was found along with the roadsides in wet habitats, and according to the respondents, the plant grows best along with roadside areas. Similar observations have also been reported by Chikuruwo *et al*. (2017), where the plant has a dominant land cover and preferred to grow in streambeds and beach habitats.

The study indicated that this plant's invasion has significantly reduced the species richness in areas of its infestation. This invasion poses a threat to biodiversity, causing homogenization of native communities and competing with food crops reducing their yield, as reported by Chikuruwo *et al*. (2017), Saeed *et al*. (2020) and Hussain *et al.* (2014). Economically important crops like maize, cotton, wheat, beans, and brassica are the main plants affected by its invasion, especially in the plain areas of Peshawar-Nowshera and Southern districts like Lakki and Bannu. This plant invasion may cause irrepairable loss to native and other invasive plant species, ultimately resulting in the famine of food crops. Presently it is reported and recorded as a principal alien invasive weed in many crops and vegetable fields of different countries, i.e., South Africa, India, and Zimbabwe (Chikuruwo *et al*., 2017; Debnath *et al*., 2015; Semenya *et al*. 2012), and affect not only the native plant populations but also the fauna and ecosystem services. Allergic reactions are reported by interacting with its sticky bur and other toxic effects in animals (Kaur *et al*., 2014; Kamboj and Saluja, 2010). It causes a reduction in the yield of many bowls of cereal crops such as wheat and maize because of its undesirable contamination in sold stocks of food; therefore, control measures are required. The present study showed that it often occurs in the gregarious form in agricultural fields and natural habitats, potentially damaging native plant populations. As an alien invasive species, it acts both as a weed as well as an invasive species aid in enhancing disturbance in vegetation and can also cause serious health problems that may even lead to the death of animals if consumed (Weaver *et al*., 1983; Love and Dansereau, 1959).

Many previous findings confirmed the results of our study, e.g., Hussain *et al.* (2014) reveal that staple crops such as cotton, soybeans, maize, groundnuts, and corns are mostly affected by the invasive behaviour of this plant in many parts of the world. *X. strumarium* was found to cause losses (31%–39%) of yield in ground nuts fields at 0.5 plants of density per meter of row and decrease the yield up to 88% if 4 plants/m of the row in the USA. Maize is a famous crop of KP, and its yield is reported to decrease by 10% if a single *X. strumarium* plant is found per meter of the row, while the yield decreases to 27% if the density per row of m increases by 4.7 (Hussain *et al.*, 2014).

Many allelopathic chemicals from this plant were found to cause damage in crop fields of *Allium cepa* L. (onion), *Helianthus annus* L. (sunflower), and many other vegetables (Rashed-Mohasel *et al*. 2007). Extract from its stem and leaves were found to marginally affect germination and seedling growth of *Zea mays* L. (maize), *Brassica napus* L. (canola), *Sesamum indicum* L. (sesame), *Brassica napus* L., (lentil), and (*Cicer arietinum* L.) chickpea. Various chemicals such as glycoside (potassium carboxyactractyloside) extracted from *X. strumarium* decreased wheat coleoptile growth (Amini *et al*. 2014). Leaf leaches of the plant decreased the germination time of maize, barley, rice, wheat, and sunflower (Hussain *et al*., 2013). In contrast, recently, Ullah and Khan (2022) and Ullah *et al*. (2021) have reported this plant species as a useful tool for phytoremediation and biomonitoring of the wasteland heavy metal pollutants.

Manual weeding is usually used to eradicate the plant species with annual expenses of more than 10,000PKR by each affected farmer. Although, Pakistan's biodiversity action plan and environmental impact assessment policies are concerned with the invasive alien species' threat and damage. However, there is no concern about the control and repair of loss done by this plant species in governmental organizations. In contrast, many other non-governmental organizations try to combat deforestation, desertification, and other related issues in which AIPs control are included. However, a significant distance still exists between the concern of governmental and non-governmental organizations regarding the spread and damage done by AIPs in the areas. On this basis, measures are urgently required for effective control of the invasive species to conserve and protect the natural environment state that is the cry of the day. The information collected from the respondents indicated that the invasion of this species causes crop reduction, native plant and ecosystem damage, economic loss, labor implementation for its removal, and health problems of animals and humans. Other invasive species can further increase the risk causes. In this regard, governmental and non-governmental organizations need to control and eradicate this plant species, especially in the plain areas of KP province in specific and the high altitude regions in general.

CONCLUSION & RECOMMENDATIONS

The majority of respondents suggested that the concerned authorities needed to conduct more research and investigation due to the increasing rate of *X. strumarium* invasion and its damage to biodiversity. They proposed an integrated management strategy, including the governmental and non-governmental organizations aided by local communities to control/eradicate and manage AIPs from the field crops, densely populated areas, and grazing lands. Invasion of *X. strumarium* is now threatening the local/native ecosystems and the agricultural fields, crop yield, and animal health in the region, and people are concerned about its control and eradication in KP Pakistan. Based on this research, we can conclude that better planning and management are needed to control/eradicate this species from Peshwar, Hazara, and Malakand division vicinities. Further assessment in the southern districts of KP province is suggested.

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