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The Effect of Aposematic Signals of Plants on Students' Perception and Willingness to Protect Them

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Abstract: Degradation of biodiversity is one of the current problems of today, and scientists are increasingly concerned with identifying the key factors influencing people's willingness to protect (WTP) wild organisms. Using a within-subject design, we investigated the influence of aposematic signals along with the presence or absence of flowers on perceived danger, attractiveness and WTP plants with lower secondary school students (mean age = 13 yrs) in Slovakia (n = 423). Aposematic plants received a higher dangerousness score (mean = 2.62 vs. 2.27), higher attractiveness score (mean = 3.45 vs. 3.32) and lower WTP plants than plants without aposematic signals (mean = 3.27 vs. 3.37). Interaction terms showed that males perceived the aposematic species as more dangerous than females and were more willing to protect species lacking aposematic signals. Females rated aposematic plants as more attractive than non-aposematic plants (mean = 3.82 vs. 3.0). The presence of flowers increased the perceived attractiveness of plants (mean = 3.75 vs. 3.02) and WTP plants (mean = 3.59 vs. 3.05) and decreased perceived dangerousness (mean = 2.70 vs. 2.20). Perceived attractiveness and WTP plants decreased with students' age. Students with a higher interest in plants rated the attractiveness of the species more positively and were also more willing to protect them regardless of the presence of aposematic signals. We conclude that the presence of aposematic signals does not directly contribute to WTP plants, but conspicuous traits with high aesthetic value, such as flowers, positively enhance WTP in Slovak students.

Keywords: flower attractiveness; plant spines; plant aposematism

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1. Introduction

Aesthetic judgment in humans is likely to play an important role in everyday decision-making [1,2]. One attributes positive qualities to attractive subjects and negatively evaluates unattractive subjects. This mechanism is referred to as "what is beautiful is good" [3,4].

Aesthetic judgment plays a role in conservation science because it significantly influences the willingness to protect (WTP) animals [5,6] by means of emotional processes [7]. Species with low aesthetic value generally activate the emotion of fear or disgust and receive low conservation support [8–11]. In contrast, species with high aesthetic value receive high conservation support from the public [12–14] and are more frequently kept in zoos than less attractive species [15,16]. In addition, there are considerable cross-cultural similarities in aesthetic preferences for animals [17,18], suggesting that the psychological processes underlying aesthetic preference are universal [19] and findings from one culture can be generalized to other cultures. Unfortunately, however, these findings are based on research on animals, whereas similar research on plants is scarce.

Humans are interested in plants much less than in animals [20–23]. Consequently, plants receive lower conservation support than animals [24], although it should be noted that the factors underlying human's WTP plants are rarely investigated [25,26]. Human

neglect and ignorance of plants are also known as plant blindness [27,28] or plant awareness disparity [29]. One of the major proposed causes of plant blindness, that is, the human natural tendency to overlook plants, is their homogeneity and the absence of apparent movement, which leads (among other things) to insensitivity to the aesthetic characteristics of plants [28]. Females are generally more attentive to plants than males [30–32]. It is therefore recommended (1) to draw attention to individual plants and species rather than to plant communities and (2) to promote positive emotional connections with plants [24,28,33].

The aim of the present study was to examine whether the human perception of plants is influenced by certain morphological plant characteristics. In particular, the present study investigated how the presence of spines as examples of aposematic signals [34–37] influences perceived danger, attractiveness and WTP plants. Previous research indicated that certain plant colours and harmful characteristics enhance retention [38,39], and certain flower traits increase the aesthetic evaluation of plants [40–43]. We therefore also included the presence of flowers among predictors of perceived danger, attractiveness and WTP plants. We hypothesised that (1) the presence of spines negatively influences perceived attractiveness and WTP plants and positively influences the perceived danger of plants, (2) the presence of flowers positively influences perceived attractiveness and WTP plants but decreases the perceived danger of plants. We also hypothesised that (3) the low perceived danger of plants and high perceived attractiveness of plants are positively associated with WTP plants and that (4) students interested in plants show greater WTP plants than those with a low interest in plants. With respect to gender differences, we hypothesised that (5) females are more sensitive to the presence of spines than males, (6) females perceive plants as more attractive than males and (7) WTP plants is greater for females than for males.

2. Materials and Methods

2.1. Participants

A total of 423 students from the 5th to the 9th grades of three lower secondary schools in the Trnava region (Western Slovakia) participated to this research. All these schools are typical middle-sized schools with 363–667 students taught by 25–56 teachers. The age of the students ranged between 10 and 16 years (mean age = 13 years, SE = 0.07, n = 423). The selection of participants was not intentional but was based on teachers' willingness to participate in the research in the accessible schools. Teachers were selected according to personal contacts with researchers. If the teacher agreed, the questionnaire was administered to all the participants in the selected classes irrespective of the students' attitudes towards plants. All the participants were unpaid volunteers who were blind to our research hypotheses, and the research was anonymous.

2.2. Selection of Plants

We used colour pictures of 18 plant species freely downloaded from Google. Half of the plants possess aposematic signals (spines). We selected two types of conspicuous spines and spines, which are typical of more than a thousand plant species belonging to the Agavaceae, Cactaceae, Asphodelaceae, Crassulaceae and Euphorbiaceae families. The second group consisted of nine species without aposematic signals (Table 1, Figure 1). Almost all the selected plants were non-indigenous species to avoid possible biases caused by personal experiences with these species in nature. The presented pictures were modified in the Adobe Photoshop graphics editor to make them standardized, cropped and placed on a uniform white background without disturbing elements.

Table 1. List of plants used in the research with percentage (%) of students who considered these plants dangerous, attractive and were willing to protect them *.

Common English Name	Scientific Name	Presence of Apparent Spines	Flower Presence	Danger (%)	WTP (%)	Attractiveness (%)
-	*Echinofossulocactus albatus*	yes	yes	19.7	44	64.5
-	*Oreocereus fossulatus*	yes	no	65.7	38.5	30.8
Melon cactus	*Melocactus oreas*	yes	no	29.6	28.4	57
Moon cactus	*Gymnocalycium mihanovichii*	yes	yes	28.2	73	70.7
Gray ghost organ pipe	*Stenocereus pruinosus*	yes	no	43.4	24.9	31
Mandacaru	*Cereus jamacaru*	yes	no	61	31.5	23.5
Parry's agave	*Huachuca agave*	yes	no	20	67.8	79.3
Mexican giant cardon	*Pachycereus pringlei*	yes	no	50.5	28.4	33.6
Shaw's agave	*Agave shawii*	yes	no	22.5	23.2	69.7
San Pedro cactus	*Echinopsis pachanoi*	no	no	34.5	29.3	21.4
-	*Notocactus uebelmannianus*	no	yes	12.4	69.7	74.9
-	*Turbinicarpus pseudopectinatus*	no	no	47.7	46.7	27.9
Sea urchin	*Euphorbia obesa*	no	no	41.3	48.8	31.5
-	*Mammillaria pectinifera*	no	no	24.6	64.8	65.3
Common houseleek	*Sempervivum tectorum*	no	no	6.3	43.7	67.8
Baseball plant	*Euphorbia obesa*	no	no	20.7	51.6	42.5
-	*Matucana madisoniorum*	no	yes	21.6	56.1	58.5
San Pedro cactus	*Echinopsis pachanoi*	no	no	23.7	24.6	30.5

* Calculations based on "agree" and "strongly agree" responses.

(**a**) (**b**)

Figure 1. Examples of plants (**a**) with apparent spines (*Melocactus oreas*) and (**b**) without apparent spines (*Turbinicarpus pseudopectinatus*) used in the experiment.

2.3. Measuring Perceived Dangerousness, Attractiveness and Willingness to Protect (WTP) Plants

During the presentation of the plants, the respondents answered three questions similar to those which Prokop and Fančovičová [10] used to examine aposematic animals: (1) To what extent do you think the displayed species is dangerous? (2) To what extent do you think the displayed species is attractive? (3) Do you think that the species shown should be protected by law? All responses were Likert-scaled (1 = absolutely disagree, 5 = absolutely agree).

2.4. Measuring Interest in Plants

Students' interest and enjoyment of plants was assessed with the 10-Likert scale items (1 = strongly disagree, 5 = strongly agree) of the Interest in plants subscale derived from the Plant Attitude Questionnaire [44]. High scores indicate high interest in plants. Example items are "I am interested in reading books about plants", "I would like to cultivate plants", "I like watching films about plants". The subscale showed high reliability (Cronbach alpha = 0.82), and the mean score was used to form an overall measure of interest in plants. Students were finally asked to provide information about their age, grade and gender.

2.5. Procedure

Students were tested as whole classes using paper-and-pencil questionnaires. First, each student was asked to write demographic variables, followed by ten Interest in plant items. We then projected 18 colour pictures of plants in lecture halls. The pictures were presented in random order. Each picture was presented for 1 min. During this time, participants rated perceived dangerousness, attractiveness and WTP each species.

2.6. Statistical Analyses

Generalized Linear Mixed Model (GLMM) was used to test whether subjectively perceived danger, attractiveness and WTP plant scores (dependent variables) were influenced by gender differences, the presence of spines and flowers (categorical predictors) and interest in plants or age (continuous predictors). School and students' ID were treated as random effects. Means are shown with 95% confidence intervals (CI). GLMM was performed in SPSS ver. 26. A power analysis in GPower revealed that our sample size would provide requested power at 0.80 to detect a medium effect (d = 0.50) with α two-tailed = 0.05 [45].

3. Results

3.1. Subjectively Perceived Danger

Plants with spines (mean = 2.62, 95% CI [2.56–2.69]) were subjectively perceived as more dangerous than plants without spines (mean = 2.27, 95% CI [2.21–2.33]) ($F(1,1687) = 67.1$; $p < 0.001$) (Figure 2). Plants with flowers (mean = 2.20, 95% CI [2.13–2.37]) were perceived as less dangerous than plants without flowers (mean = 2.70, 95% CI [2.64–2.75]) ($F(1,1687) = 137.2$; $p < 0.001$). Students more interested in plants perceived plants as less dangerous than those less interested in plants ($\beta = -0.08$, $F(1,1687) = 6.9$; $p = 0.009$). The effect of gender (males: mean = 2.47, 95% CI [2.41–2.53], females: mean = 2.42, 95% CI [2.36–2.48]) and age was not significant ($F(1,1687) = 0.52$ and 0.0, $p = 0.47$ and 0.99, respectively). A significant interaction term gender × spines emerged ($F(1,1687) = 13.06$; $p < 0.001$), suggesting that males perceived plants with spines as more dangerous (mean = 2.72, 95% CI [2.63–2.82]) than without spines (mean = 2.22, 95% CI [2.13–2.32]), and the same but weaker trend was observed for females (plants with spines: mean = 2.52, 95% CI [2.42–2.61] and plants without spines: mean = 2.32, 95% CI [2.22–2.42]). The interaction terms gender × flowers and spines × flowers were not statistically significant ($F(1,1687) = 0.77$ and 1.34, $p = 0.38$ and 0.29).

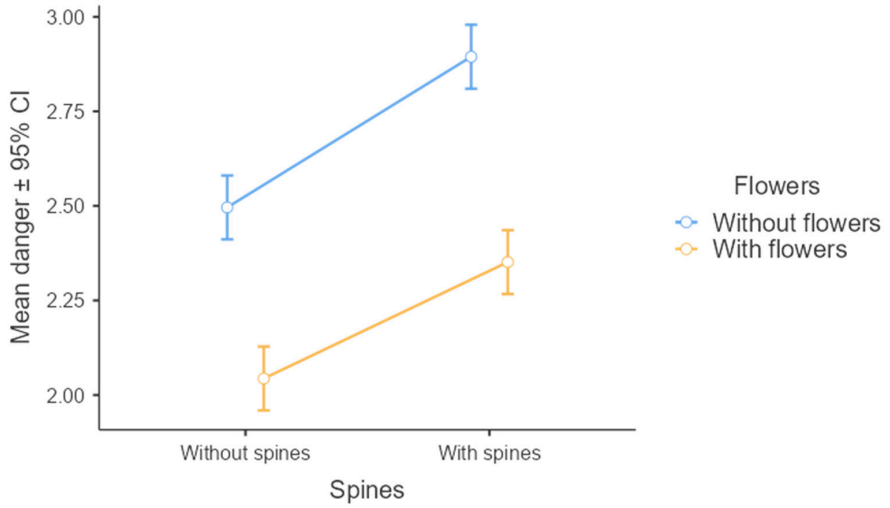

Figure 2. Comparison of perceived danger from plants with respect to spines and flower occurrence. Means are shown with 95% confidence intervals (CI).

3.2. Subjectively Perceived Attractiveness

Plants with spines (mean = 3.45, 95% CI [3.39–3.50]) were subjectively perceived as more attractive than plants without spines (mean = 3.32, 95% CI [3.26–3.39]) ($F(1,1687) = 9.65$; $p = 0.002$) (Figure 3). Plants with flowers (mean = 3.75, 95% CI [3.68–3.81]) were perceived as more attractive than plants without flowers (mean = 3.02, 95% CI [2.98–3.07]) ($F(1,1687) = 330.41$; $p < 0.001$). Students' interest in plants as well as students' age were significantly associated with perceived attractiveness of plants ($\beta = 0.17$ and -0.05, $F(1,1687) = 38.37$ and 13.85; both $p < 0.001$). The effect of gender (males: mean = 3.33, 95% CI [3.27–3.39], females: mean = 3.44, 95% CI [3.38–3.51]) was not significant ($F(1,1687) = 0.0$, $p = 0.99$). The interaction term between gender × spines was not significant ($F(1,1687) = 3.31$, $p = 0.07$). The interaction term between gender × flowers was statistically significant ($F(1,1687) = 8.25$, $p = 0.004$). Females perceived plants with flowers as more attractive (mean = 3.82, 95% CI [3.70–4.0]) than plants without flowers (mean = 3.0, 95% CI [2.85–3.11]), but this difference was not so much pronounced in males. A significant interaction term spines × flowers emerged ($F(1,1687) = 5.92$; $p = 0.015$), suggesting that plants with flowers but without spines were perceived similarly attractive as plants having both flowers and spines. In contrast, the absence of flowers resulted in higher ratings of plants having spines than plants without spines (Figure 3).

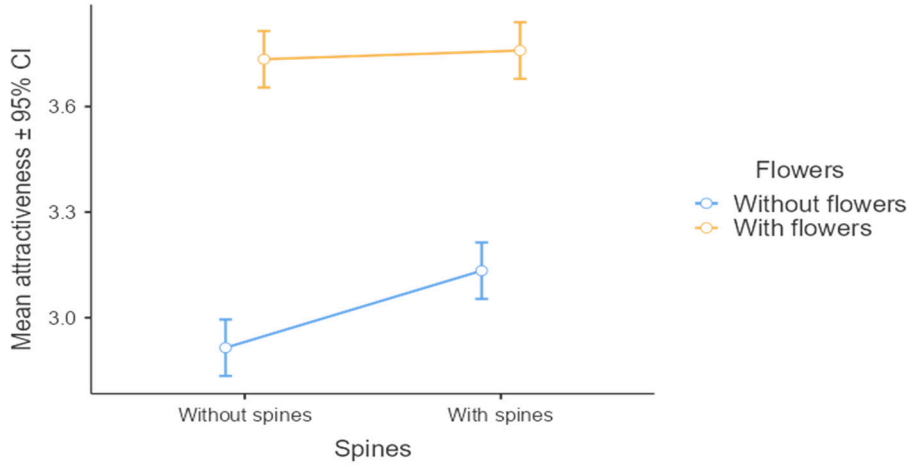

Figure 3. Comparison of perceived attractiveness of plants with respect to spines and flower occurrence. Means are shown with 95% confidence intervals (CI).

3.3. Subjective Perception of Willingness to Protect Plants (WTP)

Students showed stronger preference for the protection of plants without spines (mean = 3.37, 95% CI [3.30–3.43]) than for plants with spines (mean = 3.27, 95% CI [3.21–3.33]) or ($F(1,1687) = 4.80$; $p = 0.03$) (Figure 4). Plants with flowers (mean = 3.59, 95% CI [3.53– 3.66]) received a significantly greater perceived WTP score than plants without flowers (mean = 3.05, 95% CI [3.0–3.10]) ($F(1,1687) = 175.94$; $p < 0.001$). Students' interest in plants positively influenced WTP ($\beta = 0.16$, $F(1,1687) = 30.44$, $p < 0.001$). Students' age negatively influenced willingness to protect plants ($\beta = -0.04$, $F(1,1687) = 5.93$, $p = 0.02$). The effect of gender (males: mean = 3.21, 95% CI [3.15–3.27], females: mean = 3.44, 95% CI [3.38–3.50]) was statistically significant ($F(1,1687) = 9.72$, $p = 0.002$); females were more willing to protect plants than males. Two interaction terms (gender × spines, flowers × spines) were not significant ($F(1,1687) = 2.86$, 0.003, $p = 0.09$ and 0.95, respectively). The interaction term gender × flowers ($F(1,1687) = 6.07$, $p = 0.014$) suggests that females were more willing to protect plants with flowers (mean = 3.72, 95% CI [3.63–3.80]) than plants without flowers (mean = 3.06, 95% CI [3.0–3.15]), but this difference was not so much pronounced in males.

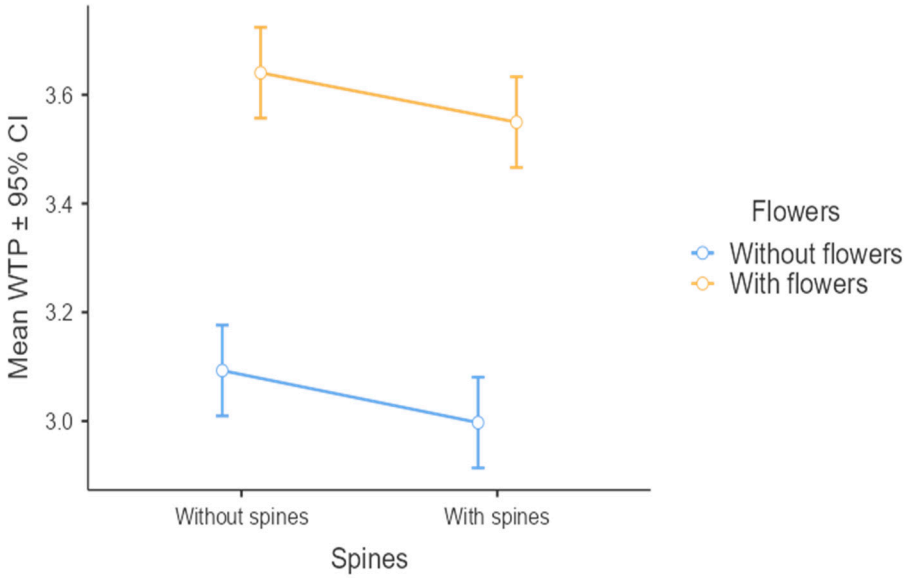

Figure 4. Comparison of willingness to protect (WTP) plants with respect to spines and flower occurrence. Means are shown with 95% confidence intervals (CI).

3.4. Relationships between Perceived Danger, Attractiveness and Willingness to Protect Plants

Simple correlations showed that WTP plants were moderately and negatively correlated with perceived danger ($r = -0.26$, $p < 0.001$) and strongly and positively correlated with perceived attractiveness ($r = 0.60$, $p < 0.001$). Perceived attractiveness was moderately and negatively correlated with perceived danger ($r = -0.36$, $p < 0.001$).

4. Discussion

This study examined the influence of the presence of spines as examples of aposematic signals and the presence of flowers on perceived danger, attractiveness and willingness to protect (WTP) plants with a sample of Slovak students. Our hypotheses were built largely on research on animals because research in this field is more abundant than research on WTP plants. As far as we are aware, this is the first study investigating the perception of plant aposematism by humans.

We hypothesised that (1) the presence of spines negatively influences perceived attractiveness and WTP plants and positively influences perceived danger of plants. This hypothesis was statistically confirmed. Spines have sharp-angled features, and such features enhance a feeling of threat because sharp objects such as teeth, claws or horns have been harmful to humans throughout our evolutionary history [46]. Not surprisingly, peace-

fulness is associated with round shapes, whereas angular shapes are associated with anger and aggression [47]. Our research shows that sharp features such as spines, which evolved as a defence against herbivores [48], also evoke a feeling of danger in humans. Interestingly, Hareli et al. [49] similarly found that sharp leaves were rated by participants as less friendly, uglier, less comforting, colder and more dangerous than round leaves. Ultimately, avoidance of aposematic plants with spines is caused by the risk of injuries which often cause septic inflammation that can be life-threatening due to transmission of pathogenic bacteria and fungi for both humans and non-human animals [50,51]. Perceived danger and fear, however, may boost memory, similar to other survival-relevant scenarios [38,39,52]. Thus, in theory, aposematic signals can be advantageous in learning, but this question requires further research.

Prokop & Fančovičová [10] showed that aposematic signals increased WTP animals, which can be seen as a contrast to the present study. Their research was focused, however, exclusively on aposematic colouration, meaning that aposematic animals were more conspicuous than non-aposematic animals. Our present research on plants is very distinct in this sense because we did not manipulate colours but exclusively the presence of sharp-angled features.

Our second hypothesis suggested that (2) the presence of flowers positively influences perceived attractiveness and WTP plants but decreases the perceived danger of plants. In line with previous reasoning, natural preferences for curved shapes positively influenced the perceived attractiveness of plants [46]. The aesthetic value of flowers [40,42,43] substantially contributed to the decreased perceived danger of plants. In turn, the low perceived danger of plants and particularly high perceived attractiveness of plants positively correlated with WTP plants (Hypothesis 3). These results agree with research on animals where dangerously looking individuals [11] and animals with low aesthetic value [8,9] received significantly lower WTP scores than neutral-looking and/or aesthetically pleasant animals.

In line with Hypothesis 4, students displaying greater interest in plants also showed greater WTP plants than students with intrinsically low interest in plants. It seems that interest in plants correlates with curiosity and knowledge about plants [32], and the present results extend these associations to WTP plants. More research about how students behave toward plants in real-life settings is required. Notably, interest in plants decreased with the age of students, which corroborates with similar findings focused on students' attitudes [44] and knowledge about plants [53,54]. We are of the opinion that since these negative trends are attributed to puberty [54] when students' interest in sexuality increases [55], it seems reasonable to heighten interest in plants by introducing topics of plant sexuality.

Contrary to Hypothesis 5, males seemed to be more sensitive to the presence of spines than females. Females did not consider plants more attractive than males (contrary to Hypothesis 6) and females showed greater WTP plants than males (Hypothesis 7). With respect to Hypothesis 5, perhaps because males behave riskier than females both actually and historically [56], their greater sensitivity to spines may help them avoid injury. The absence of greater aesthetic preferences for plants by females (Hypothesis 6) could mirror the selection of plant species in this study, which was based on the presence/absence of spines rather than on their aesthetic value. Indeed, plants with flowers were significantly more preferred by females than plants without flowers. We suggest that high aesthetic value of selected plants contributed to the occurrence of gender differences in WTP plants. Interestingly, however, Prokop & Fančovičová [10] did not find gender differences in WTP animals. More research with contrasted differences of selected plant species is required for more conclusive results.

5. Limitations

This study has one shortcoming: we did not experimentally manipulate the examined traits (spines, flowers), but we presented plant species with these traits and without them. We acknowledge that this approach does not allow for removal of potentially confounding effects due to differences in other characteristics among plant species. It is difficult to

manipulate spines using Adobe Photoshop, but perhaps manipulation with similar traits such as thorns, which are less dense than spines, can be easily performed in future research.

6. Conclusions

Because of the lack of research in this area, we view our research as a first attempt to examine the essential characteristics of plants necessary to improve the willingness of people to protect them. The presence of aposematic signals, such as spines, seems to increase perceived danger ($p < 0.001$) and slightly increase the aesthetic value of plants ($p = 0.002$) but does not positively influence WTP plants ($p = 0.03$). In contrast, the aesthetic value of plants can easily be enhanced by the mere presence of colourful flowers ($p < 0.001$), which promote WTP plants (r = 0.60, $p < 0.001$). Students with high intrinsic interest in plants showed greater WTP plants ($\beta = 0.16$, $p < 0.001$), perceived plants as less dangerous ($\beta = -0.08$, $p = 0.009$) and perceived their aesthetic value more higher than less interested students ($\beta = 0.17$, $p < 0.001$). Interest in plants was compromised by the higher age of students (perceived attractiveness and WTP plants, both $p < 0.05$). We hope that these results can be used in conservation campaigns, where correctly selected flagship species may effectively promote conservation activities. For teaching botany, the use of aesthetically appealing species may contribute to increased interest in plants and WTP. For biology education research, we recommend examining whether (1) aposematic signals in plants increase retention similar to other survival-relevant scenarios, (2) perception of plants influences students' behaviour toward them and (3) the focus on sexual reproduction in plants improves interest in plants in older students.

7. Educational Implications

Students are largely unaware of the ultimate function of aposematic signals in plants. Explaining the role of spines and thorns to them in defence against herbivores may naturally increase interest in plant topics because plants primed with animals enhance the participant's recall of plant targets [57].

Increased attention to life-threatening injuries caused by plant appendages and associated bacteria may help to change the traditional view that plants are helpless organisms. Plants can instead be viewed as active components of natural selection.

Aesthetically appealing plant species may work as an umbrella for unappealing species. Explaining that aesthetically appealing flowers evolved because of insect attraction allows for explanations of why other wind-pollinated plants (e.g., grass) do not produce attractive flowers.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Raw data and visual material available upon request.

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