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Plant blindness: A focus on its biological basis

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Plant blindness or the inability to notice plants in one's everyday life is a complex phenomenon in the field of science education. Although plant blindness is well documented in the literature, the underlying factors, whether biological or cultural, are still under research. Here I focus on its biological basis. That is, I review and discuss how plants' own inherent characteristics cause effects on human visual and cognitive processes. Animals *versus* plant differences in human attention and memory are also addressed. Grounded on that knowledge, some recommendations for effective practice in plant science education emerge. I conclude that only when we understand human-plant relationships will we know how to enhance teaching and learning about plants.

KEYWORDS

plant blindness, plant awareness disparity, science education, effective teaching, cognitive science

Introduction

Human inability to see or notice plants in one's everyday life is a phenomenon known as plant blindness. It also refers to failing to recognize the role of plants on earth and believing that plants are somehow inferior to animals (Wandersee and Schussler, 1999, 2001). See some other indicators for plant blindness in **Table 1**. Recently, a proposal to rename plant blindness as plant awareness disparity has arisen with the objective of eliminating "blindness" due to possible ableism (Parsley, 2020). However, plant awareness disparity is not a generally agreed term today (Thomas et al., 2021) and, therefore, here I will refer to this phenomenon as plant blindness.

Plant blindness has attracted research for over 20 years and it is currently accepted as a real thing, a real problem–at least- in the Western society (Balding and Williams, 2016; Knapp, 2019). Numerous investigations have provided evidences for the indicators defined by Wandersee and Schussler (2001; here listed in **Table 1**). For instance, it is well known that students and the general public (i) identify and/or recall plant species more poorly than animal ones (e.g., Bebbington, 2005; Patrick and Tunnicliffe, 2011; Kaasinen, 2019; Zani and Low, 2022); (ii) find animals more interesting and attractive than plants (e.g., Kinchin, 1999; Nyberg et al., 2021; Pedrera et al., 2021); and (iii) have a poor knowledge about plants (e.g., Kubiatko et al., 2021; Fernández-Díaz, 2022).

The potential to successfully overcome plant blindness relies to a great extent on finding factors open to change. A consensus exist that it is a complex phenomenon where biological (including human cognition) and cultural factors are major drivers (see Balding and Williams, 2016 for a short review). While other authors highlight the cultural origin, in their description of plant blindness, Wandersee and Schussler (1999, 2001) mostly focused on the biological basis. They suggested that several plant characteristics such as their uniform color and grouping together, lack of movement and lack of a face, have an effect on how humans process visual information. Note that what we see is not simply a translation of the image projected on the retina; visual perception is involved in selecting, organizing and interpreting the information. Although these authors grounded their explanations on well-known visual principles, they lacked at that time of experimental support from the field of visual perception. This came later with Balas and Momsen (2014) and Kanske et al. (2013), who demonstrated that plants indeed capture human attention less effectively than animals. It is also worth mentioning the recall study by Schussler and Olzak (2008), which provided strong evidence for a cognitive basis; either visual attention or memory were suggested as processes involved in plant blindness.

Here, I will review some of the biological factors that were suggested by Wandersee and Schussler (1999, 2001) as a cause for plant blindness. First, I focus on how an inherent morphological feature of plants, being green, has an impact in human vision. Next, I address how plants change their visual apparency and its potential implications for human visual processes. And in third place, the differences between animals and plants in human attention and memory are reviewed. All this will lead me to conclude that only when we understand human-plant relationships will we know how to enhance teaching and learning about plants. Some recommendations for an effective education practice are also given.

How being green affects human vision

As noted by Wandersee and Schussler (1999), plants usually grow in populations and blend together, which creates a chromatic and spatial continuity for the human eye. In other words, at some places and to a given distance, the consequence to the human vision is a more or less homogeneous green scene (**Figure 1**). Moreover, other morphological features in addition to color contribute to the homogeneity of the environment. For example, plants living in the same habitat usually have a number of similar morphological characteristics (Prokopy and Owens, 1983). In this regard, Givnish (1979) found that, in particular habitats, the form of the leaves (small vs. large size, entire vs. toothed margins, and simple leaves vs. compound leaves) depends on specific factors such as moist, nutrient quantity, geographical area or successional stage of the habitat. As a result, different species of plants living in the same habitat may share same morphological characteristics (making plants less prominent to the human eye).

TABLE 1 Indicators for plant blindness as defined by Wandersee and Schussler (1999).

One may suffer from plant blindness when. . .
. . .one does not see, show interest on, or pay attention to plants in his/her life
. . .one believes that the unique role of plants is to be the support for animals
. . .one does not understand what plants need to grow
. . .one does not notice that plants are essential in his/her daily routine
. . .one misunderstands the time scales regarding plant and animal activity
. . .one has never grown plants, make observations of their anatomy or processes, or identify plants
. . .one does not understand the plant model, among others, basic functions as nutrition and reproduction, and simple plant ecology
. . .one does not notice the essential role of plants in the carbon cycle
. . .one is not sensitive to the "aesthetic qualities of plants and their structures"

Note that these authors referred to them as "symptoms." [1]Saccades consist of fast sequential movements that bring the fovea from one point to another; and fixations are the periods in between of saccades, when the eyes are stable.

What happens when we look at a homogeneous visual environment? According to the eye movement research, when an individual explores a scene, two phases are distinguished. The initial viewing consists of a fast registration of the spatial layout (2 sec); the subsequent phase is a longer and more in depth and element centered analysis (Pannasch et al., 2008). The initial phase is characterized by short fixations and long saccadic movements[1]. Then, the scanning strategy changes: fixation time increases and more fixations are given in certain regions of the scene; this implies that saccadic movements are shorter (Pannasch et al., 2008). Back to the topic, one could think that a plant scene with a predominantly monochromatic green color would have a poor second phase, as there are not many elements for the eye to fixate (**Figure 1**). Note that fixations are known to be related to uptake of visual information. In addition, when the eye finds no fixations (as in our green scene), the amplitude of saccadic movements increase, resulting in uncomfortable perception (Filin, 2006). As a result, the individual may well change the focus to another scene. Therefore, less fixations carries a reduction in the collected visual data and a likely change of focus to other target element/scene.

With respect to the selection of the target in a scene, selection is governed not only by the saliency of the elements in the scene (this was already pointed out by Wandersee and Schussler, 2001), but also by the tasks to be carried out by the observer and the emotional aspects transmitted by the scene (Pannasch et al., 2008). Then, one could also think that an individual that suffers from plant blindness would have less elements to focus on than an individual that appreciates plants, as no task or emotion is leading the former.

Plants' abilities to change their visual signal

Plants adapt their visual signal values to the environment by modifying their apparency. This can be done in two ways: becoming more or less visible. This last one was proposed by Wandersee and Schussler (2001) as a factor for plant blindness. I discuss this topic in more detail below.

Decreasing their visual apparency, plants avoid recognition and, thus, predation. It is well-known that plants can conceal themselves from animals such as birds (Fadzly et al., 2009) and butterflies (Niu et al., 2017). For decreasing their apparency, two main strategies are distinguished: hiding in refuges and crypsis (Mortensen, 2013). Regarding the first strategy, some plants grow in spatial refuges, that is, in areas where herbivores cannot reach such as abrupt slopes and areas above or below the browse line for the herbivores (Milchunas and Noy-Meir, 2002). Other plants hide in temporal refuges, which consists of growing or flowering when herbivores are not active (Mortensen, 2013). With regard to the second strategy, some plants can camouflage themselves (crypsis) among other similar colored plants, which is known as background matching (Niu et al., 2018). And some other plants resemble natural elements, e.g., stones, for avoiding recognition (Mortensen, 2013).

Do plants become less apparent for humans when they reduce their visual signal to hide from herbivores? *A priori*, the answer seems to be yes. However, as far as I know, no specific investigation has been made (no comparisons with cryptic animals either).

On the other hand, becoming more visible is usually a reproduction strategy for plants to attract pollinators and seed dispersers. Bird-pollinated flowers tend to be red and insect-pollinated ones, blue (Caro and William, 2017). Similarly, mammals tend to disperse yellow or green fruits and birds, white, black, blue, or red ones (Caro and William, 2017). Moreover, trichromacy in primates is thought to help them detect fruits against a background of green leaves, young leaves against mature leaves, etc. (Regan et al., 2001). Becoming more

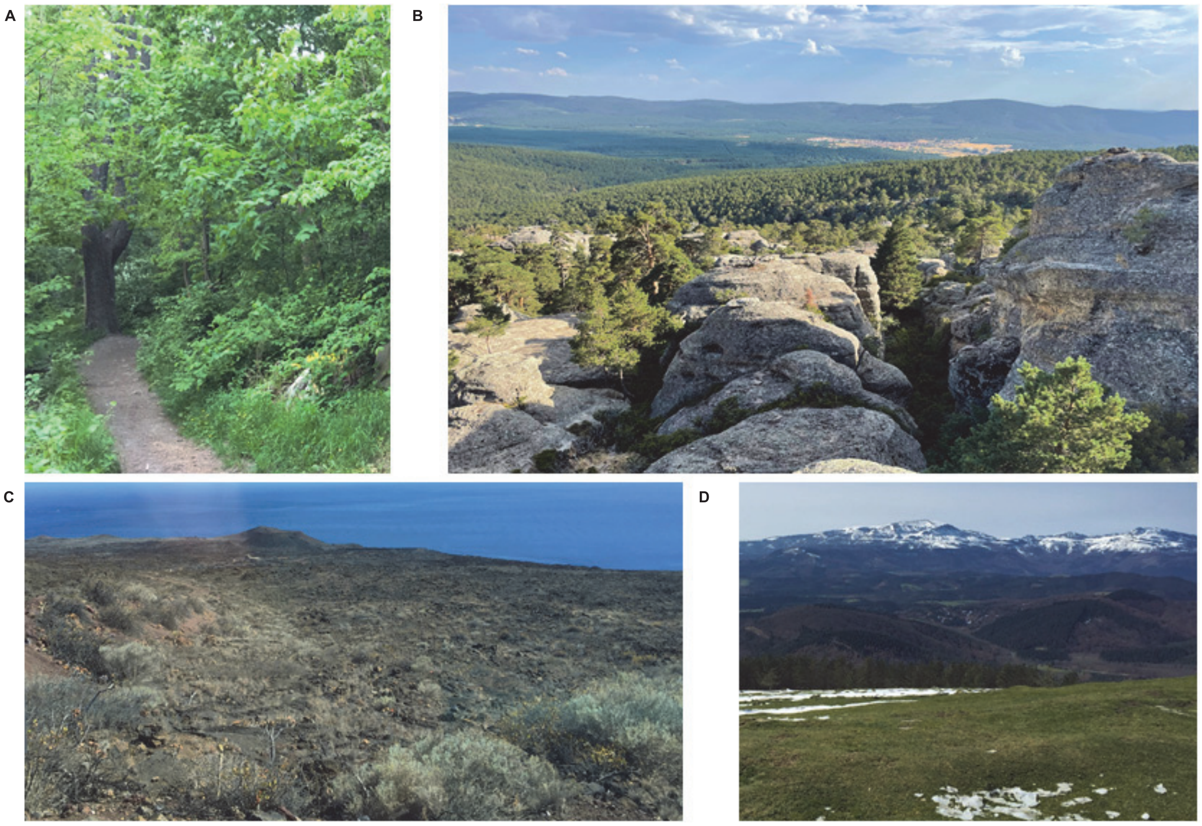

FIGURE 1
Examples of green scenes that could lead to plant blindness. **(A)** A green scene where all vegetation (grasses and trees) show a similar shade of green. **(B)** A vast pine forest from a distance forming a more or less homogeneous green view. **(C)** An arid ecosystem with soil and vegetation being hard to differentiate at a given distance. **(D)** A winter view with green, brown and white patches from a distance. All photos were taken by the author in Spain.

visible is also a way to emit warning signals to avoid a predator attack (aposematism). Yellow, orange, red, brown, black, and white are often used by spiny and poisonous plants as defense (Lev-Yadun, 2009).

A number of studies have analyzed how prominent features (colorful flowers and fruits) enhance human interest, attraction, and willingness to protect plants (e.g., Tunnicliffe, 2001; Adamo et al., 2021; Hùla and Flegr, 2021). If one applies the knowledge reviewed in the previous section (How being green affects human vision), fixations in flowers and other salient morphological characteristics would be expected to be longer and more abundant. That is, more visual data are captured, and plant blindness could be minimized.

Visual attention and memory: Animals *versus* plants

Visual attention and memory were essential parts of the explanations for plant blindness by Wandersee and Schussler (2001). I next review how humans detect and memorize animals compared to plants according to the advances in the literature.

First, one should consider how the conceptual knowledge is organized in our brain. That is, if animals and plants fall into the same "compartment." Caramazza and Shelton (1998) suggested that our brain is organized within the distinct categories of animals, plants, and artifacts. These were posteriorly condensed in the literature into animates and inanimates.

New et al. (2007) found that changes to animates (including animals and among them, humans) were visually detected by people more frequently and more quickly than changes to inanimates (including plants, vehicles, tools, and others). It was then concluded that humans give preferential visual attention to animates. Regarding memory, Nairne et al. (2013) found that animates are better remembered than inanimates, but the study did not include plants. In fact, studies on animates *versus* inanimates do not specifically compare plants *versus* animals. Moreover, most of them use fruits (e.g., Jackson and Calvillo, 2013) and flowers (e.g., Guerrero and Calvillo, 2016) as the only images of plants.

Interestingly, these authors (New et al., 2007; Nairne et al., 2013) rely their explanations on an evolutionary hypothesis. From a fitness perspective, animals have survival and reproductive value for humans; animals are potential predators and food and other humans are potential mating partners and competitors for resources. Therefore, rapid and successful identification of animates would have been a selective pressure for adaptation of visual and neural mechanisms in humans (New et al., 2007; Nairne et al., 2013). Following that hypothesis, one could think that plants would also have been a selective pressure (as they are potential food, sometimes poisonous or stinging, shelter, tooling material, etc.); however, questions remain open.

Following Nairne et al. (2013), it is fundamental to deconstruct the animacy dimension, because still we do not know which the necessary and sufficient properties for animates to produce the effect in our brain are. According to the authors, "cognitive biases may require agency (the ability to initiate causal action), movement, mental states (such as knowing or emotion), or even the ability to communicate in order for something to be considered animate." Interestingly, Kinchin (1999) found that the animal feature that generated most interest in a sample of 162 students was movement. Motion is exhibited in plants at all scales, from stomatal opening and closing on the leaf to branch movements in trees. However, most movements of plants are unnoticeable for the human eye because they are too slow for us to perceive them (Forterre, 2013). And, therefore, they are not expected to attract people's attention. In any case, future advances in this field seem indispensable to understand the phenomenon of plant blindness.

Recommendations for effective education practice

Some science instruction time could be devoted to observing green homogeneous plant scenes. Giving a task (observing) would give the eye elements to focus on (fixations). That could be made during a field trip to the forest, for example. The scientific practice of observation could be accompanied by taking data and making inferences and/or classification and description practices. Note that all those scientific practices accord with inquiry based learning. To finish, students could reflect about what they saw in the forest under the guidance of educators (reflective learning). Making students aware of their own plant blindness would be the ultimate goal of the reflection.

Prior training on plant blindness seems necessary in order for educators to be able to carry out interventions in relation to this phenomenon. This can be done during the university teacher training stage. Plant blindness fits well in the area of science didactics, as an obstacle to learning about plants. Pre-service teachers should be aware of the phenomenon, its "symptoms" and its potential biological and cultural causes. Furthermore, when advances in the cognitive area allow us to understand how attention and memory biases lead to better identification and recalling of animals vs. plants, we will be able to advance in the teaching of plants.

Conclusion

In a sustainable future world, plant blindness has no place (Thomas et al., 2021). From this reflection, I conclude that human-plant relationships in plant blindness are poorly known, and that research progresses on how human brain processes plants is a fundamental aspect to be up-to-date with from science education. Only that knowledge will guide us on how to enhance teaching and learning about plants. It is my hope that this perspective captures the attention of research aimed at deepening into the biological factors in plant blindness.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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