

## Neural Seeds: The "AI + Plants" Concept: Educating Plants to Grow and Adapt

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The idea of neural seeds highlights plants' ability to exhibit adaptive activity through intricate networks of biochemical, hormonal, & electrical signals, challenging the conventional perception of plants as passive, reactive animals. Despite having no neurons, plants can learn through long-term memory, associative conditioning, and habituation. Although repeatability is still a problem, experimental data from research

on *Pisum sativum* and *Mimosa pudica* indicates that plants can alter responses based on experience. Growth dynamics, environmental data, and plant electrophysiology may now be interpreted in real time thanks to developments in artificial intelligence (AI), especially convolutional as well as recurrent neural networks. Combining these systems with wearable sensors, biohybrid robots, and nanobionic devices can improve precision farming, environmental monitoring, and innovative computing applications. Potential applications for closed-loop AI systems and multimodal data fusion include adaptive plant-machine interactions and resource optimization. There are still

issues, though, such as sensor invasiveness, experimental validity, and moral concerns about plant agency. The Neural Seeds framework has the potential to transform the role of plants in cross-disciplinary research and sustainable technologies by fusing responsible innovation with rigorous science.

The conventional wisdom that plants are static, reactive entities is called into question by the

idea of neural seeds. Plants' complex biochemical, hormonal, and electrical signaling networks allow them to perceive, analyze, and react to their surroundings in adaptive ways, despite the fact that they lack neurons and a central nervous system (Calvo et al., 2020). Recent studies have demonstrated that plants may change their behavior in response to experience, a phenomena similar to animal learning (Gagliano et al., 2014). Complementary developments in AI have made it possible to decode intricate, non-linear biological signals. These consist of growth dynamics, gene expression patterns, & electrical impulses in plants (Vodeneev et al., 2023). When



paired with biohybrid devices, such nanobionic systems and wearable plant sensors, artificial intelligence (AI) can instantly analyze and respond to data provided by plants. This opens up the possibility of new bio-computational models and adaptive, self-optimizing agricultural systems. This study looks at the interaction of AI with plant systems, experimental findings, prospective applications, ethical considerations, and the biological underpinnings of plant learning.

## **1. The Mechanisms of Plant Memory and Acquisition of Knowledge**

### **1.1. Plant learning: A definition**

Learning in animals is a long-lasting behavioral shift brought on by experience, backed by systems for storing and retrieving memories. Similar modifications are made by plants through changes in ion-channel regulation, hormone signaling, and epigenetic modifications (Trewavas, 2016). Despite the absence of neurons, these processes satisfy operational criteria of learning, including long-term memory, associative conditioning, and habituation (Calvo et al., 2020).

### **1.2. The "Nervous System" of Plants is Electrical Signalling**

Plants generate systemic electrical responses, action potentials, and variation potentials that can pass into vascular tissues and affect defense and photosynthesis (Vodeneev et al., 2023). Together, these electrical patterns are referred to as the "plant electrome," and they may function as systems for information storage and communication.

## **2. Proof of Plant Learning through Experiments**

### **2.1. Getting used to *Mimosa pudica***

The experiment conducted by Gagliano et al. (2014) with the "sensitive plant," *Mimosa pudica*, is among the most often cited research on plant learning. The plants first closed their leaves in response to the innocuous stimulus of being dropped repeatedly from a modest height, but they gradually ceased reacting. Even after being tested in various environmental settings, this behavioral shift lasted for weeks. According to the research, plants are able to "remember" past events and modify their reactions accordingly (Gagliano et al., 2014).

### **2.2. Pea Plants That Use Associative Learning**

According to a contentious 2016 study, pea plants (*Pisum sativum*) seemed to link light and wind direction, changing their growth pattern to face the wind when light was absent (Gagliano et al., 2016). Although intriguing, this assertion was contested by attempts at replication that were unable to validate the findings (Markel, 2020). The discussion emphasizes the necessity of exacting, unbiased, and repeatable procedures in studies on plant cognition.

## **3. Plant Biohybrid Systems With AI**

### **3.1. Plants That Are Nanobionic**

In nanobionics, nanoparticles are inserted into plants to improve their sensory capacities. Carbon nanotube-based nanosensors, for instance, were created by Wong et al. (2017) to identify nitroaromatic contaminants and send signals via near-infrared fluorescence. These sensors provide living, self-sufficient detecting systems by integrating directly into plant tissues.

### **3.2. Plant Sensors That Can Be Worn**

Leaves or stems can have flexible, lightweight sensors affixed to them to track electrical activity, water

content, and sap flow. When connected to AI models, these gadgets enable automated decision-making and ongoing monitoring in precision farming (Zhang et al., 2024).

### 3.3. Combining Biohybrid Robots With Planetoids

"Plantoid" robots, which are modeled after plant root systems, combine mechanical systems and biological plant tissue to react adaptively to environmental stimuli (DeMarse et al., 2001). Space exploration and ecological monitoring may benefit from these hybrid systems.

## 4. AI to Interpret and Improve Plant Reactions

### 4.1. Processing And Classifying Signals

Signals from plants' electrophysiology are frequently complex and loud. In order to find patterns connected to stress, dietary deficits, or insect infestations, machine learning techniques, such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs), can process raw time-series data.

### 4.2. Fusion of Multimodal Data

AI can create a comprehensive model of plant health by combining electrical data from plants with hyperspectral imagery, thermal measurements, as well as environmental factors. These multimodal systems can function in field settings and increase accuracy (Zhang et al., 2024).

### 4.3. Systems With Closed-Loop Adaptation

AI may "experiment" with light, water, and fertilizer supply using reinforcement learning to find the best growing circumstances. These technologies create a feedback loop in which resource allocation is determined by the plant's real-time responses.

## 5. AI and Plant Systems Applications

- **A Precision Approach To Farming:** Farmers can optimize fertilizer and irrigation use when stress is detected early, which lowers waste and increases yield.

- **Observation of The Environment:** Nanobionic plants are able to identify poisons or other contaminants in the air and soil (Wong et al., 2017).

- **Green Infrastructure In Urban Areas:** Sensor-enabled trees and plants could offer real-time information on temperature, humidity, and urban air quality.

- **Non-traditional computing:** Neuromorphic computer systems could make advantage of plant tissues having memristive qualities (Volkov et al., 2014).

## 6. Restrictions and Ethical Issues

### 6.1. Issues With Reproducibility

It has been challenging to duplicate well-known plant learning experiments, which raises concerns regarding experimental controls and methods (Markel, 2020).

### 6.2. Invasiveness of sensors

The physiology of plants may change if sensors or nanomaterials are included into them. Ethical frameworks ought to address the permissible level of intervention.

### 6.3. Implications for philosophy

The ability of plants to learn and adapt could change how people view their moral standing (Calvo et al., 2020). However, assertions of plant sentience are still up for debate in philosophy and science.

## 7. Research Agenda

- Electromet datasets that are standardized for training AI models.

- Replicable methods for plant learning to settle disputes.
- Low-cost, scalable sensors for agricultural deployment.
- AI models that are explainable and relate patterns to physiological functions.
- Partnerships across disciplines between ethicists, AI engineers, and plant scientists.

## Conclusion

The idea of Neural Seeds, which uses artificial intelligence to train plants to learn and adapt, lies at the

nexus of biology, technology, and ethics. Although there is conflicting evidence about plant cognition, it is well known that artificial intelligence can monitor and decipher plant signals. Future developments in wearable sensors, nanobionics, and AI modeling suggest that plants will be active contributors to adaptive systems rather than merely passive crops. If such advances are explored with scientific rigor and ethical responsibility, they have the potential to transform fields such as agriculture, environmental monitoring, and even computers.

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