Electrophysiology of Mimosa pudica L

Minimum threshold charge required to trigger a thigmonastic response in Mimosa pudica

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Abstract

Certain plants like the Mimosa pudica shows thigmonastic behaviour. This is a nastic (rapid) behaviour that is communicated via electrical impulses, called action potentials, within the plant. The motive of this study is to observe the thigmonastic behaviour of M. Pudica plant by subjecting it to external electrical action potentials, applied across the pulvinus and ground. Further, find the minimum threshold charge required to trigger a thigmonastic response artificially in the plant. This study should be conducted several times under different conditions to find the exact minimum threshold charge that evokes the drooping of petiole in the plant.

Keywords: Thigmonasty, Action potential, Mimosa pudica, Minimum threshold charge, Electrical impulse, Pulvinus, Petiole, Pinnae
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1 Introduction

Certain plants like *Mimosa pudica* show thigmonastic behaviour. When their pinnae or petiole are touched or tapped, an electrical impulse (called an action potential) is generated via ionic imbalances and is transmitted through the petiole to the pulvinus. This action potential causes water to expel out of certain cells, which in turn causes a drop in turgor pressure. The shrinking of multiple cells at once causes mechanical stress, and hence drooping of the petiole and closing of the pinnae.

Many scientists have studied mechanical movements in *M. pudica* that were induced by electrical impulses (Ritter 1811; Gardiner 1888; Jonas 1970; Balmer and Franks 1975). Balmer and Franks (1975) briefly applied 200–400V between the soil and the primary pulvinus and estimated that the threshold voltage to trigger response in petiole was about 25 V with any electrode polarity. Jonas (1970) gave an electrical shock to *M. pudica* using a 0.5$\mu$F capacitor charged by 50, 100, and 150 V and found that there were oscillations of pinnae and fast petiolar movement. Yao H *et al* (2008) applied a 9 V electric pulse of 0.5 s duration to *M*. *pudica* and observed that the petioles bent downwards and the pinnae closed.

The motive of this study is to find out whether the drooping effect in *M. pudica* plant can be stimulated by an external artificial electrical signal, of magnitude 9 V, applied across the pulvinus and ground. Further, the minimum activation charge required to trigger a response will be studied. This can be done by subjecting the plant to electrical signals from a capacitor (charge bank) of different magnitudes, to estimate minimum amount of charge required to trigger a response.

This experiment is conducted several times under various conditions to map the exact behaviour of the plant.

2 Principle

*M. pudica* exhibits thigmonastic behaviour. When their pinnae or petiole are touched or tapped, an electrical impulse (called an action potential) is generated via ionic imbalances and is transmitted through the petiole to the pulvinus. This action potential causes water to expel out of certain cells, which in turn causes a drop in turgor pressure. The shrinking of multiple cells at once causes mechanical stress, and hence drooping of the petiole and closing of the pinnae.

There are two types of behaviours an *M. pudica* plant exhibits when stimulated

1. When its pinnae are gently touched - then pinnae attached to that particular secondary pulvinus fold.
2. When the petiole is gently tapped - then the whole petiole droops at the pulvinus node.

Once the plant has drooped its pinnae or petiole, then after 5-10 minutes the cells regain their turgidity and they return to their normal state slowly.

It has been observed that whenever any part of the plant (petiole or pinnae) is touched or tapped, the action potential evoked travels and converges at the pulvinus. Thus it will be appropriate to apply external electrical stimulus at that point for the experiment.
2.1 Circuit Principle

A capacitor is a device that is capable of storing electrical charge. Different capacitors with different magnitudes of capacitance are charged with a 9 V battery and used to give electric impulse in the experiment.

\[ Q = CV \]

Q = Charge stored in capacitor; C = Capacitance of capacitor; V = Potential difference

3 Procedure

1. Construct the circuit as shown in the circuit diagram (Fig.5)
2. Connect the cathode terminal to a nail and insert it into the soil of a potted M. pudica plant for grounding.
3. Gently wrap a piece of wire around the pulvinus of a stem, forming a loop. And then secure the wire firmly so that the setup is stable.
4. Connect the pulvinus wire to the anode terminal of the circuit.
5. Place the switch in the normally closed position for 5 seconds to charge the capacitor.
6. Then flip the switch to the normally open position to disconnect the battery and trigger the electrical signal.
7. Wait for a few seconds and record the behaviour of the plant.
8. Wait for around an hour for the drooped stem to regain turgidity and come back to its normal position.
9. Repeat the experiment (step 5 - step 8) by using different capacitors with different magnitudes of capacitance (10pF, 1 nF, 100 nF, 1µF, 470µF, 1000µF)
10. Repeat these series of experiments under different conditions, and by reversing the polarity of output terminals, i.e., connecting the anode terminal to the ground of the plant and the cathode to the pulvinus.

Figure 3: Experiment setup

Figure 4
4 Results

These experiments were carried out on two particular branches of the live *M. pudica* specimen, and their behaviour is summarized below.

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Time Stamp</th>
<th>Initial Status of plant</th>
<th>Voltage (across pulvinus &amp; ground)</th>
<th>Capacitor</th>
<th>Net Charge Given</th>
<th>Plant Behavior upon triggering</th>
<th>Plant Behavior after sometime</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>26/8 at 10:19</td>
<td>Plant is healthy. Soil is moderately moist</td>
<td>-9V 470µF 4230µC</td>
<td>The branch spontaneously droops at pulvinus. Leaves do not droop</td>
<td>Branch became erect after 10min</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Circuit Diagram

Figure 5: Circuit Diagram

Figure 6
<table>
<thead>
<tr>
<th>Time</th>
<th>Plant State</th>
<th>Soil Condition</th>
<th>Measurement</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>26/8 at 13:30</td>
<td>Plant is healthy. Soil is moderately moist</td>
<td>-9v 470µF 4230µC</td>
<td>The branch spontaneously droops at pulvinus. Leaves do not droop.</td>
<td></td>
</tr>
<tr>
<td>26/8 at 15:00</td>
<td>Plant is healthy. Soil is less moist</td>
<td>-9v 470µF 4230µC</td>
<td>No changes are observed</td>
<td></td>
</tr>
<tr>
<td>26/8 at 15:00</td>
<td>Plant is healthy. Soil is less moist</td>
<td>-9v 1000µF 900µC</td>
<td>No changes are observed</td>
<td></td>
</tr>
<tr>
<td>26/8 at 15:00</td>
<td>Plant is healthy. Soil is less moist</td>
<td>+9v 470µF 4230µC</td>
<td>The branch spontaneously droops at pulvinus. Leaves do not droop.</td>
<td></td>
</tr>
<tr>
<td>26/8 at 15:20</td>
<td>Plant seems healthy. Just undergone stress because electrode attached to other branches. Soil is less moist</td>
<td>+9v 1µF 9µC</td>
<td>The branch spontaneously droops at pulvinus. Leaves do not droop.</td>
<td></td>
</tr>
<tr>
<td>26/8 at 15:44</td>
<td>Small branch leaf is little weak. Soil is less moist</td>
<td>+9v 1µF 9µC</td>
<td>No changes are observed</td>
<td></td>
</tr>
<tr>
<td>26/8 at 15:44</td>
<td>Small branch leaf is little weak. Soil is less moist</td>
<td>+9v 1µF 9µC</td>
<td>Branch became erect after 6min</td>
<td></td>
</tr>
<tr>
<td>26/8 at 17:12</td>
<td>Small branch is healthy. Soil is less moist</td>
<td>+9v 10µF 0.0009µC</td>
<td>No changes are observed</td>
<td></td>
</tr>
<tr>
<td>26/8 at 17:12</td>
<td>Small branch is healthy. Soil is less moist</td>
<td>-9v 10µF 0.0009µC</td>
<td>No changes are observed</td>
<td></td>
</tr>
<tr>
<td>26/8 at 17:12</td>
<td>Small branch is healthy. Soil is less moist</td>
<td>-9v 1µF 0.008µC</td>
<td>No changes are observed</td>
<td></td>
</tr>
<tr>
<td>26/8 at 17:12</td>
<td>Small branch is healthy. Soil is less moist</td>
<td>-9v 1µF 0.008µC</td>
<td>No changes are observed</td>
<td></td>
</tr>
<tr>
<td>26/8 at 17:16</td>
<td>Small branch is healthy. Soil is less moist</td>
<td>+9v 100nF 0.9µC</td>
<td>No changes are observed</td>
<td></td>
</tr>
<tr>
<td>26/8 at 17:16</td>
<td>Small branch is healthy. Soil is less moist</td>
<td>-9v 100nF 0.9µC</td>
<td>The branch spontaneously droops at pulvinus. Leaves are erect initially, after 8s they are closed</td>
<td></td>
</tr>
<tr>
<td>26/8 at 17:17</td>
<td>Large branch is healthy. Soil is less moist</td>
<td>-9v 100nF 0.9µC</td>
<td>No changes are observed</td>
<td></td>
</tr>
<tr>
<td>26/8 at 17:17</td>
<td>Large branch is healthy. Soil is less moist</td>
<td>+9v 100nF 0.9µC</td>
<td>Branch droops at pulvinus after 1s. Leaves do not droop</td>
<td></td>
</tr>
<tr>
<td>27/8 at 12:30</td>
<td>Leaves are only partially open. The plant is not very healthy.</td>
<td>+9v 1µF 0.009µC</td>
<td>No changes are observed</td>
<td></td>
</tr>
<tr>
<td>27/8 at 12:31</td>
<td>The plant is not very healthy</td>
<td>+9v 100nF 0.9µC</td>
<td>No changes are observed</td>
<td></td>
</tr>
<tr>
<td>27/8 at 12:31</td>
<td>The plant is not very healthy</td>
<td>+9v 100nF 0.9µC</td>
<td>No changes are observed</td>
<td></td>
</tr>
<tr>
<td>27/8 at 12:32</td>
<td>The plant is not very healthy</td>
<td>-9v 1µF 0.009µC</td>
<td>No changes are observed</td>
<td></td>
</tr>
<tr>
<td>27/8 at 12:35</td>
<td>The plant is not very healthy</td>
<td>-9v 100nF 0.9µC</td>
<td>No changes are observed</td>
<td></td>
</tr>
<tr>
<td>27/8 at 12:36</td>
<td>The plant is not very healthy</td>
<td>-9v 1µF 9µC</td>
<td>Branch droops at pulvinus after 2s</td>
<td></td>
</tr>
</tbody>
</table>

Very healthy

The plant is not very healthy

The plant is not very healthy

The plant is not very healthy

The plant is not very healthy

The plant is not very healthy

The plant is not very healthy

The plant is not very healthy

The plant is not very healthy

The plant is not very healthy

The plant is not very healthy

The plant is not very healthy

Leaves droop 2 sec after branch had dropped

Leaves droop after 10min

Leaves droop after 8s they are closed

Leaves droop after 15min

Leaves droop after 10min

Leaves droop after 8s they are closed

Leaves droop after 15min
5 Observations

It is noted that the charge from at least a 100 nF capacitor is required to evoke an action potential in the plant.

Minimum charge required to trigger response = $C \times V = 9v \times 100nF = 0.9\mu C$

5.1 Further Observations

1. Most of the times when an external electrical signal is given in the mentioned manner to the plant, only the petiole droops and the pinnae mostly remain erect.

2. It is also noted that sometimes a forward potential is required to trigger a response in the plant, and sometimes a reverse potential. No regular pattern associated with this behaviour was observed.

3. When the plant is exposed to stress or is not healthy, then the amount of charge required to trigger an action potential is different from the amount required to trigger when the plant is healthy.

4. When electrode gel is applied at the pulvinus connection, then the petiole never droops. This might be because as the electrode gel is a hypotonic medium it might not allow the cells to lose turgidity thus not letting it droop.

6 Conclusion

1. An external electrical signal can indeed trigger an action potential and make the petiole of an *M. pudica* plant droop at the pulvinus.

2. A minimum of $0.9\mu C$ of charge is required to trigger an action potential.
7 Summary

From this experiment, we can conclude that, by applying a potential difference across the ground and pulvinus, it is indeed possible to make the *M. pudica* plant droop its petiole even without touching it physically. So this proves the fact that thigmonastic behaviour in *M. pudica* plants is associated with electrical signals that are naturally produced in the plant. It was also further found out that a minimum of at least 0.9µC of charge is required to trigger an action potential. However when the physiology of the plant is disturbed due to environmental stress, the threshold charge is also altered. The exact change in threshold charge can be calculated by conducting more experiments in the future.
References


