Electrophysiology of Mimosa pudica L

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Abstract

Certain plants like the Mimosa pudica shows thigmonastic behavior. This is a nastic (rapid) behavior communicated via electrical impulses, called action potentials, within the plant. The motivation of our study is to observe the thigmonastic behavior of the M. Pudica plant by subjecting it to external electrical action potentials applied across the pulvinus and ground. And to find the minimum threshold required to trigger a thigmonastic response artificially in the plant. This observation has been conducted several times under varying specific conditions to find the exact minimum threshold charge that evokes the drooping of the petiole in the plant.

Keywords: Thigmonasty, Action potenital, Mimosa pudica, Minimum threshold charge, Electrical impulse, Pulvinus

1 Introduction

Certain plants like *Mimosa pudica* show thigmonastic behavior. 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 be expelled out of certain cells, which in turn causes a drop in turgor pressure. The shrinking of multiple cells at once causes mechanical stress, hence drooping of the petiole and closing of the pinnae.

Several [1][2][3][4][5][6] scientists have studied mechanical movements in *M. pudica* that were induced by an electrical impulse. Balmer and Franks (1975)[2] briefly applied 200–400V between the soil and the primary pulvinus. They estimated that the threshold voltage to trigger a response in petiole was about 25 V with any electrode polarity. Jonas (1970)[3] 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 motivation of this study is to find out whether the drooping effect in the *M. pudica* plant can be stimulated by an external artificial electrical signal of magnitude 9 V, applied across the pulvinus and ground, and to ascertain the minimum activation charge. We have done this by subjecting the plant to electrical signals from a capacitor (charge bank) of different magnitudes and then finding the minimum amount of charge required to trigger a response.

We have carried out this experiment several times under various specific conditions to map the exact behavior of the plant.

2 Principle

The *M. pudica* exhibits thigmonastic behavior. 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 be expelled out of certain cells, which in turn causes a drop in turgor pressure. The shrinking of multiple cells at once causes mechanical stress, hence drooping of the petiole and closing of the pinnae.

Figure 1: *Mimosa pudica* plant

Figure 2

There are two behaviors an *M. pudica* plant exhibits when stimulated:

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

Once the plant has drooped its pinnae or petiole, the cells regain their turgidity after 5-10 minutes, 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 would be appropriate to apply external electrical stimulus at that point for the experiment.

2.1 Circuit Principle

We will be using a capacitor(a device capable of storing electrical charge) to transfer a fixed amount of electrical charge to the plant as an external artificial action potential. 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

The steps taken to perform the experiment have been summarised below,

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 behavior of the plant.
8. Wait for around an hour for the drooped stem to regain turgidity and return to its normal position.
9. Repeat the experiment (step 5 - step 8) using different capacitors with different magnitudes of capacitance ($470\mu F$, $1000\mu F$, $1\mu F$, 10 pF, 100 nF, 1 nF).
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: Complete experimental setup has been depicted in this picture

Figure 4: Location of the electrodes on the plant has been identified in this figure

Circuit Diagram The circuit consists of a capacitor, which is used to expose the plant to a fixed amount of electrical charge, a 9V battery which acts as the primary power source to charge the capacitor, and a single throw double pole switch to alternate between two states- at one state it disconnects the plant and charges the capacitor while at the other, it disconnects the battery and transfers the electrical signal to the plant.

Figure 5: Circuit Diagram

4 Results

Figure 6: Branches used for experimentation are shown in this picture

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

Sl. No	Time (mm/dd hh:mm)	Stamp at	Initial Status of plant	Voltage (across pulvinus & ground)	Capacitance	Net Charge Given	Plant Behavior upon triggering	Plant Behavior after sometime
1	26/8	at 10:19	The plant is healthy. Soil is moderately moist	-9v	470 μ F	4230 μ C	The branch spontaneously droops at pulvinus. Leaves do not droop	The branch became erect after 10min
2	26/8	at 13:30	The plant is healthy. Soil is moderately moist	-9v	470 μ F	4230 μ C	The branch spontaneously droops at pulvinus. Leaves do not droop	The branch became erect after 10min
3	26/8	at 15:00	The plant is healthy. Soil is less moist	-9v	470 μ F	4230 μ C	No changes are observed	

4	26/8 at 15:00 [Large Branch]	The plant is healthy. Soil is less moist	-9v	1000 μF	900 μC	No changes are observed	
5	26/8 at 15:00 [Large Branch]	The plant is healthy. Soil is less moist	+9v	470 μF	4230 μC	The branch spontaneously droops at pulvinus. Leaves do not droop.	The branch became erect after 10min
6	26/8 at 15:20 [Large Branch]	The plant seems healthy. Just undergone stress because electrode attached to other branches. Soil is less moist	+9v	1 μF	9 μC	The branch spontaneously droops at pulvinus. Leaves do not droop.	The branch became erect after 10min
7	26/8 at 15:43 [Small branch]	The small branch leaf is a little weak. Soil is less moist	+9v	1 μF	9 μC	No changes are observed	The branch became erect after 10min
8	26/8 at 15:44 [Small branch]	The small branch leaf is a little weak. Soil is less moist	-9v	1 μF	9 μC	The branch spontaneously droops at pulvinus. Leaves droop 2 sec after branch had drooped.	The branch became erect after 6min
9	26/8 at 17:12 [Small branch]	The small branch is healthy. Soil is less moist	+9v	10 μF	0.00009 μC	No changes are observed	
10	26/8 at 17:12 [Small branch]	The small branch is healthy. Soil is less moist	-9v	10 μF	0.00009 μC	No changes are observed	
11	26/8 at 17:12 [Small branch]	The small branch is healthy. Soil is less moist	-9v	1nF	0.009 μC	No changes are observed	
12	26/8 at 17:13 [Small branch]	The small branch is healthy. Soil is less moist	+9v	1nF	0.009 μC	No changes are observed	
13	26/8 at 17:16 [Small branch]	The small branch is healthy. Soil is less moist	+9v	100nF	0.9 μC	No changes are observed	
14	26/8 at 17:16 [Small branch]	The small branch is healthy. Soil is less moist	-9v	100nF	0.9 μC	The branch spontaneously droops at pulvinus. Leaves are erect initially, after 8s they are closed	The branch became erect after 6min
15	26/8 at 17:17 [large branch]	The large branch is healthy. Soil is less moist	-9v	100nF	0.9 μC	No changes are observed	
16	26/8 at 17:17 [large branch]	The large branch is healthy. Soil is less moist	+9v	100nF	0.9 μC	The branch droops at pulvinus after 1s. Leaves do not droop	The branch became erect after 10min
17	27/8 at 12:30 [small branch]	Leaves are only partially open. The plant is not very healthy.	+9v	1nF	0.009 μC	No changes are observed	
18	27/8 at 12:31 [small branch]	The plant is not very healthy	+9v	10nF	0.09 μC	No changes are observed	
19	27/8 at 12:31 [small branch]	The plant is not very healthy	+9v	100nF	0.9 μC	No changes are observed	
20	27/8 at 12:32 [small branch]	The plant is not very healthy	-9v	1nF	0.009 μC	No changes are observed	
21	27/8 at 12:35 [small branch]	The plant is not very healthy	-9v	10nF	0.09 μC	No changes are observed	
22	27/8 at 12:35 [small branch]	The plant is not very healthy	-9v	100nF	0.9 μC	No changes are observed	
23	27/8 at 12:36 [small branch]	The plant is not very healthy	-9v	1 μF	9 μC	The branch droops at pulvinus after 2s	The branch became erect after 15min
24	27/8 at 12:38 [large branch]	Leaves are only partially open. The plant is not very healthy.	+9v	1nF	0.009 μC	No changes are observed	
25	27/8 at 12:39 [large branch]	The plant is not very healthy	+9v	10nF	0.09 μC	No changes are observed	

26	27/8 12:39[large branch]	at	The plant is not very healthy	+9v	100nF	0.9μC	No changes are observed
27	27/8 12:40[large branch]	at	The plant is not very healthy	+9v	1μF	9μC	No changes are observed
28	27/8 at [large branch]		The plant is not very healthy	+9v	47μF	423μC	No changes are observed
29	27/8 12:41[large branch]	at	The plant is not very healthy	-9v	1nF	0.009μC	No changes are observed
30	27/8 12:41[large branch]	at	The plant is not very healthy	-9v	10nF	0.09μC	No changes are observed
31	27/8 12:41[large branch]	at	The plant is not very healthy	-9v	100nF	0.9μC	No changes are observed
32	27/8 12:42[large branch]	at	The plant is not very healthy	-9v	1μF	9μC	No changes are observed
33	27/8 12:42[large branch]	at	The plant is not very healthy	-9v	47μF	423μC	The branch spontaneously droops at pulvinus
34	27/8 at 4:25[small branch]		The plant looks much healthier. Leaves are still not completely open. But they are more erect than at 12:40	-9v	10nf	0.09μC	No changes are observed
35	27/8 at 4:25[small branch]		The plant looks much healthier	-9v	100nF	0.9μC	Branch Spontaneously droops at pulvinus
36	27/8 at 4:28[large branch]		The plant looks much healthier	-9v	100nF	0.9μC	Branch Spontaneously droops at pulvinus

5 Observations

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

The minimum charge required to trigger a response is given by

$$C * V = 9v * 100nF = 0.9\mu C$$

5.1 Further Observations

We have made some further observations which we note here,

1. Most of the time, 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 behavior was observed.
3. When the plant is exposed to stress or is not healthy, the amount of charge required to trigger an action potential differs 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 Concluding Remarks

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.

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

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