



## Phytochemical analysis through GC-MS in *Mimosa pudica*

**Jaivenkat Srinivasan<sup>1</sup>, Linsa Raani Anand<sup>1</sup>, Gunaseelan Poochandiran<sup>1</sup>, Tharun Aravinthan Sankar<sup>1</sup>, Nitheeshwaran Thayuman<sup>1</sup>, Ambika Singaram<sup>1</sup>, Bharathi Raja Ramadoss<sup>2</sup>, Dhanarajan Arulbalachandran<sup>3</sup>, Selvakumar Gurunathan<sup>1\*</sup>**

<sup>1</sup>SRM College of Agricultural Sciences, SRM Institute of Science and Technology, Vendhar Nagar, Baburyanpettai, Tamil Nadu, India.

<sup>2</sup>Bioriginal Food and Science Corporation, Saskatoon, SK S7J 0R1, Canada.

<sup>3</sup>Division of Crop Molecular Breeding and Stress Physiology, Department of Botany, School of Life Sciences, Periyar University, Periyar Palkalai Nagar, Salem, Tamil Nadu, India.

**\*Correspondence**

Selvakumar Gurunathan  
selvakumaragri@gmail.com

Volume: 11, Issue: 1, Pages: 12-17

DOI: <https://doi.org/10.37446/jinagri/rsa/11.1.2024.12-17>

Received: 01 October 2023 / Accepted: 28 December 2023 / Published: 31 March 2024

**Background:** The aim of the study to identify the phytochemical present in the *Mimosa pudica* plant present in the premises of SRM College of Agricultural Sciences, Chengalpattu district, Tamil Nadu, India.

**Methods:** Leaves, stem and root samples were used for the methanol extraction and the crude extract was subjected into the GCMS analysis.

**Results:** The results revealed the presence of Mome inositol; Guanosine; 3-o-methyl-D-fructose; Ether butyl isopentyl; Methyl.beta.-d-ribofuranoside; 3,4-Dichloroatropine etc., in the plant parts.

**Conclusion:** This study identified a range of bioactive compounds in *Mimosa pudica* using GC-MS analysis. Further studies to be carried out to find out more phytochemicals.

**Keywords:** *Phytochemical, GC-MS, Mimosa pudica, medicinal plant, metabolite profiling*

### Introduction

*Mimosa pudica* L. (Family: Fabaceae), a renowned ornamental plant, is commonly recognized by a multitude of names including sleeping grass, sensitive plant, humble plant, shy plant, touch-me-not, chuimui, and lajwanti. The plant's popularity in the realm of ornamentation stems from its intriguing thigmonastic and seismonastic behaviors. These physiological responses entail leaf closure and petiole drooping, orchestrated in reaction to an array of stimuli such as light variations, vibrations, wounds, air currents, tactile contact, as well as temperature fluctuations encompassing both warmth and coldness (Volkov et al., 2010a, 2010b; Herzfeld et al., 2015). This particular plant reportedly possesses a sour and puckering flavor and has been historically employed to address different health issues. While the leaves are the most frequently utilized plant component for this intention, the flowers, bark, and fruits also hold significance in traditional medicine (Sriram et al., 2011). The *M. pudica* is recognized and appreciated for its pain-relieving, anti-inflammatory (Prasanna et al., 2009), blood sugar reducing (Amalraj & Ignacimuthu, 2002), diuretic, puckering, muscle-relaxing, and blood-cleansing (Ghani, 2003) properties. As a result, it has been employed to address hypertension (Aalok, 1997), menorrhagia, and leucorrhea (Hemadri & Rao, 1983; Vaidya & Sheth, 1986). Applying a paste made from the entire plant can be effective in treating wounds while using a paste derived from the leaves can help with eczema (Singh & Singh, 2009). Both leaves and roots are employed in the treatment of hemorrhoids (Ghani, 2003). It also has various other pharmacological advantages like antifertility (Valsala & Karpagagaanapathy, 2002; Ganguly et al., 2007), and antidiarrheal (Balakrishnan et al., 2006). Antiparasitic (Marimuthu et al., 2011) and antimicrobial potentials (Ambikapathy & Gomathi, 2011; Mohan et al., 2011; Tamilarasi & Anathi, 2012). A research has indicated that *Mimosa pudica* has been utilized to calm the mind, alleviate depression, mental unease, irritability,

and memory loss. Furthermore, it is employed to boost mood, enhance blood circulation, foster proper cell development, and hinder hair loss. In Western medicine, its root was employed for addressing insomnia, premenstrual syndrome, hemorrhoids, and whooping cough. The exploration of the biochemical content of medicinal plants encompasses the intricate examination of the extract obtained. The intricate array of chemical compounds across diverse groups of secondary metabolites in these plants creates difficulties in both identifying and quantifying components within the sample. Hence, the application of accurate and trustworthy analytical techniques assumes paramount importance in studying these samples within the domain of natural and phytotherapeutic products. One of the pre-eminent analytical techniques involved in the biochemical profiling of medicinal plants is GCMS. Gas chromatography-mass spectrometry (GC-MS) is the combination of two analytical methods to separate and identify various extracts to be tested. Gas chromatography is used to differentiate the components of a mixture in peak area %. Mass spectrometer was used to identify and structural elucidation of all the chemical compounds. Numerous research investigations focusing on various *Mimosa* genus species reveal findings related to the separation and recognition of organic substances. Aguiar et al. extracted the subsequent substances from *Mimosa invisa*: pinoresinol, salicifoliol, quercetin, sitosterol,  $\beta$ -amyrin, p-hydroxy coumaric acid, 4-hydroxy-3,5-dimethoxy benzaldehyde, 4-hydroxy-3-methoxy benzaldehyde (vanillin), 4-hydroxy-3-methoxy benzoic acid, and 4',6,7-trimethoxy flavonol. Cruz et al. Successfully extracted a variety of flavonoids, including 5,4'-dihydroxy-7-methoxyflavanone, 5,7,4'-trihydroxy-3-methoxyflavone, 5,4'-dihydroxy-7,8-dimethoxyflavone, 5,7,4'-trihydroxy-6-methoxyflavonol, and 5-hydroxy-7,8,4'-trimethoxyflavonol, from the leaves of *M. tenuiflora* through their research efforts. In the aqueous extract of *M. tenuiflora* bark, Rivera-Arce and colleagues detected the presence of saponins and tannins, as outlined in their research study. Researchers successfully isolated the compound 2-(2',6'-dimethyl-3',4',5'-alkyl)-3-oxy-(alkyl or hydroxy alkyl)-5,7-dihydroxy-chromen-4-one from the entire *Mimosa pudica* plant. Hence, this current research was conducted to explore the chemical elements of *Mimosa pudica* L. using Gas Chromatography Mass Spectrometry (GC-MS). We have used the methanolic extract of the leaf, stem and root samples of touch-me-not plant for GC-MS analysis.

## Materials and Methods

*Mimosa pudica* (including root) healthy and disease free plants were collected from the premises of SRM College of Agricultural Sciences, Vendhar Nagar, Baburayanpettai, Chengalpattu district. Leaves, stems and roots are separated and shade dried for seven days. Four grams of powdered samples (leaf, stem, and root) in a test tube were taken and then 40 ml of methanol was added in each test tube. Shacked and covered with aluminum foil and incubated it for 24 hours. Whatman 1 filter paper was used to filter the extract. Then the crude extracts were used to detect various biochemical compounds by Gas Chromatography - Mass Spectrometry (GC-MS) at Nanotechnology Research Centre (NRC), SRMIST.

## Results and Discussion

GCMS analysis of methanolic extract of *Mimosa pudica* revealed different phytochemical compounds in the leaf (Table 1), stem (Table 2) and root (Table 3) (detailed results are in the supplementary file). Also, the plant samples reported with 3-o-methyl- D-fructose; Ether, butyl isopentyl; Guanosine, 1,2,3-propanetriol, diacetate; 1,3-cyclohexane-1,3-d2-diamine, cis-; etc., (complete GCMS analysis result is given as supplementary file).

**Table 1. Compounds identified in the methanolic leaf extract of *Mimosa pudica* in GC-MS**

RT	Name of the compound	Molecular formula	Molecular weight	Peak area %
18.487	Mome inositol	C <sub>7</sub> H <sub>14</sub> O <sub>6</sub>	194	32.12
18.255	3-o-methyl- D-fructose	C <sub>7</sub> H <sub>14</sub> O <sub>6</sub>	194	31.43
17.76	Ether, butyl isopentyl	C <sub>9</sub> H <sub>20</sub> O	144	10.44
14.53	Guanosine	C <sub>10</sub> H <sub>13</sub> N <sub>5</sub> O <sub>5</sub>	283	3.87
18.95	4-o-methylmannose	C <sub>7</sub> H <sub>14</sub> O <sub>6</sub>	194	2.22
25.448	(z)-3-(pentadec-8-en-1-yl)phenol	C <sub>21</sub> H <sub>34</sub> O	302	1.47
19.214	3,7,11,15-tetramethyl-2-hexadecen-1-ol	C <sub>20</sub> H <sub>40</sub> O	296	1.23
22.083	Phytol	C <sub>20</sub> H <sub>40</sub> O	296	1.11
9.36	Acetic acid, pentyl ester	C <sub>7</sub> H <sub>14</sub> O <sub>2</sub>	130	0.53
16.504	1,2-benzenedicarboxylic acid, diethyl ester	C <sub>12</sub> H <sub>14</sub> O <sub>4</sub>	222	0.5
9.425	2-propanone, 1-(1,3-dioxolan-2-yl	C <sub>6</sub> H <sub>10</sub> O <sub>3</sub>	973	0.49
4.968	Methylaurate	C <sub>8</sub> H <sub>10</sub>	106	0.43

The presence of Mome inositol was recorded in all three samples and it is a polysaccharide compound possessing anti-proliferative, anti-alopecic, anti-cirrhotic and anti-neuropathic (Das et al., 2014) activities. Previous biochemical studies in *Mimosa pudica* revealed the presence of many alkaloids, Mimosin (non-protein), flavonoids, glycosides, sterols, terpenoids, tannins and fatty acids (Kirk et al., 2003, Bum et al., 2004, Dinda et al., 2006). *M. rubicaulis* was shown to produce flavanoid and glycosides. The discovered component was useful for antifertility activity (Norton, 1978) and very effective in the treatment for snakebites (Mahanta & Mukherjee, 2001). Gas Chromatography – Mass Spectrometry (GC-MS) is a method that combines the features of gas chromatography and mass spectrometry for identifying of various components present in the given test sample based on their retention time (RT) (Kell et al., 2005). Nowadays, GC-MS has become a technical platform for profiling secondary metabolite in all the plant and non-plant materials (Fernie et al., 2004).

**Table 2. Compounds identified in the methanolic stem extract of *Mimosa pudica* in GC-MS**

RT	Name of the compound	Molecular formula	Molecular weight	Peak area %
18.49	Mome inositol	C <sub>7</sub> H <sub>14</sub> O <sub>6</sub>	194	66.75
14.89	Guanosine	C <sub>10</sub> H <sub>13</sub> N <sub>5</sub> O <sub>5</sub>	283	18.18
11.695	1,2,3-propanetriol, diacetate	C <sub>7</sub> H <sub>12</sub> O <sub>5</sub>	176	1.14
9.365	1,3-cyclohexane-1,3-d2-diamine, cis-	C <sub>6</sub> H <sub>12</sub> D <sub>2</sub> N <sub>2</sub>	116	0.85

**Table 3. Compounds identified in the methanolic root extract of *Mimosa pudica* in GC-MS**

RT	Name of the compound	Molecular formula	Molecular weight	Peak area %
18.49	Mome inositol	C <sub>7</sub> H <sub>14</sub> O <sub>6</sub>	194	66.75
14.89	Guanosine	C <sub>10</sub> H <sub>13</sub> N <sub>5</sub> O <sub>5</sub>	283	18.18
11.695	1,2,3-propanetriol, diacetate	C <sub>7</sub> H <sub>12</sub> O <sub>5</sub>	176	1.14
9.365	1,3-cyclohexane-1,3-d2-diamine, cis-	C <sub>6</sub> H <sub>12</sub> D <sub>2</sub> N <sub>2</sub>	116	0.85
10.255	Propanoic acid, 2-methyl-	C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	88	0.74
10.315	1,3-dioxolane-2-methanol	C <sub>4</sub> H <sub>8</sub> O <sub>3</sub>	104	0.64
10.1	1,3-dioxolane, 2,4,5-trimethyl-	C <sub>6</sub> H <sub>12</sub> O <sub>2</sub>	116	0.59
12.75	2-methoxy-4-vinylphenol	C <sub>9</sub> H <sub>10</sub> O <sub>2</sub>	150	0.59
16.865	1-butanol, 3-methyl-	C <sub>5</sub> H <sub>12</sub> O	88	0.53
16.5	1,2-benzoldicarbonsaeure, di-(hex-1-en-5-yl-ester)	C <sub>20</sub> H <sub>26</sub> O <sub>4</sub>	330	0.46
10.455	Propane	C <sub>3</sub> H <sub>8</sub>	44	0.45

In this report, retention time (RT), molecular formula, molecular weight (MW), peak area% gives the presence of thirteen bio-active phytochemical compounds using the methanolic extract of *Mimosa Pudica*. The presence of different biochemical on the methanol leaf extract are used for efficient wound healing and also in arresting wound bleeding (Chinmoy & Nongmaithem, 2019). Ahmad et al. (2012) found the presence of many phytocompounds like terpenoids, flavonoids, glycosides, alkaloids, quinines, phenols, tannins, saponins, and coumarins in *M. pudica* methanolic extract obtained from leaf sample. Among the identified bio-chemicals are Acetamide, N-methyl-N-[4-[4-fluoro-1-hexahydropyridyl]-2-butynyl]-, Gentamicin and mannosamine have antioxidant and antimicrobial activities (Hussein et al., 2019). Compounds with acetamide link exhibits many applicants, those are well noted. The acetamide functional group is responsible for antimicrobial (Berest et al., 2011) antioxidant and anti-inflammatory (Autore et al., 2010). The acetamides and their analogues all are experimented as chemotherapeutic agents (McCarthy et al., 2009 and Liu et al., 2012).

In our report of GC-MS analysis of methanol extract of leaf, stem and root of touch me not plant shows the presence of various bio-chemicals. Same like our estimation, the GC-MS analyses is done in various parts of many medicinal crops like leaf, flower and stem of mountain knotgrass (*Aerva lanata*) (Vidhya & Udayakumar, 2015), leaf and stem of water clover (*Marsilea minuta* L.) (Sabithira & Udayakumar, 2017), leaf and stem of Pepperwort (*Marsilea quadrifolia*) (Gopalakrishnan & Udayakumar, 2014) and leaf, fruit and latex of croton bonplandianus baill (*Croton bonplandianum*) (Vennila & Udayakumar, 2015) also reported many phyto-compounds. With reference to Dr. Duke's Phytochemical and Ethnobotanical report, the bioactive compounds of ethanolic extract of leaf and root of *M. pudica* have many pharmacological activities. The isolation of bio-active compounds in leaf, stem and root of touch me not plants can be utilised for the production of drugs to control diseases.

## Conclusion

In this analysis, the presence of various phyto-chemical compounds has been detected using GC-MS analysis in the crude methanol extract of leaf, stem and root of naturally available *Mimosa pudica* plant in the SRMCAS premises

where naturally occurring. Since, these phytochemical compounds attributing for the medicinal and therapeutic characteristics nature, isolation and purification of the identified compounds could be used to prepare medicinal drugs.

## Acknowledgment

We acknowledge the Nanotechnology Research Centre (NRC), SRMIST for providing the research facilities

## Author contributions

GS framed the research programme and corrected the manuscript. LA, GP, TARS, NT and JS are carry out the experiments and produced the article draft. AS, BRR and DA helped in writing this manuscript.

## Funding

No funding.

## Conflict of interest

The author declares no conflict of interest. The manuscript has not been submitted for publication in any other journal.

## Ethics approval

Not applicable.

## References

Aalok, P. K. (1997). Lajjalu-an indispensable drug for blood pressure. *Sachitra Ayurved*, 50(1), 21-2.

Ahmad, H., Sehgal, S., Mishra, A., & Gupta, R. (2012). *Mimosa pudica* L. (Laajvanti): an overview. *Pharmacognosy Reviews*, 6(12), 115.

Amalraj, T., & Ignacimuthu, S. (2002). Hyperglycemic effect of leaves of *Mimosa pudica* Linn. *Fitoterapia*, 73(4), 351-352.

Ambikapathy, V., Gomathi, S. and Panneerselvam, A. (2011). Effect of antifungal activity of some medicinal plants against *Pythium debaryanum* (Hesse). *Asian Journal of Plant Science and Research*, 1, 131-134.

Autore, G., Caruso, A., Marzocco, S., Nicolaus, B., Palladino, C., Pinto, A., ... & Saturnino, C. (2010). Acetamide derivatives with antioxidant activity and potential anti-inflammatory activity. *Molecules*, 15(3), 2028-2038.

Balakrishnan, N., Suresh, D., Pandian, G. S., Edwin, E., & Sheeja, E. (2006). Antidiarrhoeal potential of *Mimosa pudica* root extracts. *Indian Journal of Natural Products*, 22(2), 21-23.

Berest, G. G., Voskoboinik, O. Y., Kovalenko, S. I., Antypenko, O. M., Nosulenko, I. S., Katsev, A. M., & Shandrovskaia, O. S. (2011). Synthesis and biological activity of novel N-cycloalkyl-(cycloalkylaryl)-2-[(3-R-2-oxo-2H-[1, 2, 4] triazino [2, 3-c] quinazoline-6-yl) thio] acetamides. *European Journal of Medicinal Chemistry*, 46(12), 6066-6074.

Bum, E. N., Dawack, D. L., Schmutz, M., Rakotonirina, A., Rakotonirina, S. V., Portet, C., ... & Herrling, P. (2004). Anticonvulsant activity of *Mimosa pudica* decoction. *Fitoterapia*, 75(3-4), 309-314.

Chinmoy, B., & Nongmaithem, R. C. (2019). The sensitive plant *Mimosa pudica*: A useful weed. *International Journal of Scientific Development and Research*, 4(5), 3.

Das, S., Vasudeva, N., & Sharma, S. (2014). Chemical composition of ethanol extract of *Macrotyloma uniflorum* (Lam.) Verdc. using GC-MS spectroscopy. *Organic and medicinal chemistry letters*, 4(1), 13.

Dinda, B., Bhattacharya, A., De, U. C., Arima, S., Takayanagi, H., & Harigaya, Y. (2006). Antimicrobial C-glucoside from aerial parts of *Diospyros nigra*. *Chemical & Pharmaceutical Bulletin*, 54(5), 679–681.

Fernie, A. R., Carrari, F., & Sweetlove, L. J. (2004). Respiratory metabolism: glycolysis, the TCA cycle and mitochondrial electron transport. *Current opinion in plant biology*, 7(3), 254-261.

Ganguly, R., Brotherton, M. S., Cales, S., Scoggins, B., Shang, Z., & Vestergaard, M. (2007). Outflows and the physical properties of quasars. *The Astrophysical Journal*, 665(2), 990.

Ghani, A. (2003). *Medicinal plants of Bangladesh with chemical constituents and uses*. Asiatic society of Bangladesh.

Gopalakrishnan, K., & Udayakumar, R. (2014). GC-MS analysis of phytocompounds of leaf and stem of *Marsilea quadrifolia* (L.). *Int J Biochem Res Rev*, 4(6), 517–526.

Hemadri, K., & Rao, S. S. (1983). Leucorrhoea and menorrhagia: Tribal medicine. *Ancient Science of Life*, 3(1), 40-41.

Herzfeld, D. J., Kojima, Y., Soetedjo, R., & Shadmehr, R. (2015). Encoding of action by the Purkinje cells of the cerebellum. *Nature*, 526(7573), 439-442.

Hussein, E. M., Al-Rooqi, M. M., Abd El-Galil, S. M., & Ahmed, S. A. (2019). Design, synthesis, and biological evaluation of novel N 4-substituted sulfonamides: acetamides derivatives as dihydrofolate reductase (DHFR) inhibitors. *BMC chemistry*, 13(1), 91.

Kell, D. B., Brown, M., Davey, H. M., Dunn, W. B., Spasic, I., & Oliver, S. G. (2005). Metabolic footprinting and systems biology: the medium is the message. *Nature Reviews Microbiology*, 3(7), 557-565.

Kirk, L. F., Møller, M. V., Christensen, J., Stærk, D., Ekpe, P., & Jaroszewski, J. W. (2003). A 5-deoxyflavonol derivative in *Mimosa pudica*. *Biochemical Systematics and Ecology*, 31(1), 103-106.

Liu, Z., Zhou, Z., Tian, W., Fan, X., Xue, D., Yu, L., ... & Long, Y. Q. (2012). Discovery of novel 2-N-aryl-substituted benzenesulfonamidoacetamides: orally bioavailable tubulin polymerization inhibitors with marked antitumor activities. *ChemMedChem*, 7(4), 680-693.

Mahanta, M., & Mukherjee, A. K. (2001). Neutralisation of lethality, myotoxicity and toxic enzymes of *Naja kaouthia* venom by *Mimosa pudica* root extracts. *Journal of ethnopharmacology*, 75(1), 55-60.

Marimuthu, S., Rahuman, A. A., Rajakumar, G., Santhoshkumar, T., Kirthi, A. V., Jayaseelan, C., ... & Kamaraj, C. (2011). Evaluation of green synthesized silver nanoparticles against parasites. *Parasitology Research*, 108(6), 1541-1549.

McCarthy, O., Musso-Buendia, A., Kaiser, M., Brun, R., Ruiz-Perez, L. M., Johansson, N. G., ... & Gilbert, I. H. (2009). Design, synthesis and evaluation of novel uracil acetamide derivatives as potential inhibitors of *Plasmodium falciparum* dUTP nucleotidohydrolase. *European journal of medicinal chemistry*, 44(2), 678-688.

Mohan, K. M., Wolfe, C. D., Rudd, A. G., Heuschmann, P. U., Kolominsky-Rabas, P. L., & Grieve, A. P. (2011). Risk and cumulative risk of stroke recurrence: a systematic review and meta-analysis. *Stroke*, 42(5), 1489-1494.

Norton, S. P. (1978). Anti-fertility activity of leaves of *Mimosa pudica* linn. in early-pregnancy of albino-rats. *Indian Journal of Zoology*, 6(2), 89-93.

Prasanna, K. S., Bashith, M. A., & Sucharitha, S. (2009). Consumer satisfaction about hospital services: A study from the outpatient department of a private medical college hospital at Mangaluru. *Indian Journal of Community Medicine*, 34(2), 156–159.

Sabithira, G., & Udayakumar, R. (2017). GC-MS analysis of methanolic extracts of leaf and stem of *Marsilea minuta* (Linn.). *Journal of Complementary and Alternative Medical Research*, 3(1), 1-13.

Singh, A., & Singh, P. K. (2009). An ethnobotanical study of medicinal plants in Chandauli District of Uttar Pradesh, India. *Journal of Ethnopharmacology*, 121(2), 324-329.

Sriram, M. I., Kalishwaralal, K., Deepak, V., Gracerosepat, R., Srisakthi, K., & Gurunathan, S. (2011). Biofilm inhibition and antimicrobial action of lipopeptide biosurfactant produced by heavy metal tolerant strain *Bacillus cereus* NK1. *Colloids and Surfaces B: Biointerfaces*, 85(2), 174-181.

Tamilarasi, T., & Ananthi, T. (2012). Phytochemical analysis and anti microbial activity of *Mimosa pudica* Linn. *Research Journal of Chemical Sciences*, ISSN, 2231, 606X.

Vaidya, G. H., & Sheth, U. K. (1986). *Mimosa pudica* (Linn.) its medicinal value and pilot clinical use in patients with menorrhagia. *Ancient Science of life*, 5(3), 156-160.

Valsala, S., & Karpagaganapathy, P. R. (2002). Effect of *Mimosa pudica* root powder on oestrous cycle and ovulation in cycling female albino rat, *Rattus norvegicus*. *Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives*, 16(2), 190-192.

Vennila, V., & Udayakumar, R. (2015). GC-MS analysis of leaf, fruits and latex of *Croton bonplandianum* Baill. *International Journal of Biochemistry Research & Review*, 5(3), 187-197.

Vidhya, R., & Udayakumar, R. (2015). Gas chromatography-Mass spectrometry (GC-MS) analysis of ethanolic extracts of *Aerva lanata* (L.). *International Journal of Biochemistry Research & Review*, 7(4), 192-203.

Volkov, A. G., Foster, J. C., & Markin, V. S. (2010a). Signal transduction in *Mimosa pudica*: biologically closed electrical circuits. *Plant, cell & environment*, 33(5), 816-827.

Volkov, A. G., Foster, J. C., Baker, K. D., & Markin, V. S. (2010b). Mechanical and electrical anisotropy in *Mimosa pudica pulvini*. *Plant signaling & behavior*, 5(10), 1211-1221.