

# A systematic Review and meta-analysis to Identify and Mitigate the Relationship with the Plasma Membrane of Plant Water Stress and Resistance to Pathogens

Daniel Alejandro Kunz<sup>a</sup>, Gustavo Cortez<sup>a</sup>, Jéssica Castro de Carvalho<sup>a</sup>, Carlos Eduardo Ribeiro<sup>a</sup>, Neuton Carlos Palmeiras Galvão<sup>a</sup>, Elckson Junior Aquino<sup>a</sup>, Susana Cristine Siebeneichler<sup>a</sup>, Magno De Oliveira<sup>b</sup>, Paula Santos Alves<sup>b</sup>, Wolney Jácomo<sup>c</sup>, Richard Dias Possel<sup>b</sup>, Isabela Maria Agustini da Silveira Bastos <sup>a</sup>, Aloísio Freitas Chagas Junior<sup>d</sup> and Augustus Caesar Franke Portella<sup>b</sup>

<sup>a</sup>Laboratory of plant ecophysiology, Federal University of Tocantins, Chácara 69-72 - Rua Badejos, Lote 7, s/n - Jardim Cervilha, Gurupi, 77404970, Tocantins, Brazil.

<sup>b</sup>Postgraduate Program in Biotechnology - UFT, PPGBiotec, University Campus of Gurupi - Federal University of Tocantins - UFT.

<sup>c</sup>Distance Education - (UFT / EAD)., Public Administration Course, (UFT / EAD). Federal University of Tocantins – UFT.

<sup>d</sup>Microbiology and Phytopathology Laboratories, Federal University of Tocantins-Campus of Gurupi- UFT.

**Abstract**— *The plasma membrane has very important functions, it is composed of a phospholipid bilayer having a non-uniform and fluid structure that controls input and output of nutrients into the cell and is a way of water transport, whose excess or deficiency affects the plant development cycle. Depending on the degree of water stress, it can also affect the plant resistance against the incidence of pathogens that cause great economic losses. Fungi and viruses mostly take advantage of this deficiency, eliminating the plant defense response producing molecules for this purpose; however, the plants employ proteins produced by resistance genes.*

**Keywords**— *Water stress, pathogens, plasma membrane resistance.*

## I. INTRODUCTION

Recently researchers found that water stress is important and the effect of the level of stress. It is important for irrigation and soils. Also, conducting similar studies on different species and the different origins of the species determined to be resistant to drought in wider fields carries great importance in terms of identifying the species most resistant to drought and in this way preparing healthy landscaping planning in arid

fields (Sevik and Cetin, 2015; Cetin, 2015; Yigit et al., 2016; Cetin et al., 2018a; Cetin et al., 2018b; Cetin et al., 2016; Cetin, 2015a).

Climatic factors are affected by temperature, wind, rain, and drought recent studies with drought stress using remote sensing show monitoring of drought stress. It is envisaged that both current land uses and potential future use will be affected by the negative consequences of possible sea-level rise. The morphological structure of low elevations suggests that the effects of elevation can easily proceed to the interior (Sevik and Cetin, 2015; Cetin, 2015; Yigit et al., 2016; Cetin et al., 2018a; Cetin et al., 2018b; Cetin et al., 2016; Cetin, 2015a).

According to Taiz et al. (2017) and Epstein and Bloom (2006), plant physiology is the study of synthesis procedures for plant biological material – e.g. vegetation growth and the functional process, and its interaction with the environment in which operates. The plant cell plasma membrane is an important structure of the cell, being composed of a phospholipid bilayer in which proteins are inserted or just attached. The most abundant lipids present in the plasma membrane are the phospholipids, followed by sterols, which provides mechanical balance on the cell membrane, making it an obstacle to the transport of large

portion of hydrophilic molecules and ions (Apezzato-da-Glória and Carmello-Guerreiro, 2006; Zhou et al., 2018).

Visually observed in the plasma membrane of the plant cell that it does not have a uniform structure, but rather a heterogeneous mosaic of small territories, where some of them have drowned in specific protein and lipid constituents, appearing to be stricter and ordered the others suffering strong interactions between different molecules, especially the lipids that constitute the membrane (Gerbeau-Pissot et al., 2014; Simon-Plas et al., 2011; Taiz et al., 2017).

The plasma membrane has important functions. The selective permeability is responsible for selecting the entry and exit of substances of the cell, allowing the maintenance of its physiological conditions (Apezzato-da-Glória and Carmello-Guerreiro, 2006). In this sense, we can mention aquaporin's proteins (AQPs) that act on the plasma membrane by increasing its permeability, allowing the transport of water and small molecules through the membrane, thereby playing an important role in water regulation of the cell and the water use efficiently (Epstein and Bloom, 2006; Lu et al., 2018).

### Water stress

The plasma membrane is a phospholipid bilayer, in which various phospholipids are distributed asymmetrically between the two sheets layers of the membrane forming a primary division of the interior of the cell (protoplast), and the external space (apoplast) having a key role in the entry and exit of cell nutrients (Epstein and Bloom, 2006; Wang et al., 2018). One of the main constraints to plant is water, whose deficit in the soil can induce water stress, causing morphological and physiological changes, with falls in productivity (Dutra, 2012). The water is the main constituent of plant tissues, corresponding in some cases with 95% of the total weight of the green mass. In this sense, it is very important for the healthy development of a plant that its tissues receive permanently an optimal water amount. The high water content is directly related to the conservation of swelling of the tissues necessary for photosynthesis, flowering, fruiting and condition of origin of products. During the development of the plant, it performs transpiration, guttation (or sweating) and exudation, processes that cause the loss of 98% of the absorbed water (Pes and Arenhardt, 2015).

The concept of water stress is controversial for a long time. Inside the agronomic context, water stress is the availability of water for the plant that generates a reduction in the economic return of cultivation. In the physiological context, the problem occurs when a specific process is affected or not. The agronomic and

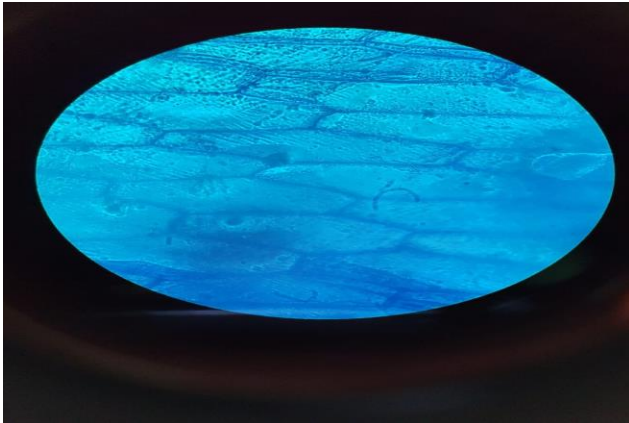
physiological stresses can be caused either by excess or shortage of water (Rosolem, 2014).

Plants placed in mangrove areas, wetlands or areas near rivers and lakes are subject to stress by excess water, which, depending on the intensity, can be lethal because it impairs gas exchange between the roots and soil, causing other stress, oxidative (Lopez, 2013). Drought is probably the most important factor in the agricultural branch, limiting crop yields worldwide, an example is corn: in tropical regions provides 95% of human consumption of cultivars are grown in areas subject to drought, which consequently generates a subversion from 10% to 50% of production, 80% in their cultivation areas.

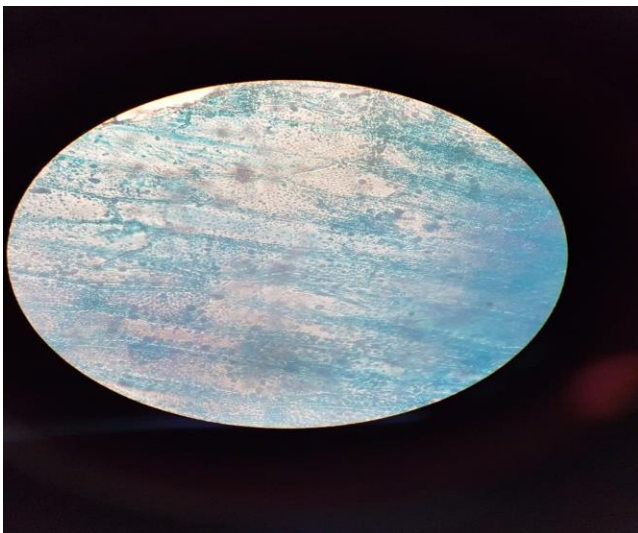
It should be noted that during the drought, one of the adaptations of this plant machinery, is the accumulation of solutes in the active cell. This event is known as osmotic adjustment, a harmony in the conservation of turgor, plant growth and photosynthesis production in low water availability values on the sheet (Pimentel, 1999). Due to its complexity, drought tolerance is probably the most difficult feature for genetic improvement through conventional breeding plants. The challenge is even greater for the development of cultivars tolerant to drought for the Brazilian environment where the occurrence and severity of drought may vary each year (Petcu et al., 2013; Rosolem, 2014).

### The effects of water stress

When the plant is in an environment with sufficient water availability, its cells are in the isotonic state (Figure 1), while with concentrations of solutes in the internal and external balance. However, when a low water availability, the cell before in isotonic state, performs a process called plasmolysis (Figure 2), in which, due to lack of water causes the extracellular medium has a higher solute concentration than the intracellular and due to this change in the concentration of extracellular solutes that the water was inside the vacuoles of the cell migrates to the external environment, resulting in the contraction of the vacuoles, giving an aspect contraction of the cell (Shigematsu et al., 2005).



*Fig.1: Plant tissue, cells in isotonic conditions, using methylene blue colored; microscopy, x400. Source: Authors, 2018.*



*Fig.2: Plant tissue, plasmolyzed cells using colored methylene blue; microscopy, x400. Source: Authors, 2018.*

According to the authors Fanti and Perez (2004), the plant when subjected to a high degree of water stress or salinity, can cause the non-viability of the germ of the seed process. In this sense, the reduction of water and osmotic potential affects the process of seed development. The absence of water may also cause the vulnerability of plants to diseases and pests and can cause the closure of stomata, thus reducing the development, resulting in the accumulation of solutes and antioxidants, reducing the development leaf area and stem. Water stress causes the synthesis of abscisic acid in the roots, where it is causing root and development and formation of secondary roots and is transported by various parts of the plant may have other responses, for example, the reduced growth of leaves and their abscission or advanced to the reproductive cycle. (Fanti and Perez, 2004; Scaloni, 2011).

Losses arising by water stress in agricultural production depend on the intensity and the duration of water stress to the crops. If the stress is severe for a long period of time, the damage can be devastating to crops. If stress is moderate, with a lower water deficit, the damage may be reversible or cause less impact on production.

Losses in yield, relate much to the genetic material and adapted cultured specimen loss or lack of water (Ryan, 1990). When the plant is under water stress is the production of proteases, which are proteins related to the digestion of other proteins (Tremacoldi, 2009); at the same time is also stimulated the synthesis of protease inhibitors to control its proteolytic activity, in the event of an uncontrolled way breaks the cell membranes of the plant damage most cellular proteins and a final causes premature senescence of the plant. Studies on the plant response to drought in molecular levels show that the protease inhibitors are also compromised multivalent proteins in plant defense against pathogens and herbivores. Inhibitors also affect the development of insects indirectly by increasing the production of digestive proteases to compensate for lower levels of amino acids available, and these amino acids would be shifted to the synthesis of more proteases to the detriment of other essential proteins (Faustino, 2015).

#### **Pathogenic agents**

According to Lopez (2013) and Righi (2012), economic loss as a result of infections in plant material caused by pathogenic agents is well documented. Fungi are the main, cause of diseases in plants in the world. A survey conducted by the Imperial College London and the University of Oxford (Fisher, 2012), demonstrates that soy crops, rice, corn, wheat, and potato have a considerable loss due to successful infection of fungicide, an exorbitant loss that could feed a population of 600 million to 4 billion people. These data reinforce the importance of phytopathological research. Viruses come in agronomic half with his percentage of losses in human cultures affecting the economies of many countries in the world. It is difficult to obtain data from the loss of crops by viral pathogens (Cavalcante et al., 2013).

Diseases caused by viruses have less conspicuous than other types of diseases caused by other pathogens. The phytopathological study of plants and viruses is important because the viruses have the ability to infect a wide variety of existing plant specimens. Economic losses caused by viral infections has already been presented since the beginning of the 90s, where in Southeast Asia rice cultivars represented annual losses estimated at one trillion dollars. In the seventeenth century, a viral infection caused frightening losses in the production of tulip flowers (Lopez, 2013; Righi, 2012).



The infection in plants by pathogens occurs when the pathogen tried to cross the cuticle, hydrophobic layer to the complex aggregate outermost cell walls of the epidermis aerial organs. This body serves as a barrier, preventing water loss and infection by pathogens; the cell wall, which serves as a physical and chemical barrier against the invasion and spread of pests and herbivores; Additionally, released cell wall oligosaccharides act as important signaling molecules, inducing defense responses against pathogens, symbionts and various other physical and chemical barriers such as the toxic secondary metabolites produced by plants themselves (Taiz et al., 2017).

Vegetables have no immune system as animals, defend cells adapting to the environment that is being submitted (Rizzardi, 2003). Generally, plants respond to infection using an innate system of two branches. The first one is constitutive, also called performed; the second is induced, also called post-training. The first group refers to structures synthesized by plants, regardless of the consequences caused by pathogens, containing various actions and functions in plant resistance in particular. It may be noted that in this group there is the presence of cuticles, stomatal and its numerous forms, conducting vessels of sap, silica pilosities layers and this group reacts molecules and common to many classes of microbes, including pathogens. The second group includes the mechanisms of resistance whose expression occurs in response to pathogen infection factors, directly or through its effects on host targets. that could be the formation of halos, buds, lignification or cellular barriers or layers of cork, abscission layers, Tylose, and gel deposition hesperidin, histological and these barriers (Jones and Dangl, 2006).

According to Stangarlin (2011), pathogens produce molecules which eliminate the defense response, however, employ vegetable protein produced by the resistance genes, this intense activity of plant defense and recognized as resistance gene-by-gene. The secondary metabolites with antimicrobial action that have a low molecular weight are known as phytoalexins, they are synthesized by plants in response to physical stress, chemical or biological. They are able to reduce or guard activities of pathogens, conditioned genotype of the host or pathogen. The operation mode of phytoalexins on fungi covers the cytoplasmic disintegration, disorder of cellular substances, protrusion of the plasma membrane, and enzymatic reduction of fungal origin (Gerbeau-Pissot et al., 2014; Simon-Plas et al., 2011; Stangarlin, 2011).

The main pathogens invasion routes are the stomata (Figure 3), and recent research has proven regulatory action is closing and opening of this structure

and the major route of contagion by pathogens. This indicates that the closure of the stomata is a functional output of pathogens and immune effector. Stomata respond to abiotic and biotic signals, and the pathogens perform the use of abiotic environmental biological conditions with a high humidity creating active virulence factors causing the closure of the activities of the stomata, as a method of its infectious process (Gudesblat et al., 2009).



Fig.3: Plant tissue. A1: stomata; A2: stoma; x400 microscopy. Source: Authors, 2018.

Viruses can seep into plant cells by foliar lesions, physical impact or insects. They can also be spread by vegetative propagation or by contaminated seeds. Since fungi secrete hydrolytic enzymes such as cutinases, pectinases, hemicellulases, among others to degrade the cell wall and into the plant cells (Lopez, 2013; Gerbeau-Pissot et al., 2014; Simon-Plas et al., 2011; Taiz et al., 2017.).

These results suggest that the perception of the plasma membrane signal can direct the cellular response, depending on how the membrane reacts and changes its inner structure. However, still, need to be explored by which mechanisms these structural changes in the membrane are translated into defensive reactions (Gerbeau-Pissot et al., 2014; Simon-Plas et al., 2011; Taiz et al., 2017; Wang et al., 2018).

In general, it is assumed that resistance to stress is cost expensive, mainly due to the need for allocation of metabolites for defense end hindering or interrupting other physiological processes of the plant, having a negative impact on its development (Bacete et al., 2018).

## II. MATERIAL AND METHODS

The methodology was based on Oliveira, (2018).

To identify articles on the subject was held search in the databases PubMed, ScienceDirect, Sciollo, Google Scholar, Dialnet, WorldWideScience.org, Tandfonline, Dialnet, Microsoft Academic. The following filters have been added to search on ScienceDirect: only journals; title, abstract; key-words: “*Water stress*” “*pathogens*” “*plasma membrane resistance*”.

After consultation, the application databases and search strategy between different studies repeated searches were identified. Inclusion criteria for articles were original research articles and conceptualize the research related to the plasma membrane of the plant cell, giving greater emphasis on their role in resistance to incoming interrelated in pathogens during water stress, in different fields of research, including research completed in Portuguese, English, and French.

The grouped articles were excluded in order: repeated irrelevant review, other publishing formats (notice, short communications, perspectives, letters), and other languages. In addition, manual searches were made in reference lists of review articles found with the predetermined keywords.

After removal of the articles repeated between the different searches, the exclusion criteria were applied, as shown in Figure 4. Of the 111 remaining articles were retrieved 35 original research articles related to the plasma membrane and plant water stress and resistance to pathogens. Through manual search were recovered 2 more items.

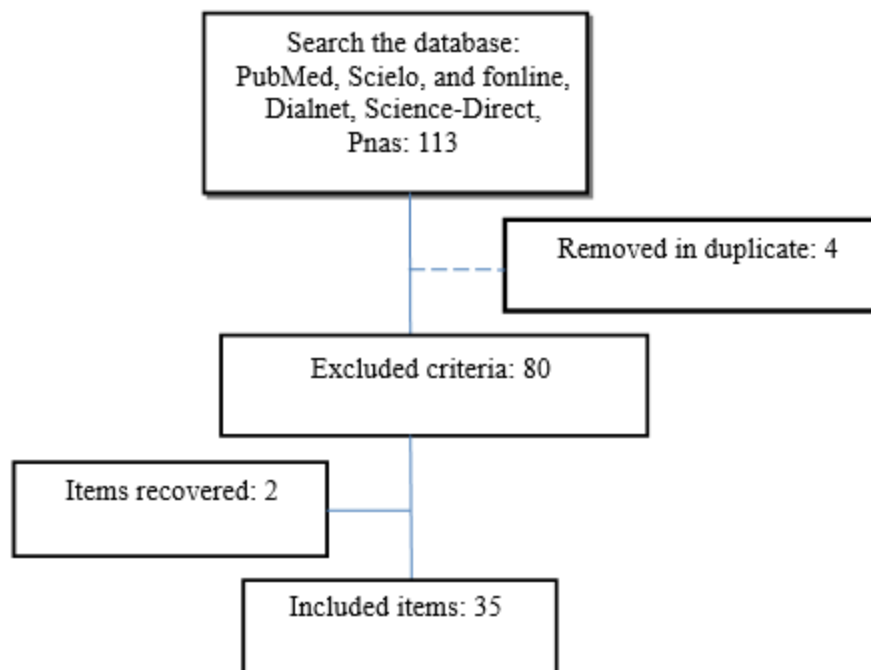


Fig.4: Flowchart of identification and selection of items. Source: Authors, 2018.

### III. RESULTS AND DISCUSSIONS

This work focuses on the issue of the operation of the plasma membrane of plant cells, giving greater emphasis on their role in resistance to drought stress and the entry of pathogens. Based on the research conducted, few papers that analyzed pathologies of bacterial origin, which indicates the need to carry out further searches of bacterial pathogens in vegetable medium demonstrating a total of 5.88% of study bacteria (Figure 1). Both through the internet, as for books surveyed for this review, it became clear the lack of information on diseases caused by both bacteria and other neglected diseases.

There was also little information about the viral origin of pathogens in plants, a fact that further limited the theme of development. In this research, it was found that the papers have a relationship study of 14.71% of fungal diseases as statistical relationships demonstrate in Table 1, summarize the work of several authors. It was evident the need to develop more studies on the origin of pathologies both bacteria with other diseases, as there are many studies on fungi in the Brazilian and international agriculture. Future prospects seek the inclusion of a greater number of researches on various plant diseases.

Table.1: Correlation of articles and pathologies found during the research and its percentages.

PATHOLOGIES	REFERENCES	TOTAL	%
VIRUS	LOPEZ., 2013	5	14,71
	TAIZ ET AL. ,2017		
	BOTÂNICA NO INVERNO 2012		
	GALDEANO, KLEINGESINDS,2013		
	MOLLIER,2014		
FUNGI	JORDI LUQUE, 1997	9	26,47
	UTA FUCHS, 2006		
	MÁRIO LÚCIO, 2003		
	CAVALVANTE FLÁVIA, 2013		
	ADNE ABBUD, 2013		
	LAURA BACETE, 2017		
	BENJAMIN PETRE, 2014		
	FANTI SILMARA, 2004		
	STANGARLIN, 2010		
BACTERIUM	LAURA BACETE, 2017	2	5,88
	FERRO, M.I.T.,2006		
FEW DISEASES STUDIED	RIZZARDI MAURO, 2003	4	11,76
	RESENDE MÁRIO,2003		
	FERRO, M.I.T.,2006		
	NAT REV MOL CELL BIOL. 2008		
Total		20	58,82

This is the fact that fungi are the causative of larger diseases in world agriculture, viruses are also a major cause of it. There is a need to conduct further study on the pathology of the Bacteriological source and its consequences for plant use in global agronomy.

During our research for this review, the authors reported in their serious problems jobs, there is no way around them completely, since these are unpredictable because the consequences will vary on the event period, the degree of intensity and the reaction presented by plants. In many cases the damage caused by water stress and/or pathogens irreversible.

It is clear to point out that there are changes in the defense mechanisms of plants when they undergo water stress, this can result in infectious agents actions, but these are not invulnerable, there will be the moment that will hit the limit (total system loss of defense) and thus suffered major damage, such as the weakening of your metabolism or even death.

Currently, transgenic approaches have been presented as a solution in research to create an opportunity to light the production of various crops in drought conditions or water deficit. Although it has a comprehensive range study of tolerance to drought, there are challenges associated with the phenotype and identification of materials tolerant to diseases during the

drought, which related to challenges of phenotyping and characterization of these, materials tolerant pathogens during stress water. In the scientific community towards the real cause of diseases during drought presents a major debate with several disagreements among researchers.

The authors mentioned that we have access to the use of technologies that can mitigate these factors, those that have provided solutions to various problems. In relation to water stress, it is possible to increase some strategies to meet the momentary need to pass the plants, such as the rational use of water dams will result in less wear of the plant, bringing benefits to the vegetation around them. Thus, it is noteworthy that the importance of studies of environmental rationing, conscious and agro-ecological, the rational use of water resources directed to agricultural production and in its different productive sectors.

We should point out that the motivating text also caveat some possible ways to partially protect plants from invading pathogens, such as the use of chemicals that can stimulate the synthesis of protease inhibitors to control their proteolytic activity, such action would help strengthen the immune system of the plant and thus generate many benefits to agriculture.

**CONFLICT OF INTERESTS**

The authors have not declared any conflict of interests.

**REFERENCES**

- [1] Appezzato-Da-Glória B, Carmello-Guerreiro SM (2006). Anatomia Vegetal. Editora UFV.
- [2] Bacete L, Mérida H, Miedes E, Molina A (2018). Plant cell wall-mediated immunity: cell wall changes trigger disease resistance responses. The Plant Journal, 93(4): 614–636. Doi:10.1111/tpj.13807.
- [3] Cavalcante F, Almeida I, Melo K, Panizzon C, Rhoden S, Pamphile J (2013). Plant Pathogen Interaction: Answers to the Attack. SaBios-Revista de Saúde e Biologia, 8 (3). Recovered from <http://revista2.grupointegrado.br/revista/index.php/sabios2/article/view/1344/545>
- [4] Cetin M, Adiguzel F, Kaya O, Sahap A (2018). Mapping of bioclimatic comfort for potential planning using GIS in Aydin. Environment, Development, and Sustainability, (2018) 20 (1): 361–375. <https://doi.org/10.1007/s10668-016-9885-5>
- [5] Cetin M, Sevik H, Yigit N (2018). Climate type-related changes in the leaf micromorphological characters of certain landscape plants. Environmental Monitoring and Assessment. 190: 404. <https://doi.org/10.1007/s10661-018-6783-3>
- [6] Cetin M (2016). Sustainability of urban coastal area management: a case study on Cide, Journal of Sustainable Forestry, 2016, 35 (7), 527–541, <http://dx.doi.org/10.1080/10549811.2016.1228072>
- [7] Cetin, M (2015). Determining the bioclimatic comfort in Kastamonu City. Environmental Monitoring and Assessment, 187(10), 640, <http://link.springer.com/article/10.1007%2Fs10661-015-4861-3>
- [8] Dutra CC (2012). Development of sunflower plants under different conditions of water supply. Seminar: Agricultural Sciences, 33(0).
- [9] Epstein E, Bloom AJ (2006). Mineral nutrition of plants: principles and perspectives. Londrina: Publisher Plant.
- [10] Fanti SC, Perez SCJGA (2004). Germination process of the seed of pannier under water and saline stresses. Brazilian Agricultural Research, 39(9): 903–909.
- [11] Faustino VA (2015). Impact of water and biotech stress (*Anticarsia gemmatilis* Hübner, 1818) on the soybean defense mechanism, 67 p.
- [12] Fisher MC (2012). Emerging fungal threats to animal, plant and ecosystem health. Nature, 484: 186.
- [13] Gerbeau-Pissot P, Der CD, Thomas, Anca IA, Grosjean K, Roche Y, Perrier-cartucho JM, Mongrand S-Plas, Simon F (2014). Modification of plasma membrane organization in cryptogenic-induced tobacco cells. Plant Physiology/ 164 (1): 273–86.
- [14] Gudesblat GE, Torres PS, Vojno AA (2009). Stomata and pathogens. Plant Signaling & Behavior, 4(12), 1114–1116. Doi:10.4161/psb.4.12.10062
- [15] Jones JDG Dangi JL (2006). The plant immune system. Nature, 444(7117): 323–329. Doi: 10.1038/nature05286.
- [16] Lopez AM (2013). Botany in Winter. Institute of Biosciences of the University of São Paulo, 202 p.
- [17] Lu L, Dong C, Liu R, Zhou B, Wang C, Shou H (2018). Roles of Soybean Plasma Membrane Intrinsic Protein GmPIP2; 9 in Drought Tolerance and Seed Development. Frontiers in Plant Science, v. 9. Doi:10.3389/fpls.2018.00530.
- [18] Oliveira M (2018). Experimental Planning Factorial: A Brief Review. International Journal of Advanced Engineering Research and Science, 5(6): 166–177.
- [19] Pes LZ, Arenhardt MH (2015) - Santa Maria, RS: Federal University of Santa Maria, Polytechnic School, Rede e-Tec Brasil, 85 p.
- [20] Petcu E, Arsintescu A, Stanciu D (2013). The effect of hydric stress on some characteristics of sunflower plants. Romanian Agricultural Research (16): 8.
- [21] Pimentel C (1999). Water relations in two-hybrid corn in two cycles of water. Brazilian Agricultural Research. Brasília 34(11): 2021–2027.
- [22] Righi AA (2012). Botany in Winter. Institute of Biosciences of the University of São Paulo, 183 p.
- [23] Rizzardi MA (2003). Herbicides action in plant defense mechanisms to pathogens. Rural Science, 33(5): 957–965.
- [24] Rosolem C (2014). The cotton and abiotic stresses Temperature, light, water and nutrientes. Mato Grosso do Sul Cotton Institute- Cuiabá, n. 1, 123p.
- [25] Ryan CA (1990). Protease Inhibitors in Plants: Genes for Improving Defenses Against Insects and Pathogens, 25 p.
- [26] Scalón SDPQ (2011). Water stress in the initial metabolism and growth Mutambo seedlings (*Guazuma ulmifolia* Lam.). Forest Science 1(4).
- [27] Sevik H., Cetin M. (2015). Effects of water stress on seed germination for select landscape plants. Polish Journal of Environmental Studies 24 (2), 689–693.
- [28] Shigematsu E, Eik NM, Kimura M, Mauro MA (2005). Influence of pre-influence of pre-treatment on osmotic dehydration of carambolas. Food Science and Technology, 25(3):536–545. Doi:10.1590/s0101-20612005000300024. z

- 
- [29] Simon-Plas F, Perraki A, Bayer E, Gerbeau-Pissot P, Mongrand S (2011). An upgrade on factory membrane rafts. *Curr Opin Plant Biol* 14 (6): 642-9.
- [30] Stangarlin JR (2011). The plant defense against pathogens. *Scientia Agraria Amanuensis*, 10(1):18.
- [31] Taiz L, Zeiger E, Moller IM, Murphy A (2017). *Physiology and Plant Development*. Porto Alegre, RS: Artmed, 6<sup>a</sup> ed., 2017. 888 p.
- [32] Tremacoldi CR (2009). *Proteases and Protease Inhibitors in Plant Defense Against Pests*, 46 p.
- [33] Wang L, Xue Y, Xing J, Song K, Lin J (2018). Exploring the Spatiotemporal Organization of Membrane Proteins in Living Plant Cells. *Annual Review of Plant Biology*, 69(1), 525–551. Doi:10.1146/annurev-plant-042817-040233
- [34] Yigit N, Sevik H, Cetin M, Kaya N (2016). Chapter 3: Determination of the effect of drought stress on the seed germination in some plant species. “Water Stress in Plants”. Intech Open, Eds: Ismail Md. Mofizur Rahman, Zinnat Ara Begum, Hiroshi Hasegawa, ISBN:978-953-51-2621-8, pp: 43-62 (126).
- [35] Zhou L, Zhou J, Xiong Y, Liu C, Wang J, Wang G, Cai Y (2018). Overexpression of a maize plasma membrane intrinsic protein ZmPIP1;1 confers drought and salt tolerance in *Arabidopsis*. *Plos One*, 13(6). Doi:10.1371/journal.pone.0198639.