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Response and Adaptation of Plants to Water Purchases

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Abstract: ***Environmental factors that affect plant growth and development can be divided into two, namely the biotic and abiotic environment. The abiotic environment can be divided into several factors, namely: temperature, water, light, soil and atmosphere. Water in plant tissues, in addition to functioning as the main constituent of tissues, is actively conducting physiological activities. Drought stress is a term used to state that plants suffer from water shortages due to limited water from their environment, which is the growing media. Water shortages in plants occur due to insufficient water availability in the media and excessive transpiration or a combination of these two factors. In the field, although there is enough water in the country, plants can experience stress (lack of water). The mechanism of plant adaptation to overcome drought stress is by cell osmotic regulation. Drought stress which has various adverse impacts on plant growth and development is a threat in the practice of crop cultivation to be developed, especially in the prolonged dry season.***

Keywords: Response, Adaptation and Water Stress

1. Introduction

Growth and development of plants can not be separated from two factors, namely genetic factors and environmental factors in which the plants grow. Environmental factors that affect plant growth and development can be divided into two, namely the biotic and abiotic environment. The abiotic environment can be divided into several factors, namely: temperature, water, light, soil and atmosphere. The water factor in plant physiology is a very important main factor. Plants cannot live without water, because water is a matrix of life, even other creatures will become extinct without water. Kramer explained how important water is to plants; that is, water is part of the protoplasm (85-90% of the total weight of the green parts of plants (growing tissue) is water.

In living plants, water exists in a variety of circumstances and is involved in all physiological processes. Hydration and imbibition water in colloidal phases such as cell walls, osmotic water in vacuoles and phloem vessels, and hydrostatic water in xylem (Harjadi and Yahya, 1988). Furthermore, it is said that water is an important reagent in photosynthesis processes and in hydraulic processes. Besides that, it is also a solvent of salts, gases and materials that move into plants, through cell walls and essential tissues to ensure turgidity, cell growth, leaf shape stability, the process of opening and closing stomata, continuous motion plant structure (Ismal, 1979). Water in plant tissues, in addition to functioning as the main constituent of tissues that actively carry out physiological activities, also plays an important role in maintaining the turgidity needed for cell enlargement and growth (Kramer, 1969). This important role has consequences that directly or indirectly the water deficit plants will affect all metabolic processes in plants that result in disruption of the growth process (Sasli, 1999).

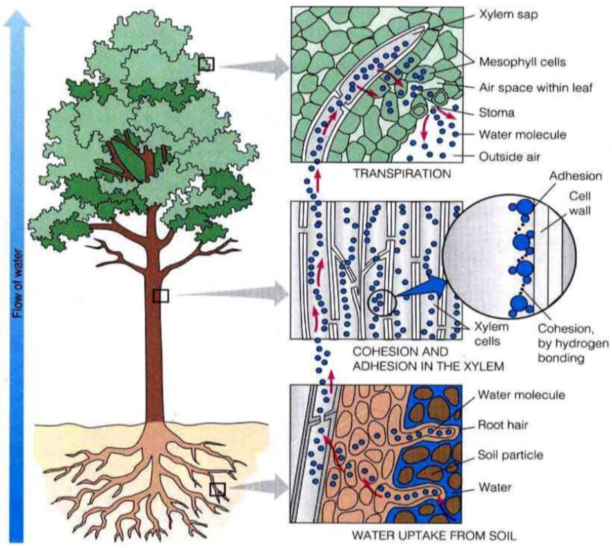

Figure 1: Cohesion, Adhesion, and Transpiration (Source:Sasli,1999)

Water Checks

Drought stress is a term used to state that plants suffer from water shortages due to limited water from their environment, which is the growing media. Drought stress in plants can be caused by a lack of water supply in the rooting area and excessive water demand by leaves due to the evapotranspiration rate exceeds the absorption rate of water despite the availability of sufficient groundwater (Toruan-Mathius et al. 2001)

Lack of water will interfere with physiological and morphological activities, resulting in the cessation of growth. A continuous water deficiency will cause irreversible changes (and can not be reversed) and in turn, the plant will die. Water demand for plants is influenced by several factors including plant types in relation to their type and development, soil water content and weather conditions (Fitter and Hay, 1981).

According to Kramer (1969), lack of water in plant tissue can be caused by excessive water loss during transpiration through stomata and other cells such as cuticles or caused by both. However, more than 90% of transpiration occurs through stomata in the leaves. Apart from acting as a tool for evaporation, stomata also act as a tool for CO2 exchange in physiological processes related to production.

Stomata consist of guard cells and closing cells surrounded by several neighboring cells. The mechanism of closing and opening the stomata depends on the turgor pressure of plant cells, or because of changes in carbon dioxide concentration, reduced light, and abscisic acid hormones (Lakitan, 1996).

The rate of growth of plant cells and the efficiency of their physiological processes reach the highest level when the cells are at maximum turgor. The absorbance of carbon dioxide crosses the moist cell wall and opens into the atmosphere which is important for photosynthesis, related to the loss of water from leaf tissue. Plant cells that have lost water and are at a turgor pressure lower than the maximum value are called water stress. When water stress increases from mild to moderate, biochemical processes are more affected. Protein and chlorophyll biosynthesis are sensitive to mild stress, whereas under moderate stress levels nitrate reductase levels, plant hormone metabolism and carbon dioxide assimilation are also affected. Moderate to severe stress can break down serious cell metabolism by increasing respiration, proline accumulation and sugar (Elliakim, et al. 2008).

Plant Response against Drought

Water shortages in plants occur due to insufficient water availability in the media and excessive transpiration or a combination of these two factors. In the field, although there is enough water in the country, plants can experience stress (lack of water). This happens if the absorption rate cannot compensate for the loss of water through the process of transpiration (Islam and Utomo, 1995). Water loss from plants by transpiration is an inevitable result of the need to open and close the stomata for the entry of CO2 and the loss of water through transpiration is greater through the stomata than through the cuticle.

The mechanism of plant adaptation to overcome drought stress is by cell osmotic regulation. In this mechanism, the synthesis and accumulation of organic compounds can reduce osmotic potential thereby reducing the water potential in cells without limiting enzyme function and maintaining cell turgor. Some compounds that play a role in cell osmotically adjustment include osmotic sugar, proline and betaine, dehydrin protein and abscisic acid (ABA) which play a role in stimulating the accumulation of these compounds (Toruan-Mathius et al. 2001).

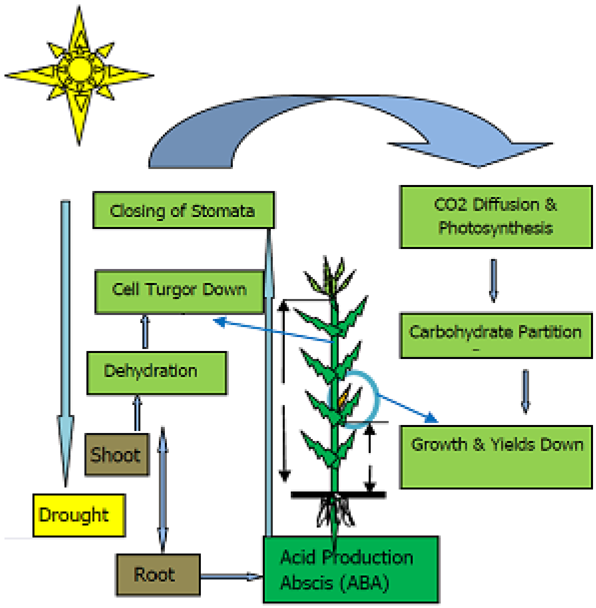

Figure 2: Mechanism of Drought Checks (Source:Toruan-Mathius et.al,2001)

Plants that grow in drought stress conditions reduce the number of stomata thereby reducing the rate of water loss. Closure of stomata and net CO2 uptake in leaves is reduced in parallel (together) during drought. The process of carbon assimilation is disrupted as a result of the low availability of CO2 in the chloroplast due to water stress which causes stomatal closure. Thus, severe drought will change/limit the process of assimilation, translocation, storage and use of carbon photoassimilate in an integrated manner. The effect of water stress on plants according to Muns (2002) can be classified based on several levels of time, namely starting from minutes, hours, days, weeks and months.

Table 1: Plant Response to Drought Stress by Time

Time	The effect was seen during water stress
Minute	instantaneous shrinkage of the rate of elongation of leaves and roots
Our	the root elongation rate returned to normal but lower than the previous rate
day	Leaf growth is more affected than root growth
A week	the final size of the leaf decreases the number of lateral shoots
A month	change when flowering, shrinking seed production

Source: Mouns, 2002

Turgor potential will decrease until it can reach zero and result in wilting if the loss of water from this plant takes place continuously outside its control limits. The results of the research Frederique et al., (1998) showed that the corn planted in a greenhouse was severely inhibited due to water stress treatment with a water potential of -1.5 MPa. Stomata play an important role as a tool for plant adaptation to drought stress. In conditions of drought stress, the stomata will close in an effort to hold the rate of transpiration. The compound that plays a role in opening and closing the stomata is abscisic acid (ABA). ABA is a compound that acts as a signal of drought stress so that the stomata closes immediately (Pugnaire and Pardos, 1999). Some plants adapt to drought stress by reducing the size of the stomata and the number of stomata (Price and Courtois, 1991).

Tolerance mechanisms in plants in response to drought stress include (i) the ability of plants to continue to grow in conditions of water shortage by reducing leaf area and shortening the growth cycle, (ii) the ability of roots to absorb water in the deepest soil layers, (iii) the ability to protect the root meristem from dryness by increasing the accumulation of certain compounds such as glycine, betaine, alcohol sugar or proline for osmotic adjustment and (iv) optimizing the role of stomata to prevent loss of water through the leaves (Nguyen et al., 1997). With the osmotic adjustment allows growth to continue and stomata remain open

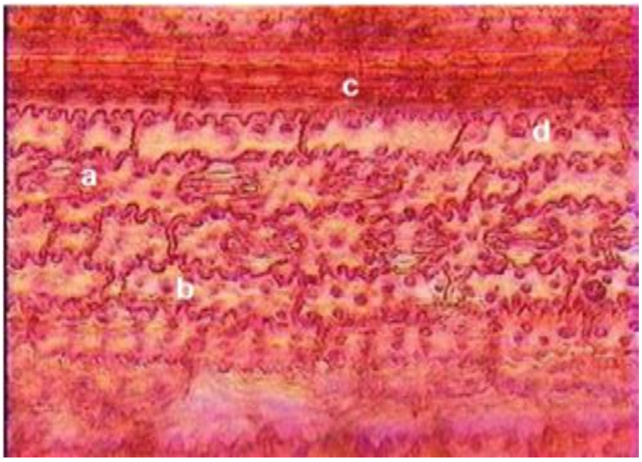

Figure 3: Epidermal incision under the stomata leaves (a) Stomata (b) long cell (c) cork cell (d) silica cell

The density of stomata in a plant is related to the resistance of plants to drought, according to the statement of Mc Cree and Davis (1994) and in accordance with the results of research Sulistyaningsih et al. (1994) that stomata size and stomata density are related to resistance to water stress. Pugnaire and Pardos (1999) state that plant adaptation to drought stress includes leaf modification by reducing leaf area.

Poejiastuti (1994) research results in the comparative study of leaf anatomy of some soybean genotypes that are sensitive to and tolerant of drought stress showed a difference in stomatal density in resistant and sensitive genotypes, the presence of watering or vice versa in the treatment of drought stress did not cause changes in stomata density. Research Poor et al. (1992) showed that stomata density was not different in plants that grew in different environments. Sulistyaningsih et al. (1972) observed stomata from several members of the Saccharum genus that were resistant to drought, and it can be concluded that the size of stomata in these plants is smaller with lower density, in addition, large uniform cells with higher density were found. In this study, the observed stomata were taken from somaclonal from callus which had been given radiation treatment and in vitro selection. Radiation using gamma rays is proven to cause changes both at the tissue level and at the cellular level. This is in accordance with the statement of Dickison (2000) that ionizing radiation can cause changes in palisade cells, sponge cells or an increase or decrease in the transport beam network, the anatomic changes are generally followed by changes in physiological activity.

Drought resistant plants develop a number of strategies related to physiological processes. The drought resistance mechanism is divided into three categories namely escape, avoidant and tolerant. Included in escape include the development of leaves becoming narrower and having a thick cuticle layer including the number of stomata in the lower epidermis, and the ability of stomata to close quickly (Courtois and Lafitte, 1999 in Lestari, 2006). Leaf genotypes of upland rice that are tolerant to drought differ from those that are sensitive when viewed from the greenish color (green), area, thickness, and shape (Soepandi et al., 1999; Chozin et al., 1999). Besides leaf anatomy such as the size of a palisade, chlorophyll and stomata determine the efficiency of photosynthesis (Sahardi, 2000). In addition to stomata, other cells are found, namely buliform cells which act as tools for adaptation to drought stress, which are commonly found in Gramineae and some monocots. These cells are larger than epidermal cells, the cell's function is to adapt to leaf rolling when the plant experiences drought stress (Price and Courtois, 1991 in Lestari 2006).

In plants that are tolerant and survive in conditions of external water deficit (although the tissue water potential is low), there is a mechanism to maintain turgor to remain above zero, so that the tissue water potential remains low compared to the potential of external water so that there is no plasmolysis (Turner and Jones, 1980). The effort to maintain this water potential is shown by the increase in the system of solutes or osmotic compounds such as proline, glycine betaine, sugar, and organic acids that function in the osmatic adjustment process. Christine, Rene and Jean-Louis (1996) proved that the concentration of amino acids in alfalfa plants increased markedly (1.8 times, at 5% level) when the groundwater potential was reduced from -0.5 to -2.0 MPa, and the response of each plant to produce varied amino acids for each different water potential. The concentration of amino acids in these alfalfa plants increases with decreasing water potential. Proline levels produced reached 150 mM in alfalfa plants with a groundwater potential of -2.0 MPa.

Christine et al. (1996) also showed that the main change in the form of N transport in alfalfa plant phases is that the levels of proline increased sharply to respond to a potential decrease from –1.0 to –2.0 MPa. Gerik (1996) proves that water shortages in cotton plants mainly affect the capacity of photosynthesis. Decreased photosynthetic capacity and increased leaf aging which adversely affects cotton production. Other negative effects due to lack of water are decreased cell growth and enlargement, leaf expansion, translocation, and transpiration.

Rahardjo and Darwati's research results (1996) showed that leaf chlorophyll content, leaf area, fresh and dry weight of tempuyung leaves decreased at 60% water stress treatment given 30 HST, the greater the water stress the greater the decrease.

2. Effect of Water Purchase on Growth and Results of Plants

a) Water stress (drought stress)

Plant growth is defined as an increase in plant size followed by an increase in dry weight. The process of plant growth consists of cell division, cell enlargement and cell differentiation (Darmawan and Baharsyah, 1982). Leaf area index, which is a measure of canopy development, is very sensitive to water stress, which results in a decrease in leaf formation and expansion, increased aging and leaf loss, or both. Leaf expansion is more sensitive to water stress than stomata closure. It was further said that increased leaf aging due to water stress tends to occur in lower leaves, which are least active in photosynthesis and in the provision of assimilates so that they have little effect on yield (Goldsworthy and Fisher, 1992). Martin, Tenorio and Ayerbe (1994) explain that water stress that occurs in the second half of the life cycle of peas plants results in a decrease in the value of LAI (leaf area index) after flowering. This results in lower yields of peas compared to results in the previous planting season, where rainfall during the first half of its life cycle is greater.

Lack of water can inhibit the rate of photosynthesis because the turgidity of stomatal guardian cells will decrease. This causes the stomata to close (Lakitan, 1995). Closure of stomata in most species due to lack of water in the leaves will reduce the rate of CO2 absorption at the same time and will ultimately reduce the rate of photosynthesis (Goldsworthy and Fisher, 1995). Besides stomata closure is a very important factor in the protection of mesophytes against heavy water stress (Fitter and Hay, 1994). The time between seed dispersal and cooking can be shortened or lengthened depending on the intensity and time of the water stress. The results of the study of Turk and Hal in 1980 and Lawn in 1982 showed that cowpea flowered and cooked earlier under moderate water stress levels, but severe water stress delayed reproductive activity (Goldsworthy and Fisher, 1992).

The depth of the roots is very influential in the amount of water absorbed. In general, plants with good irrigation have a root system that is longer than plants that grow in a dry place. The low soil water content will reduce root elongation, depth of penetration and root diameter (Islami and Utomo, 1995). Increased root growth under mild to moderate water stress conditions may be very important in tapping a new water supply for a plant. The results of a 1978 Nour and Weibel study showed that sorghum cultivars which are more resistant to drought, have more soil, have higher root volumes. and canopy root ratios are higher than drought-prone lines (Goldsworthy and Fisher, 1992).

The results of Martin, Tenorio, and Ayerbe (1994) showed that the roots of pea plants that experienced water stress in the second half of their life cycle could not explore the entire soil layer at a depth of 45 - 75 cm. In other words, the pea plant cannot extract water below a depth of 70 cm. For more details can be seen in Figure 1. Plant yield is a function of growth. Therefore, as a result, further water stress will reduce crop yields, and even plants fail to produce yields. If water stress occurs at high intensity and in a long time will result in plant death (Islami and Utomo, 1995).

The response of plant growth and yield to water stress depends on the growth phase when water stress occurs. If water stress occurs in a phase of rapid vegetative growth, the effect will be more detrimental than if water stress occurs in other growth phases. Physiological processes that result in changes in yield due to water stress, described by Hsiao et al. in 1976 as in the following picture (Islami and Utomo, 1995).

Drought stress that occurs during generative growth, for example during pod filling, will reduce production (Dornbos et al., 1987). Drought can also reduce seed weight because seed weight is strongly influenced by the amount of water given in the growing season (Scott et al., 1987). Balittan Malang (1990) reports that intensive water administration will affect the yield of soybean seeds. The provision of water every 10 days during the growing season can increase yields to 2 tons/ha compared to 3 times during the growing season (1.71 tons/ha) and without regular irrigation is only 1.47 tons/ha. (Totok Agung D. H. and Ahadiyat Yugi Rahayu, 2004).

b) Waterlogging

Excess water occurs when the soil surface becomes saturated, the pores of the soil are full of water. Excess water cannot be channeled into the channel. Water discharge can occur during periods of heavy rainfall, poor irrigation management, poor drainage, rising underground water levels. Excessive irrigation in irrigated areas causes excess water. Plants will use just as much water as needed. An excess of unused water will occur and refill the surface water system underground and cause an increase in underground water reservoirs (Anonimus, 2008).

Some of the effects of excess water on plants are: (1) Excess water causes the soil pores to have no oxygen, while plants need oxygen for their breathing and growth. (2) Plants will look yellow, growth is stunted and thin (3) Plants will be dead (4) Land becomes bare (5) Some plant species are more tolerant of water-saturated conditions and will take over the vegetation of the area. (6) Reducing yield potential between 30 - 80% in some agricultural products in pasture areas with rainfall above 400 ml (Mc Farlane and Williamson, 2001).

Inundation provides Dipak: reducing gas exchange between soil and air resulting in decreased availability of O2 for roots, inhibiting the supply of O2 for roots and microorganisms (pushing air out of soil pores or inhibiting diffusion rates), Under inundation conditions, <10% volume of pore containing air, most plant roots are stunted when <10% pore volume containing air and O2 diffusion rate is less than 0.2 ug / cm2 / minute, O2 deficient environmental conditions are called hypoxia, and environmental conditions without O2 are called anoxic (experiencing aeration stress). Anoxic condition is reached in a period of 6-8 hours after inundation because O2 is forced by water and the remaining O2 is used by microorganisms. In flooded conditions, the content of O2 remaining in the soil is more quickly depleted when there are plants. slower than in the air, the rate of decline in O2 is influenced by the texture of the soil

In sandy soils, O_2 depletion occurs 3 days after inundation, while in clay soils <1 day, clay porosity is lower than sandy soils. O_2 decline is accelerated by the presence of plants in the field, absorbing plant roots for respiration. Roots of nodular legume plants require six times more O_2 than those removed by nodules (30: 4.3 ul O_2 / g / min). Inundation in addition to causing a decrease in O_2 diffusion into the pore will also inhibit the diffusion of other gases, for example, the release of CO_2 from the soil pore. CO_2 accumulates in pores, in soils that have only been flooded 50% of dissolved gas is CO_2, some plants are unable to withstand the situation. The impact of excess CO_2 concentration has a smaller effect than O_2 deficiency.

Inundation affects the physical, chemical, and biological properties of the soil. Damaged soil structure, weak aggregate adhesion, decrease in redox potential, increase in acidic soil pH, decrease in alkaline soil pH, change in conductivity and ionic strength, change in nutrient balance. Inundated plants show typical symptoms of chlorosis in N deficiency. N Numbness occurs due to decreased N availability and decreased absorption. In inundated conditions the availability of N in the form of nitrate is very low due to the denitrification process, nitrate is converted to N_2, NO, N_2O, or NO_2 which evaporates into the air. In the denitrification process, nitrates are used by aerobic bacteria as electron recipients in the respiration process. The inundation has a negative effect on the availability of N, but there are also benefits from the emergence of a puddle, namely an increase in the availability of P, K, Ca, Si, Fe, S, Mo, Ni, Zn, Pb, Co.

Inundation influences physiological and biochemical processes including respiration, root permeability, water, and nutrient absorption, N. Inundation causes root death at a certain depth and this will stimulate the formation of adventitious roots in parts near the soil surface in plants that are resistant to inundation. Root death is the cause of N deficiency and physiological drought stress.

In legume plants, inundation not only inhibits root growth or canopy but also inhibits the development and function of root nodules. The function of root nodules is disrupted due to the inhibition of the activity of the enzyme nitrogenase and leghaemoglobin pigment, the ability of N_2 fixation will decrease. Soybean plants include plants that are resistant to inundation, able to form adventitious roots and root nodules on these roots, the inundation effect will disappear once adventitious roots are formed.

Effect of inundation on plant shoots: decreased growth, chlorosis, aging, epinasty, leaf shedding, lenticel formation, decreased dry matter accumulation, aerenchyma formation in stems. The amount of damage to plants as a result of inundation depends on the phase of plant growth. Inundation sensitive phase: germination phase, flowering phase, and filling. Inundation in the germination phase reduces the number of seeds that germinate (germination greatly requires O_2). Inundation that occurs in the flowering and filling phases causes many young flowers and fruit to fall

According to Linkemer and Musgrave (1998), inundation soybeans can reduce yield from 2,453 kg-1 to 1,550 kg ha-1, or decrease by 36.81% due to a decrease in the number of branches per plant, number of books per plant, number of seeds per plant, and weight seed. It is also known that the reproductive period is more sensitive than the vegetative period

In the inundation state, the roots of soybean plants are shorter and more horizontal to the root with more nodules in the base of the stem. Almost all genotypes tested, in the flooded state, can form adventitious and aerenchyma roots. The existence of adventitious roots can replace the real role of roots, namely as a means of supplying minerals, water, nutrients, hormones, and the role of sinks for the metabolites disappear so that plants can survive and produce seeds (Kozlowski, 1984). The aerenchyma that is formed can be an internal gas diffusion facility between oxygen-rich voiding parts into the rooting area, so the roots can function as in an aerobic state and can suppress fermentation capacity which can increase plant tolerance in stagnant conditions (Kuo, 1992).

3. Conclusion

Drought stress which has various adverse impacts on plant growth and development is a threat in the practice of crop cultivation to be developed, especially in the prolonged dry season. High investment costs are needed to create a technical irrigation system in an effort to maintain the availability of water on agricultural land.

From the above, it can be concluded as follows: 1. Water stress affects all plant growth phases, both vegetative growth and generative growth, which in turn affects plant yields. 2. Water stress during vegetative growth will affect the size and intensity of the source (leaves and roots). 3. Water stress during generative growth will affect the intensity and duration of the source and the size of the sink (eg fruit or other parts harvested). 4. The size, intensity and duration of the source and the size of the sink will affect total assimilation and ultimately affect crop yields.

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References

[1] Darmawan, Januar dan Y. Baharsyah. 1982. Fisiologi Tanaman Perkebunan. IPB. Bogor.
[2] Fitter, A.H. dan R.K.M. Hay. 1994. Fisiologi Lingkungan Tanaman. diterjemahkn oleh Sri Andani dan E.D.Purbayanti. Gadjah Mada University Press.
[3] Goldsworthy, P.R. dan N.M.Fisher. 1992. Fisiologi Tanaman Budidaya Tropik. Gadjah Mada University Press.
[4] Islami, Titik dan W.H. Utomo. 1995. Hubungan Tanah, ir dan Tanaman. IKIP Semarang Press. Semarang.

[5] Lakitan, Benyamin. 1996. Dasar-dasar Fisiologi Tumbuhan. PT. Raja Grafindo Persada. Jakarta.
[6] Martin, I., J.L. Tenorio dan L. Ayerbe. 1994. Yield, Growth and Water Use of Semileafless and Conventional Peas in Semiarid Environments. Crop Science 34: 1576 – 1583
[7] Christine, G., Rene', B., and Jean-Louis, B., 1996. Water deficit-induced changes in proline and some other amino acid in the phloem sap of alfalfa. *Plant Physiol*. 111 : 109 – 113.
[8] Gerik, T. J., 1996. Late season water stress in cotton: I. Plant growth, water use, and yield. *Crop Science*. 36 (4) : 914 - 921.
[9] Harjadi, S. S., dan S. Yahya, 1988. Fisiologi Stres Lingkungan. PAU Bioteknologi . IPB.
[10] Kramer, P.J. 1969. Plant and Soil Water Relationships. Mc. Graw Hill Book Company. Inc. New York. 347
[11] Munns, R., 2002. Comparative physiology of salt and water stress. *Plant cell and environment.* (25): 29-250
[12] Rahardjo, M., dan I. Darwati, 1996. Pengaruh cekaman air terhadap produksi dan mutu simplisia tempuyung (*Sonchus arvensis*). Balai Penelitian Tanaman Rempah dan Obat, Bogor.
[13] Salisbury, F. B. & C.W. Ross.1995. Fisiologi Tumbuhan Jilid II Penerbit ITB.
[14] Sasli, I. 1999. Tanggap Karakter Morfofisiologi Bibit Kakao Bermikoriza Arbuskula Terhadap Cekaman Kekeringan . Thesis Pascasarjana IPB.
[15] Ai Komariah, Achmad Baihaki, Ridwan Setiamihardja, dan Sulya Djakasutam, 2004, hubungan antara aktivitas nitrat reduktase, kadar n total, dan karakter penting lainnya dengan toleransi tanaman kedelai terhadap genangan, *zuriat, vol. 15, no. 2, juli-desember 2004*
[16] Endang Gati Lestari. 2006. Hubungan antara Kerapatan Stomata dengan Ketahanan Kekeringan pada Somaklon Padi Gajahmungkur, Towuti, dan IR 64. BIODIVERSITAS Vol. 7, No. 1, Januari 2006, hal. 44-48
[17] Toruan-mathius, n., gede wijana, edi guharja, hajrial aswidinnoor, Sudirman YAHYA dan SUBRONTO, 2001, Respons tanaman kelapa sawit (*Elaeis guineensis* Jacq) terhadap cekaman kekeringan. *Menara Perkebunan*, 2001, 69 (2), 29-45
[18] Elliakim, R. Sulistiani, Surianto T. Manik, 2008, Pengaruh Kelebihan Air Terhadap Pertumbuhan dan Produksi Tanaman. Paper. Program Studi Agroekoteknologi. Sekolah Pascasarjana. Universitas Sumatera Utara. Medan.
[19] Sulistyaningsih, Y.C, Dorly, dan A. Hilda. 1994. Studi anatomi daun Saccharum spp. sebagai induk dalam pemuliaan tebu. *Hayati* 1 (2): 32- 35
[20] Miskin, E.K., D.C. Rasmusson, and D.N. Moss. 1972. Inheritance and physiological efects of stomatal frequency in barley. *Crop Science* 12:780-783.
[21] Soepandi, D.M., A. Chozin, Sastrosumarjo, Suwarno, A.P. Lontoh, and T. Takano. 1999. Upland rice tolerance to shade: field screening and preliminary study on physiological mechanism. *Proceeding of International Plant Breeding Symposium.* Okayama, Japan. September 25-26, 1999.