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Efisensi Penggunaan Air dan Serapan Hara Tanaman Padi pada Kondisi Cekaman Air

Water use efficiency and nutrient uptake of Paddy under soil water stress condition

Endang Dwi Purbajanti*, F. Kusmiyati , Eny Fushkah
Agriculture Department, Faculty of Agriculture and Animal Husbandry, Diponegoro University, Jalan Prof. Sudharto SH, Tembalang, 50275 Semarang, Indonesia
Corresponding author: endang.purbajanti@live.undip.ac.id

ABSTRACT

One of the problems that limit Paddy growth and yield is low water availability. A comprehensive study of paddy response to drought is very important. The objectives of the study of the response of paddy plants to groundwater stress include protein content (stover and seeds), percentage of leaf curling, water use efficiency (WUE), relative leaf water content (RLWC), harvest index and N, P, K of paddy plants uptake. The study was conducted in the greenhouse of the Faculty of Animal Husbandry and Agriculture, Diponegoro University, from April to August 2016. The study used a 3 x 3 factorial design with 3 replications. The first factor is three types of paddy (Sidenuk, Way Apo Buru and Pepe) and the second factor is soil water stress (KA < field capacity = lack of water), field capacity (KL), water saturation (JA). The observed parameters are protein content, percentage of leaf rolled, relative water content (RWC), water use efficiency (WUE), N, P, K uptake, Rice protein content, grain protein content. Relative water content of rice plants decreases with increasing stress water that occurs in the limited water supply for the three types of rice. Sidenuk rice has the lowest N seed absorption (2.1%) compared to Way Apo Buru (3.0%) and Pepe (3.1%). P uptake in both stover and seeds was not significantly affected by ground water stress. The absorption of K stover and seeds is not significantly affected by ground water stress

Keywords: rice, relative water content, water use efficiency, protein, P content, K content

ABSTRAK

Salah satu kendala yang dapat membatasi pertumbuhan dan produksi tanaman padi adalah ketersediaan air yang rendah. Studi komprehensif tentang respons tanaman padi terhadap kekeringan sangat penting. Tujuan penelitian tentang respons tanaman padi terhadap cekaman air tanah meliputi kadar protein (brangkasan dan biji), persentase daun menggulung, efisiensi penggunaan air (EPA), kandungan air daun relatif (KADR), indeks panen dan serapan N, P, K tanaman padi. Penelitian dilakukan di rumah kaca Fakultas Peternakan dan Pertanian, Universitas Diponegoro, mulai bulan April sampai Agustus 2016. Penelitian menggunakan rancangan faktorial 3 x 3 dengan ulangan 3 kali. Faktor pertama adalah tiga jenis padi (Sidenuk, Way Apo Buru, Pepe) dan faktor kedua perlakuan kurang air (KA<kapasitas lapang=cukup air, kapasitas lapang(KL), jenuh air(JA). Parameter yang diamati adalah kadar protein (brangkasan dan biji), persentase daun menggulung, efisiensi penggunaan air (EPA), kandungan air daun relatif (KADR), indeks panen dan kadar N, P, K tanaman padi. Kadar protein padi menurun sejalan dengan meningkatnya pemberian air. Kadar air daun relatif tanaman padi menurun dengan bertambahnya stres air yang terjadi pada

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terbatasnya pemberian air untuk ketiga jenis padi. Efisiensi penggunaan air tidak dipengaruhi oleh jenis padi maupun perlakuan kurang air. Jenis padi Sidenuk mempunyai serapan N biji terendah (0.21%) dibandingkan Way Apo (0,30%) dan Pepe (0.31%). Serapan P baik pada brangkasan maupun biji tidak nyata dipengaruhi oleh cekaman air tanah. Serapan K brangkasan maupun biji tidak nyata dipengaruhi oleh cekaman air tanah.

Key words: padi, kandungan air daun relatif, protein, serapan N, K, P.

INTRODUCTION

Paddy (Oryza sativa L.) is a staple food crop in Indonesia, which accounts for 26.6% of the total area of cereal cultivation and 43.6% of total food production. Rice is the main source of energy needed every day. The main challenges faced in efforts to increase food crop production are; 1). The increasing demand for rice is in accordance with the increase in population, 2). Limited availability of world rice, and 3). The tendency of rising food prices. Indonesia's rice harvest area in 2018 is 10,903,835 ha with an average production of 5.18 tons per ha (BPS, 2019).

The stress of the water deficit causes a great loss of agricultural production throughout the world, making it a severe threat to sustainable agriculture. A population that continues to increase and a depletion of water supply requires varieties of plants that can adapt to a dry environment (Pandey and Suhkla, 2015). Drought affects the extension and growth of plants (Shao et al, 2008), and inhibits cell enlargement more than cell division (Jaleel et al, 2009). The effect of water stress on plant growth depends on the level of stress experienced and the type or cultivar planted. The initial effect of water stressed plants is the occurrence of obstacles to the opening of leaf stomata which then have a major effect on physiological and metabolic processes in plants (Penny-packer, et al., 1990). Water stress affects all aspects of growth, physiological and biochemical processes of plants causing the anatomical and morphological modification of plants. Plants that experience water stress will affect the metabolic process, the relationship between water and plants, nutrient uptake and its metabolism and photosynthesis (Shi et al, 2015). Water stress is the cause of various plant growth failures. Under conditions of dry stress, the rate of photosynthesis decreases, the results of metabolites such as proline and pinitol are accumulated by plants. Protein content is also affected, cell wall modification occurs, carbohydrate / nitrogen metabolism is disrupted, defensive signs occur in plants that program cell death which is useful for defense response to drought (Oh and Komatsu, 2015). Water stress is basically caused by drought or high soil salinity which causes a water deficit and then reduces plant growth by affecting various physiological and biochemical processes (Farooq et al., 2008). Plant growth is an essential trait for plant survival and reflects a balance between the reconstruction of damaged structures and adequate metabolic recovery. The objectives of the study of the response of rice plants to groundwater stress include protein content (stover and seeds), percentage of leaf curling, water use efficiency (WUE), relative leaf water content (REWC), harvest index and N, P, K absorption of paddy plants.

MATERIALS AND METHODS

The research was conducted in the greenhouse of the Faculty of Animal Husbandry and Agriculture, Diponegoro University, from April to August 2016. The research used a 3 x 3 factorial design with 3 replications. The first factor is three

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types of rice (Sidenuk, Way Apo Buru and Pepe) and the second factor is groundwater stress treatment (KA < field capacity = lack water, field capacity (KL), water saturation (JA)). The rice seeds are sown for 10 days on soil media and then transferred into a rectangular tub as an experimental pot (measuring 40 x 37.5 x 20 cm^3). Each pot contains 1 seed. Plants are fertilized with N, P and K fertilizers, each 300 kg N/ha, 100 kg P_2O_5/ha and potassium 100 kg K_2O/ha. The capacity of the experimental field was determined by the gravimetric method in which the value of water content in the field capacity was 42%. The water-less treatment is 75% of the field capacity water content. Water-saturated treatment means that rice plants are in water-saturated condition. Soil moisture levels are monitored for each treatment throughout the growing season by the gravimetric method every week. To achieve the expected level of dryness, a certain amount of water is added to each pot to maintain moisture. Harvesting is done when the plant is 120 days old, which is characterized by yellowing of leaves and 90% of physiologically cooked grain. The parameters observed were the number of curled leaves observed in plants aged 50 DAP, relative leaf water content (RLWC) observed in plants aged 50 DAP, water use efficiency (WUE) was calculated based on plant weight divided by the amount of water during plant growth until harvest, protein content was carried out after harvesting, the harvest index is done after harvest, the N, P, K contents are harvested. The collected data is then analyzed for variance (ANOVA), referring to Steel and Torrie (1990) and if proven to be significant, proceed with the DMRT test.

Relative Leaf Water Content (RLWC)

The relative leaf water content (RLWC) is determined gravimetrically before dawn. Ten expanded flag leaves were collected to determine the fresh weight (FW). Wet leaf weights (TW) were determined after the leaves were floating in distilled water in a closed container at 4ºC in the dark for 24 hours. Dry weight (DW) was determined for the same leaves after oven drying for 48 hours at 70ºC. RLWC is calculated as:

RLWC (%)=[(FW–DW)/(TW-DW)]×100% (Wu and Bao, 2011).

WUE calculation as follows:

$$WUE = \frac{Plant\ dry\ weight\ (grams)}{Water\ requirements\ of\ each\ plant\ (mm)}$$

(Suryanti et al., 2015).

Protein content (%) = N x 6.25, in which N is determined by the Kjeldahl method. The P level was determined with a spectrometer and the K level was determined with a flame photometer. Nutrient uptake is equal to nutrient content x plant dry weight.

RESULTS AND DISCUSSION

Protein Content

Protein content observed was stover protein content and seed protein content. ANOVA results showed that there was an interaction between rice types with groundwater stress treatment on stover protein content, rice type affected protein content and groundwater stress affected the protein yields. ANOVA results showed that there was no interaction between rice types with groundwater stress treatment on seed protein content, rice type affected protein content and groundwater stress affected seed protein content. Results of analysis of stover protein and seeds protein content were presented in Table 1.

Stover protein content indicated the interactions between plant types and water stress (Figure 1). The stover protein content of each type of rice under water-less treatment was lower than the water-saturated treatment but higher in value when compared to field capacity. Figure 2a showed the protein content of Way Apo

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rice seeds was not significantly different from Pepe. Sidenuk rice seed protein content is lowest compared to the other two types of rice. Figure 2b showed the protein content of rice seeds which decreases with the increasing of groundwater stress.

Under drought stress, plants usually respond through stomata regulation, osmotic adjustment and anti-oxidative defences, to reduce damage caused by drought stress. However, long periods of high drought intensity can inhibit plant growth, cause changes in morphological structure and biomass distribution patterns, or even death. Water stress or drought affects photosynthesis and translocation of assimilation with extreme drought stress that causes plant death. However, some plants have designed drought stress tolerance mechanisms to some extent through escape, avoidance, tolerance, or recovery (Fitter and Hay, 1991).

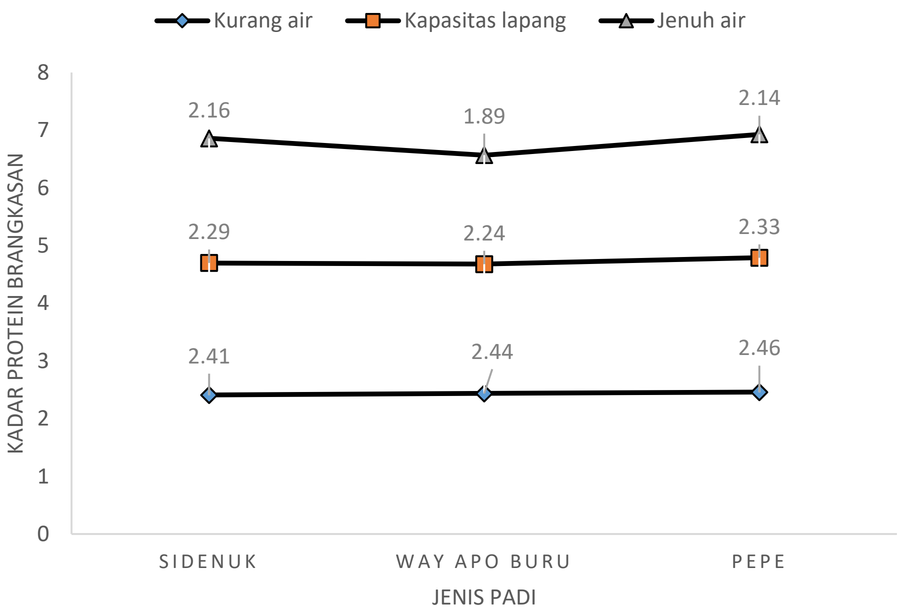
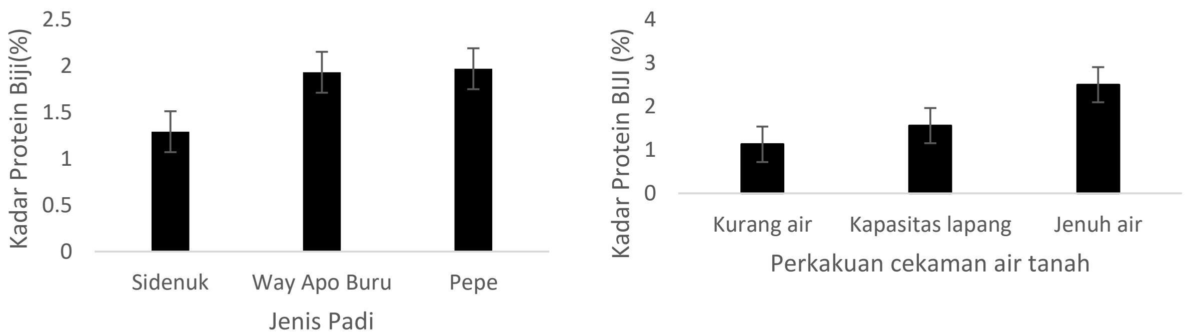


Figure 1. Stover Protein Content in Three Treatments of Ground Water Stress



a b

Figure 2. Seed protein content in three water stress treatments

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Leaf Rolling

ANOVA results indicated that there are interactions between types of rice and groundwater stress treatment. The leaves rolling in all three types of rice due to a decrease in the amount of water supplied to the plant, under water-saturated conditions, all three types of rice do not experience leaf rolling (Table 1). Applying less water resulted in leaf rolling, which is most common in Pepe rice with limited water treatment. Leaf rolling is one of the mechanisms of drought avoidance in plants to maintain the leaf water potential remains high when water shortages. Rolling the leaves resulted in a decreased transpiration rate because the area of the leaf directly exposed to the sun becomes smaller.

Leaf rolling is closely related to leaf anatomy and occurs due to the shrinking process of bulliform cells or fan cells (Zou et al., 2011). One of the morphological characters that can be observed in monocot plants when lacking water is leaf rolling. Leaf rolling can reduce the leaf surface area exposed to sunlight, thereby reducing the rate of transpiration in plants. The reduced rate of transpiration will help plants to be able to survive within a certain period when the availability of water in the environment decreases (Nio and Lenak, 2014).

Drought stress is considered a moderate loss of water, which causes stomatal closure and restrictions on gas exchange. Drying is a much broader loss of water, which can potentially cause metabolic disorders and cell structure and ultimately in the termination of the enzyme-catalyzed reaction. Lack of water affects the physiological and biochemical processes of plants and causes the anatomy and morphology of plants to occur. The average value of leaf rolling, RLWC, WUE and Harvest Index can be seen in Table 1.

Relative Leaf Water Content (RLWC)

ANOVA results indicated that there is an interaction between the types of rice plants and the treatment of groundwater stress to relative leaf water content. When the leaves experience drought stress, the leaves will experience a decrease in leaf relative water content and water potential. Plants show symptoms of stress in the form of decreased leaf water potential, relative leaf water content and transpiration rate by increasing leaf temperature.

The relative leaf water content of rice plants decreases with increasing water stress which occurs in the limited water supply for all three types of rice (Table 1). In Sidenuk rice the relative leaf water content decreased by 65.4%, way apo 57.3% and Pepe 68.9% compared to water saturated conditions.

Low relative leaf water content (RLWC) of plants showed various effects of water shortages in these plants and is the reason for the situation in which competition occurs at the top and bottom of plants to use the best possible resources and development occurs hence root development is stunted (Gholinezhad, et al., 2009).

Water Use Efficiency (WUE)

The interaction between rice types and water stress showed no significant effect on water use efficiency (Table 1). Rice types and groundwater stress factors each showed no significant effect. Plants that survive drought conditions have a mechanism with three main points: (a) Maintenance of high plant water status during stress, (b) Maintenance of plant functions at low plant water status and (c) Recovery of plant water status and plant function after stress (Zhang et al, 2005). If the groundwater content does not meet the needs of plants, the concentration of pigments, including carotenoid pigments, decreases, hence the rate and activity of photosynthesis and plant growth decreases.

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Table 1. The Average Value of Leaf Rolling, RLWC, WUE and Harvest Index in the Treatment of Three Types of Rice and Groundwater Stress

	Leaf Rolling (%)	RLWC (%)	WUE (g/mm)	Harvest Index (%)
Sidenuk - KA	10,0 c	23,3 e	10,70	26,00
Sidenuk - KL	7,4 b	48,4 c	14,60	20,23
Sidenuk - JA	0,0 a	67,3 ab	15,55	23,23
Way Apo Buru-KA	10,0 c	27,5 de	8,45	52,17
Way Apo Buru-KL	6,0 b	38,4 cd	11,84	16,13
Way Apo Buru-JA	0,0 a	64,4 b	12,37	8,47
Pepe -KA	20,0 d	24,3 e	9,96	21,07
Pepe – KL	10,0 b	66,8 ab	17,15	25,43
Pepe - JA	0,0 a	78,1 a	21,60	11,20
Sidenuk	5,5 a	46,34 b	13,62	23,16
Way Apo Buru	5,4 a	43,42 b	10,88	25,59
Pepe	10,0 b	56,40 a	16,24	19,23
KA	14,33 c	25,04 c	9,7	33,07 a
KL	7,45 b	51,20 b	14,5	20,60 ab
JA	0,00 a	69,92 a	16,5	14,30 b
Type of	*	*	ns	ns
Groundwater stress	*	*	ns	*
J*C	*	*	ns	ns

Note: * significantly different tn = not significantly different

Numbers followed by different letters in the same column are significantly different based on Duncan's Multiple Range Test at 5%

Several indicators of plants experiencing water shortages can be viewed from the aspects of physiology, anatomy and morphology, such as stunted leaf growth, rapid root growth, stomata closure, and leaf rolling which are common in Gramineae plants. Water stress affects all aspects of plant growth, physiological and biochemical processes and causes modification on plant anatomy and morphology to occur. Water stress affects photosynthesis and assimilates translocation, in which excessive water stress results in plant death. Plants respond to drought with various mechanisms (Kivuva et al., 2015: Nazar et al, 2015).

Plants need to maintain their water potential to maintain turgor and absorption of water for growth. This requires increased osmotic, either by absorption of soil solutes or by a metabolic synthesis of benign (compatible) solutes, furthermore, the role of compatible solutes in plant stress responses is not limited to conventional osmotic adjustments but also includes several functions regulatory or osmoprotective. One of its functions is in maintaining cytosolic K+ homeostasis by preventing NaCl from leakage of K+ induced from cells (Darwesh, 2013).

Harvest Index

The interaction between rice varieties and water stress showed no significant effect on the harvest index

(Table 1). Variety factor showed no significant effect on harvest index, but water stress treatment showed significantly different on harvest index. Groundwater stress induces a reduction in plant growth and rice development. Drought affects prolongation and growth and also inhibits cell enlargement more than cell division. Many aspects of plant growth are affected by drought, including reduced leaf growth due to sensitivity of cell growth to water pressure. Water stress also reduces leaf production and increases aging and absenteeism, thereby reducing the total leaf area per plant (Purbajanti, et al., 2017).

N, P and K Uptake

N stover absorption showed a significant interaction between rice types and groundwater stress (Table 2). The absorption of N stover increases with increasing water stress. With limited water, N uptake of Sidenuk rice stover increased 11.7%, Way apo Buru stover uptake increased by 30.0% and Pepe 14.7% compared to water-saturated treatment. Sidenuk rice types have the lowest N seed uptake compared to Way Apo and Pepe. P uptake in both stover and seeds was not significantly affected by groundwater stress and type of rice.

Table 2. N, P and K uptake in three types of rice and water stress

Paddy/Rice	Mineral uptake (g / plant)					
	N		P		K	
	Stover	Seed	Stover	Seed	Stover	Seed
Sidenuk - KA	3,8a	1,3	0,07	0,17	1,77	0,40
Sidenuk - KL	3,6 b	1,6	0,18	0,36	1,81	0,36
Sidenuk - JA	3,4 d	3,3	0,46	0,16	1,82	0,50
Way Apo Buru-KA	3,9 a	1,9	0,09	0,04	1,85	0,50
Way Apo Buru-KL	3,5 c	3,0	0,09	0,04	1,48	0,44
Way Apo Buru-JA	3,0 e	4,3	0,07	0,04	1,91	0,54
Pepe -KA	3,9 a	2,2	0,04	0,36	1,55	0,47
Pepe – KL	3,7 b	2,9	0,17	0,36	1,62	0,40
Pepe - JA	3,4 d	4,4	0,07	0,04	1,55	0,52
Sidenuk	3,6a	2,1 b	0,24	0,23	1,80 a	0,42
Way Apo Buru	3,5b	3,0 a	0,08	0,04	1,75 ab	0,49
Pepe	3,7a	3,1 a	0,10	0,25	1,57 b	0,46
KA	3,8 a	1,8 c	0,07	0,19	1,72	0,46
KL	3,6 b	2,5 b	0,15	0,25	1,64	0,40
JA	3,3 c	4,0 a	0,20	0,08	1,76	0,52
Type of	*	*	ns	ns	*	ns
Groundwater Stress	*	*	ns	ns	ns	ns
J*C	*	ns	ns	ns	ns	ns

Note: * significantly different tn = not significantly different

Numbers followed by different letters in the same column are significantly different based on Duncan's Multiple Range Test at 5%

The interaction between rice types and groundwater stress had no significant effect on the absorption of K stover or seeds. Rice type influences the uptake of K in rice stover. Sidenuk rice has different K uptake with Pepe but not significantly different from Way Apo Buru stover uptake.

Drought reduces the rate of diffusion of nutrients in the soil toward the roots, nutrient uptake by roots, and their transport to active transport and membrane permeability. Drought during the vegetative stage in Arabidopsisthaliana induces a decrease in the concentration of almost all minerals including Zn, Fe, Mn, Ca and Mg in leaves, except for K (Etienne.et al, 2018). N uptake from the results of research by Nuryani et al, (2010) is 76.1 kg/ha for stover and 13.12 kg/ha seeds for Mentik Wangi pies. While the absorption of P stover 0.18 kg/ha and seeds 0.31 kg/ha. Absorption of K stover 0.65 kg / ha and seeds 0.41 kg / ha.

CONCLUSION

Stover protein content is low in the treatment of less water in all types of rice. The relative leaf water content of rice plants decreases with increasing water stress which occurs in the limited supply of water for all three types of rice. The efficiency of water use is not influenced by the type of rice or groundwater stress treatment. Groundwater stress conditions have a harvest index that is the same as the field capacity. Sidenuk rice has the lowest N seed absorption (2.1 g / plant) compared to Way Apo (3.0 g / plant) and Pepe (3.1 g / plant). P uptake in both stover and seeds was not significantly affected by water stress, so was K uptake.

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REFERENCES

Badan Pusat Statistik. 2018. https://www.bps.go.id/dynamictable/2019/04/15/1608/luas-panen-produksi-dan-produktivitas-padi-menurut-provinsi-2018.html

Darwesh, R,S,S. 2013. Improving growth of date palm plantlets grown undersalt stress with yeast and amino acids applications Annals of Agricultural Science (2013) 58(2), 247–256

Etienne P.I.D, S. Diquelou , M. Prudent, C. Salon., A. Maillard and A.Ourry. 2018. Macro and Micronutrient Storage in Plants and Their Remobilization When Facing Scarcity: The Case of Drought. Agriculture 2018, 8, 14; 2-17. doi:10.3390/agriculture8010014

Farooq, M., S.M.A.Basra, A. Wahid, Z.A.Cheema, M.A.Cheema, A.Khaliq. 2008. Physiological role of exogenously applied glycinebetaine in improving drought tolerance of fine grain aromatic rice (Oryza sativa L.).Journal of Agronomy & Crop Science, 194: 325-333.

Fitter, A.H.dan R.K.M. Hay. 1991. Fisiologi lingkungan tanaman. Gadjah Mada University Press, Yogyakarta

Gholinezhad,E., A.Ayanaband, A. H. Ghorthapeh, G.Noormohamadi, I.Bernousi.2009. Study of the Effect of Drought Stress on Yield, Yield Components and Harvest Index of Sunflower Hybrid Iroflor at Different Levels of Nitrogen and Plant Population. Not. Bot. Hort. Agrobot. Cluj 37 (2) 2009, 85-94

Kivuva,B.M. , S.M. Githiri, G. C. Yencho, J.Sibiya.2015. Screening sweetpotato genotypes for tolerance to drought stress. Field Crops Research 171 (2015) 11–22

Jaleel C A, Manivannan P, Wahid A, Farooq M, Al-Juburi H J, Somasundaram R, Panneerselvam R. 2009. Drought stress in plants: A review on morphological characteristics and pigments composition. Int J Agric Biol, 11: 100–105.

Nazar,R., S. Umar, N.A. Khan, O. Sareer. 2015. Salicylic acid supplementation improves photosynthesis and growth in mustard through changes in proline accumulation and ethylene formation under drought stress. South African Journal of Botany 98 (2015) 84–94.

Nio, S.A. dan A.A. Lenak. 2014. Penggulungan daun pada tanaman monokotil saat kekurangan air. Journal Bio Logos, Agustus 2014, Vol.2, No 4: 48-55.

Nuryani, S.H.U., Haji,M., Widya, N. Y., 2010. Serapan hara N,P,K pada tanaman padi dengan lama penggunaan pupuk organic pada vertisol Sragen. Jurnal Ilmu Tanah dan Lingkungan vul 10 No 1 : 1-13

Oh, M.W. and S. Komatsu. 2015. Characterization of proteins in soybean roots under flooding and drought stresses. Journal of Proteomics. 114 (2015): 161-181.

Pandey, V.,and A.Shukla.2015.Aclimation and Tolerance Strategies of Rice under Drought Stress. Rice Science, 2015, 22(4): 147-.161.

Penny-packer, B. W., K. T. Leath., W. L. Stout, and R. R. Hill. 1990. Technique for stimulating field drought stress in the green house. Agr. J. 82 (5): 951–957.

Purbajanti,E.D., F. Kusmiyati and E. Fuskhah. 2017. Growth, Yield and Physiological Characters of Three Types of Indonesian Rice Under Limited Water Supply.
Asian J. Plant Sci., 16 (2): 101-108, 2017.

Shi,G. , S. Xia., J. Ye, Y. Huang , C. Liu, Z. Zhang .2015. PEG-simulated drought stress decreases cadmium accumulation in castor bean by altering root morphology. Environmental and Experimental Botany 111 (2015) 127–134.

Shao H B, L.Y.Chu, M.A. Shao, C.A.Jaleel, H.M. Mi. 2008. Higher plant antioxidants and redox signaling under environmental stresses. Comp Rend Biol, 331: 433–441.

Jurnal Pertanian Tropik ISSN NO: 2356- 4725/p- ISSN : 2655-7576
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Steel, R.G.D. and J.H. Torrie, 1960. Principles and Procedures of Statistics. McGraw-Hill, New York, USA.

Suryanti, S., D. Indradewa, P. Sudira, J. Widada. 2015. Water Use, Water Use Efficiency and Drought Tolerance of Soybean Cultivars. AGRITECH, Vol. 35, No. 1, Februari 2015: 114-120.

Wu,X. and W. Bao. 2011. Leaf Growth, Gas Exchange and Chlorophyll Fluorescence Parameters in Response to Different Water Deficits in Wheat Cultivars. *Plant Prod. Sci.* 14(3): 254—259 (2011)

Zhang, X., X. Chen, Z. Wu, X. Zhang, C. Huang and M. Cao, 2005. A dwarf wheat mutant is associated with increased drought resistance and altered responses to gravity. Afr. J. Biotechnol., 4: 1054-1057.

Zou L., X.Sun, Z. Zhan, P. Li, J. Wu, Tian Cai-juan, Qiu Jin-long, Lu Tie-gang (2011) Leaf rolling controlled by the homeodomain leucine zipper class IV gene Roc5 in rice. Plant Physiology 156:1589– 1602

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