Sys Rev Pharm 2020;11(8):611-618
A multifaceted review journal in the field of pharmacy

DIFFERENCES OF WATER STATUS AND RELATIONSHIP WITH ROOTS GROWTH AND YIELD OF RICE UNDER WATER STRESS

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Abstract

The ims of this study to obtain relationship between water status in rice leaves and root growth and yield of rice under water stress. Studied on 6 varieties with water stress levels of 0.35 to 0.70 bar repeatedly multistage, showed changes in rice root characters. Rice with deep, thick and solid root character were higher yield under water stress conditions. Root characters were influenced by variety and water stress. relative water content of leaf at vegetative stage have positive correlation with RWC reproductive r= 0,98 P<0,01, root depth r= 0,66 P<0,01, biomass dry weight 0,76 P<0,01 and grain weight perhill r= 0,81 P<0,01. Root to shoot ratio have negative correlation with RWC vegetatif r= 0,63 P<0,01, RWC reproductive r= -,65 P<0,01, root volume r= 0,46 P<0,05. Relative water content in leaves can be used as a key criterion for rice resistance to water stress.

Keywords: root, water stress, dry matter, accumulation, RWC

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INTRODUCTION

Rice is the main staple food crop in the world after wheat (FAOSTAT, 2016). Rice is the world's main important staple food (Maraseni et al., 2017). Both of these cereal plant's productions were limited by water shortages (FAOSTAT, 2016). Land of cereal production in the world 80% experienced of water shortages. This has continued to occur in the past decade. This situation was exacerbated by the impact of climate change which causes frequent of el nino occurance in various parts of the world (IPPC, 2007). Water stress causes a 50% decreased in world rice production). Overcoming this problem can be done with various strategic actions starting from the selection of tolerant varieties, time adjustment for seedling, planting, fertilizing and watering management. Various rice research instutes in the world have produced many water stress tolerant varieties (FAO, 2019; IRRI, 2012). In addition to the tolerant varieties produced by rice research institutes, in all regions there are landrace that have been used for a long time by local farmers and have resistance to water stress. Rice landrace are a source of germplasm to increase rice resistance to water stress. Rice landrace can help the availability of water stress-tolerant rice seeds every planting season.

The use rice landrace can naturally conserve rice germplasm in various places. This will be a resource for sustainable agricultural development. The use of water stress tolerant varieties can maintain world rice production (Rajiv et al, 2010). Tolerant water stress varieties are varieties that are capable of high production under water stress conditions (Farooq et al., 2010; Lou et al, 2010). Water stress tolerant varieties have long root characteristics and high dry weight (Maisura et al, 2014). Water stress tolerant varieties can save water use so that they can be irrigated more widely land because traditional irrigation requires water 3 to 5 times that of dry resistant rice (Bouman and Toung, 2001).

However, the efficiency of water use must adjust to critical phases of rice plants. For this reason, it is necessary to maintain soil moisture content at the panicle initiation phase in order to maintain yield stability. Water stress in the reproductive phase can reduce yields by 75 to 88% (Marcaida et al, 2014). Water stress can reduce yield by 50% (Yang et al., 2008). Drought tolerant rice has the ability to increase the harvest index (Kumar et al, 2015). Soil water potential (SWP) of -0.60 bar limits the growth of rice tillers (Chu et al., 2013), -0.70 bar were a critical point for rice transpiration (Davatgar et al., 2009). -0.70 bar limits grain production. Soil water potential greater than -0.60 bar were severe water stress 0.3 to 0,48 bar moderate water stress for rice (Toress and Henry, 2018), SWP -0.46 to -0.56 bar decreased rice productivity (Reis et al., 2018), -0.2 to -0.25 were a critical water potential for lowland rice (Santos et al., 2018).

In drought conditions, plants can increase zitin and cytokinins to increase root growth (Norton et al, 2017). Water stress causes an increase in abscisic acid which were followed by an increase in auxin growth regulators which control the balance of free radicals in water stress conditions (Pasternak et al, 2005). This is what causes rice to increase root length in water stress conditions. Up land rice productivity depends on the photosynthetic partition to grain not by the accumulation of dry matter (Kumar et al, 2006). RWC determines rice productivity (Kumar et al., 2006; Pushpam et al., 2018; Kumar dan Nilanjaya (2014). Water stress causes an increase in assimilate to grains (Kumar et al, 2006). The reproductive phase RWC influences grain yield. Determination of changes in root morphology, accumulation of dry weight, root dry weight, root was important to selected water stress tolerant varieties.

Rice yield under water stress conditions were related to root growth, root shoot ratio, root volume, dry matter accumulation, yield and RWC are needed to determine the tolerance of rice to water stress.

MATERIALS DAN METODS

Plant materials, growth conditions and water stress treatment.

The varieties used consist of 6 rice varieties, 3 were national superior varieties and 3 landraces of Aceh. Uniform and healthy rice seeds were washed with tap water for 30 minutes then soaked with water for 24 hours and incubated for 48 hours. The seeds that have come out of the roots were sowed to seedbed tray which has been filled with soil mixed with compost 3:1. Seedbad watered every morning and evening. At the age of 12 days after sowing, the seedlings were planted in PVC tubes with 10 cm in diameter and 110 cm high which had filled with podsolid soil mixed with 100 g of compost. The soil in PVC were saturated with water, stirred to formed muddy and left for 2 weeks under water saturation. Planted 1 seedling each PVC tube. PVC tubes were arranged in a splitpot randomized block design. Water stress becomes the main plot consisting of 3 levels of water stress, namely normal irrigation or non-stress (NS), moderate water stress (MWS) and severe water stress (SWS). Varieties became sub-plots consisting of V1 (Situ Patenggang), V2 (Towuti), V3 (IR 64), V4 (Sipulo), V5 (Sanbei), V6 (Bo Santeut). V1 and V2 were water stress tolerance varieties (BB Padi, 2015), V3 water stress susceptible variety (Maisura et al., 2014; Kumar et al., 2020), V4, V5 and V6 were tested varieties.

The water stress treatment started 2 weeks after planting, by saturating the soil and submerging 2 cm of surface soil in PVC tubes until harvesting for non-stress (NS) treatment. Submerging 2 cm of the soil surface in the PVC tubes then stopped irrigation and reirrigated again when SWP reached -35 bar, and repeatly until harvest (MWS). Flooding 2 cm of soil surface in a PVC tubes then stopped irrigation and reirrigated when SWP reached -0,70 bar, and repeatly until harvest (SWS). Rice was fertilized with 1 g urea, 0.5 g single super phosphate (SP36) and KCl at planting and 4.5 g NPK at planting, and 0.5 g urea at ages 30 and 60 day after planting (DAP). Plants were grown in the experimental farm of the Faculty of Agriculture, Syiah Kuala University, Banda Aceh, Indonesia from November 2015 to March 2016. Soil potential water were controled every day using tensiometer and global water logger to determined soil water potential and soil water content. Tensiometer Model 2725, Soilmoisture Equipment Corp. Santa Barbara, California, USA. global water logger II Versi 2.10 (11390 amalgam Way. Gold river CA 95670) *www.globalw.com*.

Sampling and measurement

Relative water content (RWC) were measured in the vegetative and reproductive phases. Leaf number 4 from the topest were cut 2 to 3 cm then weighed of fresh weight (FW), then soaked in petridis measuring 6 cm containing 10 ml of water for 4 hours. Then wiped the surface with tissue paper to removed surface water then weigh it as turgid weight (TW). Then the leaves were dried in an 70ºc oven for 24 hours until a constant weight and recorded as dry weight (DW). RWC were determined based on the method described by Bhushan et al. (2007) with the equation RWC (%) = [(FW-DW) / (TW-DW] X 100 where FW is fresh weight, DW is dry weight and TW is turgid weight. roots and biomass dry weight were carried out by oven at 70°C for 48 hours to a constant weight. Root volume were determined using a measuring glass filled with water by entering the oven dry roots and recording changes in water volume Root depth based on the longest root (IRRI, 2012; SES , 2002) Measurement of root depth, root length, root volume, root dry weight, biomass dry weight done after harvest.

Statistical analysis of varians (ANOVA) using Microsoft excel window 10. The difference between the level of water stress and varieties were determined by honesty significant different (HSD) P <0.05 to determine statistically significant differences. Correlation between parameters using pearson correlation SPSS 26.

RESULTS

Effect of water stress

Effect water stress on the morphological rice roots characters, leaves RWC and dry matter acumulation can be seen in table 1.

Tabel 1. Effects of water stress on leaves relative water content, root character and dry matter acumulation

Parameters	Water Stress			HSD	CV
	NS	MWS	SWS	0.05	(%)
RWC leaves at Vegatative (%)	94.42c	78.66b	56.89a	0.64	0.5
RWC leaves at Reproduktive (%)	93.53c	88.44b	80.75a	1.12	0.77
Root depth (cm)	36.78c	29.61b	24.28a	3.96	14.16

Root Volume (cm^3)	4.70c	3.39a	3.90b	0.39	10.55
Root Dry Weight (g)	7.87c	5.55a	6.49b	0.73	11.92
Biomass dry weight (g)	92.05c	53.78b	3 1.96a	4.43	8.06
Root to shoot Ratio	0.10a	0.12b	0.28c	0.01	7.43
Grains weight Per hill (g hill^{-1})	16.72c	13.78b	6.98a	1.29	11.15

Data followed by the same letter within the same row indicate no significant difference at $P< 0.05$ level HSD test.
Coefficient of variant (CV)

Vegetative relative water content (RWC) decreased sharply with decreasing water potential from 0 Bar to -0.35 and -0.70 bar. But in the reproductive phase RWC reduction were not as high as in the vegetative phase. Very high decreased in root length with increasing water stress. But the volume of the roots decreased not as much as the depth of the roots decreased. Dry root weight decreased with increasing water stress, but at severe water stress, dry root weight was higher than dry root weight under moderate water stress. The dry weight of biomass was increased in severe water streess. However, the root shoot ratio was increased with increasing water stress.

The weight of filled grain perhill were decreased with increased of water stress.

Effect of varieties

Effect varieties on the morphological rice roots characters, leaves RWC and dry matter acumulation can be seen in table 2.

Tabel 2. Effects of varieties on leaves relative water content, root character and dry matter acumulation

Parameters	Varieties						HSD	CV
	V1	V2	V3	V4	V5	V6	0.05	(%)
RWC leaves at vegatative (%)	80.37e	77.38c	68.76a	78.38d	80.44e	74.60b	0.20	0.26
RWC leaves at reproduktive(%)	89.20d	88.40c	84.47a	88.21c	88.62c	86.49b	0.47	0.53
Root depth (cm)	30.22c	21.22a	25.56b	36.22d	35.33d	32.78cd	2.80	9.63
Root volume (cm^3)	4.06c	1.52a	2.19b	6.06d	4.17c	5.97d	0.49	12.61
Root dry weight (g)	6.60c	2.53a	3.63b	10.16d	6.98c	9.92e	0.89	13.96
Biomass dry weight (g)	50.54b	51.91b	40.85a	57.85c	70.17d	84.27e	4.85	4.86
Root to shoot Ratio	0.17d	0.07a	0.14c	0.23d	0.11b	0.25e	0.02	14.37
Grains weight Per hill (g hill^{-1})	15.81c	14.77c	7.16a	14.52c	12.00b	10.69b	1.32	10.97

Data followed by the same letter within the same row indicate no significant difference at $P< 0.05$ level HSD test.
Coefficient of variant (CV)

The highest RWC in V1 is followed by V5, V4, V2 and V6, all higher than V3 which is a water stress sensitive variety. But the RWC reproductive phase was higher than the Vegetative phase, with the highest RWC was at V1 followed by V5, V2, V4, V6 and lowest at V3. The longest root depth was in V4 followed by V5 and V6 which are significantly different from V1, V2 and V3 as national superior varieties. The highest root volume in V4 was followed by V6 and V5 which were significantly different from V1, V2 and V3. The highest root dry weight was in V4 followed by V6 and V5 which were higher than V1, V2 and V3. The highest canopy root ratio was in V6 followed by V4 and V1, while V5 was higher than V3 and V2. The grain weight was as high as V1 but not significantly different from V2 and V4. But V5 and V6 were higher than V3.

Interaction effect of water stress and varieties

Effect water stress and varieties on the morphological rice roots characters, leaves RWC and dry matter acumulation can be seen in table 2.

Tabel 3. Interaction effects of water stress and varieties on leaves relative water content, root character and dry matter acumulation

Parameters	Water stress	Varieties						HSD
		V1	V2	V3	V4	V5	V6	0.05
RWC leaves at Vegatative (%)	NS	96.43l	94.41k	90.59j	94.39k	96.49l	94.19k	0.25
	MWS	81.21i	79.32h	73.38f	79.39h	81.32i	77.33g	
	SWS	63.46e	58.40c	42.30a	61.37d	63.50e	52.29b	
RWC leaves at Reproduktive (%)	NS	94.27i	93.37h	91.71g	93.97i	94.38i	93.46h	0.59
	MWS	89.41f	89.29e	84.52d	89.32e	88.97e	89.10e	
	SWS	84.01d	82.54c	77.17a	81.36b	82.51c	76.91a	
Root depth (cm)	NS	36.00c	20.67a	37.33c	45.33d	39.67c	41.67c	6.00
	MWS	29.33b	23.67a	20.67a	32.67c	41.33c	30b	
	SWS	25.33b	19.33a	18.67a	30.67b	25.00b	26.67b	
Root Volume (cm^3)	NS	2.88a	1.31a	3.28ab	8.72c	4.51b	7.50c	2.17
	MWS	2.83a	1.57a	1.01a	5.42c	5.48c	4.06bc	
	SWS	6.48c	1.70a	2.28a	4.04b	2.52a	6.36c	
Root Dry Weight (g)	NS	4.84b	2.17a	5.45ab	14.81c	7.49b	12.45c	3.66
	MWS	4.20ab	2.60a	1.67a	8.99bc	9.11c	6.74bc	
	SWS	10.76c	2.82a	3.78a	6.70bc	4.35ab	10.56c	
Biomass dry weight (g)	NS	52.81b	93.23c	66.84b	96.41c	92.42c	150.6d	25.82
	MWS	56.2b	33.9a	39.11a	44.11b	76.41c	72.96c	
	SWS	42,63b	28,59a	16,60a	33.02a	41.68a	29.25a	
Root to shoot Ratio	NS	0.10a	0.02a	0.09a	0.18b	0.09a	0.09a	0.13

	MWS	0.08a	0.08a	0.05a	0.26b	0.14a	0.10a	
	SWS	0.34c	0.11a	0.29b	0.25c	0.12a	0.56d	
Grains weight Per hill (g hill^{-1})	NS	21.68e	20.36d	11.49c	18.91e	14.95d	12.91c	3.20
	MWS	15.17c	18.49e	5.77a	17.14c	14.76d	11.33c	
	SWS	10.59b	5.44a	4.21a	7.50b	6.28a	7.83b	

Data followed by the common letter within the same row and column indicate no significant difference at P< 0.05 level HSD test. There were decreased in the relative water content in the leaves of the Vegetative phase of all varieties at soil water potential (SWP) of -0.35 bar and at -70 bar. The relative water content the highest was at V1 was not significantly different from V5, whereas V4, V6 were higher than V3 (susceptible to water stress). RWC on the reproductive phase was relatively small decreased in all varieties at SWP of -0.35 bar, but at SWP 0.70 bar the decreased in RWC was greater. The highest RWC was found in V1 which was significantly different from other varieties, while RWC V2 and V5 were not significantly different, but were higher and significantly different from V3 and V6. The root depth at 0 bar deepest was in V4 significantly different from other varieties, while V5 and V6 were not significantly different from V1 and V3. At -0.35bar. The deepest root was at V5 but not significantly different from V4, while V6 was shallower but deeper than V1 although it was not significantly different. At SWP -70bar the deepest root was in V4, but not significantly different from V6, V5 and V1 but significantly different from V2 and V3.

Roots volume decreased which were not too large from 0 bar to -0.35 bar, the largest root volume was found in V4 followed by V5 and V6 which were bigger and significantly different from V1, V2 and V3. At SWP – 0,70 bar the largest root volume in V1 but not significant different from V6 while V4 were lower but higher and significantly different from V5, V3 and lowest in V2.

Root dry weight at SWP 0 bar highest was at V4 and significantly different from V5 and V6, while V1, V2 and V3 were not significantly different, at -35 bar the highest root dry weight was at V5 but not significantly different from V4 and V6 but significantly different from V3, V2 and V1. However, SWP at -0,70 bar the largest root dry weight was in V1 but not significantly different from V6 and V4 but significantly different from V5, V3 and V2.

Biomass dry weight at 0 bar the highest was at V6 which higher and significantly different from V4, V5 and V2. The Lowest was at V1, which was not significantly different from V3. At moderate water stress, the biggest root dry weight was at V5 but not significantly different from V6 but significantly different from V1 and V4. While V2 and V3 were lower and significantly different from the others. The highest root dry weight in severe water stress was at V1 and significantly different from V5, V4 and V3, but higher than V2 and V3, the biomass dry weight V4, V5 and V6 were higher than V2 and V3.

The highest root shoot ratio in normal irrigation was in V4 and significantly different from other varieties. In moderate water stresss there was an increased in the root shoot ratio, the highest was in V4 followed by V5 and V6. But not significantly different from V1 V2 and V3. In severe water stress there were an increased in the root shoot ratio in all varieties with the greatest increased was in V6 followed by V1, V3 and V4.

The weight of filled grains per hill the highest for non-stress was at V1 and not significantly different from the V4 followed by V2 and V5, other varieties lower and were significantly different. In moderate water stress, there were decreased in filled grain weight perhill. The highest filled grains weight in moderate water stress was found in varieties V2 followed by V4, V1 V5 and V6 which were higher than V3 as water stress sensitive varieties. In severe water stress, the highest filled grain weight at V1 was followed by V6, V4 and V5, the lowest were in V3.

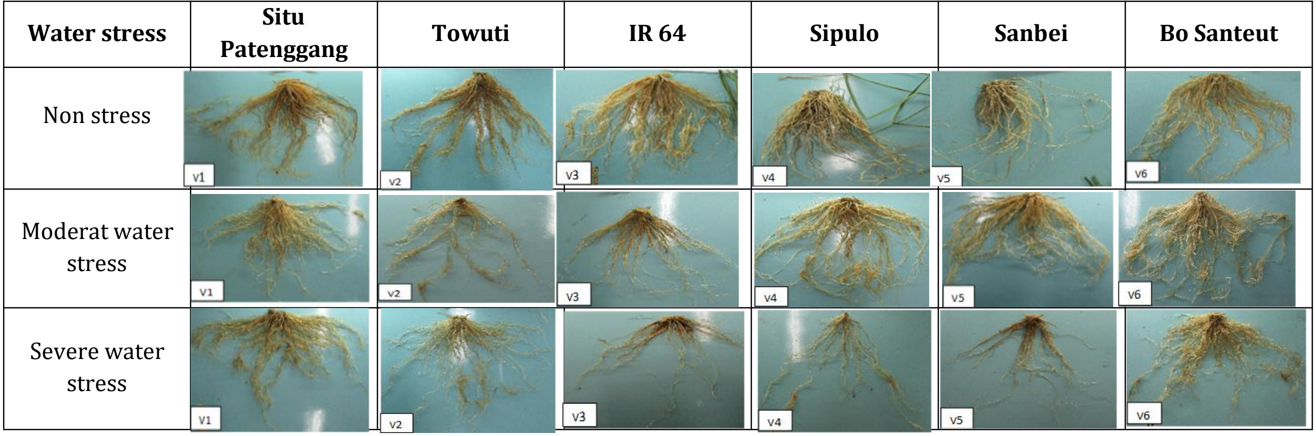

Figure 1. alteration of root under water stress

Pearson corelation

Tabel 4. Pearson corelation among leaves relative water content, Root character and dry matter acumulation

Parameter	X1	X2	X3	X4	X5	X6	X7	X8
RWC leaves at Vegatative (%)	1	.984**	.665**	0.179	0.179	.762**	-.630**	.810**
RWC leaves at Reproduktive (%)		1	.644**	0.174	0.174	.751**	-.656**	.830**
Root depth (cm)			1	.707**	.707**	.677**	-0.105	.486*
Root Volume (cm^3)				1	.999**	.478*	.468*	0.181
Root Dry Weight (g)					1	.477*	0.466	0.179
Biomass dry weight (g)						1	-0.424	.470*
Root to shoot Ratio							1	-0.342

Grains weight Per hill (g hill^{-1})								1

RWC leaves at Vegatative (X1), RWC leaves at Reproduktive (X2), Root depth (X3), Root Volume (X4), Root Dry Weight (X5), Biomass dry weight (X6), Root shoot Ratio (X7), Grains weight Per hill (X8). * significant different at P<0.05, ** very significant different at P<0.01 respectively.

Vegetative phase RWC leaves are closely related to RWC reproductive phase of leaves at (r= 0.98), root length (r = 0.66), biomass dry weight (r= 0.76), root shoot ratio (r= -0.63), weight of filled grain perhill (r = 0.81). The RWC of the reproductive phase leaves was closely related to root length (r= 0.64), biomass dry weight (r = 0.76), root shoot ratio (r= -0.65), weight of filled grains perhill (r= 0.83). Root length was closely related to root volume (r= 0.70), root dry weight (r= 0.70), biomass dry weight (r = 0.67). Root volume was closely related to root dry weight (r = 0.99).

DISCUSSION

Changes in rice roots are influenced by the soil water potential. At low soil water potential, there was more accumulation of dry matter to the roots in tolerant varieties. Changes in root growth under water stress are related to leaf water content. There was a greater decreased in relative water content in the vegetative phase because in the vegetative phase the plant cells still lacked dry matter so that if drought occurred it would greatly affect cell activity. The vegetative phase of rice plants cells does not have a lot of compatible organic solutes so they have not been able to increase the water content in cells. This is in line with the results of the study (Jayaweera et al., 2016) that osmotic adjustments affect relative water content depends on the response of varieties to water stress, the longer the osmotic adjustment water stress is greater RWC increased or can be maintained (Kumar dan Nilanjaya, 2014).

The RWC in the reproductive phase were higher than the vegetative phase because the cell contains more photosynthates and organics compound that can draw water from the surrounding tissue so that the RWC in the leaves increased (Zicvak et al., 2016; Maisurah., 2014; Larkunthod et al., 2018). This can be seen from the RWC vegetative phase leaves were closely related to the reproductive phase RWC leaves (r = 0.98). The relative water content in the vegatative phase leaves was closely related to the reproductive phase (r = 0.98), root length (r = 0.66), biomass dry weight (r = 0.76), root shoot ratio (r = 0.63), weight of filled grain perhill (r = 0.81). This shows that the Vegetative phase RWC determines photosynthate which can be formed in vegetative phase to be used for root extension at vegetative and reproductive phase as well as assimilate embossed on plant tissue will later be used for filling grain in the maturation phase. This is in line with the results of Singh et al. 2017; Affrianningsih et al, 2017).

Shallow root depth was found in IR 64 as a susceptible water stress variety. This is in line with the results of the research of Henry et al. (2012). The deepest root depth in severe water stress was found in V4 which were not significan different from V6, V5 and V1. This shows that V4, V5 and V6 have the capacity to take water in deeper soil layers. This can be seen from V4, V5 and V6 which have more deep roots than V1, V2 and V3. Deep roots were main characteristics of water stress resistant rice (Kim et al., 2015; Pushpam et al., 2018). Root depth is highly dependent on the variety (Xu et al., 2015; Koie et al., 2018). Root characteristics determine growth and production under water stress conditions (Ghosh and Xu, 2014). Therefore, important to increase the ability of roots to adapt lack water environment (Kim et al., 2020; Satoh et al., 2019).

The highest Root dry weight at severe water stress (SWS) was found at V1 followed by V4 and V6. Similarly, the biomass dry weight, the highest at V1 was significantly different from V5 and V4. But the biomass dry weight of V4, V5 and V6 were higher than V2 and V3. This shows the ability of V4, V5 and V6 to increased dry matter accumulations as in V1. This shows the ability of landraces to adapt to severe water stress conditions. This is in line with the results of the study (Gowda et al, 2011; Henry et al., 2012). An increased in the root shoot ratio in V4, V5 and V6 under severe water stress with the greatest increased in V6. This indicates that there was a greater photosynthate partition to the roots in V6, V4, V5 and V1 at SWS. This is in line with the results of the study (Farooq et al., 2010; Wang et al., 2010; Kumar et al., 2020). The ability to formed deep and thick roots were important to avoided drought (Yoshida and Haseegawa, 1982; Pushpam et al., 2018). Roots that grow well can compensate for water loss due to transpiration (Davatgar et al., 2009; Bidadi et al., 2009). The high root shoot ratio at V4, V5 and V6 under SWS were due to thicker, deeper, longer, root length by higher accumulation of dry matter so that root dry weight increased and the root shoot ratio increased at SWS. This is in line with the results of research Nardini et al. (2002); Wason et al. (2012); Kato et al. (2008).

The highest filled grain weight in SWS was at V1 followed by V6, V4 and V5, the lowest at V3. This shows that V4, V5 and V6 were able to maintain osmotic balance in cells so that cell activity can take place under SWS. This shows that the V4, V5 and V6 have the potential to be improved to be water stress tolerant varieties based on leaf RWC, root dry weight, root shoot ratio and filled grains per hill. This is in line with the results of Pushpam et al. (2018); Matsuo et al., (2009). This can be seen in the RWC correlation of the reproductive phase was closely related to root depth (r = 0.64), biomass dry weight (r = 0.76), root shoot ratio (r = 0.65), weight of filled grains per hill (r = 0.83). This shows that the relative water content in the leaves of the reproductive phase determines root length, biomass dry weight, root shoot ratio and weight of filled grain per hill. Because the reproductive phase RWC determines the photosynthates that were accumulated in tissue to be allocated to the roots.RWC at reproductive closely related to biomass dry weight, also for the formation of yield components, especially panicles in the reproductive phase. The higher RWC the higher accumulation of dry matter, the higher root shoot ratio, the deeper root, the heavier filled grains per hill. This is in line with the results of research Davatgar et al., 2009; Sabetfar et al, 2013 and Kumar et al., 2014; Xu et al., 2015).

The biggest root volume in SWS at V1 was not different from V6 and V4. This shows that roots of V1, V6 and V4 have high dry matter accumulation so they were better and able to adapted to SWS. Root volume describes the state of 3-dimensional roots, namely the length, width and thickness which were characteristics of dry-resistant varieties (Pushpam et al., 2018). The highest root dry weight was at V1 but not significantly different from V6 and V4. This shows the ability of dry matter accumulation to the roots of V1, V6 and V4 were not significantly different. This shows that V6 and V4 have the character of bigger photosynthate partition to the root in SWS. This were a trait of dry-resistant varieties (Pandey and Shukla, 2015). The highest biomass dry weight was at V1 but not significantly different from V5, V4 and V3. But the biomass dry weight of V4, V5 and V6 were higher V2 and V3. This shows that V4, V5 and V6 have a greater ability to accumulated dry matter. There was also a specific characteristic of dry-resistant varieties (Kumar et al., 2020; Kim et al., 2020; Henry et al., 2012). The increased of root shoot ratio in SWS was found in V6, this shows that V6 has a greater capacity to increase the root dry weight under SWS. There is the naturely of dry-resistant varieties characteristics (Kim et al., 2020; Xu et al.,2015). The weight of filled grain per hill greatest at SWS was found in V1 followed by V6, V4 and V5. This shows that V6, V4 and V5 were able to form the yield component in SWS. This shows the close correlation of the filled grains weight with RWC (r= 0.83). This shows that RWC in V1, V4, V5 and V6 under SWS reflected osmotic balanced in cells that can maintain activities to perform various functional processes and physiological responses, so can produce high photosynthates for allocated to grain. This is in line with Jayaweera's et al, 2016; Xu et al., 2015; Kumar dan Nilanjaya, 2014).

The difference in root character in this study with research conducted by other researchers is because this study uses water stress repeatedly from the vegetative phase to harvest. The study also used podsolid soil which is the dominant soil for upland rice in Indonesia. Podsolid soil is denser when it is dry so that it requires more energy for roots to develop. Also, this study uses different fertilizers from other studies. Because it is adjusted to conditions in Indonesia which often experience drought. The accumulation of dry matter in varieties can be increased by increasing the leaves water content of the leaves so that cell activity can take place so that they can translocated carbon proportionally for root development. This is important so that the roots develop properly and it can take up water and nutrients under water stress conditions. The results suggest the importance of increasing root depth, root thickness, root distribution with various argronomic technic and genotype selection with deep root character and leaf water content to obtain water stress tolerant in rice. The selected genotype not only has the character of water stress-resistant roots but also considers the proportional shoots. This is what distinguishes this study from other studies. In this study, biomass dry weight was not the main criterion for drought resistance but rather on the character of the roots and the relative water content of the leaves.

CONCLUSION

Water stress affected Root growth and development. The ability to form deep roots were found in Sipulo, Sanbei and Bo Santeut varieties with a root length of more than 30 cm. Having a higher root shoot ratio indicating the ability to accumulate dry matter to the root both for depth and for larger and high dense roots so that the root dry weight was greater and the ability for deeper panetration to get water in deeper soil layers. The ability of plants to maintain relative water content were related to the ability to increase depth, root dry weight, root shoot ratio and filled grains weight. Test variety has the ability to increased root depth, biomass dry weight and root shoot ratio under severe water stress. Tested variety Sipulo, Sanbei and Bo Santeut have better root characteristics than checked varieties based on acumulation of dry metter proportion to roots characters. Root depth, root dry weight, root to shoot ratio and yield can be key criteria for rice tolerance to water stress. The relative water content of the leaves can be a key criterion for resistance to water stress in rice and have big impact on rice yield.

ACKNOWLEDGEMENTS

"This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors." Thank you for chief of physiology laboratory, laboratory of experimental farm and green house and Dean of Agriculture Faculty of Universitas Syiah Kuala for supporting and facilitated this research.

NO CONFLICT OF INTERESTS

The authors declare that there are no conflicts of interest related to this article.

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