The hydraulic redistribution on cashew (*Anacardium occidentale* L.) at nursery stage

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Abstract. Cashew plants can distribute soil water vertically from waterier subsoil to drier topsoil, called as hydraulic lift (HL). There is no report on its ability to distribute soil water laterally or hydraulic redistribution (HR). This study was conducted at ISMCR greenhouse from March-October 2018. Cashew varieties B-02 were planted in pot, then set in three treatments: (1) two parts of the roots in water sufficient (WW), (2) one part of the roots in drought stress and one part in water sufficient (WD), and (3) both parts of the roots put in drought stress conditions (DD). The study was arranged in a complete randomized design, nine replications. The results showed proportion of root biomass in drought stress to total root biomass was relatively same between WD and DD (0.4). The soil moisture value in WD plants were significantly higher than that of DD (1-3%) for 7 days period. Water status in plant tissue presented by the leaf water potential, showed the same tendency. The leaf water potential value of WD plants was between DD and WW. These indicated that cashew plants possessed HR ability, being able to transfer soil water laterally and maintained relatively high soil moisture in the roots.

Keywords: *Anacardium occidentale*, drought stress, soil moisture, bio-conservation

1. Introduction
Cashew is one of the estate commodities that are widely developed in dry climates such as in NTB, NTT, Central Java, East Java, South Sulawesi and Southeast Sulawesi. In addition to providing high economic value from nuts and CNSL, cashew also has the potential for ecological functions. Cashew has been used in reforestation program in 1972 in the Southeast Sulawesi region, due to its extensive and strong root structure [1]. Therefore, the potential of cashew related to its ecological functions in conserving soil moisture in dry region becomes important as the strategy to support dry land development in the future.

Previous research results, both in the field and pot experiment, indicated the hydraulic lifts ability on cashew. Hydraulic lifts is the ability of the plants to restore soil moisture at night to replace water loss in the upper layers of the soil due to the high evapotranspiration during the day [2] [3]. This result complement previous findings that more than 30 forest and desert plant species have been identified possessing hydraulic lift capabilities [5] [6] [7] [8] [9] [10].

The process of replenishing groundwater by passive activity of plant root tissue during the night period consisted of two mechanism, vertical direction with a hydraulic lift mechanism and other direction with hydraulic redistribution mechanism [11] [12] [13]. The ability of hydraulic redistribution
was reported in *Eucalyptus kochii subsp. borealis, Guiera senegalensis, Parkia biglobosa, Piliostigma reticulatum, Vitellaria paradoxa* [14] [15] [16]. Hydraulic redistribution process is entirely based on the activity of the root network. Ryel et al. [17] in their modeling simulation concept suggested that the distribution of root biomass have a great influence on the hydraulic redistribution process in the field.

Therefore, it is interesting to study cashew ability to identify whether cashew plants also have the ability of lateral hydraulic redistribution aside from hydraulic lifts ability. The confirmation of hydraulic redistribution existence in cashew will improve its strategic value as an alternative component of soil moisture bio-conservation to enhance land productivity in dry climate region in the future. The main goal of this study was to examine the ability of cashew to perform lateral hydraulic redistribution in pot experiment.

2. Material and method

The study was conducted in the greenhouse of Indonesian Spice and Medicinal Research Institute, Bogor from March - September 2018. Cashew plants was maintained in the field until 7 months old and then transferred to the greenhouse for hydraulic redistribution evaluation until the end of the study.

2.1. Pot construction

The pots were made from two PVC pipes which were cut longitudinally then put together side by side, allowing the roots to grow and fill both chambers, as shown in Figure 1. The PVC pipes were 7.5 cm in diameter and 40 cm in height.

![Figure 1. The pots construction for evaluating the hydraulic redistribution on cashew](image)

2.2. Planting media

Planting media consisted of soil, sand and compost (1: 1: 1), which was the best media for cashew growth based on previous research [2]. The media composition provided the highest daily soil moisture recovery value in the cashew hydraulic lift process.

2.3. Cashew planting

The seeds used was superior varieties of cashew B-02, which are relatively drought tolerant. Cashew seeds were soaked for 24 hours, and then germinated in moist sand media for 10 days. Root arrangement was required to evaluate hydraulic redistribution. Right after germinated, one third of the root tip of rooted-seedlings were cut off to form root branching and then the seedlings were replanted into the nursery. Seedlings were transplanted into the pot after root branching developed about 5 cm in length. The roots were then divided proportionally to fill both chambers hence cashew roots can be well developed and distributed in the two chambers.
2.4. Plant maintenance
The plants were intensively maintained to avoid pest attacks, nutrient deficiency and water shortages. Irrigation was regularly given until the commencement of hydraulic redistribution evaluation. Nutrient availability was fulfilled by applying 7.0 g NPK/kg media [17]. Wooden frames were installed to hold the pots erect.

2.5. Plant treatments
At 7 months after planting, cashew were set in three treatments: (1) two parts of the roots were always in water sufficient condition (WW), (2) one part of the roots situated in drought stress condition and one part of the root was in water sufficient condition (WD), and (3) both parts of the roots put in drought stress condition (DD). The study was proposed in a complete randomized design with nine replications.

2.6. Observation
The parameters observed were soil moisture, leaf water potential, root biomass, and greenhouse microclimate (temperature and humidity). Soil moisture was monitored every 20 minutes with a soil moisture sensor connected to the datalogger unit, following the previous cashew hydraulic lift measurement method [2]. The soil moisture sensor was mounted 20 cm from the bottom of the pot. Leaf water potential was quantified with a Wescor HR-33T Dew Point Microvoltmeter to assess the response of the water status of the canopy. Leaf water potential parameter was observed frequently on fully grown young leaves during drought stress treatment period.

Greenhouse microclimate (air temperature and relative humidity) were only observed during the evaluation period of hydraulic redistribution. Air temperature and relative humidity parameters measured every 20 minutes with a DHT-11 sensor connected to the datalogger unit.

3. Results

3.1. Soil moisture
Soil moisture was the main parameter for evaluating hydraulic redistribution in this study. Soil moisture gradually decreased in both WD and DD plants after drought stress treatment (Figure 2). On the 3rd day after drought stress treatment, the soil moisture in the dry chamber of WD plants appeared consistently higher than in DD plants. These results indicated that in drought stress conditions, there was a transfer of a certain amount of soil water from the wet chamber to the dry chamber in WD plants. The lateral soil water transfer mechanism was solely caused by the activity of cashew root. Water diffusion by aggregates of soil particles was impossible considering the isolated pot construction. The wet chamber and the dry chamber were completely separated and only connected by cashew root.

3.2. Leaf water potential
After drought stress treatment, water status of plant tissue, represented by the negative leaf water potential ($\Psi_{\text{leaf}}$), increased both in WD plants and DD plants compared to control plants (WW) (Figure 3). The response pattern during drought stress conditions showed consistency, the increase of $\Psi_{\text{leaf}}$ of WD plant was always between WW and DD plants. The highest $\Psi_{\text{leaf}}$ of DD plants was due to the total interruption of water input after drought stress treatment. Meanwhile, WD plants can maintain water status in the plant tissue better than the DD plants, because one of the chambers was still in wet conditions.

3.3. Ratio of root biomass
The ratio of root biomass was measured at the end of the study to discover the correlation between root biomass and hydraulic redistribution mechanism in cashew. The ratio was obtained by measuring the weight of the root biomass in the dry chamber of WD plants and the total weight of the root biomass of WD and DD plants. However, there was no significance difference between the root biomass ratio of
WD and DD plants (Figure 4). This might due to the short period of drought stress (two weeks) during evaluating hydraulic redistribution. It was insufficient to stimulate the difference in the root biomass ratio between those two treatments. These results indicated root biomass did not affect hydraulic redistribution under short period of drought stress. The mechanism might be more influenced by the presence of the roots that have access to the groundwater.

Figure 2. Soil moisture in the dried chamber of WD treatment (blue) and in the pot of WW (green), and DD treatments (red). The values were mean ± se of 9 plants.

Figure 3. The value of leaf water potential ($\Psi_{\text{leaf}}$) of cashew on WW (green), WD (blue) and DD (red) treatments. The values were mean ± se of 9 plants.
Figure 4. The ratio of root biomass of dried chamber of WD plants and the total root biomass of WD and DD plants. The values were mean ± se of 9 plants.

3.4. Microclimate

Daily air temperature in the greenhouse was changed dynamically between 20°C-46°C, while the relative humidity was between 36%-94% (Figure 5). These circumstances were quite effective in stimulating the drought conditions of the potting media required for redistribution hydraulic evaluation in cashew.

Figure 5. The air temperature (A) and relative humidity (B) in a greenhouse during hydraulic redistribution evaluation.
4. Discussion
The results of soil moisture evaluation in this study indicated that there was a lateral soil water transfer by cashew roots from the wet soil to the dry soil as shown by the WD plants (Fig. 2). Therefore, the soil moisture in WD plants tended to be higher than in DD plants during drought stress periods. This confirmed that cashew could perform the hydraulic redistribution laterally, aside of having hydraulic lift capabilities [2] [3]. Several species of woody plants also were reported having the ability of hydraulic redistribution [14] [15] [16].

These characteristics improve the importance and strategic value of cashew in agriculture development in the dry land at arid region. Cashew can be contributed both as income source and ecologically as tool for soil moisture bio-conservation in the dry land. Previous study confirmed cashew ability to perform hydraulic lift by increasing groundwater availability and transferred water to maize in pot experiment [18]. Similar results were also reported in savanna environments which had limited water sources. The trees with hydraulic lift capability could facilitate the water requirement of grass species grown under their canopy to survive the dry season well [19] [20] [21].

Drought stress for a relatively short period of about two weeks in this study caused no differences in the ratio of root biomass in dried chamber to the total roots between WD and DD plants (Figure 4). With the limited root development conditions in the chamber, the indications of hydraulic redistribution of cashew, as shown by WD plants, did not appear to be directly affected by root biomass. However, previous study on Artemisia tridentata indicated that the root biomass distribution significantly affected hydraulic redistribution process in the field [17].

The presence of some roots that still have access to soil water caused WD plants were able to maintain leaf water potential better than DD plants (Figure3). However, the leaf water potential of WD plant was 12.5% lower than control plants (WW). Further studies were necessary to evaluate the effect of leaf water potential decrease on photosynthesis process and plant biomass production.

5. Conclusion
Based on soil moisture dynamic evaluation, cashew plants had capability to perform hydraulic redistribution laterally as well as hydraulic lifts vertically. The relatively short drought stress period in this study resulted in the insignificant difference on the ratio of root biomass in dried chamber to the total root biomass between WD and DD plants. The hydraulic lift and hydraulic redistribution capabilities improve strategic value and potency of cashew as a component of soil moisture bio-conservation technology for agricultural development in dry climates in the future.

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References
[1] Asmin and Witjaksono J 2016 Di Sulawesi Tenggara Prosiding Forum Komunikasi Nasional Jambu Mete II, ed N Maslahah, Ediningsih and Efiana (Bogor : IAARD Press) pp 31–44
[2] Pitono J, Maslahah N, Setiawan and Permadi R A 2016 Recovery lengas tanah harian jambu mete pada variasi media tanam Forum Komunikasi Jambu Mete Nasional II (Bogor: Indonesian Spices and Medicinal Crops Research Institute )
[3] Pitono J, Maslahah N, Setiawan, Permadi R A, Suciantini and Nandar T 2016 Hydraulic lift dan dinamika lengas tanah harian pada pertanaman jambu mete Bul. TRO 27 104–14
[4] Caldwell M M, Dawson T E and Richards J H 1998 Hydraulic lift: Consequences of water efflux from the roots of plants Oecologia 113 151–61
[5] Prieto I, Padilla F M, Armas C and Pugnaire F I 2011 The role of hydraulic lift on seedling establishment under a nurse plant species in a semi-arid environment Perspect. Plant Ecol. Evol. Syst. 13 181–7
[6] Bleby T M, McElrone A J and Jackson R B 2010 Water uptake and hydraulic redistribution across large woody root systems to 20 m depth Plant, Cell Environ. 33 2132–48
[7] David T S, Pinto C A, Nadezhdina N, Kurz-Besson C, Henriques M O, Quilho T, Cermak J, Chaves M M, Pereira J S and David J S 2013 Root functioning, tree water use and hydraulic redistribution in Quercus suber trees: A modeling approach based on root sap flow For. Ecol. Manage. 307 136–46
[8] Evaristo J, Jasechko S and McDonnell J J 2015 Global separation of plant transpiration from groundwater and streamflow Nature 525 91–4
[9] Rocha S, Duarte F, Da Silva L, Waechter and Luiz J 2014 Positive association between Bromelia balansae (Bromeliaceae) and tree seedlings on rocky outcrops of Atlantic forest J. Trop. Ecol. 31 195–8
[10] Nadezhdina N, David T S, David J S, Ferreira M I, Dohnal M, Tesar M, Gartner K, Leitgeb E, Nadezhdin V, Cermak J, Jimenez M S and Morales D 2010 Impacts of disturbance on soil properties in a dry tropical forest in Southern India Ecohydrology 130 126–30
[11] Neumann R B and Gardon Z G 2012 The magnitude of hydraulic redistribution by plant roots: a review and synthesis of empirical and modeling studies New Phytol. 194 337–52
[12] Prieto I, Armas C and Pugnaire F I 2012 Water release through plant roots: New insights into its consequences at the plant and ecosystem level New Phytol. 193 830–41
[13] Bayala J, Heng L K, van Noordwijk M and Ouedraogo S J 2008 Hydraulic redistribution study in two native tree species of agroforestry parklands of West African dry savanna Acta Oecologica 34 370–8
[14] Brooksbank K, Veneklaas E J, White D A and Carter J L 2011 The fate of hydraulically redistributed water in a semi-arid zone eucalyptus species Tree Physiol. 31 649–58
[15] Kizito F, Dragila M I, Senè M, Brooks J R, Meinzer F C, Diedhiou I, Diouf M, Lufafa A, Dick R P, Selker J and Cuenca R 2012 Hydraulic redistribution by two semi-arid shrub species: Implications for Sahelian agro-ecosystems J. Arid Environ. 83 69–77
[16] Ryel R J, Caldwell M M, Yoder C K, Or D and Leffler A J 2002 Hydraulic redistribution in a stand of Artemisia tridentata: Evaluation of benefits to transpiration assessed with a simulation model Oecologia 130 173–84
[17] Trisilawati O, Towaha J and Daras U 2012 Pengaruh mikoriza dan pupuk NPK terhadap pertumbuhan dan produksi jambu metu muda Bul. Littri 3 91–8
[18] Pitono J, Maslahah N and Setiawan S 2017 Peran hydraulic lift jambu metu pada pemeliharaan lengas tanah dan status air jagung saat kekeringan J. Penelit. Tanam. Ind. 23 55
[19] Dohn J, Dembele F, Karemba M, Moustakas A, Amevor K A and Hanan N P 2013 Tree effects on grass growth in savannas: Competition, facilitation and the stress-gradient hypothesis J. Ecol. 101 202–9
[20] Ward D, Weigand K and Getzin S 2013 Walter’s two-layer hypothesis revisited: Back to the roots! Oecologia 172 617–30
[21] Priyadarshini K V R, Prins H H T, de Bie S, Heitkönig I M A, Woodborne S, Gort G, Kirkman K, Ludwig F, Dawson T E and de Kroon H 2016 Seasonality of hydraulic redistribution by trees to grasses and changes in their water-source use that change tree-grass interactions Ecohydrology 9 218–28