The Effectiveness of AM Fungal in Improving the Tolerance of Sweet Potato Plants to Drought Stress

Conference Paper · May 2012

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PREFACE

Dear Distinguished Delegates and Guests,

The Organizing Committee warmly welcomes our distinguished delegates and guests at Planetary Scientific Research Centre's International Conferences scheduled on *May 26-27, 2012 Phuket (Thailand)*. Currently, PSRC is organizing six conferences under two multi-conferences named as *International Conference on Arts, Applied Sciences, Medical & Environment Sciences (ICAAMES'2012)* and *International Conference on Electrical, Electronics, Mechanical & Systems Engineering (ICEEMSE'2012)*.

These conferences are managed and sponsored by Planetary Scientific Research Centre and assisted by ISEM Society, SRM University and King Mongkut's University of Technology. PSRC is striving hard to compile the research efforts of scientists, researchers and academicians across the broad spectrum of Science, Engineering, Social Sciences, Management, Environmental, Pharmaceutical and Medical Sciences. These conferences are aimed at discussing the wide range of problems encountered in present and future high technologies among the research fraternity.

The conferences are organized to bring together the members of our international community at a common platform, so that, the researchers from around the world can present their leading-edge work. This will help in expansion of our community's knowledge and provide an insight into the significant challenges currently being addressed in that research. The conference Program Committee is itself quite diverse and truly international, with membership from the America, Australia, Europe, Asia and Africa.

The main conference themes and tracks are Engineering, Science, Environment and Management. The conference has solicited and gathered technical research submissions related to all aspects of major conference themes and tracks. This proceeding records the fully refereed papers presented at the conference.

All the submitted papers in the proceeding have been peer reviewed by the reviewers drawn from the scientific committee, external reviewers and editorial board depending on the subject matter of the paper. Reviewing and initial selection were undertaken electronically. After the rigorous peer-review process, the submitted papers were selected on the basis of originality, significance, and clarity for the purpose of the conference. The main goal of these events is to provide international scientific forums for exchange of new ideas in a number of fields that interact in-depth through discussions with their peers from around the world.

The program has been structured to favor interactions among attendees coming from many diverse horizons, scientifically, geographically, from academia and from industry. We would like to thank the program chairs, organization staff, and the members of the program committee for their work. We like to thank and show gratitude to Editors from PSRC. We are grateful to all those who have contributed to the success of *PSRC May'2012 Phuket Conferences*. We hope that all participants and other interested readers benefit scientifically from the proceedings and also find it stimulating in the Process in their quest of achieving greater heights. Finally, we would like to wish you success in your technical presentations and social networking.

We hope you have a unique, rewarding and enjoyable week at PSRC Conferences at *beautiful Phuket!!!*

With our warmest regards,

Organizing Committee

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The Effectiveness of AM Fungal in Improving the Tolerance of Sweet Potato Plants to Drought Stress

Prabawardani Saraswati, Wasgito D. Purnomo, and Nouke L. Mawikere

***Abstract*—** Identification of drought tolerance of 10 local sweet potato clones which are commonly grown in Papua had been carried out in the previous trial, but no drought-tolerant clones was obtained. This study was aimed to determine the effectiveness of the Arbuskula Mycorrhizal Fungi (AMF) in increasing the tolerance of sweet potato plants to drought stress. The study was designed using Complete Randomized Design (CRD) with two factors. The first factor was composed of AMF inoculation, namely without inoculation (M0), indigenous AMF inoculation (M1) and the introduced AMF inoculation (M2). The second factor was the soil water content which consisted of 20% (K2) and 80% (K8) of water from field capacity. Each treatment was repeated 4 times. The results showed that drought stress depressed leaf relative water content, fresh and dry root weight, root length, transpiration and water use efficiency in sweet potato plants. AMF inoculation enhanced the adaptation of sweet potato plants to drought stress as indicated by higher values of leaf relative water content, root dry weight, root length, transpiration and water use efficiency as compared to non AMF plants. There was an interaction between AMF inoculation and drought stress on leaf area, weight of fresh and dry biomass of sweet potato plants. This suggests that the AMF is effective in enhancing the growth of sweet potato plants in water stress conditions. Indigenous AMF was more effective and efficient in improving the adaptation of sweet potato plants to drought.

***Keywords*—** Arbuskula Mycorrhizal Fungi, drought stress, sweet potato (*Ipomoea batatas*), water use efficiency.

I. Introduction

SWEET potato is an important food source in Indonesia which is cultivated from the lowlands to the highlands. It is one of the important root crops in Papua, Eastern Indonesia. It is the main staple food, where it accounts for nearly 90 % of the people's diet [14, 17], whereas 60% of the lowland Papuan consume sweet potato as an alternative staple food. Therefore, production of sweet potatoes is of great importance of people in this region; however drought is the major problems for sweet potato production in this area [2, 17]. Due to the effect of *El Niño*, prolonged and severe drought occurred in 1997. As a consequence, many crops including sweet potato died [2, 13] and many people of Papua suffered from starvation to the point of widespread deaths throughout the region.

Sweet potato is considered as a drought tolerant crop [3, 7] but it is also sensitive to water deficit stress [6]. Water, therefore plays an important role in sweet potato growth and yield. Sweet potato requires a constant water supply throughout the growing season to produce high yields [12]. Water deficits reduce leaf water potential and total water use, and subsequently reduce stomatal conductance, leaf area, root mass, tuber development, and total plant mass [18]. Improvement of plant productivity under water stress needs an understanding of physiological mechanisms by which water stress affects plant growth. Identification of drought tolerance of 10 local Papuan clones had been done, but none of drought-tolerant clones were obtained [15]. Mycorizzal Fungi (AMF) application is an alternative way of increasing plant resistance to drought stress.

The presence of mycorrhiza in root increased drought tolerance and nutrient uptake [11[. Mycorrhiza forms a symbiotic relationship between mutualistic fungal and plant roots. Mycorrhiza has the ability to associate with almost 90% of plants and improved the efficiency of nutrient absorption (especially phosphorus) on marginal land. The use of AMF improved the adaptation to drought stress in crop plants such as soybean [8], pakchoy [11], onion [19], AMF is also known as biological fertilizers which increased soil productivity and crop. AMF increased soybean production in dry land [9].
To date, there have been few studies of the AMF's role in water relations of sweet potato. The experiment was carried out to find out the effectiveness of AM fungal in improving the tolerance of sweet potato plants to drought stress.

II. Materials And Methods

Research was conducted at the Greenhouse and Laboratory of Agriculture Faculty, the State University of Papua, from June to December 2010. The experiment was laid out in a Completely Randomized Design (CRD) with two factors. The first factor is composed of: (1) no inoculation, (2) inoculation with indigenous AMF and (3) inoculation with AMF introduction, while the second factor was the soil water content with two levels: (1) 20% which represented severe water stress and (2) 80% of soil field capacity, represented well watered supply with the assumption that below 20% of

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soil field capacity the growth and yield of sweet potato plants decreased and above 80% the sweet potato plants grew poorly as a consequence of poor soil aeration [14]. Each treatment was replicated 4 times.

Experimental Procedures

The inoculant used for introduced AMF was the AMF mycoffer inoculant of mixed spore of *Manihotis glomus*, *Gigaspora margarita*, *Acaulospora* and *Glomus etunicatum*, while the indigenous AMF was collected from the root growth zone of sweet potato. Sorghum was used as host plant.

Sweet potato shoot cuttings were ± 25 cm length. Until the age of 4 week after planting all the pot water level is maintained at 80% KL. After that, the water content of soil in the pot was adjusted to the water content of each treatment to harvest. Watering was done every day in the morning according to the treatment soil water content from field capacity. Harvesting was done when the plant reaches the age of 4 months.

Observations were taken as the following:

- Degree of AMF infection (%).This was done at 8 week after planting. The infected roots were characterized by the presence of at least one of the internal structure of the AMF, the internal hyphae, arbuskula, vesicles and spores. Quantification of the degree of AMF infection was carried out using gridline method [4] and was calculated by the formula: The degree of AMF infection (%) = ($\Sigma yn/\Sigma Xn$) x 100%, where Yn is the infected root in the n lattice; Xn is the bserved root in the n lattice and n is the lattice number.
- Relative water content (RWC) of leaves (%). Determination of leaf RWC according to [24]. Leaf samples of 10 leaf / pot were perforated with a size of 1 cm2, and then fresh weight of leaf was determined. Once weighed, the leaves were soaked in distilled water for 5 hours to get turgid leaf weight, and then were dried to get leaf dry weight in an oven for 24 hours at a temperature of 70°C. Calculation of leaf relative water content was as follow (Leaf fresh weight – Oven-dried weight / (Turgid weight – Oven-dried weight) X 100%.
- Leaf area (cm^2/plant). Leaf area was measured with a digital leaf area meter CI-202. Measurements were conducted at 12 weeks after planting.
-Top biomass fresh and dry weight (g). Top biomass fresh weight was obtained by weighing the fresh crop plants at 16 weeks after planting. Dried biomass weight was obtained by oven-dry the top biomass at 70 ° C for 2-4 days.
-Root length (cm). Root length was measured at the end of the observation.
-Root fresh and dry weight (g). Roots were weighed to get root fresh weight, and then oven-dry to obtain dry weight.
-Transpiration (ml / plant). Transpiration was measured by the amount of water lost from the plant periodically by weighing the pots and plants once every 2 days.
-Water use efficiency (WUE). WUE indicates the amount of water needed to form a gram of dry matter, calculated by: Weight of dry material (g) / Water needed during the growth (l).

The data were analyzed using an analysis of variance. When the effects of various treatments were significant, the Honestly Significant Difference (HST) was carried out at 95% confidence level.

III. RESULTS

The percentage of root infection was higher in AMF inoculated treatment both in well water and drought stress conditions. There was low root infection without AMF inoculation.

TABLE I
EFFECT OF AMF INOCULATION AND SOIL FIELD CAPACITY ON THE DEGREE OF INFECTED ROOT, FRESH AND DRY BIOMASS, AND LEAF AREA OF SWEET POTATO

Treatment	Infected root (%)	Leaf Area (cm^2/plant)	Fresh biomass weight (g/tan)	Dry biomass weight (g/tan)
M_0K_2	30	1115.17 b	5.25 b	4.59 b
M_1K_2	100	1531.84 b	36.33 b	10.12 b
M_2K_2	100	1508.31 b	18.95 b	9.25 b
M_0K_8	40	4634.51 b	71.30 b	27.68 b
M_1K_8	100	9593.52 a	200.88 a	56.27 a
M_2K_8	90	10944.09 a	254.10 a	61.95 a

M_0 = without AMF; M_1 =Indigenous AMF; F_2 = Introduced AMF; F_2 = 20% of soil FC; F_8 = 80% of soil FC.
$_0$ = without AMF; M_1 =Indigenous AMF; F_2 = Introduced

The highest leaf area was produced by M2K8, but was not significantly different from M1K8. The highest leaf area was produced by the inoculation of introduced AMF followed by indigenous AMF in well-water whereas the highest leaf area was produced by indigenous AMF inoculation on drought stress conditions.

The highest fresh biomass weight was produced by M2K8, while the lowest was produced by M0K2. Dry biomass weight on the interaction of both introduce and indigenous AMF inoculation and soil water content (M1K8, M2K8) was higher, and was significantly different from non-AMF inoculation (M0K8).

The highest leaf RWC was produced by introduced and indigenous AMF inoculation. Well-water condition produced higher leaf relative water content than water stress treatment. Soil water content and AMF inoculation significantly affected transpiration. The highest transpiration was produced by AMF inoculation. Transpiration on well-water was higher than the stress water conditions.

AMF inoculation and soil water levels were significantly affected water use efficiency. The highest water use efficiency was resulted from the introduced followed by indigenous AMF inoculation. While, well-watered condition produced higher water use efficiency than drought treatment.

AMF inoculation and soil field capacity significantly affected root length. The highest root length was produced by the introduced and followed by indigenous AMF inoculation; well-watered condition produced the highest root length.

TABLE 2
EFFECT OF AMF INOCULATION AND SOIL FIELD CAPACITY ON LEAF RELATIVE WATER CONTENT, TRANSPIRATION AND WATER USE EFFICIENCY OF SWEET POTATO

Treatment	RWC (%)	Transpiration (ml/plant)	WUE (g/ml)
1. FMA Inoculation			
-Non-FMA inoculation	65.09 b	6630.63 b	0.0022 b
-Indigenous FMA inoculation	74.22 a	9501.25 a	0.0034 a
-Introduced FMA inoculation	74.23 a	9743.75 a	0.0035 a
2. Soil Water			
-20% of soil FC)	68.13 b	3423.33 b	0.0026 b
-80% of soil FC)	74.23 a	13827.08 a	0.0035 a

Note: Figures in a column followed by the same letter are not significantly different in the test HST at 95% confidence level; RWC = Leaf Relative Water Content; FC= Soil Field Capacity; WUE= Water Use Efficiency

TABLE 3
EFFECT OF AMF INOCULATION AND SOIL WATER LEVELS ON ROOT LENGTH, FRESH AND DRY ROOT WEIGHT OF SWEET POTATO

Treatment	Root length (cm)	Root fresh weight (g)	Root dry weight (g)
1. AMF Inoculation			
-Non-AMF inoculation	58.81 b	1.66	0.75 b
-Indigenous AMF Inoculation	93.81 a	22.73	1.96 a
-Introduced AMF Inoculation	97.42 a	21.33	2.51 a
2. Soil water			
-20% of soil FC	71.94 b	4.68 b	1.11 b
-80% of soil FC	94.75 a	25.80 a	2.38 a

Note: Figures in a column followed by the same letter are not significantly different in the test HST at 95% confidence level.

Inoculation of AMF did not affect fresh root weight, but it affected root dry weight. Whereas soil water levels affected fresh and dry roots weight. The highest fresh and dry root weight was produced by the indigenous and introduced AMF noculation. Well-watered condition produced greater root fresh and dry weight.

DISCUSSION

Plants supplied with well-watered conditions (80% of FC) showed higher Mycorrhizal infection in the root of sweet potato compared to the drought stress condition (20% of FC). AMF was in its active external hyphae form. The presence of external hyphae on the roots of infected AMF plants may help in absorbing water in the soil micro pores which normally cannot be reached by roots of other plants (Yusnaini *et al.*, 999). AMF thus play an important role in increasing plant water relation in drought stress conditions, and therefore ncreasing the drought resistance of host plants (Nelsen, 1987 in Lozano *et al.*, 1995). According to Kabirun (1990) VAM fungi help plants grow better during water shortages as it is also increase the nutrient availability.

Drought decreased the growth of sweet potato plants. Almost all plant growth variables declined due to drought stress. The decline occurred in leaf relative water content, root length, fresh and dry root weight, transpiration and water use efficiency. This indicates that water is vitally required for plant growth, as it serves as a solvent and the medium of chemical reaction, organic and inorganic solutes transport, cell turgor, transpiration, photosynthesis and hydrolysis of raw materials.

Relative water content declined in drought stress treatment. Relative water content of inoculated AMF was higher than non-AMF inoculated plants. According to [21] drought stress change water potential, osmotic potential, turgor potential of the cell, which affect changes in stomata. This change affects the nutrients absorption and translocation, transpiration, photosynthesis and translocation of photosintate. The decreases of water uptake due to drought stress cause the decrease in leaf water potential and will followed by leaf deterioration [20].

There were an interactions between AMF inoculation and soil water content on leaf area, fresh and dry weight of top biomass per plant. Leaf area, fresh and dry weight of biomass per plant was higher in plants inoculated with AMF on well-water conditions compared with plants without AMF inoculation and stress water plants. Under conditions of water stress, plants inoculated with AMF had broad leaves. Fresh and dry biomass weight per plant was not significantly different in well-water plants of no-AMF inoculation. This suggests that the AMF play a significant role in increasing water stress resistance. Under water stress conditions, AMF inoculated plants showed an increase in leaf water potential, maintain turgor, stomatal opening and transpiration [1]. AMF also increased the uptake of plant nutrients, especially P. According [17] the increased of P uptake will be followed by the absorption of other elements. This is because P will form ATP (Adenosine Triphosphate) which is very useful for the absorption of mineral nutrients. Increasing P uptake has an impact on higher root hydraulic conductivity, and hence a greater roots ability to absorb more water [22].

High leaf area of infected AMF plants increase the ability of plants in maximizing photosynthesis, this is because leaf is a source in the formation of organic compounds for plant growth and development. Thus, leaf area is one factor that determines the radiation interception, photosynthesis, biomass accumulation, transpiration and the energy transfer by plant canopy [22]. Sunlight is the main source of energy in the process of photosynthesis. The product of photosynthesis which exhibited by the greater dry biomass weight in mycorrhizal infected plants than with uninfected mycorrhizal plants.

Water stress in sweet potatoes decreased plant biomass, leaf area and leaf weight and also tuber yield [16]. The decline in biomass due to water stress affected carbon assimilation, resulting in lower assimilate production for the development of vegetative plants. Drought stress also reduced dry weight of 15 cultivars of sweet potato between 31% - 46% compared to the well-soil water conditions. According to [11], increased water and nutrient uptake increased biomass production, especially top biomass (stems and leaves) with the provision of mycorrhizal fungi. In contrast, the limited water availability decreased both top biomass and root dry weight linearly with the increasing level of given drought stress.

Mycorrhizal Arbuskula Fungal (AMF) improve plant roots conditions, as shown by the increasing of root length and root fresh and dry weight under indigenous and introduced AMF inoculation. AMF inoculation can overcome the problems drought stress in sweet potato. This is because the indigenous and introduced AMF involved in the adaptation to drought stress mechanism by colonized roots of sweet potato. In non-inoculated AMF plants, AMF colonization occurred, but tends to be lower. This colonization explained that sweet potato plants associated with AMF.

The highest transpiration during the growth occurs on sweet potato plants which were subjected to well-water conditions compared to water stress conditions. The highest transpiration occurred in inoculated AMF plants, while the lowest one showed in non-AMF inoculation plants. The high transpiration of AMF inoculation plants was a result of the greater leaf relative water content, biomass fresh and dry weight.

AMF improved sweet potato growth through its effect on increasing water use efficiency. The highest water use efficiency of sweet potato crops was on the plant with well-water conditions. Sweet potato plants with AMF inoculation produced higher water use efficiency while plants with the lowest efficiency produced by non-AMF inoculated plants. The low efficiency of water use under water stress conditions was a result of high drought stress treatment given to the plant, causing stunted growth. Thus water is needed to achieve the maximum growth and yield. Therefore, many efforts have been used to provide an optimal growth and yield under water stress growth condition. Plant inoculated with AMF is one of efforts in increasing the extent of sweet potato roots in absorbing water economically and providing better growth and yield.

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