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Assessing the salt tolerance of Xyliaxylocarpa

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ပျဉ်းကတိုးသစ်မျိုး၏ဆားငန်ဓါတ်ခံရည်ရှိမှုကိုလေ့လာဆန်းစစ်အကဲဖြတ်ခြင်း

ဒေါက်တာအစ်အစ်ရွှေဇင်
ကထိက၊ သစ်တောနှင့်ပတ်ဝန်းကျင်ဆိုင်ရာတက္ကသိုလ်၊ ရေဆင်း

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သစ်မျိုးများ၏ ပထမနှစ်ကြီးအတွင်း ပျိုးပင်ငယ်အဆင့် ကြီးထွားမှုအပေါ် မြေဆီလွှာ ဆားငန် ဓါတ်ပေါက်ခြင်း၏ သက်ရောက်မှုကိုပျိုးပင်အတွင်း ဆားငန်ဓါတ်ပျံနှံစိမ့်ဝင် နိုင်သော စွမ်းရည် (Plant Osmotic Potetial) နှင့်အရွက်အတွင်းရေပါဝင်မှု (Leaf Water Content) နှင့် ၎င်း၏အခြောက်အလေးချိန် (Dry Weight) တို့အကြား ဆက်သွယ်မှုကို တိုင်းတာခြင်းဖြင့် သိရှိနိုင်ပါသည်။ ယခုပြုလုပ်ခဲ့သောသုတေသန စာတမ်းကို Göttingen University ရှိဖန်လုံအိမ် (Green House) တွင် သုတေသန စမ်းသပ်မှုပြုလုပ်ခဲ့ခြင်း ဖြစ်ပါသည်။ ပျဉ်းကတိုးသစ်မျိုး၏ ပျိုးပင်ငယ်ဘဝတွင် ဆားငန် ဓါတ်ခံနိုင်ရည်ရှိမှုအား တိုင်းတာနိုင်ရန် မြေသားကြားခံ အမျိုးအစား နှစ်ခုဖြစ်သော (Commercial Potting Soil and Hydroponic Gravel Culture) တို့တွင် ဆိုဒီယမ် ကလိုရိုက် ဆားပျော်ရည်လောင်းခြင်းနည်းဖြင့် စိုက်ပျိုး ဆောင်ရွက်ခဲ့ပါသည်။ ပျဉ်းကတိုးသစ်မျိုးသည် မြေဆီလွှာဆားငန်ဓါတ်ကို Commercial Potting Soil တွင် Hydroponic Gravel Culture ထက်ပိုမိုခံနိုင်ရည်ရှိသည်ကို တွေ့ရှိခဲ့ရပါသည်။ သုတေသနစမ်းသပ်မှုရလဒ်များအရ မြေသားကြားခံ နှစ်ခုစလုံးတွင် နေ့လယ်ပိုင်း အချိန်ရှိ ပျိုးပင်အတွင်းဆားငန်ဓါတ်ပျံနှံစိမ့်ဝင်နိုင်သော စွမ်းရည်သည် ရေပြည့်ဝချိန် ၌ရှိသော ပျိုးပင်အတွင်း ဆားငန်ဓါတ်ပျံနှံစိမ့်ဝင်နိုင်သော စွမ်းရည်ထက် နည်းပါးသည်ကို တွေ့ရှိခဲ့ရပါသည်။ ထို့ကြောင့်နေ့လယ်ပိုင်း အချိန်တွင် ရှိသော ပျိုးပင်အတွင်း ဆားငန်ဓါတ် ပျံနှံစိမ့်ဝင်နိုင်သော စွမ်းရည်ကိုပျဉ်းကတိုး သစ်မျိုး၏ မြေဆီလွှာ ဆားငန်ဓါတ် အမြင့်ဆုံးခံနိုင်ရည်ဟု သတ်မှတ် နိုင်ပါသည်။ ပျဉ်းကတိုးသစ်မျိုး၏ အနိမ့်ဆုံး မြေဆီလွှာ အတွင်းဆားငန်ဓါတ်ပျံနှံစိမ့်ဝင် နိုင်သော စွမ်းရည် (Soil Osmotic Potential) အပေါ် ခံနိုင်ရည်ရှိမှုသည် -1.5MPa or 300mM NaCl (~ 30dSm^{-1}) ဖြစ်ပြီး၊ နေ့လယ် ပိုင်း အချိန်ရှိဆားငန်ဓါတ်ပျံနှံစိမ့်ဝင်နိုင်သောစွမ်းရည်သည် -3.7MPa or ~ 740mM NaCl ဖြစ်သည်ဟု သတ်မှတ်နိုင်ပါသည်။ Hydroponic Gravel Culture မြေသားကြားခံတွင် နေ့လယ်ပိုင်း အချိန် ဆားငန်ဓါတ် ပျံနှံစိမ့်ဝင်နိုင်သောစွမ်းရည် (Plant Osmotic Potetial) နှင့်အရွက်အတွင်း ရေပါဝင်မှု (%Dry Weight) တို့မှာ ($p<0.05$) တွင်ထင်ရှားစွာ ကွဲပြားသည် ကိုတွေ့ရှိရပြီး Commercial Potting Soil တွင်ကွဲပြားမှု မရှိသည်ကို တွေ့ရှိရပါသည်။ ရရှိလာသောသုတေသန ရလဒ်များအရ မြေသားကြားခံနှစ်ခုစလုံး တွင် ပျဉ်းကတိုး ပျိုးပင်ငယ်၏ Soil Solute potential မှာ -1.5MPa နှင့် -1.2MPa တို့ ဖြစ်ကြပါသည်။ထို့ကြောင့်သစ်မျိုးများ၏ Root Zone တွင်မြေဆီလွှာ ဆားငန် ဓါတ်ခံနိုင်ရည်ရှိမှု အခြေအနေကိုပျိုးပင်ငယ်အဆင့်တွင် အချိန်တိုအတွင်း လေ့လာနိုင်သည်ကို တွေ့ရှိရပါသည်။

Assessing the salt tolerance of *Xylia xylocarpa*

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Abstract

The effects of soil salinity on young seedlings during the first year of growth can be quantified by measuring plants' internal osmotic potentials and their leaf water contents in relation to their dry weight. This study was performed in the greenhouse at the Georg- August University of Göttingen in order to evaluate the response and salt tolerance of young *Xyliaxylocarpa* seedlings by applying an NaCl salt solution to the plants on two different media (commercial potting soil and a hydroponic gravel culture).*Xyliaxylocarpa* seedlings in the former media showed better tolerance to soil salinity than those in the latter under the same environmental conditions. In this experiment, the midday osmotic potentials were lower than the plant saturated osmotic potentials among all sample trees in the commercial potting soil and hydroponic gravel culture. The midday osmotic potentials of all seedlings were therefore applied to define the species' maximum ability to cope with soil osmotic stress. This study proved that *Xyliaxylocarpa*'s threshold values had the lowest soil osmotic potential, with -1.5 MPa or 300 mMNaCl (≈30 dSm-1), and the minimum osmotic potential at midday (-3.7 MPa or ≈ 740 mMNaCl). There was a significant difference between the midday plant osmotic potentials and the leaf water content (% DW) at $p< 0.05$ for the hydroponic culture, but no such differences for the commercial potting soil. This study found that the soil solute potentials of *Xyliaxylocarpa* seedlings for the commercial potting soil and hydroponic gravel culture were -1.5 MPa and -1.2 MPa respectively. Young plants can therefore be used to assess salt tolerance in a tree's rootzone or rhizosphere over a short period.

Keywords: salinity, NaCl, commercial potting soil, hydroponic gravel culture, osmotic potential

Assessing the salt tolerance of *Xylia xylocarpa*

1. Introduction

Environmental stressors such as salinity and drought affect tree growth and productivity in natural forests; unfortunately, they are also increasing due to global climate changes (Munns 2008). Salinity is usually caused by either groundwater salinity or irrigation salinity, although it may also be the result of soil leaching, where saline water enters groundwater basins and causes damage if the water table rises or the groundwater is used for irrigation (Letey 2000).

High salinity affects plants' growth, development, and survival in numerous ways, including water stress, ion toxicity, nutritional disorders, oxidative stress, alteration of metabolic processes, membrane disorganization, reduction of cell division and expansion, and genotoxicity (Hasegawa et al., 2000; Munns, 2002; Zhu, 2007). Initially, soil salinity reduces plant growth via osmotic stress, followed by ion toxicity (Rahnama et al., 2010; James et al., 2011). Over long-term exposure to salinity, plants experience ionic stress, which can lead to the premature senescence of adult leaves (Cramer & Nowak, 1992). Under such environmental stresses, plants adapt to spatially and periodically altered soil solute concentrations which must be osmotically absorbed (NaCl and other salts from the soil) or processed (non-ionic osmotica such as sucrose and other organic compounds) within the cells (Mitlöhner and Köpp, 2007). Improper management of site salinity may lead further to soil sodicity, a damaged soil structure, and water stress, which in turn reduces leaf expansion.

These experiments focus on observations and measurements of 1) the immediate effects of soil salt concentration, 2) the effects of a gradually increasing soil salt concentration, and 3) plant-soil osmotic potential via cryoscopy. The slowly increasing salt concentration via the application of 20 ml (25% or 0.25 M) of NaCl solute allows for osmotic adjustment during the initial phase of the experiments. After continuous salt application, the osmotic effects of salinity stress can be immediately observed, among them cell expansion and cell division, as well as stomatal closure during the exposure time (Munns, 2002; Flowers, 2004).

Plant species differ widely in salinity tolerance (Munns, 2002) but their tissues need definite mechanisms for intercellular ionic concentration (Bartels and Sunkar, 2005). Plant adaptations to salinity are of three distinct types: osmotic stress tolerance, Na (+) or Cl (-) exclusion, and the tolerance of tissues to accumulated Na (+) or Cl (Roy et al, 2014). In these experiments, *Xyliaxylocarpa* obviously lacked both distinct features of special Na or Cl exclusion and the special tolerance of its tissues to plant adaptation strategies (unlike for example the dominant tree species *Ruprechtiatriflora* in its natural habitat in the dry forests of Paraguay) (Mitlöhner and Köpp, 2007). Here, the osmotic potential values primarily indicate the plant's osmotic adaptation to salt-affected sites; they are also indicating plant's adaptation to water deficiency during the dry season.

*Xyliaxylocarpa*is occasionally found in TNR as dominant and evergreen species, but in Myanmar it frequently appears deciduous (Kermode, 1964). It grows in pure patches in the intermediate forest between the eastern tropical evergreen and the moist deciduous forests of Myanmar (Kermode, 1964). *Xyliaxylocarpa*processes bipinnate leaves with one pair of pinnae; each pinna has two to six pairs of leaflets. The bark is fairly smooth, thin and yellowish or reddish-grey; it exfoliates in irregular, rounded plates (Troup 1921). This species is widely utilized as a construction material in buildings, railway sleepers, ships, agricultural implements, tool handles, etc., due to its strength, durability, and relative abundance (Shin 2006). Under favorable conditions, the tree reaches a height of 36 m and a DBH of 117cm or more, but it is stunted on poor ground (Troup, 1921).

Xyliaxylocarpa species grow well below an altitude of 150 m and cover well-drained, sandy soils. In the Tenasserim lowland areas (Tanintharyi Division), the degraded parts have a higher clay percentage. Xylia is widely distributed in the TNR lowlands areas but its growth quality is poor obviously as result of limited hydraulic water transfer from the soil (rhizosphere); the fine micropores of clay soil are so tight that extracting water to the leaves becomes difficult (DeGomez, 2015). Moreover, forest degradation affects soil organic carbon (SOC) (Corsi et al., 2012 and Banwart et al., 2015) and may change the water-holding capacity. It is therefore essential to assess the soil salinity of *Xyliaxylocarpa* sites and its osmotic adaptation.

2. Objectives

To evaluate the salinity adaptation of *Xyliaxylocarpa*(from the moist deciduous forests) by applying NaCl salt solution and determine the effect of land degradation on that adaptation.

3. Material and methods

3.1 Selection of plant material in the natural habitat

In the study, *Xyliaxylocarpa*. Roxb. Taub (Mimosaceae) was selected for the assessment of its upmost adaptability to salinity in the greenhouse. In Myanmar, this important timber species is mostly occurring in association with *Tectonagrandis.*Linn.f (Teak). Large areas of *Xyliaxylocarpa* have been established since 1980 (Shin 2006); however, natural forest resources have rapidly declined in recent years due to over-exploitation, illegal logging, and shifting cultivation. *Xyliaxylocarpa* plantations have as a result become a major option for both domestic use and export, but only a limited number of studies have examined its site limitations. *Xyliaxylocarpa* seedlings can grow well under high temperatures in natural stands (Phukittayacamee et al., 1993) and tolerate potentially damaging heat stress (Saelim, 1977); it therefore appears suitable for the reforestation of dry sites. However, only limited information is available with which to see its osmotic sites adaptability.

3.2 Plants preparation for the greenhouse experiment

For the experiment, *Xyliaxylocarpa* seeds were collected from the TNR moist deciduous forests during a period of data collection in February 2014. In March of 2015, *Xyliaxylocarpa* were sown in potting soil in a greenhouse at the Georg-August University of Göttingen, Germany. In July 2015, the seedlings were divided into two groups, three months after germination, 9 seedlings (≈ 10 cm in height) with one pair of leaves were transplanted into pots filled with a commercial potting soil, while 9 seedlings were planted in a potometer device filled with a hydroponic gravel culture; in the latter, an automatic water refilling device constructed on the basis of the hydroponic system ensured a continuous supply of water to minimize the effects of water stress to the plant.

Khaing (2013) described native *Xyliaxylocarpa* species as responding to soil osmotic stress differently than to water stress; she found the highest adaptation to soil salinity to be 20.4 dSm^{-1} ≈ 204 mM NaCl with a salt concentration for *Xylia* leaves at 24.5 dSm-1 ≈ 245 mM NaCl (Minimum osmotic potential -2.0 MPa; [as reference i.e. seawater is ≈ - 2.3 MPa]), in the dry land area of Central Myanmar, under field conditions. Khaing reported

Xyliaxylocarpa to be moderately tolerant to soil salinities. In TNR, native *Xyliaxylocarpa* in the degraded moist deciduous forests responded to soil osmotic stress with (24 dSm-1 ≈ 240 mMNaCl) a minimum osmotic potential ≈-1.6 MPa under field conditions (Section 6.3).

3.3 Plant treatment and soil media preparation

Salt-affected soil can hamper the growth and development of plants because of the high concentrations of soluble salts (DeSutter, 2008) which may include different rates of ion compositions such as Na, Ca, Mg, K, Cl, SO_4, and CO_3 (Orcutt and Nilsen, 2000; DeSutter, 2008). However, sodium salts are the most soluble in nature (Munns and Tester, 2008; Munns, 2009). In this study, the salt tolerance and stress of *Xyliaxylocarpa* was assessed by using exclusively sodium chloride (NaCl) in the commercial potting soil and hydroponic gravel culture in order to compare results with previous experiments.

The applications of each 20 ml of 0.25M NaCl solute (initially 0.125M for testing purposes) began after the plants became well adapted to a sand medium; the initial daily application was delayed in order to avoid osmotic shock. The different periods of applications allowed us to measure the values of osmotic potential (for the soil/plants) at different stress levels. The first step of the experiment was therefore to apply ionic osmotic solutions of NaCl at the above rates to the *Xyliaxylocarpa* seedlings in the commercial potting soil. In the hydroponic potometer system, plants were irrigated with an addition of sodium chloride and when these old leaves demonstrated wilting and osmotic stress, these leaves were harvested along with the soil water solution through the filler tube. The soil water solution was then collected from the tube and measured with a semi-micro osmometer (Knauer, Germany). To measure the saturated osmotic potential value, mature leaves were collected, soaked in a water container, and then covered with a black plastic sheet in order to prevent evaporation during the rehydration process. After one night the saturated leaf samples were weighed and treated in the same way as the midday leaf osmotic potential in the procedure described above. The sampled leaves for the midday and saturated potentials were dried in an oven at $105\ ^0$ C for 12 hours along with the soil samples from the pot; afterwards, the mixture was pulverized in a grinder (Fritsch, Germany). The calculation of leaf water content (LWC) related to the dry weight was applied using the following equation:

$$LWC\ (\%) = 100\ *(FW-DW) / DW$$

Where: FW is the fresh weight of the leaf and DW is the kiln dry weight of the leaf.

Each 1 g (≈ 1 g) of leaf powder was mixed with demineralized water (7 ml of distilled water) to make a dilute solution. The suspension was kept in a water bath at $55\ ^0$ C for 24 hours before the leaf material solution was extracted by centrifuging it for 15-20 minutes at 4,000 rotations per minute to separate the solute and solution. The finalized solution was kept for further analysis in the refrigerator. Finally, the freezing point depression of the solution for one sample was measured twice using a cryoscope (osmometer) (Knauer GMBH, Germany). The cryoscope was likewise used to measure the leaf osmotic potentials for the midday and saturated values in order to determine the freezing point depression as introduced by Kreeb (1990, cited by Mitlöhner and Köpp, 2007).

$$\Psi\pi = 0.1013 \text{ x } [0.021\ (\Delta_t)^2 - 12.06\ \Delta_t]$$

$$\Psi\pi, t\ °C = \Psi\pi, 0\ °C\ (1 + t\ °C/273)$$

Where: Δ_t is the temperature depression at freezing point; $\Psi\pi,0^0$ C is the osmotic potential at 0 ^{0} C, and $\Psi\pi$,t ^{0} C is the osmotic potential at t ^{0} C. The measurement error in the whole processes is approximately ± 2 bar or ± 0.2 MPa (Kreeb, 1990).

3.5 Statistical analysis

The results were performed in Statistical software for Windows (Version 12.0, Statsoft, Inc., Tulsa, USA) to find the correlations between the leaf and soil osmotic potentials. In this experiment, non-parametric statistical analysis (e.g., the Kruskal-Wallis one way ANOVA test by rank) and linear regression analysis were used to examine the significance differences between plant internal osmotic potentials and cryoscopy soil osmotic potentials.

4. Results

4.1 *Xyliaxylocarpa* responses to two different media

According to Marschner (1990) and Munns (2002), salinity slows plant growth via osmotic and ionic effects on the soil solution, which decrease cell expansion and slow plant water uptake by lowering the soil osmotic potential (Orcutt and Nilsen, 2000; Läuchli and Grattan, 2008). Moreover, plants frequently absorb excess salts and then suffer ionic stress, leading to premature leaves and a reduction of the photosynthetic area needed to maintain plant growth over the long-term effects of salinity (Munns, 2002). Plants have the mechanisms to cope with these effects (Munns, 2002) but they require other mechanisms to adjust the ionic concentration in their tissues (Bartels and Sunkar, 2005).

In Table 8.1, *Xyliaxylocarpa* seedlings developed well in the commercial potting soil and hydroponic gravel culture in the greenhouse in Göttingen; in addition, they responded to the given NaCl solution and showed different responses to salt in the two media. In two experiments, 9 seedlings were selected for the commercial potting soil and 9 seedlings for the hydroponic gravel medium over the course of two months. In both systems, the seedlings developed well in their respective media, their solution was gradually increased adding NaCl.

At the end of the application period, obvious salt stress showed significant differences in the *Xylia* leaves. The mean values of the midday osmotic potential and saturated plant osmotic potential at full cell hydration were a respective -2.9 MPa and -2.7 MPa in the commercial potting soil. Again, *Xylia*leaves exhibited moderate tolerance to soil salinities, with a minimum midday leaf osmotic potential of -3.7 MPa in response to a soil osmotic potential of -1.5 MPa in its potting soil rhizosphere; the soil water content (SWC) was 58% (Table 1).For control plants in the commercial potting soil, the minimum midday leaf osmotic potential was -1.6 MPa in response to a soil osmotic potential of -0.2 MPa. In addition, the relative leaf water content (LWC) was 210% (treated samples) and 236% (control samples) (Table 1).

In the non-parametric test, significant differences were found between plant internal osmotic potentials (midday and saturated) and soil osmotic potentials in the Kruskal-Wallis ANOVA test: H (2, N= 27) =16.52205 p =0.0003. According to the results of Table 1, *Xyliaxylocarpa*seedlings with an application of NaCl salt solution in the hydroponic system showed intermediate tolerance to salinity, with a minimum plant osmotic potential of -3.6 MPa; this was consistent with a soil water potential of -1.2 MPa

Table 1: Leaf osmotic potentials of *Xyliaxylocarpa* seedlings and soil osmotic potentials of their potting soils grown in different media in the green house.

Category	Salt solution application (NaCl)			
	Potting soil	**Control**	**Hydroponic**	**Control**
Plant samples				
LWC (%)	210 ± 7.0	236 ± 7.8	236 ± 7.5	277 ± 2.5
Minimum Ψπ (MPa)	3.7	1.6	3.6	1.7
Midday Ψπ (MPa)	2.9 ± 0.2 (7)	1.5 ± 0.09 (2)	No data	No data
Saturated Ψπ (MPa)	2.7 ± 0.1 (7)	1.4 ± 0.08 (2)	2.5 ± 0.2 (6)	1.6 ± 0.1 (3)
Soil samples				
Minimum Ψπ (MPa)	1.5	0.2	1.2	0.05
Mean Ψπ (MPa)	1.1 ± 0.09 (7)	0.2 ± 0.04 (2)	1.0 ± 0.08 (6)	0.03± 0.006(3)
SWC%	58 ± 6.4	57 ± 19.5	Saturated (100%)	Saturated (100%)

The leaf water content related to dry weight was 236% without control and 277% with control for the control plants in the hydroponic system. In the hydroponic gravel culture, the continuous supply of water provided saturating conditions for all plants; as a result, the minimum osmotic potential of control *Xyliaxylocarpa* seedlings on this medium (-1.7MPa) was lower than control seedlings in the commercial potting soil (-1.6MPa), as the former had more water uptake by osmotic stress. In the non-parametric test, there was a significant difference between the plant internal osmotic potentials (saturated) and the soil osmotic potentials for the hydroponic gravel culture with a Kruskal-Wallis ANOVA test: H (1, N= 18) =12.78947 p =0.0003.

4.2 Leaf osmotic potentials versus soil osmotic potentials

In the case of two experimentsillustrated in Figure 1, a freezing point osmometry of plant materials and soil water extracts was conducted independently at each phase with an equal number of seedlings.

Table 2: Regression analysis of the relationship between the soil osmotic potentials and leaf osmotic potentials of *Xyliaxylocarpa* seedlings grown in different media.

Media	Regression equation	r^2	n*
Commercial potted soil	y= 1.617x – 11.87	0.94*	9
Hydroponic gravel culture	y= 1.104x – 14.71	0.78*	9

*n = Number of seedlings, *$p < 0.05$

In Figure 1, midday leaf osmotic potentials instead of saturated osmotic potentials were used to compare the leaf osmotic potentials and soil osmotic potentials of the commercial potting media.In the commercial potting soil of this experiment, the midday values were

lowered by a) concentrating the existing tissue solutes through water loss (transpiration) and/or b), increasing the solute content per cell during the day. The values of the midday *Xylia* osmotic potentials ranged from -3.7 MPa to -1.4 MPa; the soil osmotic potentials in the commercial potting soil ranged from -1.5 MPa to -0.1 MPa.

Figure 1 shows that in the hydroponic gravel culture, the values of plants' osmotic potentials were from -1.3 MPa to -3.6 MPa, while the soil osmotic potentials ranged from -0.02 MPa to -1.3 MPa. The soil osmotic and midday leaf osmotic potentials in the potting soil with the application of anNaCl salt solution were lower than those of hydroponic culture. The correlation between the soil osmotic and midday leaf osmotic potentials were significantly different, for potting media and the hydroponic gravel media at $p < 0.05$.

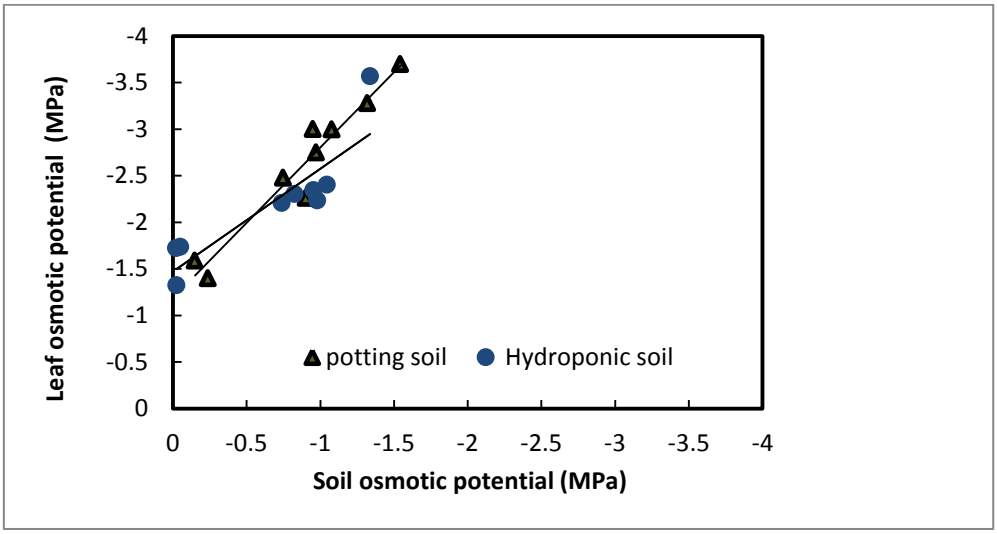

Figure 1: Relationship between soil osmotic potential and *Xylia*leaf osmotic potential at the rhizosphere responded to NaCl salt solution in commercial potting soil and hydroponic gravel culture in the green house.

Their regression parameters and r^2 values were described in Table 2. In these two experiments with *Xyliaxylocarpa* seedlings, the differences between plant osmotic potentials and soil solute potentials were -2.2 MPa in the commercial potting soil and -2.4 MPa in the hydroponic gravel culture.

4.3 Commercial potting soil versus hydroponic gravel media

Figure 2 illustrates the responses of nine *Xyliaxylocarpa* seedlings grown in a commercial potting soil and in a hydroponic culture. In this case, the midday leaf osmotic potentials and related leaf water content to dry weight in the two different media were used to examine the osmotic situation under the same environmental conditions.

Table 3: Linear equations of the relationship between midday leaf osmotic potential $\Psi\pi$ and related leaf water content (% dry weight) of *Xyliaxylocarpa* seedlings developed in two different media.

Media	Regression equation	r^2	n
Commercial potting soil	y= - 7.5182+ 0.0227x	0.42	9
Hydroponic gravel culture	y= - 8.2427 + 0.0242x	0.93*	9

n = Number of seedlings *p< 0.05

The leaf water contents (% DW) were 210% and 236% respectively for the commercial potting soil and hydroponic culture. Furthermore, the leaf water content in the hydroponic system was the same as that of the commercial potting soil (control) because both the soil water content in the potting soils and the continuous supply of water in the hydroponic growing media was maintained. The curve of *Xyliaxylocarpa* in the potting soil was steeper than in the hydroponic culture with NaCl salt application (Figure 2) due to the accumulation of solutes—obviously a response to salt stress in the potting soil plus cell dehydration.

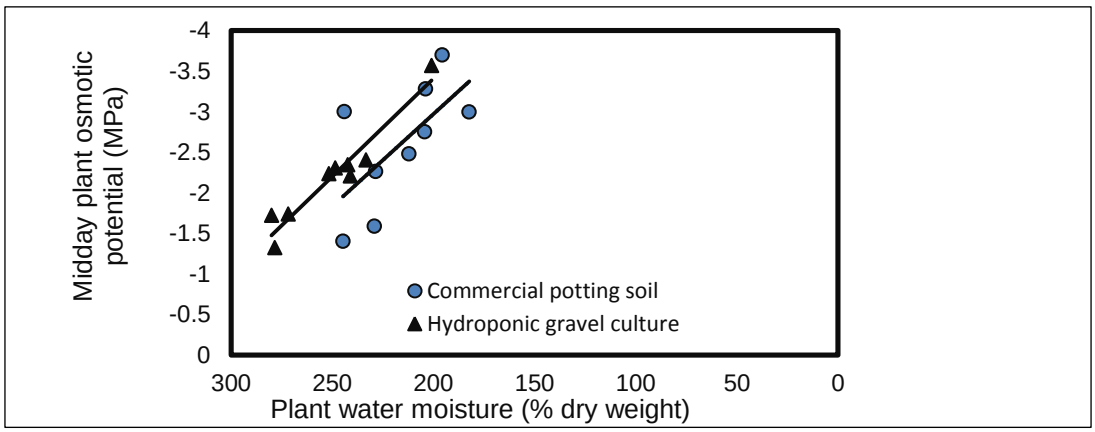

Figure 2 Cryoscopically measured midday Xylia leaf osmotic potential $\Psi\pi$ (MPa) and related leaf water content (% dry weight) at midday in the potting soil and hydroponic culture.

According to Sun (2002), variation in leaf water content during the drying process corresponds to tissue water losses. The related leaf water content of plants (% DW) in the hydroponic culture was slightly higher than that of the plants in the potting soil media, the result of a) solute accumulation in the plant tissues and b) a water deficit that occurred in the potting soil. The hydroponic gravel media showed significant differences between the midday plant osmotic potentials and its leaf water content (% DW) at p< 0.05 (r^2=0.93 for the hydroponic culture), but no such differences existed between the midday plant osmotic potentials and leaf water content in the commercial potting soil. This may be due to the fact that many sample plants possessed lower plant water moisture in relation to their dry weight (%).

5. Discussion

The methods discussed serve to identify the threshold value of a species' osmotic adaptatility as well as the adaptation to its site. In this experiment, *Xylia* had even higher adaptive capacity to soil salinities (concentrations) up to the minimum osmotic potential of -3.7 MPa.

In these two experiments, the related leaf water contents of plants (%DW) were lower than 230% (LWC) in the potting soil plants, the result of cell dehydration. This could also be attributed to the excessive solute accumulation in the plant tissues in tandem with a water deficit during the day. However, the related leaf water content of the hydroponic media plants (%DW) was slightly higher than in the potting soil.

The saline media have an adverse effect on plant growth due to the low osmotic potential of the soil solution (osmotic stress), specific ion effect (salt stress), nutritional imbalances, or a combination of these factors (Ashraf, 1994; Marschnner, 1995). In this case, the midday plant osmotic potentials significantly decreased with the increasing salt concentration (NaCl) treatments as compared to the control group; the result of this is that *Xyliaxylocarpa* seedlings sequester more NaCl while growing their stems. In doing so, these seedlings develop a maximum ability to limit NaCl sequestration. Finally, the plant cells were seen to have lower osmotic potentials due to the reduction in water uptake or hydraulic conductance from the roots to the upper parts of the stem. Because osmotic stress causes a very slow water uptake (resulting in a salt increase in the leaf tissues of the two media), excess ions will gradually accumulate in in the transpiration of older leaves (Greenway and Munns, 1980; Nikam and McComb, 2000)—leading to pre-mature senescence (because of rising toxin levels) and reducing the photosynthetic capacity that sustains plant growth (Munns et al., 2002). With this salt effect, the leaves turned yellow over the weeks of the experiment.

From the greenhouse results produced by Mitlöhner and Köpp (2007), it is clear that the interaction between plant internal osmotic potential and soil osmotic potential provides an option for the approximation of soluble salt accumulation at the root zone. The findings in this study are consistent with their observations of the strong relationship between plant internal osmotic potential and the root medium solute concentration (Figure 8.1). In this study, such a relationship was found between the midday osmotic potentials and the root medium solute concentration. The plant internal osmotic potentials between the plant and soil ranged from -0.5 to -1.0 MPa, especially in the less stressed plants (Breckle, 2002). These results for the differentiation between plant internal osmotic potential and soil osmotic potential were lower than the different means between plant internal osmotic potential and soil osmotic potential of salt-stressed plants like *Prosopisjuliflora* (vide Khaing 2013) which possessed a higher tolerance to soil salinity with a minimum midday osmotic potential of -9.4 MPa and a low soil osmotic potential of -7.8 MPa(Khaing, 2013). In this study, the minimum midday osmotic potentials of *Xyliaxylocarpa* plants in the potting soil and hydroponic culture were a respective -3.7 MPa and -3.6 MPa, with their lowest osmotic soil potentials reaching -1.5 MPa (300 mMNaCl) and -1.2 MPa (240 mMNaCl). These values were accompanied by significant and visible symptoms, i.e., permanent wilting. The minimum values for plant osmotic potential (-3.7 MPa) and soil osmotic potential (-1.5 MPa) for potting soil can therefore be regarded as the threshold values of *Xyliaxylocarpa* salt tolerance. It is clear, then, that *Xyliaxylocarpa* is a moderate salt-tolerant species.

6. Conclusion

The method discussed above can be used to assess the internal osmotic potential of small plants in a short time frame in the context of a wider reforestation program because leaves in the greenhouse responded to Na+ and Cl- retention capacity during development. The midday leaf osmotic potential exhibited the maximum adaptability to salt stress in young *Xyliaxylocarpa* seedlings. This method can be regarded as an easy and robust technique for assessing salt tolerance in tropical tree species.

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