Growth and Water Use Efficiency of Major Tree Species for Rehabilitation and the Impacts of Planting Trees on Microclimate Condition in Central Dry Zone of Myanmar

Go Eun Park1*, Chan Beom Kim2, Jiae An1, Tluang Hmung Thang4, Wai Phyoe Maung5, Khaing Hsu Wai4, Jino Kwon2 and Chanwoo Park3

1Center for Forest and Climate Change, National Institute of Forest Science, 57 Hoegi-ro, Dongdaemun-gu, Seoul, Korea
2Division of Forest Restoration, National Institute of Forest Science, 57 Hoegi-ro, Dongdaemun-gu, Seoul, Korea
3Division of Forest Ecology, National Institute of Forest Science, 57 Hoegi-ro, Dongdaemun-gu, Seoul, Korea
4Dry Zone Greening Department, Ministry of Environmental Conservation and Forestry, No. 39, Forest Department, Nay Pyi Taw, Myanmar
5Forest Research Institute, Yezin, Nay Pyi Taw, Myanmar

(Received November 20, 2016; Revised December 9, 2016; Accepted December 21, 2016)

ABSTRACT

The Bagan, the central part of Myanmar, is dry zone where the mean annual precipitation is less than 600 mm for the last ten years. Forest in this region has been degraded due to biotic and abiotic disturbances. While there have been various efforts to rehabilitate the degraded area, the information on growth and physiological characteristics of planting species and the impacts of planting trees in the region still lacks. Therefore, this study was conducted to determine the growth and physiological water use efficiency characteristics of five species (Azadirachta indica A. Juss., Acacia catechu Willd., Eucalyptus camaldulensis Dehn., Acacia leucophloea (Roxb.) Willd. and Albizia lebbek (L.) Willd.) which are utilized as rehabilitation species in the dry zone and to identify the impacts of tree planting on microclimate change in dry zone. The growth and the foliar carbon isotope composition of seedlings and the above mentioned five species planted in 2005 were measured. And from February 2015 to January 2016, microclimatic factors air temperature and relative humidity at 60 cm and 2 m above soil, soil temperature, soil water contents and precipitation were measured at every 30-minute interval from the two weather stations installed in the plantation located in Ngalinpoke Mt. Range. One was established in the center of A. indica plantation, and the other was in the barren land fully exposed to the sunlight. Among the five species, A. indica and A. lebbek which showed higher water use efficiency could be recommended as rehabilitation species in dry zone. Planting trees in the dry area was shown to affect the change of microclimate with shading effects, declining temperature of the land surface and aridity of the air, and to contribute to conserving more water in soil by preventing direct evaporation and containing more water with fine roots of trees.

Key words: Adaptation, Arid region, Rehabilitation, Shading effect

* Corresponding Author : Go Eun Park
  (goeunpark@korea.kr)
I. Introduction

The Bagan, the central part of Myanmar, is a dry zone where the temperature is high and the mean annual precipitation is less than 600 mm for the last ten years (Fig. 1). Hence ‘the water deficit’ is the major limiting factor in the life of local people and also the forest ecosystem. It has been shown that the dry condition tends to become more serious than the past decades. According to the 2010’s report from National Commission for Environmental Affairs (NCEA) and United Nations Environment Program (UNEP), prior to 1977, the average number of rainy days per year used to be around 144, but it reduced to 103 in 1997. From 1988 to 2000, the monsoon duration was shortened by about three weeks in the northern part and by one week in other parts of Myanmar compared to the 1951 - 2000 average. El Nino was severe in 2009 with decreased annual rainfall, with heavy rains in some areas and with droughts in others. These severe droughts with extreme heatwave in this region had brought the risk of health loss, food scarcity, wildfire, etc. to local people.

Fig. 1. Warkihingyi stream in the dry zone of Myanmar has been dried up to date.

Under the climate change, forest ecosystem in Myanmar has been also degraded. Global Forest Resource Assessment (2015) reported that annually 407,100 ha of the forest land in Myanmar has been deforested during the last two decades (1990-2015). It also added that 44.2% of territory is currently covered with forest in Myanmar (Fig. 2). The forest land in the representative dry zone of Myanmar (Sagaing, Mandalay and Magway) occupies 39% of coverage (3,168,013 ha), and more than 56% forest land in dry zone has been degraded due to over-utilization of fuel wood, over-grazing and wildfire.

Fig. 2. Changes of forest land and deforestation rate FAO, 2015.

There have been various efforts to rehabilitate the degraded forest. Tree planting activities have been implemented as rehabilitation measures. Forest Department of Myanmar formulated the Integrated Plan for Greening the Dry Zone of Central Myanmar for long term of thirty years (2001-2030). The plan is implemented with international cooperative projects. ‘The Project for the Greening of the Dry Zone of Central Myanmar’ is one of the international projects which has been implemented by the Dry Zone Greening Department with the assistance of Korea International Cooperation Agency (KOICA) in Nyaung U Township, Nyaung U District, Mandalay Region. Through all project phases, totally 840 ha of tree plantation was established and among the planted area 50 ha was established in old Bagan area in 2005. Because each tree species shows different growth and physiological responses under water deficit condition, information on the characteristics of species is needed for seeking successful outcomes about rehabilitation activities (Cao, 2008). However, there is still a lack of information about the major tree species which have been utilized for rehabilitation in the central dry zone of Myanmar. Considering the major limiting factor in the plants’ growth and survival, water,
species characteristics of intrinsic water use efficiency would be more important criteria of species selection in the dry zone than any other traits (Farquhar et al., 1982; Farquhar and Sharkey, 1982; Yan et al., 2005; Lambers et al., 2008; Yin et al., 2015). As Morris et al. (2004) also emphasized, considering water use efficiency of the planted tree species is necessary because it can affect the water in soil with transpiration. To ensure more successful rehabilitation, integrative growth status of seedlings such as sturdiness should also be considered. According to the previous studies, smaller sturdy seedling showed a higher chance of survival, especially on windy or dry sites (Roller, 1977; Moore et al., 2008; Trubat et al., 2010).

Trees in forest are not only influenced by climate but also affect the microclimate variation in forest. Planted trees can produce cooling effect by making shade (Bolwer et al., 2010; Leuzinger et al., 2010). Sida et al. (2013) indicated that shade under the planted tree species (ex. Faidherbia albida) contributed to enhancing crop yields, making buffer zone toward extremely high temperature. Soil water in the dry zone is also influenced by the trees with variation of gross rainfall partitioning through the crown, stem and root levels (Yin et al., 2015). In the dry zone in Myanmar, however, there is no enough meteorological evidence which can contribute to raising awareness of people on the real impacts of planting trees on the microclimate conditions.

Therefore, this study was conducted with two aims. One is to provide one of criteria for species selection by investigating the growth and physiological characteristics of five species (Azadirachta indica A. Juss., Acacia catechu Willd., Eucalyptus camaldulensis Dehn., Acacia leucophloea (Roxb.) Willd. and Albizia lebbek (L.) Willd), which are utilized as rehabilitation species at the both level of seedling and mature tree and by determining the characteristics on physiological adaptation to the dry zone. The other is to suggest scientific evidence of benefit of planting trees in dry area in Myanmar by assessing the impacts of tree planting on microclimate change.

II. Methods and Materials

2.1. Plant materials and growth measurement

Targeting the five species (A. indica, A. catechu, E. camaldulensis, A. leucophloea and A. lebbek), the growth of one-year-old container-grown seedlings height and root collar diameter in the Palingone nursery was measured (n=10). In the Ngalinpoke Mt. Range (N21°3’10.5” E94°58’10.0”), ten trees per each species planted in 2005 were selected and the height and DBH were measured. To identify seedling sturdiness roughly without harvesting, we calculated ‘sturdiness quotient’, which Durvea (1985) introduced as comprehensive indicator of the seedlings’ ability to withstand physical damages such as wind, drought, and frost. Value on the sturdiness of each species was obtained by dividing height (cm) by root collar diameter (mm).

2.2. Water use efficiency

To estimate the characteristics of water use efficiency of each species, more than two leaves per each seedling were collected from ten seedlings. After being dried 72 hours under 65°C, the foliar carbon isotope composition (δ^{13}C) of the seedlings and the planted trees was analyzed with below formula.

\[ δ^{13}C (\text{‰}) = \frac{[(13C/12C)_{\text{sample}} - (13C/12C)_{\text{standard}}]}{(13C/12C)_{\text{standard}}} \times 1000\% \]  

2.3. Monitoring microclimate conditions

Two weather stations (HOBO U30 Station, Onset Computer Corporation, Bourne, Massachusetts, USA) were installed in the KOICA II plantation located in Ngalinpoke Mt. Range. One was established in the center of forest where A. indica was planted in 2005, and the other was in the barren land fully exposed to the sunlight (Fig. 3; Table 1).
Table 1. Structural characteristics of *Azadirachta indica* forest in Ngalinpoke Mt. Range

<table>
<thead>
<tr>
<th>Age (year)</th>
<th>Density (n/ha)</th>
<th>Mean Height (m)</th>
<th>Mean DBH (cm)</th>
<th>Mean Crown Coverage (m²/tree)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>700</td>
<td>5.3</td>
<td>11.1</td>
<td>17.6</td>
</tr>
</tbody>
</table>

Air temperature and relative humidity were measured at the two different levels from the above ground using S-THB-M002 (Onset Computer Corporation, Bourne, Massachusetts, USA). One was installed at the 60 cm and the other was at the 2 m height from the above ground. Sensors for measuring soil temperature (12-Bit Temperature Smart Sensor, S-TMB-M002, Onset Computer Corporation, Bourne, Massachusetts, USA) and water contents (Soil Moisture Smart Sensors, S-SMD-M005, Onset Computer Corporation, Bourne, Massachusetts, USA) were installed at the 10-20 cm depth. Precipitation was recorded at the 2m height from the above ground using Rain Gauge Smart Sensor (S-RGA-M002, Onset Computer Corporation, Bourne, Massachusetts, USA). Data was logged from February 2015 to July 2016 at every 30-minute interval. From February 2016, the upper air temperature and relative humidity data were not logged in the forest land as sensor was out of order. To determine the impacts of planting trees on soil water contents (SWC), variations of SWC were calculated by normalizing each measured data with following formula.

$$\text{Normalized SWC} = \frac{(W_m - W_f)}{W_f} \times 100$$  \hspace{1cm} (2)

Where \( W_m \) is monthly mean soil water (contents m³/m³) and \( W_f \) is mean soil water (contents m³/m³) measured in February 2015.

To identify aridity in the air, vapor pressure deficit was obtained with following formula.

$$V_{PD_{air}} (kPa) = V_{P_{sat}} - V_{P_{air}}$$

$$= 0.361078 \exp(17.2697/(237.3 + T)) - V_{P_{sat}} \times RH/100$$  \hspace{1cm} (3)

\( V_{P_{sat}} \) is saturation vapor pressure, \( V_{P_{air}} \) is vapor pressure of the air, and \( T \) and \( RH \) refer to temperature and relative humidity in the air, respectively.
2.4. Statistical analysis

Differences in the mean values of physiological variables of species and climatic factors were analyzed using ANOVA and multiple comparisons were performed using Duncan’s multiple range tests (Duncan, 1955). In addition, t-test was performed to compare physiological variables of species between two different growing status and microclimate characteristics between the barren land and forest land.

III. Results and Discussion

3.1. Growth of five major tree species at the early stage seedling and the mature tree level

Height and root collar diameter of seedlings were shown in Fig 4a, b. At the 11-year-old tree level, while _E. camaldulensis_ was the highest, _A. indica_ showed the biggest DBH value (Fig. 4c and 4d, p<0.05).

In terms of the sturdiness of seedlings in the first year, _E. camaldulensis_ showed the highest value and _A. lebbek_ showed the lowest (Fig. 5, p<0.05). According to the results, seedlings of _A. lebbek_ seemed to be able to be more resistant under climatic stress. Roller (1977) stated that black spruce seedlings with sturdiness quotients greater than six were seriously damaged when exposed to wind, drought, and frost. In this study, however, all values on sturdiness quotients of five major species seedlings were over six. To enhance the resistance of each species at the seedling level, developing technology on seedlings’ growth improvement such as irrigation treatment and selecting seed source by provenance test seems to be needed.

![Fig. 4. Growth characteristics of 1-year and 11-year-old seedlings.](image)
3.2. Water use efficiency of five major tree species at the early stage seedling and the mature tree level

At the both of seedling and tree level, *A. indica* and *A. lebbek* showed less negative value on $\delta^{13}C$ than other species while *E. camaldulensis* showed more negative. As a result of t-test between two different ages of each species, however, *A. leucophloea* tree showed less negative value on $\delta^{13}C$ than that of seedlings. Park et al. (2016) proved that Siberian elm trees which are distributed in the wide range of water condition from riverside to arid regions is adaptive, increasing water use efficiency under water deficit condition. Study results on the five major species also indicated that they had been adapted to the field’s environmental condition by improving water use efficiency (Fig. 6).

*A. indica* and *A. lebbek* have also been utilized in multiple ways such as a main recourses of medicine, furniture, food, etc. Considering their water availability and usage in dry zone, *A. indica* and *A. lebbek* can be preferentially used for rehabilitation.

3.3. Impacts of planting trees on the microclimate conditions

Although the distance between the forest land and the barren land which is fully exposed to the sunlight was only within 100 m, the soil temperature and the air temperature at the 60 cm above soil surface showed differences (Fig. 7, 8). Soil temperature at the 15-20 cm depth in the barren land was higher than that of forest (Fig. 7, $p<0.05$).

The error bar is one standard error. The different letters indicate significant differences according to Duncan’s multiple range tests at a 5% significance level.
From February 2015 to July 2016, it rained for 103 days (Fig. 9). Myanmar has rainy season which called monsoon season from May to October. Reflecting the seasonal variation of Myanmar in 2015, 84.4% (456.21 mm) of rainfall was concentrated during July to October (rainfall days = 53 days). The measured values on monthly precipitation and soil water contents at the same 15-20 cm depth (Fig. 9) showed no significant differences between the two sites ($p>0.05$).

Considering the relationship between tree and soil water contents, shade under tree’s crown contribute to mitigating speed of soil water loss by preventing evaporation and conserving water with fine roots. Soil water can be lost through tree’s transpiration (Cowan et al., 1965; Belsky et al., 1989). As Maithani et al. (2011) and this study indicated, A. indica, the planted species, is known to be drought tolerant with higher water use efficiency compared to other species. Because this species has leaves from June to next March, it can be expected that both of water loss by transpiration and conserving water by shade effects occurred during this period. Shown in the Fig. 9, the variation of soil water contents (%) in the forest was more dynamic than the barren land. This difference between the two sites can be attributed to the gaps in the speed of rain falling on the soil and the hydraulic availability to conserve water in soil. Parker (1983) indicated that the mean stemflow is 12% of rainfall. Therefore the infiltration rate in the barren land can be inferred to be faster than the forest land because the rainfall infiltrate though stem. Compared to first measurement in February 2015, soil water contents in the forest increased over four times in October 2015. As Kwon et al. (2016) suggested, soil in the forest land seems to hold water for maximum 15 days more than the barren land. From these results it can be expected that planted tree influenced soil water conservation by preventing evaporation and containing waters with the fine roots of trees while the barren land

**Fig. 8.** Air temperature measured at the 60 cm height (a) and at the 2 m height (b) from the above ground.

**Fig. 9.** Monthly precipitation (a) and normalized soil water contents (b) of the barren land and forest land.
lost more water by absence of shade effect of crown and conserving system of fine roots.

Air temperature at the 60 cm above soil surface in the barren land was about 0.05 to 1.55°C higher than forest \((p<0.05)\). At the 2 m height, however, the difference was not significant (Fig. 10). From these results, it can be inferred that planting trees can affect cooling temperature of the soil and the air at around 60 cm height. This effect can also influence the soil water condition (Shin et al., 2013).

**IV. Conclusion**

At the seedling level, A.lebbek might have more chance to survive than other species especially on windy or dry sites, showing the lowest value on sturdiness. As a result of t-test between two different ages of each species, A.leucophloea tree showed less negative value on \(\delta^{13}C\) than that of seedlings. A.leucophloea might have significantly improved water use efficiency after transplanted in the dry area. In terms of water use efficiency, however, A.indica and A.lebbek might show good performance on adaptation with less negative value on \(\delta^{13}C\) under water deficit condition at the both of seedling and tree level. Although the height and the DBH of E.camaldulensis were highest at the both of levels, \(\delta^{13}C\) showed lowest. Considering water use efficiency, this species should be re-considered as a rehabilitation species in dry zone. Planting trees in the dry zone in Myanmar seemed to affect change of microclimate in the dry zone with shading effects, declining temperature of the land surface and aridity of the air. Variations of soil water contents in the forest were more dynamic than the barren land by increasing water contents more than four times in October 2015. According to these results, planting trees can contribute to conserving more water in soil by preventing evaporation and containing more water with fine roots of trees. In conclusion, considering water use efficiency of species, planting trees in the dry zone can bring benefits to life of plants and people.
으로 수분이용효율이 양호하여 조림에 적합한 수종을 선발하고, 둘째, 조림이 해당 지역의 미세기후변화에 미치는 영향을 구명하는 것이다. 5개 주요 조림 수종(Azadirachta indica, Acacia catechu, Eucalyptus camaldulensis, Acacia leucophloea, Albizia lebbek)을 대상으로 각각 1년생 유묘와 2005년에 이식한 11년생성목의 생장을 측정하고, 양엽에서 추출한 탄소동위원소함량(δ13C, ‰)을 분석하여 수종별 생장단계별 수분이용효율 변화를 분석하였다. 한편 조림이 건조지의 미세기후상관에 미치는 영향을 구명하기 위해 Ngalinpoke산지에 2005년 조림된 A.indica 숲과 전광 노출지를 대상으로 미세기후특성을 측정하였다. 2015년 2월부터 이듬해 7월까지 기온, 상대습도, 토양온도 및 토양수분함량을 측정하였으며, 특히 조림에 따른 지표면의 복사열 차이를 구명하기 위해 지면으로부터 60 cm, 2 m 높이에서의 기온과 상대습도를 측정하였다. 위의 주요 조림 수종 중에 수분이용효율이 상대적으로 높은 수종은 A.indica와 A.lebbek였으며, E.camaldulensis은 수고생장이 좋은 반면 수분이용효율이 가장 낮았다. 지상 2 m 높이에서는 기온 및 상대습도가 조림지와 노출지 사이의 차이를 보이지 않았으나, 토양온도는 두 지역간 통계적으로 유의한 차이를 보였다. 지상 60 cm 높이에서는 기온 및 상대습도가 조림지에서 노출 전광지에 비해 낮았다. 한편, 조림지에서의 토양수분함량은 전광 노출지에 비해 적절한 변동폭이었으며 2015년 10월에는 전광 노출지에 비해 약 4배 상승하였다. 결과적으로 이 지역에서의 조림은 지표 온도를 낮추고 지표에서의 직접적 인 증발을 막아줌으로써 토양 내 수분 보존에 기여하는 것으로 사료된다.

Acknowledgements

This study was supported by the Project for Capacity Building for Forest Management to Address Climate Change in Central Dry Zone of Myanmar (P2013-00194-2).

REFERENCES


Cao, S. X., 2008: Why large-scale afforestation efforts in China have failed to solve the desertification problem. Environmental Science and Technology 42(6), 1826-1831.


Kwon, Jino., Kim, chan beom, Park, Ki-Hyung, and Kim, Yong-Suk, Kahing Hsu Wai, Tluang Hmung Thang, Wai Phyoe Manug, 2016: Effect of forest stands (Azadirachta indica) on soil water contents during rainfall: A case study on the central dry zone of Myanmar. IUFRO Regional Congress for Asia and Oceania 2016. 87pp


