Global Ecology and Conservation 8 (2016) 31–40

Contents lists available at ScienceDirect

Global Ecology and Conservation

journal homepage: www.elsevier.com/locate/gecco

Original research article

Variation in the response of eastern and southern Africa provenances of *Faidherbia albida* (Delile A. Chev) seedlings to water supply: A greenhouse experiment

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ARTICLE INFO

Article history:
Received 3 March 2016
Received in revised form 9 August 2016
Accepted 9 August 2016

Keywords:
Faidherbia albida
Provenance x treatment interaction
Age to age correlation
Selection
Genetic variation

ABSTRACT

Rural communities value *Faidherbia albida* in farming systems and pastoralism. *Faidherbia albida* provides products such as medicine, fodder, fuel, wood, food and services such as shade, soil fertility and nutrient cycling. Excessive browsing by animals, branch lopping and pod harvesting, have critically reduced the natural regeneration in some areas which exposes it to challenges due to dependence upon natural regeneration. The objective of this research was to evaluate response of *Faidherbia albida* provenances from eastern (Taveta Wangingombe) and southern Africa (Lupaso, Kuiseb Manapools) to different watering regimes to aid in selection of provenances for domestication. The observed difference in growth was analyzed to determine whether they are genetic or environmentally induced. Genotype × interaction were significant at ($p \leq 0.001$, $p \leq 0.05$) in seedling height, diameter and leaf numbers. Seedling height (r=0.94 p=0.001) recorded the highest correlation coefficient among all the growth variables analyzed. The growth variation was greater for seedling height than that of diameter and leaf numbers (h^2=0.97). Hierarchical cluster analysis grouped the provenances into three clusters with cluster iii consisting of Taveta, Kuiseb and Lupaso while cluster ii and i composed of Wangingombe and Manapools respectively. Manapools recorded the highest genetic distance from Taveta, Kuiseb and Lupaso at 84.55 units. Wangingombe and Manapools are closely related genetically at a distance of 7.32. The maximum inter-cluster distance between cluster i and iii indicated wider genetic diversity between the provenances in these clusters and selection should be from this clusters for hybridization program to achieve novel breeds.

1. Introduction

Tree domestication and improvement programs must understand patterns of variation in tree species in order to effectively select, manage and conserve their genetic resources. Pattern of natural variation in adaptively important traits is essential in development of tree improvement and conservation strategies for native hardwood species

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http://dx.doi.org/10.1016/j.gecco.2016.08.005

(Weber et al., 2008). This is particularly urgent for *Faidherbia albida* (del.) A. Chev (Bastide and Diallo, 1996; Billand and De Framond, 1993; Dangasuk et al., 1997; Roupsard et al., 1998; Sniezko and Stewart, 1989; Wanyancha et al., 1994) and other species that are over extracted (Arnold, 2004; Bowen et al., 1977; Dawson and Powell, 1999; Diallo et al., 2000; Ofori and Cobbinah, 2007; Ofori et al., 2007; Tchoundjeu et al., 1997). Ræbild et al. (2003) report the findings of FAO and the Danida Forest Seed Centre who analyzed several trials to identify provenances from Africa and other continents for reforestation. The number of provenance trials for exotic species outnumber that of native hardwoods as reported by (Appiah, 2003; Diallo et al., 2000; El Amin and Luukkanen, 2006; Loha et al., 2006; Ofori and Cobbinah, 2007; Raddad, 2007; Weber et al., 2008; Wolde-Mieskel and Sinclair, 2000). The situation is worrying because of the changing pattern of climate necessitating the need to focus research on native better adapted provenances. The adaptive capacity that is required to mitigate the effects of climate change will be achieved among others by selection of species that make up a farming system (Afreen et al., 2011). While there has been significant effort to select and breed drought tolerant crop species, there is need to also consider trees when exploring species for consideration in climate smart agricultural systems. This is because trees provide multiple important benefits to farmers and their farming systems (De Leeuw et al., 2014). First, trees positively influence microclimatic and edaphic conditions that are relevant to the production of crop species; second trees provide many goods such as fruits and energy that are relevant to farmers.

Of particular interest for consideration to include in climate smart agriculture are those tree species that have a wide climatological niche. These species are interesting because the adaptation of trees to climate change is dependent on response to the present temperature and rainfall conditions (Austin, 1992; Langlet, 1971). *Faidherbia albida* is such a species; it is distributed throughout the African continent spanning a wide range of environmental conditions (Barnes and Fagg, 2003). It grows well under deep sandy-clay soils, rocky, heavy and cracking clays and remarkable gradient of 50–1800 mm average annual rainfall across which the species occurs. This broad distribution with respect to rainfall is due to the fact that *Faidherbia* is a groundwater dependent species (Roupsard et al., 1999).

Aside from its distribution across diverse habitats, *Faidherbia albida* has a unique reverse phenology of shedding leaves during the rainy season allowing it to grow among field crops without overshadowing them during the wet season and provides shade during dry season (Roupsard et al., 1999). Falling leaf mulch promotes higher microbial activities in the soil, thus improving the soil structure, stability and permeability under the canopy. Increase in yield from the crop grown below the trees has attributed to increase fertility due to nitrogen fixation, dung from the stocks browsing and fallen leaves and pods (Dangasuk et al., 1997). In addition, *Faidherbia albida* has remarkable capacity for recycling nutrient from underground to the surface due to its very deep root system (Okore et al., 2007).

Beside the benefits mentioned above, *Faidherbia albida* is appreciated by herdsmen and farmers in arid and semi-arid regions of Africa (Okore et al., 2007). The leaves and pods are palatable to livestock like cattle, goats and sheep. Pastoralist lops the branches to provide dry season browse for their stock (Barnes and Fagg, 2003). Ground pods are highly recommended cattle feeds for milk production (Bwire et al., 2004). The wood of *Faidherbia albida* is used for construction of dugout canoes, boats, paddles, kitchen utensils, art objects, troughs and fencing (Mokgolodi et al., 2011). The wood ash is used for soap and as a depilatory and bark used as fish poison in Botswana (Barnes and Fagg, 2003). The bark has a high concentration of active component that treats kidney pain and mental illness (Okore et al., 2007). The crushed tree bark homogenized in water is used to treat diarrhea in human (Wondimu et al., 2007). In Nigeria leaf and fruit decoction help to cure leprosy while bark infusions are taken to treat fever, coughs and aid in child birth (Oluwakanyinsola et al., 2010). Seeds of *Faidherbia albida* are eaten by humans as famine foods although seed requires a long preparation to remove toxins (Barnes and Fagg, 2003).

Because it has many uses, there is intensive extraction pressure on *Faidherbia albida* in African dry lands. Excessive browsing by animals, branch lopping and pod harvesting, have critically reduced the natural regeneration in some areas which exposes it to challenges due to the fact that it is entirely dependent upon natural regeneration (Wahl and Bland, 2013). Wild animals such as elephants and giraffes have been in many cases identified as the cause of population decline in *F. albida* leading to this population deficit through low regeneration. Despite adequate seed production, natural regeneration by seed may be limited because of heavy seed predation and high seedling mortality (Turnbull et al., 2008). This, together with the fact that few communities protect and manage natural regeneration, has dramatically reduced the abundance of *Faidherbia albida* in many areas. In addition, farmers and pastoralists state that many trees are dying due to increasingly hotter, drier conditions in the dry lands and the relatively slow growth during the first few years after planting (Okore et al., 2007). The situation is worsened by little systematic research on genetic variation in growth and survival of native hardwood species in Africa. FAO initiated, and the Danida Forest Seed Centre analyzed several trials to identify some superior provenances from Africa and other continents for reforestation in arid and semi-arid zones in Africa (Ræbild et al., 2003). Numerous provenance trials of several exotic species have been established and evaluated (Andrew et al., 2004; Khasa et al., 1995; Langat and Kariuki, 2004; Pedersen et al., 2007; Ræbild et al., 2003). In contrast, there are relatively few publication of genetic variation in growth, survival and other commercially or adaptively important traits of native African hardwoods (Diallo et al., 2000; El Amin and Luukkanen, 2006; Raddad, 2007; Roupsard et al., 1998).

This paper therefore, evaluated response of five provenances of *F. albida* to different watering regimes and analyses the observed difference in growth to determine whether the difference is genetic or environmentally induced to aid in selection of suitable provenances for domestication in different environments.