Evaluation of major Acacia species in the nursery towards apicultural landscape restoration around Southwestern Saudi Arabia

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A R T I C L E   I N F O

Article history:
Received 30 April 2020
Revised 31 August 2020
Accepted 1 September 2020
Available online 8 September 2020

Keywords:
Acacia species
Beekeepers’ ranking
Morphometric parameter
Native honeybee flora
Degraded land restoration
Saudi Arabia

A B S T R A C T

Southwestern Saudi Arabia is described by a unique ecosystem and composed of apicultural landscapes where nearly 70% of the beekeeping activities are concentrated. However, this economically important resource is under continuous degradation threat urging restoration. Besides, profound information on the possible major biological components of future restoration; nursery level performances of the native plants, Acacia species is lacking. Hence, the study was aimed at evaluating performances of selected native Acacia species at nursery level as candidate biological tool for apicultural landscape restoration. For this, nine native Acacia species’ seedlings were prepared in accordance to appropriate techniques of nursery operations recommended for arid areas. Meanwhile, species were evaluated and compared based on some performance parameters. Accordingly, significant (P < 0.005) variations were observed among the species in shoot height, collar diameter, height to collar diameter ratio, number of leaves and seedling survival. Acacia origena Hunde, A. gerrardii Benth., and A. johnwoodii Boulos. were superior over the others in most parameters while A. etbaica Schiweinf. and A. asak (Forssk.) willd. were less vulnerable to chanced pathogens. Generally, nursery level performances of all Acacia species under experimentation were within the acceptable range and showed a remarkable score which may lead them to be considered as competent biological tools in the incorporation of the genotypes in apicultural landscape restoration efforts.

1. Introduction

In the Kingdom of Saudi Arabia, the remainder natural forests are primarily found in the Southwestern highlands of the country and are known as unique ecosystem in the region (El-Juhany, et al. 2009). Acacia species take the substantial share in the floral composition in these areas. According to Al-Ghamdi (2007), nearly 70% of the beekeeping production in the country is concentrated in this region, where these plant types play the major role as honey bee flora. However, Hall et al. (2010) reported the apicultural landscapes (forests) are under continuous degradation both in quality and quantity and some tree species become endangered with only little or no regeneration. Hence, worth to think of restoration of degraded apicultural landscapes before conditions are worsened.

Moreover in the region, the presence of die-back and poor regeneration of trees and extensive declining of woodlands were reported (El-Juhany, 2009). Furthermore, Hall et al. (2010) reported that the remaining patches of relict forest habitats are under continuous declining both in quality and quantity and some tree species become endangered with only little or no regeneration. Hence, worth to think of restoration of degraded apicultural landscapes before conditions are worsened.

Rehabilitation of these degraded apicultural landscapes is less focused as compared to the current priority needs to revert the human living environment which is distracted due to multifaceted factors. So far, the effort is negligible and incorporation of native honeybee flora as biological tools in the restoration works was almost ignored. Furthermore, most afforestation and reforestation efforts failed to attain their goals due to consideration of inappropriate plants, non-native species in their scheme without proven adaptation (Mohammed, 2013). Besides, unavailability of information on the nursery level management practices and performances of dominant honey bee forages, particularly native Acacia species will trigger omission than inclusion of the genotypes in rehabilitation works. However in reality, using native honeybee flora as an
apicultural landscape rehabilitation tool is like hunting two birds in a single stone; achieving the restoration goal and developing of the honey bee floral condition. Today, according to many scholars including Arnaud et al. (2002), agree in accordance with the principles of ecological restoration, will be choosing the adapted species to the environment.

In the effort of realizing restoration of degraded apicultural landscape, maximizing the use of honey bee flora as the plantation component will have a paramount importance in developing the land and its environmental safety values. However, performances and the silvicultural practices of the dominant native bee plants, Acacia species shall be experimented to point out the best performing and surviving ones in relation to the specific ecosystem of application. As planting nursery-grown seedlings is just one of several complementary options for successful restoration (Blakesley et al., 2000), the current nursery level native species evaluation line of investigation will have a vital reputation for pre-screening and selection of best performing biological tools for a successful restoration. In doing so, relevant information was availed to enhance restoration of degraded apicultural landscapes and other environmental and climate change adaptation and mitigation development works. Besides, it helps to have defined levels of growth and survival for a particular planting site as well as predicting floral field performance. Therefore, this particular line of investigation is aimed at evaluating nursery level performances of selected native Acacia species towards apicultural landscape restoration in the Southwestern part of Saudi Arabia.

2. Methodology

2.1. Nursery level evaluation of native honey bee forages, Acacia species

2.1.1. Study area

The study was carried out in Southwest Saudi Arabia (Al-baha Region, Baljurashi district). The landscape constitute the remainder of the forest stock of the country (Al Shiha and Darfaoui, 2012). Due to the geographical diversity, this land feature has diverse climates thus favoring the growth and flowering of greatly diversified bee plant genotypes rich in nectar and pollen including Acacia species. As a result, most of the beekeeping activities of the country are concentrated in this region. The area is severely degraded despite its relatively good vegetation coverage and only relic woodland patches exist. These situations believed to easily impulse stakeholders in rehabilitation of the vegetation (apicultural landscapes) of the area for both environmental and economic reasons.

The particular experimentation was conducted at Baljurashi, Al-Baha region, located at 19°51′45″ N and 41°36′15″ E, at 2021 m above sea level. The area is categorized as being under the mid to highland physiographic and climatic conditions. The humidity ranges from 52% – 67% while the rainfall from 229 – 581 mm/annum. The mean annual temperature is 23.5°C (https://en.tutiempo.net/).

2.1.2. Selection of species

Species of interest were primarily selected based on the information from previous related plant research project (Determining special and temporal distribution, and relative values of honeybee flora in the Al-Baha region) and local informants. Group discussions comprising of 8 representative beekeepers and 4 focal persons, were made to prioritize different honeybee flora based on their suitability to restore degraded apicultural landscapes around the study area, honeybee colony strengthening and their relative advantage to honey production. Socio-economic importances, adaptation to moisture prone areas, tendency of fast growth and establishment, tolerance to harsh climate, indigenousness to the region, and species’ apicultural value intens of pollen and nectar sources were considered in the appraisal.

Accordingly, Ziziphus spina-christi (L.) Desf., Acacia origena Hunde, Acacia tortilis (Forsk.) Hyne., Acacia ehrengbergiana Hyne., Acacia asak (Forsk.) willd., Acacia etbaica Schweinf., Acacia gerardii Benth., Acacia hamulosa Benth., Acacia johnwoodii Boulos, Acacia oerfota (Forsk.) Schweinf., Dodonaea viscosa subsp. angustifolia (Lf.) J.G.West, and lavandula dentata L. were the most prioritized species thereby included for the relative ranking of the Acacia species. Eight of the beekeepers, members of the group discussion were asked to rank the prioritized species (1 up to 12). Besides, previous studies including Al-Mefarrej, (2012) (who studied Acacia species distribution) revealed that, these species has been found to survive and used as good sources of nectar and pollen around the study area. Moreover, their use as source of foliage for animals, gave additional confidence for the selection process. Native species, which have better co-existence adaptability to the targeted areas and have better ecosystem functions (soil and water conservation) and socioeconomic values (honey source and fodder plants) to the local communities were also focused.

2.1.3. Preparation of seedlings

Seedling were prepared based on appropriate techniques of nursery operations in arid areas (FES, 2008). Following the procedures, seeds of selected and prioritized species were collected and checked for quality, germination, and viability. Following recommended seed treatment techniques, all species were treated with hot water soaking for 24 h except Acacia hamulosa, soaked for 48 h. Containerized or pot seedlings were prepared and evaluated starting from the begunning of the spring. In doing so, equal proportion of organic fertilizer (Potgrond H, Klasmann-Deilmann, Germany), local agricultural soil and sand were used. All nursery management practices kept homogenous and constant to all species following appropriate dryland nursery managemnt practices as mentioned in FES, (2008).

2.1.4. Performance evaluation

The nursery level evaluation and grading were done based on germination date, 50% emergence date, number of leaves, growth heights, number of branches, collar diameter, vigorosity, pest and disease infestation scores. Scoring was in relation to local experiences and standards. Ten plantes were sampled per each replication, totaling 30 seedlings per each species for every record. Growth was monitored monthly and researchers observation was done every two days to follow-up the performances and any infestation of pests and diseases.

2.2. Data management and analysis

The experiment was conducted following a completely randomized design (CRD) format. Nine of the Acacia species were the treatments used in three replications. Morphometric, adaptability, survival tendency, seedling vigoarity and health condition parameters were periodically recorded and managed using MS excell, and analysed using SAS-JMP statistical software (SAS, 2002). Ranking of species by the focus group discussions was summarized by simply computing the average ranks. Descriptive statistical tools, Analysis of variance (ANOVA), and qualitative (narrative) analysis techniques were used to analyze and interpret primary data.
3. Results and discussion

3.1. Beekeepers ranking of Acacia species

Relative ranking of the Acacia species related to the most common honey bee flora are shown in Table 1. Accordingly, nine of the Acacia species held the top 10 ranks where 3 of them ranked among top 5 while 6 others were between 5 and 10.

Ranking of A. tortilis, A. gerrardii and A. origena were among top 3 which might be related to their high economic value in honey production. In agreement to this, Nuru et al. (2017) reported the high honey production potentials of these plants and Adgaba et al. (2014) found the honey originated from these species are among the top sales in the local markets. Discussants did not deny the significant benefits of the other Acacias under experimentation as bee plants; however, their primary preference had been inclined to honey source plants which they ranked in the top 3. Generally, they affirmed the socio-economic and environmental importance of the species under experimentation, thereby targeting them to future apicultural landscape restoration exertions.

3.2. Emergence dates, vigor scores and health conditions

Seeds of the current Acacia species under experimentation, in general attained their first and 50% emergence dates earlier (Table 2) implying acceptable seed treatment (hot water) technique.

Similarly, El-Azazi et al. (2013) found highest germination rate by treating seeds of A. tortilis using boiling water; while (Aref et al. 2011 andAzad et al. 2011) also reported good result from hot water seed pretreatment in Acacia species. The fastest emerging ones were Acacia johnwoodii followed by A. origena and A. gerrardii, respectively, which could be indicative of fast growing during nursery level seedling establishment and can help in rapid apicultural landscape rehabilitation endeavor. Moreover, these species had relatively high vigor scores which could still complement nursery level seedling establishment and can help in rapid apicultural landscape rehabilitation endeavor.

During the study period, the common factors affecting seedling health were Powdery mildew (Fungal disease caused by Podosphaera xanthii) and Cottony cushion scale (Insect pest, Icerya purchase), where A. etbaica and A. asak were the least affected species, respectively. Likewise, Borah et al. (2012) also found powdery mildew affecting Acacia species in nursery and Royal Botanic Gardens, Kew in its Bulletin Vol.1889 (32) stated cottony cushion scale loving Acacia. However in general, all of the species were affected from mild to medium levels but managed to grow and survive effectively. This earlier better performance and survival of the species could probably give a confidence for rehabilitating degraded landscapes using these types of native species.

3.3. Nursery level morphometric performances of Acacia species

Bellow, Table 3 presents the morphometric performances of the nine Acacia species compared for consideration. The average shoot height of the Acacia species under experimentation ranged from 26.6 to 52.5 cm and collar diameter between 3.1 and 5.9 mm while number of leaves from 71.7 to 205.8 at the age of 4 months since date of emergence.

Acacia origena was significantly (P < 0.05) tallest than all species except A.johnwoodii and these tallest species had significantly (P < 0.05) thickest collar diameter than others except A. gerrardii. Hence, according to Haase and Rose, 2004, these species likely possessed relatively higher photosynthetic capacity and transpiration area which in turn may favor faster growth and development. Besides, the long developed adaptation of A. origena and A. gerrardii to the surrounding environment might contribute to have taller height and thicker collar diameter. Hence, in relative terms, their nursery level performances probably imply their prior tendency to grow and survive onsite superiorly than others in water fair growing conditions. In agreement to this, Dumroese et al. (2011) revealed survival and growth of planted seedlings under vegetative competition typically increases with initial plant size. Mohammed, (2013) also reported that production of high-quality seedlings in nurseries is important for successful establishment of trees and forests, thus contributing to the rehabilitation of degraded lands.

Acacia ehrenbergiana and A. asak had significantly (P < 0.05) higher height to collar diameter ratio, hence relatively less sturdily. The number of leaves of A. origena, A. gerrardii, and A. tortilis was significantly (P < 0.05) higher than the other 6 species which may comparatively favor the plants in nutrient conversion and utilization as they can have relatively higher leaf area to accomplish photosynthesis there by attaining better growth and development tendency. Koester et al. (2014) also reported that leaf area growth determines the light interception capacity. The observed significant phenotypic variations among the current Acacia species may give a green light for species diversity opportunity at hand for future apicultural landscape restoration efforts in the country (Saudi Arabia) in which its Acacia species are reported to be threatened because of their narrow genetic diversity (Al-Mefarrej, 2012).

3.4. Seedling survival

Fig. 1 below, presents the survival rate of seedlings in the first four months after date of emergence. During the early stages of

| Species of interest | Ranks given out of 12 | Sum | Average rank |
|--------------------|----------------------|-----|--------------|
| R1 | R2 | R3 | R4 | R5 | R6 | R7 | R8 |
| A. ehrenbergiana | 4 | 8 | 10 | 9 | 10 | 7 | 8 | 9 | 65 | 8 |
| A. tortilis | 3 | 2 | 5 | 2 | 2 | 2 | 1 | 19 | 2 |
| A. hamulosa | 6 | 10 | 10 | 7 | 8 | 9 | 6 | 11 | 67 | 8 |
| A. johnwoodii | 5 | 7 | 9 | 9 | 8 | 6 | 8 | 8 | 60 | 8 |
| A. nerfota | 11 | 8 | 8 | 9 | 12 | 8 | 11 | 9 | 76 | 10 |
| A. osak | 7 | 6 | 7 | 8 | 7 | 8 | 7 | 4 | 54 | 7 |
| A. origena | 7 | 4 | 3 | 4 | 4 | 4 | 4 | 34 | 4 |
| A. gerrardii | 7 | 4 | 3 | 4 | 4 | 4 | 4 | 34 | 4 |
| A. etbaica | 10 | 11 | 6 | 6 | 8 | 8 | 7 | 62 | 8 |
| Ziziphus spina-christi | 1 | 1 | 2 | 1 | 1 | 3 | 3 | 1 | 13 | 2 |
| Lavendula dentata | 2 | 3 | 1 | 3 | 3 | 1 | 1 | 3 | 17 | 2 |
| D. v. angustifolia | 12 | 12 | 12 | 12 | 11 | 12 | 12 | 95 | 12 |

Where R stands for the rankers and the least number implies the most preferred. D. v. angustifolia = Dodonaea viscosa subsp. angustifolia (L.F.)J.C.West
establishment, higher deaths were recorded in *A. tortilis* and *A. oerfota* while *A. hamulosa's* and *A. ehrenbergiana's* survival decreases steadily around the second month of establishment period. This might be due to the challenge to adapt to the change in growing altitudes (low to mid altitudes), though the study was conducted in a nursery, where many factors kept controlled at the higher altitudes using greenhouse.

Throughout the experimentation period, more than 55% of the species, *A. gerrardii*, *A. etbaica*, *A. origena*, *A. asak* and *A. johnwoodii* showed higher survival rates, showing good adaptation potentials of the species which will benefit for any possible incorporation in to apicultural landscape restoration programs within their growing ecologies. Moreover, these species might have been advantaged of the experimentation site, situated within their growing altitudinal range. *Acacia hamulosa*’s relatively higher death rate might be related to the higher infestation of Powdery mildew (Table 2) like the case in Mzoma, (1988), where the fungal disease had been the major threat to his trial involving 14 Acacia species. In addition, its relatively lower adaptability to altitudinal change and associated environmental variations might have been additional reasons as the test had been done ex-situ.

### 4. Conclusion

In attaining the objective of evaluating nursery level performances of selected native Acacia trees, species were prioritized, seedlings were prepared and compared. Based on results, beekeepers confirmed that the major Acacia species under study are still
important in rehabilitation works. Nursery level performances of all Acacia species under experimentation were within the acceptable performance ranges. This information may be helpful to consider the species as competent biological tools for apicultural landscape restoration efforts. However, the later idea shall be confirmed through the conduction of onsite studies to evaluate their performance in their specific growing ecologies.

Acknowledgement

National Plan for Science, Technology and Innovation (MAARIFAH), King Abdul-Aziz for Science and Technology, Kingdom of Saudi Arabia is the fund provider with a grant number of 13-AGR2118-02, to which authors are grateful.

References

Adgaba N. Al-Ghamdi A., Shenkute A. G., Ismaiel S., Al-Khtani S., Tadesse Y., Ansari M.J., Abebe W., Abdulaziz M. Q. A. 2014. Socio-economic analysis of beekeeping and determinants of box hive technology adoption in the Kingdom of Saudi Arabia. Journal of Animal and Plant Science. 24(6), Pp: 1876-1884, ISSN: 1018-7081.

Al-Ghamdi, A. A. 2007. Beekeeping and honey production in Saudi Arabia. Fifth Conference of Arab Beekeepers Association held Nov. 25-28/2007. Tripoli, Libya.

Al-Shiha, M., Darfaoui, M., 2012. Forest conservation and sustainable management in Saudi Arabia. Ministry of Agriculture and Food and Agriculture Organization of the United Nations. unpublished.

Martin, Arnaud, Khater, Carla, Mineau, Herve, Puech, Suzette, 2002. Rehabilitation ecology by revegetation. Approach and results from two Mediterranean countries. Korean. Journal of Ecology 25 (1), 9–17. https://doi.org/10.5141/JEFB.2002.25.1.009.

Azad, S., Manik, M.R., Hasan, S., et al., 2011. Effect of different pre-sowing treatments on seed germination percentage and growth performance of Acacia auriculiformis. Journal of Forestry Research 22, 183. https://doi.org/10.1007/s11676-011-0147-y.

Blakesley, D., Anusarsunthorn, V., Kerby, J., Navakithbunrug, P., Kuarak, C., Zangkum, S., Hardwick, K., Elliott, S. 2000. Nursery technology and tree species selection for restoring forest biodiversity in northern Thailand. In Forest Restoration for Wildlife Conservation; Elliott, S., Kerby, J., Blakesley, D., Hardwick, K., Woods, K., Anusarsunthorn, V., Eds. Chiang Mai University: Chiang Mai, Thailand. 2000. pp. 207–222.

Diane Haase and Robin Rose. 2004. Evaluating Seedling Quality: The Basics. Accessed, Jan., 22/2020. Available: http://www.cfffa-owoa.org/NWWoodlands/reforestation-planting-seedlings/2004winter-EvaluatingSeedlingQuality.pdf

El-Azaiz, El-Sayed, Sourour, M. M., Belal, A. H., Khalilah, E. A. 2013. Improving Acacia tortilis seeds germination by breaking dormancy treatments. International Journal of Advanced Biological Research, 3(1), 103-109. ISSN 2250 – 3560.

El-Juhany, L.L, Aref, I.M., Al-Ghamdi, M.A., 2009. Effects of Different Pretreatments on Seed Germination and Early Establishment of the Seedlings of Juniperus procera. World Applied Sciences Journal 7 (5), 616–624.

El-Fadl, Mohammed A., 2013. Growth performance and physiological characteristics of seedlings of six tropical dryland forest tree species in the Sudan. Journal of Natural Resources and Environmental Studies 1 (2), 25–33.

Elfadl, Mohammed A., 2013. Growth performance and physiological characteristics of seedlings of six tropical dryland forest tree species in the Sudan. Journal of Natural Resources and Environmental Studies 1 (2), 25–33.

El-Juhany, L. I., Aref, I. M., Al-Ghamdi, M. A., 2009. Effects of different pretreatments on seed germination and early establishment of the seedlings of Juniperus procera. World Applied Sciences Journal 7 (5), 616–624.

El-Fadl, Mohammed A., 2013. Growth performance and physiological characteristics of seedlings of six tropical dryland forest tree species in the Sudan. Journal of Natural Resources and Environmental Studies 1 (2), 25–33.

El-Juhany, L. I., Aref, I. M., Al-Ghamdi, M. A., 2009. Effects of different pretreatments on seed germination and early establishment of the seedlings of Juniperus procera. World Applied Sciences Journal 7 (5), 616–624.

FES (Foundation for Ecological Security). 2008. Ecological Restoration. FES international sourcebook. Pp 109.

Hall, M., Neale, S., Al-Abhasi, T.M., Miller, A.G., 2010. Arabia’s tallest trees: ecology, distribution, and conservation status of the regionally endangered tree species Mimmosops laurifolia. Nordic Journal of Botany 28 (2), 240–245.

Al-Mefarrej, H., 2012. Diversity and frequency of Acacia spp. in three regions in the Kingdom of Saudi Arabia. African Journal of Biotechnology 11 (52), 11420–11430. https://doi.org/10.5897/AJB12.1703.

Koester, R.P., Skoneczka, J.A., Cary, T.K., Diers, B.W., Ainsworth, E.A., 2014. Historical gains in soybean (Glycine max Merr.) seed yield are driven by linear increases in light interception, energy conversion, and partitioning efficiencies. J. Exp. Bot. 65, 3311–3321. https://doi.org/10.1093/jxb/eru187.

Elfadl, Mohammed A., 2013. Growth performance and physiological characteristics of seedlings of six tropical dryland forest tree species in the Sudan. Journal of Natural Resources and Environmental Studies 1 (2), 25–33.

Ngulube, Mzoma R., 1988. Survival and growth of seedlings of 14 Australian dry zone Acacias under nursery conditions in Zambia. Malawi. Forest Ecology and Management 25 (3–4), 291–297.

Nuru adgaba, Ahmad Al-Ghamdi, Yilma Tadesse, Awraris Getachew, Awad M. Awad, Mohammed J. Ansari, Ayman A. Oways, Seif Eldin A. Mohammed, Abdulaziz S. Alqarni. 2017. Nectar secretion dynamics and honey production potentials of some major honey plants in Saudi Arabia. Saudi Journal of Biological Sciences (2017) 24, 180-191.

Borah, Rajib Kumar, Gogoi, Jitu, Gogoi, Bhadesh, Sharma, Gauri Sankar, 2012. New record of powdery mildew on Acacia mangium willd. in India. Journal of Plant Protection Research, 52 (1).

SAS Institute Inc., 2002. JMP-5 Statistical Software, Version 5.Cary, NC, USA.