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RESEARCH ARTICLE

ASSESSING BIOMASS PRODUCTION OF ACACIA AMPLICEPS USING DIFFERENT WATER SALINITY LEVELS IN ENTISOLS UNDER HYPERARID CONDITIONS OF UNITED ARAB EMIRATES

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ABSTRACT

Salinity problem in crop production will become worse in areas with rapidly growing human population and limited water resources, which necessitates the use of saline water for irrigation. Cultivation of salt tolerant perennial trees using saline water is potentially an important strategy to save fresh water resources and maximize the forage yield of small-scale farms in the marginal and saline environments. With the population growth, increased per capita consumption, higher living standards the meat consumption will rise to nearly 73% and dairy consumption 58% by 2050 over current levels. Therefore, livestock numbers are expected to be doubled by 2050, which means 30% more forage would be required to meet this increased demand, which will be major challenge because salinity and fresh water scarcity are becoming major constraints to agricultural productivity, with most of the rangelands already under stress from overgrazing. To exploit alternate forage production systems, a three-year (2014-2016) trial has been conducted on Australian tree '*Acacia ampliceps'* which has diversified benefits and highly salt tolerant. *A. ampliceps* have extensive root system and can fix atmospheric nitrogen, survive for many years after establishment and are resilient to high temperatures, salinity and strong winds. The *A. ampliceps* was grown with and without fertilizer application owing to its leguminous nature (atmospheric nitrogen fixation) to evaluate the difference in biomass production. The trees were irrigated with three water salinity levels (10, 20, 30 dS/m) over three years (2014-2016). The trees were harvested once a year and fresh as well as dry biomass determined to evaluate forage production under salt stress and hyperarid sandy soils '*Entisols*' environment of United Arab Emirates. Comparison of fresh biomass production with the application of different salinity waters clearly shows that the salinity increase has devastating effect on the reduction of fresh biomass, the highest being with 10 dS/m salinity water and the lowest with 30 dS/m. This reduction is universal with the increase of salinity regardless of whether fertilizer was applied or not. The fresh biomass with 10 dS/m water salinity ranged between 14.49 and 17.64 tons/ha/year compared to the lowest fresh biomass range between 4.80 and 5.96 tons/ha/year with the highest water salinity application (30 dS/m). With 20 dS/m water application fresh biomass ranged between 7.77 and 8.83 tons/ha/year. The results have shown great promise to introduce *A. ampliceps* in infertile sandy desert soils owing to its adaptability in hot environment and nitrogen fixation capacity to save fertilizers.

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INTRODUCTION

Salinity problem in crop production will become worse in areas with rapidly growing human population and limited water resources, which force growers to use poor quality saline water for irrigation, however, it should be noted that soil salinity is a serious threat limiting crop production (Munns, 2002), as it adversely reduces the overall productivity of the ecosystem. With the population growth, increased per capita consumption, increasing urbanization and higher living standards the meat consumption will rise to nearly 73% and dairy consumption 58% by 2050 over current levels (Thornton, 2010; FAO, 2011). Much of the future forage demand will be met by large scale intensive animal rearing operations. As per Steinfeld *et al* (2006) livestock numbers are expected to be doubled by 2050, which means that more feed and forage will need to be

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produced. Bouwman *et al* (2005) estimated that 30% more grass would be required to meet this increased demand, which will be major challenge because salinity and fresh water scarcity are becoming major constraints to agricultural productivity, with most of the rangelands already under stress from overgrazing (Rao *et al*., 2017). In the context of the Middle East and North Africa (MENA) region, water scarcity is one of the most important food-security issues, with fresh water availability in the region expected to drop 50% by 2050 (World Bank, 2007). Agriculture already accounts for >80% of the water withdrawals in the region and increasing competition for good-quality water among different water-use sectors is expected to limit severely the availability of freshwater for irrigation. To reduce the pressure on fresh water, non-conventional sources of water will have to be tapped to meet the needs of agriculture, especially in the dry areas. Hence, alternative agronomic or management practices that allow the use of marginal-quality water such as saline and brackish water will be important. In this context, growing salt tolerant trees and grasses for livestock feed production offers a major opportunity to use land and water resources that are too saline for conventional forage crops (Malcolm, 1996; Swingle *et al.,* 1996; Glenn, 1999; Qadir *et al.,* 2014). Although higher salinity levels increasingly restrict productivity and the range of plants that can be grown, several plant species can grow successfully under saline conditions, including forage species that fit well into livestock and mixed farming systems (Panta *et al*., 2014). However, only a limited number of on-farm studies have evaluated such species on a large scale under irrigation with water of high salinity for forage production and animal use.

In this context, growing salt tolerant trees offers economic and ecological advantages. Considering the mitigation impact of trees, it removes atmospheric carbon (C) and stores in the terrestrial biosphere through photosynthesis, which have been proposed to compensate greenhouse gas (GHG) emissions. Forest lands are believed to be a major potential sink and could absorb large quantities of C if trees are introduced to the agricultural system (Agroforestry) which is judiciously managed together with crops and/or animals. Forage production under hot arid climate and saline water conditions is a challenge, however, if local forage production is not made, then the countries under such harsh climate conditions must pay significant finance to other countries to import forages to feed their livestock or import meet with huge costs. *A.ampliceps* is a shrub or tree belonging to the genus Acacia and the subgenus Phyllodineae. It is native to an area in the Northern Territory and the Kimberley and Pilbara regions of Western Australia.

The bushy and glabrous shrub or tree typically grows to a height of 1.5 to 8 meters (5 to 26 ft). It blooms from May to August and produces cream flowers. *Acacia ampliceps* is one of the most successful plant species tried in many countries, from Central Asia to North Africa. The tree fixes atmospheric nitrogen and provides forage/fodder for animals and is also a source for bio-energy. The plant provides a favorable environment conducive for under-storey plants. The seeds of certain Australian Acacias have formed a part of traditional diets of Australian Aborigines and their usage has been well documented (O'Connell *et al*., 1983; Latz, 1995; Devitt, 1992). These species generally occur in the hot dry arid semi-arid tropics of Australia and are well adapted to similar regions of the Sahelian zone of West Africa such as at Maradi, Niger. Tree species on nutrient-exhausted sandy soils or interplanting them with crop species is a common silvicultural practice that utilizes the ability of N_2-fixers to replenish nutrient stocks and increase the productivity of agro forestry and silvopastoral systems, particularly in tropical regions. Afforestation, as an alternative land use system for degraded agricultural areas, can be further enhanced by planting both N_2-fixing trees and non-N-fixing grasses that also provide fuel wood, high-protein livestock fodder and timber. Increased production per unit area and nutrient management are very important factors in increasing forage production. To be competitive, an agricultural system must be cost-effective and should result in better products. Moreover, in less productive areas and wastelands, mineral deficiency, especially nitrogen, is a major limitation. The addition of expensive fertilizers in such wastelands makes the whole system unprofitable for farmers. Production of salt tolerant trees using saline waters and soils and feeding them to livestock is one of the most sustainable methods of conservation in desert ecosystems, in addition to accomplishing livelihood improvement of the farmers. This is very relevant under United Arab Emirates conditions where such adverse climatic conditions exist. To assess the forage production under such conditions a long-term (2014-2016) experiment was conducted on salt tolerant tree (*Acacia ampliceps*) using saline waters of salinity 10, 20 and 30 dS/m.

Scientific classification of A. ampliceps (common name salt wattle)

Kingdom	Plantae
Clade	Angiosperms, Eudicot, Rosids
Order	Fabales
Family	Fabaceae
Genus	Acacia
Species	A. ampliceps

The botanical name is derived from the Latin amplus (large) and -ceps (head) in allusion to the large flowers heads which are typical of this species. It has shallow root system and high tolerance to saline and sodic and water logged conditions, but intolerant of acid soils.

A. ampliceps – distribution and ecology: According to Wikipedia (http://worldwidewattle.com/speciesgallery/descriptions/pilbara/html/ampliceps.htm) *A. ampliceps* is widespread in northwest and northern Western Australia to north-central Northern Territory. It also widespreads in the Pilbara and has been recorded from Enderby Island and West Lewis islands in the Dampier Archipelago, and from the Montebello Islands; it is also possibly on Thevenard Island (about 150 km southwest of Enderby Island). It typically grows along watercourses (in sand or clay) but also occurs in swales within coastal sand hills in some areas; it commonly forms dense stands or thickets on account of its root-suckering habit.

Why *Acacia ampliceps* as forage crop?: There is great potential of using Australian Acacias, for example *A. ampliceps* under arid conditions. *A. ampliceps* have extensive root system and perennial, therefore, they survive for many years after establishment and are resilient to high temperatures, salinity and strong winds. They are an example of a crop that is drought-tolerant, yields well and requires minimal nitrogen inputs due to its capacity to fix atmospheric nitrogen (N fixing tree)-leguminous crop.

It creates multiple benefits for the agricultural system, they are drought-tolerant, increase fertility, produce leaf material for mulching, when pruned the feedstock can be used for biochar production-thus handling green waste sustainably, very much suitable to produce livestock feed and nectar for bee fodder, and in the UAE and perhaps other countries *A. ampliceps* is also used as windbreaks preventing crop damage and controlling wind erosion. The *A. ampliceps*, in addition to fixing atmospheric nitrogen, provides forage/fodder for animals, a source for bioenergy and an environment conducive for under-storied plants. Further details on its utilization potential, silviculture and ecologicl preferences are provided by various researchers (Marcar *et al*., 1995; Turnbull, 1986; Doran and Turnbull, 1997). In general, the Australian Acacia species have great untapped potential as multipurpose tree species in agroforestry systems in hot regions. This multi-purpose Acacia, which also produce highly nutritious seed, have great potential to become a significant component of a new 'green revolution' for the Sahelian zone of West Africa (Harwood *et al.,* 1999). However, Vietmeyer (1996) has argued that the '*green revolution'* that had a dramatic impact on food production in the tropical and sub-tropical world has by-passed the semi-arid zones of Africa. If there is to be a '*green revolution'* for arid and the semi-arid tropics, then it needs to come through plants that thrive under such conditions, yield well and require minimum inputs (Rinaudo *et al.,* 2002). Therefore, plants need to be domesticated to suit the prevailing environmental conditions, rather than a '*green revolution'* to suit the plants by modifying the environment (i.e. via irrigation, fertilizers, herbicides, pesticides). Therefore, we see great potential of *A. ampliceps* in Africa and middleeast region.

Objectives

The following are the objectives of the study:

- To assess the potential of *A. ampliceps* for biomass production at three (10, 20, 30 dS/m) water salinity levels under hot arid climate of UAE
- Evaluate the need of fertilizers for *A. ampliceps* forage production in infertile sandy soil

MATERIALS AND METHODS

The experiment was conducted at International Center for Biosaline Agriculture (ICBA), Dubai, United Arab Emirates (25◦13"N and 55◦17"E). The experimental station is in an arid desert climate where temperature is high, and rainfall is negligible from April to November (Karim and Al-Dakheel, 2006). The experimental trial was conducted over a period of three years (2014-2016) to assess the biomass production of *A. ampliceps* using three water salinity levels (10, 20, 30 dS/m) and with and without fertilizer application.

Landscape and soil classification of the trial site: The experimental site is level, loose sandy surface, very deep and calcareous. Due to sandy nature, the soil has very high drainage capacity (well to somewhat excessively drained) and is moderate to rapidly permeable. The soil is developed from windblown sandy calcareous material and is highly prone to wind erosion, and to avoid the effect of wind the experimental site is protected by wind breakers (*Prosopis cinerarie* -Ghaf trees).

The views of experimental trial are presented as plate 1. The experimental site was assessed for taxonomic class using the norms and standards of the United States Department of Agriculture "Soil Taxonomy" (Soil Survey Division staff, 1993; Shahid *et al.,* 2014; Soil Survey Staff, 2014). The dominant soil of the station is "Carbonatic, Hyperthermic Typic Torripsamments" where:

Carbonatic is the mineralogy class i.e., more than 40% $CaCO_3$ equivalents in fine earth fraction (i.e., less than 2mm). *Hyperthermic* is soil temperature regime (the mean annual soil temperature is 22ºC or higher, and the difference between mean summer and mean winter soil temperature is more than 6ºC at a depth of 50 cm from the soil surface). *Typic torripsamment* indicates typical desert sandy soil at soil subgroup level of USDA Soil Taxonomy.

Raising nursery of A. ampliceps and transplantation: To initiate *A. ampliceps* plants, seeds were sown in 1L volume plastic bags with hole at the bottom. A mixture of soil and green compost (4:1 by volume) was prepared and properly mixed to have uniform mixture. The seeds were treated with hot water to break the dormancy. The soil/compost mixture was added to plastic bags and seeds of *A. ampliceps* were placed at 1 cm depth and irrigated with fresh water. All seeds were fully germinated within 4-6 days. The propagules were divided into three groups then acclimatized for 8 weeks to finally accomplish irrigation with EC of 10, 20 and 30 dS/m. The acclimatization took place in green house where required salinity levels were achieved through stepwise increase of water salinity, e.g., final EC of 10 dS/m was reached from 2.5, 5, and 10 dS/m over a period of 8 weeks, similarly EC 20 was achieved through 4 steps (5, 10, 15 and 20 dS/m) and 30 dS/m (5, 10, 20 and 30 dS/m). Ten weeks old acclimatized trees were transplanted to trial site and irrigated with three water salinities (10, 20 and 30 dS/m). Prior to transplantation, pits of 50 cm wide and 50 cm deep were prepared as per trial layout plan. The pits were then filled with mixture of soil and compost (4:1 volume basis) and trees were transplanted. For the current trial, eighty grams of compound 20:20:20 ($N:P_2O_5:K_2O$) fertilizer was mixed with upper 15 cm of soil surface in the pit once a year and pits were irrigated through bubbler irrigation system using water salinity of 10, 20 and 30 dS/m. Half of *A. ampliceps* trees did not receive fertilizer application. Data was collected during 2014, 2015 and 2016 to assess biomass using three salinity levels and with and without fertilizer application.

Irrigation water salinity and irrigation systems used in experimental trial: Three water salinity levels (EC 10, 20, 30 dS/m) were used in the trial from three different wells at ICBA station. The irrigation was accomplished using bubbler irrigation system. The three salinity levels were maintained constantly throughout the cropping season during all the years. Each salinity level was monitored twice a week using a portable EC meter.

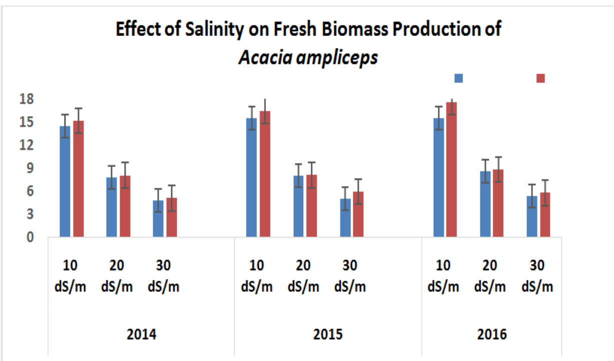
Basin irrigation system – Bubbler system: In basin irrigation, bunds were created around the circular basin to prevent the water flowing out, thus, confining the irrigation water to the target area. This method is commonly practiced for date palms and trees grown in small basins, with the tree being planted in the center of the basin. It should be kept in mind that the basin method is most suitable for sandy soils where water leaches down quickly. However, if the crops or trees are sensitive to ponding water, this method should be avoided. In basin irrigation system, surface salinity is controlled, although at the subsurface wetting zone soil salinity will develop. In the basin a bubbler is installed for irrigation which supplies water as circular water system. When the trees were small, immediately after transplantation, each tree was irrigated through bubbler irrigation system based on standard ETc requirement and continued till the trial completed in 2016. *Prosopis cineraria* (Ghaf trees) were already roadside planted as strategy to protect ICBA trials from wind effect.

Biomass assessment: The harvested biomass from various trees was composited and extrapolated in terms of tons/hectare/year in three years 2014 to 2016. The biomass was recorded as fresh (weighed immediately on-site using balance) biomass and dry biomass after drying at 65 ^{o}C to constant weight and expressed as tons/ha/year.

RESULTS AND DISCUSSION

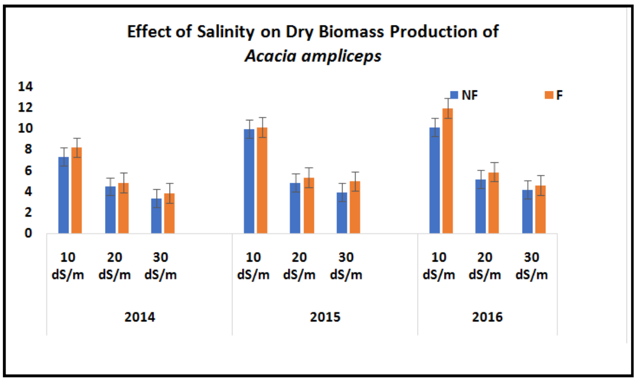
The increasing and decreasing trend of fresh biomass of *A. ampliceps* with and without fertilizer application is shown in tables 1,2 and figures 1,2 respectively.

Assessment of fresh biomass of *Acacia ampliceps:* Productivity of the *A. ampliceps* is evaluated under three salinity levels (10, 20, 30 dS/m) with and without any fertilizer treatments (N:P:K (2:20:20)@ 80 grams/tree). The results in terms of fresh and dry biomass are presented in figures 1, 2 and tables 1 and 2 for three years (2014, 2015 and 2016).



(NF = no fertilizer; F = with fertilizer; TFW = Total fresh weight)

Figure 1. Fresh biomass of *A. ampliceps* with the application of 3 water salinity levels



(NF = no fertilizer; F = with fertilizer; TDW = Total dry weight)

Figure 2. Dry biomass of *A. ampliceps* with the application of 3 water salinity levels

Plate 1. *Acacia ampliceps*-harvested biomass (top); *Acacia ampliceps* grove

Table 1 and Figure 1 clearly demonstrate that the highest fresh biomass was recorded with the application of low salinity water (10 dS/m), however, at same water salinity (10 dS/m) a slight increase was recorded over the years and maximum fresh biomass (17.64 tons/ha/year) was recorded during 2016 with fertilizer application and 10 dS/m irrigation water. Overall increase in fresh biomass at all water salinity levels was recorded with the addition of fertilizers. However, variable increase was recorded, such as in six locations biomass increase was less than 6% and in two locations biomass increase was 14% (30 dS/m year 2015) and 12% (10 dS/m year 2016), which indicates that the plant can grow under poor mineral conditions. Comparison of fresh biomass production with the application of different salinity waters clearly shows that the salinity increase has devastating effect on the reduction of fresh biomass, the highest being with 10 dS/m salinity water and the lowest with 30 dS/m. This reduction is universal regardless of with or without fertilizer application. The fresh biomass ranged between 14.49 and 17.64 tons/ha/year compared to the lowest fresh biomass range between 4.80 and 5.96 tons/ha/year with the highest water salinity application (30 dS/m). With 20 dS/m water application fresh biomass ranged between 7.77 and 8.83 tons/ha/year (table 1, Figure 1). It is believed that *A. ampliceps* survived under increasing salt stress by already established mechanisms that include vacuolisation of toxic Na^{+} and Cl^{-} in mature or senescing leaves, secretion of excess salts by salt glands, and accumulation of osmolytes such as proline and glycine betaine (Roy and Chakraborty, 2014).

Table 1: Assessment of fresh biomass of *A. ampliceps* (tons/ha/year) with respect to different water salinity levels during 2014 to 2016

Water salinity EC (dS/m)	2014		2015		2016	
	NF	F	NF	F	NF	F
10	14.49	15.16	15.52	16.49	15.56	17.64
20	7.77	8.05	7.98	8.09	8.61	8.83
30	4.80	5.10	5.07	5.96	5.36	5.77

NF = no fertilizer application; F = fertilizer application

Table 2: Assessment of dry biomass of *A. ampliceps* (tons/ha/year) with respect to different water salinity levels during 2014 to 2016

Water salinity EC dS/m	2014		2015		2016	
	NF	F	NF	F	NF	F
10	7.32	8.21	9.98	10.16	10.12	11.96
20	4.49	4.88	4.87	5.36	5.17	5.89
30	3.41	3.86	3.95	4.99	4.22	4.65

NF = no fertilizer application; F = fertilizer application

Foliage of *A. ampliceps* harvested at 2 m height from ground surface produced approximately 7.5 tons dry matter/ha/year at higher salinity levels. To determine the forage potential of the leaves, younger and older leaves of the plants were also evaluated for moisture, ash and protein content. No significant differences were observed among different salinity treatments and between young and old leaves for dry matter, moisture content, organic matter and ash content.

Assessment of dry biomass of *Acacia ampliceps*: Portion of fresh biomass was dried at 65 ^{o}C in an oven to a constant weight. The results are presented in table 2 and Figure 2. A similar trend as observed in fresh biomass has been found in the dry biomass production. In general, the highest dry biomass is recorded with low salinity water (10 dS/m) and the lowest with the application of the highest salinity water (30 dS/m). Regardless of fertilizer application the dry biomass has been decreased with the increase of water salinity levels. At lowest (10 dS/m) salinity water dry biomass ranged between 7.32 and 11.96 tons/ha/year (table 2, Figure 2). At medium water salinity (20 dS/m) level it ranges between 4.49 and 5.89 tons/ha/year, whereas at the highest water salinity dry biomass ranged between 3.41 and 4.99 tons/ha/year. In general, higher dry biomass was recorded with fertilizer application relative to where fertilizer was not applied, however, the decrease is less than 15%, which indicates that the *A. ampliceps* can grow under poor mineral conditions. Minimum increase in dry biomass due to fertilizer application is 2 % (water salinity 10 dS/m in 2015) and maximum increase is 15% (water salinity 10 dS/m in 2016). The slight difference in biomass increase can be attributed to N fixing capacity of *A. ampliceps*.

Conclusions and Recommendations

The results of this study show that *A. ampliceps* provides excellent alternatives for sustainable forage production in saline water and infertile sandy soil 'Entisols'. It is apparent that the level of salinity in the water is the prime determinant for *A. ampliceps* forage production. Higher salinity levels increasingly restricts productivity. Comparison of biomass at different water salinity levels and with and without fertilizer application suggests that at higher salinity levels, the effect of fertilizers is not very prominent, and other measures must be taken to maximize productivity at high levels of salinity. The *A. ampliceps* performed well in the UAE hot arid conditions, however, it is proposed to evaluate, select and breed other varieties as well. There is scarce information about seeds nutritional values, therefore efforts are required to analyze seeds for human and animal food potential. Direct seeding instead of growing first in nurseries need to be assessed to ensure rapid, reliable and cost-effective propagation in the field. Re-evaluation of a broader genetic base of other deeper rooting Acacia species suitable for hot arid climate need to be done.

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