Suitability of exotic *Acacia* as fodder species on highly saline silty black soil of wild ass sanctuary (WAS) of little rann of Kutch, Gujarat

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Abstract

Acacia ampliceps (salt wattle) is a very fast growing shrub/ small tree from northwestern Australia that has considerable promise for fodder plantings on alkaline/ saline soils, especially where its roots have access to a shallow brackish water table. *A. bivenosa* (two nerved wattle) makes a complex with *A. ampliceps*. Research trials were laid on black silty clay (medium), soil depth: 40-75 cm at Kordha, Sami Range in Patan, Gujarat at the fringe of Wild Ass Sanctuary in July 2007 to find out suitable exotic fodder plant species with appropriate planting practice. Trials were laid with control (T₁), wheat husk (1/2 kg) (T₂), FYM (5kg) (T₃), wheat husk + FYM (T₄), barley husk (250g) (T₅) and FYM + barley husk (T₆) treatments. Randomised block design with three replications was applied. Spacing was 4 m X 4 m for *A. bivenosa* (12 plants/ treatment and 3m x 3m for *A. ampliceps* (16 plants/ treatment). Plantation suffered badly due to heat shock during summer in 2009. The initial mean survival of *A. ampliceps* was 72.6 % and growth was 161.3 cm (height) and 169.5 cm (crown diameter) at 18 months. Plants maintained which were shrubby in nature and the survived plants were estimated for total biomass production ranging from 13kg in T₃ and T₅ treatments with 5.6 and 6.7 kg leaf mass respectively. Performance of *A. bivenosa* was better than *A. ampliceps*. It maintained 86.9% mean survival at 18 months and 40.5% at 48 months ranging from 66.1% in T₂ and 22.2% in control. Treatments influenced the biomass yield and all the treatments recorded higher biomass as compared to control (3.43 kg) at 36 months of age in case of *A. bivenosa*. Maximum (12.68 kg tree⁻¹) biomass yield was obtained in T₃ (wheat straw) treatment followed by in treatment T₂ (10.22 kg tree⁻¹). Both the species flowered and produced viable

seed. Natural germination of *A. ampliceps* was observed. They did not suppress the native vegetation, thus have potential to be introduced as fodder species.

Key words: *Acacia ampliceps*, *A. bivenosa*, survival, growth, biomass, wheat and barley husk, FYM

Introduction

Salt affected soils are wide spread in all climatic zones but these dominantly occur in arid and semi-arid regions. In India, large area 6.7 m ha (Sharma et al. 2004) suffers from salinity and alkalinity problems in different states. Approximately 2.60 m ha area is affected with salt problem in states of Rajasthan (0.38 m ha) and Gujarat (2.22 m ha). In case of Gujarat these are both inland and coastal salt affected soils and mainly distributed in Kutch, Patan, Surendranagar, Banaskantha, Jamnagar, Porbander, Junagarh, Bhavnagar, Ahmedabad, Bharuch and Surat districts. The coastal saline area of Gujarat (0.714 m ha), especially Saurashtra and Kutch, receives lowest rainfall and thus, in presence of high saline ground water, poses more serious problems of management. Appropriate tree species and planting methods can help rehabilitation of arid salty areas.

The Wild Ass (*Equus hemionus khur*) Sanctuary (WAS) is located in the Little Rann of Kutch of the Gujarat State in India. It covers an area of 4954 km². The sanctuary lies between the latitude 23.26° North and longitude 71.20° East (Anon 1999) and is spread out in the districts of Surendranagar, Banaskantha, Patan, Kutch and Rajkot in Gujarat. The Rann is one of the most remarkable and unique landscapes of its kind in the entire world. It is a vast desiccated, unbroken bare surface of dark silt, encrusted with salts, which transforms into a spectacular coastal wetland after the rains. Vegetation is largely xerophytic with the ground cover predominated by ephemerals. Their active growth is triggered by the advent of monsoon rains. Although the islands and fringes both have been colonized by *Prosopis juliflora*, the islands have a richer floral diversity including indigenous plants like *Suaeda* spp., *Salvadora persica*, *Capparis decidua*, *Calotropis procera*, *Tamarix* sp., *Aeluropus lagopoides*, *Cressa cretica*, *Sporobolus* spp. and *Prosopis cineraria* etc (Anon 1999).

A. ampliceps Maslin (salt wattle) belongs to family Mimosaceae is native to South Western Australia. It is a fast growing dense shrub or small tree 2- 8 m high, with a spreading crown (6-12 m wide) having multi stems (1- 4 no.) per stump. It can be found on sandy or loamy alluvial soils with an alkaline reaction and is highly tolerant to salinity but intolerant to acid soils and water-logging. It has great potential for use in reclamation of salt-affected areas and as a low windbreak. *A. bivenosa* (two nerved wattle), a shrub normally 1-3 m in height, sometimes reaching 5 m, makes a complex with *A. ampliceps* (Midgley et al. 1986; Aswathappa et al. 1987). Research trials were laid with *A. ampliceps* and *A. bivenosa* on black silty clay at Kordha, Sami Range in Patan, Gujarat at the fringe of WAS in

July 2007 to find out suitable exotic and indigenous fodder plant species with appropriate planting practice. Results of 42 and 48 months of *A. ampliceps* and *A. bivenosa* shrubs for their survival, growth and biomass are presented here.

Materials and Methods

The area is characterized by dry (semi-arid) tropical monsoon climate. It receives an average annual rainfall of less than 400 mm. Average maximum and minimum temperatures are about 42⁰ C and 12⁰ C, respectively. The area has highest annual evaporation rate in the country. The soil has vast desiccated bare mud-flats consisting of dark silt and encrusted with salts. Though it is flooded by tidal and freshwaters every year, the mud-flats of the Rann have not become soft or slimy except in a few isolated patches (Anon, 1999). An area (~ 2 ha) was selected near Kordha village in Sami range, Patan. The initial soil status of the experimental site was summarized in Table 1. Black silty clay soil (medium) texture and Soil depth: 40-75 cm. The periodic annual rainfall is summarized in Table 2.

Table 1. Soil status of soil of Kordha (Patan) experimental site

Soil depth (cm)	pH ₂	EC ₂ (dSm ⁻¹)	% SOC	% CaCO ₃
0-20	9.23	7.82	0.17	6.27
20-40	8.35	17.00	0.26	7.02
40-60	8.35	20.7	0.31	7.59
60-80	8.30	15.82	0.19	7.48

Table 2. Periodic annual rainfall

Year	Rainfall data (mm), Patan	Rainfall data (mm) Kordha, Hariz
2006	-	728.0
2007	849.5	678.0
2008	573.3	-
2009	295.7	214.0
2010	868.8	524.0
2011	720.2	560.0

Technical programme

Trials of *A. ampliceps* and *A. bivenosa* were laid with following six treatments (T₁, T₂, T₃, T₄, T₅, T₆) in July 07 after first monsoon rain. Randomized Block Design was used with 3 replications. Spacing was 4m x 4m for *A. bivenosa* and 3m x 3m for *A. ampliceps*. Twelve plants per treatment were taken for *A. bivenosa* and 16 plants / treatment for *A. ampliceps*. Four irrigations were provided in the months of October, December 07 and February, March 08 along with soil working in plant pits. Again irrigation was given in Dec 08 and March 09.

Heat Shock

The year 2009 was characterized by record high mean annual temperature and most parts of the country experienced one of its worst droughts during the southwest (summer) monsoon and North Gujarat was also part of it. Plantation suffered with heat shock in May 09. Around 26-28 May 09 all the plants of *A. ampliceps* were scorched due to salt laden hot winds from Rann side. At that time there was no water in the Vadilal pond. Irrigation was provided immediately after the damage and second after 20 days. Some new leaves were observed. Damage was less in case of *A. bivenosa* followed by deficient monsoon in 2009; plantation faced second heat shock during long intense heat wave in summer 2010. However, the plants did not suffer with any major disease during the whole study period. Casualty replacement was done in June 2008 in *A. ampliceps* trial only. One weeding in experimental trials was done in the month of October 2008 and 2009 respectively, however, subsequently no weeding was done. *A. bivenosa* and *A. ampliceps* plants were periodically grazed by Wild Ass and blue bull in January 2009 to March, 2011.

Field Observations

Plant growth

Initially in the first year survival, height and crown diameter were recorded quarterly, six monthly in the second year and annually afterwards. Collar diameter was recorded with the help of Vernier calipers at the time of biomass estimation for every species. The initial survival and growth of *A. ampliceps* up to 24 months and 36 months for *A. bivenosa* are published earlier (Arya et al. 2010)

Biomass estimation

Component wise biomass study was carried out for *A. bivenosa* in September (post monsoon) 2010 and *A. ampliceps* in March 2011. Mean heights and crown diameter were calculated and were used as selection criteria to select average plant. As survival was less only one plant per treatment was selected for every biomass study and a total of six plants were felled for *A. bivenosa* and five for *A. ampliceps* as there was no survival in control treatment. Above ground biomass was estimated by cutting the plant from the ground level and leaves, branches and stem were separated manually to determine the fresh weight of each parts of the plant in the field. The representative samples from each part were taken to laboratory for estimating oven dry biomass at 65⁰C. Weed mass was estimated by laying 1m x1m quadrates randomly in control plots across the experimental area in all the trials annually. Vegetation was dominated by *Chloris* spp. and *Aristida* spp.

Data analysis

The data collected were analyzed using SPSS statistical software package. The analysis

of variance (two-factor ANOVA) was performed for the various periodic growth parameters of different tree species.

Results and Discussion

A. ampliceps trial

Survival

Periodic percent survival of *A. ampliceps* is summarized in Table 3. After one year, *A. ampliceps* recorded 74.6 % mean percent survival in August 2008. No appreciable change was recorded in mean survival at 18 months (72.6%). Treatments influenced the survival at 12 and 18 months control recorded the minimum while T₂ recorded the maximum survival. Treatments T₂, T₃, T₄ recorded significantly higher survival as compared to T₁, T₅ and T₆ treatments. Effect of replication was also significant. R₃ replication recorded significantly less survival than other two replications. It was 63 to 80% at 12 months and 61 to 78 % at 18 months. Shallow soil depth should be the reason. Similar results are also reported by Ashraf et al. 2006 working on five species of *Acacia*. Although they observed maximum growth under low to medium salinity patches (4-12 dS m⁻¹) showing survival percentage 80-90. However, at high salinity (12-16 dS m⁻¹) the percent survival of *A. ampliceps* was 50%.

Table 3. Periodic % survival (Mean $\pm$ SE) of *A. ampliceps* with different treatments

Treatments	12 m*	18 m	24 m	36 m
T ₁	60.4 $\pm$ 1.0	56.2 $\pm$ 7.2	45.7 $\pm$ 5.4	6.0
T ₂	87.5 $\pm$ 0.0	87.5 $\pm$ 0.0	56.3 $\pm$ 14.4	9.3
T ₃	81.2 $\pm$ 6.3	81.2 $\pm$ 6.3	68.8 $\pm$ 9.6	18.7
T ₄	81.2 $\pm$ 5.7	77.1 $\pm$ 14.6	56.4 $\pm$ 15.6	16.5
T ₅	70.9 $\pm$ 0.4	68.7 $\pm$ 22.5	48.0 $\pm$ 24.0	9.0
T ₆	66.7 $\pm$ 1.1	64.5 $\pm$ 20.5	48.0 $\pm$ 24.5	16.5
Mean	74.6	72.6	53.9	12.7
LSD(0.05)	13.8	14.1	NS	-

T₁: control, T₂: FYM, T₃: Wheat Husk, T₄: FYM + WH, T₅: Bajra Husk, T₆: BH + FYM, *age in months

During the heat shock *A. ampliceps* suffered the maximum damage probably due to its being on the border with maximum height. Initial resprouting was observed in most plants of *A. ampliceps* which were scorched due to salt laden hot winds from Rann side in May 09. However, there was 23% decrease in mean survival which was 53.9% at 24 months to 74.6%

at 12 months. Now it recorded 45.7 % (control) to 68.8% (Wheat husk) survival in different treatments. Treatments positively influenced the survival and T₃ treatments recorded significantly higher survival (68.8%) compared to all other treatments. Due to high soil variation data is not statistically significant. In general causalities were high in shallow soil depth for both the *Acacia* spp. *A. ampliceps* suffered the maximum damage in the summer 09 and after the second successive hot summer mean survival was further reduced to only 12.7% at 36 months, ranging from 06.0 % in control to 18.7% in T₃ (Wheat husk) in different treatments. At 36 months, replacements were undertaken in August 2010. There was no change in survival between 36 - 42 months for the original plants. Arya et al. 2009 reported that management practices enhanced the growth of the two species under arid conditions on black soils. *A. ampliceps* and *A. bivenosa* flowers and produced viable seed within a year while on sandy soil they took three to five years.

Growth

Periodic annual growth is summarized in Table 4. *A. ampliceps* is fast growing species and attained 42.7 to 65.7 cm height, 25.6 to 37.9 cm crown diameter in different treatments within one month. It displayed shrubby nature recording more crown diameter than height.

Table 4. Periodic growth (Mean $\pm$ SE) of *A. ampliceps* with different treatments

Treatments	Height (cm)				Crown diameter (cm)		
	9 m*	18m*	24 m*	36 m*	9 m	24 m*	36 m*
T ₁	92.3 $\pm$ 13.7	159.3 $\pm$ 20.6	139.9 $\pm$ 13.2	138.8 $\pm$ 23.7	105 $\pm$ 13.1	108.4 $\pm$ 8.4	79.1 $\pm$ 12.4
T ₂	118.5 $\pm$ 10.6	177.9 $\pm$ 19.5	167.4 $\pm$ 24.1	165.4 $\pm$ 20.4	132.8 $\pm$ 10.1	145.8 $\pm$ 16.7	98.4 $\pm$ 13.4
T ₃	104.4 $\pm$ 20.9	195.8 $\pm$ 10.8	160.3 $\pm$ 12.4	184.5 $\pm$ 5.5	112.2 $\pm$ 21.5	142.7 $\pm$ 15.6	101.6 $\pm$ 0.3
T ₄	94.0 $\pm$ 14.3	148.5 $\pm$ 20.1	133.0 $\pm$ 28.8	135.5 $\pm$ 22.8	103.2 $\pm$ 16.7	111.4 $\pm$ 27.2	82.3 $\pm$ 14.8
T ₅	92.6 $\pm$ 19.9	144.4 $\pm$ 18.1	115.2 $\pm$ 35.2	114.6 $\pm$ 39.6	107.3 $\pm$ 12.5	89.4 $\pm$ 34.3	59.1 $\pm$ 17.4
T ₆	94.7 $\pm$ 22.8	142.0 $\pm$ 32.3	151.1 $\pm$ 3.9	162.1 $\pm$ 1.6	104.7 $\pm$ 27.6	124.1 $\pm$ 29.9	97.3 $\pm$ 16.0
Mean	99.4	161.3	144.5	150.1	110.9	120.3	86.3

*mean of two replications only

After nine months it reached to 99.4 cm mean height and 110.9 cm as mean crown diameter. Monsoon rains it recorded appreciable incremental growth between 12-18 months. At 18 months of age of *A. ampliceps* plants recorded 55.5% more mean height (161.3 cm) and 38.9% more crown diameter (169.5 cm). The incremental growth in height was ranging from 47.3 to 63.6% and crown diameter 29.6 to 48.9% in various treatments (Table 4). After

heat shock, plants suffered growth damage and at 24 months of age both height (-12%) and crown diameter (-41%) decreased as compared to their values at 18 months. Maximum growth 167.4 cm as height and 145.8 cm as crown diameter was obtained in T₂ treatment (Table 4). With drastically reduced survival, growth also reduced at 36 months while there was slight increase in height (150.1 cm) but crown diameter decreased to 86.3 cm with 28.3% reduction.

Above ground biomass estimation

After Heat shock mean survival was reduced to only 12.7% ranging from 6.0% in control to 18.7% in T₃ (wheat husk) in different treatment. However, some of the surviving trees attained good growth. Based on average growth (height and crown diameter) one tree per treatment was cut and aboveground green and dry biomass data given in Table 5. Since there was only one tree in control hence its biomass was not estimated.

Table 5. Aboveground green and dry biomass yield (kg tree⁻¹) of *A. ampliceps* at 42 months

Treatments	Leaf	Thin Branch	Thick Branch	Stem	Total
Green					
T ₁	-	-	-	-	-
T ₂	5.2 (50.5)*	1.6 (15.5)	1.4 (13.6)	2.1 (20.4)	10.3
T ₃	5.6 (43.0)	2.2 (16.9)	1.8 (13.8)	3.4 (26.2)	13.0
T ₄	2.6 (47.3)	0.4 (7.3)	1.0 (18.2)	1.5 (27.3)	5.5
T ₅	6.7 (51.9)	1.6 (12.4)	2.1 (16.3)	2.5 (19.4)	12.9
T ₆	3.7 (46.8)	1.0 (12.7)	1.2 (15.2)	2.0 (25.3)	7.9
Mean	4.76 (48.0)	1.36 (13.7)	1.5 (15.1)	2.3 (23.2)	9.92
Dry					
T ₁	-	-	-	-	-
T ₂	1.4 (35.0)	0.8 (20.0)	0.7 (17.5)	1.1 (27.5)	4.0
T ₃	1.5 (28.3)	1.1 (20.8)	0.9 (17.0)	1.8 (34.0)	5.3
T ₄	0.7 (31.8)	0.2 (9.1)	0.5 (22.7)	0.8 (36.4)	2.2
T ₅	1.8 (35.3)	0.8 (15.7)	1.1 (21.6)	1.4 (27.5)	5.1
T ₆	1.1 (33.3)	0.5 (15.2)	0.6 (18.2)	1.1 (33.3)	3.3
Mean	1.3 (32.7)	0.68 (17.1)	0.76 (19.1)	1.24 (31.2)	3.98

* Percent contribution to the total biomass

The yield was ranging from 5.5 kg & 2.2 kg in T₄ to 13.01 kg & 5.3 kg in T₃ treatment per tree for green and dry biomass, respectively. Three treatments T₃ (13.01 kg & 5.3 kg), T₅ (12.9 & 5.1 kg) and T₂ (10.3 & 4.0 kg) recorded more green and dry biomass than mean (9.92 & 3.98 kg) respectively. Percent component wise maximum contribution was from leaf (48%) followed by branch (28.8%) and stem (23.2%) in the total green biomass. Results from Auroville Pondicherry, India also in conformity with our experiment and showed that *A.*

ampliceps survived and grew very well at highly saline eroded black soil wasteland and gave sufficient biomass production (Anon 2015).

***A. bivenosa* trial**

Survival

Periodic plant survival is summarized in Table 6. After twelve months, *A. bivenosa* recorded appreciably high mean survival (94.4%) ranging from 91.6% in T₃ to 100% in T₂ treatment. There was slight decrease and after one year, it recorded maximum mean percent survival (87.4%) in August 2008 (Table 6). There was no significant change in survival upto 18 months (86.9% mean survival) but after heat shock in summer, both the *Acacia* species suffer damage. Rain in monsoon season helped in revival and in July 2009, *A. bivenosa* recorded 84.1% as mean survival with 3.9% decrease (Table 6) at 24 months compared to 12 months (87.4%). Heat shock effect continued and *A. bivenosa* maintained high survival after one summer and one drought year with 10.2 % decrease in mean survival, 77.3% at 30 months compared to 12 months (87.4%). There was no effect of treatments on survival of till 30 months.

Table 6. Periodic % survival of *A. bivenosa* (Mean $\pm$ SE) with different treatments

Treatments	12 m	18 m	24 m	30 m	36 m	48 m
T ₁	86.1 $\pm$ 5.5	86.1 $\pm$ 5.5	86.1 $\pm$ 10.0	77.7 $\pm$ 18.2	33.3 $\pm$ 8.3	22.2
T ₂	94.4 $\pm$ 2.8	91.6 $\pm$ 4.8	88.8 $\pm$ 5.6	83.3 $\pm$ 0.0	72.2 $\pm$ 11.1	66.1
T ₃	91.6 $\pm$ 4.8	88.8 $\pm$ 2.8	88.8 $\pm$ 2.8	88.9 $\pm$ 2.8	66.7 $\pm$ 8.3	62.8 $\pm$ 19.4
T ₄	77.7 $\pm$ 10.0	77.7 $\pm$ 10.0	77.7 $\pm$ 12.1	66.7 $\pm$ 16.7	19.5 $\pm$ 5.5	19.5 $\pm$ 4.8
T ₅	88.8 $\pm$ 11.1	88.9 $\pm$ 11.2	88.8 $\pm$ 11.2	83.3 $\pm$ 12.7	52.8 $\pm$ 19.5	46.9 $\pm$ 25
T ₆	86.1 $\pm$ 10.0	88.8 $\pm$ 2.7	74.2 $\pm$ 9.0	63.9 $\pm$ 15.5	33.5 $\pm$ 9.8	25.0 $\pm$ 11.1
Mean	87.4	86.9	84.1	77.3	46.3	40.5
LSD	NS	NS	NS	NS	32.3	-

T₁: control, T₂: FYM, T₃: Wheat Husk, T₄: FYM + WH, T₅: Bajra Husk, T₆: BH + FYM, *age in months

However, second consecutive summer effected the species and the survival was significantly reduced (40.0%) in summer 2010 and recorded as 46.3 % at 36 months of age. Treatment wise maximum reduction was 70.9% in T₄ to 13.3 in T₂. Treatments influenced the survival and T₂ & T₃ recorded significantly higher survival than T₄, T₁ & T₆ treatments. Similar influence of treatments are also reported by Ashraf et al. 2006 working on five species

of *Acacia*. Although they observed maximum growth under low to medium salinity patches (4-12 dS m⁻¹) showing survival percentage 80-90. However, at high salinity (12-16 dS m⁻¹) the percent survival of *A. ampliceps* was 50%. Reduction was influenced by wind direction, hot winds coming from south-west (*Rann* side) damaged the plantation and plants on the border suffer most. Damaged was less on border in the north direction in the vicinity of *P. juliflora* shelter belt. The Shrubby nature of species with very good crown spread may have resulted in continuous water requirement resulting in casualties. Pruning in winter may have checked the casualties. Border row at extreme east with soil depression recorded 70% survival at 36 months.

In June 2011, mean survival of *A. bivenosa* decreased from 46.8% to 40.5% between 36 to 48 months period. Plants were under extreme moisture stress with strong weed competition. Non creation of drainage trench and non removal of weed resulted in non-leaching of salts and competition for available moisture. Thus, excess of salts and moisture stress may be responsible for casualties.

Growth

Periodic data on height and crown diameter growth are summarized in Table 7 and 8, respectively. *A. bivenosa* is a fast growing species At 12 month's mean height and crown diameter was 60.9 cm and 110.1 cm respectively with T₂ recorded maximum 71.5 cm height and 129.3 cm crown diameter. Treatments positively influenced and the height obtained in T₁, T₅ and T₆ treatment was significantly less than T₂ treatment. However, for crown diameter difference of T₂ and T₁ only was significant. Bushes attained 97.9 cm and 183.3 cm as mean height and crown diameter at 18 months. The incremental growth was 60.8% and 66.5% for height and crown diameter respectively between 12-18 months of growth period. Treatments continued to influence and indicated that T₂ and T₃ treatments recorded significantly higher growth than other treatments.

Experimental area suffered with heat shock in May 2009 at 22 months of age. However, there was no growth damage due to heat shock and at 24 month; there was gain in height and crown diameter, over their values at 18 months. It attained maximum crown growth among all the plant species. Now, the mean height, 112.6 cm, is significantly less than the mean crown diameter (208.5 cm).

Table 7. Periodic height (Mean ± SE) of *A. bivenosa* with different treatments

Treatments	Heights (cm)				
	12m*	18m*	24m*	36m*	52m*
T ₁	52.5±4.3	86.9±8.0	92.9± 8.9	122.0	130
T ₂	71.5±10.9	115.5± 16.1	129.7± 14.2	138.7	154.5

T ₃	64.4±7.7	109.3± 14.1	123.2±14.9	128.9	140
T ₄	61.5±3.1	97.5± 4.7	117±5.7	132.5	133.3
T ₅	58.5±5.2	88.7± 8.9	109±11.0	115.1	149.4
T ₆	56.8±7.4	89.6± 10.8	103.7±11.0	123.3	148.3
Mean	60.9	97.9	112.6	126.7	142.6
LSD	11.68	15.37	22.43	-	-

*age in months

Table 8. Periodic crown diameter (Mean ± SE) of *A. bivenosa* with different treatments

Treatments	Crown diameter (cm)				
	12m*	18m*	24m*	36m*	52m*
T ₁	97.6±8.2	171.8±15.0	182.7± 14.2	180.2	115.0
T ₂	129.3±18.6	210.4±20.6	240.5±22.0	232.1	134.9
T ₃	123.9±14.6	205.0±21.5	231.8± 28.9	221.6	117.7
T ₄	106.4±9.7	170.0±20.5	200.2± 21.7	211.3	130.8
T ₅	102.9±4.5	171.2±21.0	213.3±16.3	206.8	148.3
T ₆	100.2±14.0	171.4±14.9	180.7±33.2	191.0	161.6
Mean	110.1	183.3	208.5	207.2	134.7
LSD	19.9	25.5	36.9	-	-

*age in months

The height and crown diameter at 24 months were 84.9 and 89.3% more respectively, compared to their values at 12 months. Here, the percent incremental growth in height was ranging from 76.9 to 91.3 and crown diameter, 82.3 to 107.9 (Table 7 and 8) in different treatments. Two factor ANOVA analysis showed that treatments influenced the growth and both T₂ (FYM) and T₃ (Wheat husk) treatments recorded significant higher growth (height and crown diameter) compared to other treatments

At 36 months of age despite suffering with high causalities the remaining shrubs of *A. bivenosa* attained height in all the treatments (Table 7) and the mean increment was 12.5 over 24 months values. However, there was no growth in crown diameter (Table 8). To reduce water requirement 50-55% pruning was done in April 2011 and growth parameters recorded at 52 months showed 12.5 % incremental growth in height however due to pruning crown diameter decreased.

Collar diameter

Shrubs were multi-branched having 9 (T_1) to 21 (T_3) branches in different treatments (Table 9) hence quadratic collar diameter was estimated at 36 month and values were ranging from 4.4 cm in control to 5.09- T_5 , 5.21 - T_6 , 5.37 - T_4 , 6.78- T_2 and 7.35 in T_3 treatment.

Table 9. Number of branches and collar diameter (cm) with different treatments at 36 months

Treatments	No. of branch	Mean collar diameter
T_1	8	4.4
T_2	12	6.78
T_3	21	7.35
T_4	9	5.37
T_5	10	5.09
T_6	12	5.21
Mean	12	5.70

Biomass estimation

Component wise biomass estimation was done. the data is summarized in Table 10. Treatment influenced the biomass yield and all the treatments recorded higher biomass (Table 9) as compared to control (3.43 Kg). Maximum 12.68 kg biomass yield was obtained for T_3 (Wheat straw) treatment followed by 10.22 kg for T_2 (FYM) treatment. Results from Auroville Pondicherry, India also in conformity with our experiment and showed that *A. ampliceps* survived and grew very well at highly saline eroded black soil wasteland and gave sufficient biomass production (Anon, 2015). A combination of FYM and wheat straw did not yield much as treatment T_4 suffered with high causalities due to its location facing hot winds from Rann side on south west border in the randomization during trial layout. Three treatments T_3 , T_2 and T_5 recorded more biomass than the mean for green and dry biomass. They have substantial contribution from branch component. Treatments recording less biomass than mean, generally has more contribution from leaf T_6 (58.4%), T_1 (51.8%) and T_4 (46.8%).

Table 10. Aboveground green and dry biomass yield (kg tree^{-1}) of *A. bivenosa* at 36 months of age

Treatments	Leaf	Branch Green	Stem	Total
T_1	1.78 (51.8)*	1.05 (30.6)	0.60 (17.6)	3.43
T_2	3.23 (31.5)	4.90 (47.9)	2.10 (20.5)	10.22
T_3	5.93 (46.7)	5.26 (41.5)	1.50 (11.8)	12.69
T_4	3.10 (46.8)	2.52 (38.1)	1.00 (15.1)	6.62

T ₅	4.25 (50.0)	2.75 (32.3)	1.50 (17.6)	8.50
T ₆	4.35 (59.4)	2.16 (28.9)	0.95 (12.7)	7.46
Mean	3.78 (46.3)	3.11 (38.1)	1.28 (15.6)	8.15
Dry				
T ₁	0.81 (39.5)	0.81 (39.5)	0.43 (21.0)	2.05
T ₂	1.47 (21.8)	3.77 (55.9)	1.50 (22.3)	6.74
T ₃	2.71 (34.6)	4.05 (51.7)	1.07 (13.7)	7.83
T ₄	1.42 (34.9)	1.94 (47.7)	0.71 (17.4)	4.07
T ₅	1.94 (37.8)	2.12 (41.3)	1.07 (20.9)	5.13
T ₆	1.99 (46.0)	1.66 (38.3)	0.68 (15.7)	4.33
Mean	1.72 (34.2)	2.39 (47.5)	0.91 (18.1)	5.03

*Percent contribution to the total biomass

Leaf, branch and stem yield

The green and dry leaf mass was ranging from 1.78 & 0.81 kg in control to 5.93 & 2.71 kg in T₃ treatment. Three treatments, T₃, T₅ and T₆, recorded more leaf mass than mean. The green and dry branch biomass was ranging from 1.05 & 0.81 kg in control to 5.26 & 4.05 kg in T₃ treatment. Here only two treatments, T₂ and T₃, recorded more branch biomass than mean. The green and dry stem biomass was ranging from 0.60 & 0.43 kg in control to 2.10 & 1.50 kg in T₂ treatment. Three treatments T₂, T₃ and T₅ recorded more branch biomass than mean.

Phenological observations

First flowering was initiated in December 2008 and overall flowering was observed in nearly 15 and 30 % plants in *A. ampliceps* and *A. bivenosa*, respectively in January 2009. Pod setting was initiated in February 2009; however, pod setting was in 7.3% and 14.4 % plants only, in March 2009. Treatment T₃ (23.8%) in *A. ampliceps* and T₂ (38.3%), T₃ (27.3%) in *A. bivenosa* recorded significantly high pod setting than other treatments. Seeds were collected and they germinated also. After a deficient monsoon year, flowering was observed only in few experimental plants of *A. bivenosa* in January 2010 without maturing into pod. There was no flowering in *A. ampliceps*, however, its natural germination from seed was observed near to plant pit. After very good and delayed monsoon in 2011 delayed flowering was observed in 71.2 % plants ranging from 66.6 to 91.6% in different treatments

Re-sprouting was observed in December 2010 in all the six plants of *A. bivenosa* cut for aboveground biomass estimation in September 2010 but no further growth due to moisture deficiency. Re-sprouting was also observed in October 2011 in those *A. ampliceps* plants which were cut in March 2011.

Weed Biomass

Green weed-mass in September 2009 was dominated by halophytes and other salt

tolerant species. *Chloris virgata* was the most dominant species followed by *Sueada fruticosa*, *Aristida spp.* and *Zygophyllum simplex*. Overall 517.3 gm² yield was recorded however, tree species wise, variation was observed and it was 503.8 gm² (*A. bivenosa*) and 530.8 gm² (*A. ampliceps*).

Both the exotic *Acacia spp.* have the potential to revegetate the highly saline silty black soils salt affected soils. They maintain good survival, attained significantly higher growth than sandy soils. Management practices enhanced the growth of the two species under arid conditions on black soils. *A. ampliceps* and *A. bivenosa* flowers and produced viable seed within a year while on sandy soil they took three to five years (Arya et al. 2009). They suffered damage with heat shock in 2009 after that though the survival was poor but the biomass yield of *A. ampliceps* was better than on the sandy soil. The yield was ranging from 5.5 kg tree⁻¹ in T₄ to 13.01 kg tree⁻¹ in T₃ treatment per tree for green biomass, respectively. Treatment influenced the biomass yield and all the treatments recorded higher biomass as compared to control (3.43 kg) at 36 months of age in case of *A. bivenosa*. Maximum 12.68 kg tree⁻¹ biomass yield was obtained for T₃ (Wheat straw) treatment followed by 10.22 kg tree⁻¹ for T₂ (FYM) treatment. While the biomass yield on sandy soil was ranging from 8.2kg to 12.05 on deep soil and 3.88kg to 5.08 kg on shallow soil at 60 months, (Arya 2016). Performance of *A. bivenosa* was better than *A. ampliceps*. It maintained 86.9% mean survival at 18 months and 40.5% at 48 months ranging from 66.1% in T₂ and 22.2% in control. Treatment influenced the biomass yield and all the treatments recorded higher biomass as compared to control (3.43 kg) at 36 months of age in case of *A. bivenosa*. Maximum 12.68 kg tree⁻¹ biomass yield was obtained for T₃ (Wheat straw) treatment followed by 10.22 kg tree⁻¹ for T₂ (FYM) treatment. Studies from sites and countries also indicate their suitability on salty soil. Reports from CCF (Research), Haryana SFD, also indicate appreciable survival and fast growth in sandy loam soils in Jhajhar, Haryana (Arya 2016; Arya & Lohara 2016).

It can be concluded that *A. ampliceps* and *A. bivenosa* can be introduced in Wild Ass sanctuary and with management practices will enhance fodder yield. It responded to treatments applied and positively influenced the survival, growth and biomass yield and thus they may be accepted as one the fodder species in WAS. They did not suppress the growth of native vegetation.

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