Annals of Arid Zone 53(1): 43-48, 2014

Survival and Biomass Production of *Salvadora persica* on Various Types of Salt Affected Soils under Arid Conditions in Rajasthan and Gujarat

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Received: December 2012

Abstract: *Salvadora persica* (L), popularly known as miswak, toothbrush tree or khara jal, is facultative halophyte tree species growing on arid salt affected lands in Rajasthan, Gujarat, Punjab, Haryana and western Uttar Pradesh. Despite its multifold uses it is not very popular in afforestation program. Its slow growing nature may be the reason. Field trials were laid in arid sandy salt affected soils in Kaparda and Gangani in Jodhpur, Rajasthan, and highly saline black silty clay soils in little Rann of Kachchh, Patan Gujarat. It had very high survival rate at all the sites with appreciable biomass production. The survival was above 90% at Kaparda with slow growth, 85.2 to 66.7% survival and 7 to 12 kg plant^{-1} biomass yield with the use of FYM, gypsum and nitrogen on sandy soil, Gangani, Jodhpur at 72 months and 97.5 to 97.9% survival and 2.6 to 7.17 kg plant^{-1} biomass yield with FYM, wheat husk and nitrogen on silty black salty soil, Kordha Patan at 50 months. Thus, it can be concluded that with slight management *S. persica* is the best plant for various types of salt affected soils. Plantation of this important tree species will not only rehabilitate these wastelands, but also provide valuable products for livelihood support.

Key words: *Salvadora persica*, FYM, gypsum, nitrogen, wheat husk, growth.

Salvadora persica (L), popularly known as miswak, toothbrush tree or khara jal, belonging to family Salvadoraceae, is an important salt tolerant indigenous tree species growing on arid salt affected lands in Rajasthan, Gujarat, Punjab and Western Uttar Pradesh (Anon., 1986). It is a preferential halophyte that stores excess salts in mature and senescent leaves and in the bark which, when shed, remove excess salts (Amonkar and Karmakar, 1978). It is planted in saline coastal area (Makwana *et al*., 1988). It has multifarious uses: Twigs and young stems as a toothbrush; shoots as camel fodder; plant ash provides salt, bark in suppressing the bacterial growth and plaque formation in mouth; back pains, chest diseases, and stomach aches; seeds are used as a tonic and seed oil is rubbed on the skin for rheumatism. Seed is rich in oil and contains lauric, myristic, and palmitic acids with potential for making soaps, candles, and using it as a substitute for coconut oil (FAO, 1986; Hallawany, 2012; Kumar *et al*., 2012). Despite its multifold uses it is not very popular in afforestation program its slow growth may be the reason. Field trials were laid in arid sandy salt affected soils in Kaparda and Gangani (Arya *et al*., 2005; Arya and Lohara, 2005) in Jodhpur, Rajasthan, and highly saline black silty clay soil in little Rann of Kachchh, Patan, Gujarat, and salient findings are presented here-

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Materials and Methods

Trial 1

The first trial was raised on a degraded saline alkali shallow loamy sand soil at Kaparda, Jodhpur where pH_2 was 8.9-9.2, EC_2 was 12-17 dS m^{-1} and SOC was 0.12 to 0.15% with a gypsum requirement of 10 t ha^{-1}. Soil depth was 0-40 cm with rocky substratum below. Trial was laid in July 1992 with five treatments T_1: Gypsum (10 t ha^{-1}); T_2: Gypsum + Drainage Channel (DC along plant rows, 30 cm deep and 40 cm wide); T_3: Soil replacement with normal soil + FYM (5 kg plant^{-1}); T_4: Gypsum + FYM + Zn (7 g $ZnSO_4$ plant^{-1}) + DC + Nitrogen (15 g urea plant^{-1}) and T_5: Control in randomized block design (RBD) with three replications having 15 plants per replication at a spacing of 2 x 4 m. The rainfall received was 326 mm with a long dry spell of 46 days in 1993, 596 mm in 1994, 325 mm in 1995 and 406 mm in 1996.

Trial 2

Second trial was laid on a hummocky, sandy plain with a shallow, hard and compact substratum that is impervious to roots and water at Gangani, Jodhpur. The soil of the experimental site was classified as a lithic, calcid, coarse sandy to loamy sand, underlain by a thick hard pan of calcium carbonate at a depth of 25-100 cm. The soil pH ranged from 8.2 to 9.8 and EC from 4.2 to 16 dS m^{-1}. The exchangeable sodium percentage ranged from 30-60%. The organic carbon content ranged from 0.1 to 0.2%. The soil was poor in nitrogen and phosphorus, with a gypsum requirement of 6 t ha^{-1}.

The trial was laid out in September, 1997 using a factorial design with three replications, two levels of gypsum: Control (G_0) and Gypsum @ 100% soil GR (G_1) and four nitrogen levels: 0 g (N_0), 9 g (N_1), 18 g (N_2), and 27 g (N_3) of N in the form of urea. There were 9 plants in every treatment at spacing of 3 x 4 m. The area was deep ploughed after the first spell of rain. Pits of 50 x 50 x 50 cm were dug and 3 kg farmyard manure (FYM), 15 g single super phosphate (SSP) and gypsum (according to treatment) were mixed with pit soil at the time of planting. The rainfall received was 291 mm in Aug-Dec, 1997, 478.5 in 1998, 296 mm in 1999, 293.3 in 2000, 419.9 mm in 2001, 40.6 mm in 2002 and 418.7 mm in 2003.

The mean annual rainfall of the site is 350 mm, which is mainly confined to the monsoon period (from July to September). The total number of rainy days during the year varies between 8-17 days. The maximum temperature rises as high as 50°C in summer and minimum drops to 4°C in winter. Average wind velocity in the summer months is 15 to 25 km h^{-1}

Trial 3

It was laid on black silty clay soil (medium), Soil depth: 40-75 cm Kordha, Patan, Gujarat, at the fringe of Wild Ass Sanctuary in little rann of kachchh in July, 2007. The soil pH_2 was ranging from 7.6-8.4, EC_2 (dS m^{-1}) 4.04-19.4 and SOC from 0.18-0.37%. There were five treatments; T_1: Control, T_2: Wheat Husk (1/2 kg), T_3: FYM (5 kg), T_4: WH + FYM and T_5: FYM + Urea (20 g) in RBD in three replications at a spacing of 3 x 4 m with 16 plants per replication.

The area is characterized by dry (semi-arid) tropical monsoon climate with an average annual rainfall of less than 400 mm. Average maximum and minimum temperatures are about 42°C and 11°C (January), respectively with May being the hottest month. 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. During the monsoon, the whole region becomes flooded with rainwater (Anon., 1999). The rainfall during the experimental period was 678 mm in 2007, 523.3 in 2008), 214.0 in 2009, 524.0 in 2010 and 560 mm in the year 2011. 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 south-west (summer) monsoon and North Gujarat was also part of it. Plantation suffered with heat shock in May 2009, however no significant damage was observed in *S. persica* (Arya *et al.*, 2012).

Results

Trial 1

There was more than 90% survival in all the treatments after five years, but growth was slow. In first year plants grew hardly beyond the seedling stage attaining a maximum average height of 64 cm in T_3 treatment and 39 cm as minimum in T_2 with control being the second highest at 58 cm with no crown formation. Growth continued to be slow even after five year of age, attaining only 92.8 cm and 108.8 cm as mean height and crown diameter, respectively. Treatments significantly influenced the growth. Treatment wise T_4 attained the best growth with 124.3 cm height and 128.3 cm crown diameter very closely followed by T_3 (106 and 124.8 cm) height and crown diameter, respectively (Table 1). Both were significantly higher than all the other treatments . Due to poor growth biomass was not estimated (Arya *et al.*, 1997).

Trial 2

Survival and growth: Despite deficient rainfall conditions appreciable survival was recorded. It ranged from 85.2 to 66.7% in different treatments (Table 2) with no effect of treatments.

Results of sixth year of plant growth indicate that treatments positively influenced

Table 1. Survival and growth after 48 months at Kaparda, Jodhpur

Treatments	% Survival	Height (cm)	Crown dia. (cm)
T_1	94	74.0	95.5
T_2	87	90.1	104.8
T_3	94	106.0	124.8
T_4	97	124.3	128.3
T_5	94	70.0	90.5
Mean	93.2	92.8	108.8
LSD (0.05)	NS	10.3	6.3

T_1: Gypsum (10 t ha^{-1}) ; T_2: Gypsum + Drainage channel (DC along plant rows, 30 cm deep and 40 cm wide); T_3: Soil replacement with normal soil + FYM (5 kg $plant^{-1}$); T_4: Gypsum + FYM + Zn (7 g $ZnSO_4$ per plant) + DC + Nitrogen (15 g urea $plant^{-1}$) and T_5: Control.

the growth and application of nitrogen in combination with gypsum gave better growth as compared to application of nitrogen only. T_6 (gypsum + 9 g N) was the best treatment plants attained 207.0 cm of height and 212.0 cm of crown diameter. The results of analysis of variance showed that effect of gypsum application was not significant on height (p-0.07) and crown diameter (p-0.06), but was significant for collar girth (p-0.047). In case of collar girth the overall mean of gypsum treated plants was 12.4% more than the untreated plants. Nitrogen application influenced only the height (p-0.05). LSD values indicate that in case of height all the nitrogen levels (N_1-N_3) recorded significantly higher height than N_0 nitrogen level, but the height difference between them was not significant. For crown diameter only N_1 nitrogen level recorded better crown diameter than control. Interaction of gypsum x nitrogen was significant for crown diameter and collar girth.

Green biomass: The above ground green biomass was also maximum in T_6 treatment, 12.0 kg $tree^{-1}$ followed by 10.7 kg and 8.8 kg in T_8 (gyp + 27 g N) and T_2 (9 g N) treatments, respectively.

The results of analysis of variance showed that effect of gypsum was significant on the green biomass yield for leaf (p-0.05), branch (p-0.02), stem (0.010) and total biomass (p-0.013). It was due to 27.3, 32.3, 22.9 and 27.2% increase respectively over control for N_0-N_3 levels.

Effect of various nitrogen treatments was also very significant for leaf (p-0.01) branch (p-0.01) stem (p-0.003) and total biomass (p-0.03). The yield was maximum for N_1 level followed by N_3 and N_2 levels for all the biomass components with control recording the minimum yield. LSD values indicate that generally all the treatments (N_1-N_3 levels) recorded higher yield, however, the difference with control was significant for N_1 and N_3 levels only.

The contribution of leaf component to total biomass ranged from 30.0-33.8% for different nitrogen levels in control, while it was 29.5-34.5% in gypsum treated plants. The maximum contribution was from stem component ranging from 36% in N_2 level to 44% in N_1 level.

Trial 3

Survival and growth: S. persica was the best plant species facing the extremely harsh conditions of high salinity, heat stress for two consecutive summers (2009 and 2010), one drought year (2009) and erratic monsoon afterwards. It recorded 91.6% mean survival after 48 months, ranging from 87.5% in T_4 and T_5 to 97.9% in T_3 treatment. However, treatments did not influence the survival (Table 4). Plants were pruned (75%) in December 2009 (27 months) and 25% in March 2011 at

Table 2. Survival and growth (mean ± SE) with various levels of gypsum and nitrogen after 72 months at Gangani, Jodhpur, Rajasthan

Parameters	G_0					G_1				
	N_0	N_1	N_2	N_3	Mean	N_0	N_1	N_2	N_3	Mean
% Survival	81.5 (3.70)	85.2 (3.70)	74.0 (7.41)	85.2 (3.70)	81.5	81.5 (3.70)	77.8 (6.41)	70.4 (9.79)	66.7 (12.83)	74.1
Height (cm)	148.9 (13.27)	161.8 (3.88)	192.3 (14.65)	173.1 (10.68)	169.0	163.9 (11.66)	206.8 (3.76)	168.7 (11.13)	192.7 (8.28)	183.0
Crown diameter (cm)	171.3 (6.03)	172.4 (4.85)	195.8 (9.18)	172.7 (11.51)	178.1	171.3 (10.08)	212.1 (10.51)	171.5 (3.32)	204.5 (8.97)	189.9
Collar girth (cm)	19.38 (1.04)	20.02 (0.81)	24.80 (3.61)	18.43 (1.54)	20.6	21.4 (0.80)	26.12 (0.52)	20.6 (2.00)	24.7 (0.41)	23.2

Table 3. Green biomass yield (kg per tree) with various levels of gypsum and nitrogen after 72 months Gangani, Jodhpur, Rajasthan

Parameters	G_0					G_1				
	N_0	N_1	N_2	N_3	Mean	N_0	N_1	N_2	N_3	Mean
Leaf	2.12	2.64	2.46	2.58	2.45	2.72	3.54	2.73	3.49	3.12
Branch	1.93	2.61	2.18	2.07	2.20	2.35	3.17	2.57	3.56	2.91
Stem	2.51	3.53	2.65	2.67	2.84	2.80	5.30	2.77	3.79	3.49
Total	6.59	8.79	7.27	7.32	7.49	7.88	12.01	8.20	10.83	9.73
LSD (0.05)	Leaf G: 0.68 N: NS	Branch G: 0.41 N: NS	Stem G: 0.47 N: 0.66	Total G: 1.53 N: NS						

G_0 (Control) and G_1 (Gypsum @ 100% soil GR); N_0: 0 g, N_1: 9 g, N_2: 18 g, and N_3: 27 g of N in the form of urea.

44 months of age. At 48 months it attained 147.2 cm as mean height. T_5 (158.6 cm) was the best treatment followed by T_4 (152.2 cm) and LSD and were significantly higher over control (136.0 cm). Growth of crown diameter was less and at 48 months mean crown diameter (135.1 cm) was less than height. Treatment effects were significant (p-0.00) and all the treatments recorded higher growth than control.

The quadratic mean collar diameter ranged from 5.67 cm in control to 7.01 cm in T_5 treatment. ANOVA analysis indicate that difference of T_5 treatment ranged from 15.2 to 19.2% and was significantly higher than all other treatments.

Green biomass: Total green biomass yield ranged from 7.17 kg in T_5 treatment to 2.60 kg in control. Treatments positively influenced the biomass yield and all the treatments recorded significantly (p-0.004) higher biomass yield as compared to control. T_5 was the best treatment with 7.13 kg yield, which was significantly higher than all other treatments except T_3 (6.18 kg).

The leaf yield ranged from 0.653 kg in control to 2.21 kg in T_5 treatment. All the treatments recorded higher leaf yield as compared to control, however, difference between T_5 and T_3 was significantly (p-0.01) more than control.

Thin branch yield: Plants yielded substantial amount of thin branches (<5 cm) and green branches yield ranged from 0.81 kg in control to 1.78 kg in T_5 treatment. Effect of treatment was more pronounced here and all the treatments recorded significantly (p-0.002) higher branch yield than control.

Branch yield: The trend is changed in case of branch yield. In this case, although all the treatments, recorded higher branch yield as compared to control (0.82 kg), but the maximum branch yield was obtained in T_3 (1.65 kg) followed by 1.4 kg in T_2, 1.07 kg in T_5 and 1.03 kg in T_4. The difference between control and T_3, T_2 and T_5 treatmenst was significantly (p-0.001).

Stem yield: Control plants recorded very low green stem yield (0.31 kg), which was significantly (p-0.002) less than all other treatments. Again T_5 (2.11 kg) was the best treatment followed by T_3 (1.24 kg), while T_2 (1.10 kg) and T_4 (1.11 kg) were almost equal.

Table 4. Survival and growth (mean ± SE) after 48 months at Kordha, Patan, Gujarat

Treatments	% Survival	Height (cm)	Crown dia. (cm)	Collar diameter (cm)
T_1	95.8 (2.1)	136.0 (8.1)	118.6 (7.7)	5.67 (1.98)
T_2	89.5 (4.2)	144.6 (11.4)	148.5 (12.5)	5.68 (2.37)
T_3	97.9 (2.1)	144.4 (5.4)	131.7 (4.4)	5.84 (2.08)
T_4	87.5 (3.6)	152.3 (14.7)	136.3 (17.0)	5.94 (5.27)
T_5	87.5 (6.2)	158.6 (8.3)	140.4 (8.9)	7.01 (6.31)
Mean	91.6	147.2	135.1	6.03
LSD (0.05)	NS	13.9	11.9	8.8

T_1: Control; T_2: Wheat Husk; T_3: FYM; T_4: FYM + WH; T_5: FYM + Urea (20 g plant^{-1}).

Table 5. Above ground green biomass yield (mean ± SE) at 50 months of age at Kordha, Patan, Gujarat

Treatments	Green biomass (kg tree^{-1})				
	Leaf	Thin branch	Thick branch	Stem	Total
T_1	0.65±0.08	0.81±0.19	0.82±0.04	0.31±0.06	2.59
T_2	1.07±0.09	1.28±0.11	1.40±0.20	1.09±0.12	4.84
T_3	1.55±0.41	1.70±0. 33	1.65±0.32	1.24±0.82	6.14
T_4	1.21±0.02	1.25±0.16	1.03±0.09	1.11±0.04	4.60
T_5	2.21±0.30	1.78±0.27	1.07±0.27	2.11±0.74	7.17
Mean	1.34	1.36	1.19	1.17	
CD (0.05)	0.71	0.37	0.24	0.54	

The contribution of leaf component to total biomass ranged from 22.0-30.8% for different treatments, while contribution from stem component ranged from 11.9% in T_1 to 29.4% in T_5. However, leaf and thin branches together contributed 56.3% in T_1, 48.6% (T_2), 52.9% (T_3), 53.4 (T_4) and 55.6% in T_5 treatment indicating substantial forage availability from *S. persica*.

Discussion

From the results obtained in the above three trials it is clear that *S. persica* has the potential to perform on degraded arid sandy salty soil with rocky or $CaCO_3$ substratum or arid black silty mud flats of little Rann of Kachchh surviving the harshest climatic conditions. With minimum management its growth can be enhanced**.** Application of FYM, gypsum and nitrogen and FYM, wheat husk and nitrogen enhanced the growth under sandy alkali and black silty saline soil conditions, respectively. It is a very good coppicer and reported 100% sprouting after cutting above ground for biomass on both the sites indicating its tolerance for grazing. Plantation activities improved the soil condition promoted colonization and the number of plant species increased gradually.

Planting tree species is an effective way of obtaining some economic returns from salt affected areas. In similar study *S. persica* was cultivated for the restoration of salt affected black cotton soils in Gujarat (Rao *et al*., 2004). Pandey (2008) in his review paper also suggested it as suitable species for ecological and livelihood improvement in Thar Desert. Our results also showed that *S. persica* has the potential to revegetate various types of arid salt affected soils . Thus, it can be concluded that *S. persica* is the best plant with maximum survival and appreciable biomass production in various types of arid salt affected soils. In India, 6.73 Mha area has been reported to be salt affected, out of which about 50% (2.98 Mha) occurs in the states of Rajasthan, Gujarat, Haryana and Punjab. Utilization of these salt affected areas has become necessary owing to increasing need for fodder, fuel wood and minor forest produce for rural poor. Cultivation of this important tree species on unutilized wastelands with slight management effort will not only rehabilitate these wastelands, but also provide valuable products for livelihood support.

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Printed in March 2015