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Effects of Gypsum Application on Mesquite (*Prosopis juliflora*) and Soil Properties in an Abandoned Sodic Soil

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ABSTRACT

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Effects of three rates of gypsum (0, 7.5 and 15.0 t ha^{-1}) on the growth performance of mesquite and on soil properties in an abandoned sodic soil (Aquic Natrustalf, pH 10.4, exchangeable sodium percent 90) were studied in a replicated field experiment at the Gudha experimental farm of the Central Soil Salinity Research Institute, Karnal. The study indicated that in a growth period of 2 years, 48, 11 and 8% of the mesquite died in the control, 7.5 and 15 t ha^{-1} treatments, respectively. The mean plant height and basal diameter were 86 and 1.0 cm in the control; 196 and 2.8 cm in 7.5 t ha^{-1}; and 244 and 3.5 cm in 15 t ha^{-1} gypsum treatment, respectively. The 1-year biomass accumulation was about 6 and 9 times more in the 7.5 and 15 t ha^{-1} treatments, respectively, than in the control. The mean concentration of P, K, Ca, Mg, S, Mn, Zn and Cu in mesquite parts increased, while Na decreased, with an increase in level of gypsum application. Reduced pH, together with improved soil physical properties, favoured the uptake of these nutrients. Application of gypsum and mesquite growth caused significant reductions in pH and electrical conductivity and improvements in organic carbon and available N, P and K contents of the soil. The amount of water infiltrated in the soil in 24 h at 18 months after planting was 2.29 cm in no gypsum, 5.21 cm in 7.5 t ha^{-1} and 6.84 cm in 15 t ha^{-1} gypsum treatment. Pre- and post-infiltration moisture determinations indicated greater moisture contents throughout the profile in gypsum-treated than in original soil. It was noted that post-infiltration moisture in the 120-cm profile ranged from 19 to 11% in the control, 21 to 13% in 7.5 t ha^{-1}, and 22 to 18% in 15 t ha^{-1} treatment.

INTRODUCTION

Alkali or sodic soils occur extensively in the states of Haryana, Punjab and Uttar Pradesh in the Indo-Gangetic plains, where they are estimated to cover about 2.5 million ha (Abrol and Bhumbla, 1971). Such soils have been reported

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to occur in many parts of the world (Kovda, 1965). These soils are generally alkaline, platy to loose on the surface, grading to massive through various degrees of angular and sub-angular blocky in structure, and slow in water infiltration. These soils contain large quantities of sodium carbonate, and their exchange complex is often almost saturated with sodium. They may also be low in plant-available N, Ca and Zn. These soils either support no vegetation or allow the growth of only a few wild species such as *Sporobolus marginatus*, *S. diander*, *Desmostachya bipinnata* and *Suaeda maritima* (Bhumbla et al., 1972). The revegetation of such soils is of current concern. A large proportion of these sodic soils are common land belonging to Panchayats (village judicial bodies) and used as exercise grounds for their cattle. Utilization of these marginal land resources for afforestation appears a promising prospect, particularly in view of both the increasing pressure on good soils for crop production and the growing scarcity of fuelwood.

Gypsum has been the most common amendment applied to sodic soils for reclamation and revegetation, as it supplies the more favourable calcium for exchange with sodium. In recent years, successful efforts have been made to reclaim sodic soils by application of gypsum for the production of crops like rice, wheat, etc. (Abrol et al., 1973; Abrol and Bhumbla, 1980). Only a few efforts have been made in the past to raise forest plantations on such soils. Yadav (1980) reviewed the available literature and stressed the immediate need of generating more information on the performance of selected salt-tolerant tree species. Recently, some systematic research efforts were made to establish trees on highly sodic soils (Abrol and Sandhu, 1985; Grewal and Abrol, 1986; Singh et al., 1987a; Gill and Abrol, 1987). The present study, forming a part of the continuing research efforts, evaluated the effects of surface application of gypsum on performance of mesquite and soil properties in a highly sodic soil. The data on initial growth performance, biomass accumulation and chemical composition of mesquite and effects of gypsum and tree growth on soil properties are reported.

MATERIALS AND METHODS

Experimental site

The study was initiated at the Gudha experimental farm of the Central Soil Salinity Research Institute, Karnal, in March 1985. The farm is located at Lat. 29°29′ and Long. 76°56′ and is about 237 m above mean sea level. The water table fluctuates between 3 and 5 m and the groundwater is of good quality. The soils are Aquic Natrustalfs (Bhargava et al., 1980), representative of large areas of sodic soils occurring in the Indo-Gangetic plains (Table 1). The natural vegetation is very scanty (Fig. 1). There are isolated trees of *Acacia nilotica*,

TABLE 1

Soil characteristics of the experimental site

Soil depth (cm)	pH*	σ (dSm^{-1})	Mechanical analysis (%)			Organic carbon (%)	Available nutrients** ($kg\ ha^{-1}$)			Exchangeable cations (meq/100 g soil)			%Na***
			Sand	Silt	Clay		N	P	K	Na^+	K^+	$Ca^{2+}+Mg^{2+}$	
0 - 2.5	10.3	2.16	60.2	14.4	15.4	0.15	72	32	510	12.4	0.32	0.65	92.6
2.5- 7.5	10.4	2.30	56.0	27.2	16.8	0.15	70	41	518	13.2	0.35	0.60	94.0
7.5- 15.0	10.4	2.22	48.2	31.2	20.6	0.14	64	36	495	13.4	0.32	0.58	94.8
15.0- 30.0	10.3	1.82	44.6	32.6	22.8	0.13	54	30	488	12.0	0.36	0.68	91.6
30.0- 45.0	10.2	1.56	42.6	33.8	23.4	0.12	42	22	465	11.2	0.39	0.86	90.0
45.0- 60.0	10.2	1.46	42.8	33.6	23.6	0.11	38	18	420	11.4	0.40	0.84	90.0
60.0- 90.0	10.1	1.38	35.8	35.0	29.2	0.11	28	16	388	9.4	0.36	1.02	86.2
90.0-120.0	9.8	1.28	30.2	37.8	32.0	0.09	22	12	200	9.0	0.40	1.09	84.8

*Measured in 1:2 soil: water suspension.
**Available nutrients $kg\ ha^{-1} = ppm \times 2.24$.
***Exchangeable sodium percent.

Fig. 1. Landscape of an original alkali land adjacent to the experimental site.

A. tortilis, Prosopis juliflora and *Butea monosperma*, with a sparse understory of *Sporobolus marginatus, Sp. diander, Desmostachya bipinnata* and *Suaeda maritima.*

Climate

The study area represents a typical sub-tropical, semi-arid, monsoonic type of climate characterised by a dry and hot spring/early summer, a hot rainy season, a warm autumn and a cool winter. The average annual rainfall is about 700 mm, with 80% received between June and September. The temperature starts rising from February onwards until the summer maximum, often exceeding 40 °C, is reached in May or June. The mean monthly minimum temperature is recorded in January. There is ample sunshine throughout the year. Class-A pan evaporation exceeds the rainfall except in July and August.

Experimental layout

The present study is a part of the continuing field experiment which was initiated in March, 1985 with the following treatments: irrigated and rainfed conditions in the main plot; planting densities (5000 and 10 000 plants ha^{-1}) in the subplots; and gypsum levels (0, 7.5 and 15 t ha^{-1}) in the sub-subplots. The effects of irrigation and planting densities have been reported in earlier publications (Singh et al., 1987b,c). In this paper the effects of gypsum treatments are reported on both the irrigated and rainfed plots. The plot size was 6×20 m. Gypsum was broadcast at the rate of 0, 7.5 or 15 t ha^{-1} according to treatments and mixed in the upper 8–10 cm of soil. After gypsum application, planting was done immediately in dry conditions, followed by two irrigations for the proper establishment of seedlings. Subsequently, irrigation was applied based upon an (irrigation water/cumulative pan evaporation) value of 1.0 for the first 6 months and 0.5 for the later growth period up to 2 years. The saplings were raised in 1-kg-capacity polyethylene bags in the nursery in a good soil and were transplanted at around 4 months old during the first week of March 1985, in holes dug to a depth of 25 cm with a hand-hoe. After planting, irrigation was given to ensure the proper establishment of saplings.

Observations recorded

Data on survival, height and diameter of mesquite were recorded periodically but the results are discussed on the basis of observations recorded 12 and 24 months after planting. The diameter at stump height (D_S) was measured at 5 cm above ground level. The average initial height and diameter were 250 and 3.8 mm, respectively. Six and 12 months after planting, representative plants were harvested from each plot along with roots to study the biomass accumulation in the different treatments. The roots were exposed by excavating the earth following the methodology suggested by Bohm (1979).

Collection, preparation and analysis of soil samples

Soil samples were taken at 0–2.5, 2.5–7.5, 7.5–15, 15–30 and 30–45-cm depths, at 4 places for each plot, before gypsum application, giving 20 samples from each treatment. Sampling was repeated in May, 1986 (14 months after planting) to assess improvement in soil properties. After collection, samples were air- and then oven-dried, ground in a wooden pestle and mortar, passed through a 2-mm sieve and stored for analysis. The soil pH, electrical conductivity (σ), organic carbon and available N, P and K were determined by standard procedures (Jackson, 1967).

Infiltration rate

The infiltration rate of the soil was measured 6 and 18 months after planting. Metallic infiltrometers of 30–36-cm inner diameter were used for the study. The infiltrometers were driven into the soil to a depth of 15 cm using a heavy disc and hammer. An earthen ring was provided for each infiltrometer to ensure vertical movement of water during leaching. The surface soil was slightly loosened prior to ponding of water. Water was ponded both inside and outside the rings and was added carefully so as to minimise disturbance of the soil at the surface. Moisture content prior to infiltration – pre-infiltration moisture distribution – was measured taking samples near each infiltrometer ring, at 4 places. Similarly, after infiltration studies, moisture samples were taken within each infiltrometer ring – post-infiltration moisture distribution. The samples for post-infiltration measurements were taken 2 days after the removal of water from the infiltrometers.

Collection, preparation and analysis of plant samples

Stem, branch, leaf and root samples were analysed separately for chemical composition. Samples were washed with ordinary water, dilute acid (0.1% HCl), and single and double-distilled water, then air-dried and oven-dried at 70°C for 48 h, then ground in a Wiley mill, passed through a 16-mesh sieve, and stored in polyethylene bags. Samples of 1 g were digested in a di-acid mixture (HNO_3:$HClO_4$, 3:1). The filtrate was preserved in 100-ml plastic bottles. The samples were analysed for Na and K by flame photometry, and for Ca, Mg, Fe, Mn, Zn and Cu by Pye Unicam atomic absorption spectrophotometry. Total N was determined by a Kjeltec-II automatic nitrogen analyser. Phosphorus was determined by the vanadomolybdophosphoric-yellow colour method (Jackson, 1967) and S by a turbidity method (Massoumi and Cornfield, 1963), using spectrophotometer model Spectronic 21.

RESULTS AND DISCUSSION

Plant mortality, growth and biomass accumulation

Effects of rates of gypsum on mean plant mortality are reported in Table 2. Over a period of 2 years, 48% of the mesquite died when planted without gypsum application. High sodicity in the control treatment is presumed to have caused high mortality. The plants still surviving in the control treatments are likely to die eventually (Fig. 2). These observations are in agreement with earlier findings of Khan and Yadav (1962) and Yadav and Singh (1970), who reported that establishment of trees in a soil of pH more than 10 is a difficult task. Further, the mortality was higher during the summer months than in winter months, probably due to high exchangeable sodium coupled with moisture stress. Earlier studies (Acharya and Abrol, 1978; Acharya et al., 1979) have also indicated that the adverse effects of high exchangeable sodium on plant growth are accentuated under conditions of high evaporative demands.

The mean plant height ($\bar{H}$) and diameter at stump height (D_S; Table 3) attained in 2 years by mesquite were maximum in the 15 t ha^{-1} gypsum treatment. The $\bar{H}$ and D_S were significantly better in 15 t ha^{-1} than in 7.5 t ha^{-1} gypsum treatment (Fig. 2). The effect of gypsum rates on branches plant^{-1} of mesquite was negligible up to 4 months of age, but increased considerably thereafter (Table 4). The mean oven-dried biomass attained in 1 year by mesquite was maximum (1919 kg ha^{-1}) in 15 t ha^{-1}, followed by 1428 kg in 7.5 t ha^{-1} and 229 kg ha^{-1} in the control treatment (Table 5). It was interesting to note that gypsum had no effect on the root:shoot ratio during the 1-year growth period (Table 5). Earlier studies on a similar soil (Abrol and Sandhu, 1985; Gill and Abrol, 1987; Singh et al., 1987b,c) have also obtained a many-fold increase in biomass accumulation of selected tree species by treating the soil of the planting pit/posthole auger/trench with gypsum.

TABLE 2

Effect of gypsum levels on mean plant mortality up to the age of 24 months

Gypsum level (t ha^{-1})	Plant mortality (%)			
	Age (months)			
	6	12	18	24
0	27.8	33.0	43.1	48.1
7.5	6.2	11.0	11.1	11.1
15.0	5.7	6.6	7.1	7.9
LSD (0.05)	3.6	4.8	4.0	6.2

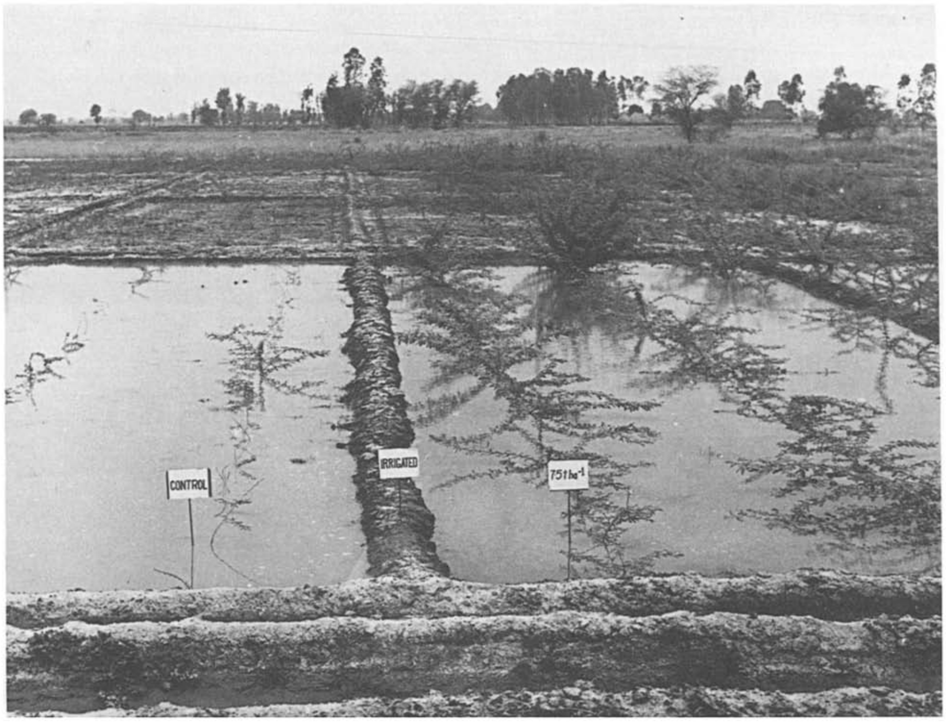


Fig. 2. Effect of gypsum levels on the growth of 6-month-old mesquite.

TABLE 3

Mean plant height (cm) and basal diameter (mm) of mesquite at the age of 12 and 24 months

Gypsum level ($t\ ha^{-1}$)	Height (H)		Basal diameter (D_S)	
	12 months	24 months	12 months	24 months
0	76	86	9.3	10.0
7.5	132	196	15.8	28.2
15	158	244	18.5	35.3
LSD (0.05)	21	28	5.6	6.0

Chemical composition

Effects of gypsum treatment on mean chemical composition in plant parts of 6- and 12-months-old mesquite are reported in Table 6. At both stages, the nutrient concentrations were highest in the leaves, decreasing in the order: leaves > branches > stem. In general, the concentrations in roots were more

TABLE 4

Effect of gypsum application on branches plant^{-1} of mesquite up to the age of 8 months

Gypsum level	Branches plant^{-1}			
	Age (months)			
	2	4	6	8
0	1.9	2.5	5.0	5.6
7.5	2.5	3.8	8.1	9.3
15.0	3.3	4.6	8.7	11.1
LSD (0.05)	ns	ns	2.6	2.2

TABLE 5

Mean oven-dried biomass of mesquite under different treatments in a growth period of 6 and 12 months

Gypsum level	Biomass production (kg ha^{-1})					
	Leaf	Branch	Stem	Root	R:S*	Total
6 months after planting						
0	53	—	125	47	—	225
7.5	145	—	387	110	—	642
15.0	180	—	487	144	—	811
LSD (0.05)	17	—	35	10	—	33
12 months after planting						
0	32	52	79	64	0.39	227
7.5	175	261	576	416	0.41	1428
15.0	260	367	748	544	0.40	1919
LSD (0.05)	29	31	54	34	—	124

*R:S=root:shoot=root wt./Σ (leaf, branch, stem).

than in stems. This nutrient concentration trend is commonly found in nutrient analysis of plant parts (Stewart et al., 1981; Singh, 1982).

At the age of 6 months, effects of gypsum treatment on mean N, P, K, Ca, Mg, S, Cu, Mn and Zn concentrations in leaf, stem plus branches, and root of mesquite were not significant (Table 6). However, the mean Na concentration was significantly less in gypsum-treated soil than in the control. On the other hand, Ca concentration in plants increased with an increase in gypsum rate, but the differences were statistically non-significant.

At the age of 12 months, the mean concentration of P, K, Ca, Mg, S, Cu, Mn and Zn was higher in gypsum-treated mesquite than in control (Table 6). Gypsum rates had little effect on N concentration. Sodium concentration further

TABLE 6

Effect of gypsum on mean chemical composition (mg g^{-1}) of leaf (L) stem (S) and root (R) of 6 and 12-month-old mesquite

Mean chemical composition	Age (months)	Gypsum level (t ha^{-1})								
		0 (control)			7.5			15		
		L	S	R	L	S	R	L	S	R
N	6	36.5	11.1	12.3	34.5	8.4	10.4	34.0	8.1	9.8
	12	33.5	8.5	11.1	32.6	8.7	11.0	31.7	8.5	11.1
P	6	2.2	1.3	1.1	2.0	1.3	1.1	2.0	1.2	1.1
	12	1.6	0.9	1.2	1.8	0.9	1.2	2.0	1.1	1.3
K	6	12.2	4.6	3.8	12.0	4.4	3.4	11.0	4.5	3.5
	12	12.5	3.6	3.6	18.5	5.2	5.5	20.0	5.6	6.1
Ca	6	9.0	1.2	3.7	9.6	1.3	4.2	11.1	1.7	4.1
	12	6.6	2.3	4.9	11.9	3.0	6.0	13.9	3.6	6.8
Mg	6	6.8	2.2	1.7	7.2	1.8	1.2	6.8	1.6	1.3
	12	5.8	2.1	2.2	6.9	2.2	2.7	6.3	2.0	3.0
S	6	6.3	2.7	1.0	6.5	2.3	0.9	5.6	2.3	1.0
	12	1.9	0.6	1.2	2.1	1.0	1.7	2.4	1.1	1.9
Na	6	7.3	1.8	1.5	6.8	1.6	1.2	5.5	1.2	1.3
	12	7.0	1.5	1.9	6.0	1.1	1.6	4.7	1.0	1.3
Na:Ca	12	1.06	0.65	0.39	0.50	0.37	0.27	0.34	0.28	0.19
Ca:Na	12	0.94	1.53	2.58	1.98	2.73	3.75	2.98	4.23	5.23

decreased with an increase in the level of gypsum. This showed that Na concentration in plant parts decreased with an increase in the gypsum level, which was due to a decrease in the exchangeable sodium percentage as a result of gypsum application. It was interesting to note that the gypsum treatment was highly effective in dropping the Na:Ca ratio. The Na:Ca ratio in leaf of 1-year-old mesquite was 1.06, 0.50 and 0.34 in the control, 7.5 t ha^{-1} and 15 t ha^{-1} gypsum level, respectively. These values are much higher than reported for woody perennials (0.10–0.20) tolerant of non-sodic conditions.

After 12 months the mean P concentration in leaf was 1.6, 1.8 and 2.0 mg g^{-1} in control, 7.5 and 15 t ha^{-1} gypsum treatments, respectively. Increased P concentration in gypsum-treated plots may be due to an increase in the availability of soil P as the soil pH was reduced. Reduced pH, together with improved soil physical properties, with an increase in the level of gypsum, favoured P uptake. Further, the root weight was much greater in gypsum-treated plots, the roots having a greater ability to exploit available P, resulting in more P uptake. Similarly, the K concentration in all parts increased with an increase in gypsum level. These results are in agreement with those of Bains and Fireman (1964), Mehrotra and Das (1973) and Singh and Abrol (1985), who reported that exchangeable sodium generally caused decrease in the absorption of K.

An increase in the level of gypsum increased Ca concentration in all parts of mesquite, which is attributed to improved Ca status of the soil. Gypsum application improved Ca:Na ratio in all parts of mesquite. The Ca:Na ratio in leaf of 1-year-old mesquite was 0.94 in the control, 1.98 in 7.5 t ha^{-1}, and 2.98 in 15 t ha^{-1} gypsum level. Earlier studies (Bernstein and Pearson, 1956; Poonia et al., 1972; Singh et al., 1981; Singh and Abrol, 1985) have also reported a decrease in the uptake of Ca in different crops with an increase in the exchangeable sodium concentration in the soil solution. Magnesium and S concentration followed a trend similar to that of Ca, but the differences between gypsum and no gypsum treatments were statistically non-significant. The higher S concentration in gypsum-treated soil may possibly due to the increased S content of soil with the addition of gypsum.

Effect of rates of gypsum on concentration of micronutrients was variable. Decrease in Fe concentration was observed with an increase in level of gypsum application. This may be due to a dilution effect. However, the reverse was true for Mn and Zn. Gypsum rates had little effect on Cu concentration. The mean Fe, Mn, Zn and Cu concentrations in leaf of 1-year-old mesquite were 660, 70, 10 and 10 $\mu g\ g^{-1}$ in the control, 640, 90, 10 and 10 $\mu g\ g^{-1}$ in 7.5 t ha^{-1}, and 620, 100 20 and 10 $\mu g\ g^{-1}$ in 15 t ha^{-1} gypsum treatment, respectively. The physiological explanations for such a variation in micronutrient composition are beyond the scope of this study. Further studies under controlled conditions in pots are suggested.

Effect on soil properties

Effects of gypsum treatment on soil properties were highly significant. Within a period of 14 months, the average pH of 0–15-cm soil dropped from 10.3 (initial) to 10.0, 9.7 and 9.3 (Fig. 3a) and electrical conductivity (σ) from 2.2

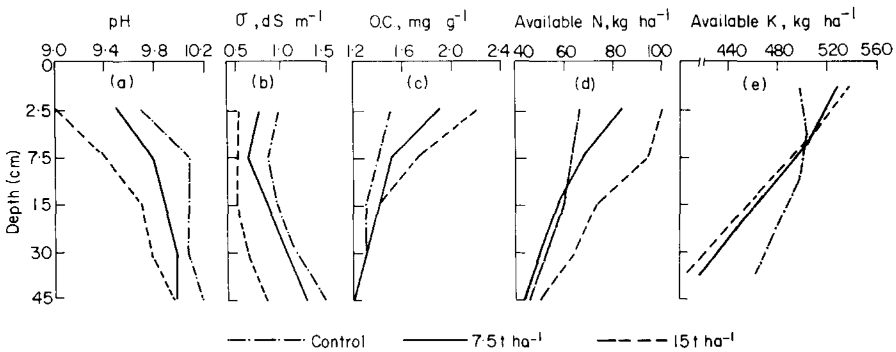
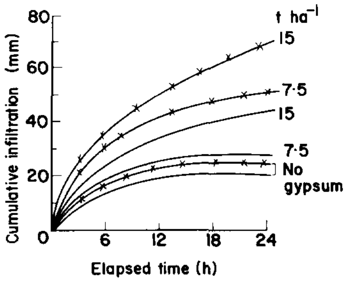


Fig. 3. Effects of gypsum on pH, σ, organic carbon, available N and available K contents of a sodic soil, 14 months after planting.

dSm^{-1} to 1.0, 0.8 and 0.6 dSm^{-1} in control, 7.5 and 15 t ha^{-1} gypsum treatments, respectively (Fig. 3b). The reduction in pH and σ were mainly confined to the surface 15-cm soil. The exchangeable sodium percent (%Na) in 0–15-cm soil dropped from 93 to 85 in the control, 52 in 7.5 t ha^{-1} and 38 in 15 t ha^{-1} gypsum level in 14 months. Organic carbon (Fig. 3c) and available nitrogen (Fig. 3d) build-up in soil was higher in gypsum-treated than in untreated soil. Increase in organic carbon and available N in gypsum-treated plots may be ascribed to the addition of leaf litter, improved physical and biological properties of the soil and enhanced N- fixation by mesquite. Field studies elsewhere (Tiedemann and Clemmedson, 1973, 1986; Rundel et al., 1982) also found that soil under mesquite canopies contains 2–3 times as much organic matter and N as soils away from mesquite canopies. Similarly, studies in a California desert found that mesquite produced 30 kg N ha^{-1} $year^{-1}$ when their crown covered 34% of the land surface area. Rundel et al. (1982) suggested that up to 100 kg of N ha^{-1} $year^{-1}$ might be fixed by mesquite, given greater ground cover and better management practices. The available K content (Fig. 3e) was slightly improved in the 0–7.5-cm soil in gypsum-treated plots, compared to the control. However, the reverse was true for lower layers of the profile up to 45 cm, wherein available K was much less than in the control treatment. It was observed that mesquite roots penetrated much deeper in gypsum-treated plots, mainly because of the improved soil environment, thereby absorbing larger quantities of K from the lower layers. However, in the control, very few roots developed and most of these were confined to 0–15-cm soil. Therefore no change in available K content of soil was observed in the no-gypsum treatment.

Application of gypsum and mesquite growth caused significant improvement in the water infiltration rate of a sodic soil (Fig. 4). At 18 months after planting, the amount of water infiltrated was 2.29 cm in the control, 5.21 cm in 7.5 t ha^{-1} and 6.84 cm in 15 t ha^{-1} treatments. Higher infiltration in gypsum-treated soil may apparently be due to reduced sodicity, better mesquite growth, enhanced biological activity of a sodic soil by tree roots and improved humus status of the soil due to litterfall and growth of understorey vegetation. Further, total root mass of mesquite was many-fold higher in gypsum-treated than untreated soil.

Effect of gypsum application on pre- and post-infiltration moisture in the profile is given in Fig. 5. The pre-infiltration moisture in 0–30-cm soil was almost same in the control, 7.5 and 15 t ha^{-1} gypsum treatments. However, beyond this, a drastic decrease in moisture was observed in the no-gypsum treatment. On the other hand, the water content in the profile increased with depth in gypsum-treated plots. The average moisture content in the 75–90-cm profile layer was 10% in the control, 13% in 7.5 t ha^{-1} and 17% in 15 t ha^{-1} treatments. This indicated that gypsum application has increased the water-



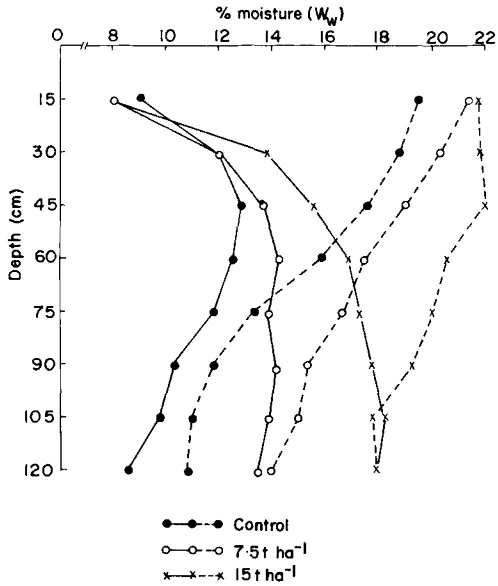


Fig. 4 (left). Effect of gypsum on cumulative infiltration 6 (——) and 18 (× × ×) months after planting.

Fig. 5 (right). Effect of gypsum on pre (——) and post (- - -)-infiltration moisture distribution in the profile.

holding capacity of a sodic soil by bringing significant improvement in physical and chemical properties of the soil.

Post-infiltration moisture measurements indicated greater moisture content throughout the profile in gypsum-treated soils compared to the control treatment. The differences were less marked in the 0–30-cm soil. However, beyond the 30-cm depth, a sharp decrease in moisture content was observed in the control, whereas the decrease was gradual and less marked in gypsum-treated soil. The average water contents in the 90–120-cm profile layer were 11, 15 and 18% in the control, 7.5 and 15 t ha^{-1} gypsum treatments, respectively. The average POM in the 0–150-cm profile ranged from 19 to 11% in the control, 21–13% in 7.5 t ha^{-1} and 22–18% in 15 t ha^{-1} treatments, showing that moisture was uniformly distributed throughout the profile in the 15 t ha^{-1} gypsum treatment, which could be very useful to the trees during the drought phase. Less moisture in no-gypsum treatment, especially in the lower layers of the profile, is ascribed to restricted water movement due to dispersed and defloculated soil conditions caused by high pH and %Na.

CONCLUSION

The study has shown that gypsum applications of 7.5 and 15 t ha^{-1} in an abandoned sodic soil resulted in 6 and 9-fold increases in biomass of mesquite, respectively over the no-gypsum treatment. In the non-amended sodic soil, 48% of the mesquite seedlings died within 2 years of planting, whereas in gypsum-treated soil, the mortality was very low: 12% in 7.5 t ha^{-1} and 8% in 15 t ha^{-1}. Calcium and Mg increased while Na decreased in all parts of mesquite, with an increase in rate of gypsum application. Application of gypsum and mesquite growth caused significant reduction in sodicity and improvement in fertility status and water relations of a barren sodic soil. From these results it is inferred that 2.5 million ha of hitherto abandoned sodic soils of the Indo-Gangetic plains of India could be successfully utilized for raising mesquite plantations after the application of 15 t ha^{-1} gypsum, thus easing fuelwood shortages in the country.

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