GYPSUM AND ORGANIC RESIDUE FOR AFFORESTATION OF SODIC SOILS

S.D. Sharma, K.G. Prasad,

Division of Forest Soil and Land Reclamation, Forest Research Institute, Dehra Dun, India

G.H. Khan & V.K. Singh

Farm Forestry Project, IFFCO, Aisha Manzil, Civil Lines, Sultanapur, Uttar Pradesh, India

Received September 1993

SHARMA, S.D., PRASAD, K.G., KHAN, G.H. & SINGH, V.K. 1995. Gypsum and organic residue for afforestation of sodic soils. A field experiment was carried out to determine a suitable source of organic residue and method of gypsum application for afforestation of sodic soil (Aquic Petrocalcic Natrustalf) in Sultanpur district of Uttar Pradesh in India. Twelve treatments consisting of four organic residue treatments (no organic residue, green manure, FYM and rice husk) and three gypsum application treatments (no gypsum, 125 q gypsum ha^{-1} incorporated either in the pit, spread 2 m apart, at the rate of 5 kg/pit or broadcasted at the rate of 125 kg in each 10×10 m plot) were applied in four replications to *Terminalia arjuna*. It was inferred that rice-husk was the most suitable source of organic residue, and gypsum applied in a pit after mixing with excavated soil was the best method of its application for afforestation of sodic soils. Combined application of rice husk and gypsum mixed with soil in the pit gave maximum survival, growth and volume yield of *T. arjuna* in Natrustalf soils. Broadcast application of gypsum applied alone or in combination with green manure or FYM resulted in drying of plant tips after two years of growth and under severe stress conditions, mortality of plants.

Key words: Rice husk - green manure - FYM - gypsum - sodic soil - afforestation - *Terminalia arjuna*

SHARMA, S.D., PRASAD, K.G., KHAN, G.H. & SINGH, V.K. 1995. Sisa gipsum dan organik untuk penghutanan tanih sodik. Satu kajian lapang dijalankan untuk menentukan sumber sisa organik yang sesuai dan kaedah penerapan gipsum untuk penghutanan tanih sodik (Aquic Petrocalic Natrustlf) di daerah Sultanpur, Uttar Pradesh, India. Dua belas rawatan yang terdiri dari empat rawatan organik (tiada sisa organik, baja hijau, FYM dan sekam padi) dan tiga rawatan penerapan gipsum (tiada gipsum, 125q gipsum ha^{-1} dimasukkan sama ada di dalam lubang, tersebar dalam jarak 2m, pada kadar 5kg/lubang atau ditabur pada kadar 125 kg dalam setiap plot 10 x 10m) digunakan dalam empat replikasi *Terminalia arjuna*. Kesimpulannya, sekam padi merupakan sumber sisa organik yang paling sesuai dan gipsum yang diterap dalam lubang setelah digaulkan dengan tanih yang digali merupakan kaedah terbaik untuk penghutanan tanih sodik. Campuran sekam padi dan gipsum yang dicampurkan dengan tanih dalam lubang memberikan kemandirian, tumbesaran dan hasil isipadu *T. arjuna* yang maksimum di tanih Natrustalf. Penaburan gipsum secara tunggal atau dengan baja hijau FYM menyebabkan pucuk tumbuhan menjadi kering setelah tumbuh selama dua tahun dan menyebabkan kematian tumbuhan di bawah keadaan tekanan yang teruk.

Introduction

Sodic soils are unable to support vegetative cover due to their inhospitable physical, chemical and biological conditions and, as such, several soil management practices have been recommended from time to time. Incorporation of gypsum and organic residue has been recognised as indispensable treatment for amelioration of such soils for agricultural and silvicultural use (Yadav 1977, Sharma *et al.* 1992, 1993). Some aspects of gypsum application such as its fineness and depth of application have been studied (Khosla *et al.* 1971, Chawla & Abrol 1980) but the information on its method of application for forestry crop is lacking. Similarly, although beneficial effects of different organic residues, viz. green manure, farm yard manure (FYM), rice husk, saw dust, etc. have been recognised (Dargan *et al.* 1976, Khosla & Yadav 1976, Mehta *et al.* 1979, Swarup 1991, Sharma & Prasad 1991), their relative potential for amelioration is not known. This field experiment was, therefore, laid out in July 1988 to find out the most suitable source of organic residue and method of gypsum application for afforestation of sodic soils.

Table 1. Physico-chemical properties of study site

Property	Horizon					
	Ap	B21	B22	B23	C1ca	C2
Depth (cm)	0-13	13-33	33-64	64-97	97-132	132-170
Sand (%)	56.0	50.0	52.0	50.0	54.0	66.0
Silt (%)	34.0	36.0	26.0	30.0	30.0	26.0
Clay (%)	10.0	14.0	22.0	20.0	16.0	8.0
Texture	SI	L	SCL	L	SL	SL
pH	10.3	10.1	10.0	9.9	9.9	9.9
E.C. (dS/m)	2.0	1.0	1.0	1.0	0.9	0.6
Water soluble salts (%)	0.5	0.5	0.9	1.2	0.6	0.6
Free $CaCO_3$(%)	9.8	9.2	8.7	8.9	9.0	9.7
Base saturation (%)	90.3	90.5	85.0	80.2	78.2	70.5
C.E.C. (m.e. %)	18.3	18.8	18.7	18.4	13.9	9.2
Exchangeable Ca (m.e. %)	2.2	2.0	2.0	1.4	1.0	0.9
Exchangeable Mg (m.e. %)	1.0	0.8	0.6	0.9	0.6	0.5
Exchangeable K (m.e. %)	0.5	0.4	0.5	0.2	0.2	0.1
Exchangeable Na (m.e. %)	12.9	13.9	12.8	12.2	9.1	5.0
Exchangeable Na (%)	70.4	73.7	68.3	66.2	65.5	54.8
Organic carbon (%)	0.14	0.06	0.04	0.02	0.06	0.04
Total N (ppm)	120.0	30.0	20.0	20.0	30.0	20.0
Available P (ppm)	4.5	2.8	4.5	3.8	2.7	2.7
Available K (ppm)	90.0	70.0	93.0	38.0	28.0	10.0

Materials and methods

Study area

The experimental site was situated in the Indo-Gangetic plains (Village Kanaksinghpur, Sultanpur district, Uttar Pradesh) at 26° 16' N and 82° 07' E. The site experiences long, dry and very hot summers accompanied by hot dry wind (*Loo*). Mean maximum and minimum temperatures are 44 °C and 3 °C respectively. Winters are chilly with frequent cold fronts. Mean annual rainfall is 967 mm, mainly received during July, August and September. The soil belongs to fine loamy, mixed, thermic family of Aquic Petrocalic Natrustalf (Prasad & Sharma 1994). The surface is hard setting and when dry has poor infiltration rate. The soil has high pH and low fertility (Table 1).

Experimental

A split plot design experiment with four replications, consisting of 12 treatments, was laid out. The main treatments consisted of gypsum application (12.5 t ha^{-1} or 125 q ha^{-1}) as Gy0 - no gypsum, Gy1 - broadcast (125 kg/plot), and Gy2 - pit (5 kg/pit) application. The sub-plot treatments consisted of different sources of organic residue (75 q ha^{-1}) applied in the pit (3 kg/pit) as Or0-no organic residue, Or1-*Sesbania cannabina* (dhaincha) green manure, Or2 - FYM and Or3 - rice husk.

Twenty-five six-month-old plants of *Terminalia arjuna* were planted in each plot (10 × 10 m) at a spacing of 2 × 2 m. Small pits (60 cm^3) were opened and a basal dose consisting of 100 g single super phosphate, 50 g muriate of potash, 2.5 g zinc sulphate, 2.5 g ferrous sulphate and 5 g BHC was applied to each pit and mixed with soil. Gypsum and organic residue as per treatment were also mixed with the soil before filling the pit. Two hundred gram urea was top dressed to all the plants in four split doses (50 g each) after 2, 6, 12 and 18 months of planting. The plants were irrigated twice a month during summer and once a month during dry winter period. Survival, height and collar circumference of plants were recorded after 2, 3, and 4 years of growth.

Volume yield of *T. arjuna* was calculated as a product of plant population per hectare (2500 * survival/100), height and one third basal area (collar circumference $^2/4\pi$), assuming the volume of plant as a cone and plant spacing as 2 × 2m. The equation for volume yield (dm^3 ha^{-1}) may, therefore, be written as $2500*S/100\ H*1/3*C^2/4\pi$ where, S is survival in per cent, H is plant height in dm and C is collar circumference in dm.

In order to compare the efficiency of treatments under different methods of gypsum application, relative efficiency of gypsum (REGy) for Gyi*Orj was calculated as 100 *(Gyi*Orj - Gy0*Orj)/Gy0*Orj). Similarly, under different sources of organic residue, relative efficiency of organic residue (REOr) for Gyi*Orj was calculated as 100 * (Gyi * Orj - Gyi * Or0)/Gyi * Or0, where i = 0, 1 and 2 and j = 0, 1, 2, and 3, provided the denominator is not zero. In order to avoid repetition, relative efficiency of treatments (REGy and REOr) was calculated from data collected after three years of growth.

Results

Examination of the data (Table 2) reveals that the plants did not survive without addition of organic residue and gypsum (Gy0 * Or0) in sodic soils. The findings with respect to suitability of the source of organic residue and method of gypsum application are presented below.

Sources of organic residue

Mean survival of *T. arjuna* was very poor (13%) when no organic residue was added (Or0) and it increased by 59% due to green manure (Or1), 105% due to FYM (Or2), and 252% due to rice husk (Or3) application two years after planting. A similar trend continued even after 4 y and maximum survival (38.7%), observed in rice husk treated plots, was 287% of Or0 treatment (Table 2).

Table 2. Effect of treatments on survival (%) of *T. arjuna*

Treatment	Gy0	Gy1	Gy2	Mean	C.D.5%	
			2 y			
Or0	0.0	7.0	32.0	13.0	Gy	10.3
Or1	3.0	7.0	52.0	20.7	Or	11.8
Or2	3.0	21.0	56.0	26.7	Gy*Or	n.s.
Or3	37.0	37.0	63.0	45.7		
Mean	10.8	18.0	50.8			
			3 y			
Or0	0.0	3.0	29.0	10.7	Gy	9.8
Or1	2.0	3.0	49.0	18.0	Or	11.3
Or2	2.0	5.0	55.0	20.7	Gy*Or	n.s.
Or3	32.0	32.0	63.0	42.3		
Mean	9.0	10.8	49.0			
			4 y			
Or0	0.0	2.0	28.0	10.0	Gy	10.3
Or1	0.0	3.0	41.0	14.7	Or	11.9
Or2	2.0	4.0	55.0	20.3	Gy*Or	n.s.
Or3	26.0	28.0	62.0	38.7		
Mean	7.0	9.3	46.5			

Similarly the data on mean height of plants indicated that plants applied with rice husk were taller than with other organic residues on all the observation dates. They were respectively 90, 44 and 30% taller for rice husk, green manure and FYM after 2 y, 126, 32 and 38% after 3 y and 155, 10 and 61% after 4 y in comparison to no organic residue treatment (Table 3).

Rice husk further proved to be the most suitable source of organic residue to increase collar circumference of plants. On an average, this increase due to rice husk treatment was respectively 147, 61 and 85% after 2 y; 107, 71 and 53% after 3 y; and 130, 112 and 61% after 4 y greater than with no organic residue, green manure and FYM (Table 4).

Volume yield of *T. arjuna* (dm^3 ha^{-1}) thus calculated by taking into account all the three parameters (survival, height and collar circumference) also corroborate the above results (Table 5). Mean volume yield when no organic residue (Or0) was applied was only 5.45 dm^3 ha^{-1} which increased by 73% due to green manure (Or1), 69% due to FYM (Or2) and 714% due to rice husk (Or3) after 2 y. A similar trend was recorded after 3 y and 4 y of growth and mean maximum volume yield (396.47 dm^3 ha^{-1}) after 4 y was recorded when rice husk (Or3) was applied. It may also be noted that volume yield due to rice husk application was significantly superior to any other organic residue applied throughout the period of observation. Further, green manure had relatively greater volume yield than FYM after 2 y but its effect diminished after 3 y and 4 y of growth.

Table 3. Effect of treatments on height (cm) of *T. arjuna*

Treatment	Gy0	Gy1	Gy2	Mean	C.D. 5%	
			2 y			
Or0	0.0	43.3	60.0	34.3	Gy	17.1
Or1	37.5	46.3	64.5	49.4	Or	19.7
Or2	20.0	53.8	60.0	44.6	Gy*Or	n.s.
Or3	58.3	60.0	77.5	65.2		
Mean	28.9	50.8	65.5			
			3 y			
Or0	0.0	32.0	79.3	37.0	Gy	22.7
Or1	20.8	41.5	83.8	48.7	Or	26.2
Or2	25.0	36.8	91.0	50.9	Gy*Or	n.s.
Or3	75.8	77.8	94.0	83.5		
Mean	30.4	47.0	87.0			
			4 y			
Or0	0.0	24.4	94.5	39.6	Gy	25.3
Or1	0.0	26.3	104.1	43.5	Or	29.2
Or2	31.9	48.1	111.1	63.7	Gy*Or	n.s.
Or3	76.6	105.6	120.9	101.0		
Mean	27.1	51.1	107.7			

Table 4. Effect of treatment on collar circumference (cm) of *T. arjuna*

Treatment	Gy0	Gy1	Gy2	Mean	C.D.5%	
			2 y			
Or0	0.0	1.7	2.8	1.5	Gy	1.0
Or1	1.3	2.3	3.2	2.3	Or	1.2
Or2	1.3	1.6	3.1	2.0	Gy*Or	n.s.
Or3	3.8	3.0	4.4	3.7		
Mean	1.6	2.1	3.4			
			3 y			
Or0	0.0	4.0	8.5	4.2	Gy	2.3
Or1	2.0	5.0	8.2	5.1	Or	2.7
Or2	2.4	5.8	9.1	5.7	Gy*Or	n.s.
Or3	8.6	8.5	9.1	8.7		
Mean	3.3	5.8	8.7			
			4 y			
Or0	0.0	4.1	9.6	4.6	Gy	2.8
Or1	0.0	5.7	9.2	5.0	Or	3.2
Or2	2.8	6.4	10.5	6.6	Gy*Or	n.s.
Or3	9.5	10.6	11.9	10.6		
Mean	3.1	6.7	10.3			

Table 5. Effect of treatment on volume yield (dm^3 ha^{-1}) of *T. arjuna*

Treatment	Gy0	Gy1	Gy2	Mean	C.D.5%	
			2 y			
Or0	0.00	1.40	14.94	5.45	Gy	20.60
Or1	1.09	4.09	23.09	9.42	Or	23.79
Or2	3.98	2.02	21.63	9.21	Gy*Or	n.s.
Or3	21.51	27.06	84.61	44.39		
Mean	6.64	8.64	36.07			
			3 y			
Or0	0.00	12.08	146.12	52.73	Gy	88.64
Or1	7.05	15.35	186.85	69.75	Or	102.35
Or2	11.97	9.27	293.40	104.88	Gy*Or	n.s.
Or3	141.89	143.75	372.04	219.22		
Mean	40.23	45.11	249.60			
			4 y			
Or0	0.00	16.37	186.61	67.66	Gy	137.26
Or1	0.00	12.41	248.78	87.06	Or	158.50
Or2	20.47	19.69	463.77	167.97	Gy*Or	n.s.
Or3	171.64	238.40	779.37	396.47		
Mean	48.03	71.72	419.63			

Methods of gypsum application

Data in Table 2 reveal the superiority of gypsum application in pit over broadcast application. On an average, mean survival of plants increased by 370% due to pit application of gypsum after 2 y, 444% after 3 y and 564% after 4 y in comparison to no gypsum application. However, only 67% increase in survival was noted by broadcast application of gypsum over control after 2 y which decreased to 20% after 3 y of planting and was 33% of zero gypsum application after 4 y.

Data in Table 3 confirm that application of gypsum, irrespective of its method of application, was significantly superior over zero gypsum application in increasing height of *T. arjuna*, although the increase in growth due to broadcast application was 75% after 2 y, 55% after 3 y and 88% after 4 y over zero gypsum application. Mean height of *T. arjuna* increased significantly by pit application of gypsum (Gy2) and was 127 and 29% more respectively than the control (Gy0) and broad-cast application of gypsum (Gy1) after 2 y, 186 and 85% after 3 y and 297 and 111% after 4 years (Table 3) indicating that the plants from the Gy2 treatment continued to gain greater height growth even during the fourth year.

Further, it was noticed that the plants receiving broadcast application of gypsum having initially better height growth died after the second year resulting in lower mean height growth of *T. arjuna* in the subsequent years. In the case of Gy1*Or3 treatment, the height growth continued to increase during the third year but decreased in the fourth year.

Mean collar circumference of plants due to pit application of gypsum (Gy2) was respectively more by 113 and 62% than the control (Gy0) and broadcast application of gypsum (Gy1) after 2 y, 164 and 50% after 3 y, and 232 and 54% after 4 y. Gypsum application, either in pit or broadcast, increased mean volume yield of *T. arjuna*; however, the increment was significantly higher in the case of pit application. Application of gypsum in pit (Gy2) resulted in 443 and 317% additional gain in volume yield over Gy0 and Gy1 treatments respectively after 2 y, 521 and 453% after 3 y, and 774 and 485% after 4 y.

Combined application of gypsum and organic residues

T. arjuna experienced complete mortality when both organic residue and gypsum were not applied (Table 2). Application of gypsum alone increased plant survival to 7% by broadcast application and 32% by pit application after 2 y, 3 and 29% after 3 y, and 2 and 28% after 4 y. Similarly, organic residue when applied alone as green manure or FYM resulted in poor survival, i.e. 3% each after 2 y, 2% each after 3 y, and 0 and 2% after 4 y respectively. However, application of rice husk alone (Gy0* Or3) resulted in 37% survival after 2 y, 32 % after 3 y, and 26% after 4 y. The survival rate increased to 63 % when pit application of gypsum was coupled to rice husk (Gy2*Or3) after 2 and 3 y and remained 62% even after 4 y of growth.

Effect of treatments on height of plants followed a similar trend (Table 3). Plants receiving gypsum alone in pit were 60 cm tall after 2 y which increased by 32% after 3 y and 58 % after 4 y. However, the height of *T. arjuna*, 43.3 cm after

2 y when gypsum was applied alone as broadcast, on an average, decreased by 26% after 3 y and 43% after 4 y. Rice husk and FYM applied alone resulted in 58.3 and 20.0 cm tall *T. arjuna* plants after 2 y which increased by 30 and 25% after 3 y and 32 and 59% after 4 y. However, the height growth of *T. arjuna* after 2 y at 37.5 cm in green manure application decreased by 44% after 3 y, and no plant survived after 4 y. Maximum height of *T. arjuna* was recorded for those plants receiving 3 kg rice husk and 5 kg gypsum (Gy2*Or3) in planting pits and were 78, 94 and 121 cm tall after 2, 3 and 4 y of growth respectively (Table 3).

Collar circumference of *T. arjuna* increased when gypsum alone was applied in pits (Gy2) or broadcasted (Gy1), by 204 and 135% in the third year and 243 and 141% in the fourth year from 2.8 and 1.7 cm respectively in the second year (Table 4). Collar circumference also increased when rice husk or FYM was applied alone by 126 and 85% respectively in the third year. Green manure applied alone increased collar circumference in the third year (54%) from 1.3 cm in the 2nd year but all the plants died in the fourth year. Maximum collar circumference during the period of observation was recorded when gypsum was applied in a pit along with rice husk (Gy2*Or3) and were 4.4, 9.1 and 11.9 cm after 2,3 and 4 y of growth respectively.

The increases in volume yield of *T. arjuna* were 878 and 1149% in the third and fourth year respectively when gypsum alone was applied in pits (Gy2*Or0) and 763 and 1069% when gypsum was broadcasted (Gy1*Or0) in comparison to volume yield after 2 y (14.94 and 1.40 dm^3 ha^{-1} respectively) (Table 5). On the other hand the application of rice husk alone (Gy0*Or3) produced volume yield of 21.51 m^3 ha^{-1} after 2 y which increased by 560 and 698% after 3 and 4 y respectively. Maximum volume yield was recorded in the application of gypsum in pit coupled with addition of rice husk (Gy2 Or3) as 84.61 dm^3 ha^{-1} after 2 y, 372.40 dm^3 ha^{-1} after 3 y and 779.37 dm^3 ha^{-1} after 4 y of growth.

It may be noted that volume yield after 2 y was better when green manure was applied along with gypsum either as broadcast application (Gy1 Or1) or as a pit application (Gy2 Or1) by 102 and 7% respectively than when FYM was applied (Gy1 Or2 and Gy2 Or2). After 3 y, Gy1 Or1 treatment remained superior (66%) to Gy1 Or2 treatment, whereas Gy2 Or1 treatment became inferior (36%) to Gy2 Or2 treatment. However, after 4 y growth, FYM was superior to green manure when applied either as broadcast (Gy1 Or2) or as a pit application (Gy2 Or2) by 59 or 86% respectively from Gy1 Or1 or Gy2 Or1 treatments.

Further, volume yield increased due to Gy1*Or1 treatment from the second to third year by 275% but decreased from the third year to the fourth year by 19%, primarily due to greater mortality and cessation of height growth.

Relative efficiency of treatments

As evident from Figure 1, the relative efficiency of gypsum (REGy) applied in pit was far superior to broadcast application, and was 2350, 304 and 311% more for survival, height and collar circumference respectively when applied with green

manure; 2650, 264 and 283% more when applied with FYM; and 97, 24 and 6% more when applied with rice husk.

Among the sources of organic residue, relative efficiency (REOr) of rice husk was maximum followed by FYM and green manure and the survivals were respectively 117, 90 and 69% more with gypsum applied in pit and 967, 67 and 0 % when broadcasted. Corresponding values for height were 19, 15 and 6% due to pit application and 143, 15 and 30% due to broadcast application of gypsum. Decrease in relative efficiency for height of FYM as compared to green manure when applied along with broadcast application of gypsum was due to the drying of plant tips and mortality of plants.

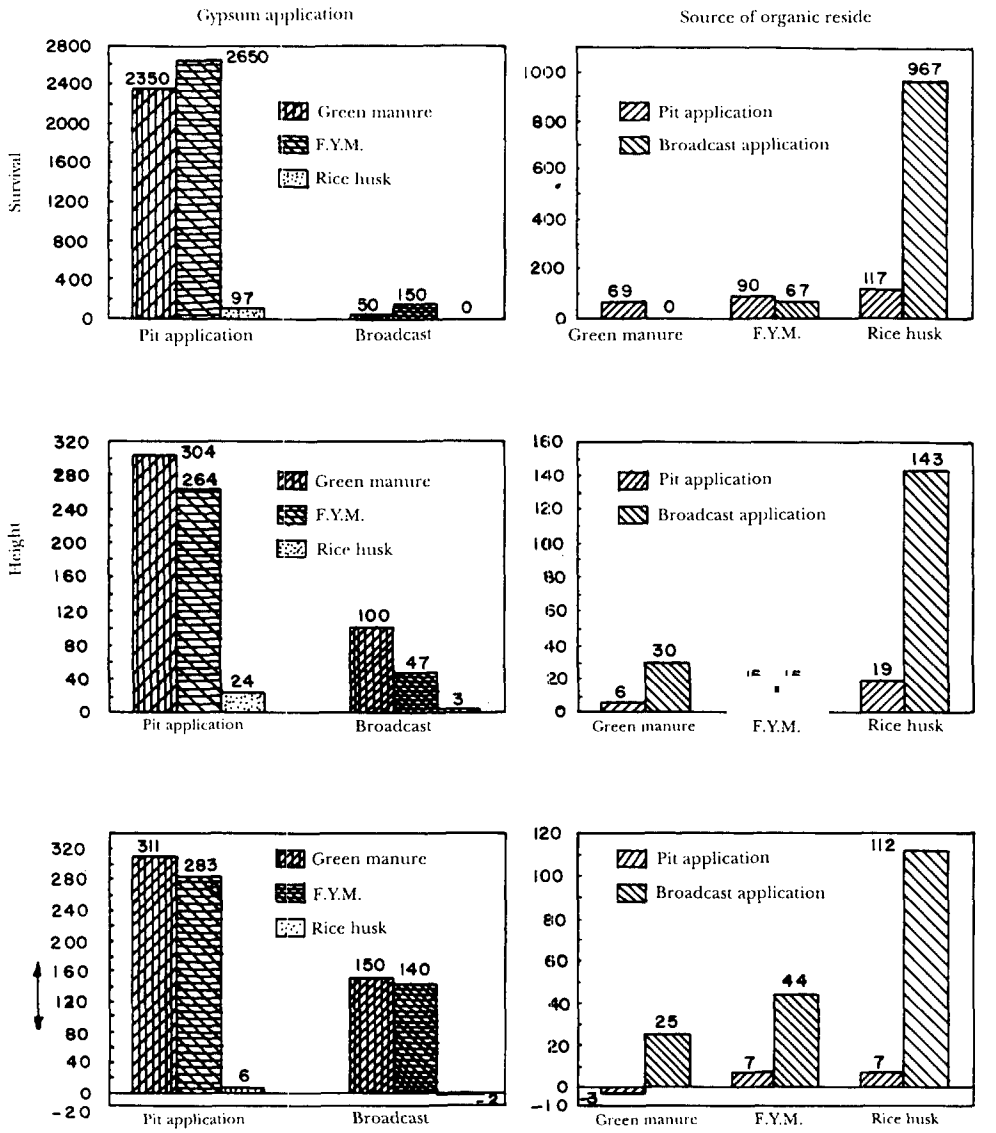

Figure 1. Relative efficiency (%) of treatments

Discussion

The results of this study very clearly lead us to infer that application of gypsum is essential for tree species when grown in sodic soil. Gypsum is a potent ameliorant which generates soluble calcium, replaces sodium and floculates clay. It also produces sulphuric acid on hydrolysis to bring down undersirably high pH value. Gypsum, therefore, improves physical (structure, porosity, bulk density, aeration, water movement), physico-chemical (pH, exchangeable sodium, sodium absorption) and chemical properties of soil by making conditions favourable for the availability of nutrients besides supplying Ca and S which are essential for plant growth. The ultimate effect is a remarkably favourable influence on the establishment and growth of plants.

The observations indicate that the pit application of gypsum is much superior to broadast application of the same amount. This result may be attributed to the fact that at the time of transplanting, the soil near the root zone must be free from the dominance of sodium and should have favourable physical conditions to allow easy exchange of air, movement of water and growth of root for establishment of tree seedlings. Moreover, due to smaller soil volume, when gypsum is applied in pit, antagonistic effect of sodium is minimised which is not true when the same amount of gypsum is broadcasted. This is one reason for the higher mortality, decreased height growth and volume yield of *T. arjuna* after three and four years when gypsum was broadcasted. The observation was further confirmed by the greater efficiency of different organic residue (REOr) in pit application than broadcast application. Broadcast application of gypsum for tree seedlings is not very effective because of improper mixing with soil and incomplete reaction with large soil volume.

Superiority of rice husk over green manure and FYM is due to its capability to improve physical properties of soil (Khosla & Yadav 1976, Mehta *et al.* 1979) that helps in easy movement of air and water which is of immense value for such soils especially during early stages of establishment and growth. Further, due to the slow rate of decomposition of rice husk, the organic residue remains in the soil for a longer period resulting in improved and modified soil structure. The authors, at the same location, observed that rice husk mixed with Natrustalfs remained partially decomposed even after five years. Beneficial effects of rice husk were found so prepon-derant that the effects of no gypsum treatments were masked when rice husk was applied as evident by the very low or even negative relative efficiency value of gypsum treatment (REGy). Similarly, low relative efficiency of gypsum in Gy2 Or3 treatment was also due to the masking of Gy2 treatment in the presence of the Or3 treatment.

Field observations and a perusal of the data collected brought out a very interesting behavior of plants grown in Natrustalfs. When ameliorative effect of treatments (organic residue and/or gypsum) start diminishing, plants start drying from the tip during dry months due to water stress, and under severe stress conditions the plants die due to high osmotic pressure caused by the presence of sodium resulting in scarce available water, restricted nutrient availability due to

high pH and sodium toxicity. Further, taller plants die first. This is the reason that plant height and volume yield in plots receiving gypsum applied through broadcast (Gy1), with or without green manure (Or1) or FYM (Or2) decreased from the second year to the third and fourth years. This is further confirmed by the continued increase in collar circumference in these treatments in spite of decreased height growth with time.

Conclusion

The study indicates that gypsum should be applied in pit after mixing with the soil along with rice husk, as source of organic residue. The effect of broadcast application of gypsum, with or without green manure or FYM starts diminishing after two years, resulting in drying of tip and under severe water stress condition, mortality of plants.

Acknowledgement

The authors acknowledge with thanks the financial assistance provided by the FAO Regional Office for Asia and the Pacific, Bangkok, through their FORSPA (Forestry Research Support Programme for Asia and the Pacific) project.

References

CHAWLA, K. L. & ABROL, I. P. 1980. Optimum gypsum fineness for reclamation of alkali soils of Indo-Gangetic Plains. *Indian Farming* 29 (11) : 23 - 24.

DARGAN, K.S., GAUL, B.L., ABROL, I.P. & BHUMBLA, D.R. 1976. Effect of gypsum, farmyard manure and zinc on the yield of berseem, paddy and maize in a highly sodic soil. *Indian Journal of Agricultural Science* 46 : 535 - 41.

KHOSLA, B. K. & YADAV, J. S. P. 1976. In sodic soils rice husk improves physical conditions and crop growth. *Indian Farming* 23(10) : 9 - 11.

KHOSLA, B.K., DARGAN, K.S. & ABROL, I.P. 1971. Mix gypsum only in shallow depths. *Indian Farming* 21 (9) : 41 - 42.

MEHTA, K.K., YADAV, J.S.P. & SHARMA, S.K. 1979. Rice husk for reclamation of alkali soils. *Indian Farming* 29(4) : 19 - 20.

PRASAD, K.G. & SHARMA, S.D. 1994. Salt affected soils of Indo-Gangetic plains. *Indian Forester* 120 (4) : 361 - 367.

SHARMA, S.D. & PRASAD, K.G. 1991. Afforestation of sodic soils. Project Report. Forest Research Institute, Dehra Dun.

SHARMA, S. D., PRASAD, K. G., KHAN, G.H. & SINGH, V. K. 1993. Development of soil technology for afforestation of sodic soils in Uttar Pradesh, India. *Annals of Forestry* 1(1) : 33 - 41.

SHARMA, S.D., PRASAD, K.G., RAI, L. & MALIK, N. 1992. Development of soil technology for afforestation of sodic soils I. Leguminous species. *Indian Forester* 118 (8) : 547 - 559.

SWARUP, A. 1991. Effect of gypsum, green manure, farm yard manure and zinc fertilization on the zinc, iron and manganese nutrition of wet land rice on a sodic soil. *Journal of the Indian Society of Soil Science* 39 : 530 - 36.

YADAV, J. S. P. 1977. Use of gypsum in reclamation of alkali soils. Pp. 83 - 95 in *Proceedings of the Seminar on Use of Gypsum in Reclamation of Alkali Soils.* Lucknow.