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Agro-techniques for afforestation of degraded coastal agricultural lands with silk cotton (*Ceiba pentendra* (L.) Gaertn.)

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Abstract
Agricultural land and agro-forest ecosystems symbolize the major background of a landscape and its sustainable management will play a key role in habitat conservation. Afforestation of degraded coastal agricultural lands with *Ceiba pentandra* (L.) Gaertn.) uplifts the income of farmers and enhances the tree cover outside the conventional forests. Accordingly, to test the agro techniques for the better establishment and growth of *C. pentandra*, a field experiment was conducted in degraded coastal agricultural land. The treatments consisted of land management methods *viz*., pit method, trench method, mound method and auger hole method of planting in the main plot and in sub plots, combination of ameliorative amendments such as FYM, composted coir pith and pressmud along with gypsum, $ZnSO_4$ and biofertilizers were employed. Based on the results of the present investigation it can be revealed that auger hole method of planting in combination with FYM @ 12.5 t ha^{-1}, gypsum @ 200 kg ha^{-1}, $ZnSO_4$ @ 25 kg ha^{-1}, *Azospirillum* @ 2 kg ha^{-1} and phosphobacteria @ 2 kg ha^{-1} significantly registered the maximum establishment percentage of 83.21 (12 months after planting), plant height of 340.12 cm, girth measurement of 19.52 cm and RGR of 3.29 cm $month^{-1}$ (36 months after planting).

Keywords: Agroforestry, agroecosystems, kapok, land deterioration, multipurpose trees, wastelands

Introduction
Silk cotton also called as kapok (*Ceiba pentandra* (L.) Gaertn.), (Bombacaceae) is one of the most important deciduous tree with multipurpose uses. The flowers are essential source of honey for beekeepers. The kapok floss is used for stuffing pillows, mattresses and cushions. It's excellent buoyancy and water repellent, making it ideal for life jackets, lifeboats and other naval safety apparatus. It is an excellent material for insulating iceboxes, refrigerators, cold-storage plants, offices and aeroplanes. It acts as a good sound absorber and is used for acoustic insulation. It is indispensable in hospitals, since mattresses can be dry sterilized without losing its original quality. As an important type of lignocellulosic plant fiber, kapok fiber has been used as a reinforcement material in polyester matrixes via hybridization with glass and sisal fabrics (Reddy *et al*., 2009) [15]. In addition, this fiber is considered to be a potential starting material for the preparation of versatile activated carbon fibers (Chung *et al*., 2013) [7]. The seed contains 20-25 percent non-drying oil, used as a lubricant and in soap manufacturing. The pressed cake is used as cattle feed containing 26 percent protein. The wood is very light, with a specific gravity of 0.25 g cc^{-1} and is used for preparation of plywood, packaging, lumber core stock, light construction, pulp and paper products, match splint, canoes and rafts, *etc*. Because of its wide range of uses, it]has been cultivated in the bunds and boundaries of farmlands and social forestry plantations (Rex Immanuel and Ganapathy, 2007) [16].
The wasteland or degraded land or land deterioration is the land which has been previously used for crop cultivation but now abandoned. The lands producing much less than their potential and which are economically unproductive, ecologically unstable and subject to environmental deterioration are degraded lands (Agarwal, 1982) [2]. It is estimated that a total of about 174 m. ha of land (53 per cent) in India suffers from different types and varying degrees of degradation and about 40 m. ha of arable land is lying barren for one reason or another (Sehgal and Abrol, 1994) [21]. The major constrains in the reclamation of potentially available arable lands in the coastal districts of Tamil Nadu are saline / alkaline soils 1.81 m. ha, degraded sandy coastal lands 0.48 m. ha and water logged soils 0.38 m. ha (Anon, 2000). Many of these sites are affected with salinity and experience standing water through much of the rainy season due to an underlying restrictive layer, most often a canker pan, resulting in an anaerobic atmosphere for roots and subsequently poor survival of vegetation (Rex Immanuel and Ganapathy, 2019) [17]. In addition to the above, the degraded coastal lands experience frequent summer drought, which also contributes to reduced vegetation (Rex Immanuel *et al*.,

2018b) [19]. This gives rise to a challenge to environmentalists for the reclamation, utilization and management of degraded agroecosystems.

Essentially the afforestation reduced the numerous plant species of no commercial value to basically few plants species made up of trees with economic significance, of the same age and on a tract of land or compartment. Afforestation in degraded sites reduces pressure on the natural forest through provision of forest resources such fuel, fruits, fodder and rafters (Dongre, 2011) [9]. At the smallholder farmers and rural community's level, afforestation and agroforestry practices with tree planting warrant sustainability of land dependent livelihoods and subsequently combating land degradation. Unfortunately degraded land reclamation with trees commonly fails when carried out as a single phased attempt. Survival rates in many afforestation programmes are awfully low, even with the plantations of indigenous species. This is because the condition of the land is far worse now than the native condition in which local vegetation/crops once thrived. Scientific management of land with agro techniques can tackle these complicated problems faced by the farming communities in the coastal regions as these constitute the basic resources of farming and meet the needs of society.

C. pentandra have a superior capacity to establish in degraded coastal agricultural soils of very low fertility soils compared with other species. The species has become popular for its potential for reforestation of degraded areas (Brondani *et al*., 2003; Celis and Jose, 2011) [5, 6]. From an ecological point of view, *C. pentandra* fulfils an vital role in protecting seasonally dry tropical forest soils due to the species low nutritional requirements, high tolerance to competition and drought and its ability to re-grow after disturbances (Lobo *et al*., 2005; Sorngmenenye-Abengmeneng *et al*., 2016; Bocanegra-Gonzalez *et al*., 2018) [13, 22, 4]. Reports on an experimentation with *C. pentandra* seedlings raised in pots filled with sand, loam or clay soils and treated with NaCl and $CaCl_2$ (2: 1 ratio) at EC values up to 15 dSm^{-1} revealed that it was a moderately salt tolerant tree (Gupta *et al*., 1986) [10]. According to Rex Immanuel and Ganapathy (2007) [16], the seed germination, morphological and physiological parameters were slightly affected by 3 to 9 dSm^{-1} salinity concentration, but were markedly reduced on the 12 and 15 dsm^{-1} salinity concentrations. With this background the field experiment was conducted to assess the efficiency of agronomic management strategies on the performance of *C. pentandra* trees planted in moderately saline non-waterlogged sandy clay loam soil.

Materials and Methods

The study site is geographically located at 11°58′ N latitude and 79°52′ E longitude with an average altitude of +8.5 M above Mean sea level. The location experienced from semi arid to sub-humid climate with mean annual rainfall of 1350 mm, of which 80 per cent is received during North-East monsoon (Oct. – Dec.) and the remaining is through South West monsoon and summer showers. The potential evapotranspiration varies from 1700 to 1900 mm resulting in an annual water deficit of 350 – 550 mm. The length of the crop growing period varies from 80 to 120 days. The mean annual maximum and minimum temperatures are 33.5° C and 23.5° C, respectively. The nutrient status is low in organic carbon (0.20 %), N (101.28 kg ha^{-1}), P_2O_5 (11.82 kg ha^{-1}), and K_2O (107.00 kg ha^{-1}). The pH, EC (dsm^{-1}) and SAR of the study area were 8.41, 6.02 and 10.40 respectively.

The experiments were laid out in split plot design with three replications. The treatment consisted of land management methods (M_1 - Pit method; M_2 - Trench method; M_3 - Mound method and M_4 - Auger hole method) in main plots and ameliorative organic amendments in sub plots (S_1 - FYM @ 12.5 t ha^{-1}, S_2 - Pressmud @ 15 t ha^{-1}, S_3 - Composted coir pith @10 t ha^{-1} and S_4 - Control (no amendments)). Along with the organic amendments, gypsum @ 200 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1} + *Azospirillum* @ 2 kg ha^{-1} + Phosphobacteria @ 2 kg ha^{-1} were mixed throughly and used. The spacing adopted is 5 m x 5m with the plot size of 250 m^2. The field was fenced, cleaned and ploughed once and leveled. Then the planting pits were prepared according to the treatment schedule. The seedlings were planted with the spacing of 5 x 5 m. The normal pits were formed with a dimension of 0.30 m^3. In trench method, the trenches should be at 0.45 m deep and the ridges were prepared with 0.75 m height. The seedlings were planted on the side of ridge about 0.50 m above the ground level. The raised mound with 0.60, 0.75 and 1.00 m wide at the top, middle and bottom, respectively and had 0.60 m height from the original soil surface was formed. A slit in the side of the mound was formed and the seedlings were planted with amendment mixture. The holes were formed with a dimension of 0.30 m at a depth of 0.60 m by using mechanical auger. The three quarter of the hole was filled with original soil and the seedling was placed in the center of the hole and back filled with the soil - amendment mixture. The biometric observations such as establishment per cent, plant height and girth at 36 months (cm) after planting and relative growth rate cm ($month^{-1}$) (RGR) recorded during the experimentations were statistically analyzed.

Results and Discussion

The development and cultivation of multipurpose tree species (MPT's) like *C. pentandra* especially for improving the agro forestry system in the coastal degraded zones is yet to strike roots. They would be of great significance in regions where they form the strongest link in the chain of measures aimed to improve the productivity of degraded soils. In the present study, adoption of auger hole method of planting with the application of FYM @ 12.5 t ha^{-1}, Gypsum @ 200 kg ha^{-1}, ZnS04 @ 25 kg ha^{-1}, *Azospirillum* @ 2 kg ha^{-1} and Phosphobacteria @ 2 kg ha^{-1} significantly recorded the maximum establishment percentage of 83.21, plant height of 340.12 cm (36 months) and girth of 19.52 cm (36 months).

Table 1: The effect of agro techniques on the establishment per cent and plant height (36 months after planting)

Treatments	Establishment percentage					Plant height (cm)				
	M_1	**M_2**	**M_3**	**M_4**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**Mean**
S_1	76.41 (60.91)	72.10 (57.68)	66.23 (54.53)	83.21 (64.90)	74.49 (59.51)	322.23	303.34	283.51	340.12	312.30
S_2	67.48 (56.71)	63.80 (52.88)	59.62 (50.84)	73.82 (57.90)	66.18 (54.58)	292.84	273.92	265.11	311.71	285.90
S_3	73.86 (58.83)	68.92 (55.90)	62.82 (52.90)	78.58 (60.81)	71.05 (57.11)	310.38	292.41	284.49	329.26	304.15

S_4	60.48 (49.90)	56.90 (48.69)	50.32 (44.95)	68.48 (53.21)	58.55 (49.19)	280.54	264.63	245.69	290.45	270.33
Mean	69.56 (56.59)	65.43 (53.79)	59.75 (50.81)	75.52 (59.21)		301.50	283.58	269.70	317.89	
	S. Ed		CD (P = 0.05)			S. Ed		CD (P = 0.05)		
M	1.29		2.60			4.52		09.37		
S	1.12		2.35			4.50		09.02		
M x S	1.83		3.81			5.12		10.56		

(Figures in parenthesis indicate arc-sine transformed values)

The principal hypothesis behind the auger hole planting technique is the management of root zone of the plants by modifying the soil environment with limited amount of amendments to a greater depth of soil profile, which has a vital role for the establishment of trees. The performance of *C. pentandra* planted with auger hole method pierced the kankar layers, and encouraging of deeper rooting. Thus the trees are able to probe deeper soil layers for water and nutrients and withstands adverse the drought conditions during moisture deficit periods. Pazhanivelan *et al*. (2006) [14] observed that the auger hole planting had significant influence on the establishment percentage of trees planted in salt affected soils under rain fed conditions. Further integrated application of FYM @ 12.5 t ha^{-1}, Gypsum @ 200 kg ha^{-1}, $ZnSO_4$ @ 25 kg ha^{-1}, *Azospirillum* @ 2 kg ha^{-1} and Phosphobacteria @ 2 kg ha^{-1} makes slow and steady availability of plant nutrients which provided a better environment for increased establishment percentage, plant height and girth of trees. Gypsum has been found to counteract salt injury by reacting with toxic sodium ions present in soil and rendering them unavailable to the plant. The negatively charged sulfate ions in gypsum bond with the positively charged sodium ions to form sodium sulfate, a highly soluble salt that is readily leached from soil.

Table 2: The effect of agro techniques on the girth and relative growth rate (36 months after planting)

Treatments	Girth (cm)					RGR (cm month^{-1})				
	M_1	**M_2**	**M_3**	**M_4**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**Mean**
S_1	18.12	17.48	16.14	19.52	17.82	2.92	2.75	2.75	3.29	2.93
S_2	17.10	15.73	15.34	17.78	16.49	2.85	2.58	2.57	2.86	2.72
S_3	17.81	16.93	15.61	18.00	17.09	3.02	2.71	2.54	3.10	2.84
S_4	15.14	15.18	14.70	15.76	15.20	2.83	2.58	2.37	2.79	2.64
Mean	17.04	16.33	15.45	17.78		2.91	2.66	2.56	3.01	
	S. Ed		CD (P = 0.05)			S. Ed		CD (P = 0.05)		
M	0.32		0.67			0.03		0.07		
S	0.26		0.53			0.03		0.07		
M x S	0.62		1.26			0.05		0.12		

Application of Zn had a positive effect on salt tolerance of plant (Khoshgoftar *et al*. 2004) [11]. Dagar *et al.* (1994) [8] confirmed that planting tree species in auger holes refilled with original sodic soil mixed with gypsum and FYM is an easier and more economic form of establishment than the pit method. Rufino *et al*. (2006) [20] reported that application of FYM counteracts the harmful effect of exchangeable sodium, improved the soil physical conditions and meets the initial nutritional requirements of plants. Pazhanivelan *et al*., (2006) [14] stated that gypsum application markedly increased the establishment percentage of tree species planted in the saline environments. Application of zinc is necessary for root cell membrane integrity and functions of the bio-membranes of plants and alleviates possible Na and Cl injury by inhibiting Na and/or Cl uptake and translocation of plants (Abd-El-Hady, 2007) [1]. Application of *Azospirillum* and Phosphobacteria improved mineralization of available plant nutrients in to the soil which enhanced the growth of seedling (Swaminath and Vadiraj, 1988; Young, 1990; Kuppurajendran, 2012; Thorat *et al*. 2013) [23, 25, 12, 24]. Under field conditions, the increment in establishment percentage, plant height, girth and RGR of trees due to combined application of gypsum, $ZnSO_4$ and biofertilizers for tree seedlings was reported by Rex Immanuel *et al*. (2018b) [19].

Conclusion
The results of the present study indicated that the planting of *Ceiba pentendra* under augur hole method of planting in combination with the application of FYM @ 12.5 t ha^{-1}, gypsum @ 200 kg ha^{-1}, $ZnSO_4$ @ 25 kg ha^{-1}, *Azospirillum* @ 2 kg ha^{-1} and phosphobacteria @ 2 kg ha^{-1} is the most suitable agro technique for the afforestation of degraded coastal agricultural land.

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