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SCREENING OF MULTIPURPOSE TREE SEEDLINGS FOR AFFORESTATION OF DEGRADED COASTAL AGRICULTURAL LANDS

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Abstract

Food security, nutritional guarantee, sustainability and environmental stability are the main focus of present and future generation's growth strategies of an ecosystem. In Tamil Nadu, India, during the last few decades, the coastal ecosystem becomes a favored area for the location of developmental activities. Sustainability of this ecosystem is dependent on its food production system, water quality and biodiversity. Nevertheless, the pressure on this imperative resource has increased to such an extent that the relationship between the living beings and the soil has become critical, and they can create or may create degradation on coastal agro-ecosystems. Adopting economically viable, scientifically acceptable and environmental friendly management practices and reclamatory measures in the agricultural degraded lands seem to be promising key to bring more area under sustainable use. At present, growing of MPT's in the degraded coastal agricultural lands could be considered as an innovative agricultural production system. However, selection of suitable tree seedlings is imperative for the successful afforestation programme in degraded lands. Accordingly, based on the relative suitability index the MPT's *viz*., *Acacia nilotica* and *Pongamia pinnata* for strongly saline waterlogged clay soil and *Anacardium occidentale* and *Ceiba pentandra* for moderately saline non-waterlogged sandy clay loam soil were selected for planting in different degraded coastal agricultural sites.

Keywords: Degraded lands, drought, rehabilitation, salinity, stress tolerance, water logging

Introduction

Land degradation is the temporary or permanent decline in the productive capacity of the land, and the reduction of the productive potential, including its major land uses, farming systems, and its value as an economic resource. In worldwide, it is negatively affecting the livelihoods and food security of billions of people. The local considerable losses account only for 46 per cent of the total cost of land degradation, while the remainder of the cost is due to the losses of biodiversity and ecosystem services, accruable largely to beneficiaries other than the local land users (Zhang *et al*., 2019). Land degradation is also increasingly becoming a major concern for Indian agriculture on which two-third of the population depends for their livelihood. It is estimated that about 44 per cent of India's land area is degraded. The causes of land degradation are complex and the factors include the expansion of crop cultivation to marginal and low potential lands or to lands vulnerable to natural hazards, overuse of agrochemicals, improper crop selection and mismanagement of the irrigation system (Mythili and Goedecke, 2016).

Coastal regions are also 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. In addition to the above, the degraded coastal agricultural lands experience frequent long dry spell, which also contributes to reduced vegetation. As a cumulative result *viz*., water logging followed by salinity buildup and drought are predominantly occurring phenomena in the coastal agroecosystem. It leads to degradation of entire ecosystem and not fit for profitable cultivation of agricultural crops (Rex Immanuel and Ganapathy, 2019a). Afforestation of degraded agricultural land can reverse the degradation processes and cause enhancement or sequestration of biomass as well as of the carbon stock. Initially there was a reduction in soil organic carbon stocks in a brief period following afforestation, as the decomposition of soil organic matter exceeded the input of organic matter from the trees. The initial decline was observed for 3–35 years following the agricultural abandonment. Over time soil organic matter input increases with the productivity of the afforested stands and soils switch from being a carbon source to a carbon sink (Holubik *et al*., 2014). If targeted afforestation also took place, it several fold increases the tree cover outside the conventional forests.

Afforestation requires the site-specific knowledge on the suitable multipurpose tree species (MPT's) and their adoption to stress environment is necessary to successful restoration of degraded agricultural lands. Land reclamation with MPT's in degraded lands commonly fails when carried out as a single phased attempt and the survival and establishment rates are very low, even the seedlings are of indigenous species. However, given the scope and urgency of the stress problem, no time should be wasted to establish a series of field trials. It was thought that, if the ill effect produced by stress on the plants could be reproduced in the laboratory on plants or parts of the plants under standardized conditions, it might be possible to measure critical changes and to use them as a test for stress resistance. Hence, the present investigations were carried out in pot culture to evaluate the suitability of MPT's for rehabilitation of degraded agricultural lands.

Materials and Methods

A systematic pot culture experiment was undertaken to identify the potential multipurpose tree species (MPT's) seedlings suitable to rehabilitation of the degraded lands in the coastal agroecosystems of Northern Tamil Nadu. The degraded soils collected from two degraded locations *viz*., Killai (11°24′ N latitude 79°45′ E longitude) (strongly saline waterlogged clay soil) and Bommayapalayam (11°58′ N latitude and 79°52′ E longitude) (moderately saline non-waterlogged sandy clay loam soil) were used for the study. The experimental soil exhibited saline pH (8.32 and 7.9), ECe (7.58 and 6.02 dSm^{-1}), low in organic carbon (0.23 and 0.20 per cent) and available N (137.35 and 101.28 kg ha^{-1}), P_2O_5 (6.75 and 11.82 kg ha^{-1}) and medium K_2O (153.76 and

107.37 kg ha^{-1}), respectively. The micronutrients *viz*., sulphur (5.08 and 11.45 ppm), zinc (0.36 and 0.29 ppm), copper (0.16 and 0.31 ppm), boron (0.22 to 0.41 ppm), manganese (9.51 and 6.56 ppm), molybdenum (0.79 and 0.29 ppm) and iron (16.18 and 54.26 ppm), respectively also presented in the collected degraded soils.

Twelve multipurpose tree species *viz*., T_1 -*Acacia auriculiformis,* T_2 -*Acacia ferruginea,* T_3 -*Acacia nilotica,* T_4 -*Anacardium occidentale,* T_5 -*Calophyllum inophyllum,* T_6 -*Casuarina equisetifolia,* T_7 -*Ceiba pentandra,* T_8 -*Eucalyptus tereticornis,* T_9 -*Leucaena leucocephala,* T_{10} -*Pongamia pinnata,* T_{11} -*Senna siamea* and T_{12} -*Tamarindus indica* were exposed for the study. In the absence of clear and unambiguous procedure for assessment of MPT's for varied local agro climatic conditions, an effort was made to categorize the MPT's on the basis of Relative Suitability Index (RSI). The representative soil samples were collected from degraded fields and filled in five kg capacity poly pots. Four months old seedlings were transplanted in to poly pot containing degraded soil. First two months the seedlings were watered regularly with good quality water. After which drought treatment was artificially induced and continued for one month (watering to the seedlings was done once in seven days). Then the seedlings were waterlogged to above the top of the soil (5 cm height) for 42 days and then drained the water freely. This situation gave the original environment of the degraded coastal agroecosystem. After thirty days of completion, the morph metric characters like height, collar diameter, root length, root volume and biomass production of each MPT's were recorded. The suitability index (SI) and relative suitability index (RSI) were calculated by using the procedure given by Singh *et al*. (1995). On the basis of RSI, the species were grouped into four categories *viz.,* Category I (RSI between 75 to 100 %): Highly suitable, Category II (RSI between 60 to 75 %): Suitable, Category III (RSI between 45 to 60 %): Moderately suitable and Category IV (RSI below 45 %): May not be suitable for planting.

Results and Discussion

The screening of multipurpose tree species (MPT's) especially for identifying the stress situation in the coastal degraded agricultural land is yet to strike roots. In strongly saline waterlogged clay degraded soils, *Acacia nilotica* (T_3) and *Pongamia pinnata* (T_{10}) were least affected by the stress treatments. The highest plant height of 56.7 cm, collar diameter of 1.9 cm and root length of 45.2 cm were observed in *Acacia nilotica* (T_3). While, the maximum root volume of 6.2 cc and DMP of 9.32 g plant^{-1} were recorded in *Pongamia pinnata* (T_{10}). The seedlings *viz*., *Calophyllum inophyllum* (T_5), *Casuarina equisetifolia* (T_6), *Ceiba pentandra* (T_7) and *Senna siamea* (T_{11}) perished before the end of the experiment. The maximum RSI was recorded in *Acacia nilotica* (100 per cent). This was followed by *Pongamia pinnata* with a maximum RSI of 94.3 per cent (Table 1).

Table 1 : The effect of stress treatments on the growth characteristics and RSI of MPT's in strongly saline waterlogged clay soil

Growth characters / MPT's	Height (cm)	Diameter (cm)	Root length (cm)	Root Volume (cc)	DMP (g plant^{-1})	SI	RSI (%)	Category
T_1	23.2	1.8	20.4	1.5	0.86	166.8	36.1	IV
T_2	49.6	1.3	27.0	2.1	4.07	293.2	63.4	II
T_3	53.0	1.5	40.8	6.2	9.32	462.4	100	I
T_4	34.5	1.2	32.0	2.5	3.82	275.4	59.6	III
T_5	00.0	0.0	00.0	0.0	0.00	000.0	00.0	IV
T_6	00.0	0.0	00.0	0.0	0.00	000.0	00.0	IV
T_7	00.0	0.0	00.0	0.0	0.00	000.0	00.0	IV
T_8	22.3	1.0	28.5	2.1	1.10	200.7	43.4	IV
T_9	35.0	1.2	22.9	1.5	1.13	211.8	45.8	IV
T_{10}	56.7	1.9	45.2	4.2	6.65	435.9	94.3	I
T_{11}	00.0	0.0	00.0	0.0	0.00	000.0	00.0	IV
T_{12}	52.2	1.2	25.5	1.2	1.96	252.7	54.6	III

The moderately saline non-waterlogged sandy clay loam soil showed variations in the growth parameters of MPT's seedlings in the stress induced treatments. The highest plant height of 62.5 cm and DMP of 5.80 g plant^{-1} were recorded by *Anacardium occidentale* (T_4), while the maximum collar diameter of 1.9 cm, root length of 37.8 cm and root volume of 8.0 cc were registered in *Ceiba pentandra* (T_7). The highest RSI of 100 per cent was recorded in *Anacardium occidentale*. This was followed by *Ceiba pentandra* with the RSI of 94.7 per cent (Table 2).

Table 2 : The effect of stress treatments on the growth characteristics and RSI of MPT's in moderately saline non-waterlogged sandy clay loam soil

Growth characters / MPT's	Height (cm)	Diameter (cm)	Root length (cm)	Root Volume (cc)	DMP (g plant^{-1})	SI	RSI (%)	Category
T_1	24.5	0.8	22.0	1.1	0.87	170.9	37.4	IV
T_2	45.7	1.0	32.5	2.4	2.00	287.6	62.9	II
T_3	41.2	0.9	26.2	1.3	1.51	224.9	49.2	IV
T_4	62.5	1.5	35.7	6.7	5.80	457.1	100	I
T_5	00.0	0.0	00.0	0.0	0.00	000.0	00.0	IV
T_6	20.3	0.5	20.1	0.7	0.65	131.9	28.9	IV
T_7	42.7	1.9	37.8	8.0	3.73	432.6	94.7	I
T_8	20.1	0.8	19.3	0.9	0.43	144.0	31.5	IV
T_9	27.0	1.1	26.0	1.0	1.53	208.7	45.7	IV
T_{10}	49.5	0.9	28.1	3.3	2.12	242.5	53.1	III
T_{11}	00.0	0.0	00.0	0.0	0.00	000.0	00.0	IV
T_{12}	20.8	1.0	12.5	0.9	0.80	144.0	31.5	IV

The observations obviously indicated that *Acacia nilotica*, *Pongamia pinnata, Anacardium occidentale* and *Ceiba pentandra* were capable to withstand adverse stress conditions *viz*., water logging, salinity and drought than the other tree seedlings. The differential survival, growth and mortality of MPT's in different degraded soils of the coastal agro ecological sub zones is supported by the hypothesis that the tree species have site specific ability to adapt either morphologically and or physiologically. Similar findings are also documented by Tomar and Gupta (2002), Villagra *et al*. 2005 and Tripathi and Singh (2005) they observed higher variability between the species to species, depending on their capacity to cope with different stress environments.

About 19 stress tolerant MPT's are recorded along the coastal regions of northern Tamilnadu and are capable to adopt well in degraded agro-ecosystem (Rex Immanuel *et al*., 2018). The stronger stress tolerant capacity of *Acacia nilotica*, *Anacardium occidentale* and *Pongamia pinnata* seedlings in terms of higher chlorophyll stability index and relative water content was reported by Rex Immanuel *et al*. (2019). This might be the active adaptability to the stress environment in order to maintain the normal photosynthesis and more dry matter production. The MPT's *Ceiba pentandra* fulfils the vital role in protecting seasonally dry tropical forest soils and in coastal regions due to the species low nutritional requirements, high tolerance to competition and drought and its ability to re-grow after disturbances (Sorngmenenye-Abengmeneng *et al*., 2016; Bocanegra-Gonzalez *et al*., 2018; Rex Immanuel and Ganapathy, 2019b). Likewise *Anacardium occidentale* is a multipurpose tree having wider agro-climatic adaptability and grows very well on wide range of soils including coastal degraded lands (Rex Immanuel and Ganapathy, 2019c).

The adaptive mechanisms helps to the survival of seedlings under induced stress. Stress tolerant tree seedlings maximize the fitness by decreasing both leaf size and stomatal conductance to water vapor in response to limited water availability or physiological drought stress. Some plants have adapted their anatomy so that they have reduced leaf surface to volume ratios and thicker leaves also allow plants to have more volume for storage of water reserves (Mauseth, 2000). Shoot and root elongation also decreased when plants are stressed, however root elongation tends to be less sensitive to drought stress than shoot elongation (Frensch, 1997). According to Taiz and Zeiger (1998), roots shrink and slow the addition of new root hairs when plants are exposed to stress condition in degraded lands. However, if drought occurs slowly, plants tend to increase root growth deeper into the soil. Decreasing root diameter would decrease the possibility that the capillary action of water within xylem would be disrupted (Helbsing *et al*., 2000). Roots of stress tolerant species tend to decrease root metaxylem vessel diameter when grown under water stress (Vasellati *et al*., 2001).

Conclusion

The relative suitability index is used to assess the suitability of MPT's for planting in degraded coastal agricultural lands. The results concluded that the MPT's *viz*., *Acacia nilotica* and *Pongamia pinnata* for strongly saline waterlogged clay soil and *Anacardium occidentale* and *Ceiba pentandra* for moderately saline non-waterlogged sandy clay loam soil were selected for planted in different degraded sites.

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