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# Standardization of agro-techniques for establishment of cashew (*Anacardium occidentale* L.) plantations in strongly saline sandy loam coastal soils

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**Abstract**

Good rhizosphere soil environment is fundamental to establishment and growth of tree crops in coastal degraded soils. Experiments were conducted at Northern Coastal Tamil Nadu, India, to determine the influence of agronomic management methods on the survival and growth of cashew (*Anacardium occidentale* L.) in strongly saline sandy loam coastal soils. To identify the suitable and sustainable agro-technology for tree establishment two methods of planting *viz*., pit method and auger hole method and combination of ameliorative amendments such as FYM, composted coir pith and pressmud along with gypsum, $ZnSO_4$ and biofertilizers were used. After three years of experimentation plant survival and growth parameters were statistically analyzed for knowing its feasibility in coastal degraded environment. The results showed that a significantly beneficial improvement in planting methods and soils with and without ameliorative amendments. Accordingly the study justified that, auger hole method of planting in combination with composted coir pith @ 25 kg pit$^{-1}$, gypsum @ 500 g pit$^{-1}$, $ZnSO_4$ @ 60 g pit$^{-1}$, *Azospirillum* @ 50 g pit$^{-1}$ and Phosphobacteria @ 50 g pit$^{-1}$ was significantly registered the maximum establishment percentage of 88.25, plant height of 231.72 cm, girth of 14.98 cm, RGR of 2.75 (cm month$^{-1}$) and taproot length of 118.36 cm.

**Keywords:** Ameliorative amendments, degraded lands, planting methods, site preparation, waste lands

## Introduction

The cashew (*Anacardium occidentale* L.) family Anacardiaceae is a multipurpose tree native of Brazil and has become naturalized in coastal regions of tropical countries of the world including India. Cashew plantations are considerable importance for the social economy of developing nations, since it is very well adapted to wide range of agro-climatic conditions and degraded/waste land soils in tropical and subtropical regions and generate revenue for small and marginal farmers and landless labours hence popularly known as 'gold mine of wasteland'. The cashew kernel is rich in protein (21%), carbohydrate (22%) and fat (47%) and a kilogram of nut yields about 6000 calories of energy (Nambiar *et al.*, 1990) [23]. Cashew kernel lipids are rich in unsaturated fatty acids such as oleic acid (73.7%), linoleic acid (7.67%) and stearic acid (11.2%) (Saroj *et al*., 2014) [35]. The cashew apple is basically intended for the manufacturing industry consists of alcoholic beverage, synthesise pectin, sweets and protein-enriched animal feed (Apine and Jadhav, 2015; Bhoomika and Sudha Rani, 2018) [2, 4]. The bark is used in tanning, insecticide, adhesive, as substitute for gum Arabic and making ink. The cashew nut shell contains 25-30 per cent dark reddish brown viscous liquid known as cashew nut shell liquid (CNSL). CNSL is a versatile industrial raw material with high technological potential due to its phenolic constitution including anacardic acid, cardanol and cardol. It is used in the cosmetic industry, pharmaceutical industry, textile industry, paper industry, ink making, plastic, varnish, insulating material, paint, lubricant, petro chemical and preservation coatings for wood (Raghavendra Prasada, 2014; Telascrea *et al*., 2014; Taiwo, 2015; Leite *et al*., 2016; Shi *et al*., 2019) [30, 40, 39, 18, 37].

The production of cashew kernels in the world exhibited an increasing trend from past three decades. The total world production of cashew was around 11.75 lakh tonnes during 1994 which rose to 48.98 lakh tonnes by 2016 (FAO, 2017) [9]. India is the largest producer, processer, consumer and exporter of cashew in the world (Elakkiya *et al*., 2017) [7]. Area under cashew nuts in India has increased from 464 to 1062 thousand ha and production has increased from 185 to 817 thousand tonnes with the productivity of 399 to 769 kg ha$^{-1}$ during 1980-81 and 2017-18, respectively (Nayak and Paled, 2018) [25]. Similarly the production of cashew nuts in Tamilnadu has also increased considerably during the years and the present production is about 67.65 thousand metric tonnes from an area of 141.33 thousand ha (HSD, 2017)[14]. India's cashew kernels export decreased from 118, 540 metric tonnes in 2006-07 to 82, 302 metric tonnes in 2016-17. In the same time the import of raw kernels increased markedly and more than one third of the overall processing need of the country is met by the imports. Around 18-27 per cent of the shell weight is with CNSL and about 1.25 lakh tones of CNSL are produced annually worldwide. Though India processes more than two million tonnes of raw cashew nut annually, the production of its shell liquid is limited, as all processing units do not produce it. Currently less than 60, 000 tonnes of CNSL is produced in the country as against the potential of 160, 000 tonnes.

In spite of its potentialities, the Indian cashew industry with a processing capacity of two million tonnes annum$^{-1}$ has been depending on other producing countries for almost half of its requirement for several decades (Nair, 2018) [22]. Further, the production growth of raw cashew nuts in India (3.1%) is far behind the world (6.3%) growth levels. In this situation, due to the world market demand, if other countries have establishing their own processing units in a big way, the availability of raw cashew for import is steadily declining. Hence, there is a need to expand the production to meet the requirement of the processing industries. As a multipurpose tree having wider agro-climatic adaptability and grows very well on wide range of soils, there is still much scope for area expansion in waste /degraded lands (Rex Immanuel and Ganapathy, 2019a) [33]. According to people's perception *A. occidentale* is flourishing well under stress situations in coastal habitat's of Tamilnadu (Rex Immanuel *et al*., 2018a) [31]. However, its survival and establishment in degraded lands is often affected due to the condition of the soil is far worse now than the native condition in which local vegetation once thrived (Topper *et al*., 2001; Hammed and Olaniyan, 2012; Nayak and Paled, 2018; Olubode *et al*., 2018; Rex Immanuel and Ganapathy, 2019b) [41, 13, 25, 26, 34]. Systematic management of degraded coastal agroecosystem soils with appropriative agro-techniques can tackle these complicated problems faced by the cashew farming communities. With the above background a field experiment was conducted to assess the effectiveness of agronomic management strategies on the performance of *Anacardium occidentale* trees planted in strongly saline sandy loam coastal soils.

## Materials and Methods

The geographical situation of study area is 12°12′ N Latitude and 79°50′ E Longitude with an altitude of +7.2 m mean sea level. The site experienced semi arid to sub-humid climate with the mean annual rainfall of 1350 mm of which 80 per cent is received during North-East monsoon (Oct. – Dec.) and the remaining is received South West monsoon and summer showers. The potential evapotranspiration varied from 1700 to 1900 mm resulting in an annual water deficit of 350 – 550 mm. The length of the crop growing period varied from 80 to 120 days. The mean annual maximum and minimum temperatures are 33.5° C and 23.5° C, respectively. The pH and EC (dsm$^{-1}$) of the study area were 8.24 and 9.78, respectively. The nutrient status is low in organic carbon (0.27%), N (68.83 kg ha$^{-1}$), $P_2O_5$ (7.34 kg ha$^{-1}$) and $K_2O$ (164.13 kg ha$^{-1}$).

The treatment consisted of two land management methods ($M_1$ - Pit method and $M_2$ - Auger hole method) in main plots and four ameliorative amendments in sub plots ($S_1$ - FYM @ 30 kg pit$^{-1}$, $S_2$ - Pressmud @ 35 kg pit$^{-1}$, $S_3$ - Composted coir pith @ 25 kg pit$^{-1}$ and $S_4$ - Control (without amendments)). Along with the organic amendments, gypsum @ 500 g pit$^{-1}$, $ZnSO_4$ @ 60 g pit$^{-1}$, *Azospirillum* @ 50 g pit$^{-1}$ and Phosphobacteria @ 50 g pit$^{-1}$ were mixed throughly and used. The experiments were laid out in split plot design with three replications. The cashew seedlings were planted under high density planting with the spacing of 5 x 5 m and 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 normal pits were formed with a dimension of 0.60 m$^3$. The auger holes were prepared with a dimension of 0.20 m and at a depth of 0.90 m by using mechanical auger. The pits and holes were filled with mixture of original soil and amendments and the seedling was placed in the center. The observations such as establishment per cent, plant height and girth at 36 months (cm) after planting and relative growth rate (cm month$^{-1}$) (RGR) were recorded. To study the treatment effects on root development pattern, root systems were exposed in the field after one year following wet excavation methodology (Bohm, 1979) [5].

## Results and Discussion

In the present study, the auger hole method of planting along with the integrated application of composted coir pith @ 25 kg pit$^{-1}$, gypsum @ 500 g pit$^{-1}$, $ZnSO_4$ @ 60 g pit$^{-1}$, *Azospirillum* @ 50 g pit$^{-1}$ and Phosphobacteria @ 50 g pit$^{-1}$ ($M_2S_3$) significantly recorded the maximum establishment percentage of 88.25, plant height of 231.72 cm (36 months), girth of 14.98 cm (36 months) and RGR of 2.75 (cm month$^{-1}$). Overall effect of site preparation techniques on survival and growth were in the order of auger hole method followed by pit method of planting. Roots of auger hole planted seedlings grew deeper soil layers (118.36 cm in 12 months after planting) and the majority of roots remained in the amended soil and followed a vertical path instead of growing horizontally. In the pit planting method, the whole root system was confined to the pit soil and formed a shallow root system. It can expose the plant to adverse climatic conditions such as moisture stress prevailed in the region. These observations ensure a way for the planting of *A. occidentale* in saline soils in a vertical direction (auger hole) is more essential than in a horizontal direction (pit method). Auger hole method pierces through hard sub soil layers (kanker pan), improved the porosity by loosening the soil and provides larger volume of reclaimed soil for the development of feeder roots during the initial years of growth. It eases the penetration and proliferation, encourages and trains deeper rooting, does not cause roots to coil or face constriction which adversely affect plant growth, improves the penetration of water through the holes thereby inducing better water storage and its availability and ensures deeper reclamation of soil was reported by Gupta *et al*. (1995) [11], Dagar *et al*. (2001) [6] and Pazhanivelan *et al*. (2006) [27].

The synergistic and cumulative effect of composted coir pith with gypsum, $ZnSO_4$ and biofertilizers could be the reason for better performance of cashew in terms of establishment per cent, plant height, girth RGR and root length. Composited coir pith with ameliorative amendments sustain growth of cashew through better nutrient recycling and improvement in soil physical, chemical and biological properties. The slow mineralization of nutrients in composted coir pith promotes crop growth over a long period and increases soil water holding capacity making the nutrients more readily available to plant. Coir pith has very high moisture retention capacity of 500-600 per cent and can be as high as 1100 per cent of dry weight (Evans *et al*., 1996) [8]. It is also reported that coir pith retained the maximum moisture after 90 days of composting (Mbah and Pdili, 1998) [20]. Geetha *et al*. (2005) [10] and Natarajan *et al*. (2005) [24] observed that addition of composted coir pith reduced the bulk density of the soil and favorably improved the physical properties *viz*., hydraulic conductivity and water holding capacity of the soil. High CEC enables it to retain large amounts of nutrients and the adsorption complex has high contents of exchangeable K, Na, Ca and Mg (Evans *et al*., 1996; Verhagen and Papadopoulos, 1997) [8, 42]. Because of its high moisture retention capacity, coir pith compost encouraged the activity of beneficial microorganisms and involved in solubilisation and mobilization of nutrients. All these characteristics make it ideal for use as a soil amendment, especially for dry and sandy areas with low moisture retention capacity.

**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) | | |
|---|---|---|---|---|---|---|
| | **$M_1$** | **$M_2$** | **Mean** | **$M_1$** | **$M_2$** | **Mean** |
| $S_1$ | 75.36 (59.85) | 82.22 (64.22) | 78.79 (62.04) | 176.92 | 192.16 | 184.54 |
| $S_2$ | 73.21 (58.19) | 77.86 (62.52) | 75.54 (60.34) | 191.20 | 213.82 | 202.51 |
| $S_3$ | 80.24 (64.69) | 88.25 (70.08) | 84.25 (67.39) | 205.30 | 231.72 | 218.51 |
| $S_4$ | 69.74 (55.20) | 74.12 (59.83) | 71.93 (57.52) | 148.02 | 165.27 | 156.65 |
| Mean | 74.64 (60.73) | 80.21 (64.16) | | 180.36 | 200.74 | |
| | S. Ed | | CD (P = 0.05) | S. Ed | | CD (P = 0.05) |
| M | 1.45 | | 3.10 | 4.23 | | 08.96 |
| S | 1.58 | | 3.25 | 5.21 | | 10.50 |
| M x S | 2.30 | | 4.62 | 5.78 | | 11.85 |

(Figures in parenthesis indicate arc-sine transformed values)

The ameliorative amendments such as composted coir pith and gypsum initially reduced the soil pH and $EC_e$ of the soil solution around the root zone and also increased the mineralization of native N due to reduction in pH and slow release of macro and micro nutrients. This resulted in steady availability of nutrients to a longer period which created a favorable environment for plant growth. In addition, the presence of organic materials during decomposition, releases organic acids and presence of acid forming $SO_4^{--}$ ion in gypsum reduced the ill effects of salinity. The superiority of these amendments in reducing soil pH and $EC_e$ have been reported by Murali and Gupta (2001) [21] and Natarajan *et al*. (2005) [24]. Gypsum application markedly increased the growth of plants planted in the saline environments (Anwar *et al*., 2003; Hamza and Anderson, 2003; Pazhanivelan *et al*., 2006) [3, 12, 27]. Addition 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 (Khoshgoftar *et al*., 2004 and Abd-El-Hady, 2007) [16, 1].

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

| Treatments | Girth (cm) | | | RGR (cm month$^{-1}$) | | |
|---|---|---|---|---|---|---|
| | **$M_1$** | **$M_2$** | **Mean** | **$M_1$** | **$M_2$** | **Mean** |
| $S_1$ | 11.66 | 12.88 | 12.27 | 2.02 | 2.52 | 2.27 |
| $S_2$ | 10.40 | 11.82 | 11.11 | 2.24 | 2.65 | 2.45 |
| $S_3$ | 13.26 | 14.98 | 14.12 | 2.37 | 2.75 | 2.56 |
| $S_4$ | 09.09 | 09.51 | 9.3 | 1.47 | 1.74 | 1.61 |
| Mean | 11.10 | 12.30 | | 2.03 | 2.42 | |
| | S. Ed | | CD (P = 0.05) | S. Ed | | CD (P = 0.05) |
| M | 0.21 | | 0.44 | 0.06 | | 0.12 |
| S | 0.42 | | 0.85 | 0.06 | | 0.14 |
| M x S | 0.53 | | 1.09 | 0.04 | | 0.09 |

**Table 3.** The effect of agro techniques on the taproot length (cm) (12 months after planting)

| Treatments | Taproot length (cm) | | |
|---|---|---|---|
| | **$M_1$** | **$M_2$** | **Mean** |
| $S_1$ | 89.15 | 104.62 | 96.89 |
| $S_2$ | 74.56 | 089.11 | 81.84 |
| $S_3$ | 96.11 | 118.36 | 107.24 |
| $S_4$ | 48.23 | 055.17 | 51.70 |
| Mean | 77.01 | 91.82 | |
| | S. Ed | | CD (P = 0.05) |
| M | 3.68 | | 7.42 |
| S | 2.94 | | 6.01 |
| M x S | 4.63 | | 9.58 |

Application of *Azospirillum* and Phosphobacteria improved mineralization of available plant nutrients coupled with fixation of atmospheric nitrogen in to the soil which enhanced the growth of seedlings. Application of *Azospirillum* during planting involved in growth promotion through the production of bioactive molecules *viz*., Abscisic acid, Gibberellic acid, Indole 3-acetic acid, Ethylene and Cadaverine, which facilitating nutrient uptake, accelerating mineralization, reducing plant stress, stimulating nodulation and providing nitrogen fixation (Somers *et al*., 2005; Perrig *et al*., 2007 and Mallik and Williams, 2008) [38, 28, 19]. In degraded soils, phosphorus might be present in considerable amounts; however the preferred form for assimilation is usually much depleted owing to adsorption to soil particles or conversion into organic complexes. Lal (2002) [17] and Kaleeswari *et al*. (2007) [15] reported that Phosphobacteria produce organic acids such as monocarboxylic acid (acetic, formic), monocarboxylic hydroxy (lactic, glucenic, glycolic), monocarboxylic, ketoglucenic, decarboxylic (oxalic, succinic), dicarboxylic hydroxy (malic, maleic) and tricarboxylic hydroxy (citric) acids, which is involved in solubilizing inorganic phosphate compounds which helps in better height, girth, RGR and root length of trees. There is an increasing evidence that phosphobacteria improved the growth due to biosynthesis of plant growth substances rather than their action in releasing available phosphorous (Ponmurugan and Gopi, 2006) [29]. Shankarappa *et al*. (2017) [36], Rex Immanuel *et al*. (2018b) [32] and Rex Immanuel and Ganapathy (2019b) [34] reported that the collective use of *Azospirillum* and phosphobacteria have more benefit in unproductive and stressful environments and significantly increased the seedling growth of trees. Hence, *Azospirillum* and phosphobacteria considered to be involved in alleviating the ill effects of stress and enhanced the growth of cashew in combination with organic amendments, gypsum and $ZnSO_4$.

## Conclusion
The observations point out that auger hole method of planting with composted coir pith @ 25 kg pit$^{-1}$, gypsum @ 500 g pit$^{-1}$, $ZnSO_4$ @ 60 g pit$^{-1}$, *Azospirillum* @ 50 g pit$^{-1}$ and Phosphobacteria @ 50 g pit$^{-1}$ is the most appropriate and sustainable agro-technique for planting of *Anacardium occidentale* in degraded coastal soils.


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