J. Indian Soc. Coastal Agric. Res. 42(2):23-35(2024) https://doi.org/10.54894/JISCAR.42.2.2024.143975

Insights on Popularizing Fruit-based Cropping Systems: An Alternate for Better Livelihood in Salt-affected Indian Sundarbans Delta

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Received: 18.12.2023 Accepted: 22.02.2024

The Indian Sundarbans Delta (ISD) is part of the delta of the Ganga-Brahmaputra-Meghna (GBM) basin in Asia. Typically, in the delta region rain-fed, single-crop agriculture and fishing are the two main sources of livelihood. The dominant crop grown in this area is the local transplanted *Aman* rice crop with low yields and some short-duration vegetables. High soil and water salinity, impact of climatic changes, and frequent occurrence of natural calamities aggravate the situation making agricultural crop cultivation challenging in ISD. Fruit plant-based cropping systems may be considered in ISD as one of the effective alternative cropping options that combat problems of soil and climatic factors with minimum loss and give more than one option to generate income besides their plenty of ecological and other benefits. To date, commendable research work in this area is lacking particularly in ISD which is gifted with wider crop diversity where many important and minor fruit crops are adapted to saline and sodic conditions along with indigenous mangrove plants that bear fruit with immense ethnobotanical uses. Upon realizing this context, the present review was framed taking help from an extensive groundwork of different researchers working on possibilities, difficulties, and advanced strategies for the successful establishment of fruit-based cropping systems in different saline tracts.

(***Key words:*** *Indian Sundarbans Delta (ISD), Livelihood, Mangrove, Natural calamities, Salinity)*

The Indian Sundarbans Delta (ISD) is part of the delta of the Ganga-Brahmaputra-Meghna (GBM) basin in Asia. The Sundarbans, shared between India and Bangladesh is home to one of the largest mangrove forests in the world. Sundarbans is the world's largest delta region that spreads over India and Bangladesh covering around 25,500 km^2 (Das, 2023). The ISD spread over about 9630 km is the smaller and western part of the complete Sundarbans delta. Still, the area is home to over 3.9 million people (Ghosh, 2011). It is spread over 13 administrative blocks out of 29 in the district of South 24 Parganas along with 6 adjacent blocks of neighboring district North 24 Parganas (GoWB, 2009). People of the Indian Sundarbans primarily depend on income from agriculture or aquaculture or both. High soil and water salinity, the impact of climatic changes (*i.e.*, longer summers, shorter winters, erratic rainfall), and frequent natural calamities like cyclones, floods, Tsunami and ingress of seawater carry out agricultural crop cultivation particularly challenging (Singh, 2020). Paddy is a dominating crop with little coverage of vegetables and pulses. Consequently, most of the land remains fallow throughout the year. The majority of the farmers are small to marginal and even landless with backward communal status (Das, 2021). The interplay of torturous climate change along with changing market forces and globalization leads to poor socio-economic status in the region (Datta *et al.,* 2011). Sundarbans have been affected by natural disasters like Aila, Fani, Amphan and Yash causing breakage of dams leading to the entry of salt water into agricultural lands. As a result, farming families had to face severe losses. However, the situation has somewhat changed as farmers have started to achieve some success by cultivating different perennial conventional fruit crops such as guava, sapota, *etc.* Moreover, fruits are more adaptive to climate change phenomena because once established, the chances of their premature death due to adverse environmental

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conditions are lessened. Besides, growing these fruits is quite profitable due to growing market demand. World Health Organization (WHO) reported that 1.7 million deaths occur worldwide due to insufficient fruit consumption (FAO, 2013). Hence, fruit-based cropping systems not only support the economic stability of the farmers but also contribute to better nutrition. Furthermore, the cultivation of fruits is labour-intensive requiring labour for the entire growing period thus generating employment and providing assured round-the-year income for the rural people. Adoption of fruit-based cropping systems in the Sundarbans can thus serve as an effective strategy to alleviate poverty among the people of ISD, making it essential to bring in more salt-affected regions under such systems.

Location, soil and climate of Indian Sundarbans Delta (ISD)

Indian Sundarbans has a shore length of 130 km out of the total 180 km coastal length of West Bengal. The location of Sundarbans in the Indian part is between 21° to 22°30' N and 88° to 88°29' E (Das, 2015). Indian Sundarbans covers the area of the south eastern part of both North 24 Parganas and South 24 Parganas (Remesan *et al.,* 2021). The entire Indian Sundarbans covers an area of 9630 km^2 bounded between the estuary of River Hugli on the West to Ichhamati - Raimangal in the East, the Bay of Bengal in the south, and an imaginary Dampier - Hodges line in the North (Raha, 2014). Sundarbans is famous for its mangrove ecosystem and about 7% of the world's mangrove falls under India and the area is estimated to be 6740 sq km (Das, 2015). Out of this, the Sundarbans of West Bengal have the largest area, which is nearly about 4200 km^2 (Danda *et al.,* 2011). Soils of the Indian Sundarbans differ from other inland soils for the severe impact of salinity and water-logging (Ray *et al.,* 2014). Soils are mostly poorly consolidated and medium in texture varying from sandy loam, and silt loam to clay loam. Soil reaction values (pH) in coastal regions range from 6.0-8.4. The organic matter content of the soils is low (1.0-1.5%) with quiet dominant deficiencies of N and P. Available potassium (K) content of the soil is low (0.3-1.3 meq 100 g^{-1} dry soil) besides widespread deficiency of micronutrients, such as Cu and Zn. Soil salinity increases from 5 ppt in the east (slight to moderate) to 30 ppt in the west (highly saline) (Mainuddin *et al.,* 2019; Sarkar *et al.,* 2024a; Sarkar *et al.,* 2024b). During the wet monsoon, the severity of the salt injury is reduced due to the dilution of the salt in the root zone of the standing crop. The region is characterized by a tropical climate with a dry season between November and April and a wet monsoonal period over the rest of the year. The total annual amount of precipitation is between 1500 and 2000 mm. During the monsoon season, tropical cyclones and smaller tidal events regularly hit the area, causing severe flooding and wind damage. Average humidity is about 82% which remains constant due to the region's proximity to the sea. Seasonal mean minimum and maximum temperatures vary from 12°C to 24°C and 25°C to 35°C, respectively (Ghosh *et al.,* 2015).

Present farming system and livelihood standard in the Indian Sundarbans Delta (ISD)

Typically, in the delta region, rainfed single-crop agriculture and fishing are the two main sources of livelihood. Nearly 95% of the population primarily depends on agriculture. About 50% of agriculturists are landless labourers (GoWB, 2011). The dominant crop grown in this area is the local transplanted Aman rice crop with low yields and some short-duration vegetables. The cropping patterns followed in the coastal areas are mainly *Kharif* rice-fallow-fallow (Datta *et al.,* 2011).

The residents of Sundarbans depend mainly on agriculture and fishing for their subsistence livelihood because of a lack of transportation, storage, and marketing facilities (Ghosh *et al.,* 2015). A substantial part of the workforce is marginal, daily wage labourers. The forest provides an opportunity to supplement the income during lean agricultural or fishing seasons as most of the Sundarbans is monocropped (Das, 2021) and fishing is restricted as well in the non-protected areas. The forest produces or the non-timber forest products (NTFP) include the collection of tiger prawn seeds or 'meen' carried out particularly by women and catching crab. In addition, honey provides an important source of livelihood to many people, contributing substantively to the local economy (Singh *et al.,* 2010). However, increasing fragmentation of land, more frequent weather hazards, rising salinity and environmental shifts now increasingly force the population to seek alternative livelihoods. Temporary out-migration rate is spectacularly high in the region (World Bank, 2014), and people travel to different, distant parts of India and of the globe in search of livelihoods and as adaptive action. The poverty rate, according to last available data, is very high. According to the West Bengal Human Development Report, 2024, South 24 Parganas recorded the following key Human Development Indices: Health Index - 0.74, Income Index - 0.47, Education Index - 0.71, and an overall Human Development Index (HDI) of 0.64 compared to state averages of 0.70, 0.43, 0.698, and 0.61, respectively.The district ranks fifth in overall HDI (GoWB, 2019).

Constraints related to crop production in ISD

The agricultural development in the coastal saline belt of ISD is constrained by various physical, chemical and social factors. Soil salinity is the main limiting factor that impedes crop growth at different growth stages, especially in the dry seasons. A greater portion of this delta is additionally affected by the saline water ingress. Poor crop production potential in this area is observed due to the low to very low status of the soil fertility with widespread deficiency of both the primary (nitrogen, phosphorus) and micronutrients (zinc and copper). Besides fertility status, soil textural properties like high clay proportion in the soil cause the development of hard cracks on the surface creating problems in land preparation. Crop cultivation is further aggravated in ISD because of the dearth of quality irrigation water during most of the dry season and the problems associated with the presence of saline groundwater table throughout the year within 1.0 m depth (Burman *et al.,* 2019). Within poldered areas, year-round water logging due to inadequate drainage facilities and unorganized operation of sluice gates curbs possibilities of utilization of lowlands. Scientific cultivation package of practices will not work out for most of the crops with narrow germplasm resources. The effects of climate change are quite prominent in ISD. The reproductive behaviour and phenology of the fruit trees get affected due to climate change as there are shifts in production belts, reduction in good quality irrigation water, and unpredictable abiotic and biotic stresses. Agriculture development in the ISD is also retarded by difficulties in communication and inaccessible marketing facilities (Haque, 2006). The above factors are common to most of the saline-prone areas in the ISD. Out of these factors, often occurrence of heavy monsoon rainfall, severe flash floods and exposure to cyclones with saline cyclonic storms make crop production more challenging in the ISD.

Fruit-based cropping system as a potential option in ISD

Many important and minor fruit crops are adapted to saline and sodic conditions (Table 1). They can provide yield even under poor nutrients and water management conditions. Shade condition under the canopy helps to prevent minimizing detrimental salt accumulation in the soil profile (Naorem *et al.,* 2023). The addition of leaf litter as organic matter and usable inter-space in fruit orchards provides an opportunity for multiple cropping that helps proper utilization of space and time. Several locally grown salt-tolerant fruit crops also have dual uses, serving both for table consumption and processing purposes. Native mangrove plants with edible fruits (Table 2) may also be included in fruit-based cropping systems as they have immense medicinal properties that may be explored by pharmaceutical industries. Besides fresh consumption, fleshy fruit, buds and tender leaves of important mangrove fruit plants like *Avicennia marina, Sonneratia apetata, Pluchea indica,*

Table 1. *Relative tolerance of fruit species to salinity**

Ranking	Tolerance threshold	Fruit crops
Tolerant	$EC_e \geq 6$ dS m^{-1}	Karonda, sapota, olive, tamarind, date palm
Moderately tolerant	EC_e 4-6 dS m^{-1}	Fig, jackfruit, ber, loquat, guava, jamun, aonla, bael, mango
Moderately sensitive	EC_e 2-4 dS m^{-1}	Citrus, custard apple, pineapple, pomegranate
Sensitive	$EC_e < 2$ dS m^{-1}	Avocado, banana, cashew, litchi, grape, papaya, passion fruit, strawberry

*Visible symptoms of salt stress do not appear up to the threshold level expressed as soil saturation extract salinity (ECe) (Source: Modified after the Rajkumar *et al.,* 2016)

Oncosperma tigillaria, etc. are used as vegetables by many inhabitants of ISD. On the other hand, pollen of fruits and mangrove plants with edible fruits are a major source of honey produced naturally or in bee boxes, thus fruit-based cropping system opens a window for more honey production and honey-based processed products which is already an income-generating option in ISD (Datta *et al.,* 2011).

Effect of salt stress on fruit crops

Among the various abiotic stresses, salinity stress seems to have an adverse effect on the growth and productivity of different fruit crops (Table 2). Salinity in irrigation water and soils is one of the major abiotic constraints on agriculture worldwide, causing a reduction in growth and leaf scorching in fruit plants. Salt damage usually manifests as leaf burn and defoliation and is associated with the accumulation of toxic levels of Na^+ and/or Cl^- in leaf cells. The inhibition of crop growth under saline conditions is commonly caused by osmotic stress and/or due to excessive ion accumulation in the plant tissues, which may cause ionic toxicity and/or nutritional imbalance. However, the extent of salt stress-induced defunctionalizes is dependent on various factors, including plant species, cultivar and phenological stage, soluble salt composition, stress intensity and duration, and edapho-climatic conditions (Soni *et al.,* 2017).

Physiological drought, a situation where water is available, but the plant cannot uptake due to increased osmotic pressure is common due to salt stress. Osmotic stress occurring in saline soil is developed through two stages. In the first stage, where the salt has not accumulated in the plant, the growth of the plant is inhibited in terms of reduced expansion of cells, conductance of stomata, and rate of photosynthesis. The

Table 2. *Effect of salinity stress on various fruits*

Fruit	Variety	Effect of Salinity	Reference
Guava	Paluma Safeda	Inhibition of photosynthetic pigment synthesis in guava plants by accumulating toxic ions, leading to chloroplast damage, protein denaturation, and membrane destabilization. Salinity reduced the shoot and root growth parameters like shoot and root fresh weight, etc.	Abrar *et al.* (2022) Silva *et al.* (2024)
Bael	NB-5	Yellowing and marginal scorching of leaves, affect branch emergence and leaf production giving a sparse look. Reduction on stomatal conductance, net photosynthesis, chlorophyll fluorescence, photon quantum yield.	Singh *et al.* (2018)
Citrus	US-942	High levels of salinity reduced plant height and stem diameter by 10.1% and 5.2%. A decline of 16.6% and 17.2% was seen in root fresh weight and leaf fresh weight. Also, the chlorophyll components were reduced by 70.2% (chlorophyll a) and 80.3% (chlorophyll b) in salinity-affected plants.	Adams *et al.* (2019)
Mango	Kurukkan	Increasing salinity levels (1-6 dS m^{-1}) significantly impacted seedling growth, reducing stem and root length, fresh and dry weights of shoots and roots, as well as chlorophyll content leading to a reduction of survival of seedlings.	Srivastav *et al.* (2007)
Dragon fruit	Pitaya	Reduction in the number of secondary cladodes, length of root, and length of secondary cladodes.	Sousa *et al.* (2021)
Grapes	140 Ruggeri	The yield of grapes was reduced by an increment of salinity level (0.7 dS m^{-1}, 1.7 dS m^{-1}, 2.7 dS m^{-1}, and 3.7 dS m^{-1}) with the highest yield reduction of 48.31% at a salinity of 3.7 dS m^{-1}.	Suarez *et al.* (2019)
Papaya	Maradol	Application of saline irrigation water inhibited young plant growth, reduced chlorophyll content, increased tissue N and Na levels, and decreased K, Zn, Cu, and Fe, while Ca, Mg, P, and Mn remained unaffected.	Parés and Basso (2013)
Jack-fruit	Hard	Increasing water salinity to 4.0 dS m^{-1} reduces leaf area, hinders biomass accumulation, and adversely impacts the quality of jackfruit seedlings.	de Oliveira *et al.* (2022)

salts enter and accumulate in the plant system in the second stage resulting in physiological abnormalities due to specific ions (Sharma and Singh, 2017).

Salt-stressed plants exhibit electrolyte leakage and lipid peroxidation that destabilize the cell membranes (Sudhakar *et al.,* 2001). Salinity triggers excessive accumulation of reactive oxygen species such as superoxide radicals (O_2^-) and hydrogen peroxide (H_2O_2) that disrupt the cell functions by causing oxidative damage to cell membranes and organelles, enzymes, photosynthetic pigments, lipids, proteins and nucleic acids (Misra and Gupta, 2006). Under saline conditions, most of the fruit species show alteration in water relations (Chartzoulakis, 2005). Salinity depletes leaf chlorophyll by disintegrating the cellular membranes and by hastening the activity of chlorophyllase enzyme (Singh *et al.,* 2015). In saline soils, plants exhibit stomatal resistance and leaf shrinkage that severely limit CO_2 supply to the chloroplast cells and its transport in mesophyll cells, respectively. Excess Na^+ and Cl^- ions in the leaf tissue also decrease the photosynthetic assimilation (Munns *et al.,* 2006).

Symptoms of salt stress in plants involve the water-deficit effect *i.e.,* plants are unable to absorb water from soil leading to a deficit of water in the plant body and ion-excess effect *i.e.,* interference of normal physiological process in plants due to entry of salt ions in plant system (Sharma and Singh, 2017). Some common salt stress symptoms include reduced height of the plant, reduced emergence of leaves and branches, faster ageing and falling of leaves. As a result of the gradual translocation of salts from roots to the leaf and branches, along with a slow rate of growth in older plants, most of fruit trees develop more sensitivity to salt as they grow old (Sharma and Singh, 2017).

Strategies for combating the salt stress to accelerate fruit-based cropping system

Selection of salt tolerant cultivar and rootstock of fruit species

Using salt-tolerant crops is one of the most important strategies to solve the problem of salinity. Plant species vary in their responses to saline conditions. While salt-tolerant plants can cope with a relatively high level of soil salinity, susceptible plants are not able to grow under the same salinity conditions (Munns and Tester, 2008). For successful fruit orcharding in salt-affected soil, foremost priority should be given to select appropriate cultivars of fruit species that are suitably grown in the locality and then commercially accepted salt-tolerant cultivars (Table 3). This rule was also followed in the case of developing quality propagating materials using rootstocks. If planting material is well established, then major obstacles are overcome in fruit orcharding and thereafter proper caring only leads to the harvest of a quality yield from the orchard. The indigenous mangrove plants having immense ethnobotanical uses of their fruit (Table 4) may also be accommodated in fruit-based cropping systems for better adaption and benefit from their medicinal property.

Adoption of precise irrigation techniques

Flood irrigation and an appropriate leaching fraction generally move salts below the root zone. Similar results can be obtained with a properly managed sprinkler irrigation system. With furrow and pressurized irrigation, soluble salts in the soil move with the wetting front, concentrating at its termination or convergence with another wetting front. In drip-irrigated plots, water moves away from the emitter and salts concentrate where the water evaporates (Soni *et al.,* 2017).

Subsurface drainage also emerged as an effective technology for the amelioration of water logged saline irrigated lands in India. The system consists of perforated corrugated PVC pipes, covered with a synthetic filter, installed mechanically at a design spacing and depth below the soil surface to control water table depth and drain excess water and salts out of the area by gravity or pumping from an open well-called sump (Gurung and Azad, 2013).

Management of poor-quality waters

Different techniques effectively installed and in use for the management of poor-quality water to make it fit for irrigation of crops cultivated in different coastal parts may also be checked and deployed in ISD are summarized below:

Skimming well technology

Skimming well is a technique employed with the intention to extract relatively freshwater from the upper

Table 3. *Salt-tolerant rootstocks and important cultivars available in India which can be grown in ISD*

Fruit crop	Salt tolerant rootstock(s)	Salt tolerant cultivars
Aonla (*Emblica officinalis* Geartn.)	Local/desi type	NA-7, NA-6, NA-10, Anand 1, Anand 2, Goma Aishwariya
Bael (*Aegle marmelos* Correa)	*A. fraeglegaboensis*	NB-5, NB-7, NB-9, CISH B1, CISH B2, Pant Shivani, Pant Aparna, Goma Yashi
Ber (*Ziziphus mauritiana* Lam.)	*Z. rotundifolia*	Seb, Gola, Umran, Banarasi Kara-ka, Kaithali, Thar Sevika, Thar Bhubharaj
Date palm (*Phoenix dactylifera* L.)	*P. reclinata.* *P. canariensis,* *P. dactylifera* L.	Hillawi, Barhee, Khadrawy, Khuneji, Khalas, Medjool, Deglet Noor, Shamran
Fig (*Ficus carica* L.)	----	Poona, Dinkar, Conardia, Deanna, Excel
Grape (*Vitis vinifera* L.)	Salt Creek, Dogridge, 140 Ru, Deegraset, 1613, 110R	Pusa Seedless, Thompson Seedless, Manik Chaman, Sonaka, Sharad Seedless
Guava (*Psidium guajava* L.)	*P. mole*	L-49, Allahabad Safeda, Hisar Surkha, Hisar Safeda
Jackfruit (*Artocarpus heterophyllus* L.)	------	Pant Garima, Pant Mahima
Jamun (*Syzygiumcumini* Skeel.)	------	Goma Priyanka
Karonda (*Carissa carandas* L.)	------	PK-1, PK-4, Pant Manohar, Pant Sudarshan, Pant Suwarna, NK-1
Loquat (*Eriobotrya japonica* Lindl.)	------	Large Agra, California Advance, Thames Pride, Tanaka
Mango (*Mangifera indica* L.)	13-1, Gomera-1, Kurrukan,ML-2 and GPL-3	Langra, Dashehari, Mallika, Amrapali, Alphonso, Kesar
Pomegranate (*Punica granatum* L.)	------	Ganesh, Mridula, Ruby, Sinduri, Bhagwa, Arakta
Sapota (*Achras sapota* L.)	Khirnee (*Manilkara hexandra*)	Kalipatti, Banarasi, Cricket Ball, PKM-1, CO1, DSH1
Tamarind (*Tamarindus indica* L.)	------	Parthisthan, PKM-1, Urigam

Source: Modified after Marathe *et al.* (2022)

Table 4. *List of mangrove plants/botanical families with fruit of immense ethnobotanical uses*

Botanical name & family	Common name	Ethnobotanical uses
Avicennia marina (Forssk.) Vierh. (Avicenniaceae)	Peyara bani	Bitter aromatic juice is used in a concoction to facilitate abortion. Mainly used by tribal population that settled in Sundarbanss during British colonial period.
Avicennia officinalis L.(Avicenniaceae)	Kalo bani	Seed bitter, but edible. Unripe fruit is used as a remedy to treat boils.
Casythafiliformis L. (Lauraceae)	Akash bel	Fruit extract is used to treat sexually transmitted diseases, eruption in pubic region and is also used for treatment of erectile dysfunction in adults. Said to have mystical properties by Muslim traditional healers (Pir baba).
Heritiera fomes Buch-Ham. (Malvaceae)	Sundari	Seed is grounded and used to treat dysentery
Nypa fruticans Wurmb. (Arecaceae)	Golpata	Production of alcohol is done by fermenting fruit pulp.
Phoenix padulosa Roxb. (Arecaceae)	Hetal	The fruit pulp is said to have a property that reduce inflammation and used during persistent fevers.
Sonneretia caseolaris Engler. (Sonneratiaceae)	Chak keora	Fruits edible and is used to prepare a local cuisine and is valued for its sour taste. Fruit extract is used as an anthelmintic medicine.
Sonneretia griffithii Kurz. (Sonneratiaceae)	Ora	Fruit is used as spice and to improve flavor of cooking.

Source: Modified after the Chowdhury *et al.* (2014)

zone of the fresh-saline aquifer. The skimming wells are low discharge (less than 28 L s^{-1}) cluster of wells drawing groundwater from relatively shallow depths. Skimming wells are generally designed for irrigation (Saeed *et al.,* 2002) or drinking water supply (Rao *et al.,* 2007) purposes.

Doruvu **technology**

A dugout conical pitlocally called Doruvu in Andhra Pradesh and Kottai in Tamil Nadu used to skim fresh water floating on the saline water. Each Doruvu occupies an area of about 200 m^2. The water collected from each Doruvu is just sufficient to irrigate 800 m^2 and 10-12 Doruvus are needed for 1 ha area. An alternative to traditional Doruvu, the AICRP center at Bapatla developed a popularly known improved Doruvu technology. In this setup, the flow of water 1.8-2.0 m below the ground surface in collectors embedded is collected in a sump. This water is pumped and used to irrigate crops using sprinklers/drip (Bhoyar and Kumar, 2015).

Bio-drainage

Tree species such as *Eucalyptus spp.*, *Acacia nilotica, Dalberjia sissoo,* and *Cassuarina equisetifolia* are quite efficient in intercepting the canal seepage. Planting 2-4 rows of these trees, 5 m away from the canal could intercept more than 80% of the seepage and relieve water logging problem along the canals.

Magnetized water

When a magnetic field is applied to normal water it restructures water molecules into smaller molecule clusters each made up of six symmetrically arranged molecules. These are so-called “bio-friendly” cell clusters due to their hexagonal shape. As toxins cannot travel in clusters so, water easily hydrates plant cells. This provides maximum hydration in less water (Maheshwari and Grewal, 2013).

Protective embankment

Land may be protected from inundation by saline water through the establishment of embankments of suitable size. The recommended size should be 1 meter high above the high tide level.

Provision of sluice gate on the embankment

There should be provision of sluice gates in the embankment system to remove excess water and to prevent ingress of saline water during high tide (Haque, 2006).

Individual farmer-based groundwater recharge structure

The structures involve the passing of excess rain and canal water under gravity through a bore well to subsurface sandy zones coupled to a recharge filter consisting of layers of coarse sand, small gravel, and boulders in a small brick masonry chamber. The recharge structures can be installed at any low-lying location prone to surface water flooding. The prolonged availability and improvement in groundwater quality in recharge wells of Gujarat increased farmers' income by INR 30000 - 75000 ha^{-1} in mango, papaya and banana plantations (Bhoyar and Kumar, 2015).

Fertilizer management

A combined source of N (organic, inorganic, and microbial) is advocated for better results. The addition of Sesbania, city compost, Azolla, and leaves of locally available trees along with inorganic N-fertilizer improves crop yield and soil health. The soil of the coastal region of West Bengal is mostly rich in almost all micronutrients, except Zn. The Zn deficiency can be addressed by the application of 10-15 kg of zinc sulphate per ha. Band application of fertilizers with high salt indices near seedlings should be avoided. Applying lime, and dolomite is a useful management practice for precluding sodium accumulation on the soil's exchange complex, maintaining soil structure, and improving water infiltration (Bhoyar and Kumar, 2015).

Application of beneficial soil microorganisms

Interactions with beneficial soil microorganisms including symbiotic nitrogen-fixing bacteria (*Frankia* and *Rhizobia*) and mycorrhizal fungi can have a large impact on plant tolerance to salt stress. Arbuscular mycorrhizal fungi (AMF) can alleviate salt stress in host plants by enhancing water absorption capacity, nutrient uptake, and accumulation of osmo-regulators to increase the osmotic potential of cells. This role of AMF was studied by (Navarro *et al.,* 2010) in citrus seedlings inoculated with a mixture of AMF (*Rhizofagus irregularis and Funneliformis mosseae*), which alleviated the negative effect of salt stress.The effects of mycorrhizal symbiosis on plant salinity tolerance have been studied in *Olea europaea* (Porras-Soriano *et al.,* 2009), Citrus tangerine (Wu *et al.,* 2010). In both these species, AMF improved plant salinity tolerance, leading to enhanced plant growth and yield, nutrient acquisition, chlorophyll content, proline concentration, and promoting higher accumulation of soluble sugars in roots (Hanin *et al.,* 2016).

Alternate land use systems

An augur hole technology for raising forest and fruit tree plantations in salt-affected soils has been developed and standardized. Pit cum auger hole technology is developed to raise fruit trees like aonla (*Emblica officinalis*), karonda (*Carissa carandus*), and guava (*Psidium guajava*) in soils having pH up to 10.00 and above, where nothing is possible to grow (Bhoyar and Kumar, 2015).

Increasing land and water productivity by raised and sunken bed system

In a raised and sunken bed system, the area is divided into the number of strips of desired width. Raised and sunken beds are constructed alternatively by digging soil from one strip and putting it on the other. The minimum width of the raised bed was taken as 2 m and the height of the sunken bed was 1.0 m above the ground surface. The average depth of sunken bed was 0.50 m below the ground surface and the side slope was 1:1. Banana plantation intercropped with vegetables (like tomato, brinjal, bottle gourd, bitter gourd, ridge gourd, sponge gourd, okra, chilly, tinda, pumpkin, cucumber, etc.) has been reported to be successful with raised and sunken bed technique and generate a remunerative profit. This system has also been found effective in crops such as pomegranate which fail to establish under shallow water table conditions (Sharma and Singh, 2017).

Mulching, cover cropping and intercropping

Mulching of soil during the dry season with rice husk and straw, organic farm waste or any other suitable materials can be used as mulch and when mulching materials are not available, the soil is to be kept ploughed instead of left unploughed. Ploughing of soil on initiation of the pre-monsoon shower and sowing of green manuring crops (like *Sesbania, Horsebean,* etc.) is done to cover and improve the soil fertility, as well as to positively impact the ecology of the land. Interspaces of most fruit plants remain vacant throughout the cropping cycle, but they can effectively be used to grow vegetables, flowers, pulses, *etc*. considered beneficial in respect of extra income generation, improvement in soil organic content and other several advantages. All these methods minimize nutrient loss and maintain water and nutrients at optimal levels and plants absorb them without showing any toxic symptoms.

Application of triazole compounds

Reports on the use oftriazole compounds to mitigate stress impacts on different fruit crops by up-regulating proline content and activities of antioxidant enzymes (Sankar *et al.,* 2007) are available in recent times. UCZ (Uniconazole) application of 1.0 + 1.0 + 2.0 g a.i. per mango tree subdivided into 30-day intervals was efficient in promoting flowering during the off-season, enabling a 167% mean increase in the number of fruits per tree and a 9.78 t ha^{-1} mean increase in productivity (Lima *et al.,* 2016).

Use of plant growth regulators

Adaptation to any stresses is associated with a metabolic adjustment that leads to the accumulation of several organic solutes like sugars, polyols, betaines, and proline (Munns and Tester, 2008; Iqbal *et al.,* 2011). Different plant growth regulators may act either close to or remote from their sites of synthesis to regulate responses to environmental stimuli or genetically programmed developmental changes (Davies, 2004) and therefore these compounds are applied largely to combat soil salinity stress. Grape cv. 'Chardonnay' cells treated with 10 µM putrescine dihydrochloride increased salinity tolerance (Soni *et al.,* 2016). In the case of banana, the addition of 0.2 and 0.4 g L^{-1} potassium humate to the rooting medium tends to increase salinity tolerance (Refaiy *et al.,* 2016) and a similar effect mitigated salinity stress in banana which was also reported with the application of PBZ @1500 mg L^{-1} (Srivastav *et al.,* 2010).

CONCLUSION

Soil salinity is a worldwide problem. Indian Sundarbans Delta (ISD) of West Bengal is no exception to it. In ISD, salinization is one of the major natural hazards hampering crop production. Salinity problems received very little attention in the past. Nevertheless, symptoms of such land degradation with salinization have become too pronounced in recent years to be ignored. The increased pressure of the growing population demands more food. In such problematic land and water conditions, fruit-based cropping system may be a better option to successfully utilize the whole land to get year-round production along with maintaining sustainability of the area if planted with some above-mentioned management practices. The government of West Bengal had set up the Sundarbans Development Board in 1973 under the administrative control of the Development & Planning Department for a comprehensive development of the region. With further emphasis on the development of this region, a new Department of Sundarbans Affairs was created in 1994 and Sundarbans Development Board was placed under its administrative control. In the recent past, this state regulatory body efficiently implemented several development works and successfully mitigated major problems related to unutilized land, and means of communication *i.e.*, concrete roads and electricity in this region. So many other national and international agencies also extend their helping hand to find better livelihood opportunities for the people of ISD. All these efforts indeed create hope for better agricultural prospects in this region. Finally, it may be concluded that the government should take necessary steps to popularize fruit-based cropping systems, as they have the potential to significantly improve the livelihoods of the people in the Indian Sundarbans who constantly struggle against the challenges pose by nature.

CONFLICTS OF INTEREST

We, the authors of this article declare that there is no conflict of interest and we do not have any financial gain from it.

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