Nursery management in fruit crops in salt-affected soils

Rajkumar, Anshuman Singh* and R. K. Yadav

ICAR-Central Soil Salinity Research Institute, Karnal-132001
*Email: anshumaniari@gmail.com

1. Introduction: Salinization of agricultural lands is a severe limitation to the sustainable crop production. Although crop lands in virtually every climatic region are salt stressed to varying degrees, salt induced crop and environmental damages are often severe in arid and semi-arid zones compared to others. The extent of the problem can be gauged by the fact that while primary salinity (natural saline soils) has been reported from over 100 countries of the world, secondary salinity (irrigation-induced salinization) is on rise in many important food producing regions (Rengasamy, 2006). Irrigation-induced salinity has adversely impacted agricultural production since the time immemorial. In contemporary times, however, the twin menaces of waterlogging and salinity have attained alarming proportions in several irrigated regions of the world (Wichelns and Qadir, 2015). Of late, secondary salinization ascribed to the replacement of perennial vegetation with annual crops has also considerably increased in many rainfed areas (Munns, 2005). In the absence of appropriate technological interventions, salinity induced losses in agricultural production (~US $12 billion) are expected to substantially increase in the ensuing decades (Shabala, 2013).

Salt affected soils (SAS) comprise of the saline and sodic soils that vary with each other in characteristics and limitation to the plant growth. The excess soluble salts present in the saline soils- mainly chlorides and sulphates of Na^+, Ca^{2+} and Mg^{2+}- raise the soil saturation extract electrical conductivity ($EC_e > 4$ dS m^{-1}) and create the osmotic stress that impairs the water extraction capacity of the plant roots resulting in physiological drought. In addition to water stress, ionic toxicities (Na^+ and Cl^-) hamper the plant growth and development in such soils. Sodic soils, on the contrary, have variable EC_e, exchangeable sodium percentage (ESP) above 15 and soil saturation extract pH (pH_s) above 8.2. High ESP adversely affects water permeability and air flow, reduces water retention, root penetration and seedling emergence. Replacement of other cations like Ca^{2+} by Na^+ on exchange complex causes clay dispersion and poor aggregate stability. Sodic soils also suffer from surface crusting, hard setting, water accumulation and oxygen deficiency (Munns, 2005; Sharma and Singh, 2015). In many cases, SAS are also underlain with marginal quality- high RSC (residual sodium carbonate) and high SAR (sodium adsorption ratio)- water that hinders their reclamation and exacerbates the salt stress for crops (Singh *et al.*, 2010). In India, the present estimated area under SAS (6.73 million ha) is expected to substantially increase in foreseeable future.

Rapid demographic expansion, urbanization and industrialization have heightened the competition for land and fresh water use among different sectors of the economy leaving little scope for agricultural expansion into prime lands. While productive soil and water resources are shrinking, the growing food requirements of the burgeoning population have necessitated productivity enhancements of the degraded, low yielding soils (Rengasamy, 2006; Sharma and Singh, 2015). In recent times, rising incomes and globalization have also caused a 'nutritional transition' with a clear dietary shift towards protein and calorie rich diets and

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health protective food including fruits and vegetables (GOI, 2007; Shetty, 2002). As productive soils and fresh water are depleting, food requirements are increasing and human diets are becoming diversified, there is no other alternative except to increase the soil productivity; especially in marginal and degraded lands, to address the intertwined goals of natural resource conservation and adequate food availability for the rising global population.

2. Salt tolerance in fruit crops: About three fourths of the total fruit species listed are sensitive to salinity (Bernstein, 1980). The bi-phasic inhibition of plant growth in saline soils involves an initial osmotic shock followed by specific ion injuries. Although osmotic stress equally affects both tolerant and sensitive genotypes, specific salt effects mainly affect the sensitive cultivars. While salt stress symptoms generally develop within few days in annual crops, perennial crops may take months or even years to manifest the salt injury (Munns, 2005). Contrary to the annuals which generally exhibit higher salt tolerance with age, most of the fruit crops tend to become salt sensitive as they grow older. It is attributed to carry over of salts stored in roots to leaves as well as slower growth rates in older plants. Again, highly salt sensitive species such as citrus tend to accumulate Na^+ to toxic levels in soils which are essentially normal (Bernstein, 1980).

Exposure to saline conditions impairs most of the physiological processes in fruit plants. 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 alsoo decrease the photosynthetic assimilation (Munns *et al*., 2006).

Fruit plants respond in a myriad of ways to lessen the impact of these adverse changes on cell structure and functions. To overcome the harmful free radicals, different antioxidant molecules (e.g., superoxide dismutase, catalase and ascorbate peroxidise) are activated (Arbona *et al*., 2003). Similarly, proline is synthesized to alleviate the osmotic stress and cellular dehydration (Agastian *et al*., 2000). Fruit species show differential response to the excess Na^+ and Cl^- ions. In citrus fruits, for example, the adverse effects of salinity are mainly due to accumulation of Cl^- ions in leaf and shoot tissues. When leaf Cl^- concentration reaches around 1.5% (on dry weight basis), ethylene production is triggered resulting in leaf abscission. Therefore, salt tolerance in many citrus species depends on ability of roots to prevent and/or reduce Cl^- uptake from the growing medium (López-Climent *et al*., 2008). Salt tolerant rootstocks in different crops significantly decrease the uptake of these ions. Threshold salt tolerance in different fruit crops is presented in Tables 1 and 2.

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 threshold level expressed as soil saturation extract salinity (EC_e).

Table 2. Relative tolerance of fruit species to sodicity*.

Ranking	Tolerance threshold	Fruit crops
Tolerant	$pH_s \geq 10$	Sapota
Moderately tolerant	pH_s 9-10	Pomegranate, ber, aonla, karonda, guava, date palm, bael, peach, jamun
Sensitive	pH_s 8-9	Pear, grape, mango

*Visible symptoms of salt stress do not appear up to threshold level expressed as soil saturation extract pH (pH_s).

3. Salinity management technologies for fruit crops: In India, a number of technologies have been developed to arrest the soil degradation and to enhance the crop production in SAS under the leadership of ICAR-CSSRI, Karnal. Technologies such as gypsum-based reclamation of sodic soils, sub-surface drainage of waterlogged saline lands and salt tolerant varieties in staple foods such as rice and wheat have become highly popular in salinity-affected parts of the country (Sharma and Singh, 2015). Over the years, emphasis has also been placed on developing suitable technologies for promoting horticultural crops in SAS. This consideration stems from the fact that many saline and sodic soils have only minor limitations that can be easily overcome to raise the salt sensitive fruit and vegetable crops. A recent study showed that an overwhelming 85% of the global SAS have only slight to moderate constraints for crop production (Wicke *et al*., 2011).

It has been shown that an appropriate combination of different techniques including improved planting methods, salt tolerant cultivars, reduced amendment application, supplemental nutrition, use of microbial inoculants and drip irrigation make it easier to grow fruit crops in saline soils. The practical utility of auger-hole planting technique in raising fruits such as aonla, ber, jamun, guava and karonda in alkali soils has been successfully demonstrated. In this method, tractor-mounted augers are used to excavate the soil and to break the hard kankar pan followed by gypsum treatment (5-10 kg per hole) to plant the trees. Raised and sunken bed technique has been found effective in crops such as pomegranate which fail to establish under shallow water table conditions (Dagar and Tomar, 2002). Guava cultivar Allahabad Safeda and bael cultivar NB-5 have been found suitable for cultivation under saline conditions. Similarly, many pomegranate genotypes collected from Rajasthan and Punjab states have shown encouraging results in SAS. Different genotypes and species of Indian jujube such as *Ziziphus rotundifolia* and *Z. spinachristi* are being evaluated for the use as salt tolerant rootstocks (ICAR-CSSRI, 2015). Salt tolerant polyembryonic rootstocks (ML-2 and GPL-3) have been identified in mango (Kannan *et al*., 2014).

4. Importance of Quality Planting Material: Available evidence suggests that easy, timely and adequate availability of elite planting stock is one of the prerequisites for commercial horticultural production. In contrast, unavailability of quality propagules continues to be a major hindrance to the successful orcharding in many developing countries. In particular, small and marginal farmers often fail to obtain superior planting material which considerably lessens the orchard profitability (FAO, 2006). As fruit tree plantations involve high initial costs and represent a long-term investment, any flaw in site selection, plating and care undermines the potential returns. Careful planning is thus essential to ensure a long economic life, optimum resource use and the maximum orchard productivity. A thorough exercise is necessary to select the best scion-rootstock combination of superior quality to obtain early and stable fruit yields (Hoying and Robinson, 1998).

In India, farm diversification through fruit crops is seen as a key to food, nutritional and economic security of the farmers. Nonetheless, smooth development of fruit industry in the country is hindered by the scarcity of reliable planting stock. The dearth of quality seedlings is evident by the fact existing infrastructure can meet hardly 40% of the present demands compelling the growers to depend on spurious planting material. In spite of the efforts of ICAR institutes, state agriculture universities and government nurseries, the demand-supply gap for elite plants remains unaddressed. Although private nurseries enjoy pre-eminence in the supply of fruit saplings, quality control to maintain and/or improve the plant quality is rather poor (GOI, 2007). As with many other developing countries, this state of affairs in India is a pointer to urgent initiatives to strengthen the existing nursery facilities and to create state-of-the-art infrastructure for the bulk multiplication of healthy and truthful plants (FAO, 2006) to fast tract the area expansion and replanting programmes through fruit crops (GOI, 2007). Realizing the fact that requirement of planting material will increase by 4% per year, establishment of model nurseries, tissue culture units, accredited nurseries and joint ventures between public and private sectors should be promoted to accelerate the pace of quality plant production and distribution (GOI, 2007).

5. Plant propagation methods: Majority of the fruit crops are multiplied through asexual means using suckers, differentiated vegetative parts and apomictic seeds. Vegetative propagation preserves the unique characteristics of a clone/genotype as it maintains the genetic stability over the generations. Vegetatively multiplied plants are true-to-type (*i.e.*, genetically identical to the mother tree), have a short juvenile phase, exhibit uniformity in growth and precocity in bearing. In fruit species producing seedless fruits (*e.g.*, banana, pineapple, grape and lemon), vegetative propagation is the only option for propagation. Use of rootstocks in budding and grafting allows the production of dwarf and stress tolerant trees amenable for high density orcharding under adverse conditions. Sexual propagation through seeds is done in fruit crops such as papaya. Non-descript as well as true breeding apomictic seeds (*e.g.*, mango and citrus) are also widely used to raise rootstocks for use in grafting. Commercial methods of vegetative propagation, salt tolerant rootstocks and important cultivars in tropical and sub-tropical fruit crops are given in Table 3.

Table 3. Methods of vegetative propagation, salt tolerant rootstocks and important cultivars in tropical and sub-tropical fruits.

Fruit crop	**Propagation method**	**Salt tolerant rootstock(s)**	**Cultivars**
Aonla (*Emblica orficinalis* Geartn.)	Wedge grafting (T-budding) /Patch budding	Local/desi type	NA-7, NA-6, NA-10, Anand 1, Anand 2, Goma Aishwariya
Bael (*Aegle marmelos* Correa)	Patch budding	*A. fraeglegaboensis*	NB-5, NB-7, NB-9, CISH B1, CISH B2, Pant Shivani, Pant Aparna, Goma Yashi
Ber (*Ziziphus mauritiana* Lam.)	*In-situ* budding (Ring / T-budding)/ Polytube budding	*Z. rotundifolia*	Seb , Gola, Umran, Banarasi Karaka, Kaithali, Thar Sevika, Thar Bhubharaj
Date palm (*Phoenix dactylifera* L.)	Offshoot (suckers)	*P. reclinata. P. canariensis, P. dactylifera* L.	Hillawi, Barhee, Khadrawy, Khuneji, Khalas, Medjool, Deglet Noor, Shamran
Fig (*Ficus carica* L.)	Hardwood cuttings	----	Poona, Dinkar, Conardia, Deanna, Excel
Grape (*Vitis vinifera* L.)	Hardwood cuttings	Salt Creek, Dogridge, 140 Ru, Deegraset, 1613, 110 R,	Pusa Seedless, Thompson Seedless, Manik Chaman, Sonaka, Sharad Seedless
Guava (*Psidium guajava* L.)	Stooling, Inarching	*P. molle*	L-49, Allahabad Safeda, Hisar Surkha, Hisar Safeda
Jackfruit (*Artocarpus heterophyllus* L.)	Inarching/Air-layering	------	Pant Garima, Pant Mahima
Jamun (*Syzygium cumini* Skeel.)	Shield & Patch budding	------	Goma Priyanka
Karonda (*Carissa carandas* L.)	Seeds/ Hard wood cuttings	------	PK-1, PK-4, Pant Manohar, Pant Sudarshan, Pant Suwarna, NK-1
Loquat (*Eriobotrya japonica* Lindl.)	Inarching, Shield Budding	------	Large Agra, California Advance, Thames Pride, Tanaka
Mango (*Mangifera indica* L.)	Veneer grafting and Inarching	13-1, Gomera-1, Kurrukan	Langra, Dashehari, Mallika, Amrapali, Alphonso, Kesar
Pomegranate (*Punica granatum* L.)	Hardwood cutting and air layering	-----	Ganesh, Mridula, Ruby, Sinduri, Bhagwa, Arakta
Sapota (*Achras sapota* L.)	Inarching	Khirnee *(Manilkara hexandra)*	Kalipatti, Banarasi, Cricket Ball, PKM-1, CO1, DSH1
Tamarind (*Tamarindus indica* L.)	*In-situ* soft wood grafting	------	Parthisthan, PKM-1, Urigam

6. Nursery management in fruit crops: Realization is growing that cultivation of high value fruits is far remunerative than annual field crops. In comparison to food crops, fruit trees require less fertilizers and water, give high yields per unit area and fetch premium price. Keeping these advantages in mind, a number of policy initiatives have been launched to encourage the farmers for commercial fruit culture. Despite several efforts to usher in a congenial environment for commercial fruit cultivation, the pace of area expansion is rather slow. Scarcity of genuine planting material is one of the most important causes behind the restricted spread of improved varieties. Due to poor access to the reliable saplings, farmers become reluctant to establish fruit orchards. In light of these facts, establishment of fruit nurseries having modern infrastructure is absolutely essential to overcome the shortages of elite planting stock in the country. Besides ensuring timely and adequate availability of the improved plants, nursery business can also open up avenues for the export of quality planting material to other countries and employment opportunities for the skilled youth and women.

7. Components of Fruit Nursery: The foregoing discussion underscores the importance of modern nurseries in the development of a sound fruit industry in the country. The entrepreneurs and farmers willing to establish the nursery units should meticulously plan taking into consideration the physical and financial resources to smoothly run the business. Different components essential to the establishment and functioning of a fruit nursery are briefly discussed as under:

7.1 Location and site: As far as possible the nursery should be established in traditional or coming up fruit belts so as to have a ready access to the market such that saleable grafts are regularly disposed. In case of land scarcity in the immediate vicinity of fruit producing tracts, the nursery may be established in nearby areas having proper road and rail connectivity to minimize the transport costs and time.

7.2 Soil and climate: The land selected for nursery should have proper drainage. As most of the fruit plants are highly sensitive to waterlogging, low-lying lands should not be chosen. The soil should be fertile, neutral in reaction (pH 6.5-7.5) and free from salts. If saline and sodic soils are to be used for nursery production, their amelioration by salt leaching and application of amendments such as gypsum is necessary. Before raising the plants, nursery soil should be analyzed to detect specific nutrient toxicities and deficiencies so that corrective measures can be implemented.

7.3 Irrigation and electricity: The nursery land should have assured supply of good quality water. As most of the fruit species are salt sensitive during germination and early seedling stages, use of marginal quality water should be avoided. The pH and electrical conductivity of irrigation water (EC_{iw}) should be regularly tested. The nursery should have regular electricity supply to ensure timely irrigation, spraying, dusting and other operations.

7.4 Labour: Multiplication, upkeep and sale of nursery plants are labour-intensive activities. Partial reduction in labour requirement may be possible through mechanization and automation of some of the nursery units. Adequate availability of both skilled and unskilled man-power should be ensured for different field works, protective sprays, grafting and budding and the care of grafts.

7.5 Mother Plants: Separate space should be provided for the establishment of mother block within the nursery premises. High yielding clones of recommended varieties should be selected for establishing the mother block. A permanent register indicating the layout of different varieties should be maintained. All the agronomic practices should be carried out as per recommendations. Regular pruning of mother trees is necessary to produce enough shoots for propagation. The health of plants should be rigorously monitored so that they are free from diseases and insect-pests.

7.6 Propagation and hardening structures: Different propagation structures (Table 4) are used for rooting the cuttings, raising the seedling and producing the grafts. Small shade and net houses are required for hardening of the nursery plants. Hardening off gradually thickens the cuticle on the leaves so that the leaves transpire less water. Hardening off also enhances the adaptive capacity of plants and minimizes the chances of transplant shock and the subsequent mortality.

Table 4. Plant propagation structures in the nursery.

Nursery structure	Utility
Greenhouses	Used for forcing the growth and extending the growing season; especially in cool climates. In India, construction of temporary low-cost polyhouses is increasing for raising fruit saplings in the off- season.
Hot frames (Hot beds)	A bed of soil enclosed in a glass or plastic frame and heated by manure, electricity, steam, or hot-water pipes. Used for forcing plants or for raising early seedlings.
Cold frame	A bottomless box with a removable top used to protect small plants from wind and low temperatures.
Lath houses	Used to protect container-grown plants from high summer temperature and high light irradiation.
Propagation frames	Enclosed frames covered with glass or plastic material and used for rooting of cuttings.
Net houses	Widely used as propagation structures in tropical areas to maintain ventilation and optimum temperature for seed germination and seedling growth.
Mist chamber	Used to maintain humidity and reduce the transpiration so as to keep the cuttings turgid until rooting takes place.

7.8 Growing media: A number of organic and inorganic materials can be used as a rooting medium for cuttings. Mixes of perlite and peat moss are commonly used. Other substrates include vermiculite and sand, either alone or in combination with other materials. All materials used for propagation should be sterilized to maintain disease free conditions. Rooting hormones are sometimes used for hastening the root development in cuttings.

7.9 Grafting tools and materials: Although a single knife can be used for both budding and grafting, it is desirable to use special knives for each operation. Such knives differ primarily in blade shape. For cleft grafting, a wooden mallet and clefting tool are useful. A good quality, fine-grained stone is important for developing a sharp edge on knife, which is essential for making smooth, straight grafting and budding cuts needed for successful graft union. Waxing is most commonly practiced to protect grafts from drying. Some waxes must be heated and applied with a brush, while others are soft and pliable enough to be applied cold by hand. Electrician's tape, adhesive cloth, or masking-type paper tape are also frequently used to protect grafts.

8. Nursery and agronomic techniques to enhance the salt tolerance: A number of different techniques have been tried with varying degree of success to enhance the salt tolerance in fruit crops. The potential of such practices is briefly discussed under the following heads:

8.1 Salt tolerant rootstocks: As previously indicated, reduced uptake of salt by plant roots can significantly enhance plant growth and yield under saline conditions. Rootstocks that reduce the absorption of Na and Cl ions and preferentially accumulate K^+ have been identified in different fruit crops (Table 3). Many of such rootstocks also exhibit drought tolerance. Considering the simultaneous occurrence of other stresses along with salinity, many current rootstock development programmes aim to combine traits such as high water use efficiency, drought tolerance and salt tolerance into a single rootstock. When improved scion varieties are grafted onto these rootstocks, they show considerably less accumulation of toxic ions in the foliage. It is worth mentioning, however, that salt exclusion capacity in many such rootstocks breaks down at high salinity (Whiting, 2012). In India, a few salt tolerant rootstocks have been identified in grapes, mango and citrus but their commercial use in propagation is limited.

8.2 Use of plant growth substances: Rooting hormones (e.g., auxin Indole-3-butyric acid) are commonly used to enhance rooting in cuttings (Centeno and Gómez-del-Campo, 2008). Similarly, gibberellic acid is known to promote seed germination in many fruit species (Chen and Chang, 1972). Experimental findings suggest that exogenous application of plant growth substances enhances the salt tolerance in fruit plants. Under stress conditions, indole acetic acid (IAA) increases water use efficiency by enhancing the stomatal resistance to transpiration. Gibberellins modulate ionic balance and endogenous abscisic acid levels in salinized plants (Prakash and Parthapasenan, 1990). Cytokinins (*e.g.*, kinetin) reduce the severity of salt stress by up-regulating endogenous polyamine levels known to enhance salt tolerance (Mansour, 2000). Paclobutrazol, a growth retardant, improves salt tolerance in fruit crops such as guava, grape, pomegranate, citrus, strawberry and mango. The ameliorating effects of PBZ are exerted through upregulation of antioxidant enzymes, reduced uptake of Na^+ and Cl^- ions, improved nutrient acquisition and water balance under saline conditions (Sharma *et al*., 2011). Salicylic acid also improves plant growth under stress conditions (Horváth *et al*., 2007). Although direct evidence is lacking, it appears that use of such chemicals may improve the survival and growth in nursery grafts where salinity is a problem.

8.3 Microbial bio-inoculants: Arbuscular mycorrhizal (AM) fungi mitigate the detrimental effects of salinity by regulating key physiological functions such as accumulation of compatible solutes to avoid cell dehydration, regulation of ion and water uptake by roots, reduction of oxidative stress by enhancing the antioxidant capacity and stabilizing photosynthesis for sustained growth (Ruiz-Lozano *et al*., 2012). Rhizospheric and endophytic bacteria (CSR-G-1, CSR-B-2, and CSR-B-3) isolated from SAS have been found promising to enhance salinity tolerance in different horticultural crops. Their growth enhancing and bio-ameloiration properties are ascribed to the higher activities of superoxide dismutase, phenyl alanine lyase, catalase, peroxidase, phenols, and proline in treated plants (Damodaran *et al*., 2014).

Concluding Remarks: The preceding account makes it evident that acute shortage of quality planting material is one of the major hindrances to the area expansion under fruit crops. Although a number of improved fruit varieties have been developed, their adoption by the farmers remains rather slow owing to difficulties in procuring elite plants of such varieties. As a congenial policy environment has significantly enhanced the farmers' interest in taking commercial orcharding as an entrepreneurship, the demand for quality planting material is bound to grow in the coming years. It is significant that degraded and salt-affected lands lying unproductive due to different reasons offer ample scope for raising the fruit plantations for socio-economic and environmental benefits. Nonetheless, as with other parts of the country, non-availability of genuine planting material is a constraint to commercial fruit cultivation in such soils. Although significant progress has been achieved, a lot remains to be accomplished to accelerate the pace of fruit cultivation in saline and sodic soils. In this regard, easy and timely availability of improved nursery plants and effective salt mitigation technologies to the farmers will be a key determinant of the future plans to up-scale the commercial fruit growing.

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