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Crop Salinity Stress and Mitigation Strategy

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Abstract

Crop stress is an adverse situation where plant is unable to perform upto its full potential hampering its overall growth and development. Both abiotic and biotic stress negatively influences crop phenomics as well as genomics. Infact, abiotic stress posing a greater threat to agriculture globally. Among these, salinity stress outsmart other stresses in a profound way as it not only affects crop production and productivity, but also causing soil salinization making it unsuitable for further cultivation limiting global economy. Also it affects almost all growth stages of crop; germination, growth, ion toxicity, photosynthetic pigments and photosynthesis, water relations, nutrient homeostasis, oxidative stress and finally yield, proving its prominence under abiotic stress category. In this chapter we are also shedding light on its transport pathway inside plant, its sensing mechanism and genes associated with it to date. One of the major mechanisms involved in salinity stress tolerance is SOS (Salt Overly Sensitive) which has been described in a broader way. Apart from plant's inherent tolerance mechanism, various approaches need to be considered such as a detailed or thorough analysis of its genetics, transcriptomics, proteomics and metabolomics. All these approaches however have a good impact under controlled condition; these have costly affair, needs careful and skilful handling and monitoring. So, in order to validate these approaches, again various strategies such as chemical, biological, physical strategies including improved field and water management practices need to be followed which are cost effective, farmers friendly in nature which are elaborated here.

Keywords: biological strategy, chemical strategy, physical strategy, Salinity stress, SOS pathway.

Introduction

Crop production and productivity is very tightly linked with various stress factors, where unpredictability of stress signals manifest crop ecology significantly. Being sessile, plants or crops are frequently exposed to several climatic (abiotic) factors such as, drought, submergence, salinity, cold, heavy metal stress, oxidative stress etc. and biotic factors such as pathogen and insect attack, herbivores etc.; influencing its morphological, physiological, biochemical and molecular behaviour.The combinatorial impact of both kinds of stress factors especially abioitc stress creating a menace for crop simultaneously prohibiting them to reach their full genetic potential limiting their yield and increasing the gap between population demands and crop yield; creating shortcoming to attain global food security by 2050. According to report reviewed by Ray *et al.*, 2013, to achieve sustainability in global food security, crop yields need to be doubled by 2050. However the yield trend (1998-2008) of four major global crops (i.e. maize, wheat, rice and soybean) constituting about two-thirds of current harvested global crop calories, revealed that the current rate of acceleration in crop yields is far slower than the ~ 2.4% per year required to double the global crop yields by 2050 (Ray *et al.*, 2013). Additionally, under field condition the commercially grown crops achieved only on average of about 50% of their potential yield due to negative impact by abiotic stress (Hatfield and Walthall, 2015; Foyer *et al.*, 2016), whereas the biotic stress contribute a yield gap of only 10% (Kerchev *et al.*, 2012), indicating the thrust of abiotic stress in limiting yield.

In nature, stress does not come in isolation rather has cumulative effect on crop growth and development; some genes up/down regulated in response to it adjusting cellular metabolism for better survival and compensatory yield, mitigating, combating and tolerating the adverse condition; yet it depends upon the plasticity of crop. Among different abiotic stresses, here we have focussed on salinity stress; covering its significance, effect on plant overall phenology and molecular biology, signalling mechanism involved and its mitigation strategies. But before explaining about salinity stress, we are briefly defining stress and its overall signal transduction pathway.

Salinity stress: Its significance

Soil salinity is affecting global crop production and productivity extensively posing a great threat to sustainability of global food security. Report suggests that soil salinization is reducing crop yields on an approximately 20% of irrigated lands (Qadir *et al.*, 2014). Also, statistics shows at least 0.3 Mha of farm land is becoming non-arable annually and another 20–46 million ha are suffering decreases in production potential each year (FAO and ITPS, 2015). Additionally, it is a global problem in agriculture particularly in arid and semi-arid regions, where water scarcity and inadequate drainage of irrigated lands severely reducing crop yields (Hanin *et al.*, 2016). This grim scenario is again supported by information displayed by food and agriculture organization (FAO). According to it, more than 6% of the total land area is under salinity stress. The same source again exhibits the total geographical area affected by salinity and sodicity which has been estimated at 397 Mha and 434 Mha respectively indicating the alarming situation posing by soil salinity across the globe. Moreover, this adversity is again exacerbated by emerging climate changes and rapid anthropogenic interferences around the world. All these reports pointing towards importance of soil salinity stress especially from agriculture point of view.

General aspect, types and causes

Soil salinization mainly refers to accumulation of various salts such as potassium, calcium, magnesium and sodium carbonates, bicarbonates, chlorides and sulphates (Bockheim and Gennadiyev, 2000) creating a wide range of physiochemical properties. However, FAO Soil Portals categorized salt affected soils into saline, saline-sodic and sodic, based on salt amounts, types of salts, amount of sodium present and soil alkalinity. Saline soils have been characterized as having a saturation soil paste extract electrical conductivity (EC) of > 4 $dS\ m^{-1}$ at 25 °C (corresponding to approximately 40 mM sodium chloride (NaCl)), creating an osmotic pressure of approximately 0.2 MPa Grieve *et al.*2008 Munns and Tester, 2008), whereas sodic soils refers to amount of sodium present in the soil. Generally high sodic soils contain > 5% of Na^+ in the overall cation content. Saline-sodic soils, as the name indicates have intermediate properties.

Recent researches have emerged focussing on effect of soil salinity on plant responses which can be categorized into two main phases Negrão et al.2017 shoot ion independent (early) responses, also known asosmotic phase (Roy *et al.*, 2014), occurring within minutes to day upon stress imposition, causing stomatal closure, reduction in photosynthesis, inhibiting leaf expansion causing overall reduction in shoot growth (Das *et al.*, 2015; Nongpiur *et al.*, 2016; Hanin *et al.*, 2016), whereas ion dependent (late) responses occurs after several days to weeks accompanying cytotoxic accumulation of Na^+ in phosynthetic tissues (Roy *et al.*, 2014), causing senescence of older leaves, photosynthesis impairment and reduced growth rate (Nongpiur *et al.*, 2016).

Salinity is divided into two categories based on their source of cause; primary salinity occurs as natural salt in the landscape such as salt marshes, salt lakes, tidal swamps or natural salts clads, while secondary salinity is because of anthropogenic activity such as urbanization and agriculture (irrigated and dry land). Moreover following are the factors responsible for two types salinity.

Table1. Types and Causes of Salinity

Primary salinity	Secondary salinity
Weathering of rocks	Introduction of irrigation without proper drainage system
Capillary rise from shallow brackish ground water	Industrial effluence, High water table and the use of poor quality ground water for irrgation
Intrusion of sea water along the coast	Overuse of fertilizers
Salt laden sands blown by sea winds	Removal of natural plant cover
Impeded drainage	Flooding with salt rich waters

Pathway of salt transport

The debate surrounding the entry of salt into plant roots and its subsequent pathway inside it is still remains elusive which is being unlocked to certain extent here. Both apoplastic and symplastic pathway are responsible for ion uptake (Maathius *et al.,* 2014). Apoplastic pathway constitutes a direct flow continuum between outside and xylem (Krishnamurthy *et al.,* 2009) which contribute < 1% of the transpirational volume flow. However in rice, it is pronounced and responsible for up to 50% of total Na^+ uptake (Kronzucker and Britto, 2011) and Cl^- translocation to shoots (Shi *et al.*, 2013), supported by reports indicating its relevance among monocots. Contrastingly, net uptake of Na^+ (Cl^-) via symplastic pathway is thought to be catalyzed by a group of transporters, but their relative contribution and physiological relevance is still obscure. Two gene families, glutamate receptor like channels (GLRs) and cyclic nucleotide gated channels (CNGCs) encoded non-selective cation channels (NSCCs) and blocked by Ca^{+2} (Demidchik *et al.,* 2018). The apoplastic Ca^{+2} concentration in root cells ranges between 0.2-0.4 mM, enough to reduce NSCC mediated flux by (30-50) %. Further remaining flux can be shrinked by a number of channel blockers such as Gd^{3+} and La^{3+} simultaneously by organic compounds like CGMP. Hence, in plants such as *Arabidopsis,* a large fraction of inward Na^+ flux is carried out by NSSC transporters but its tentative role and genetic identity is still opaque. However, in monocots, several isoforms of NSSC exist mediating ion uptake. For example, in barley, *HvHKT2;1* facilitates increased Na^+ uptake under salt stress condition (Mian *et al.,*2011). Complementary to Na^+, it was hypothesized that, Cl^- is being taken by H^+/Cl^- symport; yet its molecular nature in unclear. Interestingly, another potential class of Cl^- transporter, cation chloride co-transporters (CCCs) has been discovered in halophytic plant *Suaeda maritima* (Zhang *et al.,* 2011), where it has been observed that 100 µM bumetanide extensively reduces Na^+ uptake. The role of CCC has been studied in some detail in *Arabidopsis,* where it is shown to be expressed in roots and is involved in synchronized K^+, Na^+ and Cl^- uptake (Zhang *et al.,* 2010). So, in summary, it has been established that NSSCs are major pathways for Na^+ influx into glycophytic plant roots, but the complexity of multiple channels involved in it need a clear and detailed study further. However the study including rice regarding Na^+ and Cl^-apoplastic (bypass) transport can be considerable.

Mechanism involved in Salinity sensing in plants

The plant response to salinity stress is complex, yet involves certain mechanism to sense increase in ion concentration either in external medium or inside cell. But the way of sensing of Na^+ or Cl^- by plants remains undisclosed. From different reports, it is clear that in animals primary Na^+ sensors depend on sodium specific binding sites modulating transporter activity. However no such similar mechanisms have been revealed in plants; only rapid responses such as salt induced membrane depolarization and Ca^{2+} signals could probably form early components of salt sensing signalling. Nevertheless lack of specificity of membrane depolarization making it physiologically irrelevant. Although some reports indicate the involvement of Ca^{2+} signals to elevated NaCl concentration, unfortunately the presence of upstream components during Ca^{2+} signals is largely unknown till now, unless the research by Choi *et al.,* 2016 indicates the existence of long-distance Ca^{2+} waves in response to salinization might aid in discovery of upstream components. Similarly Annexin 1 from *Arabidopsis thaliana* sense an elevated extracellular NaCl by mediating ROS-activated Ca^{2+} influx through plasma-membrane of plant root cells making it an early key component to salinity (Laohavisit *et al.,* 2013). Nonetheless the presence of downstream components such as calcium-dependent protein kinases (CDPKs) and calcineurin B-like proteins (CBLs) along CBL-interacting protein kinases (CIPKs) (Boudsocq and Sheen, 2013), modulate protein activity and gene transcription.

Post sensing calcium signals caused by salinity, one CBL (CBL4 or SOS3; salt overly sensitive) dimerize upon binding with calcium and amplify the activity of CIPK24 (SOS2) serine/threonine protein kinase. It results in CBL4/CIPK24 (SOS3/SOS2) complex activating Na^+/H^+antiporter–SOS1 *via* phosphorylation (Munns and Tester, 2008). Albeit, cytoplasmic C-terminal of SOS1 acts as an intracellular Na^+ sensor, yet proper evidence is far from reach. Apart from three major SOS genes, this pathway bears some additional components - SOS4 and SOS5, probably indulged in Na^+/K^+ homeostasis supported by evidence given by (Mahajan *et al.,* 2008); where *sos4* mutant exhibits higher Na^+/K^+ ratio comparing to wild types and because of extracellular localization, SOS5 may be treated as potential extracellular Na^+ sensor.

The identification of SOS genes led to the discovery of SOS pathway, major mechanism involved in reinstating Na^+ homeostasis via SOS1. Besides it, it also interacts with other regulatory proteins such as *AtHKT1*, where SOS2-SOS3 complex negatively regulates *AtHKT1*, thus keeping excess salt out of the cell. SOS2 including SOS1 also interacts with Vacuolar Na^+/H^+ exchanger to elevate its exchanging activity; also with N-terminus of CAX1 (a H^+/Ca^+ exchanger). Apart from SOS2-SOS3 complex during salinity which activates SOS1, SOS1 could also be phosphorylated in a phospholipase-D (PLD) signalling pathway dependent manner (Yu *et al.*, 2010). Elevated Na^+ concentration stimulates PLDα1 enzyme activity leading to quick accumulation of phosphatidic acid (PA), a lipid second messenger, which in turn activates mitogen- activated protein kinase 6 (MPK6), capable of directly phosphorylating SOS1 (Yu *et al.*, 2010).

Subsequently SOS1 regulatory mechanism has its roots in nuclear Ca^{2+} signalling mechanism in response to salinity stress (Guan *et al.,* 2013). Upon activated by nuclear Ca^{2+}, Ca^{2+} binding protein RSA1 make complex with RITF1 (RSA1 interacting transcription factor) and subsequently this activated complex RSA1-RITF1 binds at SOS1 promoter to facilitate its transcription (Guan *et al.*, 2013). Some other early components involved in NaCl induced sensing possibly could be cyclic nucleotides such as cGMP, which shows rapid transient increase during salinity stress, reduces Na^+ influx into plant cells and promotes K^+ uptake (Isner and Maathuis, 2016). A similar role has also been detected with ROS which is elevated quickly during salinity stress resulting in activation of downstream MAPK cascade (Miller *et al.,* 2010; Maathuis, 2014). A recent report showed ROS-sensitive transcription factor ERF1 (ethylene response factor) in rice can bind to multiple promoters including MAPKs and improve plant general performance under salinity stress (Schmidt *et al.*, 2013).

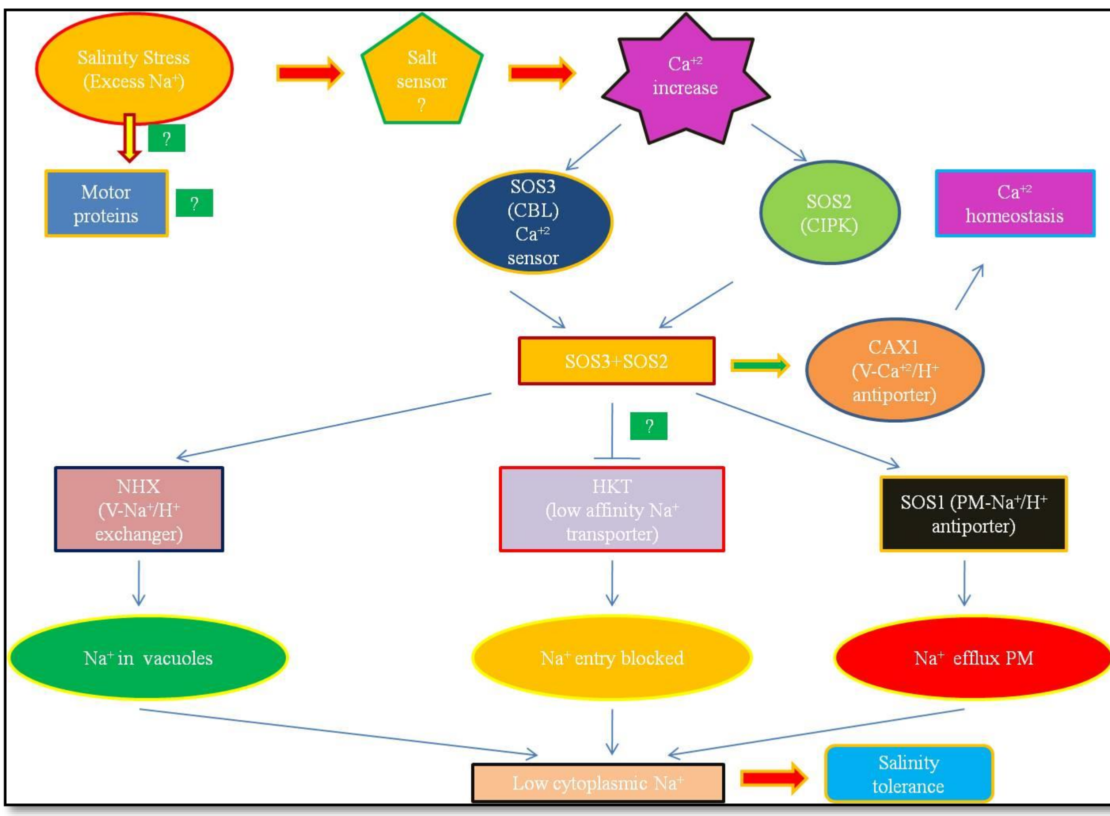

Fig 1. Ion homeostasis regulation by SOS and related pathways under salt stress

Effect of salinity on overall plant growth

Salinity induced growth inhibition in plant is mainly based upon two reasons; firstly the existence of salt in soil solution reduces water uptake ability of plant leading to reductions in growth rate known as osmotic or water deficit effect of salinity. Secondly, post entering the plant in transpiration stream, excess salts cause injury to cells in transpiring leaves and intensify the reduction in growth known as salt specific or ion excess effect of salinity. However salinity stress causes a three level effect; reduction in water potential causing ion imbalance and toxicity; this alteration results in initial growth reduction and limiting plant productivity; at the end detrimental effect is observed in terms of whole plant death or reduction in productivity. The salinity induced impact on overall plant performance has been listed below under different section.

Germination

One of the most important aspects of plant life cycle is seed germination which not only determines initial crop establishment but also determines final yield. Many crops such as rice, wheat, maize, *Brassica spp.*etc. undergo salinity stress. It changes seed imbibitions process by reducing osmotic potential of germination media, causing toxicity leading to modification in enzymes activity of nucleic acid and protein metabolism, disturbing phytohormone homeostasis and limits the utilization of seed reserves. Some reports have also findings of negative correlation between salinity level and rate and percentage of seed germination. Kaveh *et al.*, 2011 displayed delayed in germination and reduction in germination percentage in *Solanum lycoperiscum*. Similarly, another research revealed a drastic reduction in germination rate, radicle and plumule length, seedling length and seed vigour 32%, 80%, 78%, 78% and 95% respectively in *Zea mays* seed exposed to 240mM NaCl (Khodarahmpour *et al.*, 2012).

Growth

As we earlier mentioned, salinity induced growth inhibition is probably attributed to water deficit effect and ion excess effect, plant exhibits two phase growth response to salinity.

Phase 1: The growth response of this phase is an outcome of extracellular salt build up which reduces leaf growth and to a lesser extent root growth without reaching to toxic level inside cell responsible for inhibition of growth. As mersitematic tissue of phloem fed to a greater extent, facilitates the exclusion of salt and rapidly elongating cells can accommodate the salt that arrives in the xylem within their expanding vacuoles.

Phase 2:The growth response here is mainly due to increase in toxic intracellular ion concentration; initially invading older leaves, which continuously accumulate in transpiring leaves over a longer duration eventually making it die.The primary cause of injury is probably excessive salt loading succeeding the cell ability to compartmentalize in vacuoles which subsequently rapidly build up in cytoplasm causing inhibition of enzyme activity; also form salt crystal in cell wall and dehydrate the cell; increasing osmotic potential of soil thereby decreasing water uptake ability of plant. Although, both Na^+ and Cl^- are considered as major ion conferring detrimental effect on plant overall phenology, Na^+ is the primary ion interfering in K^+ ion uptake and muddle stomatal regulation causing water loss whereas Cl^- ion disorganize chlorophyll production inducing chlorotic toxicity. But Cl^- is more detrimental than Na^+(Tavakkoli *et al.*, 2011).

Salinity and ion toxicity

The existence of excess salt concentrations in soil interferes with water and essential nutrient uptake by plants for which suitable ion ratios prove to be key for proper phenology of crop. During salinity stress, ion toxicities such as Na^+, Cl^- and SO_4^{2-} are being observed reducing uptake of essential nutrients such as phosphorus (P), Potassium (K^+), Nitrogen (N) and calcium (Ca^{2+}). One report examined the extent to which specific ion toxicity of Na^+, Cl^- reduces the growth of four barley genotypes grown under varying salt concentration (Tavakkoli *et al.*, 2011); which displayed greatest reductions in growth and photosynthesis were visible under NaCl stress and mainly additives of the effects of Na^+ and Cl^- stress. Same report has also shown higher concentrations of Na^+ reduced K^+ and Ca^{2+} uptake; also photosynthesis primarily by reducing stomatal conductance whereas higher Cl^- concentration limited photosynthesis through non-stomatal effects and stomatal degradation (Tavakkoli *et al.*, 2011). The deleterious impact of salinity stress in a study including *Glycine max* where significant decreases in shoot and root weight, total biomass, plant height and leaf number were recorded (Dolatabadian *et al.,* 2011).

Photosynthetic pigments and photosynthesis

Photosynthesis being major metabolic pathway is deeply affected by salinity stress due to reduction in water potential; which further inhibited under excess accumulation of Na^{+} and/or Cl^{-} in chloroplast and reduction in chlorophyll content which is supported by a study conducted on rice (*Oryza sativa*) where not only Chlorophyll a and b contents of leaves were reduced post NaCl treatment (200mM NaCl, 14 days) but also the reduction in Chlorophyll b content in leaves (41%) was higher than chlorophyll a (33%) (Amirjani 2011). Similarly, another study in cucumber exhibited decrease in total chlorophyll contents by 12, 21 and 30% at 2, 3, and 5 ds/m of salt stress respectively compared to non-treated plants depicting a clear picture of effect of increase in salt concentrations on photosynthetic pigments (Khan *et al.,* 2013). Some other reports indicate the impact of elevated salinity on photosynthetic machinery. An experiment displayed salinity stress affects growth of barley by altering chlorophyll fluorescence (PSII) and function of oxygen evolving complex (OEC) (Kalaji *et al.,* 2011). Subsequently, Mittal *et al.* (2012) explored salinity stress affects growth of *Brassica juncea* by affecting photosynthetic (PS II) and electron transport rates, and D1 protein.

Water relation

Water potential is a key parameter determining water status of plant. However under salinity stress, it displays reduction; supported by a report on *Cucumis sativa* where a linear decrease in water potential with increasing in salinity level was observed (Khan *et al.,* 213).

Nutrient homeostasis

The fact behind salinity influenced nutrient imbalance may lies in effect of salinity in nutrient availability, competitive uptake, transport or distribution within plant. Especially availability of micronutrients in saline soil depends on solubility of micronutrients, pH and redox potential of the soil solution and the nature of binding sites on the organic and inorganic particle surfaces. In a study, it has been exhibited that elevated rhizospheric NaCl level reduced nutrient assimilation particularly, K and Ca resulting in ion imbalances in K, Ca and Mg (Keutgen and Pawelzik, 2009). A recent case study revealed that concentrations of Ca^{2+} and Mg^{2+} of all plant organs decreased transiently during external NaCl salinity (Hussin *et al.,* 2013).

Salinity and oxidative stress

Including other impacts, salinity also stimulates excessive accumulation reactive oxygen species (ROS) causing peroxidation of lipids, oxidation of protein, inactivation of enzymes, DNA damages and/or interact with other vital components of plant cell. Excess salt causes stomatal closure reducing CO_2 availability in leaves and inhibiting carbon fixation, thus uplift the generation of ROS such as superoxide (O_2 •–), hydrogen peroxide (H_2O_2), hydroxyl radical (OH•), and singlet oxygen (Ahmad *et al.,* 2010a, 2011). A recent report suggested an increase in lipid peroxidation and H_2O_2 levels in response to salinity in *Brassica napus* (Hasanuzzaman and Fujita *2011a*) and *Triticum aestivum* (Hasanuzzaman and Fujita, *2011b*).

Yield

All the above mentioned effects of salinity stress would lead to final yield reduction. One of the report suggested that by applying 250mM NaCl, a reduction of 77, 73 and 66% in yield was observed in *Vigna radiata cv.*BARI mung2, BARI mung5, and BARI mung6, respectively over control (Nahar and Hasanuzzaman, 2009). Similarly in *F. vulgare*, yield, plant height, fresh weight yield and biomass were affected to a greater extent by increasing irrigation water salinities (Semiz *et al.,* 2012).

Strategies to alleviate salinity stress

Plant adopted certain tolerance mechanisms which have been classified into three categories: ion exclusion; referring to net exclusion of toxic ions from shoot; tissue tolerance; indicating compartmentalization of toxic ions in specific tissues, cells or sub-cellular organelles; shoot ion independent tolerance; focussing on maintenance of growth and water uptake independent of the extent of Na^+ accumulation in the shoot (Negrão *et al.*, 2017). Additionally, these mechanisms can further be enhanced by understanding its molecular background, genes and/or QTLs controlling their pathways, manipulating these via gene introgression, genetic engineering, and marker assisted breeding etc. But these approaches are time consuming and having costly affair. So, to tackle these issues development of cost effective and reliable approaches is highly considerable. The strategies developed to alleviate salinity stress are enlisted below.

Chemical strategies

Many chemical agents are being used as seed and plant priming agent to improve salinity stress tolerance; efficacy of treatment relies on plant species, mode of treatment and its duration, dose of protectant used (Jisha and Puthur, 2016). Those priming agents include sugars, plant growth regulators, amino acids and their derivatives, vitamins, polyamines, which might act as osmoprotectant or antioxidant under salinity stress. The chemical pre-treatment aids in rapid and faster response to unfavourable environmental condition. The important aspect of this approach; being inexpensive as they are effective at low concentration and these are systemic in nature as these are applied to roots, seeds or leaves. Based on the above information, here we are discussing some chemical priming approach under this section.

Amino acid and their derivatives

Proline, a well known amino acid, ameliorates the adverse effect of abiotic stresses including salinity stress. A report suggested foliar sprayed proline limited the adverse effect of salinity on shoot fresh weights of two egg plant cultivars and water use efficiency in one of them (Shahbaz *et al.*, 2013). Similarly, cysteine pre-treatment of wheat (*T. aestivum*) seeds up-lift the activity of antioxidant enzymes while decreasing ion toxicity against salinity stress (Nasibi *et al.*, 2016) which probably attributed to the production of either glutathione or H_2S- molecules known for their antioxidant roles. Moreover pre-treatment of BABA (β-amino butyric acid) with mungbean (*Vigna radiata*) seeds displayed positive signs in terms of enhanced antioxidant enzyme activity, increased in biomass of seedlings from primed seeds, against salt stress via accumulation of proline, total protein and carbohydrate in seedlings (Jisha and Puthur, 2016).

Polyamines and vitamins

Certain compounds belong to polyamines group such as spermine (Spm), spermidine (Spd), putrescine (Put) are naturally exist in plant tissues, interact with membrane phospholipids, stabilizing cellular structures during salinity stress; thus alleviating its effects. In a report, it has been displayed that exogenous foliar spray of Spd on tomato plants decreases ROS and malondialdehyde (MDA) content upon exposure to salinity-alkalinity stress for 7 days (Zhang *et al.*, 2016). Simultaneously, an increase in antioxidant enzyme activities and non-enzymatic components of the antioxidant system was observed, resulted in chloroplast protection from oxidative damage. Including polyamines, vitamins also play an important role in reducing the salinity stress impacts in legumes and cereal seedlings. Post-treatment with ascorbic acid and nicotinamide of faba bean seeds exhibited elevation in content of photosynthetic pigments, soluble carbohydrates and proteins, proline, and otheramino acids, whereas transpiration and ion leakage decreased (Azooz *et al.*, 2013). Moreover the application of nicotinamide was more effective than ascorbic acid, although this combinationatorial approach was found to be synergistic in nature.

Plant growth regulators and organic or inorganic compounds

Plant growth regulators are yet another important group of chemical agents inducing abiotic stress tolerance including salinity stress in crop plants affecting growth and development. One such report displayed that, application of Salicylic acid (SA) on faba bean seeds have positive influence on germination parameters and improved seedling establishment (Anaya *et al.,* 2018) indicating that this beneficial impact is dose dependent, where lowest concentration showed the most positive influence, even under strong salinity. Similarly, in soybean seeds primed with nitric oxide (NO), applied as SNP, protected the germination and seedling development under salinity stress (Vaishnav *et al.*, 2016). The treated seeds exhibited 82% higher germinablitiy than untreated ones, accompanying longer seedlings with more lateral roots, greater accumulation of chlorophyll and endogenous proline, reduced MDA content indicating lower lipid peroxidation pointing the relevance of SNP priming in seed development. In another report, silicon supplemented *Zinnia elegans* uplifted NaCl induced salinity stress in hydroponic system (Manivannan *et al.*, 2015), which displayed enhanced growth, improved photosynthetic parameters and membrane integrity, leading to reduction in electrolyte leakage potential and lipid peroxidation levels.

The efficacy of osmo-priming and halo-priming

Osmopriming is a seed priming technique involving seed treatment with solutions containing chemicals such as polyethylene glycol (PEG), mannitol, sorbitol having lower water potential. One of the most common osmopriming agent is PEG, often used in combination with ionic salts. A report showed tomato (*Solanum lycopersicum*) seeds primed with PEG 600, displayed its beneficial effects on the germination percentage, vigour index and seedling dry weight under salt stress (Pradhan *et al.,* 2015). Similarly, in halopriming, seeds are soaked in solutions containing inorganic salts such as NaCl, KCl, KNO_3 etc. In maize (*Zea mays*), seeds priming with NaCl and $CaCl_2$ elevated germination and seedling growth parameters as comparison to non-primed seeds under salt stress (Gebreegziabher and Qufa, 2017). However, both salt treatments displayed different impact on maize physiology, where NaCl priming improved maturity and yield, $CaCl_2$ accelerated the germination process.

Biological treatments to ameliorate crop salinity tolerance

Nevertheless, the identification of physiological and biochemical responses of halophytes towards salt stress including genes involved in it has been done, much greater attention is given to role of microbiome especially rhizospheric fungi and plant growth promoting-rhizobacteria (PGPR) in salinity stress tolerance which has been overlooked earlier.

Rhizospheric fungi

The contribution of rhizospheric fungi in alleviating salinity stress has been highlighted in several reports. A research revealed inoculation of alfalfa (*Medicago sativa*) with *Glomus viscosum* showed restricted tissue wilting and increased plant height, root density, leaf area comparing to non-inoculated ones under NaCl stress (Campanelli *et al.*, 2012). Additionally, higher NaCl concentration induced a greater myccorhizal dependency, but at the same time, it negatively affects mycorrhizal colonization indicating the importance of careful identification of microbial species to be used for specific crops. Similarly, another finding made a conclusion that utilising arbuscular mycorrhizal fungi (AMF) from native saline environment provide a greater protection against oxidative damage and more efficient photosynthetic apparatus and stomatal conductance than AMF from culture collection (Estrada *et al.*, 2013).

Plant growth promoting bacteria

An extensive study on plant growth promoting bacteria (PGPB) or rhizobacteria (PGPR) unravel their potential to be used as an important tool to increase crop productivity including severe salt stress. An example revealed the interaction of *Burkholderia cepacia* SE4 and *Promicromonospora* sp. SE188 with *Cucumis sativus* seedlings enhanced shoot and root growth, nutrient uptake, chlorophyll content, photosynthetic efficiency, and the K^+/Na^+ ratio in saline environments (Kang *et al.*, 2014). Apart from successful plant-microbe interaction, PGPR also form micro-colonies or biofilms due to further multiplication, providing additional protection against salt stress. In a study, *Bacillus amyloliquefaciens* showed the highest biofilm formation simultaneously enhancing growth and recovery of salt-sensitive barley cultivar Giza 123 seedlings under NaCl stress efficiently (Kasim *et al.,* 2016).

Physical treatments to improve salt stress in crops

Physical treatments or invigoration methods, also known as physical priming is an alternative approach to both chemical and biological strategies against alleviating salinity stress which has been emphasized in this section with various examples.

Ionizing radiation

As an ionizing radiation, gamma rays proved to be very effective and suitable for seeds with soaring attention. Some recent reports have established the results supporting the idea of utilising the gamma rays to uplift the salinity stress effects on crops. A study was conducted to illustrate the effect of pre-sowing gamma radiation treatments on pigeon pea (*Cajanus cajan*) varieties, Pusa-991 and Pusa-992, growth, seed yield and seed quality under salt stress (80mM NaCl) and control (0 mM NaCl) conditions (Kumar *et al.,* 2017), where Pussa-992 showed better performance than Pusa-991 under salt stress. A positive effect of low dose gamma radiation (<0.01 kGy) was evident on pigeon pea seeds which accompanies several metabolic changes such as favourable alterations in the source–sink (shoot–root) partitioning of recently fixed carbon (14C), enhanced glycine betaine content, reduced protease activity, reduced the partitioning of Na^+, and promoted accumulation of K+ under salt stress. In another research, the effects of several doses of gamma radiation (0, 20,40 and 80 Gy) was scrutinized on damsissa (*Ambrosia maritima*) plants under salinity stress. It was observed that gamma radiation of doses 40 or 80 Gy enhanced salinity stress tolerance opposite to control ones in terms of plant height, fresh/dry weights, photosynthetic pigments, increased total sugars and total soluble phenols in plant shoots (Ahmed *et al.,* 2011).

Magneto-priming

The impact of magnetic fields on biological organisms including plants is well known, however the use of static magnetic fields (SMFs) and electromagnetic fields (EMFs) in agriculture for seed priming, known as magneto-priming for improving the performance during salt stress is strengthened with recent reports. An experiment found out the beneficial effect of magneto-priming (50mT; 2hrs) led to significant increase in plant height, leaf area and dry weight of wheat plants under both saline and non-saline conditions (Rathod and Anand, 2016). Also, this report suggested the reduction in Na^+/K^+ ratio in plant shoots from primed seeds under salt stress than non-primed ones. Interestingly, primed plants have parallel yield under salinity stress condition as un-primed plants did under normal sowing condition. In a very recent report, the impact of the pre-sowing seed treatment with MFs (200 mT; 1hrs) while alleviating salinity stress effects on germination of soybean and maize seeds was investigated, which displayed enhanced germination percentage and early seedling growth parameters values (root and shoot length, vigour indexes) under different salinity levels (0-100 mM NaCl) against non-primed seeds (Kataria *et al.,* 2017).

Ultraviolet radiation

As a non-ionizing radiation, ultraviolet radiation stimulates some specific protective responses under abiotic stresses including salinity stress, which has been elucidated with some evidences. Ouhibi *et al.*, (2014) observed that UV-C radiation priming of lettuce seeds (*Lactuca sativa*) cause a significant enhancement in fresh weight of roots and leaves, with better tissue hydration and K^+ uptake as well as reduction in Na^+ ion concentration in all plant organs; more pronounced at 0.85 kJ/m² than 3.42 kJ/m², indicating dose dependency of the treatment.

Field and water management practices

Field and water management practices act as additional approach to aforementioned strategies aim to reduce unproductive water losses, maintain soil salinity at threshold level and enhance organic matter and nutrient availability (Bezborodov *et al.,* 2010).To mitigate these constraints, various techniques have been developed. One of the most promising options is mulching of soil surface with crop residues or plastic as they will shade the top soil and prevents evapo-transpiration loss, thus increase soil moisture accumulation and reduce soil salinization; hence promoting soil quality and subsequently increasing crop yield (Bezborodov *et al.,* 2010, Xie *et al.*, 2017; Li *et al.,* 2013; Li *et al.,* 2016). Generally, the mulching material of natural origin such as straw possess beneficial effect on soil quality, as straw decomposes, organic carbon fraction mineralize into soil, stimulating soil aggregation, increasing soil porosity and limiting soil salinity on surface soil (Zhao *et al.,* 2016a, Xie *et al.*, 2017).

Discussion

In this chapter, we are mainly emphasizing and discussing regarding salinity stress, its effect on crop phenology; from germination to yield, its uptake mechanism, signalling pathway involved and various strategies to alleviate its adverse impacts on crop production. Salinity stress among different abiotic stress causes tremendous loss in terms of productivity, economy and soil quality creating hurdle for future farming globally. It leads to scientific think-tank to deliver enormous focus on it to develop suitable variety for future sustenance and meeting global food security. It can be achieved by combination of understanding its sensing mechanism and transport pathway inside plant, genes involved in tolerance imparted by plant itself as well. Also the idea is again strengthened by studying its genetics, transcriptomics, proteomics and metabolomics which needs further attention. After all these approaches again validated by various strategies such as chemical, biological and physical including field and water management strategies which are cost effective and farmers friendly in nature.

Conclusion

Among both abiotic and biotic stress, the former one causes huge loss to crop productivity globally. Further in various abiotic stresses, salinity stress influences not only crop production and productivity, but also its ecology simultaneously degrading soil health and its quality making it non-arable posing a great threat to agriculture and farmers community. As we described here, salinity affects crop growth and development starting from germination to yield causing substantial loss to overall phenology of plant. However due to advancement in genetics, its transport pathway, signalling mechanism and genes associated with it has been revealed which subsequently utilized to develop salinity stress tolerant varieties. Again, with the addition of transcriptomics, proteomics and metabolomics, development of tolerant genotypes have been facilitated. But these omics approaches need proper validation under field condition which further needs efficient strategy and skilful handling which may incur higher cost. So, to integrate these approaches several cost effective strategies such as chemical, biological and physical have been developed and adopted under field condition to alleviate salinity stress effects showing better success rate and benefiting farmers by elevating crop performance under adverse situation.

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Renewable and Alternative Energy in Agriculture

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Abstract

In Indian agriculture provides employment for 70 per cent of the population and it utilized 10 per cent commercial forms of energy. Cultivation of cropsuses animate (bullock, human power) and inanimate (tractors, tillers etc.) source of energy at different stages. The nutrient supplied to the soil and crop through organic and inorganic sources. Water management also utilizing manual energy or electric energy sources. The source of energy linked in to two basic resources in nature are gravitational and nuclear. More energy consumed on earth by utilizing the solar energy. Renewable energy resources cycling time less than 100 years, while for non-renewable energy resources is greater than a million years. The renewable energy resources are received from hydro energy, solar energy, wind, biomass, and energy from biogas, agro wastes. The renewable solar energy is grouped into direct energy and indirect energy sources. Solar energy utilized to produce electricity and also derive a chemical reaction. Solar energy indirectly drives other sources are bio- chemical or climatic – mechanical sources of energy.

Key words: Crop management, Energy management, Energy sources, Energy policies

Introduction

Energy is a critical aspect of a national development process. It is utilized in agricultural practices, food processing and production of fertilizer, pesticide and farm equipment. The precisely defined scientific unit for energy is Joule (J) is far too small unit for convenientto describe world energy supplies and resources.This objection can be overcome by the use of prefixes such as mega (10^6), giga (10^9) and tera (10^{12}). A second and more serious objection to the joule as measurement unit for large scale energy is that practical people measure the output of their oil well, or coal mine, in such units as barrels of oil or tons of coal. Hence, it is essential to be able to convert such unit rapidly to a common equivalent. The tonne of coal equivalent (t.c.e.) are such a unit and has been adopted by UN bodies. Since the chemical composition of coal is not a fixed quantity, it is assume a representative figure. A commonly used value for the t.c.e. is 2.9×10^9 J or 29 GJ. Electricity is normally quoted in terms of kilowatt hours or units.

In Indian agriculture provides employment for 70 per cent of the population and it utilized 10 per cent commercial forms of energy. Cultivation of cropsuses animate (bullock, human power) and inanimate (tractors, tillers etc.) source of energy at different stages. The nutrient supplied to the soil and crop through organic and inorganic sources. Water management also utilizing manual energy or electric energy sources. The source of energy linked in to two basic resources in nature are gravitational and nuclear. More energy consumed on earth by utilizing the solar energy. Renewable energy resources cycling time less than 100 years, while for non-renewable energy resources is greater than a million years. The renewable energy resources are received from hydro energy, solar energy, wind, biomass, and energy from biogas, agro wastes. The renewable solar energy is grouped into direct energy and indirect energy sources. Solar energy utilized to produce electricity and also derive a chemical reaction. Solar energy indirectly drives other sources are bio- chemical or climatic – mechanical sources of energy. In another way, source of energy grouped into commercial and non-commercial energy. The commercial energy sources are natural one viz., coal, oil and nuclear sources whereas firewood, biomass and animal dung are categorized under non- commercial energy sources. In other classification of energy sources are from animate and inanimate sources. It also grouped in to renewable and non-renewable energy source and conventional and non - conventional energy.

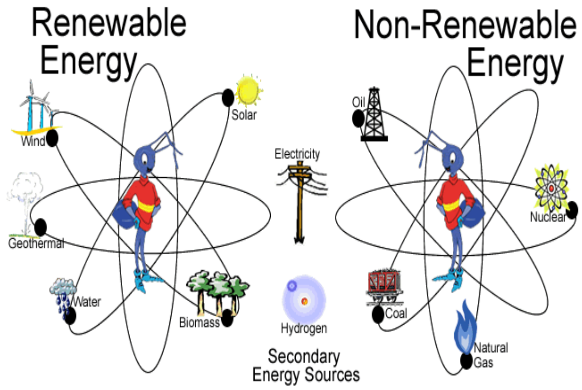

Fig 1. Renewable and Non – Renewable Energy Sources

(Devaseapathy *et al.*, 2009)

Discussion

Classification of Energy to the Basis of Source

Based on the sources, the energy is classified into direct and indirect source of energy.

Direct Source of Energy

The following categorized under direct energy sources *viz.*,labour, bullocks, electric power units like diesel engines, motor, power tiller and tractors. This energy sources further classified into renewable and non-renewable sources of energy based on the replenishment.

Renewable Direct Sources of Energy

In this category, the energy sources which are direct in natural subsequently replenished. The energetic in this group are human beings, animals, solar energy, wind energy and agricultural wastes.

Non-Renewable Direct Sources of Energy

In this category, the energy sources which are not renewable are classified. Coal and fossil fuels comes underthis category.

Indirect Source of Energy

The indirect sources of energy which are release it by conversion process. Indirect energysources are seeds, farm yard manure and poultry manure, chemicals, fertilizers and machinery.Based on the replenishment, further it categorized into renewable and non-renewable indirect source of energy.

Renewable Indirect Source of Energy

The renewable indirect source of energy are seeds and manure it can be replenished in further course of time.

Non-Renewable Indirect Source of Energy

The non-renewable indirect sources of energy are chemicals, fertilizers and machinery manufacturing comes under this group.

Classification of Energy Based on the Economic Value

Based on the economic value, energy is categorized as commercial and non-commercial energy sources.

Non-Commercial Energy

The cheapest energy sources available are characterized under non-commercial sources of energy whereas in capital intensive are comes under the category of commercial energy sources.

Human labour and bullocks exemplify from the category of non-commercial sources of energy. Human labour and animals are readily available and can be used as a source of power directly; the commonly available and less expensive materials like fuel wood, twigs, leaves agro-wastes and animal dung, etc. are categorized under non-commercial sources of energy.

Commercial Energy

The commercial energy sources which are capital intensive *viz.*, petroleum products and electricity.

Energy Input from Various Sources

Direct Sources

The energy input of human labour and a pair of large bullocks (having a body weight of 450 kg) can be assumed to be 1.96 MJ / man-h and 14.05 MJ / pair-h, respectively. The specific fuel consumption of the mechanical power source are used to find energy inputs. The energy input of various direct sources of power is given in Table 1.

Indirect Sources

The energy requirement for producing seeds, fertilizers, pesticides, weedicides are also given in Table 1.

Table 1. Energy equivalents for direct and indirect sources

Sl. No.	Particulars	Units	Equivalent energy. MJ	Remarks
A.	**Inputs**			
1.	Human labour			
	a) Adult man	Man-hour basis	1.96	1 Adult Women =0.8 adult man
	b) Woman	Woman-hour basis	1.57	1 Child = 0.5 adult man
	c) Child	Child-hour basis	0.98	NA
2.	Animals			
	a) Bullocks			NA
	i) Large	Hour basis	14.05	Body weight above 450 kg
	ii) Medium	Hour basis	10.10	Body weight 352-450 kg
	iii) Small	Hour basis	8.07	Body weight less than 350 kg
	b) He-buffalo	Hour basis	15.15	He-buffalo=1.5 medium bullock
	c) Camel or horse	Animal-hour basis	10.10	Camel or horse =medium bullock pair

	d) Mules and other small animals	Animal-hour basis	4.04	Small animal = 0.4 Medium bullock pair
3.	Diesel	Litre	56.31	Includes lubricant cost
4.	Petrol	Litre	48.23	Includes lubricant cost
5.	Electricity	KWh	11.93	NA
6.	Machinery			
	a) Electric motor	Kg	64.80	Distribute the weight of the machinery equally over the total life span of the machinery (in hours). Find the use of machinery (hours) for the particular operation in a crop.
	b) Prime movers other than electric motors(including selfpropelled machines)	Kg	64.80	
	c) Farm machinery	Kg	62.70	NA
7.	Chemical fertilizers			
	a) Nitrogen	Kg	60.60	Estimate the quantity of nitrogen, P_2O_5 and K_2O in the chemical fertilizer. Then compute the amount of energy input from chemical fertilizer
	b) P_2O_5	Kg	11.1	
	c) K_20	Kg	6.7	
8.	Farm Yard Manure (FYM)	Kg (Dry mass)	0.3	NA
9.	Chemicals			
	i)Superior chemicals	Kg	120	Chemical requiring dilution at the time of application
	ii) Zinc sulphate	Kg	20.9	
	iii) Inferior chemicals	Kg	10.0	DDT, gypsum or any other chemicals not requiring dilution at the time of application
10.	Seed			
	a) Output of crop production system and not processed			Same as that of output of crop production system
	b) Output of crop production system and is processed before using it for seed (e.g. potato, groundnut, cotton,)			Add 1.5, 1.0 and 0.5 MJ /Kg for Potato, groundnut and other seed respectively to the equivalent energy of the product of crop production system
B.	**Output**			

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	Main Product			
1.	Cereals *viz.*,wheat, maize, sorghum, bajra, barley, oats, paddy	Kg (Dry mass)	14.7	Output are grains
2.	Pulses, such as : Mash moong, lentil, arhar, soybean, peas	Kg (Dry mass)	14.7	Output are grains
3.	Oilseeds, such as cottonse ed, groundnut pods (not s helled), sesame, rape seed , mustard, linseed, sunflo wer	Kg (Dry mass)	25.0	The main output is seed except for groundnut (where it is pod)
4.	Sugarcane	Kg (harvested mass)	5.3	NA
5.	Vegetable a)Root or tuber vegetables			NA
	i) Higher food value: sweet potato, tapioca	Kg	5.6	NA
	ii) Medium food value: colocasia, potato, beet root	Kg	3.6	NA
	iii) Low food value : carrot, radish, onion, beetroot	Kg	1.6	NA
b)	Fruit or seed vegetables			
	i) Broad beans, cluster beans, ladyfinger, muskmelon, watermelon	Kg	1.9	NA
	ii) Gourd family vegetable s: cucumber family, drum stick giant, green papaya, tomato, chillies	Kg	0.8	NA
c)	Leafy vegetables			
	Cabbage, spinach, green mustard leaves	Kg	0.8	NA
6.	Fruits			

	a) Higher food value: tamarind, grapes	Kg	11.8	NA
	b) Low food value: guava, mango, amla, apple, peach, pears, pine apples, ber, sapota, cashew, citrus	Kg	1.9	NA
7.	Fibre crops: cotton sunhemp, jute	Kg (Dry mass)	11.8	Main product is fibre
8.	Fodder crops : berseem, lucerne, senji, oats, maize, bajra, sorghum, cowpea, guara, napier	Kg (Dry mass)	18.0	The main product is dry or green fodder
9.	Green manuring crops: dhaincha, cowpea, sunhemp			Energy equivalent to the amount of nutrients added to the soil through green manuring
10.	Fuel crops: sunhemp, dhaincha	Kg (Dry mass)	18.0	The main product is wood
II.	**By Products**			
1.	Straw, vines	Kg (Dry mass)	12.5	NA
2.	Stalks, cobs, fuel wood, fruit vines, plant wood	Kg (Dry mass)	18.0	NA
3.	Leaves, vines and straw from vegetables	Kg (Dry mass)	10.0	NA
4.	Cotton seed	Kg (dry mass)	25.0	NA
5.	Fibre crop seed other than cotton and fuel crop seed	Kg (Dry mass)	10.0	NA
6.	Sugarcane leaves and tops	Kg (Dry mass)	16.1	NA

(Table Adapted from Mittal *et. al.*, 1985)

Calculation of Energy Requirements in field Operation

The energy requirements for a particular field operation are calculated in summation of human, bullock and mechanical or electric energy consumed.

Operational Costs for various power sources

Manual Power

In case of human labour, the wages of an unskilled labourto the basis of hour or day are charged.

Animal Power

The charges for operating a pair of bullocks are to be calculated on the basis of the cost of a pair of bullocks, wages of an operator and cost of the feed for bullocks along with other expenses (as enforced in a particular locality) in the case of research farms. However, for the farmer's fields, the actual hiring charges are taken as the basis.

Cost Analysis for Implements

For implements which are not self-propelled, the cost of lubricating oil and fuel should be taken as zero. The wages of operator are also not to be changed if a separate labour is not engaged specifically for that particular implement.

Electric Power

The charges for electric power may be calculated on the basis of number of kWh (1xWh = 1.0 unit) consumed multiplied by the charge per unit.

Energy Use in Field Crops under Crop Rotation

The main aim of the field experiments is to develop an energy efficient farm power-machinery packages and crop management practices which reduce dependence on commercial energies supplementing and substituting with alternate energy sources for crop production and related post-harvest activities for different level of productivity with least energy input cost.

Field Experiments

Selection of Crop Rotations

The suggested crop rotation should be adopted. Every rotation should be tried at least for two years.

Selection of Draft Power

All the prevalent sources of farm power in a particular area should be used.

Selection of Agricultural Machinery

The machinery used by the farmers should be treated as control and the ones which are considered to be energy efficient (as recommended) should be considered as treatments.

Package of Practices

The proven package of practices should be adopted and the reference of the adopted package of practice should be given. The variety of seed, fertilizer levels, irrigation levels and plant protection practices should be adopted as recommended.

Experimental Design

The objectives and statistical design of the experiments in a particular year are decided to implement the treatments.

Layout and Sowing of Experiment

The site of the experiment should be carefully chosen and the soil testing should be done before the layout. As much as possible, the same site should be continued.

Recording of Agricultural Input and the Cost

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The quantity of applied agricultural inputs along with their cost to be given.

Calculation of Energy Requirement

Energy Requirements for Field Operation

The requirement of energy in field operationsare calculated on the basis of energy equivalents given in Table - 1.

Source-Wise Energy Requirements

Source-wise energy requirements in raising a crop should be analyzed.

Output-Input Energy Ratio

A systematic inventory of energy inputs and output should be made on the basis of energy equivalents.

Energy Ranking

The ranking of crop rotations and individual crops should be done according to their energy consumption.

Table 2. Abstracts of Energy Input –For cultivation of Cotton

Sl.No.	Particulars	Total energy utilized (MJ /ha)	Total cost (Rs /ha)
1	Field preparation	2124	4633
2	Manures and fertilizers	7652	6123
3	Seeds and sowing	575	2736
4	After cultivation	730	4487
5	Irrigation	973	3400
6	Plant protection	1612	3980
7	Harvest and Post-harvest Operations	346	3240
Total		**14012**	**28599**

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Fig. 2. Operation-wise energy use in cotton

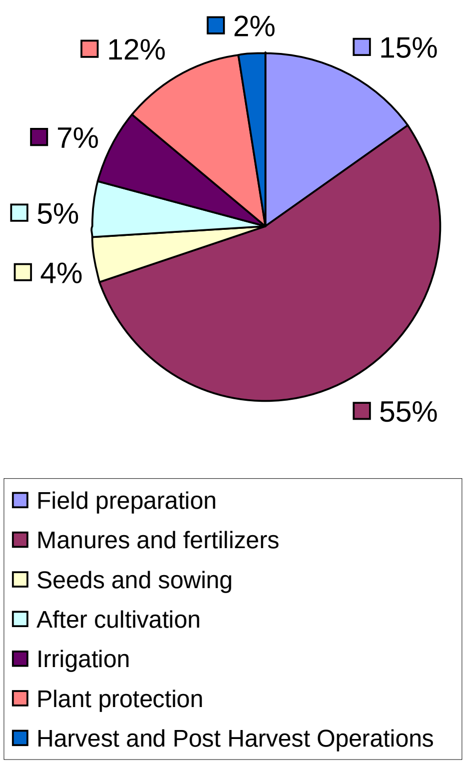

Table 3. Operation wise manures and fertilizers operation consumes more energy in cultivation of cotton

Yield	23 q ha^{-1} (Rs. 3000 /q)
Cost of cultivation	Rs. 28599
Total income	Rs. 69000
Net income	Rs. 69000 – 28599 = Rs. 40401
B: C ratio	1.42
Energy Productivity	Total productivity / Total energy = 2300 /14012 = 0.164 kg / MJ

Total output energy:	Total yield = 2300 kg I. Main product a. 33 % lint x 11.8 MJ = 759 kg x 11.8 MJ = 8956.2 MJ b. 67 % seed x 25 MJ = 1541 kg x 25.0 MJ = 38525.0 MJ
Total (Lint + Seed)	47481.00 MJ
	II. By product: a. Stalk yield = 4500 kg x 18.0 MJ Total = 81000 MJ
Total output energy (I+ II)	**128481 MJ**
Total input energy	**14012 MJ / ha**
Output – Input energy ratio	Output energy / Input energy **9.16 MJ / MJ**

Table 4. Total energy as per the sources		
Direct Energy	-	4520.7 MJ / ha
Indirect energy	-	9492.1 MJ / ha
Total	**-**	**14012.8 MJ / ha**
Renewable Energy	-	3798.8 MJ / ha
Non-renewable energy	-	10214.0 MJ / ha
Total	**-**	**14012.8 MJ / ha**
Commercial Energy	-	10589.0 MJ / ha
Non-commercial energy	-	3423.8 MJ / ha
Total	**-**	**14012.8 MJ / ha**

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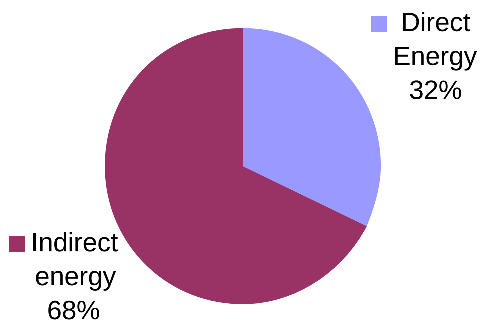
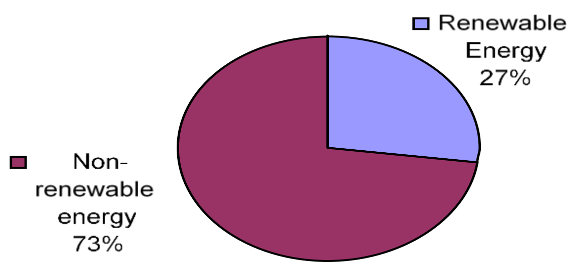
Fig. 2a. Direct & indirect energy use in cotton



Cotton uses 68 % of indirect energy mainly from fertilizer, chemical, FYM and seed etc.,

Fig. 3. Renewable & Non renewable energy use in cotton



About 76 % of commercial energy mainly from fertilizer, diesel and chemical etc.,

Table 5. Energy use and productivity of some of the crops in India

	Crop	Productivity, (Kg / ha)	Total energy (MJ / ha)	Energy productivity (kg / MJ)
Cereals	Paddy	3125	13076	0.239
	Wheat	2873	14657	0.196
	Maize	2140	9956	0.215
	Sorghum	950	4745	0.200
Pulses	Green gram	510	4315	0.118
	Black gram	406	3870	0.105
	Bengal gram	596	5464	0.109
Oil seeds	Mustard	960	8051	0.119
	Soybean	1092	6382	0.171
Cash crops	Sugarcane	61500	59192	1.039
	Cotton	938	9972	0.094
	Potato	15520	31352	0.495

(Devasenapathy *et al.*, 2009)

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Advances in hybrid development in cucurbitaceous vegetables

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Abstract:

In plant breeding development of hybrid varieties is one of the major achievements for exploitation of hybrid vigour. The availability of quality vegetable seeds is not enough in India although it occupied second position in vegetable production next to China. With the introduction of hybrid varieties, the productivity of the crops has been increased. Availability of hybrid seeds is important for increased production of vegetables. In cucurbitaceous vegetables due to minimum inbreeding depression, high percentage of heterosis, larger quantities of seed yield per fruit and lower quantities of seed requirement per unit area, give distinctive benefit in utilization of heterosis for commercial purposes. Heterosis breeding has been considered as an important tool for increasing yield and other yield contributing characters in cucurbits.Continuous decrease in land holdings due to increased population, production of vegetables is decreasing gradually. A large quantity of hybrid varieties have been developed in most of the vegetable crops such as tomato, pepper, cucumber, muskmelon, cauliflower, cabbage, broccoli, onion and brinjal.Development and evaluation of parents and combining them in to heterotic hybrids are the basic operations for development of hybrid variety.Certain cross pollination mechanisms such as dicliny, dichogamy, male sterility and self-incompatibility are used for economic production of hybrid seeds. Large number of seeds has been produced in a single cross in some cucurbitaceous vegetables. These vegetable crops economize the production of hybrid seeds and meet the demand for the same to a greater extent. Hybrids in majority of vegetable crops including cucurbits play distinctive role in vegetable production. Even though they are heterozygous in genetic constitution, they are homogenous in nearly all traits that are related either directly or indirectly to yield and adaptability to different environmental conditions. However, in self pollination, hybrids show segregation and recombination of traits therefore the seeds of hybrid varieties are to be produced each year.

Key words: Cucurbits, heterosis, hybrid vigour, sex mechanism and yield.

Introduction:

India is a heavily populated country with a projected population of 1.31 billion. The production of vegetables is decreasing due to continuous decrease in land holdings and increased population. It is very much essential to boost up the yield and total production per unit area. To realize the country's requirement of food and nutritional security and for poverty alleviation hybrid vegetable development technology is one of the best options. Remarkable efforts have been made by both private and public sectors for increasing hybrid seeds in numerous vegetables including cucurbitaceous vegetables (Kumar and Kumar, 2017). The introduction of hybrid varieties in public and private sector has greatly boosted up the vegetable production in the country (De and Bhattacharjee, 2011; Nagaraju *et al*., 2017). The earliest hybrid variety 'Pusa Meghdoot' of bottle gourd in India was developed during 1971 at IARI. In tomato the first hybrid 'Karnataka' and 'Bharat' in capsicum were developed by Indo-American Hybrid Seed Company in 1973.

Cucurbitaceae is a diverse family and it includes about 950 species and more than 90 genera. The vegetables under this family are called as cucurbits and they are distributed mostly in tropical and subtropical areas. The commercially important crops are cucumber, pumpkin and watermelon whereas *Luffa* and bitter gourd are found in Asia and in other parts of the world. In Asia the public as well as the private sectors have made maximum contribution for the improvement of genetic resources in cucurbits. Open-pollinated cultivars of cucurbits have been developed through selection from landraces. Many hybrids are developed by the private sector breeders that have gained popularity among the grower (Dhillon *et al*., 2020).

Both the terms hybrid vigour and heterosis are similar and interchangeable. A large quantity of hybrids has been developed in tomato, pepper, cucumber, muskmelon, cauliflower, cabbage, broccoli, onion, brinjal and other vegetable crops. For development of hybrid, the basic operations are the development and evaluation of parents, and combining them in to heterotic hybrids. To economize the cost of hybrid seed production certain mechanisms of cross pollination such as dicliny, dichogamy, male sterility and self-incompatibility are used. Large number of seeds has been produced in a single cross in some vegetables.These vegetable crops economize the production of hybrid seeds and meet the demand for the same to a greater extent.

Discussion:

Hybrid variety is an F_1 population obtained by crossing pure lines, inbred lines, open-pollinated varieties, clones or other populations that are genetically different. The parents or lines used in hybrid development programme may be under the same variety, different varieties under the same species, different species under the same genus or species from different genera. In most of the cucurbitaceous vegetables hybrid plays important role in increased production. They are homogenous in almost all traits which are related to yield and adaptability. Genetic constitution of hybrids is heterozygous and upon self pollination they show segregation and recombination of characters. So the seeds of hybrid varieties are to be produced each and every year. Hybrid varieties of cucurbits show heterosis in earliness and yield. Many hybrid varieties were developed in cucurbits which are resistant to various diseases and pest. In cucumber, squash and melon various inbred lines were developed without serious inbreeding depression. The first hybrid in cucumber was released during 1942 in Japan for commercial production by the farmers.

There are many advantages and disadvantages of hybrids. The superiority of the F_1 hybrids or the hybrid vigour over parents may be manifested in terms of higher productivity, uniformity, earliness and resistance to many pests, diseases and environmental stresses (Preethi *et al*., 2019). Cucurbits are exceptional group of vegetables in regards to sex mechanism and sex expression. The seed number per fruit is large in most of the cucurbits and cost of hybrid seed production is not also expensive. Most of the cucumber hybrids are successfully grown in protected cultivation. However, hybrid varieties are less tasty than local varieties and seeds are to be produced each year for cultivation is the major disadvantage.

Among the cucurbitaceous vegetables, cucumber is different with a distinctive sex expression and this characteristic can easily be exploited for the production of F_1 hybrid seeds. Significant heterosis is manifested in cucumber for various characters. Gynoecious sex expression in cucurbits, is a condition where, the plant bears only pistillate flowers therefore, it can be utilized for improvement of yield and economic production of F_1 hybrid. In India, little works have been reported in cucumber regarding utilization of gynoecious sex expression in hybrid development programme (Airina *et al*., 2013; Sharma, 2010).

Breeding objectives: The following are the breeding objectives for different cucurbits.

1. Cucumber: cluster fruit bearing habit, less number of seeds, smooth skin without spine.
2. Pumpkin: high beta carotene, fruits having high flesh recovery.
3. Water melon: deep pink and red crisp flesh, high TSS content.
4. Musk melon: thick flesh, netted skin and high TSS content.
5. Bottle gourd: smooth or non- ridge fruit surface, uniform fruit shape, light green colour skin.
6. Bitter gourd: long fruit bearing period, less ridges on fruit surface.
7. Ridge gourd and sponge gourd: early bearing habit, less fibrous fruit.
8. Pointed gourd: longer fruit bearing period, thick flesh of fruit.

Important characters to be used in improvement programme of cucurbits**:**

1. Growing habit: Medium vine characteristics are preferred.
2. Earliness: The node number, at which the first female flower appears, gives a good indication of earliness of the variety.
3. Male –female flower ratio: A low staminate to pistillate flower ratio is desirable.

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4. Fruit shape: In bottle gourd round, long or club shape, in *Luffa* thin, short and straight shape and in case of pumpkin and squashes high flesh recovery would be desirable.
5. Bitterness: Bitterness in gourds is not desirable.
6. Early and high yield are desirable characters in cucurbits.

Significance of cucurbits:

1. Annual crop
2. Quick growing habit
3. Crop duration is short
4. Inputs requirement is low
5. Cheapest source of nutrients
6. Very easy to grow.

Floral biology of cucurbits:

Depending upon the weather condition flowering in cucurbits generally starts in about 40-45 days after sowing. In most of the cucurbits the anthesis starts in morning except bottlegourd, ridge gourd and pointed gourd. The order of flowering follows a set of pattern, viz., (i) Male phase (ii) Mixed phase (iii) Female phase. Flowering time of cucurbits (in yellow flowers) mainly at 5:30 to 7:30 a.m. and 5:00 to 8:00 p.m. (in white flowers). Stigma becomes receptive 24 hours before anthesis and 24 hours after anthesis. Pollen viability remains on the day of anthesis till the next morning. Pollen tube reaches to the ovary after 24 hours of pollination. Sixty to eighty per cent cross pollination is occurred mainly by honeybees (Bhakti *et al*., 2016).

Hybrid seed production

In cucurbitaceous vegetables the hybrid seed production either by hand pollination or by insect pollination is influenced by sex expression.

Isolation distance:

For foundation seed production isolation distance is 800 m and for certified seed production the distance should be 400 m to avoid pollination with other crossable species viz., cucumber from Indian wild cucumber; muskmelon from snap melon and long melon; watermelon from round melon and wild watermelon; bitter gourd from wild species; bottle gourd from wild species; pumpkin from squashes and squashes from pumpkin.

Rouging:

The unwanted plants from the seed production site must be removed. Rouging in cucurbits should be done at three different times. First rouging should be done before flowering depending on vegetative growth of different cucurbits, second at the time of flowering and last rouging at the time of harvesting.

Steps in hybrid seed production in cucurbits:

Heterosis breeding consists of three important stages and these stages are:

1. Development of inbred lines
2. Testing of combining ability of the inbred lines
3. Production of F_1 hybrids seed in large amount

In cross pollinated crops development of inbred lines are important for hybrid seed production but in case of cucurbits by inbreeding varieties can be maintained in pure form without loss of vigour or without inbreeding depression. So in cucurbits development of inbred lines are not necessary. To achieve the uniformity in hybrids the homozygous lines can be used instead of inbred lines. The individual plant selection in cucurbits can be done very effectively.

Combining ability testing of inbred lines is the next step and this can be achieved by diallel cross. In diallel cross all possible combinations of crosses are done and specific and general combining ability are determined. This will help to select the most promising inbred lines or parents to be used in hybrid production.

The third step or final step is the production of F1 hybrid seeds.

Methods for hybrid seed production:

In cucurbitaceous vegetables, hybrid seed production can be simplified by manipulation of sex expression. The cost of hybrid seed production can be minimized by using different techniques viz., male sterility, self incompatible but cross compatible lines, gynoecious lines and plant growth regulators.

1. In hermaphrodite and andromonoecious species hand emasculation and pollination is done.
2. In monoecious species pinching of male flowers from the female parents is done before anthesis.
3. Use of genetic malesterility in cucumber, muskmelon, watermelon and squashes as female parent.
4. Use of growth regulators like ethephon in monoecious lines.

Pinching of male flowers:

This method is practical and the least costly method of hybrid seeds production.The growers can easily adopt this method. This method can be economically used for production of larger quantities of hybrid seeds. In this method male flowers are pinched off from the female parent before opening of flower and male parents are grown near the female parent to ensure normal cross pollination. Pinching should be done carefully so that there should not be any male flower bud in the female parent otherwise it will cause self pollination or sib pollination within the female parent.

In bitter gourd, bottle gourd and pumpkin the hybrid seeds are produced through protection of pistillate flowers and by hand pollination (Behera *et al.*, 2015). For production of F_1 hybrid seeds in bottle gourd, after every three rows of female parent, one row of male parent are sown. In female parent fruit setting is done by cross pollination. In bottle gourd anthesis occurs in the afternoon so the male flowers should be removed in the forenoon. There should not be any variety within a radius of 400 meter. After harvesting of fruits from the female parent F_1 hybrid seeds can be extracted. The pinching of male flower buds in bottle gourd, pumpkin and squash can easily be done due to large sized flower, long pedicels, lesser in number and moreover, the flowers are showy. In the genus *Luffa* staminate flowers are large in numbers so pinching of male flower buds are difficult and will not be completed.Crossing between two species *Luffa cylindrica* and *Luffa acutangula* is not possible. Pollinators play an important role for maximum fruit setting as well as maximum seed yield. For one hectare area of seed production one medium sized bee colony is required. Since both the crops are monoecious in sex expression, hybrid seed can be produced by bagging of unopened pistillate flower and pollination with male parent next day. After pollination again bagging of female flower is done to ensure controlled cross pollination. By using this technique hybrid seeds can be produced.

Use of growth regulators:

By using chemicals hybrid seeds can be produced. Sex modification in cucurbits is possible with the invention of various growth regulating substances. For sex modifications the growth regulating substances are applied at two true leaf stages in cucurbits. To induce femaleness and maleness specific chemicals are required. Ethrel (2 chloroethyl-phosphonic acid) 200-300 ppm at two true leaf stage and another spray at four leaf stage have to be applied in bottle gourd, pumpkin and squash to produce female flowers. At the time of flowering another spraying has to be done. Application of ethrel helps in inducing the female flowers and suppresses the male flower production in the earlier nodes of the female parent. The row of staminate flower is grown next to pistillate flower and thus facilitating normal cross pollination. Hand pollination is possible in absence of natural pollinators such as insects, when both male and female sexes are separate. Before opening of flowers the female flowers of the female parent and male flowers of the male parent have to be bagged separately and pollination by hand is done later on. During natural cross pollination, care should be taken that there is not any other variety except the parents of the hybrids. At the initial nodes four to five fruits will produce sufficient amount of hybrid seeds. In squash complete inhibition of staminate flowers can be obtained by application of ethrel at the rate of 600 ppm.

Use of gynoecious line:

In gynoecious lines, the flowering nodes of the main stem as well as secondary and tertiary branches bear female flowers in the axils of leaf. This condition in cucumber has made possible for unique exploitation of hybrid vigour. Gynoecious lines are not available in pumpkin, squashes and in sponge gourd. In ridge gourd one variety 'Satputia' with hermaphrodite sex form is found. Stability of gynoecious lines are observed only at moderate temperature regimes and it is affected when the temperature exceeds 30°C.

Among cucurbits cucumber is extensively studied for hybrid seed production. Development of fruits without fertilization or parthanocarpy is important character found in cucumber. Gynoecious lines are mostly used in greenhouse condition. In gynoecious cucumber there is no need to remove the male flower since gynoecious lines produce only the female flowers. In the field for hybrid seed production, the ratio between female and male parent iskept generally 3:1 and for pollination, bees are essential.

There are different techniques that have been projected to produce hybrid seeds in cucumber by using gynoecious lines. These methods are gynoecious x monoecious, gynoecious × gynoecious, gynoecious x hermaphrodite and gynoecious x andromonoecious. Among these systems, the gynoecious x monoecious hybrid is most widely grown in cucumber due to the advantages of earliness (Jat *et al*., 2017).

Maintenance of gynoecious lines in cucurbitaceous crops by application of growth regulators:

Gynoecy sex expression is one of the most important sex forms which have made unique utilization of heterosis in cucumber, bitter gourd and muskmelon (Munshi *et al*., 2017). The gynoecious inbred lines could produce hybrids if a growth substance is applied to induce staminate flowers. Different gynoecious lines showed varied response when gibberellic acid (1500-2000 ppm) was used for initiation of staminate flower and the male flowers produced by this method were not adequate for hybrid seed production. Therefore, silver nitrate (250-400 ppm) is applied to induce the staminate flowers. Silver nitrate ions restrain ethylene action and promote the production of staminate flowers in gynoecious cucumber. Nowadays, due to phytotoxic effects of silver nitrate, 400 ppm silver thiosulphate is generally used by seed producers for the maintenance of gynoecious parental lines in cucumber.

Use of male sterile line:

Male sterile plants can be used as female parent and particular recessive gene is responsible for male sterility in cucumber, melon, squash and watermelon. In cucurbits there is no cytoplasmic factor to interact with any male sterile genes so male sterile lines can be maintained by crossing between heterozygous plants with homozygous line for male sterile gene, using homozygous line as female parent.

There is large quantity of F_1 hybrids developed by various public sector organizations, which were accepted by the farming communities. Some of the important hybrid varieties are mentioned below.

1. Cucumber : Pusa Sanyog
2. Bitter gourd: Pusa Hybrid 1, Pusa Hybrid 2
3. Bottle gourd: Pusa Hybrid 3, Kashi Bahar, Pant Sankar Lauki 1, Narendra Sankar 1

4. Musk melon: Pusa Rajras, Pusa Hybrid 1
5. Pumpkin: Pusa Hybrid 1
6. Summer squash: Pusa Alankar
7. Water melon: Arka Jyoti
8. Ash gourd: Pusa Shreyali, Pusa Urmi

Conclusion:

Hybrid variety is cost-intensive and an attractive input in agriculture. For development of hybrids and economic production of its seeds technical knowledge and skill is required. Development and evaluation of parental lines of hybrid varieties is vital in hybrid development. Hybrid variety offers guarantee for productivity, adaptability, uniformity and profitability. The limitations in development of hybrid and production of quality seed at low cost should be identified and overcome. Concentrated interdisciplinary attempt for research for economic hybrid seed production is very much important. The mode of pollination, floral biology, pollination control mechanisms, genetic variability in a crop for yield and other important characters, techniques for development and improvement of parents are the important factors for the success of hybrid breeding and economic seed production.

Agro -forestry is a science and art of careful managing of agricultural crops with woody perennials crops such as forest trees and horticultural crops per unit of land to enhance the productivity as well as profitability. The country like India, agriculture is one of the principal sectors which plays important role in contributing GDP. Diversification of agriculture sector is possible by combining both agro-forestry and horticulture to enhance food security, supply of wood and sustainable natural resource management. The union of these two disciplines is complementary to each other which can provide larger share in employment with environment friendly options (Bijalwan and Dobriyal, 2015).

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Nanotechnology in Fruit Crops

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ABSTRACT

Agriculture and horticulture currently use nanotechnology extensively. Nano-fertilizers (NF) are the most widely researched and developed factors in fruit trees. They play a key role in promoting vegetative growth, improving reproductive growth and flowering, thereby increasing productivity, product quality, and ultimately extending shelf life and reducing fruit waste. These nanoparticles are also called growth accelerators because they are sprayed onto trees in very small amounts at different intervals and repeated intervals. Fruit trees such as pomegranate, strawberry, mango, date, coffee and grape have been shown to benefit from macro- and micro-scale NF, such as zinc, boron, chitosan, and fertilizer nanocomposites such as nitrogen, phosphorus, potassium, magnesium, calcite, zinc, Iron, manganese and boron. There is a lack of knowledge about the effects of NFs on fruit trees and the biological interpretation of their effects on different traits, and more research in these fields is urgently needed.

Key Words: Enhancement, Fruit Trees, Nano-Fertilizers, Nano-Technology, Nano-Particles

Introduction

The need for high-quality food will rise as the world's population continues to expand. Fruits are a valuable source of nutritious health goods, but soil nutrient depletion is hurting fruit production. Traditional fertilizers improved food output after the Green Revolution, but intensive agriculture resulted in soil degradation and chemical contamination of food. Traditional fertilizers are inefficient: about 20-30% of fertilizer is utilized by agricultural plants, while the remainder is mineralized or dissolved in groundwater and rivers, resulting in increased expenses, eutrophication, and human health issues. Nano-fertilizers, on the other hand, appear promise since nanoparticles have distinct qualities due to their nanoscale physicochemical properties.

Nano-technology has gotten a lot of press in recent years because of its numerous uses in fields including medicine, pharmaceuticals, catalysis, energy, and materials. Nanoparticles having a tiny size but a big surface area (1–100 nm) might be used in medicine, industry, and agriculture. Scientists have made considerable attempts to synthesis nanoparticles using a variety of techniques, including physical, chemical, and biological approaches (Ghidan *et al.*, 2017). Because of the hardships of increasing the cycle, partition and decontamination of nanoparticles from the miniature emulsion (oil, surfactant, co-surfactant, and watery stage), and the utilization of a high number of surfactants, these methodologies have various downsides (Pilarska *et al.*, 2013).

Green nanoparticle union strategies with plant extricates are useful in light of the fact that they are simple, helpful, eco-accommodating, and need insignificant response time. Nanomaterials made utilizing harmless to the ecosystem and green advancements can possibly further develop horticulture by upgrading manure, plant development controllers, and insect sprays (Ghidan *et al*., 2017). This innovation helps with the decrease of toxins in the climate (Kah and Hofmann, 2014), also, nanotechnology has of late obtained prevalence attributable to its various uses in areas like medication, the climate, and agribusiness (Huang *et al.*, 2015).

Nanotechnology in farming has acquired a great deal of footing in the new decade because of a ton of government financing, yet the phase of advancement is still acceptable, regardless of whether many methodologies have fallen under the horticultural umbrella. This might be because of the exceptional person of rural creation, which works as an open framework in which energy and materials are unreservedly moved. As opposed to mechanical nanoproducts, the size of interest for input materials is continually high, and there is no power over the contribution of nanomaterials (Mukhopadhyay, 2014).

Nanotechnology offers novel agrochemical specialists and conveyance strategies to support crop creation while likewise bringing down pesticide use. Nanotechnology has a few uses in horticulture, including: (1) nano-formulations of agrochemicals for applying pesticides and composts for crop improvement; (2) the utilization of nano-sensors in crop insurance for recognizing illnesses and agrochemical buildups; (3) plant hereditary designing utilizing nanodevices; (4) analysis of plant infections; (5) creature wellbeing, creature rearing, and poultry creation are terrifically significant parts of the business; (6) after-reap care.

Nanomaterials have compound, physical, and mechanical attributes that are extraordinary to them. Farming byproducts have acquired prevalence lately as a wellspring of sustainable crude materials that might be handled and utilized in an assortment of uses, just as a crude material for nonmaterial assembling. Perhaps the best occasion of development happening on a biological time scale is insect spray opposition. Bug spray opposition research is vital both in light of the fact that it prompts a superior information on ongoing cycles and on the grounds that it is financially significant. The current situation with information on the utilization of nanoparticles for feasible natural product creation is talked about in this section. Besides, the possibilities and potential worth acknowledgment of nanotechnology-related natural product creating frameworks have been investigated.

Nanotechnology in Fruit Crops

Fruit crops are nutrient heavy feeders, necessitating a sound nutrient management approach for optimum development and output (Rivero *et al*., 2009; Ramrez *et al*., 2011; Kumari *et al*., 2020). The nourishing condition of plants changes relying upon the species, the environment, the developing medium, and the accessibility of supplements (Cabriales *et al.*, 2002; Benton 2012). Plants' fundamental wholesome parts are separated into macronutrients and micronutrients. As indicated by certain specialists, just 30% of applied manures are utilized by plants, with the rest of filtering, mineralization, and bioconversions (Bollag *et al.*, 1992). Accuracy preparation, incorporated supplement the board, isolated or confined situation, fertigation, and the utilization of nano-composts are a portion of the methods that have been made to handle this issue (Chhipa, 2017). Nano-composts are one of nanotechnology's most important resources, with the possibility to support creation in the agrarian business (Chhipa and Joshi, 2016).

The utilization of nano-manures has been displayed to limit abiotic stressors and increment supplement take-up by crops (Abou *et al*., 2010). Besides, nanoparticles might be a practical strategy for improving the development, creation, quality, and time span of usability of organic products as a substitute wellspring of supplements and bundling (Chowdhury *et al.*, 2017; Kaphale *et al*., 2018).

Nanofertilizers (NFs) are generally used in natural product crop sustenance as soil-based (Dehghanipoodeh et al., 2016) and splash based (Zahedi *et al*., 2019; Zahedi *et al*., 2019) treatments that supply supplements with high productivity and negligible waste attributable to their faster and more noteworthy movement to various locales of plants (Rico *et al*., 2011). Subsequent to infiltrating the fingernail skin tissue of the leaf or root, NFs travel through different pathways (apoplastic, symplastic, lipophilic, and hydrophilic), which influence their viability, last destiny, and may likewise change their properties and accordingly their reactivity, conveyance, and movement inside plant tissues, bringing about an assortment of reactions from various plant parts to similar NP (Barrios *et al.*, 2016).

By joining to transporter proteins, aquaporins, particle channels, endocytosis, or natural mixtures in plant tissues, nanoparticles (NPs) can infiltrate plant cells and appropriate supplements (Rico *et al*., 2011). Nanostructured materials (NMs) are a lot more modest than regular materials, and on account of their higher surface region to-weight proportion, various shapes, and vulnerability, they might have more critical consequences for development and formative cycles, and they can enter leaf tissues straightforwardly through stomata (Barrios *et al*., 2016; Sabir *et al.*, 2014). Subsequently, NMs are regularly treated and exemplified (Rai *et al.*, 2012) or combined with other advantageous material to get better return and lesser damage, as found in date palm plants (Sabir *et al.*, 2014; Refaai *et al.*, 2014).

Translocators in Fruit Trees

Development, natural product creation, support, usefulness, and organic product quality are completely impacted by macro-elements and microelements (Ojeda *et al.*, 2014; Petousi *et al.*, 2015). In cultivation, NFs are right now the main utilization of nanotechnology (Rai *et al.*, 2012). The assimilation of NPs has been the subject of a few in vitro considers (Horie *et al.*, 2012). NPs have a high assimilation rate contrasted with different particles, and may quickly retain different proteins and salts from the medium, conveying them to the plant by means of vascular tissue (Horie *et al.*, 2012).

In organic product trees, to build assimilation rate, NPs are splashed on tree limbs and leaves to further develop development, physiological and usefulness attributes since these accumulates can without much of a stretch infiltrate into plant tissues through stomata (Zagzog *et al.*, 2017). A foliar shower with zinc (Zn) (120mgL−1) and boron (B) (6.5 mgL−1) NPs expanded the levels of these two components by 60.9% and 19.9%, separately (Davarpanah *et al.*, 2016) A foliar application to pomegranate (Punica granatum L.) of selenium (Se) NPs at 1 and 2 μmolL-1 worked on the wholesome status of trees (Zahedi *et al.*, 2019).

As this NFs was splashed at a pace of 2 gL^{-1} on the branches and leaves of three almond cultivars (Shokufeh, Monagha, and Sahand), the degree of micronutrients (Zn, Fe, copper (Cu), and manganese (Mn) expanded essentially when contrasted with the non-NF treatment (Kamiab and Zamanibahramabadi, 2016). In Shokufeh, for instance, Fe and Mn focuses arrived at 80 and 25 mgL-1, individually, contrasted with 75 and 20.3 mgL^{-1} in the control (110.4 and 73.7 mgL^{-1} versus 80 and 25 mgL^{-1} in Monaghah, and 115.4 and 70.9 mgL^{-1} versus 80.2 and 28 mgL^{-1} in Sahand) (Kamiab and Zamanibahramabadi, 2016).

Growth Stimulator in Fruit Trees

When gone against to conventional mass manures, NFs have supplements at the nano even out and contain high measures of supplements that may handily interface with various particles in soil and delivery various supplements in an exceptionally sluggish and stable way by covering them with polymers (Subramanian *et al.*, 2015).

By splashing tree limbs and leaves with Zn, Fe, Mn, B (zinc, iron, manganese, boron) NPs at 0.04%, all development attributes, photosynthetic shades, and supplements of date palm cv. Sakkoti were emphatically affected. At the point when NPs were utilized rather than 0.05 percent of typical Zn, Fe, Mn, B (8.29 and 1.94 mgg^{-1} FW, individually), absolute chlorophyll (8.71 mgg^{-1} new weight (FW)) and all out carotenoids (2.12 mgg^{-1} FW) were higher (El-Sayed, 2018). The utilization of nano-B at 0.25–0.1% joined with wheat seed sprout extricate at 0.5–2.0% emphatically influenced the length, width and space of pinnae and leaves, number of new leaves, number of spines and spine length in date palm (Li *et al.*, 2012).

Mango plants are poisonous to weighty metals, despite the fact that silicon (Si), a metalloid, has been demonstrated to be helpful in dry season circumstances (Helaly *et al.*, 2017). In strawberry cultivar Camarosa, the use of nano-silica (Si-NPs) at 5mM decreased happening (29.92 versus 33.57 mmolm-2s-1 in the control), explicit leaf region (the proportion of leaf region to dry mass) (1.22 versus 1.60 cm2g-1 in the control), and petiole length (8.56 versus 11.15 cm in the control), just as emphatically influencing different qualities like leaf number (6.84 versus 6.11 in the control) and water use productivity (3.63 versus 2.52 $\mu molmmol^{-1}$ in the control) (Dehghanipoodeh *et al.*, 2016).

Enhances Flowering in Fruit Trees

Branches and leaves of grape plants treated with 0.3 gL^{-1} calcite NF bloomed before and created better blossoms than non-NP treated plants (days to full sprout = 24.1 in the control and 23.1 in the NF treatment). The amount of blossom panicles and created panicle organic products expanded after Zn NPs (1 gL^{-1}) were splashed on mango tree limbs and leaves (Zagzog *et al*., 2017).

Si-NPs, similar to common Si, have changed physical and synthetic properties and might be more successful at reducing different ecological pressing factors (Cui *et al*., 2017; Tripathi *et al*., 2017). When showered as nano-silica (SiO2), silicon helped strawberry blooming and was powerful as a splash or soil soak (Dehghanipoodeh *et al*., 2018). Since there is an increment in Si during the change of crown buds from the vegetative to the sprouting stage in strawberry plants, splashing with Si-NPs can trigger quicker blossom organ separation (Dehghanipoodeh *et al*., 2018).

Enhances Fertility and Fruit Set in Fruit Trees

In the wake of showering NF iron chelate + ZFM at 2 gL^{-1} on branches and leaves of three cultivars of almond trees (Shokufeh, Monagha, and Sahand) got the most noteworthy branch yield (around 350 g) and the least branch yield (around 120 g) in the control (Kamiab and Zamanibahramabadi, 2016). In contrast with the benchmark group, this treatment decreased organic product abscission by generally 25%. In pomegranate, Davarpanah *et al*., (2016) tracked down that a foliar splash containing humble amounts of Zn (120 mgL^{-1}) and B (6.5 mgL^{-1}) NPs was more successful than bigger fixations.

Organic product yield and natural product number per branch expanded because of this fixation, and B-NPs greater affected these provisions than untreated controls or Zn-NPs. Wheat seed sprout separate (1.00 %) and B-NPs (0.05 %) applied together helped date palm yield and bundle weight, bringing about preferred treatment of these trees over control trees (Refaai, 2014). B is engaged with dust tube lengthening, preparation, natural product set and yield, sugar movement, nucleic acids, and plant chemicals overall (Marschner *et al*., 2012).

Fruit number (1 $molL^{-1}$: 39.45, 2 $molL^{-1}$: 48.06 versus control: 38.65), fruit diameter (1 $molL^{-1}$: 69.33 mm, 2 $molL^{-1}$: 74.67 mm versus control: 67.33 mm), and peel thickness (1 $molL^{-1}$: 29.83 mm, 2 $molL^{-1}$: 36.13 mm, and control: 28.40 mm) were all significantly enhanced in pomegranate (Hasan, 2015).

At the point when plants are lacking in nitrogen, nitrogen-containing NFs discharge nitrogen (Naderi and Danesh, 2013). Splashing N-NPs at 0.25 and 0.50 gL^{-1} to pomegranate branches and leaves expanded natural product yield more than urea (4.60 gL^{-1}: 21.2 gL^{-1}; 9.20 gL^{-1}: 19.1 kg per tree), while showering with N-containing NFs at full sprout and multi month after the fact was extremely compelling, expanding leaf N focus by 2% comparative with the non-NP control (Davarpanah *et al*., 2017). As a rule, N assumes a physiological and metabolic part in giving carbs to blossoming and organic product development (Borghi and Fernie, 2017).

Enhancemcent on Fruit Growth In Fruit Trees

NFs have been exhibited to be more viable than customary manures in boosting the development, usefulness, and nature of certain organic product crops in certain tests (Sabir *et al*., 2014; Refaai, 2014; Davarpanah *et al*., 2017).

In contrast with control trees, showering Zn-NPs (1 gL^{-1}) on mango shoots and leaves prior to blossoming diminished distortion by 42–55 percent, further developed organic product weight by 33.74 percent, and expanded yield per tree by 57.36 percent. They additionally found that applying chitosan-NPs at 5 mLL^{-1} to mango plants helped organic product number per tree (35.28 percent more than the control), natural product contortion opposition (38–40 percent more than the non-NF treatment), organic product quality, and physical and substance credits (Zagzog and Gad, 2017). Protease inhibitors, glucanases, and peroxidase, proteins that animate development and metabolic exercises in turmeric, were completely helped by a splash of nano-chitosan (0.1 % w/v) (Anusuya and Sathiyabam, 2016).

The last examination additionally showed that the expansion in phenolic parts was because of an increment in the statement of qualities coding for the biosynthesis of phenolic compounds initiated by Zn and B (Liakopoulos and Karabourniotis, 2005; Song *et al*., 2015). Treatment with N-containing NFs at 0.25 (N1) and 0.50 (N2) gL^{-1} likewise worked on the nature of pomegranate organic products by expanding aril juice (ml 100 g^{-1} arils) (control: 62.5; N1: 63.3; N2: 68.3), absolute sugars (g 100 g^{-1} juice) (control: 14.18; N1: 14.56; N2: 15.54) and TA (%) (control: 1.74; N1: 1.84; N2: 1.89) of natural products (Davarpanah *et al.*, 2017). An expansion in N fixation further developed turgor pressure (Kumar et al., 2014), carb supply (Borghi and Fernie, 2017) and movement of natural acids (Tegeder and Masclaux, 2018). In strawberry, natural product immovability was improved by treatment with 50–15 $mmolL^{-1}$ Si-NPs (control: 0.54 and 10 $mmolL^{-1}$: 0.62kgm−2) (Dehghanipoodeh *et al.*, 2016).

Increase in Abiotic Stress Resistance

Many plant species have developed to withstand brutal climatic conditions. Nonetheless, in most of cases, these preventive responses consume a large chunk of the day to kick in, and the harm might be irreversible. Thus, in plant creation frameworks, triggers are needed to help plants (Brown and Saa, 2015). Many examinations on plants have as of late been attempted utilizing nano-triggers, which can be normal plant concentrates, synthetics, or a blend of the two (Jedrszczy and Ambroszczyk, 2016).

Calcite NFs at 0.5 g (calcium carbonate, $CaCO_3$ (40%), silicon dioxide, SiO2 (4%), magnesium oxide, MgO (1%), and iron (III) oxide, Fe2O3 (1%) gL^{-1} abbreviated the time it took for grapes cv. Narince to arrive at three formative stages (full sprout, véraison, and development) in calcareous plantations.

Expansions in berry weight, group number and weight, and pruning weight might be because of the gainful impacts of Zn, which affected the combination of tryptophan, an auxin forerunner to indole-3-acidic corrosive (IAA) union (Hanafy *et al.*, 2012), added to dust creation and development, and further developed berry creation and unification in grape bundles and shoots (Sabir *et al.*, 2014). Any boost that builds the centralization of endogenous Zn in plants, for example, NF showering, improves IAA blend and subsequently shoot, berry, and dust development, while diminishing immature shoot berries (Arrobas *et al.*, 2014).

Conclusion

The main benefit of nanotechnology in expanding the development, yield, and strength of organic product crops has been as NFs, which have represented most of exploration in this subject. On various organic product trees like pomegranate, almond, grapes, mango, date, espresso, mulberry, and strawberry, NFs like N, B, Zn, ZnO, chelate, Fe and its mixtures, and chitosan have had great outcomes. These substances directly affect the development, extreme items, and nature of these organic products when showered at very low amounts on trees. Higher measures of these synthetic compounds might have unfortunate results, including harmfulness, anyway this has just been seen in one examination on wild pear seedlings, which was done before the yield creation stage.

Since NMs work on supplement take-up in some natural product trees, they might assist them with withstanding ecological and organic pressure. Nonetheless, there has been almost no exploration done to assess this. As a general rule, extra exploration on the effects of NPs on natural product trees is required, just as the investigation of new cultivars, in light of the fact that the responses fluctuate incredibly among species and cultivars. The system fundamental the ideal advantages of these substances on the development and usefulness of natural product trees can be found through such examination, just as the appraisal of any conceivable adverse results.

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Multipurpose Urban Forest

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Abstract

Urban forest is a human centred ecosystem found in the concrete jungle of cities. It provides a number of benefits including environmental, sociological, economic and recreational opportunities. Modifications in adoptive features in wild animals ensure urban forests as a new address for biodiversity conservation. The myriad values associated with urban trees are vulnerable to climate change. Integration of climate change mitigation and adaption technologies in the management framework of urban forest is essential for sustained supply of ecosystem services.

Key words: Climate Change, Ecosystem Services, Urban Forest, Ecotourism, Noise Abatement

Introduction:

Urbanization trend in India is taking at very fast rate. It is being accelerated by rapid economic growth and industrialization. People mostly younger generation are moving towards cities for employment, better education of their children and improved lifestyle. The number of cities increasing steadily every census from two digit numbers in 1951 to 7935 numbers in 2011. 31.16% of Indian population (37.7 crore) are living in urban areas and their number likely to cross 35% by next census. 42 % of these urban populations are residing in only 53 numbers of metropolitan cities (2011 census, Government of India). Limited space as well as poor economic condition compels these immigrants to live in existing slums or create new urban sprawl. In metropolitan and big cities multi-storeyed apartment culture is gaining its pace. Unprecedented urbanization process swallows many prime agricultural lands, natural water bodies, wet lands, common pasture lands, scrub lands etc. High population density and scarcity of space adversely affects the natural & environmental resources. These create noise and pollute air and water resources. Urban green spaces or multipurpose urban forestry is the key solution for mitigating the adverse effect of urbanization (Brandt et al. 2016). This will also enable the residents accessing quality basic natural resource like air, water and natural setting for leisure and recreation.

What is multipurpose urban forest?

Urban forestry is the art, science and technology of managing trees in urban community ecosystems for environmental, sociological, economic and aesthetic benefits (Young 2010). Urban forest is human cantered ecosystems where the attitude and involvement of urban residents is pivotal. The choice and articulation of tree species is mostly decided on type of services desired by educated mass in a society. Urban parks, gardens and natural landscapes, zoos are better known for their intangible benefits than tangible benefits. Often tender leaves of bahunia, jamun fruits, neem flowers, fuel wood etc. are collected form roadside block or avenue plantations by slum dwellers and sold in door steps for some earnings. But great share of services provided by urban forest were intangible like carbon dioxide sequestration, oxygen release, rainfall interception, dust retention, biodiversity conservation, positive psychological effect to city dwellers etc. Trees laden parks/gardens are often preferred for morning and evening walks/exercises and recreation by all kinds of people. Increased green canopy coverage by trees in concrete jungle has cooling effect, reduces energy consumption.

Importance of Urban Forest:

Urban forests are critical for making cities sustainable, healthy and energy efficient. For deriving maximum benefits from these greens they have to be planned, developed, and maintained appropriately so that they are accessed in terms of area and population wise. Services provided by urban forest are not different from those of natural forests but by virtue of its location some benefits accounts much attention. These includes microclimate amelioration,

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addressing engineering problems of cities, architectural and aesthetic benefits, increasing real estate values, enhancement of wildlife habitat etc. (Fig.1). Important engineering problems of cities addressed by trees and/or combination of shrubs with trees include noise abatement, air purification, waste water management, glare, reflection and traffic control. Apart from this trees in urban green spaces sequester atmospheric carbon considerably and contribute substantially to climate change mitigation.

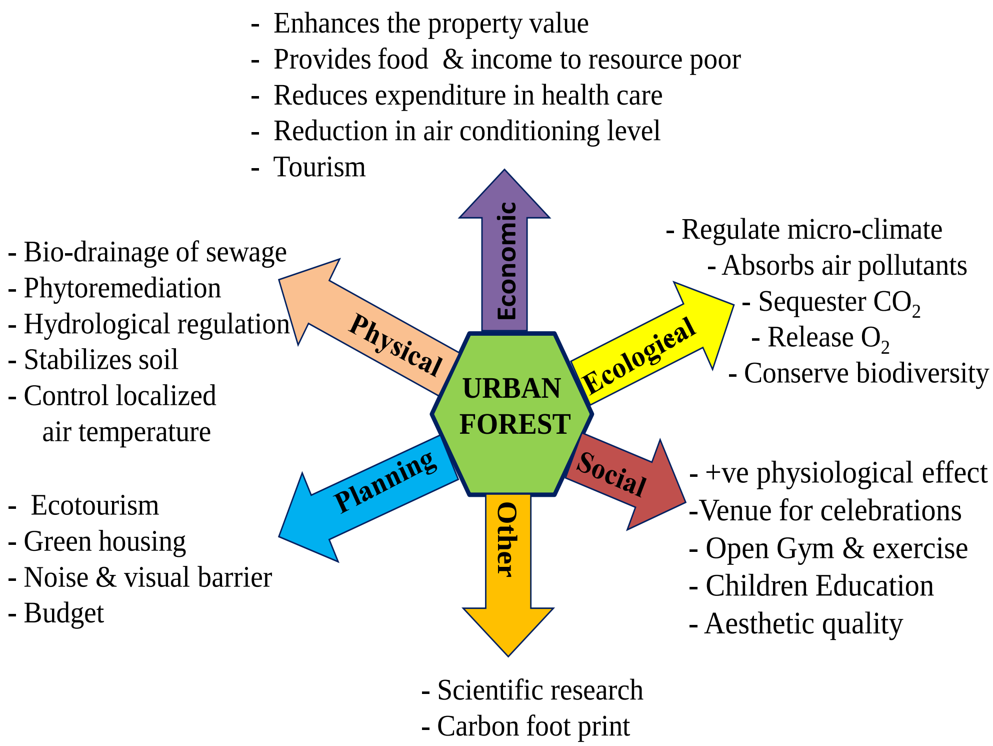

Fig.1. Myriad values associated with urban forest

Different forms of Urban Forestry:

In urban amenities green space are normally meant for recreational uses. These areas include parks, playgrounds, botanical gardens, open spaces, water bodies and other natural features which bridge the gap between the people and nature. As per Ministry of Urban Development guide lines (1996), the proportion of recreational areas to the total developed area should be between 12-14% in small towns, 18-20% in medium towns and large cities, and 20-25% in metropolitan cities. Different forms of urban forests include planting trees along roads; individual trees in common places or private gardens, recreational parks etc. (Fig.2). Trees along roads may be in the form of avenue planting, group planting, mixed planting or informal planting. Avenue planting consists of planting trees in single or double rows along highways depending on the land area available. Evergreen shade trees, ornamental flowering trees or both in combination may be planted to give an attractive look. Tree planting may be done at irregular spaces or off-setting trees by few meters from uniform alignment for breaking the monotonous view. Group planting consists of planting a clump of 3 or 4 trees along the highway to overcome the monotony of avenue planting. For more effective the spacing of group should be irregular or staggered. Mixed planting consists of selecting different varieties of trees, rather than one. Matrix of features of like canopy structure, height, foliage colour and senescence, blooming time & colour etc gives a pleasant look and thus the aesthetic value of avenues is preserved throughout the year. Where ever if formal plantation is not feasible single tree having desired characteristics may be planted in an informal way in the premises of buildings, market complex and business centres etc. Green strip and woodlots may be developed in vacant lands like under high tension power supply lines or along the arterial roads separating residential areas from other uses.

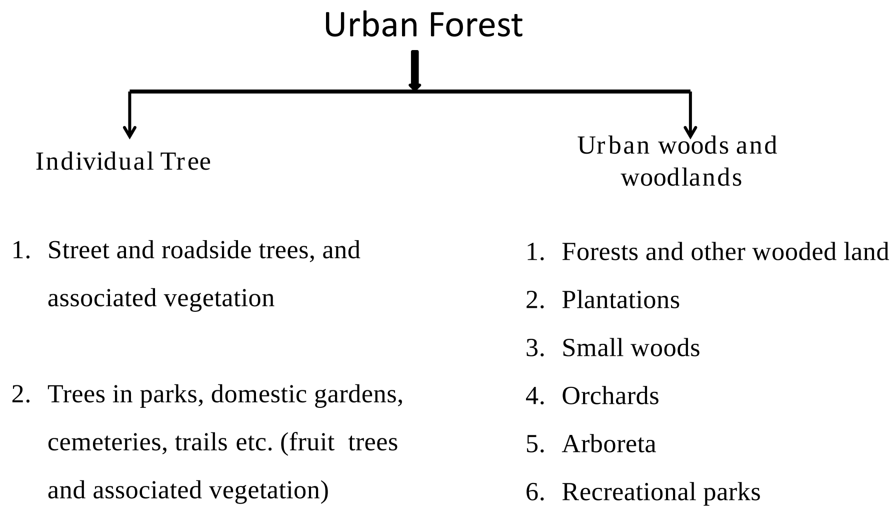

Fig.2 Different forms of urban forest

Selection of species:

Apart from cultural, commercial and aesthetic value of a species the following criteria should be taken into account while selecting a tree species for plantation in urban free spaces.

i). Suit to the local soil and climatic conditions
ii). Fast growing, hardy, non-browsing, robust, easy to establish and needs little attention once they have achieved certain growth
iii). Evergreen or semi evergreen with long rotation period
iv). Deep rooted, wind firm and self pruning one
v). Free of spines, stony fruits etc.
vi). Plants bearing attractive foliages, geometric branching, fancy trunk, colourful flowers or flowers having pleasant aroma are often preferred.

List of suitable tree species for urban forestry in tropical and subtropical regions of India is given in Table-1.

Urban forest in mitigating climate change

Urban forest mitigates climate change by reducing concentration of green house gases from atmosphere and limiting energy consumption. Carbon sequestration by urban trees may not significantly contribute to global or national level climate change mitigation strategy (Tallis *et al*., 2011). But selecting native adaptable fast growing multipurpose tree species in greening urban spaces and retaining for a considerable long period may address to local carbon budget (Akbari, 2002). Sustainable management framework inclusive of climate change considerations can strives to sustain the myriad values (Fig.1) associated with urban forest (Brandt *et al*., 2016).

Urban forest as new home of restoring Biodiversity

Biodiversity conservation through preservation of vast areas of natural habitat is not always feasible especially in highly urbanized locations. Moreover, many wild animals are changing their habits to adapt urban settlements for food and shelter. Urban forest ecosystem like avenue plantations, recreational parks, block plantations in shelter belts, vegetation in office premises and residential areas can be the potential place for biodiversity conservation (Alvey, 2006).

Table 1 Tree species suitable for urban forests in tropical and subtropical regions of India (Hegde 2012, Chaudhry 2006)

Botanical Name	**Family**	**Habit**	**Plant Ht. (m)**	**Crown shape**	**Flower colour**	**Flowering time**	**Fragrance**
Alstonia scholaris (L.) R. Br.	Apocynaceae	E	25-40	Pagoda, dense & tiered	Small Creamy/ off-white	Oct-Nov	Spicy & pungent
Azadiratchta indica A. Juss.	Meliaceae	E	15-30	Round	Small, White	Jan-Mar	Sweet
Butea monosperma Lam. Taub.	Fabaceae	E	12-15	Spread	Bright orange red	Jan-may	No
Calophyllum inophyllum L.	Calophyllaceae	E	10-20	Pyramidal round	White	Spring-summer	Sweet Fragrant
Cassia fistula L.	Fabaceae	D	10-20	Oval	Yellow	Mar-may	Pungent
Delonix regia (Hook.) Raf.	Fabaceae	D	9-20	Umbrella	Bright red & orange	Apr-May	Slightly fragrant
Ficus racemosa L.	Moraceae	D	10-16	Irregular	In form of fruits	Year round	-
Gmelina arborea Roxb. ex. Sm.	Verbenaceae	D	25-30	Irregular	Bright yellow	Feb-Apr	Mild
Jacaranda mimosifolia D. Don.	Bignoniaceae	D	15-25	Spreding, Vase	Blue/purple	Spring	Mild
Kagelia pinnata DC.	Bignoniaceae	E	15-25	Spreading	Red	Aug- Sept.	Fragrant
Lagerstroemia speciosa L. Pers.	Lythraceae	D	7-15	Round	Purple	Mar-Jun	No
Melia azedarach L.	Meliaceae	D	7-12	Round & open	Small White	Mar-may	Sweet
Michelia champaca L.	Magnoliaceae	E	20-30	Narrow Umbellifo rm	Mustard yellow	Dec-Apr	Pleasant
Millettia pinnata (L.) Panigrahi	Fabaceae	E	15-25	Broad spreading	White, purple & pink	Apr-May	Mild pleasant

Mimusops elengi L.	Sapotaceae	E	10-12	Round	Creamy-white	Mar-May	Mild
Neolamarckia cadamba (Roxb) Bosser	Rubiaceae	E	30-45	Umbrella	Red-orange	Jul-Aug	Sweet
Nyctanthes arbour-tristis L.	Oleaceae	D	9-10	Irregular	Orange - white	Oct-May	Honey scented
Peltophorum pterocarpum (DC.) K. Heyne	Fabaceae	E	15-25	Umbrella	Yellow	Mar-May	Mild
Polyalthia longifolia (Sonn) Thwaites var. Pendula	Annonaceae	E	7-10	Columnar	Pale green	Mar-Apr	Mild
Saraca asoca (Roxb.) Willd	Fabaceae	E	7-10	Round	Yellow-orange & red	Mar-Aug	Mild pleasant
Spathodea campanulata Beauv.	Bignoniaceae	D	15-25	Round, spreading	Orange-yellow	May-Jun	No
Sterculia foetida L.	Sterculiaceae	E	25-35	Globose	Crimson-brown	Feb-Mar	Foul smell
Syzygium cumini (L.) Skeels.	Myrtaceae	E	12-30	Irregular dense	Small Creamy/ off-white	Apr-may	Mild Fragrant
Tamarindus indica L.	Fabaceae	E	12-18	Dome or umbrella	Yellow-red & orange	May- Aug	Mild
Terminalia arjuna (Roxb.) Wight & Arn.	Combretaceae	E	20-25	Spreading	Creamy-white	Spring-summer	Honey scented
Terminalia catappa L.	Combretaceae	E	25-35	Spreading	Greenish white	Thrice in a year	Sweet & delicate

E- Evergreen D-Deciduous

Management options for urban forests

Urban forest contains different components and hence the management should aim at linking all components, their forms and functions. If required specific techniques may be adopted in an integrated and strategic manner. Traditional forest management techniques are often not directly applicable to urban green spaces. For example Arboriculture plays an important role in parks and gardens, avenue plantations but here management of other types of vegetation also needs attention. Management of arboriculture should base on a detailed understanding of tree biology and its natural reaction to wounding, pruning, pollarding, training, thinning etc. Management options like applying thinning regime, policies and planning should not base on only preliminary information about tree like number, age, height etc but also collecting detailed knowledge on vitality, special characteristics and their place in a wider urban forest context.

Conclusion

Trees situated within developed places like cities, towns and suburban areas provides a set of benefits that span from ecosystem services to livelihood of slum dwellers. Urban forests facilitate in ameliorating microclimate of city, mask undesirable odours, abate vehicular noise, conserve biodiversity and provide spiritual and emotional comfort to city dwellers. Selection of most acceptable species and their management in accordance to the stressful environment is a big challenge. However successful urban forest management in association with other natural resource management programmes inculcating within all aspects of land development can lead to a healthier, tolerant and resilient forest for modern city communities.

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