Training Manual

Summer School on Climate Change & Abiotic Stress Management Strategies for Doubling Farmers Income

भाकृअनुप - राष्ट्रीय अजैविक स्ट्रैस प्रबंधन संस्थान

ICAR - National Institute of Abiotic Stress Management

(समतुल्य विश्वविद्यालय/Deemed to be University)

माळेगाव(खु), बारामती-४१३ ११५, पुणे

Malegaon (Kh), Baramati-413 115, Pune

राअस्ट्रैप्रसं NIASM

Training Manual of ICAR Sponsored
Summer School on Climate Change & Abiotic Stress Management Strategies for Doubling Farmers Income

(September 07-27, 2018)

Compiled & Edited

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Citation: Yogeshwar Singh, Mahesh Kumar, NP Singh(2018) Training Manual of ICAR Sponsored Summer School on Climate Change & Abiotic Stress Management Strategies for Doubling Farmers Income. ICAR-National Institute of Abiotic Stress Management

Publication No. 26

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Abiotic Stress Management for Climate Resilient Agriculture

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Prime Minister Narendra Modi's aim of doubling farmer's income by the year 2022, has evoked strong responses from various analysts, experts and the media. The goal has been dubbed as impossible and unrealistic. It is the responsibility of all agriculture stakeholders to make it possible so that India will produce sufficient food to achieve food and nutritional security. For this we have to work in scientific and holistic manner so that we may increase the agriculture production besides increasing the input use efficiency in eco-friendly manner. Indian agriculture is passing through difficult times due to two consecutive drought situations in several parts of the country, thereby resulting into wide spread distress among farmers. The rural areas in these parts are facing food and livelihood crisis, more specifically the shortage of fodder and drinking water. Despite the earlier history of famines and continuing patterns of droughts, remarkable successes have been achieved towards food security at the national level. Yet the country continues to face challenges in terms of availability, access, balanced diet, diversity and equity associated with consumption of nutritious food at sufficient levels. For meeting requirement of the burgeoning population, the country will need an estimated 400 million tonnes of food grains by 2050, from a current level of about 260 million tonnes. current population is 1.21 billion, it is projected to reach 1.6 billion by 2050.

Agricultural production continues to be vulnerable to unexpected and extreme weather events, the incidence and intensity of which is increasing with climate change (IPCC 2014). Abiotic stresses such as drought, salinity and extreme temperature together with the growing population and per capita food consumption are challenging sustainability of food security. With substantial water consumption in agriculture, quality and quantity of ground water is becoming more critical for human as well as soil health. With 1/3 of the geographical area prone to degradation due to soil erosion, flood, waterlogging etc. Expansion of agricultural land is a remote possibility. With 2/3rd of the cultivated area prone to drought, uncertainty looms large over stability of food production and price. Consequence of adverse impact of drought on agricultural crops and forages are evident even in livestock production and also reflected in the reduction of inland fisheries. India experienced trails of unusually widespread and untimely drought, flood and most recently hailstorm events on frequent basis. The increased frequencies of these adverse events demand appropriate measures to minimise their impact on agricultural crops. On one hand side conservation agriculture should be promoted on large scale and other side more research is needed on micro-irrigation strategies like partial root zone drying and drip irrigation and fertigation systems. These measures are critical to develop location/situation wise recommendations for achieving the goal of sustainable agriculture production by harnessing maximum per unit applied water. Remote sensing and GIS tools are becoming increasingly useful tools to delineate abiotic stress at regional level. With further inputs like edaphic factors derived from soil maps, cropping pattern and their responses to stressors, regional models can be put forth for forecasting abiotic stresses using GIS based statistical tools.

Development of stress tolerant transgenics using gene transfer approaches needs much more understanding of plant stress-tolerance and gene-regulatory network systems. Apart from feeding regimes and dietary strategies, genetic improvement of livestock is essential to ensure permanent and cumulative changes in performance and this can be accomplished through biotechnological interventions.

Some of the measures including nutritional supplement, plant bio-regulators and canopy management should be developed on location and case specific to minimise yield losses and increase farmer's income. Plant bioregulators (PBRs) play key role in the ability of plants to adapt under changing climatic conditions, by mediating growth, development, nutrient allocation and source sink transitions. With the use of specific bioregulators, crops can be grown under various abiotic stresses namely drought, salinity and heat with minimum yield losses. Yield losses in arable crops under drought stress can be minimized by 15 to 20 % with the use of bioregulators. The future prospective is to identify the crop and condition specific bioregulators as well as optimization of the dose, frequency and stage of sprays for achieving the maximum benefits under stress conditions. In these aspects attempts have already been initiated to identify suitable agrochemicals/plant bioregulators like KNO_3, spermidine, thiourea, salicylic acid, ortho-silicic acid etc to minimise the adverse effect of heat, drought and water logging stress in arable and orchard crops as per level and nature of stress.

In the recent past, India experienced trails of unusually widespread and untimely hailstorm events during February–May 2014 and 2015 (Rathore, 2016). These events have caused a large scale destruction of crops in Indian states mainly North and Central part, being the worst hit with varying levels of damage. There is need to adapt low cost protected structures for cultivation of high value crops like grapes and pomegranate to check the losses incurred due to frequent hailstorm incidences.

Attempts have also been initiated to identify beneficial microbes that can contribute in minimising stress impact on crop performance under harsh agro-ecologies. Since microorganisms represent the significant fraction of molecular and chemical diversity in nature. Microbes contribute to basic ecosystem processes such as the biogeochemical cycles and food chains, as well as maintain vital relationships with higher organisms and plants.

Conservation Agriculture (CA) is a strategy for mitigating climate change and as an adaptive mechanism for alleviating climate change effect. CA practices can help in sequestering atmospheric CO_2 in the form of soil organic matter, as well as reduction in GHG emissions through efficient production system. CA facilitates soil management without excessive disturbance, protection from erosion, compaction, aggregate breakdown, loss in organic matter, leaching of nutrients etc.

Organic Agriculture is a possible option for stress mitigation and adaption to climate change. It is an alternative sustainable, eco-friendly production system that assists in biological pest control and crop rotation, supply green manure and composts/FYM to maintain soil fertility. According to an estimate, organic agriculture combined with reduced tillage techniques has the potential to sequester 500 kg C/ha/yr. This maximum organic scenario would mitigate about 4 Gt CO_2 equivalents/yr or 65 per cent of the agricultural GHG. There are opportunities to use this approach for sustainable and eco-friendly farming models that meet on-farm requirement of organic inputs through biochar, biomass transfer from agroforestry for direct application on farm and composting for farm nutrient recycling.

It is the need of hour to uncover complexity of harsh agro-ecologies and in-field variabilities through modern technologies and accordingly adaptation options through combination of key traits and genes for genetic improvement in tolerance to stress. In addition micro-irrigation strategies, mitigation options through conservation agriculture along with use of second generation machines, organic farming, use of plant bio-regulators, nano-particles and other relevant technologies are essential for addressing the issues of increasing farmers income under resource limiting climate change era. Beside these above mentioned aspects, attempts should also be focused in scaling up the proven technologies like use of stress tolerant varieties, conservation agriculture, integrated farming system, fertigation etc. to build up the confidence amongst farmers that agriculture can be a fruitful business with the assistance of Pradhan Mantri Fasal Bima Yojana.

Elemental Profiling in Plant, Animal and Human through Inductively Coupled Plasma-Mass Spectrometry (ICP-MS)

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Inductively coupled plasma-mass spectrometry (ICP-MS) is a powerful analytical tool which is used for analyzing trace elements with excellent sensitivity in biological and non-biological environmental samples. A large range of elements can be detected using an ICPMS, which are summarized in Figure. The ICP-MS employs argon plasma (ICP) as the ionization source and a mass spectrometer (MS), usually with a quadrupole mass filter, to separate the ions produced. It can simultaneously measure most elements in the periodic table and determine analyte concentrations down to the sub nanogram per litre or parts per trillion (ppt), level. It can perform qualitative, semi quantitative, and quantitative analysis, and compute isotopic ratios on water samples, and in waste extracts and digest In an ICP-MS instrument, liquid samples are introduced by a peristaltic pump to the nebulizer where a sample aerosol is formed. A double-pass spray chamber ensures that a consistent aerosol is introduced to the plasma. Argon gas is introduced through a series of concentric quartz tubes, known as the ICP torch. The torch is located in the Se centre of a RF coil. A Tesla coil ionizes the argon gas and free electrons are accelerated by a 27 MHz radio frequency field. Collisions between the accelerated electrons and the argon gas generate high temperature plasma. The sample aerosol is instantaneously decomposed in the plasma to form analyte atoms, some of which are ionized. The ions produced are extracted from the plasma into the mass spectrometer region, which is maintained at a high vacuum (typically 10^{-6} torr) using differential pumping. The analyte ions are extracted through a pair of orifices, approximately 1 mm in diameter, known as the sampling cone and the skimmer cone. The analyte ions are then focused by a series of lenses into a quadrupole mass analyzer which separates the ions based on their mass-to charge ratio (m/z). Finally, ions are detected using an electron multiplier, and data at all masses are collected and stored through a computer interface. The use of high resolution or magnetic sector mass spectrometers has become more common in ICP-MS, allowing the user to eliminate or reduce the effect of interferences due to mass overlap. The instrument like ICP-MS has both a magnetic sector and an electric sector and is used to separate and focus the ions. The magnetic sector is dispersive with respect to both ion energy and mass and focuses all the ions with diverging angles of motion coming from the entrance slit of the spectrometer. The electric sector is dispersive only to ion energy and focuses the ions onto the exit slit. Such an arrangement is called a double-focusing high resolution mass spectrometer.

Generally most of the element are not synthesise in the human, plant and animal body, however, it provided through dietary source. Further, we can determined elements in the plant, animal and fish to know the level of particular elements in biological and non-biological samples and in order to find out whether there is a deficiency of an element or if there has been excessive exposure to an element. From the analytical point of view, these two aims may make a big difference as the concentrations analyzed may differ by orders of magnitude, and the analytical methods applied may thus be markedly different. Even the stability of a specimen on storage may be different, depending on the concentration of the element. In dealing with contamination, the most common source of error in trace element analysis in the laboratory, the level of the analyte in the specimens is also a decisive factor. However, when the concentrations in the specimens are high, they tend to be so in the environment of the sample collection as well. The risk of contamination during sampling is important irrespective of analyte level. Hence, a very sensitive and accurate instrument are available to determined element in different biological and non-biological samples called Inductively coupled plasma mass spectrometry (ICPMS). Inductively coupled plasma mass spectrometry (ICPMS) is an analytical technique that performs elemental analysis with excellent sensitivity. The ICP-MS instrument employs argon plasma (ICP) as the ionization source and a mass spectrometer (MS), usually with a quadrupole mass filter, to separate the ions produced. It can simultaneously measure most elements in the periodic table and determine analyte concentrations down to the sub nanogram per litre or parts per trillion (ppt), level. It can perform qualitative, semi quantitative, and quantitative analysis, and compute isotopic ratios on water samples, and in waste extracts and digest In an ICP-MS instrument, liquid samples are introduced by a peristaltic pump to the nebulizer where a sample aerosol is formed. A double-pass spray chamber ensures that a consistent aerosol is introduced to the plasma. Argon gas is introduced through a series of concentric quartz tubes, known as the ICP torch. The torch is located in the Se centre of a RF coil. A Tesla coil ionizes the argon gas and free electrons are accelerated by a 27 MHz radio frequency field. Collisions between the accelerated electrons and the argon gas generate high temperature plasma. The sample aerosol is instantaneously decomposed in the plasma to form analyte atoms, some of which are ionized. The ions produced are extracted from the plasma into the mass spectrometer region, which is maintained at a high vacuum (typically 10-6torr) using differential pumping. The analyte ions are extracted through a pair of orifices, approximately 1 mm in diameter, known as the sampling cone and the skimmer cone. The analyte ions are then focused by a series of lenses into a quadrupole mass analyzer which separates the ions based on their mass-to charge ratio (m/z). Finally, ions are detected using an electron multiplier, and data at all masses are collected and stored through a computer interface.

Principle of ICP-MS

The sampled material is introduced into high-energy argon plasma that consists of electrons and positively charged argon ion. In the plasma, the material is split into individual atoms. These atoms will lose electrons and become (singly) charged positive ions. To allow their identification, the elemental ions produced in the plasma (ICP) must be transferred from 7000 K to room temperature and from atmospheric pressure to high vacuum. To do so, the ions are extracted through a number of apertures. Besides ions also photons are produced in the plasma. Photons also pass through the apertures. They are not removed by vacuum and produce high background signal when they reach the detector. To minimize this background, also called photon stop is present this is a small metal plate placed in the centre of the ion beam, which reflects the photons away from the detector. The positive ions are not stopped by the photon stop because a positively charged cylinder lens guides them around it. Subsequently, the ion beam enters the quadrupole mass analyser. In the quadrupole the ions are separated on the basis of their mass-to charge ratio. Each element has its own characteristic isotopes and masses and will therefore produce its own mass spectrum. After passing the quadrupole the ions hit a special detector .It contains two stages to allow simultaneous measurements of high and low signals. This allows simultaneous detection of main components and ultra trace elements in single run, the ICP-MS a perfect tool for survey analysis of totally unknown samples.

Figure 1: The layout of an ICP-MS

Important components of ICP-MS

1. Sample introduction system – composed of a nebulizer and spray chamber and provides the means of getting samples into the instrument
2. ICP torch and RF coil–generates the argon plasma, which serves as the ion source of the ICP-MS
3. Interface – links the atmospheric pressure ICP ion source to the high vacuum mass spectrometer
4. Vacuum system – provides high vacuum for ion optics, quadrupole, and detector
5. Collision/reaction cell – precedes the mass spectrometer and is used to remove interferences that can degrade the detection limits achieved. It is possible to have a cell that can be caused both in the collision cell and reaction cell modes, which is referred to as a universal cell

6. Ion optics – guides the desired ions into the quadrupole while assuring that neutral species and photons are discarded from the ion beam
7. Mass spectrometer – acts as a mass filter to sort ions by their mass-to-charge ratio (m/z)
8. Detector – counts individual ions exiting the quadrupole
9. Data handling and system controller- controls all aspects of instrument control and data handling to obtain final concentration results.

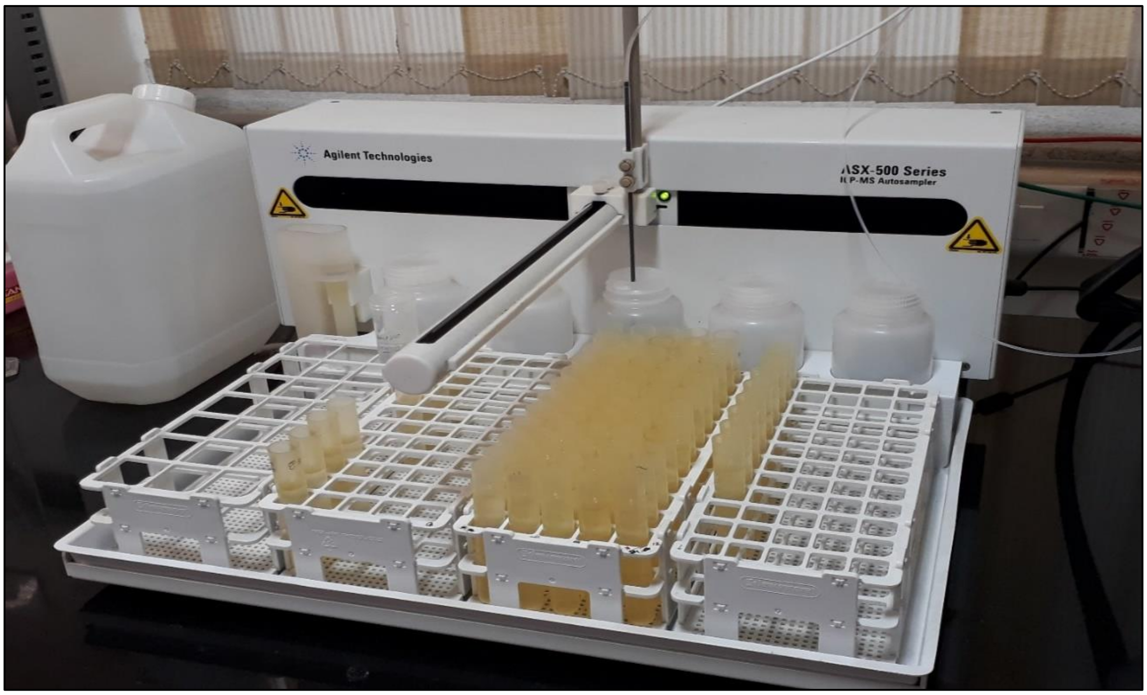

Figure 2: Autosampler

Sample preparation for elemental analysis

Sample Digestion

Biological (Fish tissue, blood, plant materials) and non-biological (Soil, water) samples were acidic digestion with different composition as given below:

1. HNO_3 and HCl (5:1)

   $3HCl + HNO_3 \rightarrow 2H_2O + NOCl + Cl$ (The nitric acid destroys organic matter and oxidizes sulphide material. It reacts with concentrated hydrochloric acid to generate aqua regia and considered adequate for dissolving most base element sulphates, sulphides, oxides and carbonates)

2. HNO_3 + HCl + HF (5:0.5:0.5

   HNO_3 + HCl + HF (5:0.5:0.5) mixture provide satisfactory dissolution of silica matrices

3. HNO_3+ HF (5:1)

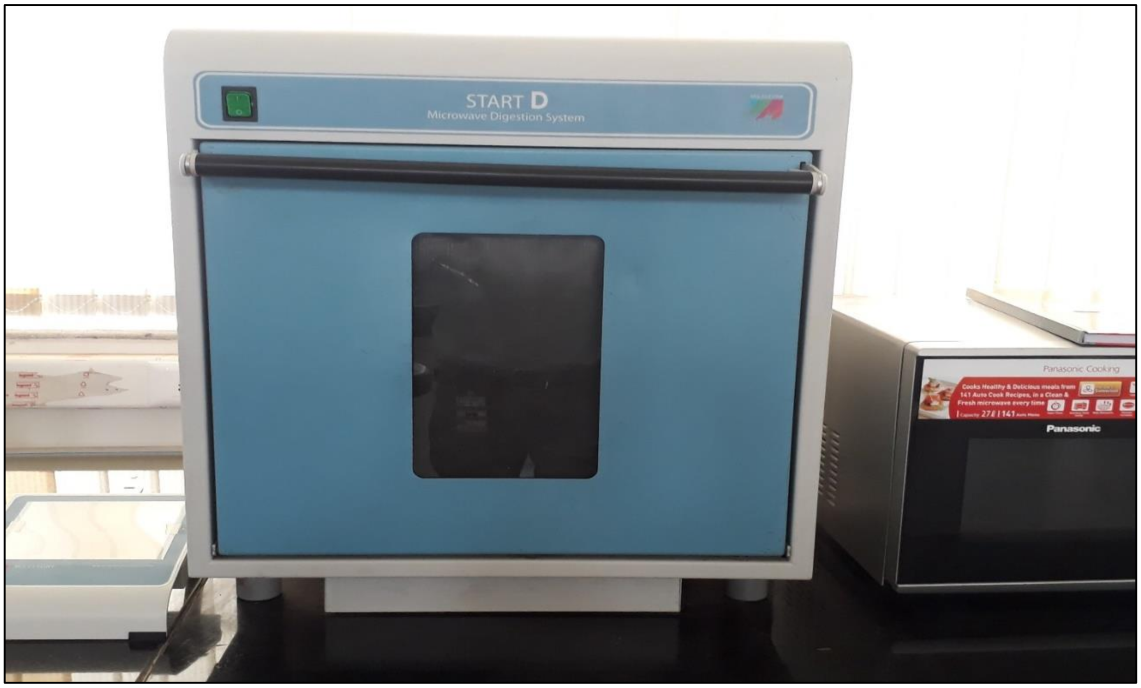

Figure 3: Microwave Digestion System

Table 1: Importance of different acid used for digestion

Nitric acid	Oxidizing acid, frequently mixed with H_2O_2, HCl, HF, H_2SO_4
Hydrogen peroxide	Increased oxidation potential
Hydrochloric acid	Non-oxidised acid, form soluble chloride, dissolves the salts weaker acids
Nitro hydrochloric acid	Forms NOCl and release chlorine as the active components, digestion of precious metals, sulphide
Hydrofluoric acid	Non-oxidized, digestion of silicates,
Sulphuric acid	Non-oxidized, dehydration of organic materials,

Guidelines for microwave acid digestion

The acids used in microwave digestion may be classified in two main groups:

1. Non-oxidizing acids, such as hydrochloric acid, hydrofluoric acid, phosphoric acid, diluted sulfuric acid and diluted perchloric acid;
2. Oxidizing acids, such as nitric acid, hot concentrated perchloric acid, concentrated sulfuric acid and hydrogen peroxide.

Nitric acid

Nitric acid has the following properties:

1. Boiling point is 120°C at 65% concentration
2. Poor oxidizing strength at concentrations less than 2M; oxidizing strength increases with
   concentration and reaction temperature
3. The most common acid for oxidation of organic matrices with this typical reaction: $(CH_2)X + 2HNO_3 \rightarrow CO_2(g) + 2NO + 2H_2O$
4. It dissolves most metals forming soluble nitrates, exceptions are Au and Pt (non oxidized) and Al, B, Cr, Ti and Zr (passivated)
5. These metals require acid mixtures or diluted nitric acid
6. Often mixed with H_2O_2, HCl and H_2SO_4
7. Available in high purity for trace level analysis.

Hydrogen peroxide

Hydrogen peroxide is an oxidizing agent ($2H_2O_2 \rightarrow 2H_2O + O_2$); added to nitric acid it reduces the nitrous vapors and it accelerates the digestion of organic samples by raising the temperature.

Hydrochloric acid

1. Hydrochloric acid has the following properties:
2. Boiling point of azeotropic mixture with H2O with 20,4% HCl is 110°C;
3. Available with 38% concentration;
4. It dissolves salts of weak acids (carbonates, phosphates) and most metals are soluble with the exception of AgCl, HgCl and TiCl;
5. Excess of HCl improves the solubility of AgCl, converted into $AgCl_2$

6. Strong complex nature
7. Widely used for iron-based alloys because of its ability to hold large amounts of chloro-complex in solution
8. Other complexes formed are Ag (I), Au (II), Hg (II), Ga (III), Tl (III), Sn (IV), Fe (II) and Fe (III).
9. It does not dissolve oxides of Al, Be, Cr, Ti, Zr, Sn and Sb; sulphates of Ba and Pb, group II fluorides, SiO_2, TiO_2 and ZrO_2.

Hydrofluoric acid

Acid digestion

1. Boiling point is 108°C at 40% concentration
2. Non-oxidizing, strong complex nature
3. Used in digestion of minerals, ores, soils, rocks and even vegetables containing silicates
4. Major use is the decomposition of silicates according with this reaction: $SiO_2 + 6HF \rightarrow H_2SiF_6 + 2H_2O$
5. Often used in combination with HNO_3 or $HClO_4$.

Evaporation/concentration

1. Following dissolution, many analyses require removal of HF to prevent equipment damage or to resolubilize insoluble fluorides;
2. Many analytes such as As, B, Se, Sb, Hg and Cr may volatilize.

Complexation

Alternative approach to remove HF from the solution, by addition of Boric acid;

1. Following reactions take place: $H_3BO_3 + 3HF \rightarrow HBF_3(OH) + 2H_2O$ and HBF3(OH) + HF -> HBF3 + H_2O;
2. 10-50 times excess Boric acid enhances reaction rate.

Sulfuric acid

1. Sulfuric acid has the following properties
2. Boiling point is 340°C at 98% concentration, exceeding the maximum working temperature of TFM Teflon vessels

3. Careful reaction monitoring is required to prevent vessel damages
4. It destroys organics by dehydrating action
5. Many sulfates are insoluble (Ba, Sr, Pb)

Perchloric acid

Perchloric acid has the following properties:

1. Boiling point is 203°C at 72% concentration;
2. Hot and concentrated is the strongest oxidizing acid;
3. Rapid, sometimes explosive, reaction with organic matrices;
4. Often mixed with nitric acid for a controllable digestion of organic matrices;
5. All perchlorate are soluble with the exception of KClO4;
6. Perchloric acid decomposes at 245°C in a closed microwave vessel, developing gaseous byproducts and a tremendous excess pressure.

Aqua regia

1. Aqua regia properties are the following:
2. Made up by hydrochloric acid and nitric acid in a 3:1 (volume/volume) mixture;
3. It produces NOCl (nitrosyl chloride), which decomposes in NO and Cl_2 up on heating;
4. It dissolves precious metals;
5. It must be freshly prepared and used immediately, otherwise it evolves chlorine gas
6. Over pressurizing and venting the vessel

Benefits of Microwave Assisted Digestion

1. Cleanliness of preparation environment
2. Reproducible digestion,
3. Improved QA/QC
4. Reduces skill level as a factor
5. Greatly reduces preparation time

Uses and applications of ICP-MS

1. One of the largest volume uses for ICPMS is in the medical and forensic field, specifically, toxicology. A physician may order a metal assay for a number of reasons, such as suspicion of heavy metal poisoning, metabolic concerns, and even hepatological issues. Depending on the specific parameters unique to each patient's diagnostic plan, samples collected for analysis can range from whole blood, urine, plasma, serum, to even packed red blood cells.
2. Another primary use for this instrument lies in the environmental field. Such applications include water testing for municipalities or private individuals all the way to soil, water and other material analysis for industrial purposes.
3. This technique is also widely used the field of radiometric dating, in which it is used to analyze relative abundance of different isotopes. ICP-MS is more suitable for this application than the previously used Thermal Ionization Mass Spectrometry, as species with high ionization energy such as Osmium (Os) and Tungsten (Hf-W) can be easily ionized.
4. In the field of flow cytometry, a new technique uses ICP-MS to replace the traditional fluorochromes. Briefly, instead of labeling antibodies (or other biological probes) with fluorochromes, each antibody is labeled with a distinct combination of lanthanides.
5. Regardless of the sample type, blood, water, etc., it is important that it be free of clots or other particulate matter, as even the smallest clot can disrupt sample flow and block or clog the sample tips within the spray chamber. Very high concentrations of salts, e.g. sodium chloride in sea water, can eventually lead to blockages as some of the ions reunite after leaving the torch and build up around the orifice of the skimmer cone. This can be avoided by diluting samples whenever high salt concentrations are suspected, though at a cost to detection limits.
6. Quantification of proteins and bio molecules by icp-ms: There is an increasing trend of using ICP-MS as a tool in speciation analysis normally involves a front end chromatograph separation and an elemental selective detector such as AAS and ICP-MS. For example, ICP-MS may be combined with size exclusion

chromatography and quantitative preparative native continuous polyacrylamide gel electrophoresis for identifying and quantifying native metal in bio fluids. Also the phosphorylation status of proteins can be analyzed.

7. A new type of protein tagging reagents called metal coded affinity tags (Me CAT) were introduced to label proteins quantitatively with metals, especially lanthanides. The Me CAT labeling allows relative and absolute quantification of all kind of proteins or other biomolecules like peptides. Me CAT comprises a site specific biomolecule tagging group with at least a strong chelate group which binds metals.
8. The Me CAT labeled proteins can be accurately quantified by ICP-MS down to low attomol amount of analyte which is at least 2–3 orders of magnitude more sensitive than other mass spectrometry based quantification methods.
9. By introducing several Me CAT labels to a biomolecule and further optimization of LC-ICP-MS detection limits in the zeptomol range are within the realms of possibility. By using different lanthanides Me CAT multiplexing can be used for pharmacokinetics of proteins and peptides or the analysis of the differential expression of proteins e.g. in biological fluids.

Case Study

The study has been conducted in Dhimbe reservoir in Maharashtra and evaluated fourteen metals namely chromium (Cr), manganese (Mn), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), selenium (Se), arsenic (As), strontium (Sr), cadmium (Cd), tin (Sn), antimony (Sb), mercury, (Hg) and lead (Pb) has been studied in freshwater mollusk, *Lamellidens marginalis*

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Table 1 Concentrations (ppm) of Cr, Mn, Co, Ni, Cu, Zn, and Se in *Lamellidens marginalis* muscle tissue sample collected from 20 different sites of Dhimbe reservoir

Sites	Cr	Mn	Co	Ni	Cu	Zn	Se
S1	3.99 ± 0.11	170.49 ± 4.89	0.29 ± 0.08	5.54 ± 0.07	2.29 ± 0.06	10.00 ± 0.26	1.68 ± 0.18
S2	6.25 ± 0.11	55.53 ± 1.05	0.48 ± 0.07	9.12 ± 0.05	5.14 ± 0.09	20.00 ± 0.30	3.18 ± 0.09
S3	3.35 ± 0.12	57.46 ± 2.24	0.22 ± 0.05	4.67 ± 0.04	1.96 ± 0.07	15.09 ± 0.51	1.75 ± 0.03
S4	3.60 ± 0.11	399.95 ± 13.70	0.26 ± 0.02	5.47 ± 0.03	1.46 ± 0.05	12.54 ± 0.34	1.37 ± 0.02
S5	6.19 ± 0.17	49.06 ± 1.34	0.30 ± 0.03	7.08 ± 0.04	1.78 ± 0.05	9.82 ± 0.20	2.03 ± 0.03
S6	5.91 ± 0.23	201.75 ± 8.17	0.30 ± 0.06	5.64 ± 0.02	3.31 ± 0.13	13.63 ± 0.45	2.09 ± 0.45
S7	2.98 ± 0.14	11.65 ± 0.55	0.29 ± 0.04	5.16 ± 0.03	1.13 ± 0.05	9.83 ± 0.40	1.39 ± 0.28
S8	4.22 ± 0.14	5.17 ± 0.18	0.36 ± 0.03	7.14 ± 0.03	1.55 ± 0.05	11.63 ± 0.34	1.90 ± 0.04
S9	2.85 ± 0.15	24.05 ± 1.36	0.29 ± 0.01	5.42 ± 0.03	1.62 ± 0.09	5.63 ± 0.27	1.25 ± 0.09
S10	2.45 ± 0.12	7.57 ± 0.42	0.25 ± 0.03	5.87 ± 0.04	1.52 ± 0.08	5.04 ± 0.25	1.31 ± 0.16
S11	2.65 ± 0.13	48.32 ± 2.55	0.33 ± 0.03	7.12 ± 0.06	2.43 ± 0.12	8.68 ± 0.43	1.63 ± 0.04
S12	2.38 ± 0.12	46.70 ± 2.70	0.36 ± 0.01	6.25 ± 0.04	2.11 ± 0.12	8.23 ± 0.45	1.84 ± 0.31
S13	1.68 ± 0.12	14.72 ± 1.16	0.23 ± 0.03	4.09 ± 0.04	0.97 ± 0.07	5.08 ± 0.38	1.21 ± 0.21
S14	2.92 ± 0.12	81.52 ± 3.86	0.41 ± 0.02	7.46 ± 0.03	2.09 ± 0.09	9.03 ± 0.39	2.12 ± 0.22
S15	1.28 ± 0.11	35.87 ± 3.46	0.21 ± 0.02	3.33 ± 0.02	0.53 ± 0.05	3.61 ± 0.32	1.05 ± 0.12
S16	1.56 ± 0.09	6.00 ± 0.38	0.30 ± 0.02	4.42 ± 0.02	1.13 ± 0.07	4.85 ± 0.31	1.54 ± 0.25
S17	1.30 ± 0.08	2.20 ± 0.15	0.27 ± 0.08	3.67 ± 0.02	1.34 ± 0.10	3.72 ± 0.26	1.27 ± 0.14
S18	1.60 ± 0.08	23.92 ± 1.49	0.33 ± 0.03	4.46 ± 0.02	0.89 ± 0.05	5.75 ± 0.32	1.55 ± 0.09
S19	1.09 ± 0.08	26.12 ± 2.32	0.25 ± 0.02	2.97 ± 0.03	1.30 ± 0.11	5.38 ± 0.45	1.18 ± 0.23
S20	0.95 ± 0.006	29.96 ± 2.47	0.27 ± 0.002	3.02 ± 0.02	0.42 ± 0.003	2.91 ± 0.020	1.20 ± 0.005

Data expressed as mean ± SE ($n = 6$)

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Table 2 Concentrations (ppm) of As, Sr, Cd, Sn, Sb, Hg, and Pb in *Lamellidens marginalis* muscle tissue sample collected from 20 different sites of Dhimbe reservoir

Sites	AS	Sr	Cd	Sn	Sb	Hg	Pb
S1	0.36 ± 0.05	5.21 ± 0.15	0.14 ± 0.03	1.09 ± 0.02	0.10 ± 0.06	5.18 ± 0.01	0.92 ± 0.02
S2	0.40 ± 0.01	3.26 ± 0.06	0.08 ± 0.08	1.58 ± 0.03	0.08 ± 0.08	5.66 ± .0.01	1.20 ± 0.02
S3	0.22 ± 0.02	2.00 ± 0.08	0.11 ± 0.04	0.79 ± 0.03	0.03 ± 0.04	2.15 ± 0.07	0.55 ± 0.02
S4	0.26 ± 0.02	10.06 ± 0.34	0.06 ± 0.02	0.86 ± 0.03	0.03 ± 0.03	2.32 ± 0.02	0.56 ± 0.02
S5	0.27 ± 0.01	2.56 ± 0.07	0.06 ± 0.06	1.11 ± 0.03	0.04 ± 0.03	2.52 ± 0.03	0.61 ± 0.01
S6	0.51 ± 0.01	6.29 ± 0.28	0.09 ± 0.02	0.71 ± 0.02	0.03 ± 0.02	1.83 ± 0.01	0.44 ± 0.01
S7	0.25 ± 0.02	1.37 ± 0.07	0.06 ± 0.02	0.61 ± 0.03	0.03 ± 0.04	1.57 ± 0.05	0.43 ± 0.02
S8	0.29 ± 0.05	1.35 ± 0.05	0.05 ± 0.07	0.88 ± 0.03	0.04 ± 0.02	2.21 ± 0.09	0.47 ± 0.01
S9	0.29 ± 0.04	1.23 ± 0.07	0.04 ± 0.09	0.59 ± 0.03	0.02 ± 0.02	1.48 ± 0.03	0.32 ± 0.01
S10	0.22 ± 0.01	1.17 ± 0.06	0.04 ± 0.03	0.61 ± 0.03	0.02 ± 0.02	1.36 ± 0.05	0.34 ± 0.01
S11	0.26 ± 0.01	2.14 ± 0.11	0.04 ± 0.09	0.62 ± 0.03	0.02 ± 0.02	1.51 ± 0.01	0.30 ± 0.01
S12	0.29 ± 0.06	1.71 ± 0.10	0.05 ± 0.01	0.55 ± 0.03	0.02 ± 0.02	1.45 ± 0.04	0.27 ± 0.01
S13	0.17 ± 0.03	1.00 ± 0.08	0.03 ± 0.07	0.41 ± 0.03	0.01 ± 0.01	0.97 ± 0.03	0.19 ± 0.01
S14	0.44 ± 0.08	2.87 ± 0.13	0.06 ± 0.09	0.67 ± 0.03	0.03 ± 0.01	1.64 ± 0.04	0.32 ± 0.01
S15	0.15 ± 0.02	0.91 ± 0.08	0.03 ± 0.02	0.28 ± 0.02	0.01 ± 0.01	0.74 ± 0.04	0.15 ± 0.01
S16	0.26 ± 0.06	0.57 ± 0.04	0.04 ± 0.01	0.39 ± 0.02	0.02 ± 0.01	1.05 ± 0.05	0.21 ± 0.01
S17	0.18 ± 0.02	0.52 ± 0.04	0.03 ± 0.02	0.30 ± 0.02	0.02 ± 0.01	0.88 ± 0.03	0.16 ± 0.01
S18	0.25 ± 0.04	1.14 ± 0.07	0.05 ± 0.05	0.38 ± 0.02	0.02 ± 0.01	1.13 ± 0.03	0.20 ± 0.01
S19	0.21 ± 0.06	0.74 ± 0.06	0.03 ± 0.01	0.24 ± 0.02	0.01 ± 0.01	0.78 ± 0.02	0.13 ± 0.01
S20	0.19 ± 0.009	0.81 ± 0.006	0.03 ± 0.009	0.22 ± 0.001	0.01 ± 0.001	0.79 ± 0.007	0.12 ± 0.005

Data expressed as mean ± SE ($n = 6$)

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Plant Bio–Regulators for Improving Crop Productivity and Post–Harvest Quality under Climate Change

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Abstract

Reliable large−scale agriculture production is an essential component of global food security; however, sustained efforts are needed to ensure optimized resilience under diverse crop stress conditions. Climate changes are expected to increase the frequency and intensity of both abiotic and biotic stress. Plant bio−regulators (PBRs) play an important role in stress resilience, yet the concentration and composition of these PBRs are also dependent on climate variables. In this research, impact of PBRs on crop yields, water productivity and post−harvest quality of major crops (wheat, soybean, sorghum, onion and eggplant) under water scarce conditions was studied. Potential PBRs included: potassium nitrate (KNO_3), salicylic acid, sodium benzoate (SB), thio−urea (TU), gibberellin (GA_3) and ortho-silicic acid (OSA) were applied exogenously at 3−4 critical growth stages of specific crop as main treatments. The uniquely designed line−source sprinkler system (LSS) was used to apply varied levels of irrigation water (IW) ranged between 0−1.0 times the CPE (cumulative open pan evaporation) as sub–treatments. The application of PBRs mitigated water stress and significantly improved yields, water productivity and post−harvest quality. The PBRs maintained higher leaf water content, lower canopy temperature, modulated the stomatal opening and ultimately the source–sink relations thereby improving the yield and productivity under deficit irrigation. Particularly PBRs like thio–urea (10 mM), sodium benzoate (100 mg L^{-1}), KNO_3 (1.5%) and salicylic acid (10 µM) were found effective to mitigate water stress in wheat, sorghum, onion and eggplant, respectively. Thus relative response of PBRs is highly specific environment conditions and varies with crop to crop. PBRs also helped to improve significantly physicochemical and functional quality characteristics *viz.*, rehydration ratio, protein content, total soluble sugar, total phenolics content and pyruvic acid in water deficits. It is concluded that conjunctive use of PBRs along with

supplemental irrigation present viable water stress mitigation strategy, improved crop quality and water productivity under the climate change.

Introduction

The crop productivity is exposed to different types of abiotic stresses (heat, cold, drought, flood, salinity, mineral deficiency, toxicity, chilling or freezing stress etc.) and potential yield are seldom achieved with stress. The present challenges *viz.,* water and soil pollution, urbanization, global climate change etc. further add up to the situation. Overall effect of abiotic stresses depends on the intensity and length of stress varies with growth stages and cultivars. Abiotic stresses are linked with natural phenomenon and their scale varies at temporal and special dimension. The changing climate poses serious threats to global agricultural production and place unprecedented pressures on the sustainability of agriculture industry. On the other hand, population growth and health–conscious consumers demand more and better food products. In addition to restricting carbon emission and conserving resources, adaption of abiotic stress mitigation strategies for sustainable vegetable production will be the single most important step that we take in the future.

Water stress and moisture availability in soil exert great influence on plant growth through direct and indirect effects viz., root development, vegetative growth, uptake and mobilization of nutrients. It also affects turgidity, normal metabolism, cell division and enlargement which influence overall crop growth response. Bio−regulators (PBRs) play an important role to control the physiological metabolic activities in crops under water stress conditions. The research needs to be focused on increasing water use efficiency and control of metabolic activities in crops through use of PBRs under varied irrigation water regimes in different crops cultivated in water stressed regions. For this purpose, creation of large number of water levels which vary systematically from one end of single plot to the other are needed. The line source sprinkler technique facilitates the application of progressively decreasing amounts of water at increasing perpendicular distance from the line source (Hank, 1980). Therefore present research aimed to develop of crop water functions and impact of bio−regulators and supplemental irrigation on productivity and post-harvest qualities of different crops grown under different water stressed regions using line source sprinkler plot irrigation system as stress mitigation strategy for climate resilient agriculture.

Crop yield is primarily water-limited in arid and semi-arid regions. Under limited irrigation water, reduction in grain yield and its post-harvest quality due to restricted water availability depends on degree, duration and timing of imposed water deficit. Many studies on plant responses to water deficits (stress) were carried out by investigators concerned with agricultural production, environment and resources, and macroscopic physics of soil, plant, and atmospheric water. As expected, the physiological and metabolic aspects of these studies were often weak and, on the other hand, studies carried out by metabolism-oriented biologist's frequently slighted important physical facets. Nevertheless, laudable investigations, especially during the last few years, have been sufficient to warrant optimism about substantial progress in the near future. Overall research on crop resistance or tolerance to abiotic stresses has not received much attention. Therefore, well understanding of plant responses to the interactive effect of water and nutrients deficits, how these deficits may theoretically affect plant processes using PBRs are the needs of the future line of research.

The helpful role of PBRs in improving the crop yields and water productivity through the regulation of physiological processes and plant–water relations has recently been elaborated through several reports (Khan *et al*., 2015; Srivastava *et al*., 2016; Wakchaure *et al*., 2016a&b). Though the most of PBRs have been tried under pot or controlled conditions, those reported for their viability include salicylic acid (Fayez and Bazaid, 2014); sodium benzoate (Beltrano *et al*., 1999; Kumar *et al*., 2014); thiourea (Bhunia *et al*., 2015; Wakchaure *et al*., 2016) and potassium nitrate (Gimeno *et al*., 2014). Nevertheless, there is general lack of information on the relative responses of PBRs under field conditions (Wakchaure *et al*., 2016a&b). So, the other objective was to evaluate the effectiveness of selected PBRs on yield, water productivity and post-harvest quality under variable water deficits in semi-arid Deccan Plateau of India.

Case studies and salient research findings

1. Responses of Wheat (HD−2189) to PBRs under varied water deficit

The interactive effect of irrigation regimes and PBRs on grain yield and water productivity of spring wheat (*Triticum aeastivum* L) were evaluated during three years (2012−15) using LSS (Fig.1). PBRs applied through exogenous sprays included: 10 mM thio-urea (TU), 10 uM salicylic acid (SA), 15 g L^{-1}potassium nitrate (KNO_3), 25 ppm gib-berellic acid (GA_3), 8 ppm ortho-silicic acid (OSA) at crown root initiation (CRI), flag leaf and seed milking stages and control (no PBR). Seven irrigation levels were generated through a line source sprinkler system (LSS) viz., application of irrigation water (IW) equalling 1.0, 0.85, 0.70, 0.55, 0.40, 0.25 and 0.10 times the CPE (cumulative open pan evaporation). The maximum yield obtained with PBRs varied between 4.11–4.46 Mg ha^{-1} at IW: CPE 0.85 against 4.09 Mg ha^{-1}without PBR. While the yield decline equalled 0.35–0.42 Mg $ha^{-1}$for every 0.1 IW: CPE for PBRs against 0.43 Mg ha^{-1}without PBR (. The overall improvement in grain yield and total biomass with PBRs ranged between 5.9–20.6% and 4.8–15.3%, respectively. Specifically TU and SA showed a major role under medium (IW:CPE 0.40–0.69) and severe (0.10–0.39)stress conditions in terms of maintenance of leaf water content, modulating the stomatal opening and better water usage and thereby improved yield by 0.41–0.88 Mg ha^{-1} The maximum water productivity ranged between 1.20–1.35 kg m^{-3} with different PBR's while it was 1.18 kg m^{-3} without PBR and the latter could be achieved with 19–56% lesser irrigation water with PBRs. Overall conclusions are that the effects of deficit irrigation could be substantially enhanced in terms of grain yield and water productivity when used conjunctively with PBRs like TU and SA. Thus for integrating PBRs with supplemental irrigation, large scale testing is required for defining their economic spray schedules under water scarcity conditions (Wakchaure *et al*., 2016a).

Fig.1. Experimental setup and evaluation of PBRs using line source system (LSS)

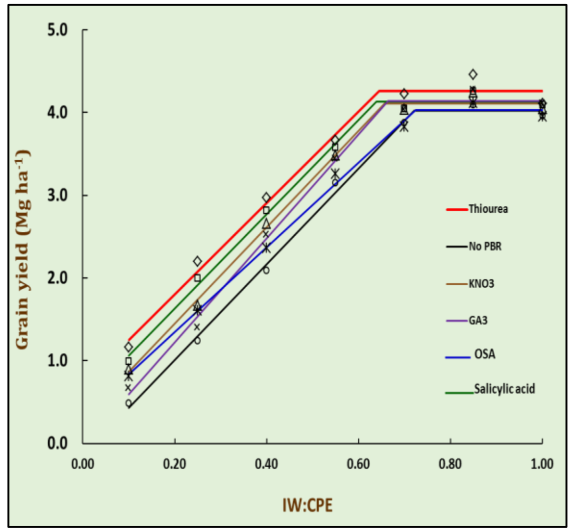

Fig.2 Relative response of PBRs to grain yield of wheat

2. Effect of plant bio-regulators on growth, yield and water production functions of sorghum [*Sorghum bicolor* (L.) Moench]

Effect of plant bio-regulators (PBRs) and supplemental irrigation on growth and grain yield of sorghum [*Sorghum bicolor* (L.) Moench] was evaluated (Fig.3) during two years (2015−2016). Exogenous application of PBR's included: 10 μM salicylic acid (SA), 100 mg L^{-1} sodium benzoate (SB), 500 ppm thiourea (TU), 1.5% potassium nitrate (KNO_3) at seedling elongation (20 DAS), reproductive (50 DAS) and panicle emergence (75 DAS) stages and control (no spray of PBR). The maximum grain yield (3.60–3.88 Mg ha^{-1}) was obtained at IW: CPE 0.80 and declined @ 0.43–0.49 Mg ha^{-1} for every 0.1 IW: CPE for PBRs and the corresponding values were 3.49 and 0.53 Mg ha^{-1} without PBR. The application of PBR's mitigated water stress and improved gain yield, straw yield and water productivity by 6.8–18.5%, 5.7−14.7% and 1.16−1.41 kg m^{-3}, respectively (Fig.4). SA was more effective under moderate (IW: CPE 0.79–0.50) while SB and TU were better under severe water deficits (IW: CPE 0.49–0.05). Thus SB and TU present viable option to reduce water use by 25.2-49.7% under the conditions of deficit irrigation (Wakchaure *et al*., 2016)

Fig.3. Sorghum response to PBRs

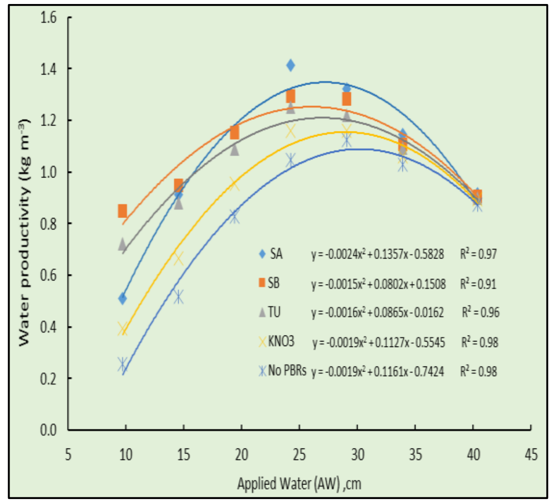

Fig.4. Water productivity as expressed as the function of PBR's at various quantities of applied water (AW)

3. Growth, bulb yield, water productivity and quality of onion (*Alliumcepa L.*) as affected by deficit irrigation regimes and exogenous application of plant bio–regulators

Effect of plant bio–regulators (PBRs) viz., potassium nitrate (KNO_3, 15 g L^{-1}), thio–urea (TU, 500 ppm), salicylic acid (SA, 10 μM), gibberellic acid (GA3, 25 ppm) and sodium benzoate (SB, 150 mg L−1) for two years (2015–17) under various levels of deficit irrigation created using line source sprinkler system (LSS) was evaluated in onion (*Allium cepa* L.) (Fig.5). The crop could sustain little water deficits and its bulb yield declined to 0.84, 0.66, 0.48, 0.35, 0.24 and 0.16 when irrigation water (IW) applied equalled 0.85, 0.70,0.55, 0.40, 0.25 and 0.10 times the pan evaporation (CPE) against maximum yield at full irrigation (IW:CPE1.00). Application of PBRs helped to mitigate the water stress through maintenance of leaf water content, modulating the canopy temperature and better water usage thereby improving average bulb yields by10.1–25%. Especially KNO_3 and TU were more effective under low to medium water deficits. The water productivity ranged between 7.78 and 9.61 with PBRs against 7.36 kg m^{-3} under control (Fig.6). The overall water saving was 18.3, 25.7, 48.4 and 63.8% with PBRs namely GA3, SA, TU and KNO_3, respectively. The marketable quality monitored in terms of bulb weight, geometric mean diameter and sphericity was significantly reduced with water deficits while it improved with PBRs. Among the other physicochemical and functional quality characteristics of the onion bulb, rehydration ratio, protein content, total soluble sugar, total phenolics content and pyruvic acid were lowered by water deficits. These were improved significantly with PBRs. Thus it was concluded that combining PBRs like KNO_3 and TU can further facilitate to implement deficit irrigation technology for sustaining productivity and quality of onion under water scarce conditions.

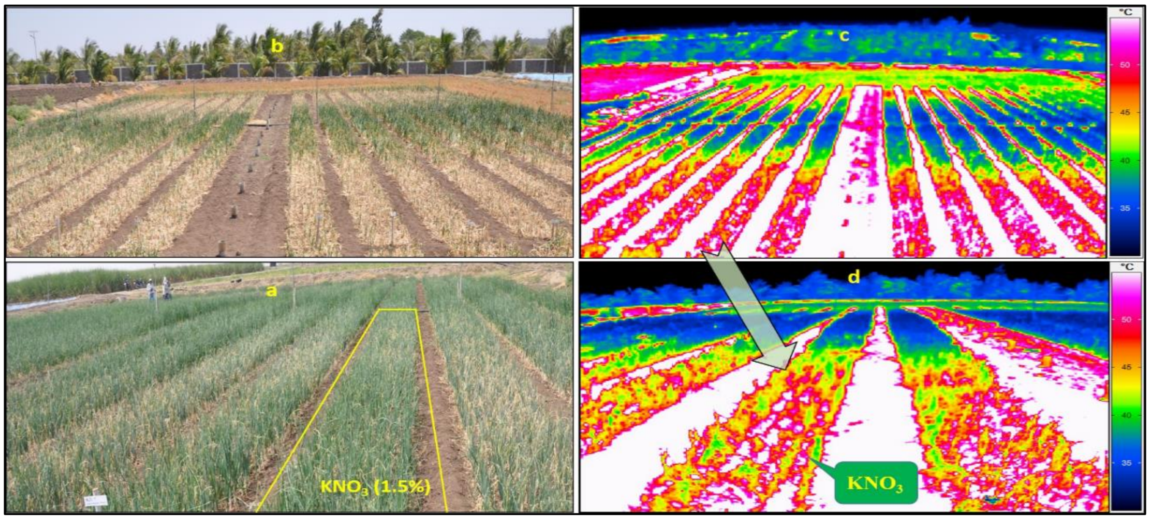

Fig.5. Onion responses to PBRs under varied irrigation water levels as depicted in IR image

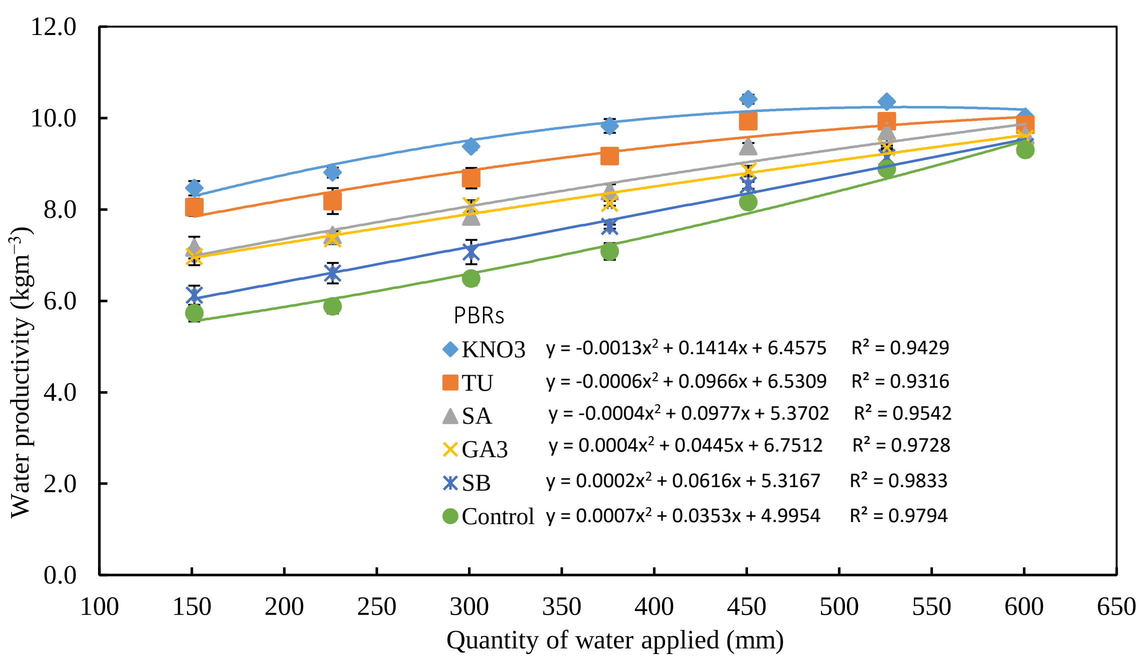

Fig.6. Water productivity as a function of PBRs and quantity of applied water (AW) during onion growth period

4. Exogenous application of PBRs for enhancing water productivity of eggplant (cv. Panchganaga)

Exogenous sprays of PBRs viz., 15 g L^{-1} potassium nitrate (KNO_3), 10 mM salicylic acid (SA), 500 ppm thiourea (TU) and 100 ml L^{-1} microbial biopolymer (BP) were applied at vegetative, flowering, fruit formation and development stages of eggplant. The interactive effect of PBRs, BP and supplemental irrigation on yield formation was evaluated using line source sprinkler system (LSS) at seven levels of irrigation water (IW) equalling to 0.90, 0.75, 0.60, 0.45, 0.30, 0.15 and 0.0 times of cumulative open pan evaporation (CPE). Application of PBRs and biopolymer significantly improved marketable yield and water productivity over control (Fig.7) . PBRs like salicylic acid (10 µM) at higher and KNO_3 (15 g L^{-1}) at lower irrigation levels present viable option to mitigate water stress and reduce water use by 50 per cent. Nutritional quality (TSS, protein contents and antioxidant enzymes activities) of brinjal enhanced significantly with PBR’s underwater deficits. Identified plants PBR’s like KNO_3, SA help to mitigate water stress and can help to boost the productions vis-a-vis profitability of onion under water scarcity conditions. Similarly use of microbial biopolymer can be better alternative for chemical PBRs for enhancing yield

Fig. 7. Relative response of PBRs and biopolymer to eggplants

Conclusions

- PBRs like thiourea (10 mM), sodium benzoate (100 mg L^{-1}), potassium nitrate and salicylic acid (10 µM) helped to mitigate water stress for wheat, sorghum, onion and eggplants, respectively
- The response of PBRs is highly specific environment conditions and varies with crop to crop
- The post-harvest quality measured in terms of physiochemical and functional characteristics (TSS, protein contents, total phenolics and antioxidant enzymes activities) of vegetable crops enhanced significantly with PBRs under water deficits
- Overall use of PBRs can help to boost the productions vis-a-vis profitability of crops under climate change in water scarce regions

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Mushroom Farming an Agribusiness for Doubling Farmers Income under Climate Change

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Introduction

A mushroom, is the fleshy, spore–bearing fruiting body of a fungus, typically produced above ground on soil or on its food source. Edible, medicinal, and wild mushrooms are the three major components of the global mushroom industry. Out of 2000 edible mushrooms species, hardly 20–30 are cultivable commercially. The commercial mushroom cultivation has grown up 30 folds in almost all the parts of the world during last three decades, the world mushroom production achieved the growth rate of about 10%. Lentinula and four other genera (*Pleurotus*, *Auricularia*, *Agaricus*, and *Flammulina*) account for 85% of the world's total supply of cultivated edible mushrooms. Globally, China is the leading producer of mushrooms with more than 70% of the total global production, which is attributed to community based farming as well as diversification of mushrooms.

Mushroom production-recycling of agro-wastes

Diversification in any farming system imparts sustainability. Mushrooms are one such component that not only impart diversification but also help in addressing the problems of quality food, health and environmental related issues under current climate change. Commercial production of edible mushrooms represents unique exploitation of the microbial technology for the bioconversion of the agricultural, industrial, forestry and household wastes into nutritious food (mushrooms). Indoor cultivation of mushrooms utilizes the vertical space and is regarded as the highest protein producer per unit area and time-almost 100 times more than the conventional agriculture and animal husbandry. This hi-tech horticulture venture has a promising scope to meet the food shortages, without undue pressure on land. For the people of a developing country like India, the two main issues are the quality food and unemployment besides the environmental issues and these issues can be resolved by popularizing mushroom cultivation amongst the rural masses and the young generation. Thus one of the major areas that can contribute towards goal of conservation of natural resources as well as increased productivity is recycling of agro-wastes including agro-industrial waste for mushroom farming. Even if we can recycle 2% of agrowastes, we can produce >4 times of present world mushroom production. Utilising these wastes for growing mushrooms can enhance income and impart higher level of sustainability.

Can mushroom cultivation: an agribusiness under Climate Change?

India produces about 700 million tonnes of agricultural wastes per annum and a major part of it is left out to decompose naturally or burnt *in situ*. This can effectively be utilized to produce highly nutritive food such as mushrooms and spent mushroom substrate can be converted into organic manure/vermi–compost. Even if we can recycle 2% of agro-wastes, we can produce >4 times of present world mushroom production. India having diversified (temperate, subtropical and tropical) agro-climatic conditions of varied temperature (–15 to 40°C) and relative humidity (52–95%). Thus considering the surplus agro–wastes, diversified agro-climatic conditions and high water productivity of mushrooms (1 kg/25 L water); mushroom cultivation definitely as an agribusiness under climate change for doubling the farmer's income.

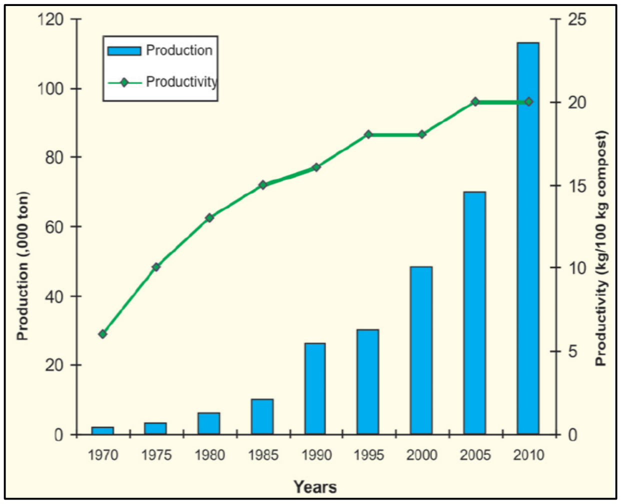
Mushroom farming statistics and round the year cultivation

Mushroom farming today is being practiced in more than 100 countries and its production is increasing at an annual rate of 6-7%. In some developed countries of Europe and America, mushroom farming has attained the status of a high-tech industry with very high levels of mechanization and automation. China alone is reported to grow more than 20 different types of mushroom at commercial scale and mushroom cultivation has become China's sixth largest industry. Presently, three geographical regions– Europe, America and East Asia contribute to about 96% of world mushroom production. With the rise in the income level, the demand for mushrooms is bound to increase in other parts of the world as well. China has been producing mushrooms at very low costs with the help of seasonal growing, state subsidies and capturing the potential markets in the world with processed mushrooms at costs not remunerative to the growers in other mushroom producing countries.

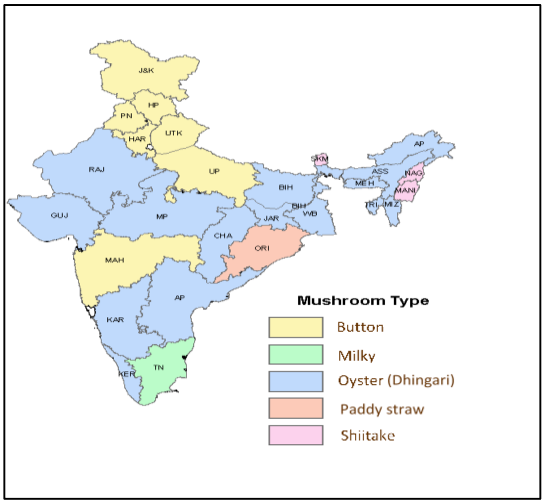
In India the mushroom production systems are mixed type i.e. both seasonal farming as well as high-tech industry (Fig. 1). Mushroom production in the country started in the 70s but growth rate, both in terms of productivity as well as production has been phenomenal (Fig.2). In seventies and eighties button mushroom was grown as a seasonal crop in hills, but with the development of the technologies for environmental controls and increased understanding of the cropping systems, mushroom production shot up from mere 5000 tonnes in 1990 to over 2,00,000 tonnes in 2015. Today, commercially grown species are button and oyster mushrooms, followed by other tropical mushrooms like paddy straw mushroom, milky mushroom, etc. The concentrated areas of production in India are the temperate regions for the button mushroom, tropical and sub-tropical regions for oyster, milky, paddy straw and other tropical mushrooms. Two to three crops of button mushroom are grown seasonally in temperate regions with minor adjustments of temperature in the growing rooms; while one crop of button mushroom is raised in North Western plains of India seasonally. Oyster, paddy straw and milky mushrooms are grown seasonally in the tropical/sub-tropical areas from April to October. The areas where these mushrooms are popularly grown are Orissa, Maharashtra, Tamil Nadu, Kerala, Andhra Pradesh, Karnataka and North Eastern region of India. The different areas of mushrooms production in India as given in fig. 2. Some commercial units are already in operation located in different regions of our country and producing the quality mushrooms for export. The present production of white button mushroom is about 85% of the total production of mushrooms in the country.

Commercial mushroom unit Seasonal mushroom growing

Fig. 1. Mushroom production systems in India



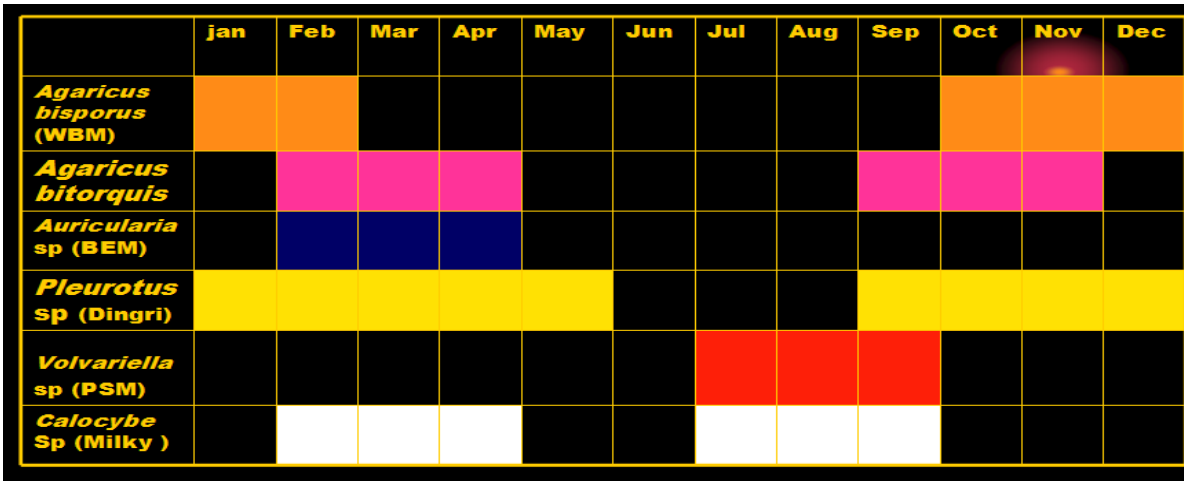
Mushroom production and productivity



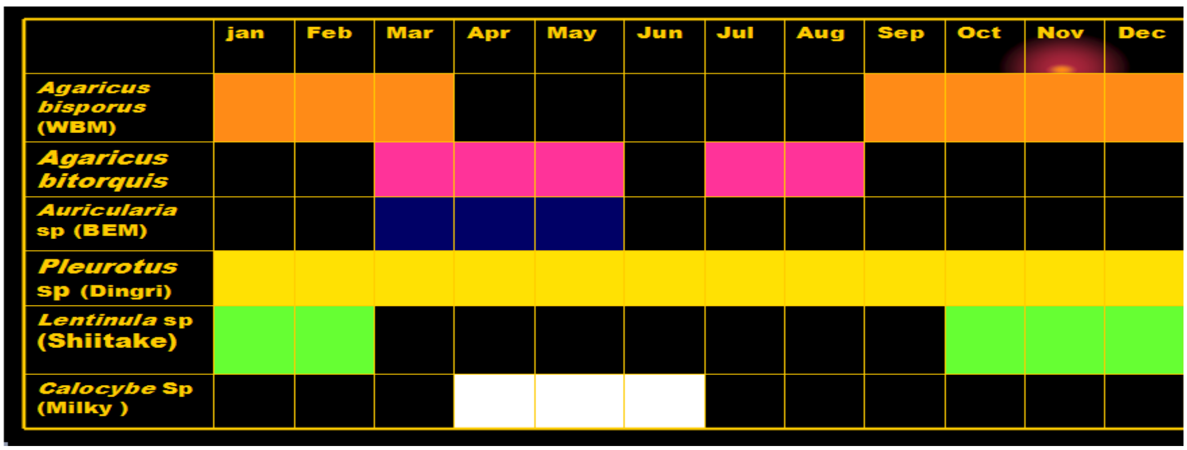
Diversified mushroom growing areas

Fig. 2. Mushroom production, productivity and diversified mushroom growing areas in India

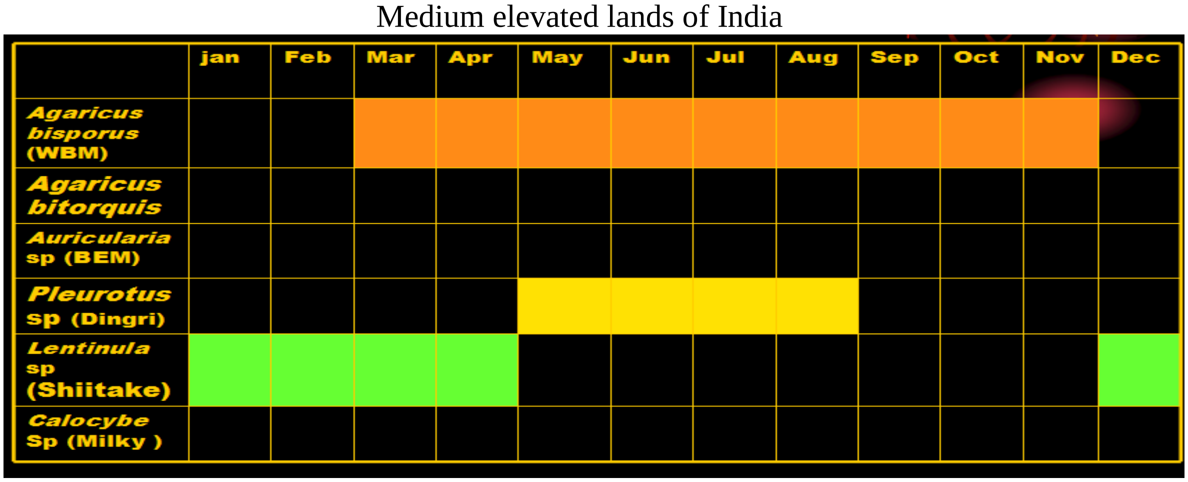
Mushrooms are grown seasonally as well as in state-of-art environment controlled cropping rooms all the year round in the commercial units. Mushroom growing is a highly labour-oriented venture and labour availability is no constraint in the country and two factors, that is, availabilities of raw materials and labour make mushroom growing economically profitable in India. Moreover, scope for intense diversification by cultivation of other edible mushrooms like oyster, shiitake, milky and medicinal mushrooms are additional opportunities for Indian growers. By just diverting 1% of agro-wastes towards mushroom production, India can produce 3 million tonnes of mushroom and about 15 million tonnes of compost. Being an indoor crop, the commodity provides immense opportunities for empowerment of rural and urban women through cultivation and also the production of value-added products. Mushrooms possess significant health benefits and medicinal properties including anti-cancer effect. India can enter into a big and lucrative international trade in the medicinal mushrooms, presently monopolized by some East Asian countries and America. There is tremendous scope for diversifying mushroom export by including other mushroom species. With the current growth rate of the Indian economy, the domestic market too for the mushrooms is likely to enlarge sooner than later. India endowed with varied climate and thus has the inherent advantage for the diversification of mushroom is in different regions and seasons of the country.



Plains of India



Medium elevated lands of India



High elevated hilly lands

Fig.3. Round the year mushroom cultivation- diversification of mushroom

Thus different mushrooms can be cultivated round the in plains, medium elevated and hilly areas (Fig.3). Scientific and technical manpower on mushrooms in the country coupled with the skill-upgradation will cater to the technological needs of the industry.

Mushroom industry is getting its due support both from the public as well as private funding agencies and is making rapid strides under the Govt.'s policy of liberalization and globalization.

Major issues which are confronting and are likely to continue to do so in foreseeable future are: i) population growth, ii) income growth and iii) urbanization. During the next 18- 20 years these factors will determine the demand for food in general and mushrooms in particular throughout the world, especially in the developing countries. The important lesson to be learnt from this scenario is that it will be appropriate to diversify in terms of different types of mushrooms, the mushroom products as well as the regions for supply of different mushrooms and products. This will provide buffering to counter the ill effects of fluctuations in prices and demand. It is possible to cultivate mushrooms under varied climatic conditions. Some of the important mushrooms for temperate, sub-tropical and tropical conditions are briefly described below details (fig.4).

Diversified Mushrooms types

Temperate mushrooms

a. Button mushroom: The button mushroom is most popular variety both for domestic and export market. At global level it ranks first. The main problems are quality of raw materials particularly, wheat/paddy straw, chicken manure and sometimes gypsum resulting in poor quality of compost and poor yield. Besides, high cost of imported cultures/ spawn, machineries and casing material are other impediments. In recent years even increasing cost of electricity has given severe blow to the mushroom industry. Several medium scale projects have started growing mushroom targeting big city markets utilizing indigenous machinery and equipment. However, during winter season hundreds of seasonal growers undertake button mushroom production particularly in Northern States targeting big cities like Delhi, Chandigarh, etc.

b. Oyster mushroom: This mushroom has species suitable for both temperate and sub-tropical regions. For temperate region *Pleurotus ostreatus, P. florida* (winter strain) and *P. fossulatus* (Kabul dhingri), *P. eryngii* (King oyster) are ideal. The areas suitable for button mushroom are equally suitable for the cultivation of these species. Oyster mushroom in dried form can be exported.

c. Shiitake: This is one of the most popular mushrooms both as food and medicine. At global level it has second position and contributes 24% to total mushroom production. In India, its cultivation is neglegible. However, experiments show that this variety can be successfully grown on saw dust when temperature is about 20˚C. There is good scope for the cultivation in the country. This may become a popular variety in domestic market and has good potential for export.

d. Flammulina velutipes: Flammulina velutipes, commonly referred as winter mushroom, is popular in East Asian countries and is known for its nutritional and medicinal value. It can be cultivated on saw dust of broad leaves supplemented with 10% wheat bran. This is a temperate mushroom fruiting in the temperature range of 10-14˚C. This mushroom can be grown in variety of containers

Subtropical mushrooms

a. Summer white button mushroom: This variety also belongs to genus *Agaricus* - *A.bitorquis*. Since it grows well in temperature upto 24˚C it is suitable for cultivation in subtropical region. However it is sensitive to false truffle due to its production at higher temperature and thus the perfect pasteurization of compost & casing material is a must.

b. Oyster mushroom: Most of the oyster mushroom species are subtropical in nature and grow well in temperature range of 20-32˚C. The most popular ones are *P. sajor-caju, P. flordia, P. flabellatus, P. eous*. These varieties particularly *P. florida* and *P.sajor-caju* are most popular in the country.

c. *Shiitake:* There are strains of *Lentinula edodes* which can be grown in temperature range upto 24-25˚C. Hence ideal in subtropical areas.

Tropical Mushrooms

a. *Paddy straw mushroom (Volvariella* spp.*):* This variety is most popular for its taste and flavour in South East and far East Asian countries. Its flavour is excellent and cropping cycle is short. However, this variety has low yield and poor keeping quality. In India, its cultivation is restricted to Orissa. It can be grown in temperature range of 25-40◦C. Pasteurized paddy straw substrate supplemented with cotton seed hulls gives better productivity.

b. *Milky mushroom (Calocybe indica):* This is indigenous tropical mushroom most suitable for tropical regions. At present this variety is being commercially cultivated in South India (Tamil Nadu, A.P. and Karnataka). Recently its production has started in North India.

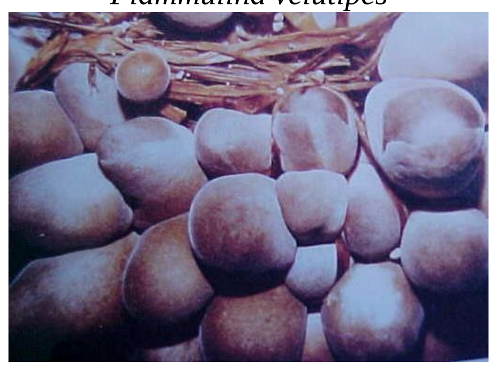
Button (A. bisporus)

Winter oyster mushroom

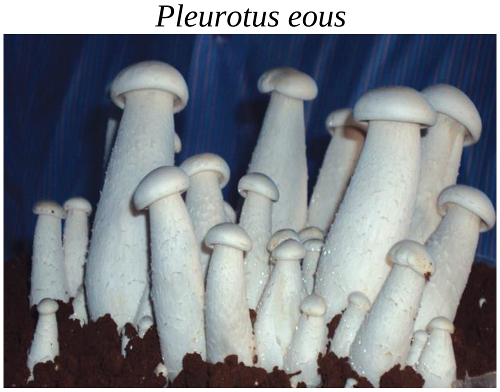
Shiitake mushroom

Flammulina velutipes

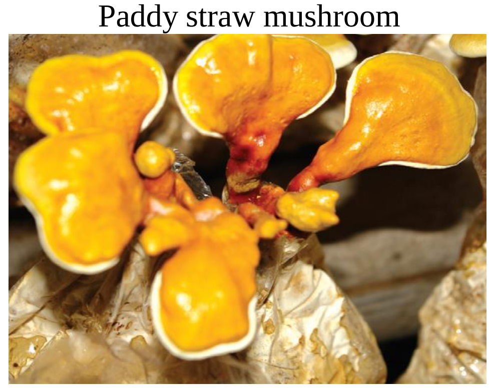
Pleurotus eous



Paddy straw mushroom



Milky mushroom



Reishi mushroom

Fig. 4 Different types of edible mushrooms

c. Reishi mushroom (Ganoderma lucid): This is also a tropical mushroom growing in temperature range of 30-350C with high humid climate. The world production is estimated to be 6000 tonnes and share of China is 4000 tonnes/annum. Its cultivation technology has been standardized in India. There is good scope of this mushroom both in domestic and export market. Caution, however, is required in disposal of spent substrate as the fungus is a phytoparasite. It may be ensured that filters are in place in cropping rooms and substrate is disposed after heat kill or is burnt after drying.

Future Prospects

India has tremendous potential for mushroom production and all commercial edible and medicinal mushrooms can be grown. There is increasing demand for quality products at competitive rate both in domestic and export market. Though growth of mushroom will depend on increasing and widening domestic market in coming years, export market will be equally attractive. To be successful in both domestic and export market it is essential to produce quality fresh mushrooms and processed products devoid of pesticide residues and at competitive rate. It is also important to commercially utilise the compost left after cultivation for making manure, vermi compost, briquettes, etc. for additional income and total recycling of agro-wastes. Overall future of the mushroom industry in India depends on the strength, weaknesses, opportunities and threats as given below.

***Strength:* -** Climatic diversification**,** abundant raw material and man power**,** strategic location

***Weaknesses:* -** Higher cost of finances, packaging materials, energy and transportation**,** poor quality of raw materials and higher cost machineries

***Opportunities:* -** Decline production of other countries and breaking down of international trade barrier, well adaptation of modern technologies and PHT management

***Threats:* -** Competition from China**,** demand shifted towards the fresh consumption

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Enhancement of Water Stress Tolerance in Crop Plants Employing Genetic Engineering Tools

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Introduction

Abiotic stress, mainly drought, reduces average yields for most major crop plants by more than 60%. Water stress or water deficit is one of the major environmental factor, which prevents plants from realizing their full genetic potential and has a major impact on crop yield (Araus *et al.* 2002, Morison *et al*. 2008, Salekdeh *et al*. 2009). Abiotic stress leads to a series of morphological, physiological, biochemical and molecular changes that adversely affect plant growth and productivity (Wang *et al.* 2001). To counter this adverse environmental factor, plants try to avoid the drought condition through various ways. They try to escape the season of drought by early flowering. They may decrease the leaf area (LA), increase the efficiency of roots to acquire water or may decrease activity of stomata. Slowing growth, osmotic adjustments and synthesis of antioxidants are some other mechanisms adapted by plants to combat adverse environmental conditions. These adaptations help plants to adapt to drought conditions. Some plants are able to adapt to water deficiency by shortening their growth cycle or they avoid drought stress by augmenting root growth to increase their water uptake (Molnar *et al*. 2004)). Unfortunately, the mechanisms by which crops maintain yield under drought stresses are poorly understood since drought can occur at different stages of the plant's development, with different effects on plant function, and thus requires distinct mechanisms for tolerance. In addition, a variety of abiotic stresses commonly occur during drought, such as high temperatures, high concentrations of salt and other toxic solutes and low availabilities of nutrients (Fleury *et al*. 2010, Salekdeh *et al*. 2009, Mittler 2006), and these vary by location and time.

Signaling pathways are induced in response to environmental stress and recent molecular and genetic studies have revealed that these pathways involve many components. The multiplicity of information embedded in abiotic stress signals underlies one aspect of the complexity of stress signaling (Chinnusamy *et al.* 2004). Nevertheless, most studies on water stress signaling have focused on primarily salt stress because plant responses to salt and drought are closely related and the mechanisms overlap (Zhu 2002). Responses to stress are not linear pathways, but are complicated integrated circuits involving multiple pathways and specific cellular compartments, tissues, and the interaction of additional cofactors and/or signaling molecules to coordinate a specified response to a given stimulus. Plants respond to these stresses at molecular and cellular levels as well as physiological level. Expression of a variety of genes has been demonstrated to be induced by these stresses. The products of these genes are thought to function not only in stress tolerance but also in the regulation of gene expression and signal transduction in stress response (Yamaguchi-Shinozaki *et al*. 2002, Shinozaki *et al*. 2003).

In addition, the sensitivity of many crops to a particular abiotic stress varies depending on their developmental stage. For example, rice is sensitive to salt stress at the young seedling stage, but much less at the reproductive stage (Flower *et al.* 1981, Lutts *et al.* 1995). It is suggested that stress tolerance mechanisms in a plants are controlled by a variety of genes, which are expressed at different times during the life of the plant (Witcombe *et al*. 2008, Fleury *et al.* 2010). Plant adaptations to most abiotic stresses involve a range of traits which combine to contribute plant tolerance. Individual genes have been reported to improve the stress tolerance in some crops, for instance, the transcription factor ZmNF-YB2 has been reported to improve drought tolerance in maize (Nelson *et al*. 2007). While in majority of cases, it is not a simple matter of identifying the single gene that will provide resistance to a particular abiotic stress. This review describes recent advances in improvement of crop plants for water stress tolerance using biotechnological tools. This review deals with transgenic approach for improvement of crop plants for water stress tolerance.

Advancement in understanding and identification of the components involved in drought tolerance mechanism.

The genetic model of model plant *Arabidopsis* has allowed the identification of numerous pathways important to growth under limiting water (Umezawa *et al*. 2006, Hirayama and Shinozaki 2010], and these pathways tend to be conserved among agricultural crops (Nakashima *et al*. 2009). In the last decade, researchers made promising breakthroughs in understanding ABA biosynthesis, ABA receptors, and other components of the ABA signal transduction pathway (Joshi-Sahat *et al*. 2011, Kline *et al*. 2010). This valuable new mechanistic understanding of the complex ABA signaling pathway will help in expediting innovations around managing plant responses to drought.

Biotechnological approaches to improve drought stress tolerance in plants may involve over-expression of genes involved in particular aspects of cellular homeostasis such as osmotic adjustment, chaperones, or antioxidants (Umezawa *et al*. 2006,Yang *et al*. 2010). Alternatively, ectopic expression or suppression of regulatory genes could potentially activate multiple mechanisms of stress tolerance simultaneously (Century *et al*. 2008). Genes encoding members of the AP2/ERF transcription factor family including the Dehydration Responsive Element Binding Proteins (Xu *et al*. 2011), ABA Response Element Binding Proteins, and NAC transcription factors (Nakashima *et al*. 2009) have all shown promise, as well as genes encoding proteins involved in other aspects of signal transduction, such as kinases and protein modification enzymes (Yang *et al.* 2010). In addition, progress in identification of plant microRNAs, including those with expression altered by drought stress (Covarrubias and Reyes 2010, Wang *et al*. 2011), provides exciting new targets for controlling drought response pathways. Demonstration of drought stress tolerance in crops in controlled environments is proceeding at an encouraging rate (Yang *et al*. 2010). Many of these recent discoveries have been in rice, which is both an excellent model species for basic research, and one of the world's most important crops. Study of rice mutants with altered stress tolerance led to the identification of genes in three pathways that can be manipulated to improve stress tolerance (Du *et al*. 2010, Huang *et al*. 2009, Zhang *et al*. 2009). Several genes that can provide drought stress tolerance were identified by altered expression of genes shown to be induced by drought stress in rice (Zheng *et al*. 2009, Takasaki *et al*. 2010, Song *et al*. 2011, Huang *et al*. 2009,Ouyang *et al*. 2010,Ning *et al*. 2011, Seo *et al*. 2011, Liu *et al*. 2009). Findings from Arabidopsis continue to be a rich source of drought leads (Lu *et al*. 2009, Gao *et al*. 2011, Gao *et al*. 2009, Zhang *et al*. 2010, Zhang *et al*. 2010, Zhang *et al*. 2010, Quan *et al*. 2010, Li *et al*. 2011, Malikarjune *et al*. 2011, Morran *et al*. 2011, Gao *et al*. 2011). Some transgenes were derived from extremely stress-tolerant species such as *Thellungiella halophila* (Lv *et al*. 2009), a salt-tolerant relative of Arabidopsis, and Atriplex hortensis (Wang *et al*. 2010), although direct comparison of alleles from less tolerant species is needed to validate this approach. Overexpression of some regulatory proteins has led to dwarf phenotypes with reduced yields, but use of drought-inducible (Xu *et al*. 2011, Xiao *et al* 2009) or tissue-specific (Jeong *et al*. 2010) promoters may overcome this issue. The magnitude and consistency of gene effects may be improved by co-expression of 2 or more transgenes that each provide drought efficacy, ideally through different mechanisms (Wei *et al*. 2011).

Genes involved in many of the essential steps of the stress response have been identified and characterized. In particular, the recent discovery of ABA receptors, progress in understanding the transcriptional and post-transcriptional regulation of stress-responsive gene expression, and studies on hormone interactions under stress have facilitated addressing the molecular basis of how plant cells respond to abiotic stress. Genetic approaches with more complex genomes are becoming increasingly tractable as genomic information in non-model crops increases and even whole crop genomes can be re-sequenced. Thus, genetic approaches to elucidating the molecular basis to abiotic stress tolerance in crops are becoming more easily achievable. This knowledge can be delivered to breeders through marker-assisted selection or genetic modification technologies. The mechanism underlying the environmental stress response in plants is probably more advanced and prominent than in animals. Moreover, the question of how plant cells react to various environmental stresses is one of the most attractive topics not only to plant biologists but also to agronomists, because abiotic stress is a particular threat to crop productivity. It is estimated that abiotic stress such as drought, salinity and extreme temperatures, which usually cause primary crop losses worldwide, lead to an average yield loss of >50% for most major crop plants (Boyer 1982). Furthermore, world food production needs to be doubled by the year 2050 to meet the ever-growing demands of the population (Tilman *et al*. 2002). For these reasons, understanding the mechanisms underlying plant abiotic stress responses and the generation of stress tolerant plants has received much attention in recent years. However, because of the complexity of stress tolerance traits, conventional approaches are less effective at directly connecting tolerance traits to the determinant genes that play key roles in the stress response. Owing to recent progress in functional genomics, genes involved in many of the essential steps of the stress response have been identified and characterized. In particular, the discovery of ABA receptors, progress in understanding the transcriptional and post-transcriptional regulation of stress-responsive gene expression, and studies on hormone interactions under stress have facilitated addressing the molecular basis of how plant cells respond to abiotic stress. Importantly, the physiological functions of a number of genes have been investigated in transgenic model plants and some crops, and an approach for utilizing useful genes for crop genetic improvement by gene transfer has been proposed. This review describes recent progress towards understanding plant abiotic stress responses, primarily focusing on ABA receptor identification, stress-responsive gene expression regulation by transcription factors (TFs), signal transduction mediated by protein modification and the roles of phytohormones in plant stress responses and development. The roles of small RNAs and RNA-directed DNA modifications in this regard have been extensively reviewed elsewhere (Sunkar and Zhu 2004, Sunkar *et al*. 2007, Chinnusamy and Zhu 2009).

Transition of drought tolerance capability in crop plants from laboratory to farmer's field

Many genes have been identified that can improve traits contributing drought tolerance. Demonstration of drought efficacy in the field is a critical step for showing commercially relevant drought tolerance, but resources for this testing are limited for many researchers, and governmental regulation of transgenic crops is often a barrier to field testing (Fgedoroff *et al*. 2010).

Benefit from several transgenes has been demonstrated in field trials (Table 1). One example is the Cold Shock Protein B (CspB) RNA chaperone from Bacillus subtilis. CspB plays a role in adaptation of bacteria to low temperatures, and its overexpression was shown to provide stress tolerance to Arabidopsis, rice and maize (Castiglioni *et al*. 2008). Results from field testing at multiple locations with controlled irrigation showed that maize lines expressing the CspB gene had higher yield under water-limiting conditions than controls, and also had yields equivalent to controls under optimal growing conditions. While this transgene provided significant yield improvements, it is expected that the addition of transgenes with different modes of action can complement the performance of this gene, and may expand the geographic regions and growing conditions under which benefit may be obtained.

Several other recent examples in which transgenic lines have demonstrated improved drought tolerance in field testing. In one experiment, several transgenes with ability to improve stress tolerance in model species were tested in transgenic rice in field trials over two years (Xiao *et al*. 2009). Each gene was tested with two promoters, one constitutively expressed and the other drought-responsive. Efficacy in promoting drought tolerance was demonstrated for six of these genes with one or both promoters. This experiment provides an excellent example of fairly rapid movement of transgenes with known efficacy from models into crops, and it is hoped that some of these genes will ultimately have commercial utility. An example that demonstrates the importance of testing the translation of greenhouse experiments to field performance was reported for the AP37 and AP59 genes in rice (Oh *et al*. 2009). Over-expression of these genes in transgenic rice showed that either gene improved drought tolerance phenotypes in the growth chamber, but only AP37 showed yield improvement under drought in the field. One phenotype that may lead to a difference in greenhouse and field results is reduced plant size. Smaller plants use less water and thus have more water available compared to larger control plants in identical pots. However, in the field this mode-of-action may not give benefit, and may even produce yield drag (Blum 2011). Testing drought tolerance in field trials is difficult, even if controlled irrigation is available, because of the unpredictable variability of weather, soil, rain, and pests or diseases. Furthermore, some transgenes may function in pathways that interact with environmental parameters, leading to variable results. The conceptually simplest way to deal with these issues is to test at many locations over multiple years. However, this kind of testing is expensive and time-consuming. More thorough characterization of transgenic lines may improve the ability to predict which lines are likely to show benefit in field conditions. This characterization may be enhanced by use of high-throughput phenotyping methods, which are often based on non-destructive imaging techniques to quantify biomass, shoot architecture, photosynthesis, pigmentation, water content, transpiration rate, and other traits (Skirycz

2011, Berger 2010, Reuzea *et al*. 2010). High-throughput methods for imaging root architecture have been developed (Zhu *et al*. 2011), creating opportunities to generate a more complete phenotypic profile. Field performance data from transgenic plants can be combined with thorough phenotypic data obtained in a greenhouse, using different stresses and taken at a variety of developmental stages, to develop models for predicting field performance based on greenhouse results (Tardieu and Tuberosa 2010). Such modeling could improve the success rate of greenhouse to field translation. Based on results obtained, it may be desirable to modify screening protocols. Screen modifications could involve the level of drought stress used, and also the developmental stage. Most drought research has been conducted by screening and testing under severe drought conditions. The types of mechanisms that can protect against this level of stress such as reducing plant size or decreasing stomatal conductance may be accompanied by reduced productivity under well-watered conditions. Identification of new gene leads by screening under moderate rather than extreme drought may identify genes that provide a mode-of-action more suitable for typical agricultural environments (Skirycz *et al*. 2011). Most non-field screens for drought tolerance have focused on vegetative stages, because of the relative ease and speed of obtaining data, despite the knowledge that water limitation at the time of flowering is the most damaging to crop productivity. Therefore, it may be productive to conduct screening and follow-up testing using stress applied around flowering.

Enhancement of drought stress tolerance in agricultural crops employing genetic engineering

Many plants have multiple physiological, biochemical and molecular mechanisms that enable them to tolerate environmental stresses. Understanding the mechanisms by which plants perceive and transduce the stress signals to initiate adaptive responses and their engineering using molecular biology and genomic approaches are essential for improving abiotic stress tolerance in crop plants. Several efforts in this direction have been carried out in many laboratories targeting manipulation of genes belonging to diverse categories. Genetic engineering strategies rely on the transfer of one or several genes that are either involved in signaling and regulatory pathways, or that encode enzymes present in pathways leading to the synthesis of functional and structural protectants, or that encode stress tolerance-conferring proteins. Attempts have been made to confer drought resistance to plants through biotechnological approaches and drought tolerant varieties of crops such as wheat, soya bean and rice have been produced.

Engineering genes involved in plant's stress surveillance

Sensors initiate a signalling cascade to transmit the signal and activate nuclear transcription factors to induce the expression of specific sets of genes. Genes involved in stress signal sensing and a cascade of stress-signaling in model plant such as *Arabidopsis thaliana* has been of recent research interest (Winicov and Bastol 1997; Shinozaki and Yamaguchi-Shinozaki 1999). Components of the signal transduction pathway may also be shared by various stress factors such as drought, salt and cold (Shinozaki and Yamaguchi-Shinozaki 1999). Although there are multiple pathways of signal-transduction systems operating at the cellular level for gene regulation, ABA is known component acting in one of the signal transduction pathways, while others act independently of ABA. The early response genes have been known to encode transcription factors that activate downstream delayed response genes (Zhu 2002). Although, specific branches and components exist (Lee *et al*. 2001), the signaling pathways for salt, drought, and cold stresses all interact with ABA, and even converge at multiple steps (Xiong *et al*. 1999). Abiotic stress signalling in plants involves receptor-coupled phospho-relay, phosphoionositol-induced Ca2+ changes, mitogen activated protein kinase (MAPK) cascade, and transcriptional activation of stress responsive genes (Xiong and Zhu 2001). A number of signaling components are associated with the plant response to high temperature, freezing, drought and anaerobic stresses (Grover *et al*. 2001). One of the merits for the manipulation of signaling factors is that they can control a broad range of downstream events that can result in superior tolerance for multiple aspects (Umezawa *et al*. 2006). Alteration of these signal transduction components is an approach to reduce the sensitivity of cells to stress conditions, or such that a low level of constitutive expression of stress genes is induced (Grover *et al*., 1999). Over-expression of functionally conserved At-DBF2 (homolog of yeast DBF2 kinase) showed striking multiple stress tolerance in Arabidopsis plants (**Lee *et al*. 1999**). Transgenic tobacco plants produced by altering stress signaling through functional reconstitution of activated yeast calcineurin not only opened-up new routes for study of stress signaling, but also for engineering transgenic crops with enhanced stress tolerance (Grover *et al*. 1999). Overexpression of an osmotic-stress-activated protein kinase, SRK2C resulted in a higher drought tolerance in *A. thaliana*, which coincided with the upregulation of stress-responsive genes (Umezawa *et al*. 2004). Similarly, a truncated tobacco mitogen-activated protein kinase kinase kinase (MAPKKK), NPK1, activated an oxidative signal cascade resulting in cold, heat, salinity and drought tolerance in transgenic plants (Kovtun *et al*. 2000, Shou *et al*. 2004). However, suppression of signaling factors could also effectively enhance tolerance to abiotic stress (Wang *et al*. 2005).

Drought stress induced genes

The complex plant response to abiotic stress involves many genes and biochemical-molecular mechanisms. Various genes respond to drought-stress in various species, and functions of their gene products have been predicted from sequence homology with known proteins. Many drought-inducible genes are also induced by salt stress and low temperature, which suggests the existence of similar mechanisms of stress responses. Genes induced during drought-stress conditions are thought to function not only in protecting cells from water deficit by the production of impor-tant metabolic proteins but also in the regulation of genes for signal transduction in the drought stress response (amaguchi-Shinozaki *et al*. 2002, Shinozaki *et al*. 2003). Thus, these gene products are classified into three major groups. (1) those that encode products that directly protect plant cells against stresses such as heat stress proteins (HSPs) or chaperones, LEA proteins, osmoprotectants, antifreeze proteins, detoxification enzymes and free-radical scavengers [Bray *et al*.2000]. (2) those that are involved in signaling cascades and in transcriptional control, such as MAPK, CDPK [Ludwig *et al*. 2004] and SOS kinase [Zhu *et al*. 2001], phospholipases [Frank *et al*. 2000], and transcriptional factors [Shinozaki *et al*. 2000, Choi *et al*. 2000], those that are involved in water and ion uptake and transport such as aquaporins and ion transporters (Blumwald 2000). Stress-inducible genes have been used to improve the stress tolerance of plants by gene transfer. It is important to analyze the functions of stress-inducible genes not only to understand the molecular mechanisms of stress tolerance and the responses of higher plants, but also to improve the stress tolerance of crops by gene manipulation. Hundreds of genes are thought to be involved in abiotic stress responses (Seki *et al*. 2003).

Engineering genes involved in transcriptional regulation.

Transcription factors (TFs) are small molecules that attach to specific sites on a DNA molecule in order to activate or deactivate the expression of certain genes. A single gene encoding a specific stress protein does not always result in sufficient expression to produce useful tolerance, because multiple and complex pathways are involved in controlling plant drought responses (Bohnert *et al*. 1995) and because modification of a single enzyme in a biochemical pathway is usually contrasted by a tendency of plant cells to restore homeostasis Konstantinova *et al*. (2002)]. Targeting multiple steps in a pathway may often modify metabolite fluxes in a more predictable manner. Another promising approach is therefore to engineer the overexpression of genes encoding stress inducible transcription factors. Transcription factors typically regulate several genes and are likely to be used extensively in the next generation of genetically modified crops (Yamaguchi-Shinozaki and Shinozaki 1994, Chinnusamy *et al* 2005). Numerous transcriptional regulators are known to be involved in plant responses to drought stress (Yamaguchi-Shinozaki and Shinozaki 2006); most fall into one of the large transcription factor families (AP2/ERF, bZIP, NAC, MYB, MYC, Cys2His2 zincfinger, NFY and WRKY); and some cis-elements, bound by these transcription factors, have been identified (Yamaguchi-Shinozaki and Shinozaki 2006). For example abscisic acid-responsive elements (ABRE) (Mundy *et al*. 1990) are 50 upstream regions of abscisic acid-responsive genes that are bound by AREB/ABF transcription factors belonging to the basic leucine zipper family. These mediate at least one of the abscisic acid-dependent pathways involved in responses to drought stress. Another cis-element is the dehydration responsive element/C-repeat (DRE/CRT) which is involved in one of the abscisic acid-independent pathways (Yamaguchi-Shinozaki and Shinozaki 1994).

Various DRE/CRT-binding proteins, coding for ERF/AP2 transcription factors, are induced by desiccation, salt treatment, and cold in some plant species (Yamaguchi-Shinozaki and Shinozaki 2006). The first examples of transcription factor engineering to improve abiotic stress tolerance were overexpression of the ERF/ AP2 factors CBF1, DREB1A and CBF4. Overexpression of these factors resulted in cold, drought and salt tolerance in Arabidopsis [Jaglo-Ottosen *et al*. 1998, Kasuga *et al*. 1999, Haake *et al*. 2002) and it was later shown the similar tolerance could be induced in many crop plants by overexpression of these factors [Agarwal *et al*. 2006, Pellegrineschi *et al*. 2004). Numerous transgenic Arabidopsis varieties with improved drought tolerance due to overexpression of various stress-regulated transcription factors have been reported, but similar results have also been obtained in crop plants (Saibo *et al*. 2009). Typically a gene coding for a transcription factor in Arabidopsis is isolated, characterized and shown to improve drought response when overexpressed. The gene is then transferred to a crop plant where it often confers the same drought-tolerant phenotype. The HRD gene, coding for an AP2/ERF-like transcription factor (Karaba *et al*. 2007) exemplifies this approach. Arabidopsis plants with a gain-of-function mutation in the HRD gene (hrd-D mutants) are droughtresistant, salt-tolerant, and overexpress abiotic stress marker genes. Overexpression of the same gene in rice significantly improves water use efficiency both under well-watered conditions (50–100% increase) and under drought (50% increase). These plants also show enhanced photosynthetic assimilation and reduced transpiration (Karaba *et al*. 2007). HRD gene overexpression conserves drought tolerance in both dicots and monocots.

Engineering genes for osmotic regulation and ionic balance.

Early attempts to develop transgenic plants resistant to water stress focused on single action genes responsible for the modification of a single metabolite or protein that would confer increased tolerance to drought stress. Recent reviews {Bhatnagar-Mathur *et al*. 2008, Umezawa *et al*. 2006) document progress in this area. Osmoregulation is one of the most effective ways evolved by stress-tolerant plants to combat abiotic stress, but most crop plants lack the ability to synthesize the osmoprotectants naturally produced by stress-tolerant plants. Therefore genes concerned with the synthesis of osmoprotectants have been incorporated into transgenic plants to confer stress-tolerance (reviewed in (Bhatnagar-Mathur *et al*. 2008, Umezawa *et al*. 2006). Overproduction of compatible solute osmoprotectants such as amino acids (e.g. proline), quaternary and other amines (e.g. glycinebetaine and polyamines), and sugars and sugar alcohols (e.g. mannitol, trehalose and galactinol) has been achieved in various target plants. Glycinebetaine in particular has been extensively studied as a compatible solute, both by genetically engineering its biosynthesis in agriculturally important species and by its exogenous application (Chen and Murata 2008).When maize plants were transformed with the betA gene from Escherichia coli that encodes choline dehydrogenase, they accumulated glycinebetaine in tissues and were more tolerant to drought stress than wild-type plants at different developmental stages. Most importantly their grain yield was 10–23% higher than that of wild-type plants after three weeks of drought stress (Quan *et al*. 2004). In some cases the accumulation of compatible solutes also protects plants against damage by reactive oxygen species (ROS) (Bohnert and Shen 1999); in other cases the solutes have chaperone-like activities that protect other proteins maintaining their structure and function (Diamant *et al*. 2001, McNell *et al*. 1999]. Genes coding for heat-shock proteins, molecular chaperones and LEA proteins (reviewed in [Bhatnagar Mathur *et al*. 2008, Umezawa *et al*. 2006) have been extensively used to improve drought responses in plants. An interesting recent example is the use of RNA chaperones of bacterial origin by Castiglioni *et al*., to confer abiotic stress tolerance in several species, and improved grain yield in maize under water-limiting conditions (Castiglioni *et al*. 2008). These authors demonstrated that constitutive expression of two cold shock proteins – CspA from E. coli and CspB from Bacillus subtilus (both RNA chaperones) – conferred abiotic stress tolerance to transgenic Arabidopsis, rice, and maize. They obtained a greater than 20% increase in maize grain yield under water-limiting conditions in field trials, without observing pleiotropic effects on plant development. The improvement in drought response was observed in the late vegetative/flowering period as well as the grain-fill period: during these periods, three consecutive days of wilting can reduce grain yield by 30–50% (Claasen and Shaw 1970). Stress tolerance conferred by manipulation of cold shock proteins is not only novel, but also appears as a highly promising approach to improving plant productivity in suboptimal growth conditions.

Table 1: Transgenic crops for water stress tolerance

Pathway targeted	Gene family	Trans gene	Transgenic expression	Crop	Reference
Osmoregulation	H+-PPase	AVP1	CaMV35S	cotton	Pasapula *et al.* 2011
Osmoregulation + glycinebetaine biosynthesis	H+-Ppase + choline dehydrogenase	BetA and TsVP	Zm Ubiquitin	maize	Wei *et al.* 2011
ABA biosynthesis	LOS5/ABA3	LOS5	OsHVA22P (stressinducible) and OsActin1	rice	Xiao *et al.* 2009
ABA sensing; farnesyltransferase	farnesyltransferase	BnFTA	RNAi with AtHPR1 promoter (drought induced in shoot)	Canola	Wang *et al.* 2009
Stress response	AP2/ERF	AP37	Os.Cc1 (constitutive)	rice	Oh *et al.* 2009
		CBF3	OsHVA22P (stressinducible) And OsActin1 (constitutive)	rice	Xiao *et al.* 2009
		HARDY	CaMV35S	berseem	Abogadallah *et al.* 2011
	NAC	OsNAC10	RCc3 (root) (constitutive expression not efficacious)	rice	Jeong *et al.* 2010
	C2H2-EAR zinc finger protein	ZAT1	OsHVA22P (stress inducible) And OsActin1	rice	Xiao *et al.* 2009, Mittler *et al.* 2006]
	MAP kinase	NPK1	OsHVA22P (stressinducible) And OsActin1	rice	Xiao *et al.* 2009
Ion transport	Na+/H+ antiporter	NHX1	Actin1	rice	Xiao *et al.* 2009
	Ser/Thr kinase	SOS2	OsHVA22P (stress inducible)	rice	Xiao *et al.* 2009, Batelli ***et al.*** 2007

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Nutritional Management for Abiotic Stress Management in Livestock in Drought Prone Areas of India

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Nutritional resource management is the important aspect of abiotic stress management in livestock in addition to genetic management. Abiotic stress is defined as the negative impact of non-living factors on the living organisms in a specific environment. The present classification of abiotic stress i.e. edaphic, drought, and atmospheric is based on the basic requirements of plants on these factors for their growth and production. Although edaphic factors have influence on whole biosphere, they do not directly influence animal growth and production. The nutritional requirements of animals are mostly fulfilled through plants which provide various required nutrients such as proteins, carbohydrates, fats, vitamins, minerals etc. However, nutrient requirements of animals are fulfilled through varied sources and not by any single type of plant alone. Hence, edaphic factors which directly influence plants have only indirect impact on animals. Besides climate and water, other abiotic factors that influence animals directly are very complex, depending on abiotic requirements for their sustenance, growth and production. The indirect effects of climate driven changes in animal performance result mainly from alterations in the nutritional environment (Valtorta 2010) besides direct effects of heat and water scarcity during drought cycles. Therefore, the edaphic, atmospheric and drought factors influence livestock by altering nutrient availability.

The inappropriate environmental factors influence directly as well as indirectly by altering supply of nonliving requirements to livestock in the specific production system. Drought is an extended period of water scarcity due to scarcity or the absence of rainfall, but related to inefficient water resource management. Drought is the frequent climatic condition adversely affecting agriculture/livestock production in drought prone areas of India. Drought is a natural hazard that differs from other hazards since it has a slow onset, evolves over months or even years, affects a large spatial extent, and cause little structural damage. Livestock plays important role in the economy of landless or marginal farmers besides sustaining farmers' income during scarcity/drought periods. Hence, uplifting nutritional strategies for livestock may be highly essential in drought prone areas for successful doubling of farmers' income mission.

Drought Prone Areas in India

Out of the total geographical area of India, almost one-sixth area with 12% of the population is drought prone; the areas that receive an annual rainfall up to 600 mm are the most prone. The Irrigation Commission (1972) had identified 67 districts as drought prone. These comprise 326 talukas located in 8 states, covering an area of 49.73m ha. Subsequently, the National Commission on Agriculture (MOA 1976) identified a few more drought prone areas with slightly different criteria. Later, based on detailed studies, 74 districts of the country have been identified as drought prone. The districts having less than 60% of cultivated area under irrigation and possessing arid (31), semi-arid (133) and sub-humid (175) agro-ecosystems were identified and prioritized for Rainfed Area Development Programme (RADP). Recently extensive studies conducted under NICRA have led to identification of 100 districts in peninsular India highly prone to drought (Prasad *et al.*, 2012). Adverse impact of drought is evident from the vast agricultural land left uncultivated and severe forage crisis for animals.

Broadly, the drought affected areas in India can be divided into two tracts. The first tract comprising the desert and the semi-arid regions covers an area of 0.6 million sq km. It is rectangle shaped area whose one side extends from Ahmadabad to Kanpur and the other from Kanpur to Jullundur. In this region, rainfall is less than 750 mm and at some places it is even less than 400 mm. The second tract comprises the dry region lying in the leeside of the Western Ghats up to a distance of about 300 km from coast. It is known as the rain shadow area of the Western Ghats; rainfall in this region is less than 750 mm and is highly erratic.

Outside these two main regions, there are isolated pockets which experience frequent droughts and are termed as drought prone areas. They are Coimbatore and Nellai Kottabomman districts in Tamil Nadu, Saurashtra and Kachchh regions, Janshi, Lalitpur region, Mirzapur plateau, Kalahandi region, Odisha, Purulia district of Paschim Bengal etc. (Sarkar 2011.).

Impact of Drought on Livestock

Besides direct impact of scarcity of water, drought also results in scarcity of nutritional resources and exposure of animals to adverse climatic conditions mainly heat stress. Scarcity of forages during drought can increase the risks of animal poisonings and nutritional imbalances. The impaired water quality, feed quality, nutritional deficiency and increased incidence of plant poisonings are some drought-related threats to cattle health and productivity. (Poppenga and Puschner). Due to reduced availability of fodder, animals are forced to consume other vegetations or non-conventional feed stuffs with increased risk of exposure to anti-nutritional factors. In addition, once the drought-breaking rains occur, the grazing conditions for cattle may dramatically change and pose additional health risks. The conditions mostly commonly associated with the end of severe drought conditions include bloat, certain deficiency problems, plant poisonings, and clostridial diseases. The other impacts of drought are changes in production systems which include migration of livestock farmers to surplus areas, sale of animals for slaughter and shifting from large ruminant based systems to small ruminant systems.

Drought Stress Management through Nutritional Technologies

There are many challenges for sustaining livestock wealth due to recurrent drought or delayed monsoon like situations in drought prone areas in the country. Research efforts regarding suitability of fodder species for increasing production, alternate fodder sources and optimization for their use, storage and transport of fodder, optimizing nutrient availability and utilization by the different livestock species in target areas are warranted for sustainable livestock production in drought prone areas. Special attention need to be provided for recommendation of plant and animal based mixed production system where forage needs of the useful animals are fulfilled. There are several research initiatives and innovations happened during last few years which help in enhancing productivity which need to be adopted.

Development and use of drought tolerant fodder varieties

Research efforts should be for increasing the fodder yield of cultivated fodder crops on agricultural lands as well as on wastelands and community pastures (Hegde, 2010). The strategy should include selection and breeding of high yielding and stress tolerant as well as short duration fodder crops and varieties. Importance may be given to improve the yields through sustainable production practices, efficient conservation practices and strengthening the value chain of dairy and meat producers by providing various critical services required to improve productivity and sustain livelihood. For this joint efforts of various government and non- government agencies are important. A comprehensive review of the improved fodder crop varieties released/notified during the past three decades, fodder production systems and packages of practices for important fodder crop, intensive forage sequences recommended for different regions has been provided in Handbook of agriculture, (2010).

Hydroponics

There is renewed interest in hydroponic fodder as a feedstuff for sheep, goats, and other livestock. The yield and quality of sprouts produced is influenced by many factors such as soaking time, grain quality, grain variety and treatments, temperature, humidity, nutrient supply, depth and density of grain in troughs and the incidence of mould (Sneath and McIntosh 2003). The technology of hydroponic systems is changing rapidly with systems today producing yields never before realized. The future for hydroponics appears more positive today than any time over the last 50 years. Methods and technologies that can contribute to improved water use efficiency and productivity merit closer consideration like hydroponic technique (Al-Karaki and Al-Hashimi 2012). Hydroponically produced fodder was found to enhance the efficiency of water use. Bradley and Marulanda (2000) reported that hydroponic green fodder production technique requires only about 10–20% of the water needed to produce the same amount of crop in soil culture. More research efforts regarding water saving options including use of treated waste water for hydroponic green fodder production need to be carried out for applying in drought prone areas of India.

Hay and Silage making

Hay making and ensiling are the only options available to farmers wanting to conserve forage on a large scale. In drier climates, haymaking is still important. However, there has been a trend over the last 30 years or so for the proportion of forage conserved as silage to increase, while the proportion dedicated to hay has declined

(Wilkinson *et al*. 1996). Ensiling offers many advantages over haymaking. Large quantities of forage can be conserved in a short time, forage conservation is less weather dependent and thirdly, silage is well suited to mechanization. However, a major disadvantage associated with silage making is that the feeding value of the resultant forage is reduced relative to that of the original crop (Charmley, 2000). Silage is made of forages, crop residues, or agricultural and industrial by-products that have been preserved by natural or artificial acidification, for use as animal feed in periods when feed supply is inadequate (Mannetje, 1999)

According to Charmley, 2000, the possibility that in future, silages will have superior feeding value to the original crop is realistic. Physical treatments can break down barriers to improve intake and digestibility. Predictable silage fermentation can be used to optimize rumen function. More research efforts, besides popularization of technique, to improve silage intake and utilization using locally available forages are required to overcome the scarcity of fodder during drought cycles in different regions of India.

Making silage from drought damaged crops, need to be assessed in drought prone areas in India as a nutrition management option. Availability of sugarcane tops in the drought prone areas need to be exploited as effective drought stress management option. During drought conditions plant growth is impaired and nitrates can accumulate in the plant. Nitrates are normally taken up by plants from the soil and utilized for the synthesis of plant protein. Elevated nitrate levels can also occur in summer annual forages subjected to drought stress. Weeds commonly found in corn fields such as pigweed, ragweed, lambsquarter, nightshade, and Johnsongrass can also accumulate toxic levels of nitrates, under drought conditions. High nitrates concentrations in corn plants and corn silage can potentially be toxic to cattle (Wright, 2015).

Complete feed blocks

The crop residues have low nutritional value and are bulky and fibrous. In addition, availability of crop residues varies with season and region. In some regions there is deficiency of crop residues, while in some other regions they are available in abundance but are largely wasted. Under emergency situations complete feed technology has been used to save the animals from hunger and death. Based on the productivity levels of animals, the Densified Total Mixed Ration Blocks (DTMRBs) or the densified total mixed ration pellets (DTMRPs) of different formulations can be made using different ingredients, including minerals, vitamins and feed additives. Thus, the technology of straw-based densified complete feed as blocks or pellets could play an important role in providing balanced rations to livestock in the tropical regions of green forage scarcity. The technology offers a means to increase milk and meat production in the tropics apart from having other advantages such as: decrease in environmental pollutants (including methane emission), increase in income of farmers, decrease in labour requirement and time for feeding and reduction in transportation cost of straw. The technology also has the potential to alleviate regional disparity in feed availability, as the block or pellet making units can be set up to act as 'Feed Banks' in regions of abundant crop residue availability. It could also provide complete feed to livestock under emergency situations created by natural calamities such as drought and man-made conflicts (Walli *et al*., 2012). However, there is a need to take up further research on energy cost of straw transportation and feed densification and how to reduce it. Research may also be taken up for monitoring the quality of the processed feed to check that the nutrients are not diluted by the addition of more of non-nutritional feed additives. Feeding of complete ration in mash form is beneficial in terms of feed intake, body weight gain, nutrient utilization and feed conversion efficiency in growing crossbred female calves in comparison to conventional feeding system and also with complete feed in block form (Sharma *et al*., 2010).

Urea molasses treatment

It is generally recommended to avoid urea treatment during periods of drought. However, urea treatment of poor quality fodder if done judiciously under controlled condition is beneficial to sustain the periods of drought.

Nutrient management during drought stress

During periods of scarcity nutrient management of individual animals is important to sustain health and production or even save the life of animals. Mineral/vitamin supplementation based on the requirement may be provided under the guidance of experts.

Novel feed resources/ Alternate feeds

Search for alternate feed resources and research for its judicious use need to be carried out for the different agro-ecological systems. Several newer feed resources have been evaluated and found useful for feeding. Incriminating factors have been identified in unconventional feeds and methods for their detoxification have been evolved. Protein cakes after oil extraction from seeds of neem, castor, karanj, palm and mahua have been evaluated and found suitable after detoxification to use for feeding. However, largely this technology is not yet adopted by end users.

Drought Stress Management through Management of Nutritional Resources

During periods of drought cycles there is overall shortage of feeds and fodder for livestock in the area. Unavailability of forages results in shortage to provide the needed dry matter intake and subsequently overall nutrients the animal needs. In these situations it becomes necessary to provide a supplemental forage source to meet this need. In many cases, these forages are substandard so additional supplementation may be needed as well to maintain a base-line production level. Providing inadequate levels of protein and energy always reduces performance in some manner and is stressful to the animal.

In a survey conducted in villages of Ghorawal and Chopan blocks of district Sonbhadra, Uttar Pradesh to find out the nutritional status and reproductive performance of dairy cattle it was observed that the nutrients intake through different feed ingredients was not enough to fulfill the requirement of the animals as per the standard (Vidya Sagar *et al.*, 2013). Pantgne *et al*. (2002) reported that farmers, in general do not fed their animals with required amount of nutrients. Singh *et al*., (2008) reported that the dairy animals in Middle Gangetic Plain were fed with traditional manner and they were deficient in DM, CP and TDN supply.

The data/estimates of fodder production in the country vary widely. Fodder production and its utilization depend on the cropping pattern, climate, socioeconomic conditions and type of livestock. At present, the country faces a net deficit of 61.1% green fodder, 21.9% dry crop residues and 64% feeds (Anonymous, 2010).

Although there are variable estimates of feed and fodder availability in the country, all of the estimates point towards overall deficient status of feed and fodders for livestock even in absence of drought. The projected deficit of green and dry fodder appears to be agrevated during near future.

Table: Status of feed and fodder (DM basis) in India

Feeds	Available (MT)	Required (MT)	Deficit (%)
Dry fodder	**365**	**412**	**11**
Concentrate	**34**	**47**	**28**
Green Fodder	**126**	**193**	**35**
Total	**526**	**652**	**19**

NIANP 2005

During drought cycles these situations of deficit forages are further aggravated in drought prone areas with severe negative impact on livestock population. To address these problems following strategies are suggested by National disaster management authority (NDMA).

Strategies suggested by NDMA	Interventions needed
Assessment of need for fodder will be done well in advance. If a deficit is identified, ways and means to fill the gap will be explored including supplies from the nearest area, within the mandal, within the District, or in the nearby State.	Timely and realistic assessments and ensuring availability of fodder. Exploring alternative sources.
Raising of fodder in Government as well as farmers' lands with buy back arrangements for fodder cultivated will be promoted.	Initiatives of government agencies with area specific programmes required.
Use of tank bunds for fodder cultivation.	Suitable guidelines with area specific varieties needed.
Utilizing the period between crops for fodder cultivation.	Suitable guidelines with area specific varieties needed.
Distribution of fodder produced within a State in nearby areas.	Initiatives of government and non-government agencies
Establishment of fodder banks.	
Conserving fish and aqua culture during droughts.	Need to be coupled with water conservation practices
Utilizing the assistance of Ministry of Railways in transport of fodder and drinking water from unaffected areas to those affected.	Initiatives of government agencies required.
Organizing online availability of information relating to demand and supply of fodder	
Undertaking market intervention to keep the prices reasonable.	
Intensification of water conservation measures in the	

villages.	

Deficiency or excesses of nutrients

Livestock farmers feed their animals based on their traditional knowledge and availability of forages. In general there is lack of scientific/balanced feeding of livestock. Imbalanced feeding leads to excess feeding of some nutrients whilst others remain deficient. This not only reduces milk production and increases costs per kg milk, but also affects various physiological functions including long term animal health, fertility and productivity.

The nutritional requirements of animals not only vary with species but also with stage of growth and status of production. The nutrient requirements of young animals, lactating as well as pregnant animals are different. The nutritional stressors in livestock are highly complex in nature as per the highly variable nutrient contents of feed resources and nutrient requirements of individual animals. The nutritional requirements of herbivorous animals are mostly fulfilled by plants. The nutritional requirements of productive animals are mostly met with various dry/green forages and concentrate mixtures which mostly contain cereals, cakes, mineral mixtures, salt, vitamins etc. Therefore, nutritional stress in animals can be due to deficiency or excesses of nutrients in diet. The nutrient requirement of animals is fulfilled through plants from varied sources viz. crop residues (54%), cultivated fodder (28%) and grazing (18%).

Nutritional requirements in Indian livestock are generally met through crop residues, fodder crops or tree fodders as well as grazing and concentrate mixtures. The optimum productivity of livestock depends upon regular supply of balanced nutritional requirements. Knowledge of livestock owners about balanced nutrient requirements of livestock and availability of ingredients in terms of quality and quantity has also impact on livestock and their production.

Ration balancing

The diet of livestock needs to be balanced in terms of fodder, protein, energy and minerals. Depending on the local feed/fodder resources and nutrient requirement of livestock, various combination of ration can be formulated to suit the productive potential of animals. Based on the data on nutrient profile of feeds /fodders and requirement by livestock, software program models have been developed by National Dairy Development Board (NDDB) and National Institute of Animal Nutrition and Physiology (NIANP) and they can be conveniently used at Krishi Vigyan Kendra (KVK) or Cooperative society level.

Anti-Nutritional Factors in Fodder Plants

Anti-nutritional factors (ANF) are compounds which reduce the nutrient utilization and/or food intake of plants or plant products used as human foods or animal feeds and they play a vital role in determining the use of plants for humans and animals (Soetan and Oyewol, 2009). Poor digestibility of protein in the diets of developing countries, which are based on less refined cereals and grain legumes as major sources of protein, is due to the presence of less digestible protein fractions, high levels of insoluble fiber, and/or high concentrations of anti-nutritional factors present endogenously or formed during processing (Sarwar *et al.*, 2012). The deleterious role of anti-quality components depends upon its concentration, rate of degradation by the microbes and accordingly it will influence the growth and the performance of the animal. The major antiquality components that adversely affect the nutritional value of the forages are tannins and saponins (Gilani *et al.*, 2012). Intensive rearing practices restrict the exposure of livestock to toxic plants, and therefore cases of plant poisoning occur considerably less frequently than in other regions of the world practicing extensive livestock management, and where the free-ranging animals must eat whichever plants are available, usually non-cultivated, and often under highly unfavorable climatic conditions including periods of drought. The various toxic and antinutrional components observed in plants are *Alkaloids, Glycosides, Phytoestrogens Lectins/ phytohemagglutinins, Oxalates and phytates, Nitrates, Plant phenolics, Saponins,Toxic amino acids and proteins, Heavy metals and Phytoallexins.* During drought conditions, suitable precautions need to be taken to prevent the access by livestock to the sources of these anti-nutritional factors.

Drug and pesticide residues in feed stuffs

Animal feeds and forages contain a wide range of contaminants and toxins arising from anthropogenic and natural sources (D'Mello, 2000). Animals intended for human food may absorb pesticides from residues in their feed, water or during direct/indirect exposure in the course of pest control. Pesticides, agricultural and industrial chemicals, heavy metals and radionuclides may pollute animal feed and forages. The methods available for controlling pollution from these sources are well understood from a technical point of view although the effective implementation of controls can be difficult (Hinton 2000). This is true in Indian conditions as detailed information about feed and fodder residues at field level and required monitoring facilities are not available at grass root level.

In India, 38,000 MT of technical grade pesticides are used annually to control pests and plant diseases. The pesticides are classified as insecticides, fungicides, weedicides, herbicides, nematodicides and rodenticides; of which insecticides constitutes 77% of the total pesticides used in different agricultural and animal husbandry practices and in public health operations (Chauhan, 2012). The contaminants exert wide range of effects in livestock including acute to chronic toxicity with loss of production, growth retardation, systemic toxicity, infertility and carcinogenicity. It is essential to develop suitable binders that can be included in feed to minimize the absorption of these residues in order to prevent their entry into the food chain.

Conclusions

As most of the abiotic stressors affect livestock through their diet and impacts of most of stressors may be managed by providing appropriate nutrients, nutrition and nutritional resource, nutritional management is important aspect of abiotic stress management in livestock for doubling farmers' income mission. 2022. Defining the availability of various nutritional resources, their nutritional composition, judicious use and strategic management through silage making, hydroponics techniques and TMR blocks is required to avoid stress in productive animals and sustain the livestock population in drought prone areas.

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Deficit Irrigation Strategies for Improving Water Productivity and Management of Abiotic Stress in Horticulture Crops

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Introduction

Water is also becoming scarce not only in arid and drought prone areas but also in regions where rainfall is abundant. Also, due to climate changes and increased demands of different water users (agriculture, industry, domestic) water becomes scarce resources worldwide. Since, irrigated agriculture is the one of the largest consumer of these resources (so-called blue water footprint), irrigation management must be shifted from maximal production per crop area to maximal production per unit of water used by crops. To cope with the water shortage, it is necessary to adopt water-saving agriculture counter measures. Efficient use of water by irrigation is becoming increasingly important. Among the strategies for reducing water footprints, changing the full irrigation to the reduced crop's water supply (deficit irrigation techniques) is one of the options. In recent years, water-saving irrigations techniques such as deficit irrigation (DI) and partial root zone drying (PRD) or alternative irrigation (AI) have been developed with micro irrigation system for field and horticulture crops. These systems improve the water productivity (WP) and quality of produce in horticulture crops as well as in cereal crops.

Water efficient technologies/strategies

Deficit irrigation (DI)

Deficit irrigation is an optimization strategy in which irrigation is applied during drought-sensitive growth stages of a crop. The correct application of DI requires thorough understanding of the yield response to water (crop sensitivity to drought stress). In regions where water resources are restrictive it can be more profitable for a farmer to maximize crop water productivity instead of maximizing the harvest per unit land.

Concept of deficit irrigation

Water restriction is limited to drought-tolerant phenological stages, often the vegetative stages and the late ripening period. Total irrigation application is therefore not proportional to irrigation requirements throughout the crop cycle. While this inevitably results in plant drought stress and consequently in production loss, DI maximizes water productivity, which is the main limiting factor (English, 1990). In other words, DI aims at stabilizing yields and at obtaining maximum WP rather than maximum yields (Zhang and Oweis, 1999).

In the literature, the terms 'supplemental irrigation' and 'deficit irrigation' are both used. The first term generally refers to a rain-fed crop receiving additional irrigation during the whole season or during sensitive growth stages, whereas DI generally refers to fully irrigated crops from which water is withheld during certain tolerant growth stages. Since drought tolerance varies considerably by genotype and by phenological stage, DI requires precise knowledge of crop response to drought stress for each of the growth stages (Kirda *et al*., 1999). In addition, correct application of DI requires a thorough assessment of the economic impact of the yield reduction caused by drought stress (English, 1990; English and Raja, 1996; Sepaskhah and Akbari, 2005; Sepaskhah *et al*., 2006). In areas where water is the most limiting factor, maximizing WP may be economically more profitable for the farmer than maximizing yields (English, 1990). As these examples suggest, DI requires a highly integrated approach to agricultural water policy.

Advantages

- Maximizes the water productivity.
- Although a certain reduction in yield is observed but the quality of the yield (e.g. sugar content, grain size) observed to be equal or even superior to rain-fed or FI cultivation
- Allows economic planning and stable income due to a stabilization of the harvest in comparison with rainfed cultivation
- Decreases the risk of certain diseases linked to high humidity (e.g. fungi) in comparison with full irrigation

- Reducing irrigation applications over the crop cycle will also reduce nutrient loss through leaching from the root zone, resulting in improved ground water quality
- Over-fertilization may cause crops to be more susceptible to dry spells and may lead to decreased harvest indexes.
- Lower fertilizers needs as compared to in full irrigation. DI reduced fertilizer application. Combining DI and optimum fertilizer application leads to a higher yield increase (higher WP) than the sum of the separate yield increases obtained by both factors
- Controls of vegetative growth and canopy density (reduce pruning in grapevine)
- Improvement of irrigation water use efficiency and saving water for irrigation
- Increases in nutrient use efficiency (especially N)
- Improvement of fruit or yield quality (potato, grape, tomato, pepper, apple, maize)
- DI is the possibility of controlling sowing dates by irrigation, which allows improved planning of agricultural practices
- Due to drought stress in particular growth stages, the length of the cropping cycle might change under rain-fed cultivation. Farre´ and Faci (2006) report a delay in flowering (7 and 17 days) and maturity (5 and 12 days) for sorghum and maize, respectively, under water deficit conditions. McMaster and Wilhelm (2003) find that drought decreases crop cycle length for wheat and barley.

Constraints

- Exact knowledge of the crop response to water stress is important.
- There should be sufficient flexibility in access to water during periods of high demand (drought sensitive stages of a crop).
- A minimum quantity of water should be guaranteed for the crop, below which DI has no significant beneficial effect.
- An individual farmer should consider the benefit for the total water users community (extra land can be irrigated with the saved water), when he faces a below-maximum yield

- Because irrigation is applied more efficiently, the risk for soil salinzation is higher under DI as compared to full irrigation.
- Determining optimal timing of irrigation applications is particularly difficult for crops with CWP functions in which maximal WP is found within a small optimum range of ET
- Irrigators should have unrestricted access to irrigation water during sensitive growth stages.

The effect of water stress on plants at physiological, biochemical and molecular levels and a crop that is imposed to PRD as a water-saving irrigation may show diverse responses to water stress in terms of these three responses levels according to the severity and timing of the water stress (Fig 1).

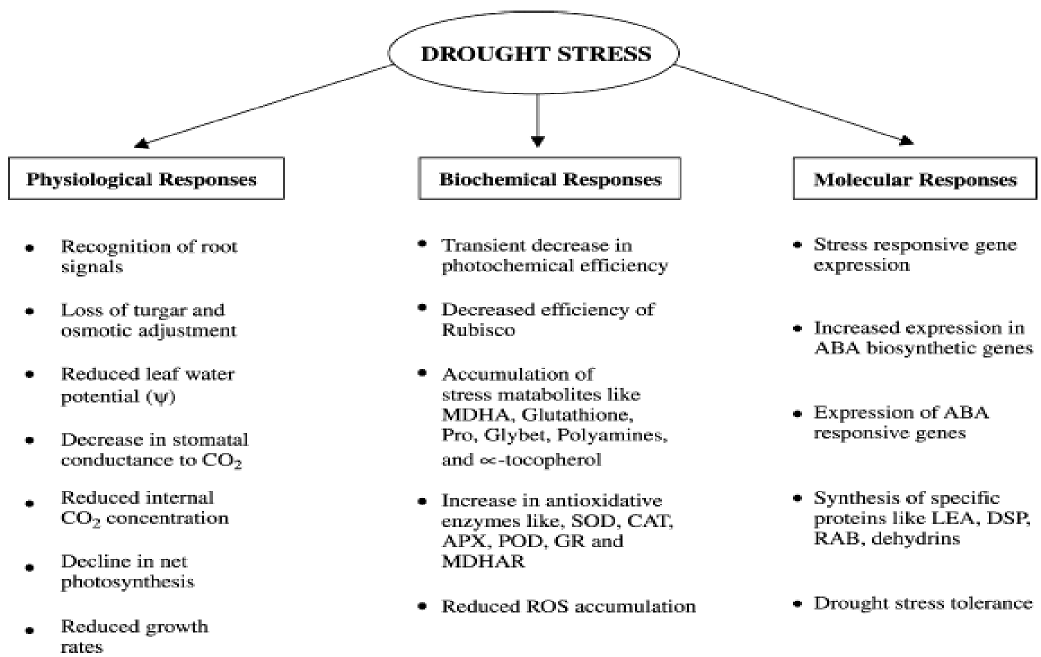


Fig 1. Physiological and molecular bases of drought stress tolerance. (After Shao *et al*., 2008)

Strategies to improve water productivity under water scarcity

There are two ways to improve water productivity of crop**:**

1. Cultivation of plants with high water-use efficiency or plants with greater drought tolerance

2. Investment in water-efficient technologies for growing plants as in deficit irrigation techniques

In recent years, the two main approaches for developing practical solutions to manipulate vegetative and reproductive growth used. That has been regulated deficit irrigation (RDI) and Partial root zone drying (PRD).

RDI

- Irrigating at less than the full requirement of the plants and potential evapotranspiration (maintaining soil moisture at a relatively low level).
- imposes **plant deficit** during prescribed crop growth period

PRD

- Applying irrigation to alternately wet and dry (at least) two spatially prescribed parts of the plant root system to simultaneously maintain plant water status at maximum water potential and control vegetative growth for prescribed parts of the seasonal cycle of plant development
- Imposes **soil deficit** within alternating sides of rootzone but plants remains turgid

RDI and PRD have become established water management techniques. Therefore, great emphasis is placed in the area of crop physiology and crop management with the aim to make plants more efficient in water use through RDI and PRD irrigation practice under dry conditions.

Partial root-zone drying irrigation (PRD)

Partial root-zone drying (PRD) is a modified form of deficit irrigation (DI) (English *et al*., 1990), which involves irrigating only one part of the root zone in each irrigation event, leaving another part to dry to certain soil water content before rewetting by shifting irrigation to the dry side; therefore, PRD is a novel irrigation strategy since half of the roots is placed in drying soil and the other half is growing in irrigated soil (Ahmadi *et al*., 2010a).

Principle of PRD

When a part of the root zone dries out, ABA produced in the roots in drying soils and is transported by water flow in xylem to the shoot for regulating the shoot physiology. The increase in abscisic acid in the xylem flow roots to leaves triggers the closure of stomata as response to water stress and reduced shoot growth and transpiration. After 10–15 days, the wet and the dry root zone are inverted. However, due to alternating wet and dry zones, roots have continuous access to water. Thus, the plant continues to grow and flowering and fruit development will not affect. Alternating the wet and dry zones of the roots means that repeated surges of ABA are delivered to the shoots, maintaining conditions of reduced shoot growth and reduced transpiration, but with no significant effects on flowering and fruit development (Fig 3)

Fig 2: Schematic of the irrigation pattern in FI, DI, and PRD
(After Davies and Hartung, 2004).

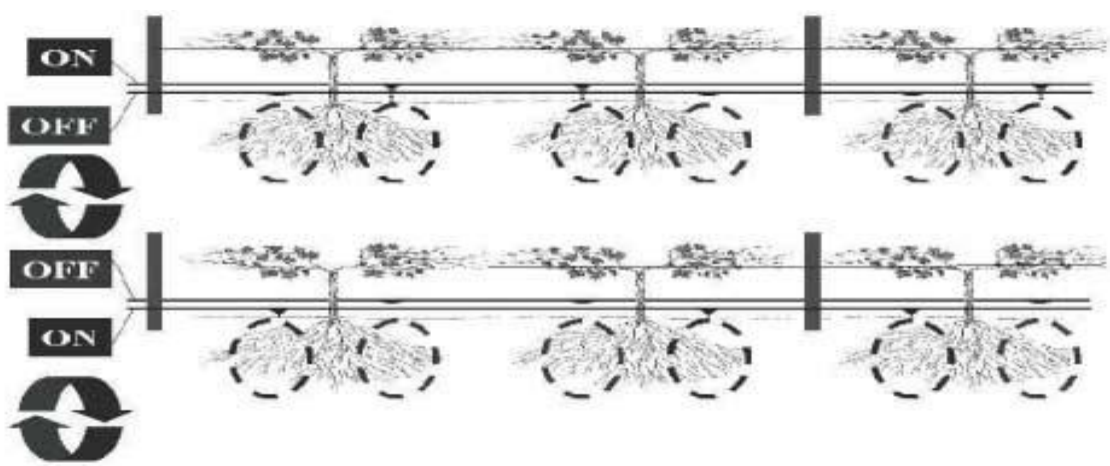


Fig 3: Partial root zone drying using two above-ground drip lines in a vineyard

Chemical and hydraulic signaling in PRD

In drought, soil drying induces restriction of water supply and these results in a sequential reduction of tissue water content, growth and stomatal conductance. The plants have some mechanism for sensing the availability of water in the soil and regulating stomatal conductance and leaf growth accordingly. It has been termed non-hydraulic or chemical signaling. Hydraulic signaling, which represents transmission of reduced soil water availability *via* changes in the xylem sap tension. Roots in drying soil produce more ABA than under normal conditions and it is moved as an anti-stress root chemical signal to shoot through transpiration stream and limits the stomatal conductance. At mild water stress, ABA as a major chemical signal (CS) acts earlier than the change in plant water status i.e hydraulic signal, HS. However, under severe water stress, both CS and HS may be involved in regulating plant physiological processes. At severe water stress, the leaf water potential in mesophyll cells decreases and stomata will close to a greater extent that inhibits the photosynthetic rate (Taiz and Zeiger, 2006). In some plants, CS and HS occur independent of each other, while in others they take place dependently. A balance between CS and HS occur in PRD. In PRD, roots on the irrigated side absorb enough water to maintain high shoot water potential, and the roots on the non-irrigated side produce ABA for possible reduction in stomatal conductance. This mechanism optimizes water use and increase water productivity.

Difference between RDI and PRD

RDI	PRD
Site must be responsive to irrigation	
Can be used with furrow irrigation	Drip irrigation preferred, alternate row furrow possible
Water must be available on demand	
Control of fruit size	No/ negligible effect on size
Vegetative growth control	Vegetative growth control
Potential for yield loss	No loss of yield
Positive effects on fruit quality	Possible improvement in quality
Marginal water savings	Significant water savings
No irrigation hardware modification	Significant changes required. Can be retrofitted.
Soil water monitoring recommended	
High-level management skills required	
Source: Regulated deficit irrigation and Partial rootzone drying, Irrigation insights no 4	

Agricultural benefit of root-to-shoot chemical signaling

PRD reduced vine vigour, canopy density and increased the quality, yield of fruit and improved water-use efficiency (Loveys *et al*., 2000). It also resulted in leaf expansion rate in wheat (Ali *et al*., 1998), maize (Bahrun *et al*., 2002), soybean (Liu *et al*., 2005a), potato (Liu *et al*., 2006c), and tomato (Topcu *et al*., 2007). Excessive plant vigour is a major problem for many fruit crops, since the use of assimilates in leaf growth restricts fruit set and development.

The frequency of the switch is determined according to soil type and other factors such as rainfall and temperature. In most of the published data the PRD cycle includes 10 to 15 days (Davies *et al*., 2000; Stoll *et al*., 2000).

Advantages and disadvantages of PRD irrigation

PRD irrigation may have benefits on water use, WUE, fruit quality and nutrient uptake It is important to assess how much water PRD can save in a growing season. Water-saving considerations have resulted in most PRD treatments receiving less water (usually 50%) than control plants. In addition to water savings, PRD has also been reported to have beneficial effects on fruit quality and nutrient uptake with no, or minimal, losses in yield (dos Santos *et al.*, 2003).

Water use and WUE

Water use as percent of fully irrigated treatment is decreased and irrigation water use efficiency (IWUE) is increased essentially by PRD as reported in a number of species, e.g. cotton, tomato, pear grapevine and hot pepper (Table1). In maize PRD irrigation reduced water consumption by 35% with a total biomass reduction of 6–11% as compared with fully watered plants (Kang and Zhang, 2004). Another experiment with hot peppers and drip irrigation showed that PRD reduced water used for irrigation by about 40% and maintained similar yield as in fully watered plants (Kang *et al*., 2001).

PRD was tested in peach and apple orchards at Yangling, Shaanxi, China by using a drip irrigation system (Gong *et al.*, 2001), and in a pear orchard in Victoria, Australia by using a flood irrigation system (Kang *et al.*, 2002b). Results showed water savings of 52% in peach and 23% in pear, respectively (Kang and Zhang, 2004).

Fruit quality

PRD can improve the quality of fruits of several species; in grapes, cotton, tomato, and hot pepper (Table 1). In grapes sugar content was increased by PRD (e.g. Stoll *et al*., 2000, dos Santos *et al.*, 2003). They have shown that this is largely a result of better control of vegetative growth of the grapevine. Also Dry *et al*., (2000) found that wine quality was consistently higher from PRD Wine yards.

Table1. Effect of PRD on water use, WUE and fruit quality

Plant	**Water use as % of fully irrigation**	**Fruit Quality**	**IWUE as % of fully irrigation**	**Reference**
Cotton	70	I*	134	Tang *et al*.,(2005)
Tomato	50	I	163	Kirda *et al* (2004)
Pear	55	n.m	145	Kang and Zhang(2004)
Grapevine	50	I	152	Dry *et al*(2000)
Hot Pepper	50	I	166	Dorji *et al*. (2004)

*I= improvement of quality n.m= not measured

Nutrient uptake

An extra benefit from PRD-induced new roots may be related to their function in nutrient uptake. The drying and rewetting cycle by PRD induced new roots, and this may make the nutrients in soil zone more available to the plants (Kang *et al*., 2001, dos Santos *et al.*, 2003).

Root development and water uptake

Root development and distribution are affected by spatial and temporal soil water distribution (Wang *et al*., 2006). Further, they affect water and nutrient uptake from the soil to maintain the physiological activities of the above-ground part of the crop. Mild water stress in soil leads to preferential root growth into the moist soil zone and water uptake through root system expansion and increasing root length density (RLD, cm root per cm3 soil) (Benjamin and Nielsen, 2006; Songsri *et al*., 2008). Earlier studies indicated that PRD enhanced the extension and inhibition of primary and secondary roots (Kang *et al*., 2000b), increased root growth (Dry *et al*., 2000) and root mass (Kang *et al*., 2000a; Mingo *et al*., 2004), improve ABA-induced root hydraulic conductivity (Glinka, 1980; Taiz and Zeiger, 2006; Thompson *et al*., 2007), and increased the nutrient uptake (Wang *et al*., 2009).

Plant water uptake rate is enhanced after re-watering in water stress condition compared to full irrigation. This is obtained due to improvement of hydraulic conductivity of root systems that is subjected to water stress (Kang and Zhang, 2004). The root system can partially compensate for the increasing limited water availability on the non-irrigated side of PRD due to an increase in root hydraulic conductivity.

Disadvantages of PRD irrigation

PRD may be reducing biomass production as CO_2 uptake is partly restricted due to stomatal closure causing water savings. Biomass reductions are often in the range of 10% in cereal crops, while in fruit trees hardly any yield reduction has been found.

The value of benefits from water savings should be balanced with value of yield reductions and cost of implementing PRD irrigation system compared with traditional systems. As PRD irrigation is in the research phase further experiences are needed to evaluate economical advantages of PRD irrigation.

Practical application of RDI and PRD: Irrigation management strategies

Before making irrigation plan it is important to know the characteristics of soil in the field including:

- Number and thickness of layers (identifying impermeable layers in the soil that may cause
  drainage and surface run-off problems)
- Soil texture,
- Soil structure
- Field water capacity, wilting point
- Rate of infiltration
- Rooting depth of plants that will be growing
- Soil chemical analyses to identify possible chemical/nutrient problems (e.g. acidity, salinity, nutrient deficiency).

Irrigation methods for applying RDI and PRD

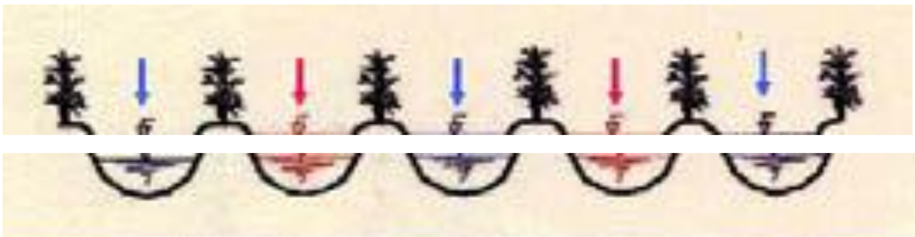
PRD and RDI could be applied in the field by different irrigation methods including:

• Furrow irrigation

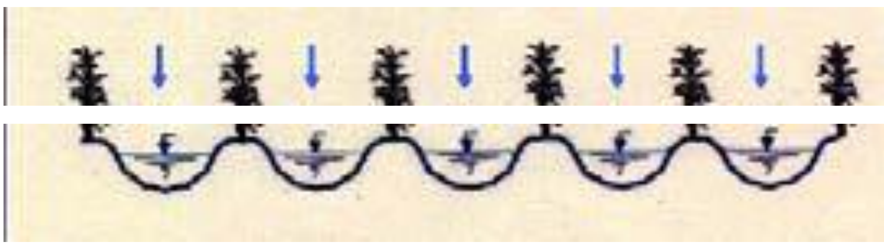
• Drip irrigation

Furrow irrigation system

PRD System should be applied as the two rows configurations and the both furrows should be irrigated alternately. After the switching period, wetted furrow started to dry out and dry furrow will be irrigated.



RDI System should be applied at the same time in all rows, but with 50-70% water amount needed for full treatment



In drip surface or subsurface for PRD irrigation two irrigation lines should be set up and operated separately with the distance between emitters of 60cm (for potato). This way lateral of one emitter will irrigate one part of the root system and emitters of other lateral will irrigate other half of root system. In FI and RDI irrigation one lateral is used for irrigation with the distance of 30 cm between emitters. Irrigation in FI and RDI should cover a total root area.

Precaution to be taken while implementing PRD

- Best PRD responses occur in soils with high values of readily available water (RAW). Shallow soils with low RAW can allow relatively small volumes of applied water to deplete rapidly. To some extent this can be overcome by more frequent irrigation.
- Use of PRD in soils with poor infiltration characteristics may also cause problems if sufficient water cannot be supplied through what is effectively 50% of the normal soil surface area.
- The amount and timing of irrigation applied to the 'wet' side should be sufficient to prevent the development of significant water deficits (soil moisture tension should remain higher than 50 kPa).
- If soil moisture monitoring is available, the irrigated side of the plant should be switched when water extraction from the "dry" side becomes negligible. In sandy soils and under hot dry conditions this may be only a few days. In soils with a higher water retention characteristic and under less stressful conditions, the cycle time may become several weeks.
- Use of PRD should not result in significant reduction in midday leaf water potential when compared with standard irrigation practice.
- When PRD is being implemented in an existing orchard, total soil area wetted by the irrigation system (wet plus dry sides) should not vary significantly from that wetted by the original irrigation system. For example, conversion from flood to drip may wet only a small fraction of the available roots. The PRD irrigation system should aim to wet about half the roots at any one time.
- Correctly implemented PRD should not result in major effects on fruit quality. With Navel oranges, PRD using very low water application rates saw a reduction in fruit size in heavily cropped trees but this problem was not evident at higher water inputs. A reduction in water input, applied by flood or by drip, may result in a small but significant reduction in the percentage of juice and an increase in acid. There should be no effect on sugars and sugar/acid ratios may change accordingly.
- Response to PRD varies between species. It is still not known how some plants will respond.

Conclusion

In areas where the available water supply limits agricultural production, deficit irrigation will gain importance over time as farmers strive to increase the productivity of their limited land and water resources. Farmers must choose crops and irrigation strategies carefully to maximize the value of their crop and livestock production activities, while ensuring the sustainability of agriculture. Deficit irrigation will play an important role in farm-level water management strategies, with consequent increases in the output generated per unit of water used in agriculture.

Partial root zone drying strategy is a very useful and significant step in improving the water use efficiency, increasing productivity, and improving quality of produce of perennial horticultural crops. The cost of implementing PRD is economical where the cost of irrigation water is high and as water becomes an increasingly valuable and scarce resource.

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Phenotyping for Abiotic Stress Tolerance in crop plants

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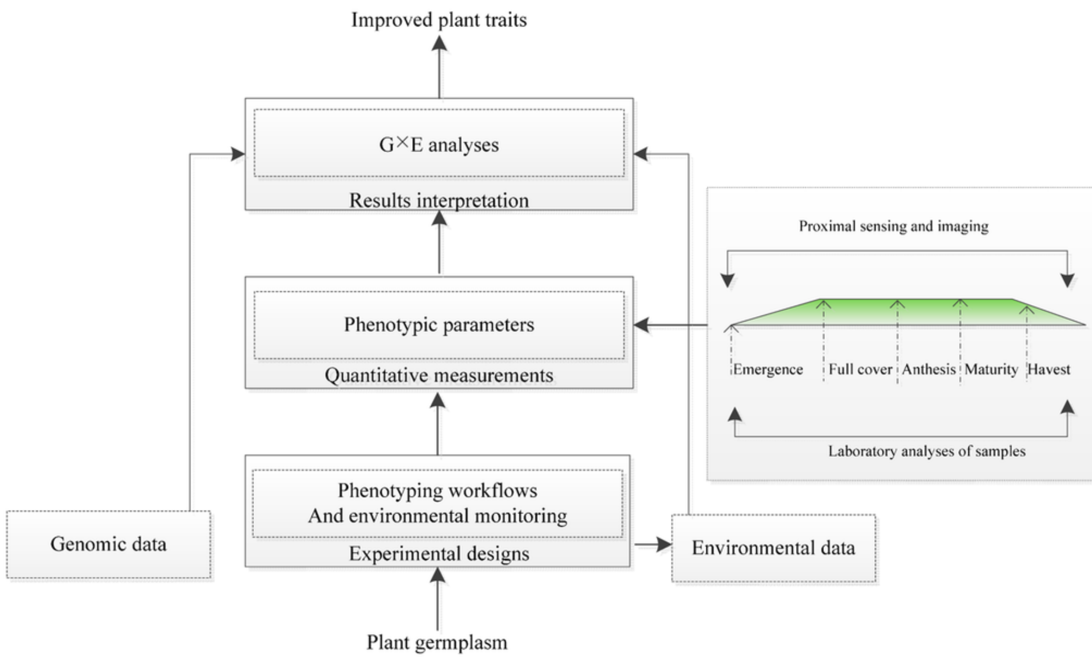
Introduction

The poor and depleted soil fertility remains a primary constraint to agricultural productivity in most of tropical and sub-tropical regions. The elevated temperatures, changing precipitation patterns and extreme weather events also greatly affected on agriculture production (IPCC, 2007). The average rate of crop production increase by only 1.3% per year, but it cannot keep pace with population growth. By connecting the genotype to the phenotype, high yielding, stress-tolerant plants can be selected far more rapidly and efficiently than is currently possible. However, the lack of access to phenotyping capabilities limits our ability to dissect the genetics of quantitative traits related to growth, yield and adaptation to stress. Now days, plant phenotyping greatly helps the genetic analysis of abiotic stress tolerance to further elucidate the stress tolerance mechanisms. However, conventional methods of plant phenotyping are laborious and destructive as compared to the recently developed high-throughput, non-destructive imaging technologies (Roy *et al*. 2011; Yang *et al*. 2013). The recent phenotyping techniques, being non-destructive, enable acquiring quantitative data on plant growth, health, and water use under abiotic stress by taking multiple images of the same plant at different time points and at different wavelengths (Morison *et al*. 2008 and Jones *et al*. 2009). Therefore, these technologies are being routinely applied to quantify traits related to stress tolerance in a number of crop plants (Berger *et al*. 2010 and White *et al*. 2012).

A scheme for plant phenotyping



Phenotyping under controlled condition

Although filed phenotyping is the best option to select genotypes of our interest in the target environment for yield and its component, the phenotyping in controlled environment facilities is advantageous for imposing abiotic stresses uniformly, which is not possible in field conditions. The studies on influence of abiotic stress factors like excess or limited moisture stress, high temperature and salinity are conducted under controlled conditions. The controlled condition under which the plants are grown should be relevant to the conditions prevailing in the field (Izanloo *et al*. 2008). Evaluation under controlled conditions is advantageous in terms of collecting data at a particular stage when genotypes being tested differ in durations to attain certain phenological stage. Growing plants in pots allows for strict control of water stress imposed on test genotypes and the homogeneity of stress severity; such control is seldom achieved under field conditions, particularly when genotypes under test differ in phenology and biomass.

Phenotyping under field condition

Ultimately, evaluation of crop plants for yield performance under particular abiotic stress needs to be done under field conditions. Field phenotyping helps to identify tolerance traits in the ultimate target environment and helps in evaluating many genotypes at a time. Unlike controlled growth condition, in field evaluations, there are certain factors which impact the quality of the phenotypic data to be collected (Tuberosa, 2011) listed the following factors to be evaluated carefully to ensure the collection of meaningful phenotypic data in field experiments under water limiting conditions. The factors are the experimental design, heterogeneity of experimental condition between and within experimental unit, size of the experimental unit and number of replicates, number of sampled plants with in each experimental unit and genotype-by-environment-by-management interaction. Though the field evaluations are conducted on the ultimate target environmental conditions or crop management during the experimentation might influence the plant's phenotype. Thus the variability caused by these factors must be kept to the minimum so as to collect quality phenotyping information. In field evaluation, techniques like measuring canopy spectral reflectance (Gutierrez *et al*. 2010) and screening under high temperature stress (Hazra *et al*. 2009) and drought stress (Ashraf *et al*. 2005) are employed. The phenotyping methodologies like line source irrigation, withholding irrigation to impose water stress (Rao and Bhatt, 1992), imposition of salinity stress and conducting evaluation trails during high-temperature periods in the hotspot areas are a few techniques that are followed under field condition.

Phenotyping sites for different abiotic stress

Drought stress:

- Long-term daily climate data and soil data are required to ensure a site allows drought stress to be applied at the required growth stage, with minimum variation in soil properties.
- Drought phenotyping is often conducted during the off (dry) season to control the timing, intensity and duration of the period of water stress and avoid the climatic uncertainty associated with conducting drought trials during the main season.

- Rainout shelters in the main season can be used as an alternative to screening in the dry season but cost and limited space are important considerations.

Nutrient stress:

- Remove depleted nutrient from the soil.
- The initial selection of a suitable site is essential.
- The development of N stress can be increased by the selection of a site with sandy soil as sandy soils generally tend to have low levels of mineral N and organic matter.
- Information on cropping history is important so fields which have previously had two distinct cropping systems on the field can be avoided.

Saline stress:

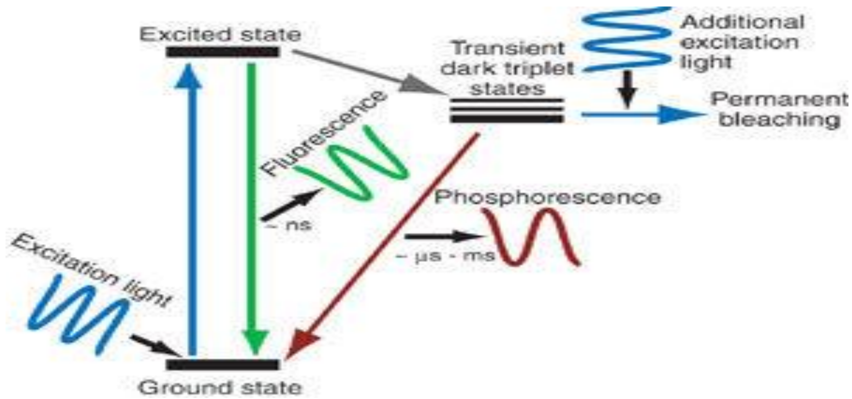
- Automatic saline solution circulatory system
- Perforated pots in saline water tanks
- At booting stage transfer of plants to saline condition to checked flag leaf condition
- Supported hydroponics system used for imposing a controlled and homogeneous salt-stressed

Thermal stress:

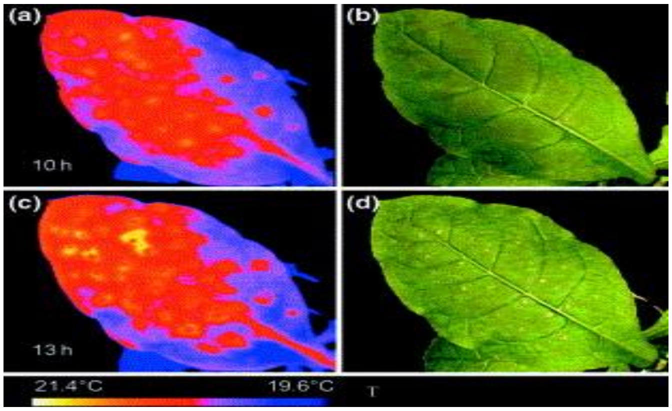
- Off season planting/ staggered planting
- Maintained heat stress condition in phytotron facility

Different imaging techniques in plant phenotyping used to detect abiotic stresses

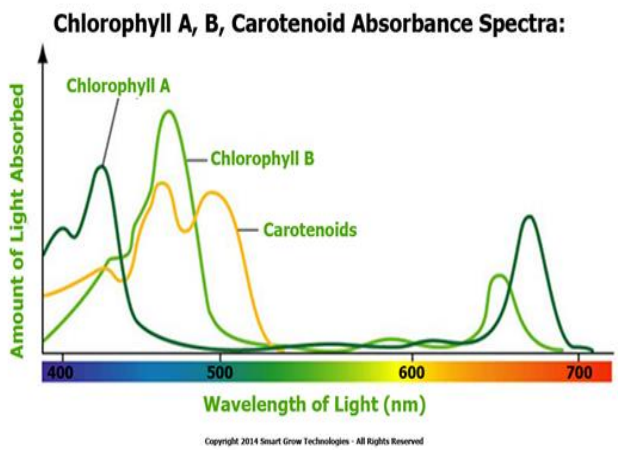
Imaging Techniques	Sensor	Resolution	Phenotype Parameters	Examples	Environment conditions
Fluorescence imaging	Fluorescence cameras	Whole shoot or leaf tissue, time series	Photosynthetic status (variable fluorescence), quantum yield, non-photochemical quenching, leaf health status, shoot architecture	Wheat (Bürling *et al*., 2010), Tomato (Mishra *et al*., 2012)	Controlled environment, field

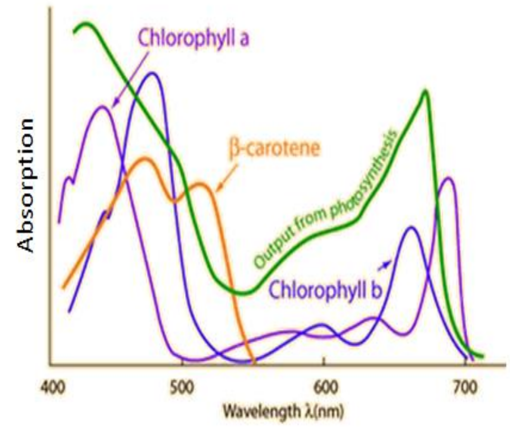


Imaging Techniques	Sensor	Resolution	Phenotype Parameters	Examples	Environment conditions
Thermal imaging	Near-infrared cameras	Pixel-based map of Surface temperature in the infrared region	Canopy or leaf temperature	Wheat (Manickavasagan *et al*., 2008)	Controlled environment, field

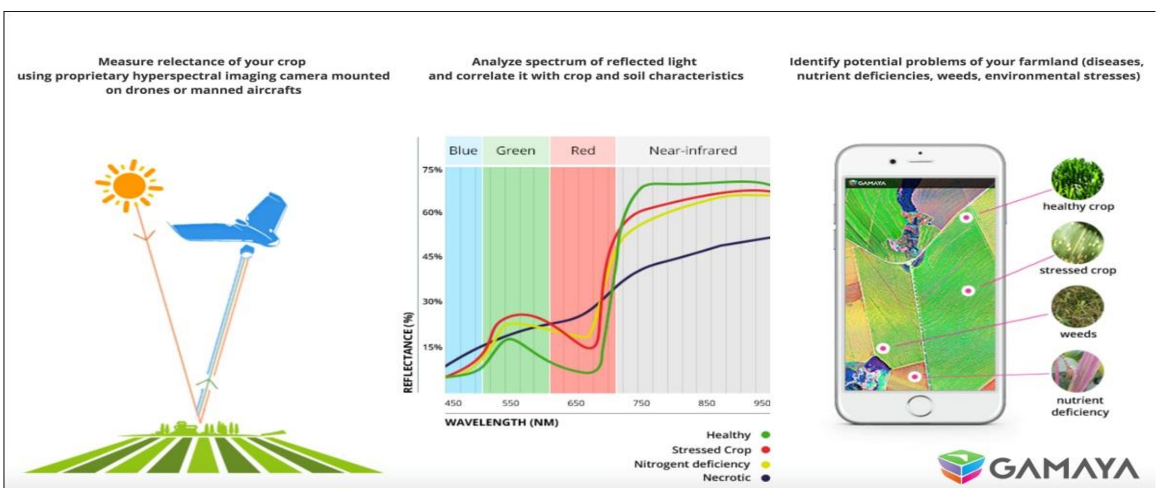


Imaging Techniques	Sensor	Resolution	Phenotype Parameters	Examples	Environment conditions
Visible light imaging	Visible spectral range	whole organs or organ parts, time series	Projected area, Growth dynamics, Shoot biomass, Yield traits, Panicle traits, Root architecture, Imbibition and germination rates, Early embryonic axis growth, Height, Size morphology, Flowering time	Arabidopsis thaliana (Joosen *et al*., 2012), Rice (Clark *et al*., 2011)	Controlled environment, field



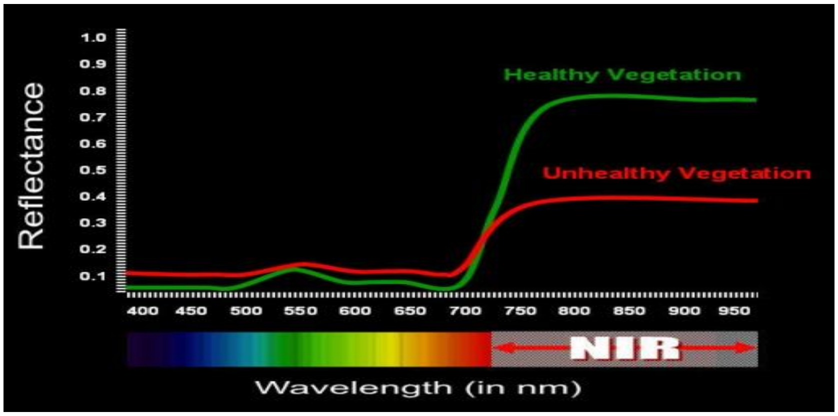


Imaging Techniques	Sensor	Resolution	Phenotype Parameters	Examples	Environment conditions
Hyperspectral imaging	Near-infrared instruments, spectrometers ,hyper spectral camera	Crop vegetation cycles, indoor time series experiments	Leaf and canopy water status; Leaf and canopy health status; panicle health status; leaf growth; Coverage density	Wheat (Moshou *et al.*, 2005)	Controlled environment; Field



Imaging Techniques	Sensor	Resolution	Phenotype Parameters	Examples	Environment conditions
Near	Near-infrared	Continuous or	water content	Soybean	Controlled

infrared imaging	cameras, multispectral line scanning cameras, active thermography	discrete spectra for each pixel in the near-infrared region	composition parameters for seeds, leaf area index	(Bolon *et al*., 2011)	environment



Conclusion

The quick development of germplasm and their tolerance to several complex polygenic inherited abiotic and biotic stresses combined is critical to the resilience of cropping systems in the face of climate change. Plant phenomics is a simply plant physiology in 'new clothes', but it promises to bring physiology up to speed with genomics by introducing the incredible recent advances made in computing, robotics and image analysis to the wider field of plant biology. Phenomics provides the opportunity to study previously unexplored areas of plant science, and it provides the opportunity to bring together genetics and physiology to reveal the molecular genetic basis of a wide range of previously intractable plant processes. The future challenges of characterizing crop plant for desirable traits require the advances we have seen in information technology, and there is a need to build on these advances for global food security. The better knowledge of the physiological, biochemical, molecular and genetic basis of the mechanisms promoting tolerance to abiotic stress will enhance the capacity to improve crop yield under hostile environments.

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National Innovations in Climate Resilient Agriculture (NICRA): A Flagship Project of ICAR Addressing Climate Change in Agriculture

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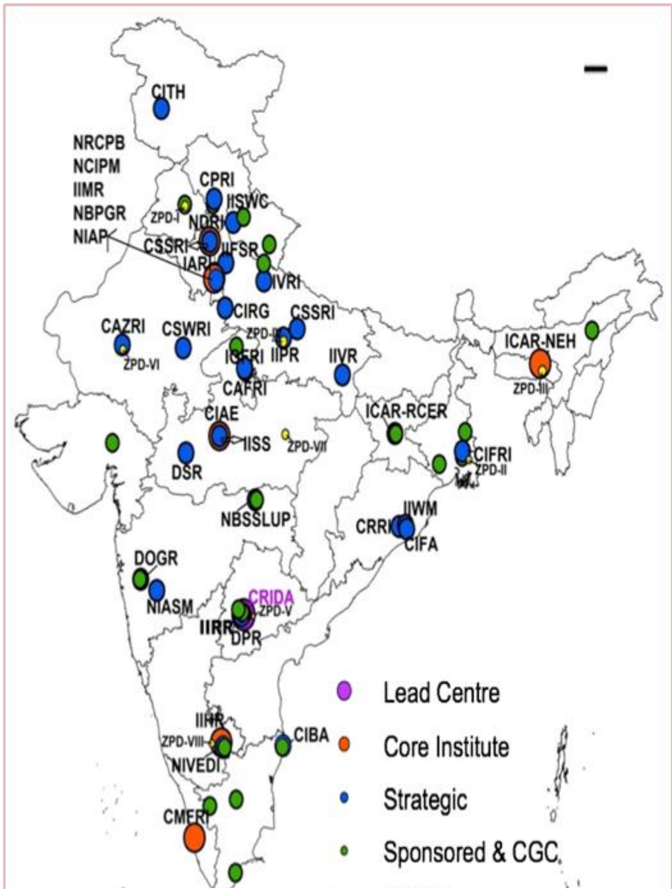
Introduction

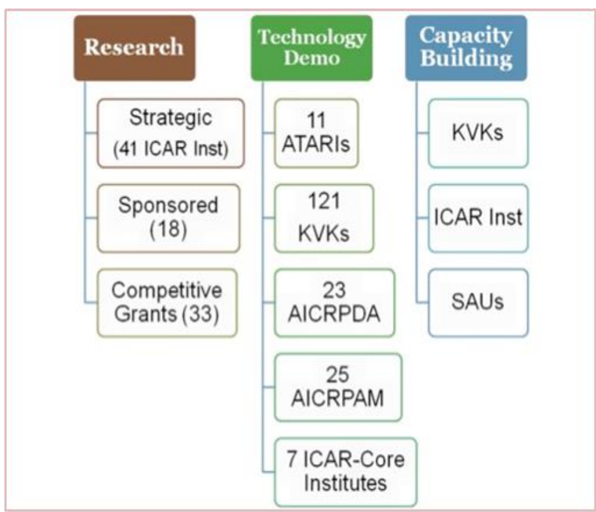
There is now a growing consensus that climate is changing and world will experience a much warmer climate because of the greenhouse gases that have accumulated in the atmosphere over time. These greenhouse gases are known to be persistent which means that the beneficial effects of best possible mitigation options will be realized only after some decades. The climate change is manifested in terms of rising temperature, more variable rainfall patterns, rise in sea level, increased frequency of extreme climatic events such as drought, floods, cyclones, heat wave, etc. Though climate change is a global phenomenon, the impacts are more inequitable in the sense that developing countries will be more affected. India, being a developing country, with a large population depending on agriculture will be more affected by climate change. Climate change affects agriculture directly through crop yields and indirectly by influencing water availability and changes in pest and pathogen incidence.

Climate change projections suggest that an increase in temperature by 2 to 3.5°C would reduce net agricultural income by 25%. Although an increase in carbon dioxide is likely to be beneficial to several crops, associated increase in temperature and increased variability in rainfall would considerably affect food production. The AR-5 of IPCC indicates a probability of 10 to 40 percent loss in crop production by the year 2080-2100. It is also evident through modeling studies that loss of 4 to 5 million tons in wheat production in future with every 1°C rise in temperature. Climate change is likely to aggravate the heat stress in dairy animals and adversely affect their productive and reproductive capabilities. A preliminary estimate indicates that global warming is likely to reduce milk production in India to the tune of 1.6 million by 2020. Increasing sea and river water temperature is likely to affect fish breeding, migration and harvest. Indian coastline, which is about 7,517 km, is vulnerable to climate change impacts such as water intrusion and coastal salinity. A rise in temperature as low as 1°C could have a profound impact on survival and the geographical distribution of different fresh water &marine fish species. Therefore, it is very important for farmers and other stakeholders to adopt climate resilient technologies and reduce the losses. Simple adaptations such as change in planting dates and crop varieties could help reduce the adverse effects of climate change to some extent. In the recent past increased extreme weather events have been experienced in some or other parts of the country viz., droughts (2000-2004, 2006, 2009, 2011, 2012, 2014 & 2015), floods (2005, 2006, 2012, 2014 & 2015), cyclones (2012, 2015), heat wave (2003, 2004, 2005, 2007, 2010 & 2016), cold wave (2005, 2006, 2008, 2011, 2012, 2013 and 2017), hailstorm (2014, 2015). Increased number of mid-season droughts and high intensity rains that take away fertile soil leading to water stress reduced food production, stability and livelihoods of the farmers in the country. Small changes in temperature and rainfall would have significant effect on the quality of cereals, fruits, aromatic and medicinal plants. Pests and diseases are highly dependent upon temperature and humidity, and therefore will greatly be influenced by climate change. The recent outbreak of whitefly on cotton in northwest India and pink bollworm at several cotton growing areas of the country is attributed to aberrant changes in weather.



NICRA Net Work

Therefore it is evident that climate change has become an important area of concern for India to ensure food and nutritional security for growing population. To meet the challenges of sustaining domestic food production in the face of changing climate and generate information on adaptation and mitigation in agriculture to contribute to global fora like UNFCC, it is important to have concerted research on this important subject. With this background, Indian Council of Agricultural Research (ICAR), under the Ministry of Agriculture and Farmers Welfare launched a network '*National Innovations in Climate Resilient Agriculture*' (NICRA) during the year 2011. NICRA aims to evolve crop varieties tolerant to climatic stresses like floods, droughts, frost, inundation due to cyclones and heat waves. Under this project about 41 Institutes of ICAR are conducting research under Strategic Research Component covering various theme areas viz., development of multiple stress tolerant crop genotypes, natural resource management, quantification of green house gas emissions in agriculture and the develop technologies for their reduction, climate resilient horticulture, marine, brackish and inland fisheries, heat tolerant livestock, mitigation and adaptation to changing climate in small ruminants and poultry. Sate of the art infrastructure required or climate change research such as high through-put phenotyping platforms, free air temperature elevation (FATE), carbon dioxide and temperature gradient tunnels (CTGC), high performance computers, automatic weather stations, growth chambers, rainout shelters, animal calorimeter, shipping vessel, flux towers and satellite receiving station were established in the research institutes across the country under NICRA project.



Components of NICRA

Technology Demonstration Component (TDC) under NICRA aims to demonstration of location specific practices and technologies to enable farmers cope with current climatic variability. Demonstration of available location-specific technologies related to natural resource management, crop production, livestock and fisheries is being taken up in the climatically vulnerable districts for enhancing the adaptive capacity and resilience against climatic variability. Technologies with a potential to cope with climate variability are being demonstrated under Technology Demonstration Component (TDC) in 121 most vulnerable districts selected across the country through Krishi Vigyan Kendras (KVKs).

Institutional intervention Component under NICRA aims at creating enabling support system in the village comprising of strengthening of existing institutions or initiating new ones (Village Level Climate Risk Management Committees (VCRMC)), establishment and management of Custom Hiring Centers (CHCs) for farm implements, seed bank, fodder bank, creation of commodity groups, water sharing groups, community nursery and initiating collective marketing by tapping value chains. 100 custom hiring centers (CHCs) for farm machinery were setup under NICRA project, which are being managed by Village Climate Risk Management Committee (VCRMC) comprising of villagers. Module on use of ICT for knowledge empowerment of the communities in terms of climate risk management is also being planned in select KVKs for generation of locally relevant content and its dissemination in text and voice enabled formats. 121 KVKs associated under NICRA projects have also taken initiatives such as participatory village level seed production of short duration, drought and flood tolerant varieties, establishment of seed banks involving these varieties were established in the KVKs, demonstration and of improved varieties of fodder seeds and establishment of fodder bank in NICRA villages. Details on the research under this project is as under.

Climate Smart Crop Varieties

Large number of germplasm screened for drought, heat, salinity, submergence tolerance etc. in different field and horticultural crops, for identifying donors for stress tolerance. Number of advance breeding materials was generated and evaluated at multi-locations for developing new cultivars. Germplasm lines of rice and wheat tolerant to drought and heat stress have been collected from different climatic hot-spot regions of India. So far a total of 184 rice accessions were collected. Evaluation of wheat germplasm for drought tolerance with 1485 accessions was conducted to identify drought tolerance lines based on 22 morpho-physiological traits. Based on the drought susceptible index a reference set will be developed for allele mining using micro satellite markers. Marker assisted back cross breeding was carried out using molecular markers link to the

QTL governing drought tolerance into Pusa Basmati-1. rice varieties. Two rice genotypes for submergence tolerance was registered with National Bureau of Plant Genetic Resources (MBPGR), New Delhi. One salinity tolerant variety is in final year of All India Coordinated Research Project trials. Three superior heat tolerant hybrids were developed. Four drought tolerant rice varieties were released for Tripura. Two extra-early (50-55 days) green gram varieties were identified for summer cultivation (IPM 409-4, IPM 205-7) and one multiple stress tolerance redgram wild accession (*C. scarabaeoides*). A large number of soybean genotypes were evaluated for drought. Lines JS 97-52, EC 538828, EC 456548 and EC 602288 identified as relatively tolerant. These lines have been crossed among each other and with lines with superior agronomic background and are in F_{2-3} generations. Five heat tolerant and 12 drought tolerant genotypes in tomato. Number of mapping population in rice, wheat, maize were developed for identifying QTL for various abiotic stresses in these crops for utilization in maker assisted selection (MAS) breeding.

Natural Resource Management

GHG emissions (CO_2, CH_4& N_2O) due to implementation of climate resilient interventions in various production systems (annual and/perennial crops, irrigated rice, inputs, livestock, forestry and land use change) were converted to an equivalent value (tonne CO_2 equivalent) in 7 villages of Gujarat and Rajasthan, which were found to be negative suggesting a sink in GHG emissions. Direct-seeded rice (DSR) with mungbean residue incorporation, brown manuring (BM) with *sesbania*, rice residue retention (RR) in zero till (ZT) wheat/rabi crops are important conservation agriculture (CA) practices. It was observed that mung bean residue (MBR) + DSR – ZTW – ZT summer mung bean (ZTSMB) gave highest system productivity, net return, water productivity and low GWP. In long term efforts to assess CA practices on productivity enhancement, nutrient use efficiency, soil health and quality, it was observed that seed (3.8 t ha^{-1}) and stover (5.6 t ha^{-1}) yields in maize in CA were on par with conventional system (CT). Also, significantly higher grain (5.3 t ha^{-1}), stover (6.5 t ha^{-1}) yields and harvest index (0.44) were realized with balanced fertilization with NPKSZnB. Analysis of Resource Conservation Technologies (RCT) in NEH zone indicated that conventional Tillage (CT) has higher cumulative soil respiration (> 18%) compared to zero tillage. Agroforestry offset carbon dioxide from atmosphere is 0.77 tons of $CO_2 ha^{-1}$ $year^{-1}$and agroforestry system are estimated to mitigate 109.34 million tonnes CO_2 annually from 142.0 million ha of agriculture land. Further, it is estimated to offset 33 per cent of total GHGs emissions from agriculture sector annually at country level. The net eco-system methane exchange during rice growth period was the highest between active tillering to maximum tillering stage in rice. The diurnal variations in mean Net Eco-system Exchange (NEE) in submerged rice eco-system in both dry and wet seasons varied from + 0.2 to - 1.2 and + 0.4 to - 0.8 mg CO_2 m^{-2} s^{-1}. The cumulative seasonal methane emission was reduced by 75% in aerobic rice as compared to continuously flooded rice. The seasonal emissions were lower in slow release N fertilizer, especially, when applied on the basis of Customized Leaf Colour Chart (CLCC). Zero tillage in wheat lowered the GWP as compared to tilled wheat. Similarly, CO_2, CH_4 and N_2O fluxes were influenced by tillage / anchored residue and anchored residues of 10 and 30 cm in zero till reduced the N_2O emissions in rainfed pigeonpea-castor system. In efforts on mitigation strategies by reducing carbon foot prints through conservation agriculture in rainfed regions, carbon foot print from various practices like decomposition of crop residues, application of synthetic N fertilizers, field operations and input production indicated that there is a scope to reduce carbon foot prints by reducing one tillage operation with harvesting at 10 cm height with minimal impact on the crop yields. Long-term conservation horticultural practices in mango orchards improved the quality of soils through enhancing the organic carbon fraction and biological status, especially near the surface. Soil aggregates and water stability improved under conservation treatments. Cover crop, Mucuna, could conserve maximum moisture and reported higher Glomalin content in soil indicating the improvement in soil aggregation. Assessment of biochar on productivity, nutrient use efficiency and C sequestration potential of maize based cropping system in North-Eastern Hill region indicated a higher soil microbial biomass carbon (SMBC), dehydrogenase enzyme activity (DHA) and soil organic carbon (SOC) with application of biochar @ 5.0 t/ha along with 75% RDF + 4 t/ha FYM, while exchangeable aluminium and exchangeable acidity were reduced. GHG inventory for different cropping systems and production systems. GHG emissions quantified from Conservation Agriculture (CA) – 15 to 20% reduction, Resource conservation technologies (Biochar, zero tillage, reduced tillage, mulching etc.). C Sequestration in different agroforestry systems (16-22 t C ha^{-1}).

Greenhouse Gas Emission from Agriculture and Allied Sector

Under NICRA, emphasis has been placed on the development of technologies, which can reduce the green house gas emissions without compromising on yield. As part of this initiative, various ICAR institutes such as Indian Agricultural Research Institute (IARI), New Delhi, Indian Institute of Farming Systems Research (IIFSR), Modipuram, Indian Institute Soil Science (IISS), Bhopal, Central Arid Zone Research Institute (CAZRI), Jodhpur, ICAR Research Complex for NEH Region (ICAR-NEH), Umiam are working on various themes related to the GHG emissions. Facilities like, Eddy Covariance towers are established at IARI, New Delhi and National Rice Research Institute (NRRI), Cuttack for continuously monitoring the GHG emissions from the crop fields during growing season so as to quantify precisely the extent of GHG emissions from the paddy systems. Research Facilities like Rainout shelter, Carbon dioxide Temperature Gradient Chamber (CTGC), Free Air Carbon dioxide Enrichment (FACE), Free Air Temperature Enrichment (FATE) etc. have been established to understand the impact of elevated carbon dioxide (eCO_2) and temperature and develop crop varieties that can withstand these stresses. Practices which can further reduce the GHG emissions such as improved systems of paddy cultivation, fertilizer management, improved fertilizer materials, crop diversification, etc. are explored for further reducing the GHG emissions from the paddy based systems. The proven mitigation practices, which can reduce the GHG emissions, are being demonstrated to farmers as part of the Technology Demonstration Component (TDC) of NICRA. The TDC of NICRA is being implemented in 121 climatically vulnerable districts of the country by taking one or cluster of villages in each of the vulnerable district.

Location specific, crop specific mitigation practices such as system of rice intensification, direct seeded rice cultivation (dry and wet methods of cultivation), soil test based fertiliser application, rational application of nitrogen, integration of trees especially fruit trees in the arable systems, efficient irrigation systems such as drip method and sprinkler method of application which can reduce the energy use while irrigating field crops, demonstration of zero tillage cultivation as an alternate to burning crop residues in rice-wheat systems of Punjab and Haryana where large quantities of rice residues are being burnt, integration of green manure crops in the existing cropping systems, promotion of green fodder crops and greater use of green fodder for livestock, etc. are being demonstrated as part of the technology demonstration component of NICRA in the 121 climatically vulnerable districts of the country. The proven resilient practices are being integrated in the development programs such as the Crop diversification in traditionally paddy growing regions as part of the National Food Security Mission (NFSM) wherein 1.02 lakh ha is being diversified from paddy to other less water consuming crops in the country during the year 2015-2016. Similarly the paddy systems of cultivation such as System of rice cultivation, direct seeded rice are being promoted by the development programs as part of the NFSM where in 1.63 lakh ha area was brought under these improved methods of paddy cultivation in the country during the year 2015-2016. Such kind of efforts would contribute to reduction of GHG emissions in the country.

Horticulture

Climate change impacts several horticultural crops in the country. Flooding for 24 hours severely affects tomato during flowering stage. Onion during blub stage is highly sensitive to flooding, where as warmer temperatures shorten the duration of onion bulb development leading to lower yields. Similarly, soil warming adversely affects several cucurbits. Reduction in chilling temperature in the recent years in Himachal Pradesh drastically affected apple production, and the farmers are shifting from apple to kiwi, pomegranate and other vegetables. More importantly, temperature and carbon dioxide are likely to alter the biology and forging behavior of pollinators that play key role in several horticulture crops. Under NICRA project research has been initiated at 5 ICAR Institutes viz., Indian Institute of Horticultural Research (IIHR), Bengaluru, Indian Institute of Vegetable Research (IIVR), Varanasi, Central Potato Research Institute (CPRI), Shimla, Central Institute of Temperate Horticulture (CITH), Srinagar and Directorate of Onion and Garlic Research (DOGR), Pune. High throughput screening of germplasm using plant Phenomics, Temperature Gradient Chambers, FATE Facility, Root imaging system, Environmental Chamber, TIR Facility, Photosynthetic System and Rainout shelter enabled to characterizes large number of germplasm lines and identify suitable donors for breeding against drought, heat stress and flooding in tomato, brinjal and onion. The technique for inter-specific grafting of tomato over brinjal has been standardized and large-scale demonstrations have been taken up to withstand drought and flooding in tomato. Environmentally safe protocol was developed for synchronizing flowering in mango, which is induced due to changing climate. A microbial inoculation with osmo tolerant bacterial strains have been developed to improve yield under limited moisture stress in tomato. Several resource conservation technologies viz., mulching, zero tillage, reduced tillage, biochar etc. have been demonstrated in climatically vulnerable districts across the country through Krishi Vigyan Kendras (KVKs). Large-scale adoption of this climate resilient technologies enable to adopt the changes associated with global warming and also keep pace with increasing demand for horticulture products in the country in the years to come.

Livestock

Under NICRA project climate change research facilities for livestock viz., CO_2 Environmental Chambers, Thermal Imaging System, Animal Calorimeter, Custom Designed Animal Shed etc. have been established at ICAR-National Dairy Research Institute (NDRI), Karnal and ICAR-Indian Veterinary Research Institute (IVRI), Izatnagar. Biochemical, morphological and physiological characterization of indigenous cattle breeds were carried out and compared with exotic breeds. The traits identified in indigenous breed viz., heat shock proteins, air coat colour, wooly hair etc. that impart tolerance to heat stress could be used in future animal breeding programs to develop breeds that can withstand high temperature. Different feed supplements have been identified and tested successfully to withstand heat stress in cattle. Studies on prilled feeding in cattle showed that they help lowering stress levels and methane emission. Custom designed shelters system and feed supplementation with chromium propionate, mineral supplements (Cu, Mg, Ca and Zn) both in feed and fodder significantly improved the ability to withstand heat stress. At ICAR-North Eastern Hill Region, Umiam, the local birds of Mizoram are predominantly black in colour, small size, crown appearance on head, light pink comb with black, poorly develop wattle, small ear lobe, shank is brown to black and elongated. The average annual egg production of local birds is 45-55 eggs. Local birds are more tolerant to common diseases of poultry. Innovative deep litter pig housing model was developed that offers the advantages of better micro-environment both summer and winter, better physiological adaptation, protecting animal welfare and behavior, faster growth rate of piglets and higher performance and productivity and low incidences of diseases/ conditions. The performance of Vanaraja poultry under backyard farming at different altitude under diversified agro-climatic condition was evaluated. Vanaraja birds have high tolerance to incidence of diseases and showed wide adaptability under different altitude. Many of these climate resilient technologies viz., feed supplement, shelter management, improved breeds, silage making, de-warming etc. have been demonstrated in the farmers field through KVKs in the 121 climatically vulnerable districts across the country. Up-scaling of these technologies through respective State Governments would enable the livestock farmers in the country cope with vagaries associated with climate change.

Fisheries

Under NICRA project climate change research facilities for Fisheries viz., Research Vessel, Green House Gases analyzer Agilent 7890A GC Customized, Fish Biology Lab, CHNS/O analyzer, Automatic Weather Station installed etc. have been established at ICAR- Central Marine Fisheries Research Institute (CMFRI), Kochi, ICAR- Central Inland Fisheries Research Institute (CIFRI), Barrackpore, ICAR- Central Institute of Brackish water Aquaculture (CIBA), Chennai and ICAR- Central Institute of Freshwater Aquaculture (CIFA), Bhubaneswar. Relationship of temperature and spawning in marine and freshwater fisheries sector is being elucidated so that fish catch in different regions can be predicted by temperature monitoring. A shift in the spawning season of oil sardine was observed off the Chennai coast from January-March season to June-July. Optimum temperature for highest hatching percentage was determined in Cobia. A closed poly house technology was standardized for enhancing the hatching rate of common carp during winter season. An e-Atlas of freshwater inland capture fisheries was prepared which helps in contingency planning during aberrant weather. For the first time a green house gas emission measurement system was standardized for brackish water aquaculture ponds. Cost effective adaptation strategies like aeration and addition of immuno-stimulant in the high energy floating feed helped freshwater fish to cope with salinity stress as a result of seawater inundation in Sundarban islands. Relationship was established between increase in Surface Sea Temperature (SST) and catch and spawning in major marine fish species. Simulation modeling was used to understand the climate change and impacts at regional/national level.

Micro Level Agro Advisory

Under ICAR-NICRA project a concept of micro level Agromet advisories at block level was developed and on a pilot basis with the help block level forecasts provided by IMD, Agrometeorologists of AICRPAM cooperating centers and KVK subject matter specialists initiated in 25 selected blocks in 25 selected districts. AICRPAM introduced a new concept "Field Information Facilitators (FIFs)" who acts as the interface between the farmer and AICRPAM & KVK for Crop data collection and dissemination of MAAS.

The Dissemination mechanism was strengthened with different methods used by the AICRPAM centers viz. Dandora, pasting posters at different important places where people frequently watch, through SMS to the mobile phones of the farmers who are registered with AICRPAM center and KVKs. Special mobile applications were also developed by AICRPAM centers for dissemination of AAS. The feedback obtained from the farmers stated that many of them were satisfied with the timely Agromet advisories which are benefitted them a lot. some of the success stories presented below. In reality expansion of these services throughout the country will benefit of farming community and helps in doubling of their income.

Policy Support

Vulnerability assessment map prepared under NICRA is being used by different Ministries and several NGOs/CBOs.

- NICRA is also contributing to National missions like NMSA, Water mission, Green fund and INDC

- GHG inventory by NICRA partner institutes contributes to BUR reports
- Outcome of NICRA project supported some of the policy issues in Sates of Maharashtra (BBF Technology), Million farm ponds in the Sates of Andhra Pradesh and Telangana, ground water recharge initiatives (Southern states), drought proofing in Odisha, NABARD action plans, NICRA model village expansion in Assam etc.
- Contingency planning workshops organized every year in different States helps in preparedness to face weather aberrations.

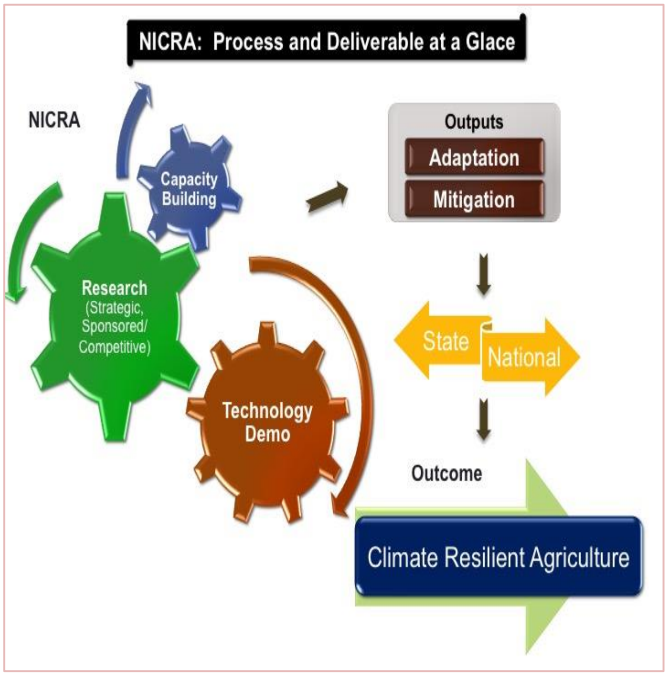
Over all, NICRA project is contributing towards developing adaptation and mitigation strategies in the country and enabling to make Indian agriculture more resilient to climate change.

Conclusions

NICRA is a unique project, which brings all sectors of agriculture viz. crops, horticulture, livestock, fisheries, NRM and extension scientists on one platform for addressing climate concerns. It is very important to sustain the efforts made in the past few years and take forward the project for some more years. Over the past five years, the state of the art infrastructure facilities have been established, standardized and put in to function in core institutes of ICAR to undertake the climate change research. Manpower (Scientists, Research Associates, Research Fellows, Technical Officers etc.) have been trained to handle and operate these facilities. However, some of these precious research facilities are yet to be utilized to the full potential. In other words, a large platform related to climate change research has been created in the country. Crop improvement for multiple stresses takes several years of research and multi location testing. Efforts made under this project, in some cases resulted in development of varieties/hybrids ready for large-scale cultivation. Whereas, many are under different stages of development which may require few more years to be released as variety/hybrid/breed. Simulation modeling to assess the impact of climate change at regional level is still at initial stage. Standardization of minimum data sets and compilation of data from different sources have shown good progress. In the next phase, these data sets will be used for modeling.

Capacity building for this activity will be emphasized and a dedicated group will be formulized. Research, essentially long term in nature, should continue further to achieve the intended outputs and outcomes

Though there are some positive lessons and experiences emerging out of technology demonstration component, there is still considerable need to continue this activity to identify and demonstrate technologies that help deal with climate change. In fact, the technologies found to be performing well are getting fed into programs such as NMSA. There is still need to develop variety of adaptation options for different sub-sectors within agriculture, for different regions and for farmers with varying resource endowments. Such an effort is to be accompanied by identification of factors that help adopt technologies on a wider scale.



The commitments of the country to emission reductions require generate appropriate information and data on emissions as well as options that help reduce emissions. Techniques standardized so far under NICRA for estimation of GHG emissions from different management practices will be used for further reducing the carbon footprint of production systems in the country. Government of India has committed for the reduction of emission intensity of GDP by 32-35% by 2030 from 2005 levels, and the outputs of NICRA project contributing to several national project reports i.e., Intended Nationally Determined Contribution (INDC), Biennial Update Report (BUR), Nationally Appropriate Mitigation Action (NAMAs), National Mission on Sustainable Agriculture (NMSA) and several other Missions under National Action Plan on Climate Change. The system-wide impacts and responses to climate change need to be understood better and more comprehensively. The efforts in this direction, which have begun, recently have to be taken through their logical course for such an understanding is necessary to identify and prioritize various adaptation options. To sum up, the activities initiated few years back under NICRA should continue and expand in scope and content, and enable to develop multi location multi sector mitigation and adaptation strategies so that we combat major challenge posed due to climate change in Agriculture.

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Farm Pond based Aquaculture Model in perspective of Doubling Farmers Income

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Prologue

The majority of the Indian population is dependent on agriculture and allied sectors for their livelihood and income. Therefore, maximum emphasis is given to the development and improvement of these sectors. However, limited irrigation is one of the important and critical constraints in these sectors as only 35% of the net sown area in India is under complete irrigation. To overcome irrigation problems as well as to boost the agriculture production the government encouraging construction of farm ponds which can harvest of rainwater and subsequently storing this water for later (during drought) use of agriculture. These farm ponds which are constructed under different agricultural scheme in the farmers land has scope to utilize for aquaculture without affecting the water level in farm pond. The farm pond based aquaculture is potential option to improve farmer's surplus income and ensure their sustainable livelihood. Fish culture in such water bodies has potential to increase fish production and economic return per unit area of land. This model of producing fish fingerlings results in increasing the fingerling production and will take 'Mission Fingerling' programmes as forward linkage in Blue revolution scheme. It is expected that this additional water area will prove a boon to 'Mission Fingerling' programmes to achieve blue revolution.

Introduction

Past strategy for development of agriculture sector in India has focused primarily on rising agricultural output and improving food security. It is obvious that if inflation in agriculture price is high, farmer's income in nominal terms will double in much shorter period. This implies that the ongoing and previously achieved rate of growth in farmer income has to be accelerated. Therefore realise the need to pay special attention to the farmer, the Ministry of Agriculture and Farmers Welfare set the goal of doubling farmers income by the year of 2022 and took strong measure for the same to harness all possible sources of growth in farmers income within as well as outside agriculture sector. MoA mentioned the major sources of growth operating within agricultural sector are:

1) Improving in productivity
2) Resource use efficiency or saving in cost of production
3) Increase in cropping intensity
4) Diversification towards high value crop
5) Shifting cultivator from farm to non-farm occupation
6) Improvement in terms of trade for farmers or real price

So, keeping in the view of above major possible sources of growth of income, the farm pond based aquaculture, based on two above sources i.e. 1) Resource use efficiency or saving in cost of production and 2) Diversification towards high value crop.

Farm ponds a boon for farmers

Since Climate change impacts agriculture by reducing yield due to intensity of drought, rise in temperature, variability in precipitation and reducing the availability of several natural resources, water being the most prominently commodity. To overcome this Agriculture Department of the Government of India has initiated a '*National Horticulture Mission'*, *Maharashtra Rural Employment Guarantee Scheme*, *Rashtriya Krishi Vikas Yojana* (RKVY). Maharashtra State initiated significant efforts in this direction and a scheme popularly known as *"Magel Tyala Shet Tale*" (Farm pond on Demands) and *Jalyukt Shivar* (JYS). In Andhra Pradesh, mandal committee will prepare a plan on '*Neeru-Chettu'*, NREGA and farm ponds construction. Under '*Panta-Kunta'* programme, two to five small farm ponds will be dug in every village. All schemes offers a subsidy for digging and lining the farm ponds which to ensure water storage for longer period. Farm ponds are manmade tanks constructed for holding water which could be used during scarce season to ensure lifesaving irrigation for the crops. Very Few studies conducted on aquaculture of farm pond provides information on the aquaculture.

Smallholder fish production systems

Todays, the majority of the individual farmers have farm pond and has scope to utilize for aquaculture without affecting the water level for future use. At the same time scarcity of water is a major problem faced by the farmers and a slew of measures to protect remuneration, keep input costs low and open up alternative forms of income will help the farmers getting surplus income. So, Fish culture in farm pond has potential to increase fish production system and economic return per unit area of land. The investment costs are small and a return on the investment is possible in as little as three months which is totally surplus income of the farmers in existing resources. It appears to be a highly suitable livelihoods option for people who have farm pond with limited capital investment and operating costs of around Rs.7650 for a 30 X 30X 3 m farm pond, generating ₹ 28000-30000 of revenue.

Now days, major concern in freshwater aquaculture is to increase production per unit area by applying different innovations and technologies in existing water resources. The production from marine sector has almost reached its potential as most of the resources have already been overexploited and therefore there is little scope for increasing the production from that source. On the contrary, most of the inland fishery resources are underexploited and there is tremendous scope for triggering fish production from different inland fisheries resources. A study made by the International Water Management Institute (IWMI) revels that by 2025 nearly $1/3^{rd}$ of world population would live in the regions of severe water scarcity and the same proportion of the population in India could face absolute water scarcity. Therefore a major focus will be on the judicious management of water resources like farm pond and do develop strategies for its efficient and multiple uses.

These water bodies' uses for agriculture use during the drought period and it can be parallel used for aquaculture by stocking fish species such as *Labeo rohita, Catla catla* and *Cirrihinus mrigala*, GIF Tilapia *Oreochromis niloticus*, *Pangasianodon hypophthalmus*. This model of producing fish fingerlings results in increasing the farmer's income. It is also expected that this additional water area will prove a boon to 'Mission Fingerling' programmes to achieve blue revolution. In the light of this perspective, Farm Pond based Aquaculture Model could take a viable option for doubling farmer income in India.

Boosting fingerling supply

A key constraint to aquaculture in large water bodies is the supply of fingerlings especially those of a sufficiently large size to grow quickly to market size, in seasonal ponds or to avoid predation in perennial ponds. The DARE realised the fish fingerling production is the single most important critical mission visualised to achieve fish production targets under the Blue Revolution, The *Neel Kranti* Mission. The mission seeks to enhance fisheries production to 15mmt from 10.79 mmt by the end of the year 2020-21, under the Blue Revolution. Large-scale implementation of farm pond excavation scheme is going to be a major boon for the fingerling production. There was no systematic supply chain for fish fingerling in the India, where it can make backward linkages for fish growers. Farm pond based aquaculture makes bridge between fish hatchery to fish grower.

Farming strategies

Nursing fish seed is arguably the simplest component of farm pond based aquaculture and a suitable entry-point into aquaculture for farmers and fishers. Between hatchery operations, which produce spawn, and on-growing operations, which raise carp to market size, is a short but vital stage where spawn are nursed in farm pond to fingerlings – the size at which they can be stocked in larger seasonal or perennial ponds. The nursery rearing involve nurturing of 3 days old spawn which has just begin to eat and continue for the period of 3 months to raise the fingerling size. The different management strategy involved to fingerling production is:

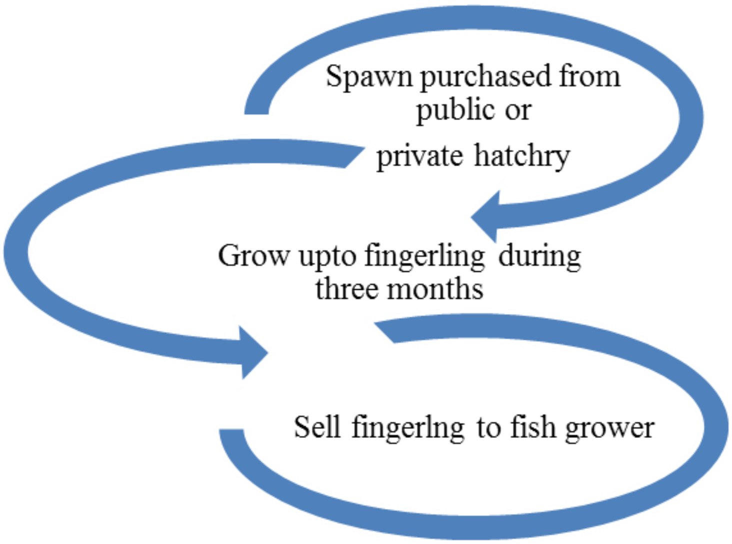

Fig.1 Backword and farwrd linkage of farmers

Nursery farming and management in Farm pond

In farm pond based aquaculture model, emphasis is given on boosting the primary productivity by manure and fertilization. This will ensure enough availability of plankton as natural food. In addition, supplementary feed plays an important role and fed @ of 5-8 % of body weight. Broadly, the various steps involved in the management of farm ponds may be classified as (i) Pre-Stocking Management, (ii) Stocking Management (iii) Post-Stocking Management operations

Pre-stocking management

Pre-stocking management aims at proper preparation of pond to remove the causes of poor survival, unsatisfactory growth, etc. and also to ensure ready availability of natural food in sufficient quantity and quality for spawn/fry/fingerlings to be stocked. The first step in pre-stocking management is to ploughing (without lining farm pond), eradicate aquatic vegetation and predatory & weed fishes. The pond is fertilized with organic manures and inorganic fertilizes, the cow dung is applied generally @ of 1000 kg/ha, urea @ 100 kg/ha/year and single supar phopsphte @ 50 kg/ha/year. The oil emulsion dose (diesel and detergent @ 0.5 litre & detergent 200 gm) should be applied prior to 2-3 days of stocking. Pre-stocking part of the management involves the following sequential measures (Fig. 1-6).

Fig. 1 Pond bottom drying

Fig. 2 Ploughing

Fig. 3 Liming

Fig. 4 Manuring

Fig. 5 Netting for irradiation of insect

Fig. 6 *Hapa* installation

Stocking management

This may be conveniently done under fixed conditions by fixing a '*Hapa*' in a pond and releasing spawn (6 mm) in it. Comfortable behaviour of spawn for about 24 hours confirms complete detoxification and the pond should be regarded as ready for stocking (See fig. no 7-8).

Fig. 7 conditioning of spawn

Fig. 8 Acclimatization of seed

Nursery ponds are stock with self-produced or procured 3 – 4 old spawn usually in the morning hour. Acclimatization is an important aspect for spawn survival and needs attention to avoid any abrupt change in a water quality, importantly temperature & pH. The rate of stocking in a well prepared farm pond with adequate fish food organisms can be as high as 1.5-2 lakh spawn/ farm pond (30 x 30 x 3 m farm pond). However, the survival level decreases with the increase in stocking density.

Table 1. Rates of stocking density and its biomass in farm pond

Pond size in M	Area in m^2	Spawn stocking	Biomass (gm) (Avg wt 0.0014 gm)
15 X 15	225	50000	70
20 X 20	400	100000	140
30 X 30	900	200000	280

Post-stocking management

Post-stocking management involves maintenance of pond environment are harnessing the pond productivity in the form of natural fish food and maintain supplementary feeding and health care.

Supplementary feeding

Soon after stocking, the fish start grazing natural food available in the pond irrespective of their stage of life cycle. Spawn feeds voraciously on plankton. Therefore, immediate steps must be taken for providing supplementary feed. In the case of nursery ponds where spawn are reared for about a fortnight up to fry stage, the form in which the supplementary feed is given is also important. In the nursery ponds the feed should be provided in finely powdered form and may be broadcast over the pond surface. In the case of rearing, stocking and brood stock ponds, the supplementary feed mixture should be mixed with enough water to make dough and applied into feeding trays fixed in the ponds. Better results can be obtained if the feed mixture is pelletized and fed to fish.

Table 2. Rates of Daily Supplementary Feeding management of farm pond

Period (Day from the date of stocking)	Rate of feeding	Amount of feed for 1 lakh spawn
1 -5	2 times the total initial weight	280 g/day
6 - 15	4-6 times the total initial weight	560-840 g/day
16-30	8-10 times the total initial weight	1120-1400 g/day
30-90	50-80 % the total initial weight	-

Health management

Under, feeding leads to malnutrition, resulting in growth retardation and low disease resistance. Liver lipoid disease, scoliosis and lordosis *etc*. are the examples of such mal-nutritional disorders. Many of the fish may carry small numbers of pathogens like bacteria, virus, fungi and parasites, either at chronic low-grade infections or serving as carriers. The best way to avoid disease outbreak in the pond during culture is through taking preventive measures which are ensured by proper management of the soil and water quality, following proper feeding schedule, use of balanced feed, periodic sampling for health check, etc.

Economics of Fingerling production in Farm pond (30 X 30 X 3 M)

After due rearing phase it is proposed to harvest and sell live Fingerlings by way of oxygen packing to needy fish farmers and fishermen.

Table 3. Economics of Fingerling production in Farm pond during three months

Sr. no	Particulars	Unit	Rate (₹/Unit)	Quantity (Unit)	Amount (₹)
1	Spawn of catla, Rohu & Mrigal	Lakh	1500	2.0	3000
2	Cow dung	KG	0.5	1000	500
3	Inorganic fertilizer (Urea & SSP)	KG	0.5	10	50
4	Supplementary feed	KG	60	35	2100
5	Miscellaneous	-	-	-	2000
6	Total Expenditures	7650			
7	Yield (Fingerling)	No.	0.6	60000	36000
8	**Net profit (7-6)**	₹ **28350**			

Keeping in the view the local climatic condition with shorter growing period, the better management practice is introduces in farm pond based aquaculture system. The local availability of carp seed strengthen the private fish farming and adopting this management the farmers will generate ₹ 28000-30000 of revenue from 30 X 30 X 3 m farm pond every year.

Medicinal and Aromatic Plants- An Alternative Crops for Abiotic Stress Prone Regions for Doubling Farmers Income

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Introduction

Indian farmers have been looking for some better alternative to diversify from traditional agriculture due to gradual reduction in profitability owing to decline in productivity, influence of abiotic stresses, biotic stresses in traditional crops, contingent upon their hardy nature and higher returns, medicinal plant cultivation is a better option. India has a large plant biodiversity and they are distributed in various climatic zones from sub-humid to arid and providing particular landscapes and agro ecosystems. Abiotic stresses such as drought, waterlogging, high and low temperature, salinity, poor structure and problematic soils etc. are not favourable for crop production. In western Maharashtra which is mostly characterized by low rainfall, poor and degraded soils are also inherited many dry land native medicinal plants. In these conditions medicinal and aromatic plants can be cultivated with a minimum effort. Most of these plants are adapted to extreme weather, dry areas and poor soils so that which promisingly supplied raw drugs to pharmaceuticals industry apart from providing income to farmer and collectors. Among such species of dry land medicinal plants, periwinkle, ashwagandha, *Aloe vera*, steroidal solanum, senna, isabgol, coleus, sweet flag, Safed musli, guggal, bael, *Butea monosperma*, noni, neem, aonla, jamun, aromatic plants such as sandalwood, vetiver, citronella, patchouli etc can fetch good income to farmers by cultivation them commercially. Many crops such as vetiver, citronella, aloe, ashwagandha, guggal, senna, liquorice can be cultivated in saline soils and poor soils. Many medicinal crops are suitable as intercrops in perennial fruit orchards and other food crops, sugarcane during initial stages of crop. There are specific herbs that are suitable for all problematic soils, dry land conditions and almost all kinds of unutilized and underutilized lands for better remuneration to the farming community. These crops can be small holder crop and can be cultivated in poor and degraded soils. Therefore, afforestation with medicinal trees, avenue plantation and utilization of barren and degraded soils for growing hardy plant species can be better possibility to sustain the nature and conserve the rare and endangered species

Possibilities of cultivation of medicinal plants in existing cropping systems

1. Agroforestry system with timber, medicinal trees, fodder trees
2. Intercropping with fruit crops and other annual crops
3. Monoculture of tree species having both timber value and medicinal properties.
4. Cultivation along the farm roads, boundaries and water sheds

Need of medicinal and aromatic plants cultivation

- The forests of India are estimated to harbour 90% of India's medicinal plants diversity
- Medicinal and aromatic crops are mostly wild plants collected and commercially cultivated in small scale for example sarpagandha is harvested for root purpose and it leads to destructive sampling which makes the species endangered, like wise many root and bark importance crops such as asoka, arjun, sandalwood, red sanders, ginseng, etc are being endangered to due to destructive harvesting.
- High demand and limited wild availability makes higher scope for cultivation
- To get uniform quality and sustainable supply of raw material. Any drug industry needs continuous supply of raw material with uniform quality of drug. This is not possible with wild plants which are different in growth stage, growing condition makes them to give varied quality raw material
- To avoid burden on natural sources mainly forests for collection of medicinal plants
- To conserve, cultivate and utilize the medicinal plants for human kind
- Best suited for intercropping in annual and perennial systems
- Low water requirement, few can sustain water logging, wider climatic adoptability
- Ecological balance and soil reclamation by cultivating crops

Important plants that can assure good income to farmers are given below. Most of the plants are being wild and suitable for stressed environments; they can adopt and perform better with minimum management practices.

Table: Important medicinal and aromatic plants suitable for abiotic stress affected areas

Sr. No	Common name	Botanical Name
1	Sandalwood	*Santalum album*
2	Red Sanders	*Pterocarpus santalinus*
3	Malabar Neem	*Melia dubia*
4	Stevia	*Stevia robudiana*
5	Shatavari	*Asparagus recemosus*
6	Sweet Flag	*Acorus calamus*
7	Senna	*Cassia anguistifolia*
8	Ashwagandha	*Withania somnifera*
9	Vettiver	*Chrysopogan zazinoides*
10	Lemongrass	*Chrysopogan flexiosus*
11	Palmrosa	*Chrysopogan matinii*
12	Terminalia species	*Terminalia chebula, T bellarica, T arjuna*
13	Safed musli	*Chlorophytum borivilianum*
14	Isabgol	*Plantago ovata*

MAPs in agroforestry systems

Traditional agroforestry systems: Many plants in traditional agricultural systems in the tropics have medicinal value and are found in home gardens, as scattered trees in crop lands and grazing lands, on field bunds and as live fences. Trees species like arjuna (*Terminalia arjuna*), bael (*Agele marmelos*), Amla (*Emblica officinalis*), Neem (*Azadirectha indica*) and herbs such as tulsi (*Ocimum sanctum*), drumstick (*Moringa oleifera*) and curry leaf (*Murraya koenigii*) are common backyard plants in many Indian households and are routinely used for common ailments or in food preparations but are seldom used for commercial purposes. In fact, many of these plants are valued for fuel wood, fodder, shade, boundary demarcation, etc. and their medicinal value is secondary.

MAPs for reclamation of wastelands and problem soils In India: Degraded lands occupy 20.16 % of total geographical area and these degraded lands have reduced productivity and lacks the capacity to support desirable vegetation and maintain yield levels. A number of researches across the globe have found that many species of medicinal plants can grow successfully in degraded lands as well as reclaim such lands. The use of trees for rehabilitating marginal sites is a well-known forestry practice. Plantations of *Phyllanthus emblica* and *Azadirachta indica* were found to improve biological diversity viz., number of ground flora species, diversity index, population of bacteria, fungi, nematodes, micro arthropods and VAM fungi spores and available NPK status of degraded lands (Verma, 2004). The cummulative affects, over decades, of adding water with dissolved salts to the soils of arid and semi arid region has resulted in major problems of sodicity affecting about 1.5 billion hectares. Experiments on sodic wasteland management have shown the prospects of cultivation of aromatics crops like palmorosa (*Cymbopogon martini*), lemon grass (Cymbopogon flexuosus), vetiver (*Vetiveria zizanioides*) and German chamomile (*Matricaria chamomilla*) (Singh, 1997) and fruits plants like aonla, guava, ber, bael and karonda on sodic soils (Pandey and Singh, 1997).

Dry land areas in India account for 68.4% of the net sown area and contribute 44 % to the total food grain production in India. These dry land areas are usually characterized by crop failures and low and unstable yields due to abnormal weather patterns and traditional crops are no more economical to the dry land farmers. With the changes in the climate due to global warming the conditions under dryland areas are bound to get more erratic and abnormal. Plants like Ashwagandha (*Withania somnifera*), Kalmegh (*Andrographis paniculata*), Senna (*Cassia angustifolia*), Makoi (*Solanum nigrum*), Tulsi (*Ocimum sanctum*), Sarpagandha (*Rauvolfia serpentine*), Guduchi (*Tinospora cordifolia*), Gudmar (*Gymnema sylvestre*), Shatavarai (*Asparagus racemosus*) and Langali (*Gloriosa superba*) can be suitably cultivated under dry land conditions (Narashima Reddy, 2006) [10]. These plants have wider adaptability to the adverse climatic conditions, does not require high maintenance and input cost and grow relatively fast with high reproduction rates and can be easily incorporated in such areas. About 10.3% of total net sown area is waterlogged in India and these lands are either lying vacant or the productivity is very low mainly because there in unavailability of suitable agricultural crops for economic utilization of such lands. Rice is the most predominant crop in these areas however; rice soils are one of the potential sources of methane emissions moreover excess water leads to failure of rice crop, poor soil structure and fertility, etc. MAPs like bacha *(Acorus calamus)*, brahmi *(Bacopa monnieri)*, nagar motha *(Cyprus scariousus)* and vetiver *(Vetiver zizanioides)* are found to suitably grow under water logged conditions and may be a better alternative to traditional rice based cropping systems (Singh *et al.* 2003) [18]. Cultivation of MAPs in degraded land will not only help minimize the pressure on croplands and reclaim the degraded lands but also help save the diversity of these herbal plants.

Sandalwood

Sandalwood (*Santalum album* L.) is a prized gift of the plant kingdom woven into the culture and heritage of India. It is one of the most valuable trees in the world. The natural distribution of sandalwood extends from 30°N to 40°S from Indonesia in the east to Juan Fernandez Islands (Chile) in the west and from Hawaiian Archipelago in the north to New Zealand in the south. It is a small to medium-sized hemiparasitic tree, distributed rather widely in India. The populations are more concentrated in the southern region, especially Karnataka, Tamil Nadu and Kerala. For more than 5000 years, India has been the traditional leader of sandalwood oil production for perfumery and pharmaceuticals. The aroma of the oil and the wood is esteemed by people belonging to three major religions of the world –Hinduism, Buddhism and Islam.

Over 70 years ago, nearly 90% of the natural sandalwood populations occurred in the southern part of Karnataka and northern part of Tamil Nadu17. Excessive harvesting without replenishment of this invaluable resource has substantially reduced the sandalwood industry, resulting in global shortage and soaring of market prices. Importantly, *S. album* has been categorized as 'vulnerable' by the International Union for Conservation of Nature (IUCN) in 1997. In Karnataka, sandalwood populations are sparse and devoid of larger girth classes; mature trees have been nearly vandalized. The major cause of the decline of sandalwood has been smuggling.

Uses of sandalwood

Sandalwood is commercially known as the East Indian sandalwood and its oil the East Indian sandalwood oil. The heartwood that constitutes the central part of the tree and is valued for its fragrance. The outer wood (sapwood) or any other part of the tree has no scent. Sandalwood is sacred and is used in religious ceremonies and is an important ingredient in ‘homa’ (havana). The sapwood is white or yellow and not scented, and is used in preparing turnery item and agarbattis. Sandalwood oil is obtained by steam distillation of heartwood powder. It is expensive and sold by weight. Each kg of oil costs about 5 lakhs. The essential oil is being good fixatives these are highly valued in perfumery and toiletry industry, especially for certain delicate scents that are extremely rare and fragile.

Table 1. Classification of sandalwood sorted before being passed for sale (according to the Karnataka Forest Manual Rule No. 95)

Sl. no.	Class	Description	Fixed price (rupees in lakhs) per metric tonne of wood for 2010–11
1	Vilayat Budh (Class I billets)	Sound billet weighing not less than 9 kg and not exceeding 112 pieces per tonne.	41.00
2	China Budh (Class II billets)	Slightly inferior billet weighing less than 4.50 kg and not exceeding 224 pieces per tonne.	41.00
3	Panjam (Class III billets)	Billets having small knots, cracks and hollows weighing not less than 2.2 kg and not exceeding 448 pieces per tonne.	37.00
4	Ghotla (billets of short length)	Includes short and sound pieces. There are no limits of weights and numbers per tonne.	41.00
5	Ghatbadla	Billets with knots, cracks, small hollows, weighing not less than 4.5 kg and not exceeding 250 pieces per tonne.	41.00
6	Bagardad	Consists of solid pieces without limit as regards dimensions, weight or number.	39.50
7	Roots (Class I)	Pieces weighing not less than 6.75 kg and not exceeding 150 pieces per tonne.	36.25
8	Roots (Class II)	Consists of pieces weighing not less than 2.25 kg and not exceeding 448 pieces per tonne.	37.40
9	Roots (Class III)	Consists of small and side roots below 2.25 kg in weight	33.70
10	Jajpokal or Badla (Class I)	Consists of hollow pieces weighing not less than 3.10 kg and not exceeding 320 pieces per tonne.	40.75
11	Jajpokal (Class II)	Hollow pieces weighing not less than 1.3 kg per tonne.	37.10
12	Ainbagar	Consists of solid, cracked and hollow pieces weighing not less than 450 g.	40.10
13	China Sali or Large Chilta	Consists of pieces and chips of heartwood weighing not less than 2.25 g.	32.20
14	Ain Chilta	Consists of small pieces of heartwood.	28.20
15	Hatri Chilta	Consists of heartwood and chips obtained by plaining billets with Hatri or Randha (plane).	19.00
16	Milva Chilta	Consists of pieces and chips having fair proportions of heartwood and sapwood.	15.50
17	Basola Bukni	Consists of small heartwood and sapwood chips.	11.50
18	Saw dust	Sawn powder obtained while sawing the sandalwood.	7.50

Figure: Sorted sandalwood billets and its classification

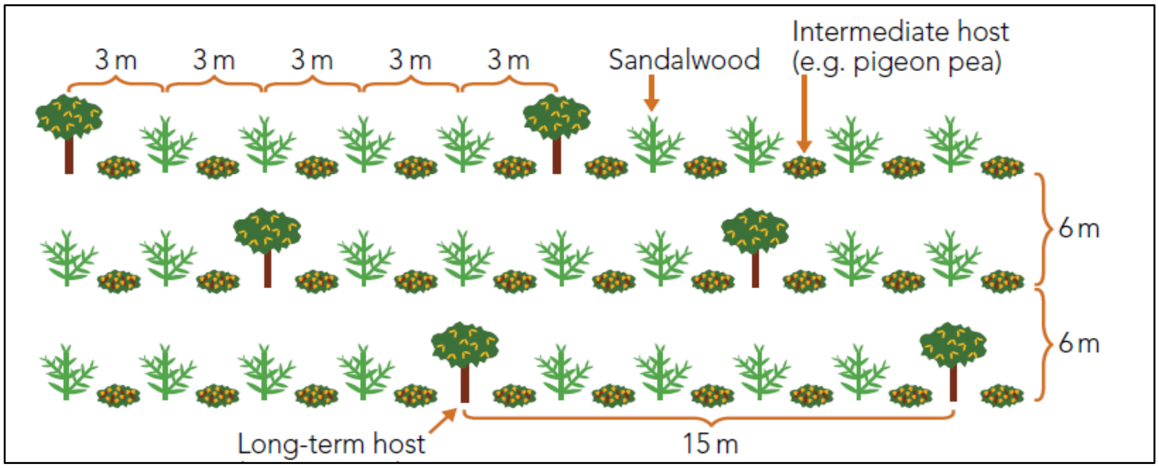
Host plants, planting and care of sandalwood

- Site for sandalwood planting should be having well drained, volcanic soil, having slight slope and harvest good sunlight. If few perennial trees are available may be retained in the field which serves as host plant for sandal wood.
- The distance between sandalwood and host trees is necessary to ensure good growth over the entire rotation of the plantation. The minimum spacing of sandalwood trees is 3 m × 6 m or 5 m × 5 m, with large, long-term host trees planted at least every fifth tree within each row. At a spacing of 3 m for sandalwood, the host trees would be spaced every 15 m. It is recommended that each row is 'offset' so that every sandalwood is within 5–6 m of a long-term host.
- The number of intermediate host trees will depend on the size of the host tree. In the example below, pigeon pea has been included as primary host and planted next to sandalwood seedling. Different types of hosts and example is provided below

Primary host or temporary host is used in nursery stage, Secondary host is used for initial period of growth in field up to 6 years, Permanent host is used till harvest of sandalwood and these are perennial and preferably legume and deep rooted. Permanente host will remain till end of the sandalwood and provides moisture and nutritional support for the sandalwood.

Primary host	**Secondary host**	**Permanent host**
Pigeion pea	Sesbania	Pterocarpus
Crotolaria	Curryleaf	Pongamia
Alternanthera sp.	Drumpstick	Dalbergia
Phyllanthus sp.	Subabul	Mango
Sesbania	Mulbery	Jamun
Mimosa pudica		Casurina
		Tamarind

Sandalwood seedlings may be planted in newly established fruit orchards or planned agroforestry system. The distance between sandalwood and host trees is critical to ensure good growth over the entire rotation of plantation. The minimum spacing of sandalwood trees is 3m x6m or 5m x 5m with large and long term host tree planted at least every fifth tree in each row. At spacing of 3m for sandalwood the host trees would be spaced every 15m. In between two sandalwood trees intermediate or secondary host needs to be planted.



Pruning in sandalwood

Proper shape and size of the tree trunk is important factor that decides the heartwood recovery and yield. Since seedling stage training and pruning of seedlings is important to achieve better framework of tree. In formative pruning lateral shoots of young seedlings are pinched off to encourage central leader system. In case of form pruning tree is pruned to have single trunk which is straight. This is effective in seedlings upto four years age and as age advances any pruning methods will become ineffective in maintaining single stem in sandalwood.

Harvesting and processing

Sandal wood plants under good management comes to harvestable stage in 15 years, but harvesting at 25-30 years age give more economic returns with higher heartwood yield. Entire tree will cut to ground level and matured portion of root is also dug out during harvesting. Yield of heartwood may vary between 10-15 kg after 20 years depending upon management practices.

Agarwood

Dark colour fragrant resin produced by the certain plant members of family Thymaleaceae. Most commonly, the resin is known as Agarwood, Aloes wood, Eaglewood, Gaharu, Agalocha or Oudh (In Arabic). However, species of the genus

Aquilaria are mostly known for the production of agarwood – it's a fast growing, evergreen tree. Agarwood or oudh forms as a tree reacts to an infection, form a protective oil using its defense mechanism, which exudes a fragrance, into wounded areas, which gradually become harder and darker in color.

Aquilaria species that produce agarwood are found throughout Asia, more commonly in South and Southeast Asia. Today Agarwood plantations exist in a number of countries, including Bangladesh, Bhutan, India, Laos, Myanmar, Papua New Guinea, Thailand and Vietnam. Sadaharitha Plantations has paved way for the introduction of this plant to Sri Lanka.

The plant can grow on a wide range of soils. Seedlings of most species establish best in shady, moist conditions. Although sometimes matured, adult trees have emerged in forests with the ability to fully withstand the sun. Some species can be found growing on steep, rocky, exposed slopes, and in regions that experience a hot, dry season. In Sri Lanka low country wet zone has proven suitable for Aquilaria plantations.

Agarwood is a billion dollar industry, in which the ever increasing price is attributed to the constantly growing demand in larger markets such as Middle- East, China, USA and Europe for chips, oil, carvings and incense products. Additionally, Chinese medicine uses powdered Aquilaria as a treatment for cirrhosis of the liver and for other medicines. It has also been used as a treatment for lung and stomach tumors.

Low yield from plant material, typical and labor intensive process of extraction, high demand and supply gap are a few reasons for the high costing of Agarwood oil. Another reason for Agarwood to be expensive is the threat of becoming endangered. The most important resin-producing species of Aquilaria are protected worldwide under the CITES (The Convention on International Trade in Endangered Species of Wild Fauna and Flora) convention as well as by the World Conservation Union, IUCN.

Resin-producing agarwood trees are endangered throughout their known habitat all across Southeast Asia. The main driving force, which initiated this project, was the recognition of unsustainable Aquilaria harvesting in natural forests that resulted in the near extinction of this tree genus in Viet Nam and elsewhere. Aquilaria crassna is now a protected species in Viet Nam. Trade and harvesting restrictions will be virtually impossible to implement and enforce if no alternative is developed to forest-based harvesting. In addition, both in the short and long-term, a natural resource base needs to be maintained to supply present and future Aquilaria plantations with genetic source material in order to prevent plant decease, maintain diversity, and possibly improve resin production.

Anticipated yield and income generally comprise of two phases. As an interim yield, 40% of the selected Agar plants are harvested in the first phase. This is done with the objective of gaining interim income and reducing the density of Agar trees so that remaining 60% can grow well in the next 10 years.

- Yield of distillable wood (low-quality Dum/Boya) from 10-year-old trees – approx. 20 kg per tree at ₹10 per kg.
- Yield of 'Dum' quality from 20-year-old trees is approx. 50 kg per tree at ₹50 per kg.
- Yield of 'Batli Mal/kalagachi' in 20 years is approx. 0.5 kg per tree at ₹2000 per kg.

Malabar Neem

Melia dubia (*Malai Vembu* in Tamil) is a promising tree highly suitable for farm forestry and agro forestry for generating higher income in the semi-arid regions. Agro-forestry is a sustainable land management system which increases the overall yield of the lands; combine the trees and shrubs with agricultural crops and or livestock on the same unit of land, either simultaneously or sequentially. One of the main problems that farmers face today is decreasing income from an acre per year against sudden increase in the value of agricultural lands. Planting certain tree varieties such *Melia dubia* which fetch a handsome price in the market, assured buyback, and require low maintenance expenditure may help in this regard. In addition, the trees also aid the planet by preventing temperature rise and checking gas emission into the atmosphere. *Melia dubia* is the fastest growing tree and the wood from this tree is used in Plywood Industry. *Melia* is a money spinning tree of short duration. Since there is a total mismatch between demand and supply for wood, block planting of 300 to 400 trees per acre can ensure a minimum profit of rupees one lakh per year from an acre.

It grows on a variety of soils; however, it grows well in deep, fertile and sandy loam soils. It has the unique feature of growing to 40 feet within two years from planting and can be mechanically pruned and harvested. It is commonly found in the hills at elevations ranging from 600 – 1800m. It does well in moist regions, with a mean annual rainfall exceeding 1000 mm. However, it can be successfully grown in dry region also with supplemental irrigation. The rooted saplings are planted onset of the monsoon or during the monsoon. The suggested pit size is 2' x 2'- 0.60 m Cube. Spacing of 3 m x 3 m is recommended. This will give better girth in shorter duration. Straight pole fetches good price in the market. Under irrigated condition in fertile soil, the plant produces 3 to 4 branches at the height of 12-14 feet. Pruning of side branch should be done at this stage. When planted in dry lands and in drought prone areas, the tree branches at the height of 6-8 feet.

Each tree is expected produce 5-7 cu.ft. of timber and the farmers may get 15 lakh from one hectare of land after six years with current price of wood (Rs. 300 per cu.ft.) After seeing the successful establishment and good growth of this tree species, many farmers in the watershed came forward for taking up this tree as agro-forestry. Three thousands number of *Melia* were planted by the farmers on the bunds surrounding their field with 3 m spacing as single row. Many line department officials, WDT members and farmers visited the site and were convinced that this kind of farm forestry can be taken up on commercial basis.

Benefits of growing Malabar neem

1. Fast growing and comes to harvesting in 8 years
2. High demand for plywood and paper industry
3. Tree branches can be used as fodder for sheep and goat
4. It can be grown all along the bunds, farm roads or as a sole crop
5. It act as wind break when grown along the farm fence

Stevia *(Stevia rabudiana)*

Stevia commonly known as the "sweet leaf, sugar leaf, and honey leaf" and much related other names in the local. Stevia plant is also known as "Meethi Tulsi" in the local. Basically, stevia leaves widely used for its higher sugar content & also to treat some of the health conditions by the local. Stevia leaves are also a good source of Zero calorie Sweet. Stevia leaves are 30 times sweeter as compared to the normal sugar. The essence of the stevia *Rebaudioside-A* is something around 300 to 400 times sweeter than the normal sugar. The sweetness of stevia leaves can be sensed over a long time.

It is being cultivated for its leaves and being an perennial type crop can be cultivated for four years without planting every year. It is propagated by stem cuttings of 15 cm longer from the leaf axils part, of present year growth. Stevia plant can be cultivated though out the complete year. However, the best period for the propagation of Stevia plant is from February to March that is cold weather. In high-density planting in stevia crop leads to higher production of leaves. So, plant about 25000 plants of stevia per unit acre land for high density planting is beneficial in optimum production of leaves.

Pruning of flowers: Stevia is cultivated for its leaves and which is severely affected by flowering. Even it deteriorates market price due to poor quality of leaves. Hence periodical removal of flowers in this crop should be done at regular interval because flowering leads to overgrowth of plant while producing less amount of stevia leaves. Perform the pinching of flowers repeatedly to obtain maximum leaves production. Flowering more in the crop may be due to high temperature, lower moisture content or any other abiotic stress conditions causes to reduction of stevia leaves quality. If flowering is not removed for more than two days, then it will directly reduce the amount of stevioside in the leaves (reduce about 50 %); a huge loss to the cultivars & mostly to the consumer.

Figure: Stevia grown in raised beds

Harvesting and drying

After harvesting stevia leaves, proper care of them should be taken to maintain their quality for getting a high market price. Here is some task to perform after harvesting leaves.

1. Remove the twigs leave & make them dry
2. To make them dry, make use of dryer or keep them in sunlight
3. After that, store these dry leaves in glass jars or in air tight polythene packs.

By selecting high yielding cultivar with good crop management an avg. production of 3000 kgs of dried stevia leaves can be produced per unit acre land. However, the leaves production of stevia plant can be raised by proper care & good farm management practices. if the sale of Stevia is considered to be at Rs 100 per kg, then in the first one auction, you will be easily able to earn 5 to 6 lac from a one acre land**,** and it will increase in the following years. This profit is much more than the total investment made in the initial, and the profit will increase more in the coming years. In the last three years, the net profit of about 1 to 5 lac can be easily obtained by cultivation of stevia plant in a one-acre land.

Asparagus *(Asparagus racemosus)*

Shatavari roots are used mainly as galactagogue which stimulates the secretion of breast milk. It improves the body weight and also considered as very good energy provider to the weak body system. Useful in treating the ailments like dysentery, tuberculosis and diabetes (Singla and Jaitak 2014). Commonly, it supports to maintain the health by giving immunity to diseases.

Highly suitable for shaded areas and as intercrop in fruit orchards or agroforestry system. It can be propagated either by seeds or by tuber cuttings. Seeds are sown in April in raised beds at 5 cms apart to facilitate decay of its hard seed coat by the time monsoon commenced. Germination start in 8 to 10 days after the first shower of monsoon in June. The seedlings were transplanted on ridges at 60 x 60 cms apart and provided bamboo stakes when the plants attained a height of 45 cms. Vegetative propagation is by division of rhizomatous disc present at the base of the aerial stem. The rhizomatous disc develops several vegetative buds around the aerial shoots. The disc is divided in such a way that each piece possessed at least two buds along with 2-3 tuberous roots. These pieces are planted conversing the buds with 1 cm of soil followed by irrigation. The sprouting commenced in 8-10 days after plantation.

The plants are harvested after 40 months in winter. The roots are dugout collected and cleared. The roots are peeled off with the help of sharp knife immediately after harvesting. It is observed that in case the roots are not peeled off within a few days, it is a bit difficult to remove the skin as such. In such a condition the roots are kept in boiling water for about 10 minutes, followed by cold-water treatment to facilitate peeling. After removing the skin, it is cut transversely into small pieces and dried in shade. Yield The average yield is reported to about 2607 gms fresh weight per plant after 40 months age. Estimate yield of 5-7 tons/hectare dry roots is reported Precaution may be taken for rodents and rats which occasionally eat tender shoots. On an average, 12,000 to 14,000 kg of fresh roots can be harvested from one ha area and on drying it yields about 1000 to 1200 kg of dried roots. each kg root costs Rs.200/-.

Indian Lavender Or Burcera *(Bursera penicillata)*

Bursera is an aromatic essential oil plant introduced into India by two private enterprising Scotsman - P. J. Anderson and G. N. Hamphries in 1912 at Thatgunni estate near Bangalore, Karnataka State (Somatta and Uppin. 1979). Forest department has started it's cultivation since 1958. Plants are dioecious and known to regenerate both by artificial and natural means as well as by sexual and asexual methods, cuttings being the commercial method. The fragrance is often described as a mixture of lemon and sandal, close but not identical to European lavender

It grows well on lateritic red soils and prefers arid tropical climate with temperature variation between 18 ° C and 35 ° C and rainfall between 450mm and 650mm annually. The climatic conditions around Bangalore are found to be very much condusive to grow this species on a large scale. The cuttings are planted in 0.5m cube pits dug at 6 × 6m interval. Being a deciduous species tree remains leafless from November to March and new flush starts during April-May with simultaneous flowering. Trees starts bearing 3 to 4 years after planting.

Harvesting is done either by picking of berries or by collecting the fallen berries during August. The oil is distilled by usual steam distillation of air dried husks which yield 10 to 14% of oil. About 25kg of oil can be expected from one hectare plantation. Trees attain maximum bearing 13 years after planting, when the yield of oil is expected to fetch Rs. 6000/- per hectare

Constraints in cultivation of medicinal and aromatic plants

1. Lack of awareness about propagation, cultivation and processing of medicinal and aromatic plants.
2. Unorganized cultivation of medicinal plants and varying demand of raw materials.
3. Lack of assured price and marketing system like other agriculture commodities where farmers can sell the raw materials directly.
4. Lack of awareness about cultivation practices, planting materials, quality management etc. among grower leads to poor acceptance and interest in farming community.
5. Inefficiency of these crops to compete with other commercial crops in terms of yield, returns and ease of cultivation.

Priorities to be addressed

1. Inventorization and documentation of information on medicinal plants available in different states and agroclimatic zones, their identification, availability and distribution for prioritization of species to be incorporated in developmental, remedial and conservational plans. This information will also help address the demands of the different stakeholders involved.
2. Systematic documentation of the plethora of information on ethnobotany and traditional indigenous knowledge of MAPs and selectively screening of some of the

interesting ethno-medicinal plants for active chemical compounds which may lead to the discovery of new novel drugs.

3. In-situ conservation of germplasm of herbal plants specially RET species and endemic plants from different agro-climatic zones supplemented by collection, propagation and conservation of MAPs through ex-situ conservation viz., field gene banks, seed banks, herbal gardens in institutions, schools, parks, etc. to support viable research and promote education and awareness of MAPs among the public.
4. Introduction of MAPs as intercrop, catch crop, companion crops, border crop, etc. for diversification of agricultural, horticultural and agroforestry systems for reducing risk and sustaining productivity through optimization of resource use.
5. Cultivation of MAPs on degraded and wastelands for generating better remuneration to the farming community, minimizing the pressure on croplands and also conserving the diversity of these herbal plants.
6. Development and implementation of region specific good agricultural and collection practices (GACP) on important medicinal and aromatic plants of the region encompassing various facets of cultivation, collection and harvesting, post harvest handling and quality assessment, etc. to ensure premium quality of the produce and also for sustainable utilization of the natural resources of medicinal plants.
7. Application of frontier technologies of biotechnology for mass multiplication of high value MAPs, marker assisted breeding of varieties, DNA fingerprinting of MAPs germplasm for protection of intellectual property right (IPR), species identification by molecular markers, detecting adulteration of raw drugs and development of new varieties with better bio-molecule productive efficiency.
8. Capacity building, training programmes, seminars, demonstrations, etc. for various stakeholders involved for effective transfer of GACP technologies in the MAPs sector.
9. Promotion of organic farming for sustainable production system of MAPs and also to ensure natural products with zero pesticides and other contaminants, which can fetch premium prices and has high demand in both national and international markets
10. Proper regulation and monitoring of both public and private sector establishments for ensuring compliance of seed producer on required practices and parameters for

quality seed production to ensure adequate availability of quality and certified seeds and planting materials.

11. Development of proper infrastructures, laboratory facilities and manpower support for post-harvest management viz., storage, drying, processing, value addition, packaging and transportation and quality control and certification viz. testing for pesticide residue, heavy metal contamination and quality of raw drug material.
12. Marketing support in terms of market intelligence, support price, modernization and establishment of mandis, buyer and seller meets, web based price information mechanism would be critical for linking small cultivators to the buyers in bigger markets.
13. Development and promotion of Public Private Partnership models (PPP) with private sector organizations, NGOs and farmers' associations/ progressive farmers interested in cultivation of MAPs.

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Impact of Abiotic Stress on Onion Crop under Climate Change

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Onion (*Allium cepa* L.) is an important vegetable crop cultivated in arid and semiarid regions across the world. It belongs to the genus Allium of the family Alliaceae playing a significant role in daily human diet (Suleria *et al*., 2015). It has a widespread nutritional, medicinal, and export potential that provide an economic security to the country. World-wide, India ranks first in area, second in production next to China but in terms of productivity it is very low *i.e.* 14.21 Tons/ha (Tirlapur *et al*., 2017). India itself supplies onion to 38 different countries throughout the world in varying quantity and Maharashtra share about 30% of total onion production of country. The value of global trade and continuously rising demand in national and international market increases the area under onion cultivation. Global warming mainly due to increased emission of greenhouse gases (GHG) from industrial and other technological advances of modern world is responsible for climate change. Further, it was well acknowledged worldwide that the concentration of GHG viz., carbon dioxide, methane and nitrous oxide is increasing at alarming rate thereby contributing the changing climatic scenario at a faster rate (Vetter *et al*., 2017). Climate change is predicted to cause by an elevation in atmospheric temperature by 1 to 4^0C, increases in atmospheric CO_2 concentration and significant changes in rainfall distribution pattern. Weather plays a predominant role in growth, development and productivity of onion crop. It is mainly a cool season crop and performs very well during winter followed by early part of summer season. In short day onion varieties, bulb initiation takes place between 10-15^0C night and 20-25^0C day temperature. Bulb development is at its best at 18-20^0C night and 25-30^0C day temperature. For maturity, day temperature between 35-38^{0}C are required. Sunshine hours of 12-13hrs during bulb development and maturity, humidity between 65-75% and 500-600 mm well distributed rainfall ensures good crop growth. However the recent aberrant weather events namely, drought, floods, elevated temperature, cold waves, hailstorms and soil salinity are the major constraints limiting onion production and quality. Even though the total rainfall intensity might not have changed but the distribution pattern has changed largely. For overcoming the challenges ahead and achieving sustainable onion production in the challenged environment it requires systematic analysis, advance planning and climate smart crop management interventions. Thus, recent changing climatic scenario might put this economically important crop at risk ultimately resulting into price hike in global market.

Onion crop and drought stress

Onion crop thrive best with cool atmospheric temperature during its early growth stage whereas warmer and sunny weather is the prerequisite during bulb maturity. In India onion is mainly cultivated in *kharif*, late *kharif* and *rabi* season with about 60-70% harvest is mostly from *rabi* season. In *kharif* season it is mainly cultivated as a rainfed crop where, frequent drought episodes arise predominantly due to erratic rainfall pattern, atmospheric temperature, humidity and soil properties (soil water retention capacity). Onion is a shallow rooted crop which restricts its water absorption capacity zone to only about 18-25cm of top soil (Drinkwater and Janes, 1955). It requires about 350-500mm of water during its growing season hence sufficient soil moisture is an important factor in onion production. This root architecture often makes the onion crop highly sensitive to water stress and hence required frequent and proper water management practices. The occurrence of water deficit stress resulted into split, double centric bulbs most likely doublers and multiple bulbs were formed sometimes skin cracking ultimately resulting into tremendous yield losses. The crop is highly sensitive to available soil moisture content in tropical and subtropical onion growing belt as compared to the temperate region. It is due to the limited water supply during the particular onion growth stage hampering the bulb growth and development, ultimately reducing the overall bulb yield, size and quality. It is found that bulb yield in onion was not found to be severely affected under 10-30% of drought stress. However drought stress beyond 30% in onion crop during any of its growth phase severely reduces the bulb yield particularly during bulb enlargement stage significant yield losses occurred with poor sized onion bulbs and minimum storage capacity. Therefore adequate water supply is vital during bulb development and enlargement stage in onion crop for obtaining sustainable yield under limited water supply. In onion seed crop the reproductive stage is highly sensitive to drought stress limiting the seed production and quality. Onion seed production is manly carried out in *rabi* with proper irrigation schedule. Any changes in irrigation frequency drastically hamper the onion seed formation and quality. Drought stress reduces the number of pollinator visits by decreasing the amount of sugary nectar produced by the onion floret and also decreases the amount of viable pollen grains and increases the floret abortion contributing to the lower seed yield. Findings by (Balla *et al*., 2013) showed that among the different growth stages in onion seed crop, bolting and anthesis stage is found to be the most sensitive for drought stress as significant reduction in seed yield and quality is being recorded as compared to water deficit stress coinciding with other growth stages. This revealed that proper irrigation management during onion seed production is necessary for getting good quality seeds with higher yield. The best onion bulb and seed yield can be obtained by implementing proper soil and irrigation management strategies. Implementation of drip and sprinkler irrigation mode increases the water use efficiency in onion crop. Soil mulching is a well-established technique for soil moisture conservation where, artificial mulching by using black polyethylene sheet found to be the superior one for attaining the highest crop water productivity thereby increasing onion yield. Identification of drought tolerant onion entries from the sourced germplasm is the perquisite in onion breeding program for the development of tolerant onion variety. The use of plant growth regulators in onion crop can be the good approach to mitigate the drought stress.

Onion crop and flooding stress

The impact of heavy rainfall or excess moisture stress is mainly arising during *kharif* or due to unseasonal rainfall. The extent of damage due to water logging mainly depends upon the growth stage that it coincides. The extent of damage is severe if excess rainfall occurred during month of August, September and October as during this period it coincide with bulb development phase of *kharif* and nursery of late-*kharif* and *rabi* crop. Water logging affects the development of roots, bulbs and accumulation of some of the important metabolites determining bulb pungency and flavour. Some of the onion genotypes which can survive under excess moisture showed vigorous vegetative growth but failed to produce the marketable size bulbs of good quality. During the entire crop growth period, early vegetative stage (1-20 days after transplanting) and bulb maturity stage (90-110 days after transplanting) was found to be less damaging as compared to bulb development stage (20 to 90 days after transplanting) as the plants showed reduction in survival percentage, various morphological and biochemical parameters determining bulb quality (Pranjali *et al*., 2018). Additionally, heavy rainfall damages the standing crop by inducing the outbreak of various diseases both in nursery and standing crop. Extensive damage is recorded due to purple blotch and *stemphyllium blight* in *kharif* season leading to poor bulb formation and development. Excessive rainfall further increase the atmospheric humidity which makes the favourable condition for diseases like purple blotch, *stemphyllium* blight, *colletotrichum* blight and basal rot ultimately affecting the crop tremendously. Prolonged wet condition favours the occurrence of these diseases decreasing its onion bulb yield and storage quality. Late *kharif* and *rabi* nursery also gets damaged and completely loss due to disease consequence as a result of excess soil moisture stress. Similarly, continuous rainfall during bulb maturity leads to secondary post harvest losses like rooting and sprouting of bulbs and such bulbs have very poor storage keeping quality. Soil flooding causes the negative impact on root growth and plant metabolism by reducing the nutrient absorption efficiency resulting into the highly poor quality, deformed shape and sized onion bulbs. Looking to the consequences of water logging stress, there is a need of hour to identify tolerant onion genotypes from the available germplasm that can be used in breeding program for the development of improved onion variety for water logging stress. The improved cultural practices like raising the nursery and transplanting the seedlings on raised bed of 10-15cm height, 1m width and length as per soil level is preferable over the flat bed during *kharif* season as it provide good soil drainage. Foliar application of nitrogen and potassium to reduce the stress induced damaging symptoms is more preferable over the broadcasting method as the roots are mostly damaged after soil flooding. Application of fungicides spray can minimize diseases incidence and soil-borne pathogen attack thereby increasing the chances of survival and growth of flooded onion seedlings. Thus by adopting improved *kharif* onion variety and production practices could help in alleviating the adverse effect of water logging stress in onion crop.

Onion crop response temperature extremes

Temperature extremes severely limits onion yield and productivity mostly in *rabi* season due to sharp increase in atmospheric temperature mostly in the month of March-April which is highly detrimental for bulb development. High night temperature at bulb initiation stage leads to poor bulb development whereas, temperature more than 42^0C at the time of bulb maturity during April-May leads to reduction in bulb size along with poor keeping quality. High temperature affects the crop fertilizer use efficiency and forces to complete its life cycle resulting into early maturity without proper bulb development. Likewise, low temperature ($<10^0$C) for more than one week from January-February during bulb development initiates bolting in onion that possesses considerable impact on its production ultimately affecting its value in domestic and international market. In late *kharif* crop low temperature during November-December resulted in bolting. In onion seed crop, dry weather with high temperature above 35^0C causes secreted nectar to become highly concentrated, making it less desirable to bees, and can decrease stigma receptivity and pollen viability ultimately affecting seed setting and yield.

Effect of temperature extremes and humidity on onion pest and disease

A shift in atmospheric temperature, humidity and rainfall distribution pattern predominately influence the pest and disease outbreak in onion crop. Heavy rainfall during *kharif* season built up the incidence of many soil borne and fungal diseases. In onion crop, thrips are the major pest causing extensive damage to the crop and also act as a vector for many viral diseases too. The onion thrips have greater adaptability for atmospheric temperature ranging from 8-380C with an optimum at 270C and relative humidity of 70%. Study on seasonal incidence and population dynamics reported that onion thrips population reached to maximum (48/plant) in August during kharif season and lowest (1/plant) in October. Whereas, it started multiplying from December and reached highest (112 thrips/plant) in February and drastically comes down to 14 thrips/plant during March. Atmospheric humidity and rainfall have negative effect on thrips population. Thrips multiply faster under hot and dry weather, whereas incidence of diseases is more pronounced under elevated temperature with high humidity. Two peaks in thrips population were recorded one in August and the second in February as low humidity during this period favours the thrips incidence (Srinivas and Lawande, 2004). Heavy rains wash out thrips off the plants causing a sudden decline in their population but, it causes resurgence of diseases like anthracnose and purple blotch in poor drained soil resulting into heavy yield reduction (Mishra *et al*., 2014).

Response of onion crop to soil salinity

Salinity is one of the serious environmental threats, affecting about 7% of world's area and is growing progressively in arid and semi-arid part of world (Munns, 2002). In future it has a devastating impact on arable land with 30% land loss in next 25 year and 50% by the middle of twenty-first century (Wang *et al*., 2003). Every day world losses about 2000 to 4000 ha land area due to soil salinization making it unfit for crop cultivation (Qadir *et al*., 2014). It decreases crop production of more than 20% of irrigated land worldwide. In India nearly 9.38 million ha area is occupied by salt-affected soils out of which 5.5 million ha are saline soils (including coastal) and 3.88 million ha alkali soils (Mishra and Dave, 2013). These occur from Jammu & Kashmir (Ladakh region) in north to Kanyakumari in south and Andaman & Nicobar Islands in the east to Gujarat in the west. Generally, onion crop are considered to be salt sensitive (Shahbaz *et al*., 2012). Its salinity tolerance is high at germination stage, very low during seedling growth and increases again at about the 3 to 5 leaf stage. The previous studies conducted in India on the influence of salinity on seed germination, growth, flavour, and yield attributes in onion showed an adverse effect on these traits (Joshi and Sawant, 2012).

Onion crop under hailstorm

In addition to the various climatic factors, severe storms with high winds, hail, rain, and blowing soil particles collectively called as hailstorms are the most damaging event in onion crop. This sudden and unpredictable event of hail storm generally occurred during late *Kharif* and *Rabi* season in India. This damaging event occurred frequently during the pre-monsoon season of March, April and May; Maharashtra has witnessed this unseasonal weather pattern in 2014 during last week of February and first week of March affecting the standing late *Kharif* as well as *Rabi* crop in Nasik, Ahmednagar, Pune, and Sholapur districts. The quality of the bulb was severely affected by the hail storm event severely limiting its keeping quality and ultimately the export. In onion crop, bulb initiation is the most sensitive growth stage for hail storm that completely damaged the foliage and bulbs. Defoliation and damage to standing crop can certainly increases the plant wounding, which enable pathogens to enter and infect plant tissues ultimately killing the plant completely. The incidence of *Stemphylium* blight and bacterial soft rot was higher due to unseasonal rainfall received during February and March. The unseasonal rain and hail storm keeps the underground bulbs intact which when harvested and exposed to the sun and heat, becomes rotten, turned black and emanate a foul smell which reduces its marketing value.

Conclusion

Climate change is global, but the impact of abiotic stresses in onion crop varies in different region and varieties. There is an urgent need to take up suitable possible measures to cope with the challenges ahead. One of the strategies is to screen the onion germplasm under hot spot areas or simulate within climate change condition and to identify genotypes which can sustain abiotic stress for year round supply. Production technology plays a crucial role in sustaining onion production, by managing irrigation, fertigation, anti-transpirants for drought or temperature stress, pest and disease management practices. There is a need to develop area specific intelligent forecasting modular with farmer friendly management strategies. Innovative methods are needed to be developed for making simulation models for onion crop and must be validated in different agro-climatic zones. Thus, various improved adaptation strategies and mitigation technologies could be worked out and farmers awareness will successfully helps in overcoming this environmental disasters and thereby saving crop.

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Fisheries Resources for Doubling Farmer's Income

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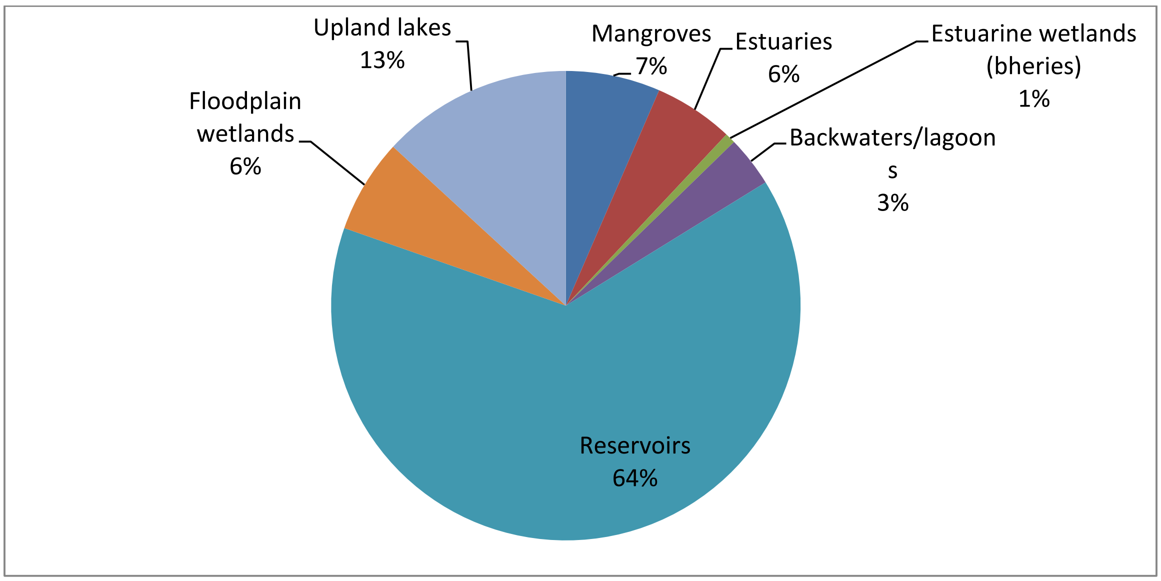
The requirement of protein in the nutritional basket is supplemented by fisheries for the rural and urban population of India. The rural folks are mainly dependent on fish for the food protein suggesting a major role of fisheries and aquaculture for producing high quality fish. In India, domestic demand is poised to increase to 16 million tonnes by 2025 against the present production of 9.58 MT from Indian inland and marine water resource (Food and Agriculture Organization, 2016). The streams, rivers, canals, reservoirs, floodplain wetlands and lakes contribute to the Inland water resource in India, where rivers cover 29,000 km, mangroves cover an area of 3,56,000 ha, estuaries 3,00,0000 ha, estuarine wetlands (bheries) cover an area of 39,600 ha, backwaters and lagoons constitute 1,90,500 ha, reservoirs constitute 35,10,000 ha, floodplain wetland constitute 3,54,213 ha and upland lakes constitute 7,20,000 ha. Culturing fish in these open waters and use of enclosures such as cage and pen systems have the potential to raise the fish production substantially. Inland fisheries exhibited an eight fold increase, from 0.16 million tonnes in 150-51 to 1.59 million tonnes during 2013-14, Table 1 (Suresh, 2017)



Availability of Inland Open water resource in India (except rivers)

Reservoir type	Area (million ha)	Current average yield (Kg/ha/year)	Average Potential yield (Kg/ha)	Total production (million ton/year)	Projection (million ton/year) 90% usage of fishery resource
Small	0.149	174	500	0.743	0.668
Medium	0.053	94	250	0.132	0.118
Large	0.114	33	100	0.114	0.103
Wetlands	0.526	1050	2000	1.108	0.997

Table. 1. Area, Current yield, Average Potential Yield, Total production and future projected yield of small, medium and large reservoirs and wetland in India.

Reservoir Fishery

Reservoir fisheries is classified into small, medium and large covering an area of <1000 ha, 1000-5000 ha and >5000 ha respectively. There are 19134 small, 180 medium and 56 large reservoirs in India covering an area of >3.42 million ha. Though reservoirs have a production potential of 500kg/ha, 250 Kg/ha and 100Kg/ha in small, medium and large reservoirs are presently producing 110 kg/ha. The production potential gap is an opportunity to sharply increase the fisheries production from inland water bodies (Das B K, 2017). Reservoirs, because of its huge resource size are an important sector with the ability to increase the fish production thereby doubling the income of fishers. Development of reservoir fisheries suffers from ownership issues not with the concerned departments, quality and quantity of fish seed availability, lack of fish seed rearing facility, un regulated fish stocking, seasonally changing water levels, destruction of fish habitat and lack of auto recruitment, destructive fishing methods, non availability of financial resource, institutional and policy support, difficulty in fish harvesting and finally non availability of trained manpower (Sarkar and Mishal, 2017).

Stock/Species enhancement

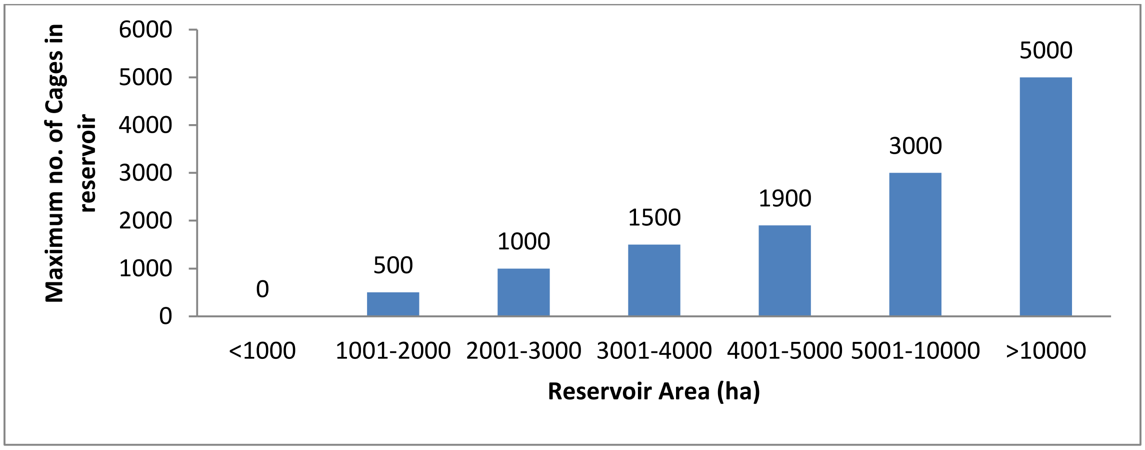
Augmentation of the desirable fish stock through stocking or natural recruitment results in stock enhancement of the reservoir. Stocking programmes using the fingerling size fish of the fish species having market demand results in increase in the fish production. Stock enhancement also supports establishment of a breeding population of a desirable fish species. The important criteria of stock enhancement are selection of species, stocking rate and size of fish at stocking. The main objective of stock enhancement is to recapture the stocked fishes and to supplement the reservoir with self-recruiting fish population. Herbivore with quick growth and a short food chain is preferred due to better feed conversion efficiency and food utilization. Fingerlings of > 100 mm size with the stocking density of 250 nos/ha/year or 500 nos/ha/year in case of availability predatory fishes in reservoirs is recommended (Sarkar and Mishal, 2017).

Culture based fisheries

Das, 2014 defined culture based fishery as an open water fishery in which the fish harvest is solely or mainly dependent on the stocking of fish (Das, *et al*., 2014) . Floodplain wetland, small reservoirs, and other water bodies are suitable for capture based fisheries. Fish growth depends on the stocking density and survival is a function of the size of fish. Culture based fishery in Aliyar, Chulliar, Markonhally and Gulariya reservoirs resulted in enhancement of fisheries to 75-316 Kg/Ha/year. Culture based fishery (CBF) is an effective method to increase fish yield when recruitment of desired fish species is lower than the carrying capacity of the reservoir or wetland. CBF relies on stocking and recapturing the stocked fish. Essential points for increasing fish yield from CBF is stocking fish of right size, time of stocking, density of stocking, fishing effort, size at capture, species selection and the type of fishing gear used (Sarkar and Mishal, 2017). In CBF, Indian major carps such as *Catla catla*, *Labeo rohita*, *Cirrhinus mrigala* and minor carps such as *Labeo bata*, Labeo *calbasu* exotic carp *Ctenopharyngodon idella* are suitable for stocking. Few essential factors playing role in CBF are stocking size and density, time at stocking after monsoon and harvesting during summer/monsoon season, period of growth and size at harvesting such as annual or six monthly harvesting at fish size of 1.0-0.5 kg, raising of seed in deep pools and cutoff areas of reservoirs.

Enclosure Fisheries

Cage and pen cultures are enclosures systems in which fish is reared to grow to marketable size. Cage and pen enclosures are excellent for rearing fish seed to desirable sizes for stocking the water bodies. In these enclosures the fish are maintained in captivity, provided with nutritional feed, no predators and are able to harvest at all sizes as required for stocking programmes. These enclosures increase the per unit area water productivity. Pens are erected along the banks of the reservoirs and wetlands are used for growing the fish at a faster rate. Enclosure fisheries optimizes the water use, in situ rearing of fingerlings, use of trophic energy for fish production, utilizes the weed infested water bodies, controlled ease of feeding and maintenance of fish health, and finally results in skill development in the rural and urban youth and generates employment and income to rural India. Cage and pen culture servers the purpose of fulfilling the ever growing demand of quality and high value high demand fish seed. The seed demand can be met through the enclosure fishery system. The enclosures can be used for maintaining a captive stock, growing it using artificial feeds, avoiding predation, maintenance of health through good water quality management, and harvesting whenever required by the farmers increase the water productivity of water and hence income of the farmers. Low cost material such as bamboo, cane, wooden logs can be used for making pens in shallow water areas in which fast growing fishes and prawns can be cultivated. Cage culture plays an important role in enhancement of fish production in reservoirs (Das, 2017).



Maximum number of cages based on area of reservoir

Enclosure culture provides advantages as follows

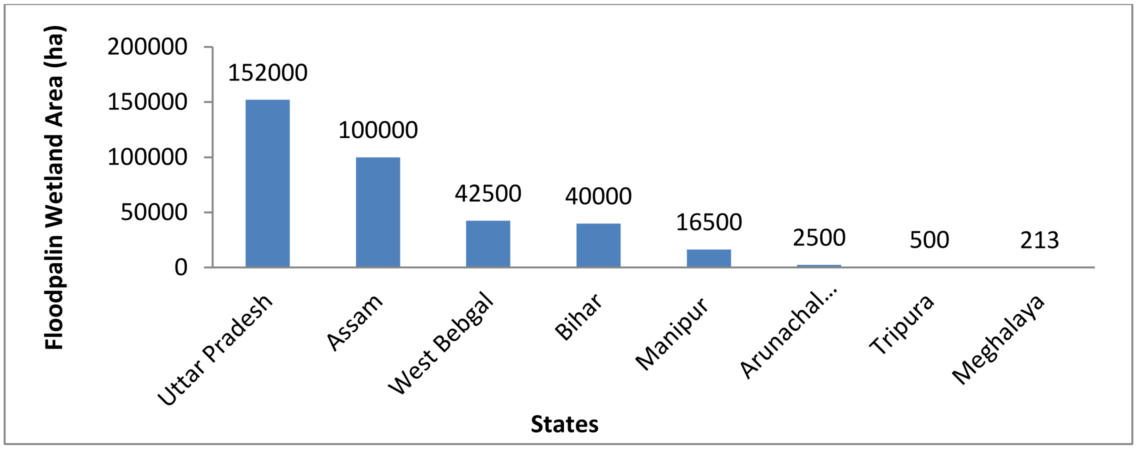
- Augmenting fish yield by optimizing the use of all available water area
- Cost effective raising of fingerlings for reservoir stocking and aquaculture

- Optimal use of the trophic structure and function for fish production
- Utilizing the weed infested and chocked water body
- Alleviation of the requirement of land resource for fish farm and nursery
- Stock in captivity for rapid, easy and complete harvesting
- Control over welfare and growth of fish
- Skill and employment through cage and pen culture

Some of the potential species for cage culture are economically remunerative *Pangasianodon hypopthalamus*, monosex GIFT Tilapia, *Oreochromis niloticus*. Based on regional demand and consumer preference species of *Labeo bata*, *Labeo rohita*, *Osteogramma belangiri* pengba, *Ompak bimaculatus* pabda, *Anabus testudineus*, *Puntius sarana*, *Lates calcarifer*, *Etroplus suratensis*, *Chitala chitala* (featherback), *Channa straita*, *Channa marulius* murrels, *Wallago attu* and shellfish *Macrobrachium rosenberghii*.

Floodplain Wetland Fishery

Floodplains are flat lands bordering rivers, which are subjected to periodic flooding from rivers, which tend to be most expansive along the lower reaches of rivers. Floodplain wetlands are associated with rivers and the streams. They are connected with the river or receive water from the backflow of rivers during monsoon floods. They are common in the Ganga and Brahmaputra river systems. Floodplain wetland forms an important source of fishery in the states of Assam, West Bengal, Bihar, Uttar Pradesh and Manipur (Das, 2017).



Distribution of Floodplain Wetland in India

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Techniques to Obviate Drought and Edaphic Stresses in Orchards Grown in Semi-Arid Regions of Western Maharashtra

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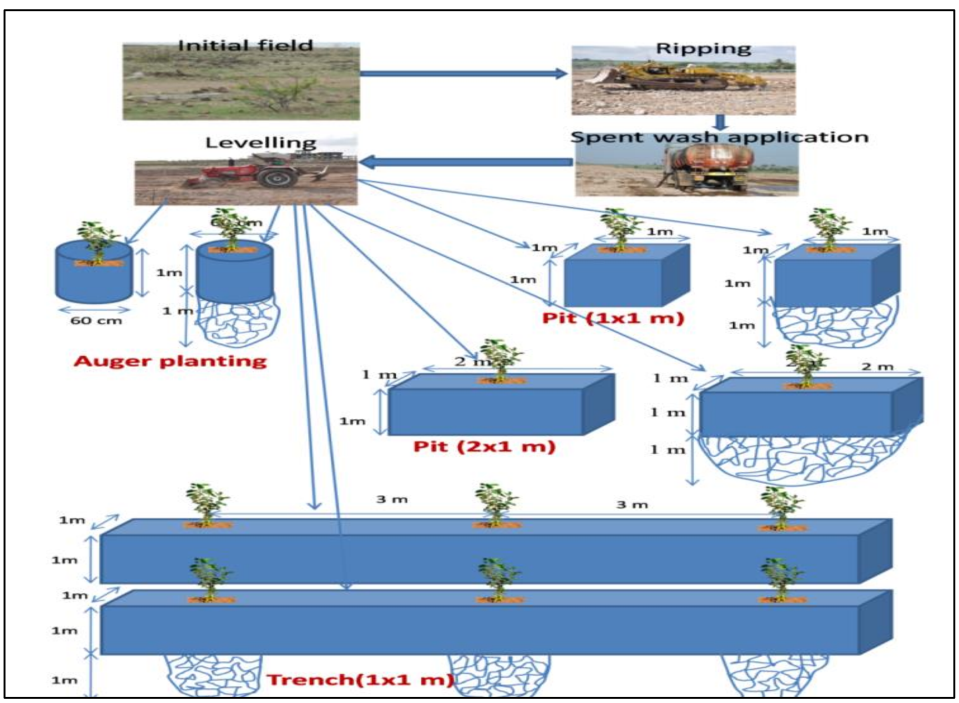
In India, presently around 9.2 m ha and 6.9 m ha area are under the cultivation of vegetables and fruits, respectively. Further increase in production is possible through bringing higher production potential crops under large area and converting waste lands, estimated to be around 11 m ha into productive lands. Farmers, scientific communities and policy makers have always been concerned about adverse impacts of abiotic stresses on agriculture and over exploitation of natural resources. About 42% (6 m ha) of degraded land in India mainly suffers with hard pan and having shallow soil depth. Resultant edaphic and drought stresses in these lands reduce the longevity and potential yields of orchards especially due to high vulnerability to droughts. Soil erosion, land degradation and multiple nutrient deficiencies are also very common features on these basaltic soils. Moreover, the impact of climate change on land degradation has drawn worldwide attention wherein the importance of geological formation has been taken as an important stress parameter to define the quantum of degradations. As proportions of productive lands are gradually declining with anthropogenic activities, it is axiomatic that the food security for ever increasing population would have to be met through adaptation and mitigation strategies for harsh agro-ecosystems in order to sustain productivity of horticultural crops. The negative impacts of shallowness in terms of low water retention, hard rocks and murrum etc. are the major constraints for establishment of orchards in shallow basaltic soils of Maharashtra. Therefore an experiment entitled "**Innovative Techniques to obviate edaphic & drought stresses on pomegranate grown in shallow basaltic soils"** has been initiated in the year 2013 at ICAR-NIASM, Baramati on Pomegranate (shallow rooted), Guava (medium rooted) and Sapota (deep rooted) crops to increase economic longevity of theses orchards and to address the issues of edaphic and drought stress.

Methodology

Experimental land was a barren basaltic rocky terrain with soil depth that seldom exceeded 0.3 m and. Therefore to hasten the pace of disintegration and soil development, the principle of physical (mechanical) along with chemical weathering processes were adopted. In mechanical process, parental rocks were targeted to be disintegrated into smaller sized either by blasting or ripping.Experiment entitled "Innovative Techniques to obviate edaphic & drought stresses on pomegranate grown in shallow basaltic soils" has been initiated in the year 2013 at ICAR-NIASM, Baramati on Pomegranate (shallow rooted), Guava (medium rooted) and Sapota (deep rooted) crops to evaluate the various planting methods and soil mixtures for better establishment and productivity. The planting methods included viz., auger, trench, mini trench, pit planting along with filling mixtures (native murrum soil, black soil, mixture of murrum and black soil) and in addition micro-blasting was carried out to enhance rooting depth by 1 m. Influence of spent wash, a sugarcane distillery waste was also studied. Altogether 28 treatment combinations were evaluated in randomized block design with four replications. Plant responses are being measured in terms of plant height, rootstock and scion girth, no. of branches, canopy spread, pruned biomass weight and physiological responses.



Observation revealed that there is significant influence of various treatments on pomegranate and guava orchard in terms of growth, physiological, hyperspectral responses and yield. The tallest plant height, diameter and canopy spread in pomegranate was monitored with pit and trench planting filled up with mixture of native murrum and black soil. The treatments effect was studied in terms of pruned wood biomass as it gives more precision on effect of treatments. It was observed that 1.04 kg of biomass was removed in treatment having mixture of soils and planted in pit and trench methods as compared to farmer’s practice with black soil (0.59 kg of pruned wood biomass). Similarly, net photosynthetic rate (32.44 µmol m^{-2} s^{-1}) and stomatal conductance (163.36 m mol m^{-2} s^{-1}) measured through IRGA, revealed that highest values were obtained under treatments planted by pit and trench methods having mixture of soils with additional 1 m soil depth by micro-blasting. Soil moisture observation revealed that moisture content was more with blasting (19.50%) than without blasting (14.98%). Auger planting with 100 % black soil recorded more soil moisture in deeper layer (60 cm) - 23.44% than mid layer (40 cm) - 16.49%. Mixtures of black soil and native murrum are performing better than 100 % Black soil in terms of plant growth and its physiological activities under limited moisture availability. The activity of enzymes like nitrate reductase, catalase and superoxide dismutase (SOD) activities were also lower under treatment having mixture of soils and planted in pit and trench methods with additional 1 m soil depth by micro-blasting. Better soil moisture regimes were maintained with rainwater conservation with blasting (19.5%) than without blasting (15.0%). Auger planting filled with black soil recorded more soil moisture in deeper soil. Trench or pit planted Guava and Pomegranate orchards are performing better than Auger planting under shallow basaltic region. Micro-blasting proved its superiority over without micro-blast treatments in establishment of these orchards. These cracked rocks could further facilitate the root penetration and water conservation. In pomegranate, the research findings from ICAR-NIASM revealed that the highest plant height, girth, canopy spread and pruned wood removal was recorded with pit and trench planting filled up with mixture of native murrum and black soil. Soil moisture observation revealed that moisture retention was more with blasting (19.50%) than without blasting (18.00 %). The top 20 cm soil showed more soil moisture content than 20-40 and 40-60 cm soil depths. In conclusion, the pomegranate plants planted with the mixtures of soil, micro-blasted and planted either in trench or pit performed better. In case of without blasting, the highest plant height (125.4 cm), girth (33.48 cm) and canopy spread was recorded with pit and trench planting filled up with mixture of native murrum and black soil.

Table 1. Effect of various treatments on stem diameter in pomegranate

Girth (mm)								
Planting method	**Without blasting**				**With blasting**			
	Native	**Native + spent wash**	**Native + black**	**Black**	**Native**	**Native + spent wash**	**Native + black**	**Black**
Auger	47.3	48.7	49.6	48.3	47.8	49.0	54.2	51.9
Pit	51.1	51.9	51.9		51.4	51.0	52.4	
Trench (2*1)	50.7	52.1	54.3		50.5	51.6	55.1	
Trench	50.2	52.3	53.0		53.6	52.9	54.5	
FP	45.0	45.5						

Table 2. Effect of various treatments on yield (kg/3 plant) pomegranate

Planting method	**Without blasting**				**With blasting**			
	Native	**Native + spent wash**	**Native + black**	**Black**	**Native**	**Native + spent wash**	**Native + black**	**Black**
Auger	38.5	42.3	58.5	27.8	49.4	55.1	77.0	30.5
Pit	51.2	56.8	71.7		59.1		85.2	
Trench (2*1)	57.5		69.0		63.0		90.5	
Trench	55.9		55.7		58.1		85.4	
FP	29.2	31.4						

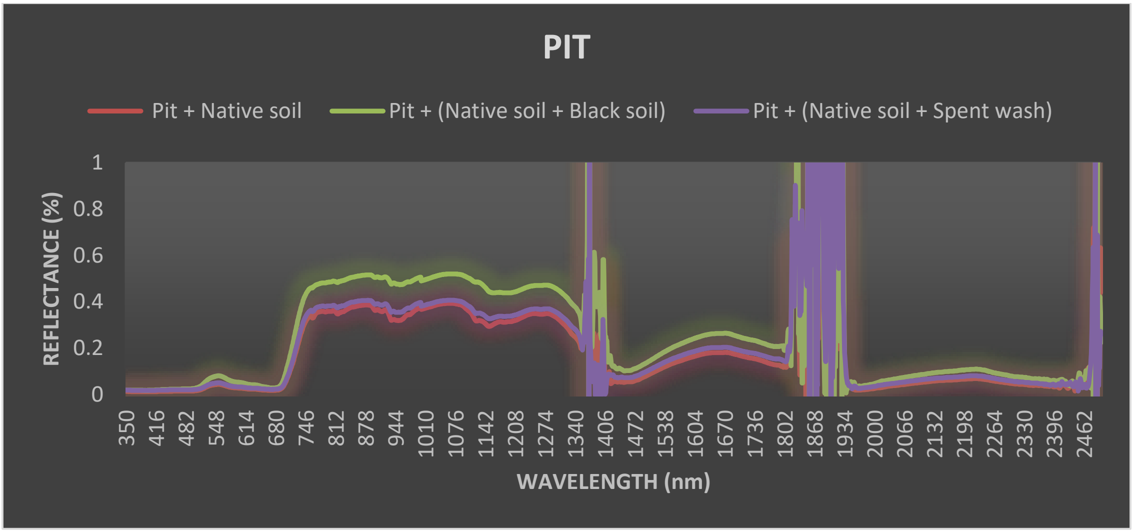


Fig. Influence of various treatments on hyper-spectral reflectance in pomegranate crop

Conclusion

Overall, the mixtures of soil with micro-blasting and planted either in trench or pit performed better than all other treatments. Black soil, in spite of popular belief resulted inferior performance than mixtures of soil and native murrum. However, it maintained cooler canopy than other treatments.

Production, Extraction of Biomolecules from Plant Growth Promoting Bacteria and Their Analysis Using HPLC

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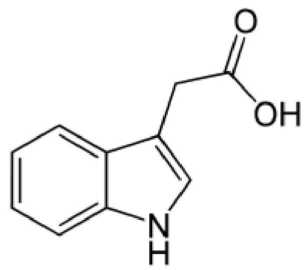
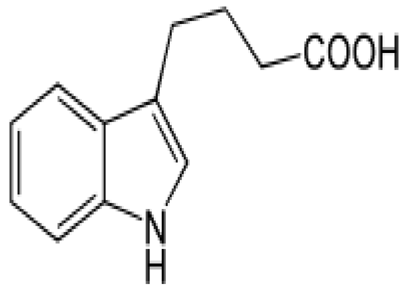
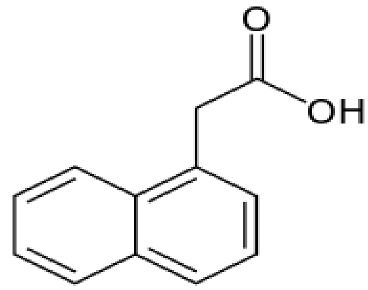
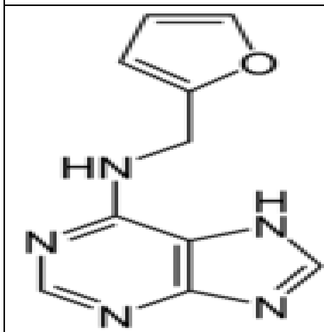
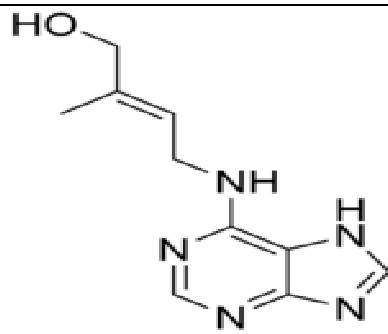
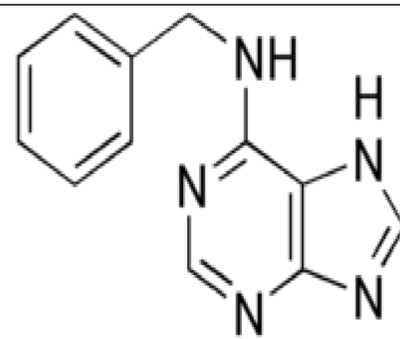
Microbial biomolecules in plant growth promotion

Microbes including bacteria, fungi and actinomycetes have been well characterized for their ability to promote plant growth, the phenomenon collectively termed as plant growth promotion (PGP). Several mechanisms have been put in elucidation of microbial plant growth promotion, e.g. microbial production of plant growth hormones (PGHs), siderophores, volatile organic compounds (VOCs), fixation of atmospheric nitrogen, solubilization of phosphate, mineral cycling, etc. High throughput estimation of these important class of PGP biomolecules is therefore critical, in light of implementing candidate microbes in sustainable agricultural practices. An array of multifaceted, cutting edge technologies are in service now a days. Ultra-high pressure liquid chromatography (UHPLC) includes one of such equipment, capable of resolving mixtures of biomolecules with great sensitivity.

This chapter will focus mainly on different aspects related to production, extraction, and UHPLC-estimation of bacterial derivatives of PGHs. Additionally some basic points to be considered while analyzing the biomolecules through UHPLC have been discussed.

Bacterial production of PGHs

Bacteria represent major fraction of microbial population associated with plants. The members of phyllosphere community including ping pigmented facultative methylotrophic (PPFM) bacteria like *Methylobacterium*, species of *Pseudomonas*, *Rhizobium*, *Azotobacter*, *Pantoea*, *Enterobacter*, etc. are known to produce PGHs in varying quantities. Major PGHs include both auxins, cytokinins gibberelins (GAs), indole acetic acid (IAA), indole butyric acid (IBA), Zeatin, abscisic acid (ABA), BAP, Kinetin.

Auxins		
 **IAA**	 **IBA**	 **NAA**
Cytokinins		
 **Kinetin**	 **Zeatin**	 **BAP**

Detection and estimation of bacterial derivatives of PGHs

Traditional recipes for detection of microbial derivatives of PGHs appear principally based on the colorimetric reactions of the functional moieties harbored by PGHs. These methods make use of thin layer chromatography, colorimeter, etc. and developing reagents, e.g. salkovsky’s reagent is extensively used for quantitative determination of IAA. However, the resolution of closely related structures remain curtained with this methods.

UHPLC mediated detection of PGHs

Liquid chromatic separation, and estimation of biomolecules have boosted the research in biomolecules several folds. Estimation of PGHs using HPLC/UHPLC have gained rapid attention owing to the high degree of accuracy and sensitivity.

a. Production and extraction of microbial derivatives of PGHs

Bacteria secrete the PGHs in surrounding environment at specific stages of growth. It is thus critical to pool the desired biomolecules from complex mixture of the cultivation medium. Further, the PGHs being metabolites, their production is highly sensitive towards the physicochemical environment. Thus ensuring controlled cultivation conditions can strengthen the probability of reproducibility. The PGHs can be pooled using specified chemical environment and organic solvents like ethyle acetate, n-hexane, resins like XAD 7, XAD 2, XAD 16, etc. (*please see working protocols below*)

Working protocols

Production and extraction of Biomolecules from plant growth promoting bacteria

Plant growth promoting bacteria generally grow well in general cultivation media without requirement of specific nutritional supplements, however during the production of biomolecules, it becomes imperative to maintain optimal microenvironment for peak production of metabolites. For instance, while studying stress-responsive metabolites, it needs to maintain known intensity of the stress condition during growth of the microbes; e.g. salt concentration in growth medium, cultivation temperature, pH of the growth medium, exposure of heavy/toxic metals, etc. Similarly certain induced metabolites can also be produced by supplementing the growth medium with the specific substrate, e.g. amending the growth medium with tryptophan for higher IAA production.

The biomolecules like microbial derivatives of plant growth hormones (PGHs), different phenolic compounds, siderophores, and variety peptides and other metabolites, etc., can be studied well using UHPLC. For analytical purposes, it is needful to carry out primary separation of these biomolecules from the cultivation medium. Thus, to achieve the same, following the cultivation of PGP bacteria, the biomolecules are extracted using different methods, like extraction using resins, organic solvents (please see flow-chart below), etc. Subsequently, the extracted biomolecules are then used for bioassay, and also analyzed by different high-throughput techniques like UHPLC, LC-MS, NMR, etc. Herein we will perform the extraction of biomolecules from bacterial culture filtrates using two different methods, i.e. resin, and immiscible organic solvent – ethyl acetate.

Growth of the PGP bacterium in appropriate medium under specified environmental conditions till late log to early stationary phase

↓

Pellet-out the cells by centrifugation and preserve the supernatant

↓

Extraction of Biomolecules

↓

Resin-based

↓

Mix preconditioned* resin (XAD 2, 7, 16, etc.) in the supernatant (adjust fine parameters like pH of the supernatant if specific class of biomolecules are targeted)

↓

Shake the slurry at **150 rpm / 30 min** to allow the resin to trap the biomolecules

↓

Pour the slurry in a glass column and wash with **three** bed volumes of milli Q water to remove undesired impurities

↓

Elute the trapped biomolecules with 100% acetone / methanol

↓

Remove the organic phase in vacuum at temperature ≤30 ^{0}C → Preserve at -20 ^{0}C for further studies

↓

Re-suspend the pelleted biomolecules in mobile phase and use for HPLC analysis

Organic solvents-based

↓

Use immiscible organic solvents like ethyl acetate, hexane, etc. to extract the biomolecules from supernatant. The organic solvents are mixed directly in supernatant and mixed thoroughly, followed by separation of the organic phase (in this case also, adjust fine parameters like pH of the supernatant if specific class of biomolecules are targeted)

↓

Allow the organic and aqueous phase to separate in a separating funnel

↓

Carefully separate and collect the organic phase

↓

Repeat the process and similarly perform the extraction two more times

↓

Remove the organic phase in vacuum at temperature ≤30 ^{0}C → Preserve at -20 ^{0}C for further studies

↓

Re-suspend the pelleted biomolecules in mobile phase and use for HPLC analysis

Preconditioning of XAD resins:

The resins may contain impurities arising out of the manufacturing and storage. The impurities may interfere with the subsequent analyses. Thus it becomes needful to make the resin free from impurities prior to use for extraction of biomolecules.

We utilize simplest method for conditioning, which makes use of milli Q water and the organic solvent to be sued as eluent. This involves washing of the resin with three bed volumes of milli Q water, then subsequent washing with the organic solvent (to be sued as eluent). The resin is then further washed several times with milli Q water to remove the traces of organic solvent. The resin is now ready for use.

b. Pre-analysis processing of samples

The solvent content from the pooled samples should either be evaporated or appropriate blank must be used otherwise during the analysis. It is always recommended to use mobile phase composition as diluent. The samples are then diluted to avoid the excessive loading. Similarly known concentration of standard PGHs also dissolved in appropriate diluent. All the samples and standards need to be filtered using 0.2µ filter. (*The selection of filter again depends on constituents of sample. A filter should not retain any of the constituents of the sample, as it can potentially hinder with the results*). Heat labile samples should be maintained on ice bath throughout.

c. UHPLC analysis

Selection of appropriate column is needful to ensure proper results. Variety of columns are available with different specifications (*see: point 'a' in section 'e'*). Use of optimum mobile phase, flow rate and the column temperature are also crucial factors for better resolution of constituents from the samples (*see: point 'b & c' in section 'e'*). Properties of the molecules from the sample are central for the selection of detector (*see: point 'e' in section 'e'*). The samples can either be injected manually or with the help of an auto-sampler. The injection volume typically range from 0.1-50 µL for analytical UHPLC. The samples injections are done in at least 5 replicates per sample.

d. Data analysis

HPLC generates huge data following the analysis. Subtraction of blank from the mean results help in reduction of probable noise arising due to mobile phase. Peak area and height are considered for quantitative determination. The concentration of desired constituents are then calculated using standards.

e. Key notes

1. The column

Variety of column are available for HPLC analysis of different samples. Most crucial aspect need to be considered prior to analysis is knowledge of the sample; e.g. composition of the sample, the constituents to be resolved from the mixture of analytes, their chemical nature, structure, predicted number of constituents, expected concentration, etc. Additionally, goals of separation should also be clearly defined, e.g. whether maximum or partial resolution is needed, level of sensitivity, economy of the method, slow/fast analysis, etc. Prediction of such characters is important as it directly relates to composition of mobile phase and selection of column as well. Clearly defined goals facilitate the selection of most appropriate column that can achieve the job; e.g. shape and size of the particles in column, internal diameter, length and pore size of the column, desired surface area, carbon load, type of bonding –(monomeric/polymeric), etc. can be determined more keenly. This approach can significantly reduce the time and efforts during optimization of method for a particular sample.

Columns of choice for primary analysis of biomolecules using HPLC include C8, C18. It has compatibility with diverse range of biological molecules. However, the compounds like sugar moieties can be better analyzed using amino columns. Therefore it is highly recommended to gain needful knowledge regarding the sample prior to proceeding for HPLC analysis. Selection of column with wide range of compatibility can suit better with complex mixtures like microbial secondary metabolites, etc.

Length of column also determines the retention time of analytes. It is thus needful to select the column of appropriate length, e.g. 50, 100, 150, 250 mm, etc. More complex analyte mixtures generally better analyzed using longer column lenght, e.g. 250 mm.

Similarly, particle size of the column also is equally important; it typically ranges between 03-20 µm. Pore size, carbon load, bonding type, etc. can also chosen similarly. Columns have a typical pH range for optimal performance. The lower and upper pH limits of the column being used must always be considered while using mobile phases with specific pH; e.g. mobile phases containing different concentrations of formic acid, orthophospheric acid, trichloroacetic acid, etc. Exceeding the limits of pH tolerance of a column can directly affect the efficiency and life of column.

2. Mobile phase

Mobile phase constitutes an important part of successful analysis. In general, mobile phase may be a single solvent like water, methanol, hexane, etc. or it can be a defined mixture of water / buffer and miscible organic solvent like methanol, acetonitrile (ACN), etc. Composition of mobile phase e.g. ratio of organic:aqueous phase, pH, exert significant influence on retention of analytes. Thus, behavior of constituent molecules from the sample in mobile phase is another important aspect that should be addressed carefully. More specifically, the polarity of a molecule and mobile phase cumulatively determine its retention in the column. It is therefore clear that an unknown sample may demand trial and error attempts with different columns as well as mobile phases.

3. Flow rate

Retention of molecules is also significantly affected by flow rate of the samples. Flow rate is directly responsible for rise in pressure. Particle shape of the packing material in the column also has equivalent function in developing the pressure, e.g. spherical shape of the particles offer reduced back pressure when compared with that of the particles having irregular shape.

4. Column temperature

Temperature has great influence on kinetics of mobile phase, as well as behavior of the analytes. Trial and error are thus needed to discover the best separation temperature. Moreover uniform column temperature ensures a constant environment during entire analysis span. However, temperature tolerance of mobile phase, particularly of the organic component from the mobile phase, as well as of the column must be taken into account while opting high temperature range. Overall, maintaining well defined temperature environment throughout the analysis yields highly reproducible results.

5. Detection

The analytes are detected by detector. Variety of detectors are available to monitor the eluting analytes. Predominant detectors include photodiode array (PDA), refractive index (RI), ultra violet (UV), fluorescence, evaporative light scattering detector, etc. Detectors vary with respect to their working principle as well as sensitivity. It is thus recommended to acquire prior knowledge regarding the properties of analytes while selecting the detector. Selection of right detector leads to detection of the analytes with high sensitivity.

PDA is relatively more versatile and popular one, particularly due to ease of monitoring the response of analytes in both UV as well as visible range. It is more convenient with unknown analytes where it is easy to monitor the response at absorption maxima, and spectral properties of the analytes. Similarly RI detector can also be used for the purpose, however there are limitations of RI detectors particularly with respect to sensitivity, and its working only under isocratic mode.

Response of the compounds with known composition, on the other hand can be monitored using other detectors as well. Fluorescence detector represent an efficient alternative for relatively sensitive and specific detection needs. For instance, IAA can also be monitored using fluorescence detector (fluorimetric detection) at excitation wavelength of 280 nm, and emission wavelength of 350 nm (λ_{ex} 280/ λ_{em} 350). This offers additional sensitivity and high degree of specificity. Similarly response of other analytes can also be monitored using literature-based data regarding their characteristic properties.

Photosensitive Crops and its PAR Pattern under Climate Change Scenario

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Plants are very sensitive to light conditions because light is their source of energy and a signal that activates the special photoreceptors that regulate growth, metabolism, and physiological development. Photosynthetically active radiation (PAR) is the part of electromagnetic radiation that can be used as the source of energy for photosynthesis by green plants. Technically, it is defined as radiation in the spectral range from 400 to 700 nm (McCree, 1972a and 1972b). It is expressed either in terms of photosynthetic photon flux density (PPFD, mmol photons m^{-2} s^{-1}), since photosynthesis is a quantum process, or I n terms of photosynthetic radiant flux density (PAR irradiance, W m^{-2}), more suitable for energy balance studies. A fundamental term in the quantification of light used by plants in the photosynthesis process is the fraction of absorbed photosynthetically active radiation (fAPAR) calculated as the ratio of absorbed to total incident PAR in a vegetation canopy. PAR changes seasonally and varies depending on the latitude and time of day. Levels are greatest during the summer at mid-day. Photons at shorter wavelengths tend to be so energetic that they can be damaging to cells and tissues, but are mostly filtered out by the ozone layer in the stratosphere. Photons at longer wavelengths do not carry enough energy to allow photosynthesis to take place. PAR is needed for photosynthesis and plant growth. Higher PAR promotes plant growth, and monitoring monitoring PAR is important to ensure plants are receiving adequate light for this process.

Factors that reduce the amount of PAR available to plants include anything that reduces sunlight, such as cloud cover, shading by trees, and buildings. Air pollution also affects PAR by filtering out the amount of sunlight that can reach plants. Atmospheric brown clouds (ABCs) are one of the factors that enhance air pollution and reduce PAR availability to plants. ABCs are atmospheric accumulations of carbonaceous aerosol particles spanning vast areas of the globe. They have recently gained much attention, from the scientific community and from the general population, as they severely impact several aspects of everyday life. Aside from affecting regional air quality and negatively impacting human health, these clouds affect biogeochemical cycles and profoundly influence the radiation budget of the Earth, resulting in severe climatic and economic consequences.

Carbonaceous aerosol particles are generated primarily by combustion processes, including biomass and fossil fuel burning. Natural emissions and transformations of volatile organic species in the atmosphere also contribute to the development of atmospheric brown clouds. Aerosols or atmospheric particles are either in solid form, such as dust or sea salt, or in liquid form, such as sulfates, nitrates or organics dissolved in water. Nature produces aerosols in the form of sea salt, mineral dust, sulphates and nitrates. Human activities either emit gaseous precursors, such as SO_2 and NOx which get converted into particles through chemical processes, or directly emit particles such as soot, which is a mixture of elemental carbon and organics. The concentrations of natural aerosols in pristine air are typically around 100 to 1000 particles per cc in continental air and about 100 to 500 per cc in marine air. It is now increasingly difficult, if not impossible, to find such pristine air. In most regions of the northern hemisphere, including over the oceans, the concentrations are larger by factors ranging from two to ten. Coincident with greenhouse gas warming is the appearance of atmospheric brown clouds. If greenhouse gases, such as CO_2, are the ultimate end product of fossil fuel burning, then particulates in the air represent an intermediate phase (Ramanathan *et al*., 2001a). Subsequently, a new NASA satellite instrument (MODIS) has identified (Kaufman *et al*., 2002 and Ramanathan and Ramana, 2003) such widespread brown clouds over most industrialized regions of the world (Molina and Molina, 2002).

Impact of ABCs

ABCs and its impact on different fields are mentioned below (*Source*: UNEP, 2002):

- **Human Health**: ABC exposure is probably associated with significant health effects.
- **Water**: Weakened Asian monsoon, 20% decrease in rainfall in the Indo-Gangetic plain since the 1980s.

- **Glacier melting**: Accelerated melting of Hindukush-Himalayan-Tibetan glaciers due to black carbon deposition on snow// ice, and atmospheric heating.
- **Climate change**: 6% decrease in solar energy reaching the surface in China and India since pre-industrial times. 20-50% increase in heating of the lower atmosphere (up to 3 km).
- **Agriculture**: Surface dimming (cooling), reduction of photosynthetically active radiation (PAR), change in rainfall (drying), increasing ground level ozone and significant loss in crop yield.

Impact of ABCs on Photosensitive crops

Reduction of Photosynthetically Active Radiation (PAR) at the Surface will be one of the potentially important environmental effects of ABCs. Their large effect will be on reducing the total (direct + diffuse) PAR (Meywerk and Ramanathan, 2002). The brown clouds over the Arabian Sea decreased direct PAR by 40% to 70%, but enhanced the diffuse PAR substantially, with a net reduction in total PAR by as much 10% to 30%. The potential impact of large reductions in direct PAR and corresponding enhancements in diffuse PAR accompanied by net reduction in total (direct + diffuse) PAR on marine and terrestrial photosynthesis and on agriculture productivity (Chameides *et al*., 1999; Stanhill and Cohen, 2001) has not been adequately studied. Similar changes in the UV spectrum due to ABCs need to be established which may have health effects due to the potential importance of UVB in producing Vitamin D (Garland and Garland, 1980; Gorham *et al*., 1989).

Soybean is a photo-sensitive crop and the yield gets negatively affected by surface dimming Brazil has started adopting indeterminate soybean varieties (Anonymous, 2012). In Brazil, the 50 per cent of cultivated area of determinate soybean genotypes were replaced and occupied by indeterminate genotypes and it is expected to eventually reach 100 per cent (Anonymous, 2012). The huge advantage of indeterminate varieties over determinate varieties was that they could recuperate after periods of dry weather. Under hot and dry weather the indeterminate varieties which are at flowering stage, may abort their flowers and pods to escape the conditions, they recovers with new flush of flowers once rainfall occurs. In India, about 70 per cent soybean area is cultivated with semi-determinate genotypes, around 20 per cent with determinate and only 10 per cent with indeterminate genotypes. Therefore, experiments were conducted to i) develop suitable shade-net structures for simulating reduced PAR condition, ii) determine the light saturation point (LSP) for maximizing photosynthesis among the soybean genotypes iii) identify the better performing cultivars under reduced PAR and moisture stress conditions (Bhagat *et al*., 2017).

An initial experiment was conducted at ICAR- NIASM, Baramati to standardize different types of shed net structures for incoming PAR and concluded that a hemispherical-dome shaped shade-net structure as an ideal option for conducting field experiments on assessing the impact of surface dimming (due to ABCs) which causes reduction in PAR availability to crops. The indeterminate soybean cultivar showed lesser impact on photosynthesis under dimmed PAR scenario and was also better suited under moisture stress conditions as compared to determinate and semi-determinate soybean cultivars. Significant interaction effect was also observed in terms of seed yield and was recorded maximum in semi-determinate (JS-335) genotype grown under normal irrigation condition which was significantly superior to determinate genotype (JS-93-05) while remain statistically at par with indeterminate genotype (Kalitur) grown under normal and restricted irrigation conditions (Bhagat *et al*., 2017). All these study were commenced to understand the effect of surface dimming and PAR reduction on few soybean genotypes due to ABCs and its mitigation options under projected climate change scenario whereas more genotypes and more photosensitive crops need to be tested to abridge the research gap on the impact of ABCs.

Summary

Particles engendered throughout the process of Industrialization causes increase in ABCs which lead to about annual deaths of 1.6 million people, reduction in photosynthetically active solar radiation, direct impacts on agriculture, lead to a large dimming of the planet, reduction in the precipitating efficiency of clouds, stabilization of the surface-atmosphere system during dry seasons, alteration in sea surface temperature gradients, affecting the regional rainfall patterns, and lead to global cooling and drying

(Ramanathan, 2006). In addition, the Asian monsoon system affecting the lives of over 2 billion people is vulnerable to ABCs. To see the impact of ABCs on PAR, hemispherical-dome shaped shade-net structure was evaluated as an ideal option for conducting field experiments on assessing the impact of surface dimming (due to ABCs) which causes reduction in PAR availability to crops. The indeterminate soybean cultivar showed lesser impact on photosynthesis under dimmed PAR scenario as compared to determinate and semi-determinate soybean cultivars (Bhagat *et al*., 2017). Therefore, a shift towards cultivation of indeterminate soybean genotypes is reasonably accepted in view of future projected climatic scenario as compared to popular determinate and semi-determinate cultivars in future. This study will pave the way in preparing ourselves for taking soybean crop in future. However, more research efforts are required to test large number of genotypes among different types, i.e., determinate, semi-determinate and indeterminate to validate this conclusion and assess it as a mitigation option.

Acknowledgement

We sincerely acknowledge ICAR-National Institute of Abiotic Stress Management, Baramati for the financial support, and Agharkar Research Institute, Regional Station, Wadgaon-Nimbalkar, Pune, India for providing breeders seed material.

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Measurement of Photosynthesis and Associated Parameters in Various Crops under Climate Change Scenario

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All living organisms necessitate energy for their growth and reproduction. Humans/ animals eat food to provide the fuel for respiration, whereas plants make their own through photosynthesis. Photosynthesis is a process during which light energy in presence of water and carbon dioxide gets converted into chemical energy in the form of carbohydrates. These carbohydrates are utilized for respiration to generate energy for governing metabolic processes essential during life cycle in plants. So, how do we measure photosynthesis which is an ultimate source of energy for plants?

Infrared gas analyzer (IRGA) of CO_2 is the most widespread method for measuring the photosynthetic and respiratory rates in plants. It is safe, non-destructive, reliable, accurate, simple and less time consuming.

Principle of IRGA

The technique is based on the principle that hetero-atomic gas molecules (like CO_2, H_2O, NH_3, CO, N_2O, NO) absorb radiation at specific sub-millimetre infrared wavebands as each gas is having a characteristic spectrum. The absorption bands are in fact made up of a series of absorption lines which correspond to the rotational states of the molecules. Gas molecules consisting of two identical atoms (e.g. O_2, N_2) do not absorb this long-wave infrared (IR) radiation, and thus do not interfere with the determination of the mole fraction of hetero-atomic molecules (Hill and Powell, 1968).

Absorption of radiation by CO_2 at any one wavelength (λ) follows Beer Lambert Law and thus depends on radiation path length through measuring gas and molar concentration of CO_2 (M, K_{mol} m^{-3})

$$\propto_\lambda = 1 - \exp(- M.1.\, K_\lambda)$$

Where,

K_λ = extinction coefficient at wavelength λ.

1 = radiation pathlength.

M = molar concentration of CO_2 in air.

The major absorption band of CO_2 is at 4.25 µm with secondary peaks at 2.66, 2.77 and 14.99 µm. The only hetero-atomic gas normally present in air with an absorption spectrum overlapping that of CO_2 is water vapour (both molecules absorb IR in the 2.7 µm region). Since water vapour is usually present in air at much higher concentration than CO_2, this interference is significant. This is overcome either by drying the air that is to be examined or by filtering out all radiation at wavelength where absorption of two gases coincides. Since, water vapour is usually present in air at highly variable and much higher mole fractions than CO_2, this interference is of significance. Most commercial leaf gas exchange systems incorporate both a CO_2 and a water vapour IRGA. This allows a software correction that will be specific to the individual instrument, to be made for this water vapour interference with CO_2 measurement (Long *et al*., 1996). Since, the absorbance will differ between specific wavelengths, the spectral distribution of energy will change with passage of the broad-band radiation through the sample; the more strongly absorbed wavelengths being depleted more rapidly. This introduces important non-linearities into the relationships of radiation absorption with mole fraction of CO_2, path-length and interference by water vapour (Long and Hallgren, 1993).

Measurement of photosynthesis and associated parameters

There are various atmospheric stress factors such as light, temperature, wind, atmospheric gases and air moisture which can be influence the photosynthetic efficiency of plants. To know the impact of these factors, the following photosynthesis and associated parameters can be measured with the help of IRGA equipment.

i) Transpiration rate (E): According to Caemmerer and Farquhar (1981) the transpiration rate is calculated as follows:

$$E = \frac{\mathrm{u_e} * (\mathrm{w_o} - \mathrm{w_e})}{LA * (1 - w_o)}$$

Where,

E = transpiration rate [mmol m^{-2} s^{-1}]

u_e = molar flow rate at the inlet of the cuvette [µmol s^{-1}],

w_o = H_2O mole fraction at the outlet of the cuvette [ppm],

w_e = H_2O mole fraction at the inlet of the cuvette [ppm],

LA = leaf area [m^2].

ii) Water vapour conductance (GH_2O): According to Caemmerer and Farquhar (1981) the total water vapour conductance GH_2O is calculated as follows:

$$GH2O = \frac{E}{VPD}$$

Where,

GH_2O = total water vapor conductance [mmol m^{-2} s^{-1}],

E = transpiration rate [mmol m^{-2} s^{-1}],

VPD = (Air-to-Leaf-)Vapor-Pressure-Deficit [Pa/kPa].

iii) Vapour pressure deficit (VPD): According to Caemmerer and Farquhar (1981) the vapour pressure deficit is calculated as follows:

$$VPD = \frac{u_e * (w_i - w_a)}{1 - \frac{(w_i + w_a)}{2}}$$

Where,

VPD = (Air-to-Leaf-) Vapor-Pressure-Deficit [Pa/kPa],

wi = Intercellular H_2O mole fraction within the leaf [ppm],

wa = H_2O mole fraction in the cuvette [ppm].

iv) Photosynthetic assimilation rate (A): According to Caemmerer and Farquhar (1981) the photosynthetic assimilation rate (A) is calculated as follows:

$$A = \frac{u_e * (c_e - c_o)}{LA} - (E * c_o)$$

Where,

A = assimilation rate [µmol m^{-2} s^{-1}],

u_e = molar flow rate at the inlet of the cuvette [µmol s^{-1}],

c_o = CO_2 mole fraction at the outlet of the cuvette [ppm],

c_e = CO_2 mole fraction at the inlet of the cuvette [ppm].

LA = leaf area [cm^2],

E = transpiration rate [mmol m^{-2} s^{-1}]

Light compensation point and light saturation point

Photosynthetic CO_2 assimilation increases along with the increase in photon flux until it equals CO_2 release by mitochondrial respiration. The point at which CO_2 uptake equilibrate with CO_2 release is called as the light compensation point. Above this point, an increasing photon flux results in a proportional increase in photosynthetic rate, characterized by a linear association between photon flux and photosynthetic rate. Under such conditions, photosynthesis is light limited, which means more the light is incident the more photosynthesis takes place. In this linear portion of the curve, the slope of the line reveals the maximum quantum yield of photosynthesis for a leaf. The photosynthetic response reaches saturation at higher photon fluxes, after which there is no longer affect on photosynthetic rates irrespective of further increase in photon flux, results in photosynthesis limit. Photosynthesis is referred to as CO_2 limited after the saturation point due to inefficient utilization of absorbed light energy. Therefore, understanding of light compensation point and light saturation point of different crops is a crucial study under climate change scenario.

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Rainfall Based Crop Planning in Rainfed Areas

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Introduction

Agricultural production in India is largely dependent on the performance of SW monsoon rainfall which contributes about 75% of the annual precipitation. Apart from its spatial and temporal variability, several climatic anomalies / extremes were found to influence the country's agricultural production. Rainfall, being considered as the prime input for agriculture has its own erratic behavior in terms of amount and distribution. Rainfall in much of the country is, on the other hand, often erratic and unreliable and can be considered as gamble; and resultant droughts due to negative departure of rainfall have historically been major causes of food shortages and famines (Bal and Minhas 2017). All facets of agricultural activity, whether it be the choice of crop rotations and cultural operations, seed bed preparation, harvest, post harvest operation, introduction of new crops in new areas, planning of plant protection measures are greatly influenced by climate. Rainfall is the major element that affects crop growth and development, particularly where rainfed farming is widely practiced. Comparison with other climatic parameters, data on rainfall are generally available for an extensive network. For better crop planning, a detailed study on rainfall behaviour is vital. Rainfall variability, both in time and space influences the agricultural productivity and sustainability of a region. Hence the chapter that follows is therefore confined mainly to methods of analysis of rainfall patterns, as these relate to crop planning. Simple criteria related to sequential phenomena like dry and wet spells can be used to obtain specific information needed for crop planning.

Status of rainfed agriculture in India

The term rainfed agriculture is used to describe farming practices that rely on rainfall for water. Rainfed agriculture occupies a prominent place in Indian economy and rural livelihoods. At present In India, about 60% of total net sown area is rainfed, contributing 40% of the total food production. Agriculture in rainfed areas continues to be a gamble as compared to irrigated areas. The crop production in rainfed region has inherent risks because rain is undependable in time and amount. The principal source of water for rainfed crops is rain, a major portion of which is received during the south-west monsoon period. The monsoon period is beset with breaks of rain in almost all parts of the country. Sudden “bursts” of rain alternated with "breaks" is common in rainfed areas. Normally, there are at least four important aberrations in the rainfall behavior, viz., i) early commencement of the rains, or considerably delayed monsoon, ii) intermittent “breaks” during the cropping season, iii) variation in spatial and/or temporal aberrations, and iv) early cessation of rainfall or continued wet spells for longer period. These situations call for attention of agricultural scientists and planners to develop contingent measures to save the rainfed crops from varied monsoon aberrations. Further, there is a need to select crops and varieties matching the effective growing seasons in different agro climatic regions of the country. The high variability of rainfall (more precisely, the soil-water) is the single factor which influences the high fluctuations in the crop yields. Drought leads to moisture stress, which in turn effects crop production adversely. IMD declares a year as All India Drought Year when the average annual rainfall of the current year falls below 10 percent of long-term mean annual rainfall and the area affected by drought conditions either moderate or severe or combined must be above 20 percent of the total geographical area of the country.

Deficit and poorly distributed rainfall induced drought-affecting productivity

Drought induced deficit in soil moisture restricts plant growth, both in terms of the total quantity of tissue produced and the time that the plant tissue is produced. Productivity of annual plants generally is reduced by drought more than that of perennial plants. Annuals are not as deeply rooted as perennial crops and therefore cannot tolerate the same degree of moisture deficit. This impact of deficit rainfall is reflected in the food grain production of a country (Fig.1).

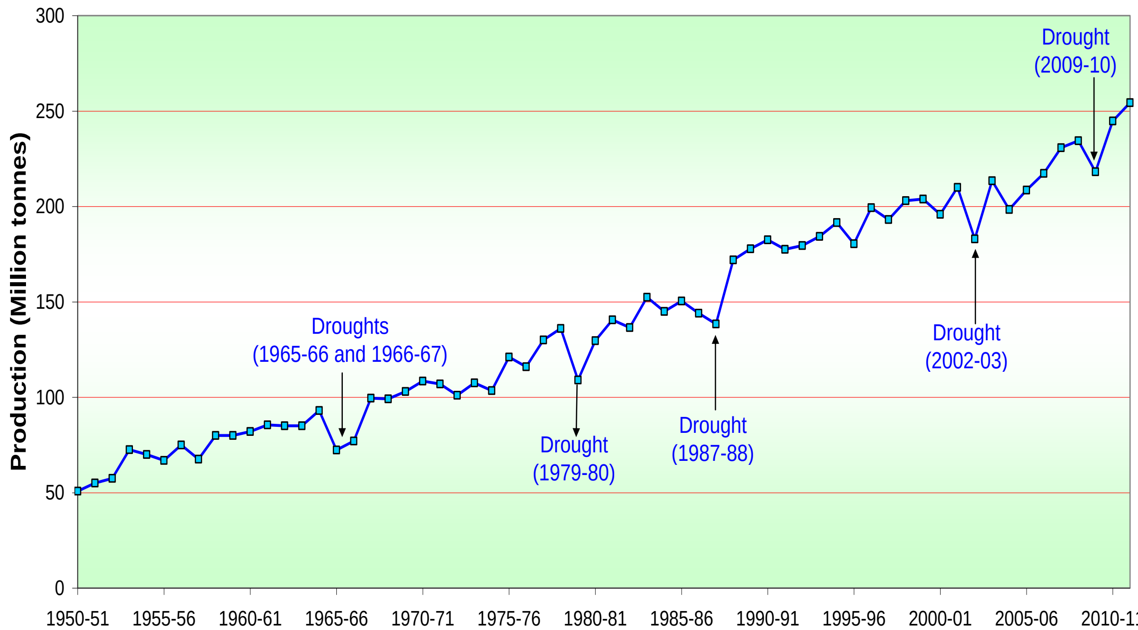

Fig.1: Food grain of production of India (1950-2011) as affected by drought

Importance of rainfall analysis for crop planning

Precipitation is considered to be a principal element in the semi-arid region. In most of the cases the crop-growing period coincides with the length of the humid period. But this period is subjected to great fluctuations. Thus the reliability of the duration and degree of humid period plays a vital role in agricultural development planning. To get the clear picture of the climate at a given place, normals or averages of long period data are taken into account. The average conditions are rarely found because of erratic behaviour of the precipitation. The average rainfall data gives simple understanding for a generalized application. Such type of information is not sufficient, when the data is applied to certain specific agricultural operations. e.g. the rainfall received at a particular station for a particular period gives only general picture regarding its sufficiency to meet crop requirements. But one is interested to know the persistency of specific amount of rainfall for a short period. Many agricultural operations revolve around the probability of receiving given amount of rainfall. Large scale operational planning often requires decision making with respect to resources, manpower needs, available workday and several other factors. The probabilities of rainfall can be used for a number of agricultural planning purposes, such as land use planning like:

- Field drying of hay
- Germination of seeds
- Disease susceptibility in periods of plant growth
- Application of fertilizer
- Application of insecticides
- Application of herbicides

Estimation of probabilities of expected rainfall

The knowledge of total rainfall, its intensity and distribution is important for efficient planning of cropping pattern. Incomplete gamma distribution can be used to predict the occurrence of rainy events of different probability for crop planning. For example, the probability of weekly rainfall greater than 30 mm is sufficient to grow crops like maize, mash, moong, bajra, arhar and soybean. There have been different techniques for determining probability distribution on rainfall analysis and best fit probability distribution function such as normal, log-normal, gumbel, weibull and Pearson type distribution have been identified as per different research studies. There are two types of probability: Initial probability and conditional. Both probabilities are computed using the long term historical data. Initial probabilities are computed without reference to the previous precipitation history (Mahi *et al*., 2001).

If a dry day is defined as one when the rainfall is less than 2.5 mm, then the probabilities can be associated with the event that specific day is dry. Conditional probability indicates the probability level at which a particular amount of rainfall is anticipated for a particular place over a specified time series data. Conditional probability is useful in predicting the receipt of particular quantity of rainfall for specific purposes based on historical data. Similarly conditional rainfall quantity can be fixed for various operations like weeding (10 mm), fertilizer application (15 mm) and plant protection (10 mm). Initial probability indicates the minimum quantity of rainfall to be expected for a particular time series data. Conditional rainfall probability (%) of getting > 20mm rainfall during next week also when there is rainfall of >20mm during this week (W/W) or there is rainfall of <20mm during this week (D/W). Similarly conditional rainfall probability (%) of getting < 20mm rainfall during next week also when there is rainfall of >20mm during this week (W/D) or there is rainfall of <20mm during this week (D/D).

Upadhaya and Singh (1998) stated that it is possible to predict rainfall fairly accurately using various probability distributions for certain returns periods although the rainfall has inconsistent nature both spatially and temporarily. Bhelawe *et al*., 2015 determined the probability of expected rainfall on monthly and weekly basis. They used the daily rainfall data of Raipur station, Chhattisgarh, India for the years (1971-2013). Rainfall at various probability levels (25, 50, 75 and 90 percent) for weekly, monthly, seasonal and annual basis has been worked out and are presented in Table 1.

Table 1: Monthly, seasonal and weekly expected rainfall amount (mm) at different probability levels at Raipur, India (Bhelawe *et al*., 2015)

Months	Probability Levels					Standard Met. Week (SMW)		Probability Levels			
	90%	75%	50%	25%				90%	75%	50%	25%
January	0	0	6	26		23	04 Jun.-10 Jun.	0	0	6	32
February	0	1	11	23		24	11 Jun.-17 Jun.	1	7	28	64
March	0	0	10	19		25	18 Jun.-24 Jun.	5	17	46	80
April	0	3	12	20		26	25 Jun.-01 Jul.	11	19	54	98
May	2	9	16	36		27	02 Jul.-08 Jul.	10	24	53	78
June	76	101	144	221		28	09 Jul.-15 Jul.	14	43	74	99
July	136	214	321	451		29	16 Jul-22 Jul.	17	38	58	111
August	160	228	349	457		30	23 Jul.-29 Jul.	6	23	60	95
September	62	100	192	232		31	30 Jul.-05 Aug.	10	35	62	110
October	1	14	34	68		32	06 Aug.-12 Aug.	16	36	71	104
November	0	0	0	16		33	13 Aug.-19 Aug.	9	27	77	126

December	0	0	0	4		34	20 Aug.- 26 Aug.	6	26	47	84
Seasons						35	27 Aug - 02 Sep.	4	23	56	93
Winter (Jan. - Feb.)	0	8	19	40		36	03 Sep.- 09 Sep.	3	22	45	82
Summer (Mar. - May)	16	25	40	70		37	10 Sep.- 16 Sep.	11	19	29	61
SW Monsoon (Jun.-Sept.)	702	795	1040	1207		38	17 Sep.- 23 Sep.	0	1	12	61
NE Monsoon (Oct.-Dec.)	8	23	52	120		39	24 Sep.- 30 Sep.	0	3	13	47

Rainfall pattern and crop success/failure

More than 70% area in India is under rainfed farming. The onset of monsoon determines the planting time and subsequent temporal distribution greatly influences the growth and development of the crop. Particularly in Indian region, *Kharif (rainy)* sowing starts in the month of early June in southern part and in the month of early July in northern part when monsoonal activity covers the whole country. The length of the *kharif (rainy)* growing season depends upon the withdrawal of the monsoon rainfall activity. Localized showers of short duration, rather than the long persistent drizzle type rain characteristics of the middle latitudes predominate during this period. Therefore success and failure of the cropping pattern especially in rainfed areas is thus closely linked with the rainfall pattern.

LGP (Length of Growing period)

The basic factor that decides the choice of crops in a given region is the Length of Growing period (LGP). The LGP, however, depends not only on the rainfall distribution but also on the soil type, depth and water holding capacity. The depth, therefore, is expressed as the sum of the length of the rainy season and the period for which the stores soil moisture meets the crop water need after the cessation of the rainy season. As per FAO (1996), LGP starts when $P > 0.5$ PET and ends with utilization of assumed quantum of stored soil moisture (100mm), after P falls below PET.

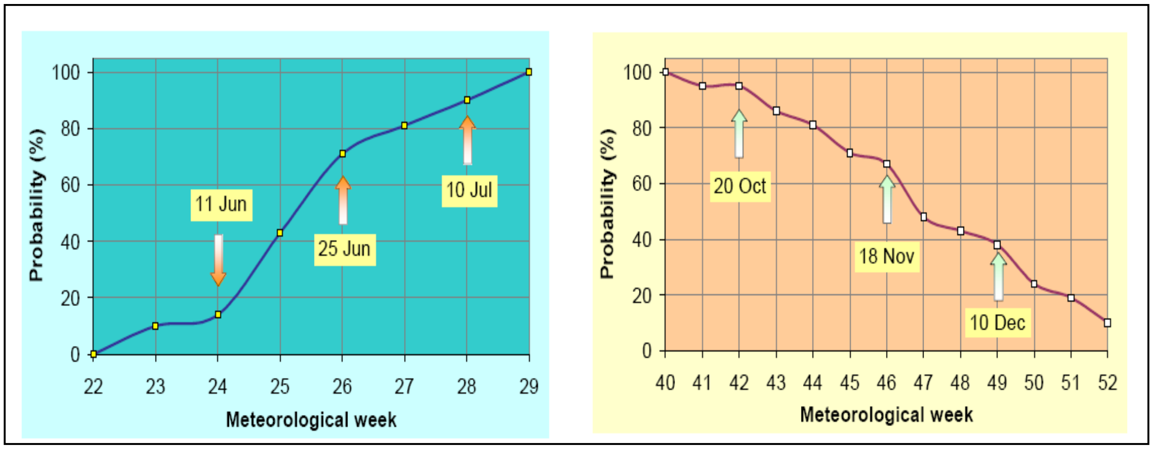

Fig.2: Variation in beginning and end of LGP at a place (Kesava Rao *et al*., 2013)

A long-term data analysis of LGP data by Kesava Rao *et al*., 2013 at Chhattisgarh, India LGP generally begins by 20th June and ends by 25 Nov (LGP, 160 days). In 3 out of 4 years, the season begins by 25 Jun and ends by 18 Nov. In 9 out of 19 years, it begins by 10 Jul and ends by 20 Oct. Therefore the assured length of season (LGP) is 21 weeks (145 days) beginning from 25 Jun and ending by 18 Nov (Fig. 2). The LGP of various crops given by FAO (1996) is given in Table 2.

Table 2: Length of Growing Period requirement of various crops

Crop	LGP (days)	Crop	LGP (days)
Alfalfa	100-365	Melon	120-160
Barley/Oats/ Wheat	120-150	Millet	105-140
Bean (green)	75-90	Onion, green	70-95
Bean (dry)	95-110	dry	150-210
Citrus	240-365	Pepper	120-210
Cotton	180-195	Rice	90-150
Grain/small	150-165	Sorghum	120-130
Lentil	150-170	Soybean	135-150
Maize, sweet	80-110	Squash	95-120
grain	125-180	Sunflower	125-130

Dhakar *et al*. (2013) studied the relationship between average LOS and average seasonal rainfall for the State over years 1982–2005, which is shown in Fig. 3a and the scatter plot between their anomalies (from their normal) is shown in Fig. 3b. A close correspondence is seen between LOS and rainfall in most of the years. The LOS decreased during drought years when less rainfall was received, like in 1987, 1991, 2002 and 2004. The Fig. 3b clearly shows that anomaly in LOS is directly related to anomaly in seasonal rainfall. The nature of relation between the two is linear with a R^2 value of 0.41 which is significant at 99% confidence level. The relation implies that, on an average the length of season decreases by about 7 days for each 100 mm seasonal rainfall deficit.

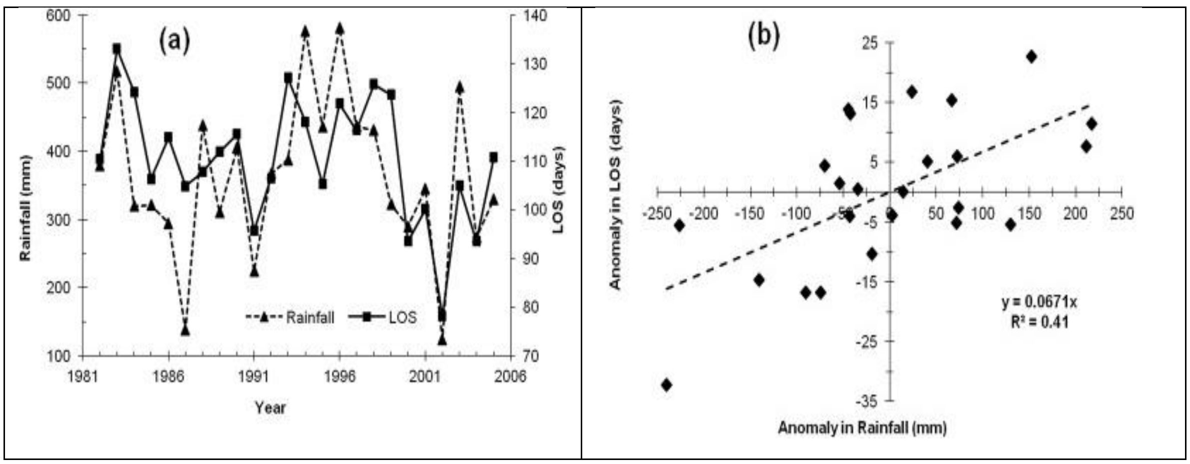

Fig.3: Relationship between length of season (LOS) and rainfall as (a) temporal pattern and (b) scatter plot of their anomalies with regression line (Dhakar *et al*., 2013)

Agro-climatic Characterization of the place

MAI (Moisture Availability Index)- Hargreaves (1971) considered the ratio of dependable rainfall (75% probability rainfall) to the PET and defined it as Moisture Availability Index (MAI). According to this concept, the LGP is the period when MAI is more than 0.33. This method has the limitation because of non-considering the soil characteristics. However, the method given by Thornthwaite and Mather (1955) enables the estimation of the period of adequate moisture availability (IMA) (Table 3). Based on the IMA values, the periods of water availability can be classified. In this way the climate type of the place can be delineated (Ramakrishna *et al*., 2006).

Table 3: Climatic classification based on period of adequate moisture availability

IMA (AET / PET)	Type of water availability
0.00 - 0.24	Dry
0.25 - 0.49	Semi-arid
0.50 - 0.74	Sub-moist
0.75 - 0.99	Moist
1.00 and above	Humid

The Studies on drought using the probabilities of dry spell runs can be done to see whether the place is prone to drought or not, if so then should be quantified. For eg. in Telangana state of India, is prone to drought conditions with a probability of more than 60% dry days (rainfall less than 4 mm/day) during the southwest monsoon season. Thus, it has to be clearly demarcated that which areas are highly prone to drought in the region. It was also found that nature of drought occurrence is different for the north, central, and southern regions. After the onset of monsoon rainfall in June, preceded by few pre-monsoon thunderstorms, the area experiences frequent drought conditions in late July and August. The rainfall again increases in September and October at the end of SW monsoon season. Occasionally storms crossing the east coast of India south of 15 ^{o}N during October and November bring intense showers. July has highest number of rainy days in all districts. The next highest number of rainy days is in August but the total amount of rain received is lower than September. This is particularly the characteristics of the southern districts of Telangana.

Analysis of extreme water balance

Thornthwaite (1948) introduced the concept of water balance in which the PET indicates the evaporative demand of the atmosphere and is considered as the expenditure while rainfall (P) is considered as income. A balance between these two parameters considering the maximum water holding capacity of the soil provides information on the status of water at a given period of time, which can be either deficit or surplus. Since rainy season is confined to 3-6 months period in various zones of the country, water deficit and water surplus can occur within the same year depending on the distribution of rainfall. Kesava Rao *et al*., 2013 reported similar work one for dry and other for wet year for Nalgonda district of Telengana India (Fig. 4). The concept of water balance has been extensively used by various researchers in agro-climatological studies to work out the water availability periods, length of growing period (LGP), agricultural drought, irrigation scheduling etc.

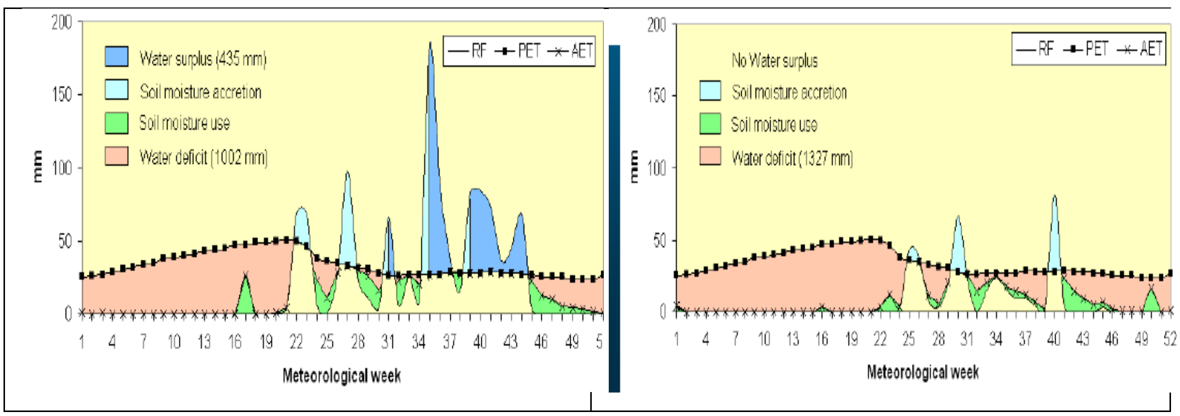

Fig.4: Extreme water balance of Nalgonda, Telangana, India (a) Wet year (b) Dry year (Kesava Rao *et al*., 2013)

Soil and cropping conditions

For eg., red and black soils predominate in the region of Telangana state of India. In red soils crops arc affected by low moisture retention and in black soil crops suffer more due to compaction, resulting in poor growth and root penetration. The most widely grown traditional crops in Telangana are sorghum, maize, gram, groundnut etc. some of which even take as long as 200 to 240 days to mature. In areas where supplemental irrigation is available, rice and tobaccos are also cultivated. However, tanks and reservoirs get filled only by rains, and the fate of the rice crop is closely linked to the rainfall pattern. Discussing water-harvesting techniques, Swaminathan *et al*. (1969) have pointed that if enough water could be stored from rains occurring early in the season to provide one or two irrigations during the drought period, a single, long-duration crop could be replaced by two short-duration crops. The development of photo-insensitive, short-duration varieties in rainfall regions of 800-850 mm with random dry spells.

Crop water requirement

Before going for decision making to choose crops for a place after knowing the climatic type of the place, agroclimatic characteristics, rainfall history, probability of minimum assured rainfall, soil properties etc. the next step is to choose a crop with respect to its water requirement given in Fig.5, Brauman *et al*., 2013).

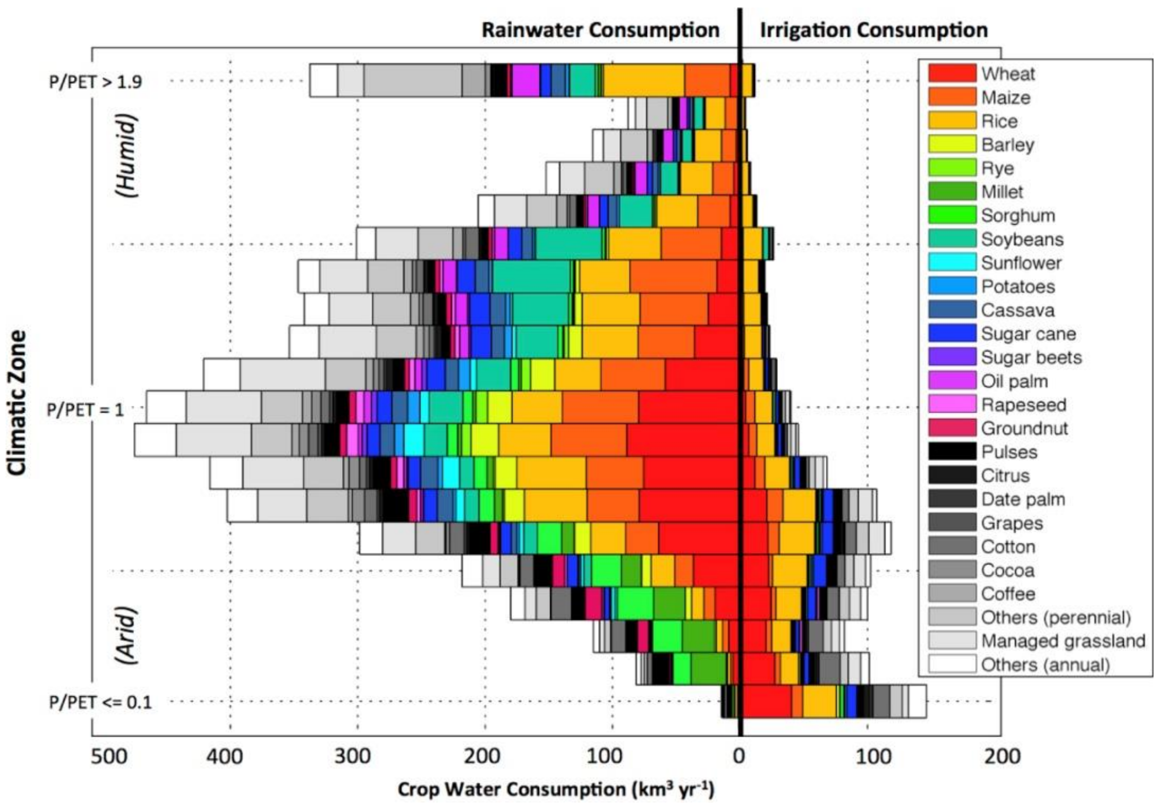

Fig.5: Crop water consumption of various crop types in different climatic conditions (Brauman *et al*., 2013)

Interactive effect of thermal and moisture regimes: A case study of Anantapur

A study was carried out by Rao *et al*., 2011 to know the impact of climatic type, increasing temperature and rainfall variability on groundnut productivity. The groundnut crop at Anantapur district experiences mostly arid conditions that occasionally move towards semi-arid. The analysis on the impact of moisture and thermal regimes on groundnut productivity in Anantapur district is presented in the Tables 4 and 5.

Table 4 : Effect of rainfall variability on average yield of groundnut irrespective of thermal regime

Scenario	Average yield of groundnut (kg/ha)	% change in yield with respect to normal season
Decrease in seasonal rainfall by 10 % or more	905	- 23.1
Seasonal rainfall in the range of ±10 % above normal	1177	0.0
Seasonal rainfall in excess by >10 % above normal	1286	+ 9.3

Table 5: Effect of seasonal temperature on yield of groundnut irrespective of rainfall regime

Seasonal mean daily temperature (ºC)	Average yield of groundnut	Percent decrease in yield due to increase in temperature
< 27.0	1366	-
27.0 - 28.0	1048	23.3
> 28.0	827	39.5

It is evident from the Table 4 that in the years when the seasonal rainfall was 10 per cent less than the normal the yields were reduced drastically by 23.1 per cent. However, during the excess rainfall years also the yields decreased may be due to the failure on the part of the farmers to capitalize on the good rainfall and not adopting proper technology and management practices to reap good yields. The effect of mean daily temperature during the growing season on average productivity of groundnut irrespective of rainfall regimes is shown in Table 5. The average productivity of groundnut during the seasons with mean temperature <27.0 °C was observed to be 1366 kg/ha. During the seasons with mean temperature between 27-28 °C, the average yields were 1048 kg/ha resulting in decline in yield by 23.3 per cent. However, during the seasons with mean temperature >28 °C, the average productivity was 827 kg/ha thereby showing a decline in productivity by 39.5 per cent. So the yields of groundnut have shown a decreasing tendency with increase in mean daily temperature during the growing season. The individual effects of rainfall regime and thermal regime on groundnut productivity were examined considering different scenarios. The crop productivity was found to increase from deficit seasonal rainfall scenario to good rainfall scenario. There was a decrease in productivity with increase in seasonal mean, maximum and minimum temperatures irrespective of the moisture regime.

Choice of crops and cropping systems

The choice of crops grown under rainfed conditions depend upon length of humid period during the crop growing period. In arid region, where rainfall is above 300 mm, the length of humid period is about 1-4 weeks. Short duration drought resistant pulses like green gram, cowpea and cereals of 10-12 weeks durations like pearl millets and minor millets are suitable. In semi-arid regions, where the length of the humid period is around 6 weeks, rainy season crops are grown in soils that have a capacity to hold less than 150 mm of water. Additional post-rainy season crops can be grown on conserved soil moisture, in soils that can hold more than 200 mm. In soils with 150-200 mm capacity, intercropping is possible. In sub-humid areas, where humid period is more than 12 weeks duration and rainfall is twice that of PET, paddy base cropping system is suitable, as other crops cannot tolerate water stagnation. Selection of cropping systems based on LGP can be undertaken as described in Table 6.

Table 6: Selection of cropping systems based on LGP

Length of growing period	Cropping systems that can be adopted
< 75 days	Monocropping - short duration pulses
75-140 days	Monocropping
140-180 days	Intercropping
> 180 days	Double cropping

The choice of base and intercrop can be decided on the distribution of rainfall. In regions with uni-modal rainfall pattern and shallow soils. the base crop should be of shorter duration and the companion could be of longer duration. In case of medium to deep soils, the base crop should be of longer duration while the companion crop can be of shorter duration. In bi-modal distribution, the choice of the crops should be such that the peak growth period of the base and companion crop coincides with prominent rainfall peaks. In long term, under aberrant rainfall scenarios and variable climatic and edaphic environments, to achieve stability in crop production he choice of cropping system is utmost important. In this scenario, a systematic evaluation of crops and cropping systems based on the land capability classes needs to be carried out. A matrix of possible land uses as influenced by resource carrying capacity (land capability class and mean annual rainfall) can be taken as an example (CRIDA Perspective Plan, Vision 2020)

Management and contingency plan for coping with deficit rain in rainfed areas

Targeted research cum adaptation and mitigation of extreme events is at beginning stage and based on the information already generated, these strategies can be broadly categorized into (a) crop based; (b) resource management based and (c) early warning systems.

Crop based approaches: These approaches encompass growing crops and varieties that fit into changed rainfall patterns, use of varieties with changed duration, tolerance for heat stress, drought and submergence. Additionally, varieties with high fertilizer and radiation use efficiency and new crops and varieties that can tolerate coastal salinity and sea water inundation are to be identified / evolved. Inter-cropping is a proven practice of insurance against crop failures due to droughts and facilitates minimum assured returns.

Resource management based approaches: Resource management strategies include *in-situ* moisture conservation, rainwater harvesting and recycling, efficient use of irrigation water, conservation agriculture, energy efficiency in agriculture and use of poor quality water. Watershed management is now considered an accepted strategy for development of rainfed agriculture.

Early warning systems: Observation and measurement of meteorological parameters with sufficient density in time and space has led to development of monitoring and forecasting systems with sufficient lead period in India. Successful predictions by IMD on the movement of tropical cyclones has resulted in the minimization of human and agricultural losses. Much progress has been made on the agrometeorology front in identification of areas prone to drought, floods, heat and cold waves, frost and hailstorms. Use of remote sensing techniques, crop modelling and GIS are making a head way to gain adequate insights on the crop responses to extreme weather and delineating regions that are likely to get affected.

Summary

It is evident that successful crop planning depends on the extent to which one can establish quantitative relationships between climate and crop varietal characteristics. But if the input data are qualitative, consisting of figures based on the number of simplifying assumptions or smoothed-out averages, one can estimate the general behaviour of crop growth under a given general climate. This gives no explanation for the abnormal behavior of crop growth in any season and for each variety, which is frequently observed in areas with low rainfall and high variability. Also, under these Circumstances, events which have practical significance under field conditions may not be always statistically significant. This is particularly true of crop-weather relationships, since it is difficult to assess accurately both the response of crops and their internal adjustments to the different soil and climatic conditions.

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Challenges and Coping Strategies in Agriculture: Atmospheric Stress Perspectives

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Introduction

Agriculture is critical to development since the majority of the world's poorest and hungry people depend on it for their livelihoods. However, agriculture in turn depends on basic natural resources: biodiversity, soil, and water and the environmental factors. In spite large scale development of soil, water and crop based technologies to optimize and sustain crop productivity in the recent past, the latter continues to be affected significantly by number of climate variability factors. These factors like temperature, relative humidity, light, availability of water, mineral nutrients, CO_2, wind, ionizing radiation, or pollutants determine plant growth and development (20). Effect of each atmospheric factor on the plant depends on their intensity and duration of act. For optimal growth, the plant requires a certain quantity of each of the environmental factors and any deviation from such optimal conditions, adversely affects its productivity through plant growth and development. These stress factors include extreme temperatures, too high or too low irradiation, extreme of water that induce drought or waterlogging etc. Some of these are induced as a result of recurring features of climate variability e.g. cold/heat waves, floods/heavy rain, cyclones/tidal waves, hail/thunder storms etc. and these critical environmental threats are often referred as extreme weather events.

As climate change has become a reality, the implications of global warming for changes in extreme weather and climate events are of major concern for agrarian as well as civic society. However, since extreme events are typically rare events, therefore only limited observational data are available for their impacts. Over the last couple of years we experienced typical events i.e., Kuwait reporting snow, USA devastated by Hurricane Katrina and Paris sweltering in 40^0C heat, Mumbai sunk under 940 mm of heavy rainfall in a single day, Delhi froze with below 0°C, Rajasthan had floods twice in a year, across pan India there were unprecedented hailstorm events and many more. The year 2016 will stand out in the historical record of the global climate in many ways. The average global temperature across land and ocean surface areas for 2016 was 0.90°C above the 20th century average. This marks the fifth time in the 21st century a new record high annual temperature has been set and also marks the 40th consecutive year (since 1977) that the annual temperature has been above the 20th century average. Heatwaves were extremely intense in various part of the world including India and Pakistan leading to thousands of deaths. Similarly, extreme precipitation led to flooding that affected areas across Asia, South America, West Africa, Europe; and dry conditions in southern Africa and Brazil which exacerbated multi-year droughts. These events have signalled and forced us to accept the unusual change in the behaviour within our atmospheric. Global food production is gradually increasing but the relative rate of increase especially for major cereal crops is declining. In these circumstances, what makes climate smart agriculture more important is ever increasing demand for food, issues with climatic variability which makes farming more vulnerable to vagaries of nature.

Changes in atmospheric composition: its effect on climate and extreme events

Since the industrial revolution, atmospheric concentrations of various greenhouse gases have been rising due to anthropogenic activities. In 2011, the concentrations of three key greenhouse gases, *viz.*, carbon dioxide, methane and nitrous oxide were 391 ppm, 1803 ppb, and 324 ppb exceeded the pre-industrial levels by about 40%, 150%, and 20%, respectively. It is evident from scientific reports that global warming is most probably due to the man-made increases in greenhouse gas emissions, which ratifies the discernible human influence on the global climate. Emissions from fossil fuels, industry and land-use change have increased greenhouse gas concentrations and led to almost 1°C rise in global mean temperature on pre-industrial levels and also influenced the patterns and amounts of precipitation, reduced ice and snow cover, as well as permafrost, raised sea level, increased acidity of the oceans, increased the frequency, intensity, and/or duration of extreme events and shifted ecosystem characteristics.

While natural variability continues to play a key role in extreme weather, climate change has shifted the odds and changed the natural limits, making certain types of extreme weather especially cold wave, frost, hailstorm, thunderstorm, dust storm, heat wave, cyclone, flood more frequent and more intense. However, year to year deviations in the weather and occurrence of climatic anomalies / extremes such as etc have become a matter of concern. As the climate has warmed, some of the extreme weather events have become more frequent and severe in recent decades. Heat waves are longer and hotter and likely that has more than doubled the probability of occurrence of heat waves in some locations. Heavy rains and flooding are more frequent. Patterns of precipitation and storm events, including both rain and snowfall are also likely to change. Besides these hailstorm has widened its horizon. In recent years, weather events especially deadly heat waves and devastating floods have necessitated in understanding the role of global warming in driving these extreme events. All weather events are now influenced by climate change because all weather now develops in a different environment than before.

Impact of Atmospheric Stresses on Agriculture

The agricultural commodities include field crops, horticultural crops, livestock, poultry and fisheries. The basic principle of agriculture lies with how crop/livestock interacts with atmosphere and soil/food as a growing medium. The system acts as path-way which regulates the intake of water/feed, nutrients and gas exchanges. Thus any change in the quality and quantity of atmospheric variables will certainly affect the pathway through changes in atmospheric and edaphic/feed factors. Besides these, climate change is also adding salt to the wound by aggravating the extreme weather events. Agriculture production is sensitive to temperature, increasing carbon dioxide concentration as well as change in precipitation. Impacts of all these forces together imply that agriculture production will respond non-linearly to future climate change. The impacts are complex to understand as it involves both physical and physiological interactions. In quantitative and qualitative terms, effect of aberrant changes in atmospheric variables on agriculture can be conjectured and most of them are estimated to be negative. The impact may be of direct (mechanical) or indirect (physiological) depending on the type of stress, type of crop, stage of crop and mode of action of the stress on the commodity. Thus the likely effect of climate change on crop production adds to the already complex problem as yield in some of the most productive regions of the world are approaching a plateau or even declining.

Management Strategies and way forward

Global climate change will have significant impacts on future agriculture and therefore climate change mitigation for agriculture is a global challenge. In a country like India, one of the most vulnerable countries owing to its large agricultural sector, vast population, rich biodiversity, long coastline, and high poverty levels will be severely affected by climate change if new strategies for amelioration are not devised. For this a thorough understanding is required for various physical, physiological, metabolic and biochemical processes that occurs in normal as well as stresses environments so as to form the basis for developing climate smart mitigation strategies. Nevertheless, plant and livestock responses to high temperatures clearly depend on genotypic parameters, as certain genotypes are more tolerant. Though plants adapt to various stresses by developing more appropriate morphological, physiological, and biochemical characteristics, analysing plant phenology in response to heat stress often gives a better understanding of the plant response and facilitates further molecular characterization of the tolerance traits. As far as atmospheric stresses are concerned, a complete insight of the biological processes behind the atmospheric stress response combined with classical and emerging technologies in production, breeding and protection engineering is likely to make a significant contribution to improved productivity and reduction in losses. The following section contains some of the adaptation and management options available to mitigate those atmospheric stresses.

Since unusual atmospheric events are becoming usual events, to make future agriculture remunerative, risk free and sustainable; at first the dynamic characteristics of atmospheric stressors have to be understood. The scientific community must respond to the need of credible, objective, and innovative scientific alternatives to tackle these impacts. There are, however, ways by which the adverse impacts can be mitigated and agriculture can be adapted to changing scenarios. The first step is to form integrated inter-disciplinary research partnerships as atmospheric stressors' already poses and will continue to pose challenges for agriculture and managed ecosystems.

As every year is becoming warmer than the previous year and unprecedented heat or cold wave conditions have become a common phenomenon, adaptation and mitigation options have to be explored either using field management practices or by applying genetic improvement tools for developing tolerant varieties. Use of chemicals like plant bio-regulators and growth hormones having minimal or no residual effects, rescheduling of sowing / planting periods need to be explored through systematic field experimentation. Regular events like extreme rain and hailstorm have necessitated focusing on developing protective structures. Especially research on designing low cost shade-net or poly structures for high value horticultural crops is the need of the hour as horticultural production in India has already surpassed the food grain production. Stresses arising out of increased atmospheric aerosol and decrease in available light needs extra attention as change in land-use pattern and crop residue burning has changed the way we have been dealing these aspects in the past. Lastly abrupt changes in the magnitude and periodicity of atmospheric variables will have impact on distribution of disease vectors and pest dynamics which needs extra attention.

With unprecedented increase in demand for animal proteins, our prime focus must be towards developing low cost environment suitable animal shelter structures for improved animal production and wellness. Future research in livestock must be done keeping a balance between competition for natural resources and projected atmospheric anomalies as unlike crop production where there will be a vertical growth, livestock production is expected to have a horizontal growth. A large agenda of work still remains concerning the robust prediction of animal growth, body composition, feed requirement and waste output in future climate. To cater the target for lowering the emission level, interdisciplinary research approach must be undertaken to lower the methane emission from animal sector. Lastly the use of biotechnology can't be ignored if we want to impart heat tolerant traits in high meat and milk yielding breeds.

Though the country has achieved food grain security for entire population, we are yet to solve the problem of poor nutrition, especially protein and mineral associated health issues in lower income groups. As poultry meat is the cheapest source of proteins, this sector has potential to provide food and livelihood securities to major chunk of Indian population. With emergence of heat stress as one of the major problem in Indian poultry industry, our primary area of focus should be to explore innovative approaches, including genetic marker assisted selection of poultry breeds for increased heat tolerance and disease resistance for better productivity. Application of modern molecular techniques in poultry breeding has great potential to improve poultry productivity in a sustainable manner. Simultaneously, the possibilities of heat stress mitigation must be explored in terms of microclimate modification including designing of suitable poultry housing for hot regions. Nutrition being one of the major factors in mitigating heat stress, study of the nutrient supplementation and feeding practices should be given priority.

Future research on fisheries must be oriented to understand the implications of greenhouse gas emission induced sea acidification on fisheries ecosystem productivity and habitat quality and quantity especially on habitat of phytoplankton. Secondly, biotechnological intervention in terms of identification of heat and hypoxia tolerance traits in fish, identifying the molecular pathways affected by atmospheric stress and marker assistant selection of fast growing and tolerant species through transcriptomic and proteomic studies.

Though a lot of scientific advances have been made related to understanding of physical and physiological aspect of various atmospheric stressors, much work remains to be done regarding quantifying its impacts and long term implications on agriculture. Thus only option left before us is to fight it in our own way. Firstly before doing so, the types and level of stresses must be properly quantified for future references. Secondly researches on finding mitigation and adaptation measures need to be scientifically planned so as to make it economically viable. By doing so, tackling the implications can be successfully adopted by growers to make future agriculture economically sustainable and less risky against atmospheric anomalies.

Canopy Temperature: Useful Traits for Selecting Drought Tolerent Crops

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We need drought tolerant crops as more than 68% of the cultivated area in India experience drought, though the time of occurrence and intensity vary widely depending on rains. The crops can be called drought tolerant if they can withstand soil moisture deficit during their growth and can provide more yield than the intolerant cultivars. Such crops are featured by inherent traits to avoid adverse effect of water stress. One of the mechanisms is to keep their canopy cool by efficiently taking up water from the deeper layers of soil during water stress. They keep their canopy cool because of a process called transpiration that involves release of water vapour from specialized pores called stomata. Thus plants capacity to avoid drought effect can be determined by their canopy temperatures. Canopy temperature is a genetically controlled physiological property of plant species. The surface temperature of the canopy is related to the amount of transpiration resulting in evaporative cooling. IR based thermometer/ camera allows canopy temperature (CT) to be directly and easily measured remotely and without interfering with the crop. It is well documented that CT is correlated with many physiological factors like plant water status, stomatal conductance, transpiration rate, crop yield etc.

CT is an integrative measurement (i.e., scoring the entire canopy of many plants within a plot), and so has advantages over other methods used for stress detection, such as stomatal conductance and water potential, because it integrates a larger area of plant/ crop measurement, is non-destructive, does not interfere with stomata (which are sensitive), and is faster and not laborious. However, trait expression shows interaction with both developmental phase and time of day (e.g., pre-heading and/or morning readings are usually lower due to lower incident solar radiation and air temperature), which can be used to relate different canopy traits and stress tolerances.

Infra-red thermometry or IR thermography measures temperature of the target by measuring the radiant thermal energy emitted by the target. Infrared is a type of electromagnetic radiation, which is emitted, to greater or lesser degree, by all objects that have temperature. IR spectral region of 8 to 13 μm is typically used for thermal remote sensing.

Interpretation of canopy temperature

Genotypes with 'cooler' canopy temperatures can be used as indicator of better hydration status. It is used for stress diagnostic and breeding selection of stress adapted genotypes: (i) under drought conditions it is related to the capacity to extract water from deeper soil profiles and/or agronomic water use efficiency (WUE); (ii) under irrigated conditions it may indicate photosynthetic capacity, sink strength and/or vascular capacity –depending on the genetic background, environment and developmental stage; and (iii) under heat stress conditions it is related to vascular capacity, cooling mechanism and heat adaptation.

How to measure canopy temperature

Many of the instruments used for measuring canopy temperature of crop plants are based on emission of infrared radiation. Hand held infrared thermometers and Infrared Imaging systems are often used for this purpose. Thermal imaging allows precise measurement under changing environment. In addition, large number of plots in field trials can be imaged at the same time. However, it is non-destructive (without interfering the crop), faster and non –laborious method. Imaging sensor calibration and atmospheric correction are often required for high efficiency. The challenge it to separate the background for e.g. soil temperature from canopy temperature for better differentiation of plants responses to soil moisture deficit which are being addressed by scientists.

With these advanced technologies, identification of drought tolerant crop plant is likely to be faster as compared to conventional methods. This can help us in identifying those genotypes of plant which can keep their canopy cool by extracting water from deeper layers of soil during drought. This type of crops can be proposed for medium to deep black soil, which supports plant growth by holding moisture at deeper zone. Other type of plants save water by closing stomata those results in warmer canopy, but plant can maintain desired water content for physiological activities. Such type of mechanisms is suitable for type of soil which is not deep and cannot hold sufficient moisture. These mechanisms can avoid desiccation for a short period and can perform better after resumption of rains following the drought. These types of mechanisms in plant can also be explored to save water required for irrigation. Thermal imaging can identify both the types of plants for improving drought adaptability in crops.

Factors influencing the canopy temperature

- Stomatal features: shape, size and structure of stomata.
- Leaf Characters: Number and orientation of leaves, presence of cuticle and waxiness on leaf lamina and stem
- Plant water status: Water content of plant/leaf in relation to that required for optimal growth.
- Crop Yield- high photosynthesis
- Emissivity of objects.
- **Time of day:** Measurements typically from 11:00h to 14:00h, Avoid cloudy and rainy days.
- **Environment condition:**Measurements must be in clear sky and there is little or no wind. The plant surfaces are dry and not wet from dew, irrigation or rain.
- **Plant phonological stage:** Stage should be objective based and interval should be roughly 5-7 days between each measurement– to give a reasonably heritable estimate of trait expression.

  Always take measurements of the part of the plot which is most exposed to the sun, and ensure to avoid the shadow of the operator and/or shadows from the neighbouring plots.

Image capturing process in Variocam HR inspect 575

- Press the button AL. The thermographic system automatically focuses and the temperature scaling of the false-colour image is automatically optimised according to the current scene. Or Adjust the view mannualy to focus the object.

- In the live mode, joystick movements ↑, ↓ change the selected temperature level and joystick movements ←, → change the selected temperature range.
- Pressing the Enter button switches between the live mode and the focus mode.
- In the focus mode, joystick movements ↑, ↓ focus over larger or shorter distances to the object.
- For Storage of the thermal image press the S button. The live image freezes, i.e. camera goes into stop mode. Pressing the S button again saves the thermal image on the SD card. Pressung the C button interrupts the saving process. The camera will return to the live mode after the saving process.
- For switch off press button CL, the dialogue for switching off is selected and confirmed by pressing Enter.

Image processing

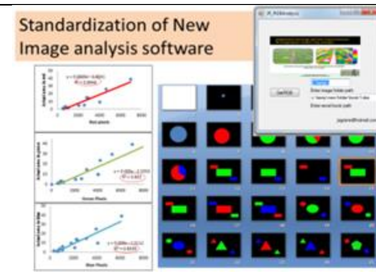
- From menu "File", select submenu "Open file" and open the desired thermograms (*.irb files).
- Select the desired colour palette via the "Scale", which is located on the right-hand of the thermogram.
- Via menu "View", you can display further image elements, measurement data, annotations and parameters in addition to the thermogram.
- By pressing the right mouse key on the colour scale, the dialogue "Level/Range", where the temperature level and range can be adjusted as desired by moving the scroll bar. The adjustment is also adopted for subsequent thermal images.
- With the help of the respective functional buttons on the symbol bar, points of measurement, areas, etc. as well as the display of temperature maximum and minimum can be activated.
- For inserting the analysed thermal images into your reports, select the menu "Report".

Prototype of tools for image based phenotyping

Taking into consideration the need to accelerate phenotyping in field efforts have been made to develop phenotyping tools. A hand operated track mounted trolley was designed for imaging purpose which hosts a camera and a Lap Top PC. The system acquires images of each plot in the experimental field after recognising the barcode. Images are stored with plot name. Tools have also been developed to rapidly analyse these images. Promising results have been obtained with image acquisition and analysis tool. This field based, semi-automated platforms potentially allow high-throughput phenotyping at a low cost.

a

b



c

Prototypes to screen genotypes in field (a) pot culture (b) tools for rapid analysis of images (c)

IR thermometer Vs Thermal camera

- A IR thermometer gives number whereas, thermal imaging cameras generate an image.
- A IR thermometer reads the temperature of one single spot whereas, a thermal imaging camera gives you temperature readings for each pixel of the entire thermal image.
- Because of advanced optics, thermal imaging cameras can also resolve temperatures from a longer distance. This allows you to quickly inspect large areas.

Limitations of thermal imaging:

- Thermal cameras are more expensive and It is greatly Influenced by being around any object and environment hence, necessitating the use of reference.
- Imaging sensor calibration and atmospheric correction are often required for high efficiency.

Addressing Nitrogen stress through smart variable rate N application in rice and wheat crops

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Introduction

Among all the yield limiting abiotic stresses, Nitrogen (N) is regarded as the most affecting stress along with the moisture stress in field crops. Though all the nutrient stresses affecting crop yield should be addressed through synchronising the crop nutrient demand for enhancing crop yields; assessing the exact crop nutrient demand has been tricky owing to variable nature of its growth environment. Among soil nutrients the spatial and temporal crop availability of N which affects crop yields significantly, is highly variable. Nitrogen is typically taken up in larger amounts than other nutrients and is the most common, and most important, limiting nutrient for non-legume agricultural crops. Not only does N nutrition affect yield, but it also affects the quality (protein or sugar content) of crops such as grain and sugar beets, for example. Plants absorb nitrogen as a mineral nutrient mainly from soil, and it can be may come in the form of ammonium ($NH4+$) and nitrate ($NO3-$). However, soil N supply is often limited, which forces farmers to increase the amount of N fertilizers in order to achieve better crop yield. However, farmers may provoke nitrogen over-fertilization, which hinders optimum plant productivity, as plants are not able to absorb the excess of N-fertilizer. This entails unnecessary expenditure on the part of farmers. Nitrate leaching, soil denitrification, and volatization are the main processes for N-fertilizer excess loss, contributing to environmental pollution. Nitrate leaching contaminates groundwater and other bodies of water, which may contribute to eutrophization. In addition, volatized N contributes to global warming by releasing nitrous oxides (i.e., NO, N_2O), which are considered greenhouse gases. Most of the crop plants generally require nitrogen throughout their growth period. Irrespective of the crop, all plants tend to grow at a slow pace in the beginning, rapidly in the "grand growth period" (the period at which elongation of cells, tissues and formation of organs take place) and again slow during maturity. Accordingly, nitrogen is also taken up by the plants in keeping with the pace of plant growth.

Therefore use of nitrogenous fertilizers should be so timed as to ensure its supply to the plant throughout its growth period especially during grand growth period. Nitrogenous fertilizers are very soluble in water, therefore liable to be leached. As such it is necessary to apply nitrogenous fertilizers in split doses of two-four, depending on the type of soil and the duration of the crop. When the fertilizer is applied at sowing time, it is called basal dressing; and the dose applied in standing crop is called top dressing. Plants require phosphorus mainly during the early root development and early growth period. Besides, almost all phosphatic fertilizers release phosphorus very slowly to the plant growth unlike nitrogenous fertilizers. They are, therefore, applied only at the time of sowing i.e. basal dressing. Having discussed the importance of split application of nitrogen as compared to single application of phosphorous and potash, the ways to optimize the nitrogen application holds relevance.

Nitrogen Management

Nitrogen fertilization rate is the most important N management decision regarding potential to achieve optimum crop yield, influence nitrate loss to water systems, and return maximum economic profitability. The first step to do this would be to know the status of Nitrogen in growing medium (for basal dose application) or the plant (for top dressing of Nitrogen). Soil nutrient testing is a management tool that can help accurately determine the available nutrient status of soils and guide the efficient use of fertilizers. Having done the Soil nutrient analysis the deficient nutrients are addressed by applying corrective fertilizer dose. However this does not ensure that the Nitrogen demand of the crop will be satisfied by soil supply because of numerous channels of N loss and therefore supplying N in synchronous with the crop N demand remains the only way to increase nitrogen use efficiency. The crop N demand is reflected by the canopy NDVI values as established by several research done across globe. The invention of analog-based, pulse-modulated, two-band, active lighting sensors (Beck and Vyse, 1995) and the equivalent digitally based sensor (Stone *et al.*, 2003, 2005) have contributed to the potential use of these technologies for variable-rate application of N fertilizers. One of the more common reflectance indices used in agriculture is the normalized difference vegetation index (NDVI). The index is computed as (NIR – Red)/(NIR + Red), where

NIR is the fraction of emitted near-infrared radiation returned from the sensed area (reflectance) and Red is the fraction of emitted red radiation returned from the sensed area (reflectance). Work by Filella and Penuelas (1994) and Liu *et al*. (2004a) noted that red edge reflectance can be indicative of plant chlorophyll content and biomass. Kanke *et al*. (2011) reported that NDVI better detected differences in plant growth, especially at early growth stages, than red edge reflectance. Spectral measurements of plants correlated with numerous physiological and morphological factors affecting growth and yield. Because of the difficulty in accounting for all confounding factors, models for computing N fertilizer rates are generally empirical and plant species specific and do not account for environmental factors, particularly rainfall, and their interactions with plant growth factors.Biggs *et al*. (2002) proposed a reference strip, where fertilizer is applied at a sufficient rate such that crop yield reaches a response plateau, that would subsequently be used to manage N fertilization. He patented a concept to measure reflectance with an optical sensor of the strip and the adjacent field rate and calculated the N application rate based on the ratio of the two readings (Biggs *et al*., 2002). The sensors were mounted on a center pivot irrigation system and paired measurements were made on-the-go.

Researchers use linear or exponential models to describe the relationship between vegetative indices and plant yield. Linear relationships have been identified between yield and NDVI for corn (Diker *et al*., 2004), wheat (Nidumolu *et al*., 2008; Liu *et al*., 2004b), tomato (Solanum lycopersicum L.) (Bala *et al*., 2007), cotton lint (Gossypium hirsutum L.)(Plant *et al*., 2000), and barley (Hordeum vulgare L.)(Kancheva *et al*., 2007). Multiple linear regression was used for winter wheat (Salazar *et al*., 2006; Kumar *et al*., 1999). Exponential relationships were used for NDVI and yield in cotton lint (Plant *et al*., 2000), winter wheat (Enclona *et al*., 2004; Raun *et al*., 2005), spinach (Spinacia oleracea L.) (Jones *et al*., 2007), canola (Brassica napus L. var. napus) (Osborne, 2007), and corn (Raun *et al*., 2005). One model incorporated additional variables to account for other confounding factors such as the date of planting (Kumar *et al*., 1999). Raun *et al*. (2005) recognized that N algorithms should account for the independence of the crop response to additional N and potential maximum yield. As such, they must be measured individually. Because N is highly mobile (Khosla and Alley, 1999), the maximum potential crop yield is temporally and spatially (Girma *et al*., 2007) variable, and the amount N available from soil nitrification or denitrification varies greatly from year to year (Johnson and Raun, 2003). Furthermore, there is a strong agronomic basis for the argument that N algorithms must account for these factors by year and location. Any algorithm that combines the two without considering their independence will result in flawed recommendations (Raun *et al*., 2011).

Algorithms using other strategies, such as the sufficiency concept for recommending fertilizer N (Varvel *et al*., 2007), do not account for the temporal variability of these factors. An example of the sufficiency approach is work done by Varvel *et al*. (2007), which used normalized chlorophyll meter readings and relative or normalized yields to calculate N application rates. The use of a sufficiency index approach is appropriate for soil nutrients that are immobile, but models based on data averaged across years disregard the variability of yield responsiveness to N applied preplant and the yield response to unlimited N, both bound by the environment (year). As a result, the final N rate recommended is fixed to a sufficiency percentage determined from historical data and not tied to the yield level that would be achievable that year. Furthermore, the potential yield achievable is fundamental to calculating the total N demand for cereal crops in any crop year.

Lukina *et al*. (2001) proposed that the midseason N fertilizer required to maximize the grain yield for a specific season could be used to calculate the midseason N application rate. They proposed the following to predict the N application rate: $[(YP_{max} - YP_0)GN]/0.70$, where YP_{max} is the maximum potential yield, YP_0 is the potential yield with no additional fertilizer, GN is the predicted amount of total N in the grain, and 0.70 is the expected efficiency of the N fertilizer under ideal conditions. This method of determining in-season fertilizer need was shown to decrease large-area N rates while increasing wheat grain yields when each 1-m^2 area was sensed and fertilized independently. Later research by Raun *et al*. (2005) suggested that midseason N fertilizer rates be based on predicted yield potential and a response index. Their work showed that they could increase the N use efficiency by >15% in winter wheat, compared with conventional methods, at a 0.4-m^2 resolution.Ferguson *et al*. (2002) suggested that improved recommendation algorithms may often need to be combined with methods such as remote sensing to detect the crop N status at early, critical growth stages followed by carefully timed, spatially adjusted supplemental fertilization to achieve optimum N use efficiency. Later work by Noh *et al*. (2005) confirmed that it was technically feasible to design a machinery-mounted multispectral imaging sensor to reliably and accurately detect crop N stress.

Zillmann *et al*. (2006) indicated that sensor-based measurements can be used efficiently for variable N application in cereal crops when N is the main growth-limiting factor. They further cautioned that the causes of variability must be adequately understood before sensor-based, variable-rate fertilization can be properly used to optimize N side dressing in cereals.Ortiz-Monasterio and Raun (2007) showed that using a combination of an N-rich strip, together with the use of a GreenSeeker sensor and an algorithm to interpret the results from the sensor, allowed farmers to obtain significant savings in N use and thus farm profits.

Modeling the variable rate N fertilization

Several trials on Greenseeker based N Management have been done in Indo Gangatic plains by PAU, Ludiana, DWFSR, Modipuram and few at CIAE, Bhopal for rice and wheat crops. These were found suitable for generating site specific N fertilization recommendations (Bijay-Singh *et al*., 2010) based on green seeker readings. The methodology for modeling the N dose estimation (Nitrogen fertilizer optimization algorithm) (NFOA) adopted from William Raun *et al*., 2005 of Oklahoma State University, USA, has following steps

Development of INSEY-GY relationships : first and subsequent years

1. Measuring NDVI using greenseeker sensor
2. Estimating Yield Potential/ In Season Estimate of Yield:(INSEY)
3. INSEY= NDVI/days from planting to sensing, days
4. Generating the Yield Prediction Equation

Quantifying fertilizer N requirement : second year onwards

5. Establish pre-plant N Rich Strip (NRS)
6. Determine Response Index (RI)= NDVINRS/NDVITest plot

7. Predict potential yield (YP0) with no added fertilizer N from the equation for grain yield and in season estimates of grain yield (INSEY) - - YP0 =a*(INSEY)b or exponential function using nitrogen rich strip (NRS) NDVI readings and RI

8. Predicting the Potential Response YP_N to Applied N

YPN =(YP0*RI)

9. Computing Grain N Uptake at YP_0 and YP_N

10. Generating a Fertilizer N Rate Recommendation

Fertilizer N Requirement = (grain N uptake YPN – grain N uptake YP0/(0.5 to 0.7)

11. Computing the Final Fertilizer dose based on percentage of N in the fertilizer

(eg. Urea has 46% N)

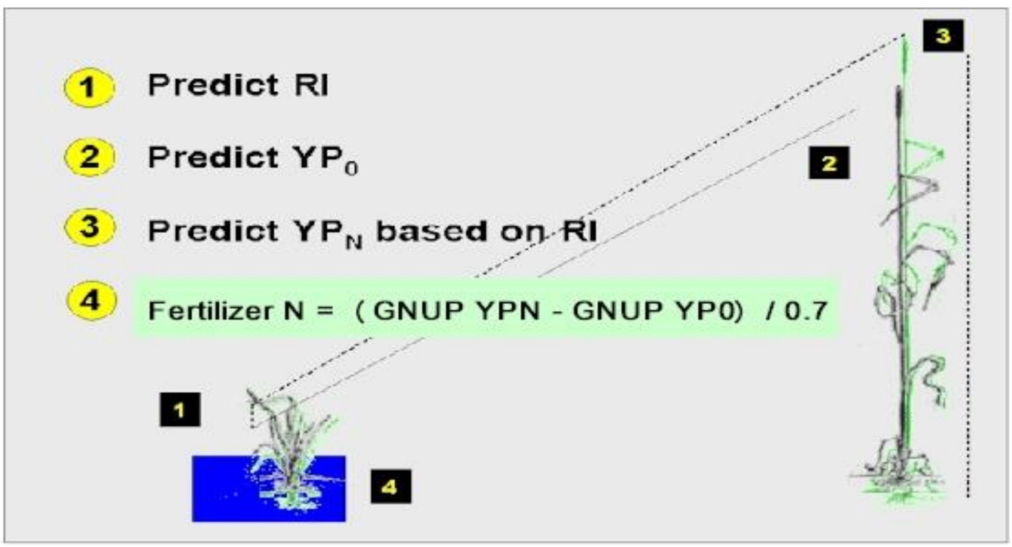

Fig.1 Nitrogen fertilization algorithm Pictorial representation

(A Hypothetical Example)

Steps

Lay out an experiment with reps and N level as shown above Table 1.

1 Take NDVI observations at different dates after emergence (DAE), from each subplot with different Nitrogen application rates, at some regular interval Note the emergence datecorrectly or else use date of planting/ sowing date. Else use the planting date as reference.

2 Count the Number of vegetation period from the emergence date or planting date, taking into account only the vegetation period with the Growing Degree Days (GDD) higher > 0 4GDD = [(Tmin + Tmax)/2] – 4.4°C >0

Table 1 Layout of the experiment for calibration of Optical sensors for N response

No	N0	N30	N60	N90	N120	N150	N180
R1							
R2							
R3							
R4							

Table 2 NDVI Measurements: Replication-I

NDVI Readings Days after first emergence*	N0	N30	N60	N90	N120	N150	N180
15							
30							
45							
60							
75							
90							
105							
120							

*Exclude the non-vegetation period (snow period) when GDD< 0 or count the period as vegetation period when GDD>0 as per equation below:

GDD = (Tmin + Tmax)/2 – 4.4°C>0)

Where, Tmin, T max are minimum and maximum air temperature expressed in ^{0}C.

1. Fill the Table 2. (above) from actual field data on NDVI Measurements
2. Calculation of Response Index (RI) using equation:

RI = (NDVINRS/NDVIi=0; n and d=0, n)

Where NDVINRS refers to NDVI of the N- Rich strip or plot where N is maximum and there is no N deficiency (hidden or otherwise. NDVIi=0; n and d=o, n refers to NDVI of each N treatment and Replication on different dates from initial date of emergence.

Table 3 Response Index calculations:

RI at days after emergence	Replication -I							R-II	RIII
	N0	N30	N60	N90	N120	N150	N180		
15									

30									
45									
60									
75									
90									
105									
120									
Yield Mg/ha									

Fill the above table with the calculated data and if possible plot all the data points on a graph and show the average trend line.

3. Calculation of INSEY (In Season Estimated Yield) using following equation:

INSEY= NDVIi=0;n; D=0,n / DAS Where DAS or DAE = Days after sowing or emergence as the case may be

Table 4 INSEY data calculations:

Note: If there is a non-vegetation period of (say of 40days where GDD <0)discount this 40days period from the total days from emergence to till time oftaking the specific reading.

Nitrogen level	**Days after sowing**							**Crop yield, Mg/ha**
	15	**30**	**45**	**60**	**75**	**90**	**105**	**120**	
N0									
N30									
N60									
N90									
N120									
N150									
N180									

Collect crop yield data from all the N level plots and treatment replications.

Table 5 Crop yield data (Rep 1-Rep 4)

Crop yield, Mg /ha	**N0**	**N30**	**N60**	**N90**	**N120**	**N150**	**N180**
R1							
R2							
R3							
R4							
Average							

4. Establish equation describing Yield as function of the INSEY.

Plot all the INSEY at different dates against averaged crop yield data for different N levels on a graph describing yield as function of INSEY.

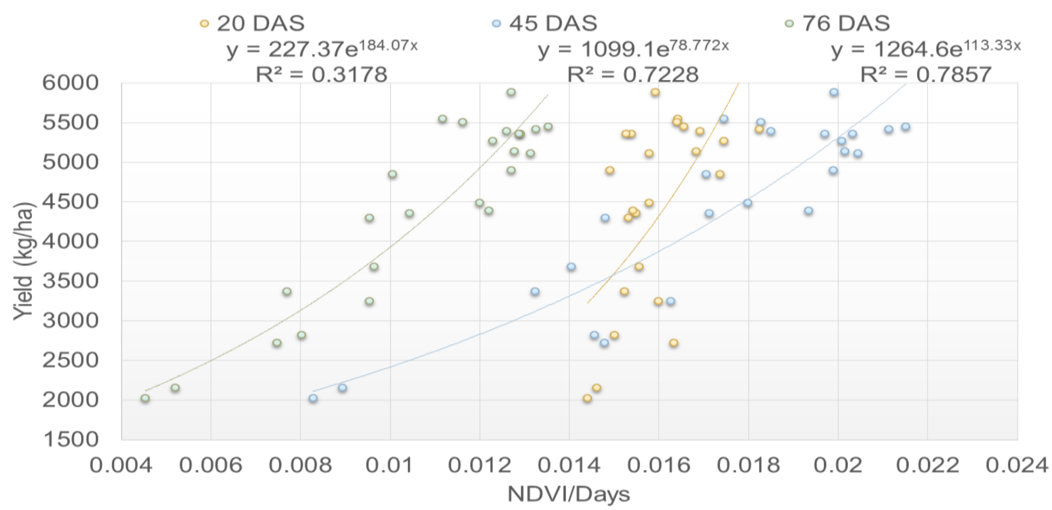

Fig. 2 Yield prediction equations

Methods for prediction of Maximum crop yield based NDVI data

1. Sense the N Rich Strip (NRS) or plot where N is maximum and there is no N deficiency
2. Sense a strip parallel to the NRS (Farmer Practice or FP)
3. Determine how many days from planting to sensing (days, GDD>0)
4. Compute INSEY (NDVI/days from planting to sensing where GDD>0)
5. Predicted yield YP0 = Predicted or potential yield based on growing conditions up to the time of sensing, that can be achieved with no additional (topdress) N fertilization (units: Mg/ha). For this purpose equation should be developed YP0= Function (INSEY)
6. YPN = Predicted or potential yield that can be achieved with additional (topdress) N fertilization based on the in-season response index (RINDVI) (units: t/ha) = (YP0)*(RINDVI)

Generating a Fertilizer N Rate Recommendation

7. RINDVI= NDVI from plots receiving adequate but not excessive preplant N, divided by NDVI from plots where no preplant N was applied

8. Computing Grain N Uptake at YP0 and YPN: The predicted amount of N that will be removed in the grain at harvest (using our equation generated from 1E) is computed as follows:

Grain N uptake, YP0 = Grain Yield (YP0) * expected % N in the Grain or Forage

GNUP_YP0 = YP0*0.0239 GNUP_YPN = YPN*0.0239

Where 0.0239 represents (0.0239 kg N uptake / kg grain 0r 2.39% N in the grain for winter wheat grown

For example, if YP0=3000 kg/ha, and desired yield is YPN=6000 kg/ha than

GNUP_YP0 = YP0*0.0239=71.7 kg/ha GNUP_YPN = YPN*0.0239 =143.4 kg/ha. N= GNUP_YPN- GNUP_YP0=143.4-71.7=71.7 kg/ha

9. Computing the Final Fertilizer N Rate: The fertilizer N rate to be applied is computed by subtracting the predicted amount of N to be removed in the grain at YP0 from the predicted amount of N to be removed in the grain at YPN, divided by Nitrogen use efficiency. This value can range anywhere from 50% to 70%.

10. By dividing N to NUE or 71.7/0.6=113.6 kg/ha we get amount of fertilizer rate should be added into the soil in order to achieve potential crop yield of 6000 kg/ha.

Case Study

Based on the above mentioned methodology Yield prediction equations were developed based on three years data at ICAR-CIAE, Bhopal for wheat and rice crops. The Nitrogen fertilizer optimization algorithm (NFOA) given in hypothetical example was used to calculate the N top-dress dose in wheat and paddy crop. Two software (multilingual android app (Fig. 3) and a web based app (Fig. 4)) were developed using these Yield prediction equation and NFOA for estimating nitrogen fertilizer requirement of the target crop based on NDVI values measured using greenseeker sensor.

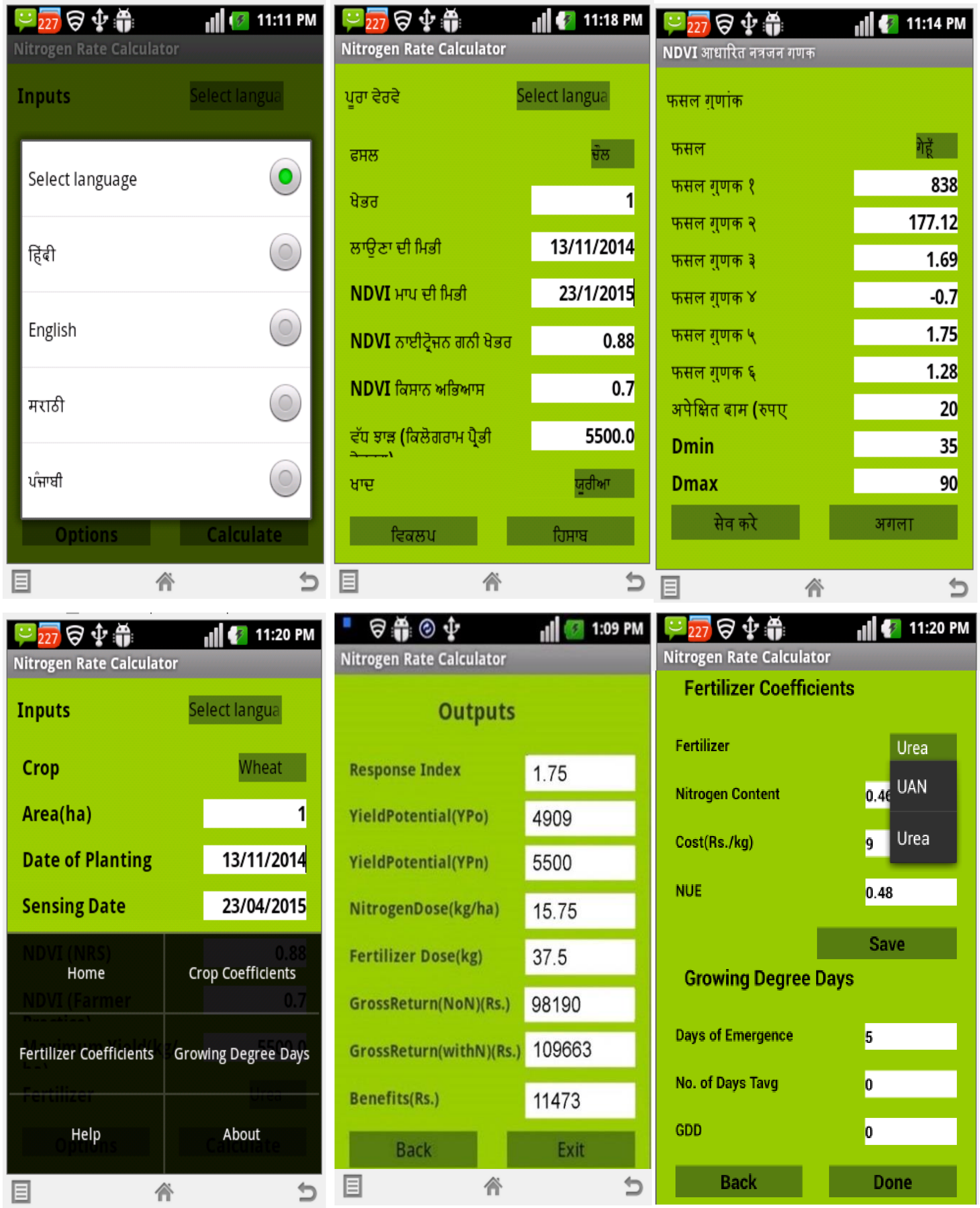

Fig. 3: Screen shots of the Multilingual Nitrogen fertilizer dose Calculator (Android App ver.1.02)

Fig. 4: Screen shots of the Multilingual Nitrogen fertilizer dose Calculator (Web App)

Validation studies were carried out to test the yield response to the Nitrogen dose recommendation generated using app. Randomized block design was used for validation of the yield prediction equation developed based on earlier field experiments by applying the NDVI based nitrogen fertilizer recommendation (generated using android app) during 3rd irrigation (Nr3I), 4th irrigation (Nr4I) and during both 3rd and 4th irrigation

(Nr3I+4I). Farmers practice (FP) (120 kg/ha N) and plot with no Nitrogen (N0) were also laid for comparison Crop and soil samples required for calculation of yield and other agronomic parameters were collected for rice and wheat crop. The results obtained showed Highest Partial factor productivity (PFP) and Agronomic use efficiency of Nitrogen in Nr3I treatment for both paddy and wheat crop. However Highest yield was observed for Nr(3I+4I) treatment in both paddy and wheat crop.(Fig. 5a &b). The potential of saving in greenhouse gas emissions/ha due to reduced urea use is summarized in Table 6.

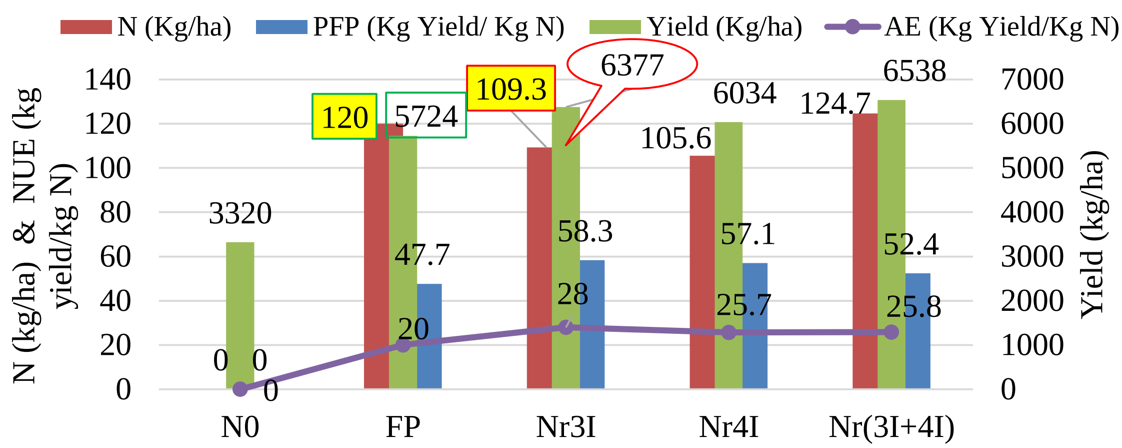

Fig. 5a: Yield and N use efficiencies for Paddy crop using NDVI based recommendation

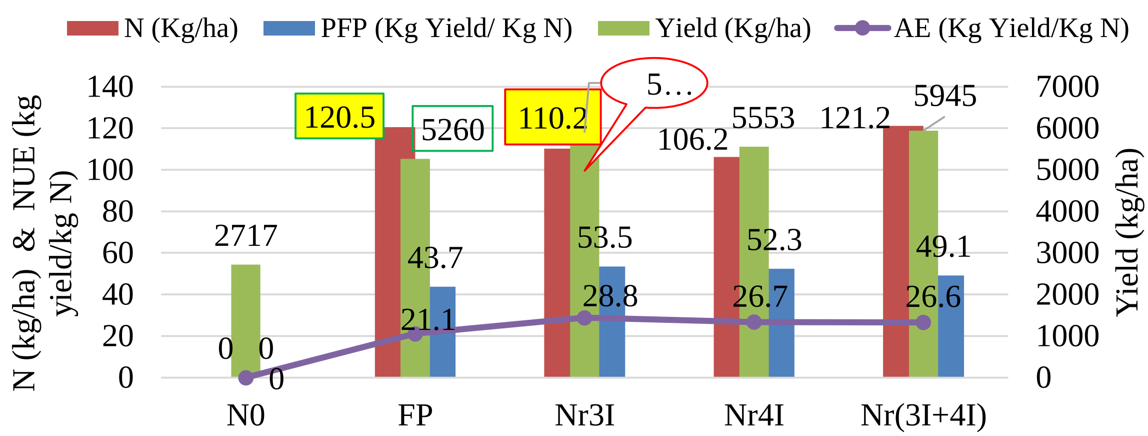

Fig. 5b: Yield and N use efficiencies for Wheat crop using NDVI based recommendation

Table 6: Potential of saving in greenhouse gas emissions/ha due to reduced urea use

Saving in emissions/ha due to reduced urea use	Paddy			Wheat		
	FP	Nr3I	Nr(3I+4I)	FP	Nr3I	Nr(3I+4I)
Average Yield (kg/ha)	5724	6377	6538	5260	5893	5945
N Dose (kg/ha)	120	109.3	124.7	120	110.2	121.2
Urea Dose (kg/ha)	260.87	237.61	271.09	260.87	239.57	263.48
Difference	0	23.26		0	21.30	
Emission coeff. for Urea (kg CE/kg Urea)	0.42					
Reduced CE emission (kg CE/ha)	-	9.77	-	-	8.95	-
CE fertilizer émission (kg CE/1000 kg grain)	19.14	15.65	17.41	20.83	17.07	18.61
Reduced CE fertilizer emission (kg CE/1000 kg grain)	0	3.49	1.73	0	3.76	2.22

Conclusions

The indication of Nitrogen stress affecting crop yield can be modelled using NFOA algorithm and other similar approaches. Most of the approaches established till date use spectral reflectance based devices that measure nitrogen stress with indices similar to NDVI. These approaches can be used for variable rate top dress nitrogen dose recommendation and application in rice and wheat crops for higher yields, reduced fertilizer consumption and overall lower carbon emissions.

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