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NET ZERO
CARBON FARMING

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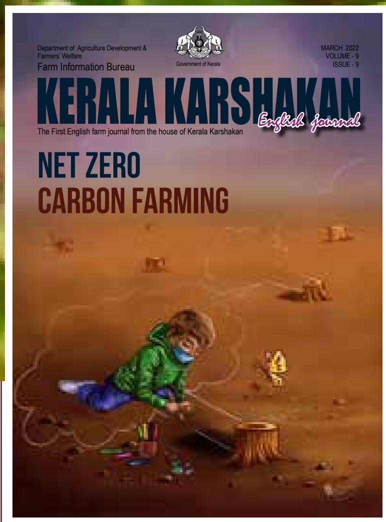

Nibu A. L, Agriculture Assistant, Anad

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NET ZERO CARBON FARMING

G. Byju
Principal Scientist and Head (A)
Division of Crop Production
ICAR-Central Tuber Crops
Research Institute
Sreekariyam P.O.
Thiruvananthapuram
Mobile: 8547441067

The industrial revolution with the invention of steam engine in 1780 by James Watt marked the beginning of a more active human interference in the web of life. The concentrations of CO_2, CH_4 and N_2O, the three most important greenhouse gases (GHG), in 1850-1900 were 280 ppm, 790 ppb and 270 ppb which in 2019, as per assessment report 6 (AR6), increased to 410 ppm, 1866 ppb and 332 ppb. Table 1 shows the annual, cumulative and per capita GHG emissions. According to AR6, starting 2020, the world is left with a total C budget of 400 billion tons for

Table 1. Annual, cumulative and per capita emissions of GHGs

CO_2 (land use change not included)					
	Unit	World	China	US	India
Annual Emission, 2020	Billion tons	34.81	10.67 (31%)	4.71 (14%)	2.44 (7%)
Cumulative Emission (1850-2019)	Billion tons	2390	235.56 (13.89%)	416.72 (24.56%)	54.42 (3.21%)
Per capita Emission,	Tons	4.47	7.41	14.24	1.77
CH_4					
Annual Emission, 2016	Billion tons	8.55	1.26	0.629	0.663
Per capita Emission, 2016	Ton	1.15	0.89	1.95	0.5
N_2O					
Annual Emission, 2016	Billion tons	3.05	0.556	0.252	0.247
Per capita Emission, 2016	Ton	0.41	0.39	0.78	0.19
Total GHG					
Annual Emission, 2016	Billion ton	49.36	11.58	5.83	3.24
Per capita Emission, 2016	Ton	4.92	6.72	14.83	1.74

Source: IPCC, 2021; www.ourworldindata.org

all times to come if we have to limit the temperature rise to the ambitious 1.5^{0}C goal of 2015 Conference of the Parties (CoP-21) or the Paris Agreement. For this, we have to bring down the current annual emission of 34.81 billion tons of CO_2 to 18.22 billion tons in 2030. In 'business-as-usual' scenario, it will be 40.66 billion tons and even if all countries meet their nationally determined contributions (NDCs), it will be 37.71 billion tons.

Compared to 1850-1900, global surface temperature averaged over 2010-2019 increased to 0.8-1.3^{0}C with a best estimate of 1.07^{0}C and is projected to increase to 1.0-1.8^{0}C (1.4^{0}C), 2.1-3.5^{0}C (2.7^{0}C) and 3.3-5.7^{0}C (4.4^{0}C) under shared socioeconomic pathways, SSP1-1.9 (low emission), SSP2-4.5 (intermediate emission) and SSP5-8.5 (high emission) scenarios. Globally averaged precipitation increased since 1950 with a faster rate of increase since 1980s. The average annual global land precipitation is projected to increase by 0–5% under the very low GHG emissions scenario (SSP1-1.9), 1.5-8% for the intermediate GHG emissions scenario (SSP2-4.5) and 1–13% under the very high GHG emissions scenario (SSP5-8.5) by 2081–2100 relative to 1995-2014. The average rate of sea level rise was 1.3 (0.6-2.1) mm/year between 1901-1971, increasing to 1.9 (0.8-2.9) mm/year between 1971 and 2006, and further increasing to 3.7 (3.2-4.2) mm/year between 2006 and 2018. Relative to 1995-2014, the likely global mean sea level rise by 2100 is 0.28-0.55 m under the very low GHG emissions scenario (SSP1-1.9), 0.32-0.62 m under the low GHG emissions scenario (SSP1-2.6), 0.44-0.76 m under the intermediate GHG emissions scenario (SSP2-4.5), and 0.63-1.01 m under the very high GHG emissions scenario (SSP5-8.5). Changes in land biosphere since 1970, poleward shifting of climate zones in both hemispheres and average lengthening of growing period up to 2 days per decade since 1950s in the northern hemisphere extratropics are the other important effects of global warming.

In 2019, GHG emissions in Indian agriculture (within farm gate and including related land use / land use change) were 0.76 billion tons of CO_2eq which is about 10% of total GHG emissions from world agriculture. Methane and N_2O emissions from crop and livestock activities contributed 0.75 billion tons of CO_2eq (98%). Methane emission from enteric fermentation in

Table 2. Global warming potential of Indian food crops

Crop/animal product	GHG emission (g/kg)			
	CH_4	N_2O	CO_2	GWP (CO_2eq)
Rice	43	0.2	75	1221.3
Pulse	0	0.8	83.3	306.8
Brinjal	0	0.1	12.5	31.1
Banana	0	0.2	10.0	71.6
Wheat	0	0.3	45	119.5
Potato	0	0.1	10	24.9
Poultry meat	0	2.7	50	846.5
Mutton	482.5	0	0	12062.7
Egg	0	2	1	588.4
Milk	29.2	0	0	729.2

Source: Pathak et al. 2010

digestive systems of ruminant livestock continued to be the single largest component of farm-gate emissions (0.39 billion tons of CO_2eq) followed by rice cultivation which contributed 0.13 billion tons of CO_2eq. The N_2O emissions from synthetic fertilizers (0.09 billion tons CO_2eq) and manure left on pastures (0.06 billion tons CO_2eq) are the two major sources contributing to 96% of total Indian emissions from agriculture. Total CO_2 emission is comparatively low (0.012 billion tons CO_2eq) mainly due to low on-farm energy use .

Carbon foot print of agriculture

Carbon emissions from farm operations can be grouped into primary, secondary and tertiary sources. Primary sources are either due to mobile operations such as tillage, sowing, harvesting and transport or stationary operations such as pumping water, grain drying etc. Manufacturing, packaging and storing fertilizers, pesticides and herbicides are the secondary sources of C emission. Tertiary sources include acquisition of raw materials, fabrication of equipment and farm buildings etc. Carbon footprint of crop production is assessed by estimating the greenhouse gas emissions from all mechanical operations performed and inputs added in a single whole cycle of crop production along with nitrous oxide emission from application of fertilizers. If the crop is rice, methane emission also needs to be considered. For understanding the carbon cost of farming, we need to know the 'emission factors' expressed in kg carbon equivalent or CO_2 equivalent for different tillage operations, sowing, fertilizers, pesticides and herbicides use, irrigation practices, harvesting, transport and residue management. This knowledge is also essential to identify C-efficient alternatives such as soil carbon sequestration, planting trees and renewable energy sources for different operations.The emission factors used for the estimation of total emissions are a mix of default emission factors available in the book, '2006 IPCC guidelines for national greenhouse gas inventories'and country-specific emission factors. Global warming potential of CO_2, CH_4 and N_2O are 1, 28 and 265 according to AR5 report and this also need to be considered while estimating the total greenhouse gas emission expressed as CO_2 equivalent.

For example, one kilo of diesel usage emits 2.6 kg CO_2 eq while consumption of one kWh of electricity emits 26.6 x 10^{-2} CO_2 eq into atmosphere. Similarly, production, transport, storage and transfer of one kilo N fertilizer emit 4.77 kg CO_2 eq while the corresponding values for one kilo P and K fertilizers are only 0.77 and 0.55 kg CO_2 eq respectively. It may be noted that application of one kilo of fresh manure releases only 0.027 kilo CO_2 eq. Considering 0.48% as average N concentration in fresh manure, on a nitrogen equivalent basis, application of fresh manure to supply 1 kilo of nitrogen (208 kg fresh manure) emits 5.61kg CO_2 eq which is actually higher than

Table 3. Per hectare global warming potential of crops in India

Crop	GWP (kg CO_2eq/ha)
Rice (continuous flooding)	3500-3700
Rice (Intermittent flooding)	900-1050
Wheat	340-350
Maize	320-365
Millets	230-250
Oilseeds	220-275
Pulses	180-240
Vegetables	440-575

Source: Pathak et al., 2014

that emitted from an equivalent amount of N fertilizer.In order to estimate N_2O emission, the equation used is, $CF_N = F_N \times \delta_N \times (44/28) \times 298 \times (12/44)$, where CF_N is the carbon footprint from direct N_2O emissions from N fertilizer (t CE); F_N is the quantity of N fertilizer (tons) applied for crop production; δ_N is the emission factor for N_2O emission induced by N fertilizer application (tons N_2O-N /tons fertilizer) (0.01); 44/28 is the molecular weight of N_2 fertilizer in relation to N_2O; 298 is the global warming potential of N_2O and 12/44 is the molecular weight of CO_2 used to derive CE of N_2O. In order to estimate methane emission from rice cultivation, the equation used is $CF_M = Area \times \delta_M \times (16/12) \times 25 \times (44/12)$ where CF_M is the carbon footprint of methane; δ_M is the methane emission factor; 16/12 and 44/12 are factors based on CH_4 and CO_2; and 25 is the net global warming potential of methane. In a continuously flooded rice field the methane emission factor is 162 kg CH_4/ha while it is only 20 when multiple aeration is practised. Tables 2 and 3 give the global warming potential of different crops in order to have an idea about it.

Ways towards achieving carbon neutral agriculture

- **Use non-conventional energy:** Use solar energy to substitute fossil fuel-based conventional energy sources. Fossil fuels will have to be replaced with green energy / bio-diesel which can result in 24-73% reduction in GHG emissions. Biogas

production from biomass through anaerobic digestion (using bacteria) is another way to meet on-farm energy demand.

- **Climate resilient crop varieties:** Adopt varieties that are tolerant to drought, heat, salinity and flood, of shorter duration and/or deep rooting with high yield. This will save water and energy, increase soil carbon and reduce GHG emissions. Deep rooting crop varieties sequester more carbon in root biomass.
- **Changing planting date:** This will aid in avoiding heat stress during flowering and maturity. If there is an early season drought due to delayed onset of monsoon, follow direct seeding with short duration rice variety such as Jyothi.
- **Nutrient saving techniques:** Technologies to improve nutrient use efficiency include site specific nutrient management (SSNM) and use of leaf colour chart (LCC). Urease inhibitors such as N-(N-butyl) thiophosphoric triamide -NBPT and hydroquinone delays hydrolysis of urea into NH_4^+ by blocking urease binding sites. Use of nitrification inhibitors such as neem coated urea, dicyandiamide, 3-4 dimethyl pyrazole phosphate-DMPP, nitrapyrin (N-serve), S benzyl thiourea-SBT butanoate, $CaCl_2$and encapsulated $CaCl_2$ inhibits nitrification (microbial oxidation of NH_4^+ to NO_2-) by suppressing the activity of nitrifying bacteria and reduce N_2O emission by 38%. Use of double inhibitors such as NBPT+DCD, super U reduce N_2O emission by 30%. Use of controlled release fertilizers (CRF) such as polymer coated urea, environmentally smart nitrogen (ESN), resin coated urea (RCU), polyolefin coated urea (PoCU) and N fusion slow the release of nutrients through inorganic or organic coatings that control the rate, pattern and duration of nutrient release thereby reducing N_2O emission by 19%.Fertilizer tablets and customised fertilizers have great scope in Kerala state for homestead and terrace farming to reduce greenhouse gas emissions. All these together are called enhanced efficiency fertilizers (EEF).
- **Water saving techniques:** Laser levelling, drip and sprinkler irrigation and fertigation need to be widely practised for increasing water and nutrient use efficiency and reduced GHG emissions.
- **Increasing soil carbon stocks:** Soil organic matter includes soil microbes mainly bacteria and fungi, decaying materials from once living organisms – plant and animal tissues, faecal material and products formed from their decomposition. Soil carbon sequestration is a process by which CO_2 is removed from the atmosphere and stored in soil C pool which is primarily mediated by plants through photosynthesis with C stored in soil organic C.Reduced tillage/ conservation tillage, erosion control (contour ploughing, terracing), addition of organic amendments (compost, manures, crop residues), use of cover crops, legume intercropping, crop rotation including off season and fallow season crops, integrated cropping/farming systems, scientific organic farming, soil and water conservation, rain water harvesting, establishment of hedgerows/trees/ woodland are the practices that need attention. Conventional tillage is the main source of soil disturbance that increases physical soil C removal due to soil erosion and CO_2 emissions due to escalated microbial activities. Conservation tillage decreases fuel consumption and increases soil C sequestration which synergistically reduce GHG emissions.Soil organic carbon pool to 1 m depth range from 30 (arid climates) to 800 (organic soils) t/ha with a predominant range of 50-150 t/ha. The rate of soil organic carbon sequestration depends on soil texture, profile characteristics (parent material, clay content, CEC), climate (temperature and

moisture) and plant residue composition and it ranges from 0-150 kg C / ha /year in dry and warm regions to 100-1000 kg/ha/year in humid and cool climates. The proportion of cellulose, hemicellulose, lignin, starch, proteins, lipids and phenolic compounds that constitute plant tissue varies with species and age and residue biochemical composition determines soil residence potential. While farmyard manure contains 22.40% total organic carbon, 16.65% recalcitrant carbon, 14.22% cellulose, 30.82% hemicellulose and 10.49% lignin, the corresponding values in ordinary compost are 29.40, 22.80, 8.67, 8.63 and 24.11%. This signifies the fact that addition of compost is important in carbon sequestration rather than addition of farm yard manure whose total organic carbon, recalcitrant carbon and lignin contents are lower than that of compost. Composted manure has more soil residence potential. If we consider an average application rate of 10 t/ha of FYM in all the 20 lakh hectares of net sown area in the state, we need 20 million tons of FYM annually (10 million tons on dry weight basis). Considering the population of cattle, buffalo and goat as 28 lakhs and an average dung production of 0.94 tons (dry weight basis) per animal, our total production capacity is 26.32 lakh tons (dry weight) which is only 1/3rd of annual FYM requirement above. This is a very important issue while considering conversion of farming completely to organic.

- **Site specific crop residue management:** The amount of crop residues generated in Kerala state in 2009 was 9.74 million tons. Considering the contents in one ton of crop residue, on average,as 12-20 kg N, 1-4 kg P, 7-30 kg K, 4-8 kg Ca and 2-4 kg Mg, 9.74 million tons can supply 116-194.8 million kg N, 9.74-38.96 million kg P, 68.18-292.2 million kg K, 38.96-77.92 million kg Ca and 19.48-38.96 million kg Mg. Nitrogen availability from crop residue (116-194.8 million kg) shows its big potential when we understand that fertilizer N consumption per year in the state was only 79.27 million kg. One important possibility is biochar from crop residues as biochar has soil residence time of hundreds to thousands of years. Biochar is a fine-grained, carbon-rich, porous product remaining after plant biomass has been subjected to thermo-chemical conversion process (pyrolysis) at low temperatures (~350–600°C) in an environment with little or no oxygen. Biochar is not a pure carbon, but rather mix of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), sulphur (S) and ash in different proportions. The central quality of biochar that makes it attractive as a soil amendment is its highly porous structure, potentially responsible for improved water retention and increased soil surface area. The conversion of biomass carbon to biochar leads to sequestration of about 50% of the initial carbon compared to the low amounts retained after burning (3%) and biological decomposition (less than 10-20% after 5-10 years). Large amounts of carbon in biochar may be sequestered in the soil for long periods estimated to be hundreds to thousands of years.While biochar mineralizes in soils, a fraction of it remains in a very stable form; this property of biochar provides it the potential to be a major carbon sink. Vermicomposting, microbial breakdown into compost, microbial breakdown into a biogas that can be upgraded to renewable natural gas (RNG) and production of cellulosic biofuels are other prospects of crop residues for carbon sequestration.
- **Wasteland management.** Develop wastelands for forestry, agroforestry and grassland.
- **Integrated farming/ cropping systems:** Include crop, livestock and fishery.
- Crop diversification by growing suitable crops to adjust adverse climate.

- **Integrated pest and disease management:** Combine physical, chemical and biological methods of pest management. Ecological engineering practices can be adopted for crop protection. This include use of parasitoids, predators (spiders, ladybird beetles, long horned grasshoppers, earwigs etc.), entomopathogens, flowering plants (sunflower, mustard, marigold, French bean, maize, cowpea) to attract natural enemies, trap crops (marigold controls thrips, castor controls tobacco caterpillar, inter row crops of Tridax procumbens in paddy enhances natural parasite and predator populations) and repelling crops as intercrop (garlic repels beetles, mosquito and tomato borer, marigold repels beetles, cucumber beetles and nematodes). Do not uproot weed plants like *Tridax decumbens*, *Ageratum sp.*, *Alternanthera sp.* etc. which act as a nectar source for natural enemies. Ecological engineering also include crop residue management, reduced tillage to save hibernating natural enemies, use of biofertilizers, mycorrhiza, PGPR, Trichoderma and Pseudomonas.
- **Rain water harvesting:** Collect and store run-off water, use harvested water for irrigation and recharge ground water.
- **Improved weather-based advisory.** Weather forecasting and timely crop management.
- Combining horticulture with forestry alongwith crop production for C sequestration.
- **Cooperative farming:** Help to adopt new technologies and bear more risks thereby reduced GHG with increased efficiency of agri-inputs.
- **Use of ITK for weather forecasting and risk management in crop production.**
- **Sustainable animal husbandry:** Improved feed (high protein diets, greater use of food additives and enhanced use of feed-grain processing for improved digestibility and reduced methane emissions, improved health of cattle and sheep, improved dung management – well managed FYM, biogas and compost pits and more sophisticated breed management – increased yield and decreased cattle herd help reducing methane emission from livestock.
- **Specific recommendations for rice cultivation**

1. Land management : Direct seeding (reduce methane mission by 70-75%), reduced tillage.
2. Modified water regime agriculture: Alternate wetting and drying. CH_4 emission is reduced by 30%. Mid-season drainage is another practice.
3. Additives: Phosphogypsum, Nitrification inhibitors / Urea super granules. Will reduce N loss and increase N use efficiency by 10-15%.
4. Site specific nutrient management (QUEFTS) and use of leaf colour chart (demand-driven N supply) will increase N use efficiency by 10-15%.
5. Urea tablets
6. Organic farming
7. System of rice intensification (SRI)

Agriculture is a leading cause of climate change, a significant victim of climate change and is potentially a key contributor to solving climate change as well.Considering the promise that India made in Conference of Parties meeting at Glasgow, England (Cop-26) during December 2021 to achieve the target of net zero by 2070, concerted efforts need to be made in the agriculture sector to reduce greenhouse gas emissions by adopting the above practices on a war footing. Despite significant mitigation potential of several agricultural practices, limited awareness and low confidence in monitoring of agricultural interventions have inhibited the inclusion of agriculture in the climate change policy and emissions offset markets.

Roy Stephen
Stephen K
Department of Plant Physiology,
College of Agriculture, Vellayani,
Kerala Agricultural University.

Temperature is expected to rise by 1 to 1.5^0 C by 2100 (COP21, Paris). With the threat of global warming a looming reality, several countries have expressed serious concern over the challenges of maintaining crop production to meet their population needs (COP26, Glasgow). Scientists have stressed on phasing out fossil fuels as energy sources, as well as to rapidly adopt carbon neutral technologies to limit the rise in temperature to 1^0 C compared to pre-industrial levels (Paris Climate Agreement, 2015). The target of achieving net-zero carbon emissions by

CROPS FOR CARBON FARMING

AN ECO - PHYSIOLOGICAL PERSPECTIVE

2050 depends on two strategies i) Phasing out fossil fuels with clean energy technologies and ii) Sequestering/storing the emitted carbon. At this juncture, scientific crop production is an option to address both the strategies.

Agriculture has major scope in reducing the carbon emissions by managing scientifically the use of fossil-fuels for operating machinery; manufacturing processes used for production of fertilizers, pesticides; methane production from paddy fields, release of soil organic carbon through tillage operations or through deforestation and biomass burning.

Mono-cropping and other intensive agricultural practices contribute significantly to atmospheric carbon. However, much of the carbon emitted can be re-utilized by the plants by fixation through the process of photosynthesis. Hence selection of crops based on photosynthetic efficiency is a scientific way to sequester more carbon per unit farm land. Agriculture contributes to mitigation/ reduction of carbon through carbon sequestration strategies, agro-forestry, bio-fuels etc. Our current focus should be directed towards making agricultural production as carbon-neutral i.e. preventing the amount of carbon emitted from exceeding the amount of carbon fixed or sequestered by crop plants.

Agriculture sector has the ability to transform from a net emitter of CO_2 to a net sequesterer of CO_2. Carbon farming can be an effective strategy to achieve this by targeting land management. Carbon farming can be defined as the scientific practice of agricultural methods that are aimed at sequestering atmospheric carbon into the soil organic carbon pool and in crop roots, wood and leaves, with the goal of creating a net loss of carbon from the atmosphere. Some of the carbon farming strategies that are important for achieving carbon-neutrality are discussed hereunder:

1. **Integrated Farming System**- In contrast to mono-cropping, the combination of components such as crops, livestock, poultry, crop rotation, aqua-culture and organic manures helps in increasing productivity along with reducing net carbon emissions. Meera et. al. (2019) compared the emissions from various components in integrated farming system models such as coconut-based, homestead-based, rice-based and banana based, with the highest net carbon sequestration recorded in homestead-based farming system with negative emissions while only rice-based model recorded positive emissions. Components such as cover crops, biochar, composting and soil amendments contribute significantly in increasing the soil carbon pool. Integrated Farming System will act as insurance system for farm family, as there will be some assured income during climate change induced crop casualties.
2. **Bio-fuel crops-** Bio-diesel and bio-ethanol produced from crops such as jatropa, sugar-beet, cassava, soybean, oil-palm, rapeseed, sorghum and sugar-cane reduce the dependence on fossil fuels while also fixing the carbon emitted through their combustion, in photosynthesis, thereby achieving net zero emissions(de Vries et. al., 2010).
3. **Soil carbon sequestration:**Soil is an important storage pool for carbon. The important aspects related to carbon sequestration in soil are soil surface management, soil water conservation and soil fertility regulation. The soil organic carbon pool is reported to be 1550 picograms (Pg) which is much higher than atmosphere (700 Pg) and land biota (600 Pg) pools (Lal and Kimble, 1997). Crops with deeper root system can contribute to sequester more carbon to soil organic pool.
4. **Conservation tillage:** Tillage methods that reduce run-off and soil erosion improve soil organic carbon (SOC) sequestration. Conservation tillage practices help in preventing the loss of soil carbon into the atmosphere compared to conventional tillage practices. The associated components involved are selecting appropriate crop species, cover crops, improved pastures, deep rooted crops, increasing humification etc.
5. **Cropping systems:** The cropping systems should be

selected with the principle that intensive cropping systems that produce more biomass per unit land area will sequester more CO_2 from the atmosphere. Chethan et. al. (2020) in their study reported that the rice-rice-daincha cropping system was able to sequester more than twice the amount of SOC compared to rice-rice-fallow system. Inclusion of leguminous crops and practicing multi storied cropping system with high radiation use efficiency is an ideal approach in this direction.

6. **Agro-forestry:** It integrates the components of crops, livestock and trees. The advantage of agro-forestry systems is that huge amount of carbon can be stored as biomass for several years. Different components of agro-forestry systems have varied advantages such as silvo-pasture, alley cropping, wind-breaks etc. Afforestation and agro-forestry techniques have immense capacity to sequester carbon in their biomass and therefore should be encouraged in crop lands, marginal or degraded ecosystems.
7. **Deeper rooting crops:** The deeper rooting crops can store carbon in the lower layers of the soil profile with lesser chance of disturbance from surface tillage operations. Manikanta et.al. (2020) found that rice varieties with deeper roots could produce more biomass especially under stress conditions.
8. **C4 crops:** The C4 crops like maize, sorghum, sugarcane etc., have efficient CO_2 utilization mechanism of photosynthesis through Kranz anatomy in the leaf which allows greater sequestration of carbon in their biomass. Liu et al. (2019) in their study noted that the cumulative carbon inputs increased with C4 crop (maize) residues compared to C3 crop (wheat) residues incorporated into the soil.

Strategies to reduce emissions

a) Replacing or reducing the use of chemical fertilizers with organic sources and biofertilizers

b) Using renewable sources of energy such as solar energy for farm operations

c) Growing bio-fuel/bio-diesel crops and using the bio-fuel to run farm operations such as spraying or other machinery thereby achieving net-zero emissions

d) Replacing flooding cultivation of rice with aerobic techniques in order to reduce the methane emissions emanating from submerged rice fields

e) Recycling or incorporating of crop stubble into the soil instead of burning which releases huge amount of carbon emissions

f) Cultivation of varieties with higher degree of tolerance to biotic and abiotic stresses

g) Encourage the use of biocontrol agents to reduce the dependence to chemical pesticides

Focus for the future

i) Policy planning– The ecological targets of carbon sequestration should be kept in mind along with crop productivity and economic factors.

ii) Crop scientists– The component of net carbon emissions should be added while researching integrated farming models.

iii) Kerala – Thrust should be given on developing carbon farming strategies adapted to the local conditions

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Smt. Namreta Sharma
Senior Team Leader, SuATI Agroecology Project

SUPPORT TO AGROECOLOGICAL TRANSFORMATION PROCESSES IN INDIA (SUATI)

INDO-GERMAN TECHNICAL COOPERATION (TC) PROJECT)

Agricultural and food system in India faces the major challenge of sustainably ensuring the livelihoods of approximately 700 million people, who are directly dependent on agriculture and natural resources, as well as providing healthy nutrition to the population in the face of an intensifying climate crisis and massive overexploitation of natural resources. As part of the National Mission for Sustainable Agriculture (NMSA), the Ministry of Agriculture and Farmers' Welfare (MoA & FW) also promotes programs for ecological agriculture (Paramparagat KrishiVikas Yojana, PKVY), natural agriculture (Bhartiya Prakratik KrishiPaddhati, BPKP), specific program on organic farming through "Mission Organic Value Chain Development for North Eastern Region" (MOVCDNER), as well as agroforestry. However, the potential of agroecological based agriculture practices is yet to be explored for larger uptake.

In 2019, the German Parliament has passed a motion to gear its Development Cooperation in the agricultural sector towards agroecological principles. In this regard, Indo-German Lighthouse initiative "Agroecology and Sustainable Management of Natural Resources" will be signed between BMZ and MoA & FW. This initiative is expected to provide a thematic focus for joint initiatives

The project "Support to Agroecological transformation processes in India (SuATI)", of the Federal Ministry for Economic Cooperation and Development (BMZ), implemented by "Deutsche Gesellschaftfür Internationale Zusammenarbeit

(GIZ) GmbH" is responsible for the implementation of planned measures to support Agroecological transformation processes in close coordination with the national partner Ministry of Agriculture & Farmers' Welfare (MoAFW) and the corresponding federal partners of Karnataka and Madhya Pradesh. The inclusion of Assam as third state is under discussion.

Objective: The project aims to "support transformative agroecological (AE) programmes and their implementation in selected states as well as the dissemination of experiences at the national level."

Outcomes of the project

- Agroecological transformation processes for sustainable agri-food systems at national and selected state levels are strengthened in convergence with sectoral objectives
- Agroecological principles and approaches are increasingly reflected in national and state programmes
- The size of the sustainably/ agroecologically cultivated area in selected states is increased
- Acceptance and share of food traded through marketing systems for agro-biodiverse, organic produces & natural farming at local and regional level is increased with positive income effects

Outputs of the project

- Strengthens public & private sector initiatives and their implementation with focus on market development & consumer awareness in Madhya Pradesh, Karnataka, and Assam
- Development of national programmes for uptake of agroecological principles & practices
- Sharing/use of knowledge on agroecological & other sustainable agricultural

practices is increased

- Capacity building support to Farmer Producers Organisations to take up climate adaption and mitigation measures under different agroecological practices to have resilient production models
- Uptake of agroecology in curricula of agriculture universities and relevant training/research institutions
- Research and evidence building/documentation on agroecology
- Planned interventions

State

- Inclusion of Agroecological (AE) approaches in agri programmes and convergence among departments
- Strengthen agri-models by producer groups
- Encourage Govt. procurement of AE produce Raising consumer awareness for safe/local food

National

- Collate and provide evidence of AE benefits
- Support MoA&FW in integrating AE into key programs

Knowledge System level

- Engage stakeholders for assimilation, dissemination of AE practices
- Strengthen capacities of institutions to deliver AE skills for research/extension
- Strengthen application of AE for Sustainable agriculture

The project therefore aims to improve the exchange and more coherent application of knowledge about agroecological and similar sustainable agricultural practices in India. It plans to establish backward and forward linkages by strengthening link between market and agricultural and food systems. Educational, research and consulting institutions need support for generating evidence-based research to strengthen agroecological knowledge systems. The project will plan interventions in consultation with implementing partners and document the outcomes scientifically to support states and national government in its policies and programmes.

By supporting application of key principles of the agroecology, the project will strengthen sustainable and inclusive agriculture and food systems, thereby benefitting rural and urban populations with better access to diversified diets/ nutritious healthy diets. Through various technical and financial Cooperation projects, GIZ is already supporting agroecology support ecosystem across various themes and geographies in India. All the projects have markers and objectives which contribute to agroecological principles. SuATI project will anchor the tools, technologies and methodologies tested and tried by these projects and apply in its project states.

The project will also enhance convergent action of Governments, public and private sector (with a focus on market development, certification, consumer awareness and developing knowledge platforms on agroecological products and practices) as well as civil society - towards the development of sustainable agricultural and food systems.

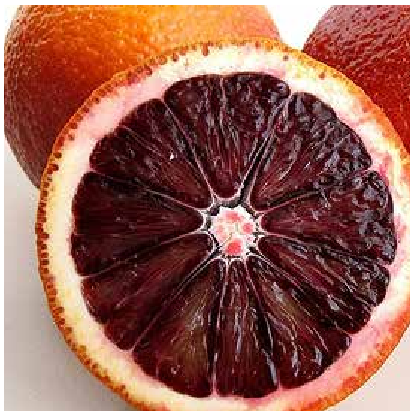
Vulnerable communities, such as small and marginal farmers (especially Scheduled Caste and Scheduled Tribes, differently abled farmers), women farmers, youths and landless farm workers would be supported through FPOs for adopting agroecological practices and linking their natural produce to markets, after their nutritional needs are fulfilled. The project will work closely with women farmers through FPOs and SHGs to implement successful business models to improve their incomes. The project plans to publicise sustainable agricultural practices and raise consumer awareness of safe and regional/local food products & reviving local traditional food system through a gender-focussed approach.

Anju[1]
Raman Selvakumar[2]
[1]College of Horticulture
Kerala Agricultural University
Thrissur, Kerala 680656
[2]ICAR-Indian Agricultural
Research Institute
Pusa Campus
New Delhi-110012, India.

THE RAINBOW AS AN APPETITE

Phytonutrients, often known as food pigments, are responsible for the bright colours found in fresh foods such as red, green, purple, yellow, and orange. They are high in antioxidants and have therapeutic properties that have a substantial influence on general human health. Based on their chemical composition, these dietary pigments are classified into six groups: heme pigments, chlorophylls, carotenoids, flavonoids, betalains, and miscellaneous pigments. These non-nutritive chemicals may activate enzymes in the human body that aid in the removal of pollutants, enhance cardiovascular and brain health, and cause cancer cells to die. As a consequence, these food colorings are very important for human health. As a consequence of the side effects and toxicity of synthetic colourants, customers all over the world have begun to show interest in natural alternatives, leading to the replacement of synthetic pigments in the food sector. Phytonutrient research


Moro


Tarocco


Sanguinello


Ruby Blood orange

is one of the most fascinating areas of nutritional study today, and it is helping us better understand the health benefits of food. Food security is a major issue all around the world. Fruits are a wonderful alternative for tackling the food security dilemma since they are rich in several health components. This article, titled "Eat by Color," seeks to detail the variances noticed from usual colours in different fruit crops, with a focus on the nutritional consequences for human health.

The natural food colours:

Natural food colours or biological pigments originate from a wide range of sources

Table 1

Sl. No.	Colours	Constituents
1	Red	Betalains, anthocyanins, betacyanins, lycopene, resteratrol
2	Blue/purple	Anthocyanin, Delphinidin, Malvidin, Petunidin
3	Green	chlorophyll-a and chlorophyll-b
4	Yellow/orange	Carotenoids (alpha-carotene, beta-carotene, beta-cryptoxanthin)
5	Black/deep purple	anthocyanins

like vegetables, fruits, minerals and other edible natural sources. These plant based pigments are given in table 1

Well, all of us are very familiar with yellow skinned varieties of mangoes that are commonly seen. But there are some varieties of mango that possess red skinned types too. The red coloured types of mango is due to the presence of anthocyanins. Some red skinned varieties of mango are as follows:

1. Tommy Atkins: It is a Florida mango cultivar with wide oval skin that is coated in a rich crimson blush with occasional orange hues. It's high in Vitamin A and C, as well as an excellent source of fibre. It also includes minerals including potassium, calcium, and iron, as well as folate and Vitamin B6.

2. Pusa Pratibha: On a golden yellow background, the fruit features a vibrant crimson peel. Vitamin C and beta-carotene are abundant in this fruit.

3. Pusa Shrestha: The fruit has a beautiful crimson skin and is high in Vitamin C and beta carotene.

4. Pusa Lalima: This type also boasts a pleasing red peel colour and a larger pulp content, as well as a high Vitamin C content.

5. Pusa Arunima: This variety's fruits also have a magnificent crimson skin.

6. Ambika: This variety's fruits are yellow with a dark crimson flush and are a good source of lycopene.

Bananas, both yellow and green, have long been a favourite fruit and vegetable of ours. However, there is a banana variation that is blue in colour. It's known as the Blue Java banana. It has a vanilla ice cream flavour to it. Fibre, manganese, and vitamins B6 and C are all abundant in them. These blue bananas are also high in antioxidants such as gallic acid, quercetin, ferulic acid, and dopamine.

The peel of red bananas is thick and brick red, with semi-soft flesh. It has a sweet, creamy flavour with raspberry undertones. It has more beta-carotene and lutein than yellow banana types and is higher in vitamin C. Potassium and magnesium are abundant in red bananas. These two minerals may aid in blood pressure reduction. They have more antioxidants than yellow bananas, which helps to protect cells from free radical damage. Carotenoids, anthocyanins, vitamin C, and dopamine are the key antioxidants contained in red bananas.

We are all acquainted with citrus fruits with orange flesh, but there are also sweet orange kinds that have a vivid orange rind tinged with crimson and are hence known as blood red oranges/pigmented oranges. Anthocyanin, the same chemical that makes blueberries blue and cranberries red, is responsible for the flesh's distinctive blood red colour, which may vary from light crimson to deep magenta depending on the variety and stage of development.

This potent antioxidant lowers the body's risk of cancer-causing free radicals. These blood oranges are packed with nutrients and are high in vitamin C, fibre, and potassium. Moro, Tarocco, and Sanguinello are the three primary varieties of blood oranges.

1. Moro: Because of its unusual flesh colour and rind blush due to the presence of anthocyanin, the same ingredient that gives purple grapes their colour, it is the most colourful of the blood

Tommy Atkins

Pusa Pratibha

Pusa Shrestha

Pusa Lalima

Pusa Arunima

Ambika

Red banana

Blue Java banana

oranges. It's also known as 'Deep blood oranges' since the flesh is strongly tinted (nearly violet-red).

2.Tarocco: The presence of anthocyanin gives it its characteristic colour. Because the flesh is not as pigmented as Moro and Sanguinello's, it is referred to as 'Half blood.' It has the highest vitamin C content and is also the sweetest.

3. Sanguinello: This type has a crimson skin and a compact yellow peel with a red tint. The flesh is orange, with blood-colored streaks running across it. 'Full Blood' is the term used to describe it. Ruby Blood, Maltese, Washington Sanguine, Vaccaro, Sanguina Doble Fina, Red Valencia, and other blood red orange varieties are less frequent.

Health wellness and impacts based on colours:

1.Red

- Anthocyanins have been shown to be potent antioxidants that aid to improve the immune system, preserve health, and prevent illness. Anthocyanins help to preserve DNA, combat oestrogen-dependent illnesses, stimulate anti-inflammatory responses, and regulate the immune system.
- Resveratrol, a phytoalexin antioxidant found in red grapes, has numerous neuroprotective properties in diseases including Alzheimer's, Huntington's, and Parkinson's disease.
- Dietary lycopene may aid in the breakdown of low-density lipoproteins in the body. Furthermore, it protects against carcinogens in the liver, brain, cervix, and prostrate, preventing or delaying the development of some cancers.

2.Blue/Purple as

the 'nutritious colour:

- Blue and purplish pigmented foods have antioxidant properties and are useful for the prevention and treatment of cancer, protection against liver injuries, and improvement of vision.
- Delphinidin is the most potent inhibitor of osteoclast differentiation and will be an effective agent for preventing bone loss in postmenopausal osteoporosis.

3. Yellow/Orange:

- Three of the most common carotenoids – alpha-carotene, beta-carotene, and beta-cryptoxanthin – can be converted into vitamin A from food in the food • Vitamin A

is essential for good vision in low light, normal growth and development, a strong immune system, and to keep the digestive and urinary tract healthy

4. Green:

- Chlorophyll may help prevent malignant tumours from forming.
- It aids in the blocking of aflatoxins (cancer-causing chemicals) absorption in the intestines, preventing dangerous aflatoxins from damaging DNA.
- Consumption of green fruits aids in the production of antioxidants in the bloodstream.

Finally, consuming plant-based meals, particularly fruits and vegetables, has various advantages. One technique for helping individuals connect with the health benefits is to associate each colour with a health benefit to help them remember to consume a range of colourful meals. Individuals who eat a variety of foods may ingest more phytochemicals in their diet, which may assist to minimise their risk of chronic illnesses.

Ayeeshya Hasansab Kolhar, S. L. Jagadeesh
University of Horticultural Sciences, Udyanagiri, Bagalkot-587104.

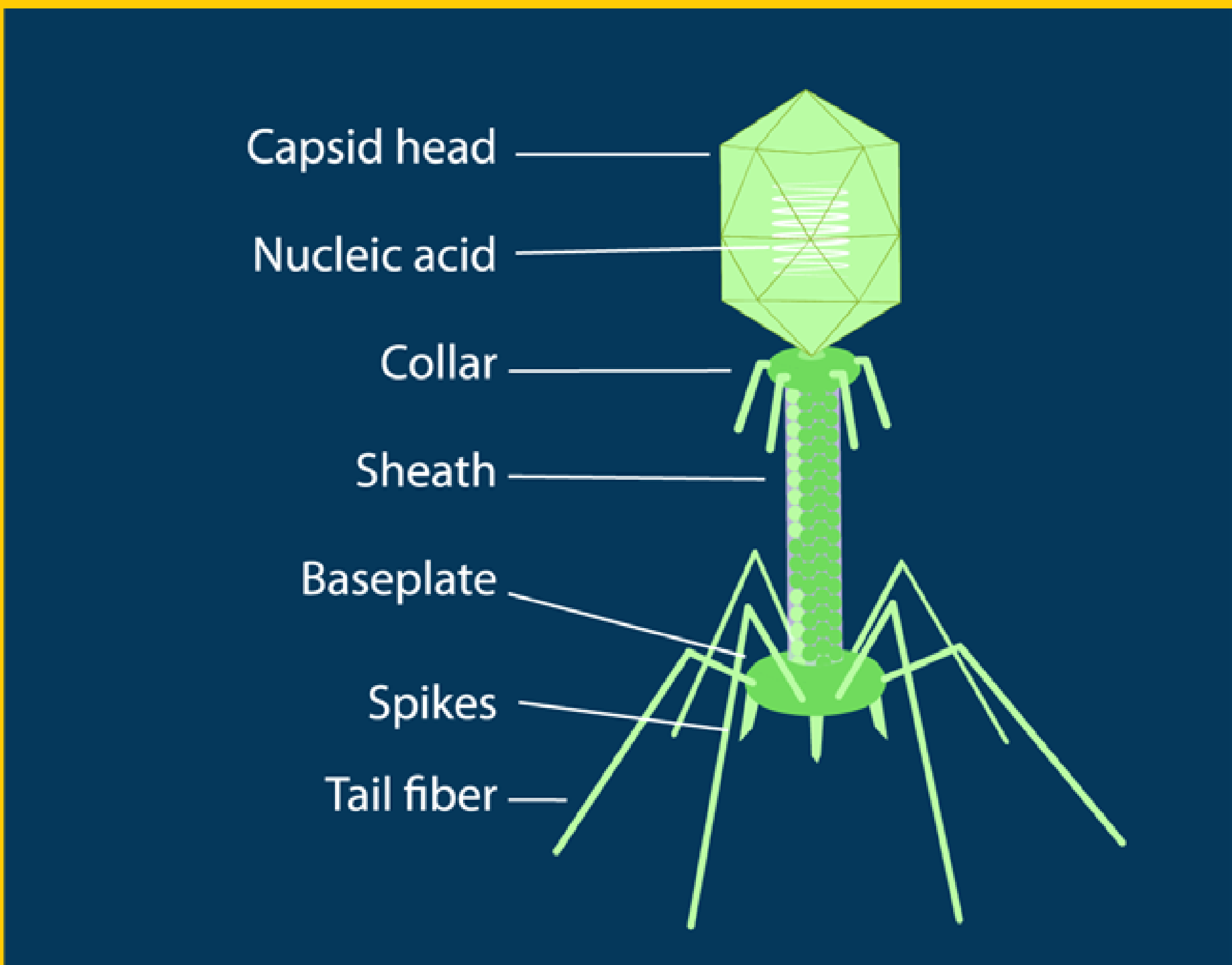
Bacteriophages

a novel tool for ensuring food safety

Across the world, the foodborne illnesses were the major human health problem as they encompass a wide spectrum of illnesses, use of chemical drugs for overcoming foodborne illnesses is a common remedy. On the other hand, the emergence of multi-drug resistance (MDR) by pathogens has increased the pressure on health authorities. Based on analysis one can tell that the use of antibiotics in food animals, is considered as the main source of bacterial resistance. India is the world's largest consumer of antibiotics. Effective control measures to reduce food-borne outbreaks and stop the spread of resistant bacteria are needed. In

Table 1: Bacteriophages and their applications against different pathogens

Area of Application	Name of Phages	Pathogen
Decontamination of surface sanitization	Phage Guard Listex Phage Guard S	*Listeria monocytogenes* *Salmonella enterica spp*
Food processing and packaging	Listex P100	*L. monocytogenes*
	Georgian bacteriophage cocktails	MDR Escherichia coli
	Phage mix derived from family Myoviridae, Siphoviridae, Podoviridae	*Staphylococcus aureus*
	Bacteriophages S16 and Felix-O1a (FO1a)	*Salmonella spp.*
	ShigaShield™	Shigella sonnei
Food spoilage and bio sanitization	Polyvalent phage isolated from a potato	Streptomyces spp.
	Bacteriophages	*Xanthomonas campestris* pv. Vesicatoria
Bacteriophages against bacterial biofilms	Phage KH1	*E. coli O157:H7*
	Phage CP8 and CP30	*Campylobacter jejuni*
	Phage P100	*L. monocytogenes*
	Phage K	*Staphylococcus aureus*



food market globalization many effective novel technologies have come into role but still, food safety issues are continuously challenging areas. The lytic bacteriophages are great alternatives for different kinds of antibiotics to combat bacterial infections. Among the many alternative medicine strategy, bacteriophages are strong candidates to act against the many foodborne pathogens. Bacteriophages are emerging as a "Green" technology to deal with the issues in food industries.

Bacteriophages

These are viruses of prokaryotes widespread in all habitats where their hosts are located. Bacteriophages are classified based on their shape, size, and kind of nucleic acids. Bacteriophages belong to order Caudovirales (tailed-bacteriophages) and considered as a ubiquitous organism present in natural and man-made environment. Phages are having strong antimicrobial properties. Along with this they are safer and more specific and effective against MDR bacteria as compared to conventional agents.

Bacteriophages have two types of life cycles i.e. lytic and lysogenic life cycle. In Lysogenic cycle, phage genome is entered into the host genome and undergoes replication along with host chromosomes and in lytic cycle phages lyse the host bacteria and thus, its antimicrobial activities are linked to lytic phage.

Due to the effective results, this technique is rapidly used in several fields such as agriculture, veterinary medicine, food safety, and wastewater treatment. Along with the antimicrobial effect against pathogenic bacteria, phages can provide an effective alternative to traditional disinfectants. Due to surface decontamination property, phages can also be applied as food bio preservatives. Thus, phage preparations against *Listeria monocytogenes* (Listshield TM), *Salmonella enterica* (SalmFresh TM), and *Escherichia coli* (Ecoshield TM) have received Generally Recognized as Safe (GRAS) designation by the FDA for direct application to food and are commercially available.

Utilization of Bacteriophages in the Food Industry

Decontamination of Surface Sanitization

Surface bacteria like *Pseudomonas spp.*, *Enterobacteriaceae* and *Acinetobacter spp* are few of the important sources of food contamination. Surface bacteria like *Stenotrophomonas maltophilia* have been reported as a major source of antimicrobial resistance emergence. Phages can be used as an attractive alternative to traditional disinfectants.

Food Processing and Packaging

Most of the bacterial contamination can be identified at the food product processing and packaging time. This contamination can be reduced through treatment with commercial phage cocktails. Many studies to investigate the use of bacteriophage to kill the pathogenic bacteria present on food products like *L. monocytogenes*, *Escherichia coli*, *Salmonella spp.*, *Shigella sonnei*, *Staphylococcus aureus*, etc. are reported. Use of phage endolysins and depolymerases to reduce number of bacterial pathogens has also been reported. Addition of these enzymes can prevent contamination while processing and packaging of food.

Food Spoilage and Bio Sanitation Preservation of food has always been an essential part of food production. Bacteriophages can be natural food preservatives. The fruits and vegetables are perishable foods and get spoiled easily by many of the spoilage bacteria.

Bacteriophages Against Bacterial Biofilms:

Nowadays, biofilm production is a major concern in food industries which cause most of the troubles while handling foods. The complex community of bacteria attached to a surface and surrounded an extracellular polymeric material. Which are resistant to most of cleaning and disinfecting agents making them most difficult to remove from surfaces.

Because of this resistance, it is having high impact on human health. To overcome this, one has to promote the development of different approaches to control or remove biofilm formation. Phages effectively eliminating biofilm formation in food industry have been reported.

Conclusion

The bacteriophages can be considered as an emerging strategy to tackle the increased foodborne illnesses. Thus, the application of bacteriophages can be encouraged to enhance food safety and hygiene.

Bholanath Saha[1]
Sushanta Saha[2]
Partha Deb Roy[3*]
[1]Dept. of Soil Science,
Dr. Kalam Agricultural College,
Bihar Agricultural University,
Kishanganj, Bihar - 855 107, India
[2]Directorate of Research,
Bidhan Chandra Krishi Viswavidyalaya,
Kalyani, Nadia, West Bengal - 741 235, India
[3]ICAR-Indian Institute of
Water Management, Bhubaneswar,
Odisha-751023, India

Heavy metal pollution of soil and water are increasingly urgent problem all over the industrialized world. Heavy metals, unlike organic contaminants, are generally immutable, not degradable and persistent in soil. High concentrations of heavy metals in soils may cause long-term risks to ecosystems and humans. Although pollution of some trace elements due to geogenic sources is observed in various parts of world including India, the anthropogenic pollution are more dominant and causing higher magnitude of soil pollution. Major heavy metal contaminated sites in Indis is given in table 1.The overall objective of any soil

REMEDIATION OF HEAVY METAL CONTAMINATED SOIL AND WATER

Table 1: Major heavy metal contaminated sites in India (CPCB, 2009)

Chromium	Lead	Mercury	Arsenic	Copper
Ranipet, Tamil Nadu	Ratlam, Madhya Pradesha	Kodaikanal, Tamil Nadu	Gangetic plain, West Bengal	Tuticorin Tamilnadu
Kanpur, Uttar Pradesh	Bandalamottu Mines, Andhra Pradesh	Ganjam, Orissa	Gangetic plain, Bihar and Uttar pradesh	Singbhum Mines, Jharkhand
Vadodara, Gujrat	Vadodra, Gujrat	Singrauli, Madhya Pradesh	Chattisgarh	Malanjkahnd, Madhya Pradesh
Sukhinda, Orissa	Korba, Chattisgarh		Assam	

Fig.1: Remediation strategies for contaminated soil and water

Remediation strategies

Physico-chemical measures

- **Soil vapour extraction**
- **Airsparging**
- **Dehalogenation**
- **Soil flushing/soil washing**
- **Immobilization/Stabilization**
- **Oxidation coupled with UV radiation**
- **electro-kinetic technique**
- **Plasma technique**

Thermal measures

- **Incineration**
- **Thermal desorption**
- **Vitrification**

Biological measures

- **Natural attenuation**
- **Bioaugmentation**
- **Biopiles**
- **Land farming**
- **Bio-airsparging**
- **Bioventing**
- **Biosurfectants**
- **phytoremediation**
  - **>Phytostabilization**
  - **>Phytofiltration**
  - **>Phytovolatilization**
  - **>Phytoextraction**

remediation approach is to create a final solution that is protective of human health and the environment. A wide array of techniques has been proposed to remediate heavy metal-contaminated soils (Fig.1). The remediation techniques of heavy metals in soils include physical remediation, chemical remediation, phytoremediation, and agro-ecological engineering techniques. Physical remediation technologies based on the excavation, removal, washing, and landfilling of metal contaminated soils are highly effective at lowering risk. In addition, phytoremediation is of limited applicability in urban soils. In order to obtain low-cost remediation methods and in situ inactivation techniques, soil chemical amendments have been recently investigated, appearing as potential valuable alternative techniques for a wide range of polluted sites (Vangronsveld and Cunningham 1998).

The remediation of these heavy metal contaminated soils can be attempted through conventional treatments such as land filling and leaching, excavation and burial or soil washing. However, these approaches are cost intensive and thus not economically viable; besides being intrusive in nature, deteriorating soil structure also destabilize natural ecosystem and often are aesthetically unacceptable. The use of specially selected and engineered metal accumulating plants for environmental cleans up is an emerging frontline technology called "phytoremediation"; which describes a system wherein plants in association with soil organisms can remove or transform contaminants into harmless and often valuable forms (Robinson et al. 2009). Excessive heavy metal accumulation can be toxic to most plants leading to reduction in seed germination, root elongation and biomass production; inhibition of chlorophyll biosynthesis as well as disturbance in cellular metabolism and chromosome distortion.

The criteria for a plant to qualify as hyper-accumulator for different metals is shoot metal concentration (oven dry basis) should be more than 1 per cent for Mn, and Zn; 0.1 per cent for Cu, Ni and Pb; and 0.01 per cent for Cd and As. This technology

is still in its infancy. However, the recent developments to identify or evolve high biomass crop plants having capabilities to accumulate heavy metals suggests that phytoremediation of metal contaminated soil will soon be a viable alternative to most conventional clean-up technologies. Recent evidence suggests that moderate accumulating high biomass producing species such as Indian mustard *(Brassica juncea)* may accumulate four times more Zn than T. *caerulescens* and higher than other *Brassica species*.

Hyper-accumulation is an eco-physiological adaptation of plants to metalliferous soils. The mechanisms of metal accumulation, which involve extra-cellular and intracellular metal chelation, precipitation, compartmentalization and translocation in vascular system, are poorly understood. Phytochelatins like low molecular weight a-Glu-Cyspeptides with high affinity for certain metals are assumed to be involved in accumulation, detoxification and metabolism of metal ions such as Cd, Zn, Cu, Pb, and Hg in plant cells. Organic carboxylic acids, e.g., maleic, citric, oxalic, succinic etc. are commonly found in crop rhizosphere as secretion/ exudation products from plant roots or associated microbes; which help further in complexing metals to ease their entry to the plant cell.

Although phytoremediation is time consuming and may require several years before contamination level is significantly lowered within the safe limits, this technology provides a cost effective environment friendly management option (Cunningham and Berti, 1995). The scope of this technology can be extended to phytomining in order to extract metals from soils or ores that are sub-economic for conventional mining. Improvements such as microcomputer software for design and implementation of phyto-remediation have revolutionized the green cure technology.

Ex situ and in situ immobilization techniques are practical approaches to remediation of metal-contaminated soils. The ex situ technique is applied in areas where highly contaminated soil must be removed from its place of origin, and its storage is connected with a high ecological risk (e.g., in the case of radio nuclides). The method's advantages are: (i) fast and easy applicability and (ii) relatively low costs of investment and operation. The method's disadvantages include (i) high invasivity to the environment, (ii) generation of a significant amount of solid wastes (twice as large as volume after processing), (iii) the byproduct must be stored on a special landfill site, (iv) in the case of changing of the physicochemical condition in the side product or its surroundings, there is serious danger of the release of additional contaminants to the environment, and (v) permanent control of the stored wastes is required. In the in situ technique, the fixing agent's amendments are applied on the unexcavated soil. The technique's advantages are (i) its low invasivity, (ii) simplicity and rapidity, (iii) relatively inexpensive, and (iv) small amount of wastes are produced, (v) high public acceptability, (vi) covers a broad spectrum of inorganic pollutants.

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Babli Mog[1*]
J.D. Adiga[1]
Mohana G.S[1]
Eradasappa. E[1]
Shamsudheen M[1]
Siddanna Savadi[1]
Veena G.L[1]
Thondaimon V[1]
Manjesh G.N[1]
Manjunatha K[1]
[1]ICAR-Directorate of Cashew Research, Puttur, D.K.-574202

THE IMPACT OF CLIMATE VARIABILITY AND CHANGE ON CASHEW CULTIVATION IN INDIA

Introduction:

Cashew is one of the most export oriented horticultural crops of India. It was introduced to India by the Portuguese travellers in the 16th century mainly for soil and water conservation and also for reclamation of degraded land. Yet, India was the first country to exploit the export potential of cashew kernels in the world. India produces about 7.0 lakh tons of raw cashew nuts annually out of which about 1.312 lakh tons are getting exported. Indian cashew processing units need about 13-14 lakh tons of raw cashewnut annually which may increase to 25 lakh tons by 2030 and 45.0 lakh tons by 2050 (DCRVision 2050) (Fig.1). At present, to meet own domestic requirement, India imports huge amount of raw cashew nuts from African and South East Asian countries. Hence, it has become inevitable to increase the raw cashew nut production in the country to achieve self-sufficiency. In order to achieve the target of raw cashew nut requirement, India must enhance the productivity of cashew to the tune of 2.5 to 3.0 tones/ha.

Cashew is presently grown in an area of about 10.62 lakh hectare with the production of 8.17 lakh metric tons and productivity of 753 kg/ha. In India, productivity level is not increasing at the expected rate over the last few years. Keeping in view the growing demand for cashew and also to meet the challenges of attaining self-sufficiency in raw cashew nut production, emerging issues such as global climate change, area expansion in other prospective locations with environmental extremes etc. need to be addressed and also to develop roadmap for achieving higher productivity of cashew by exploitation of its true potential.

Climate change and cashew:

Climate change is one of the important alerts for present era. Several recent studies indicated that annual rainfall, diurnal temperature, maximum and minimum temperatures are in a fluctuating trend (Parthasarathy et al., 2008). Climate change may pose problem for cashew cultivation since cashew is habitually grown as a rainfed crop in ecologically sensitive areas such as coastal belts, hilly areas and areas with high rainfall and humidity.In India, cashew is grown mainly in Maharashtra, Goa, Karnataka and Kerala along the West Coast and Tamil Nadu, Andhra Pradesh, Odisha and West Bengal along the East Coast. It is also grown to a limited extent in nontraditional areas such as Bastar region of Chhattisgarh and Kolar (Plains) region of Karnataka, Gujarat and Jharkhand and in North Eastern Hill region with vagaries of climate (Rupa et al, 2012). Future prediction shows that a slight increase or decrease in minimum temperature ($\pm 0.5^0$C) may not considerably affect the yield of cashew. But a decrease in minimum temperature of about 2^0C may tremendously reduce the yield of cashew in some regions of North Eastern states, Maharashtra and Andhra Pradesh by changing the area highly suitable for cashew in Maharashtra to marginally suitable and moderately suitable area in NEH regions to unsuitable, indicating the effect of climate change on cashew suitability (Rejani et al, 2013). Thus, with change in climate variability, the challenge for cashew crop will be to improve yields in marginal lands under rainfed conditions where the harsh environment strongly limits crop growth, productivity and quality of the produce. Hence, the areas such as strategic research on rainfed cashew, watershed development for raising productivity of rainfed cashew etc. may also be a priority which need more attention.

Association between cashew phenology and climate:

Cashew is an evergreen tropical tree with low branching and medium size canopy. It produces three to four vegetative flushes under normal climatic conditions. At the beginning of winter, it produces new flushes which further produces flowering panicles. The panicles are andromonoecious containing male and hermaphrodite flowers. After initiation of panicle, it takes 90 to 120 days to complete opening of flower. Cashew fruit is swollen peduncle with a nut and takes 60 days from fruit set to maturity (Salvi et al, 2020).For good performance of cashew nut, the major requirement is the warm, humid, typical tropical climate with an optimum average temperature of 24-28^0C. Cashew needs good sunshine which is critical for its leaf development, maximum stomatal conductance, leaf gas exchange and greater net CO_2 assimilation and providing leaf saturation point of about 1000 photosynthetic photon flux (PPF). Well drained, loam to clay loam, 150-300 cm soil depth acidic to near neutral soil reaction, non-saline soils with nearly 0.71% of organic carbon (OC) with high base saturation of nearly 60-65% are ideal for cashew cultivation. It has to be remembered that cashew grows well between elevations of 200 to 250 m above mean sea level (MSL) without any water stagnation.The average annual of 1300 to 2500 mm rainfall is considered to be suitable for cashew (Bhattacharya et al, 2021) (Fig.2).

Climate Change Impacts on cashew:

Cashew is mostly grown as a rainfed crop, and the yield and quality of nut is largely dependent on climatic and weather conditions. Any change in climate has direct impact on reproductive phase of cashew. With climate change, there will be various impacts on cashew production such as reduction in yields, variation in flowering, fruitsetting, nut development and kernel quality, higher incidence of pests and diseases and waterstress. It has been reported that the maximum temperature, humidity and rainfall are the major climatic factors which determine the productivity of cashew (Fig. 3).

a). Effects of Climate Change on Productivity and Quality of Cashew Nut:

The rainfed cashew crop

Fig.2: Suitability of climate and soil conditions for the growth of Cashew plantation(Taken fromOza et al, 2021)

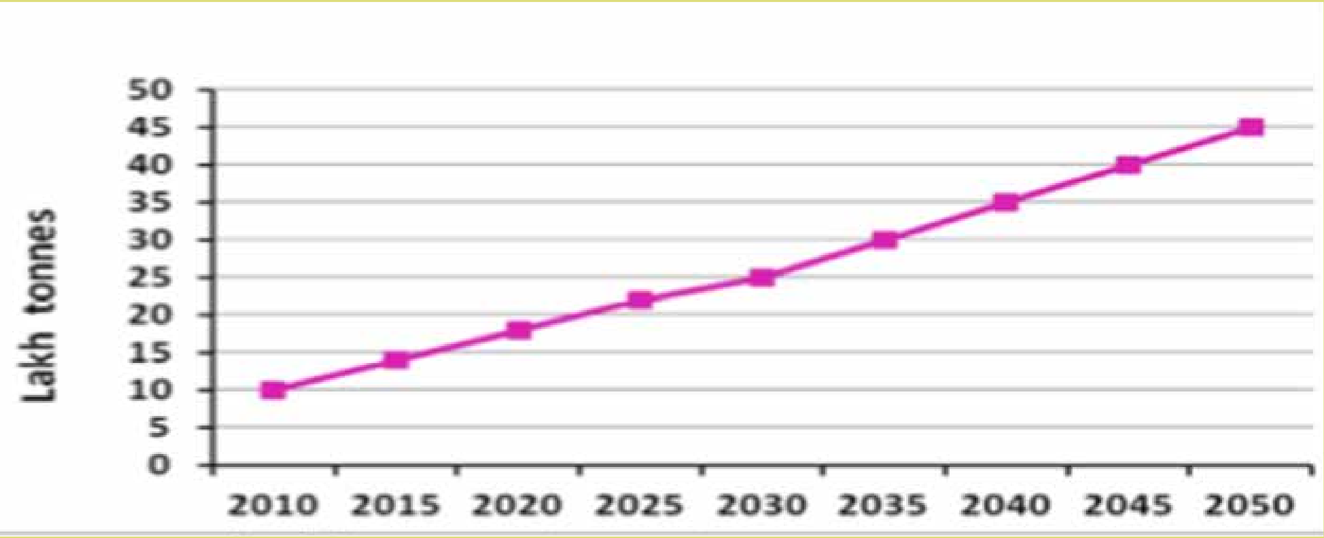


Fig 1: Projection of raw Cashewnut requirement (Taken from DCR Vision-2050)

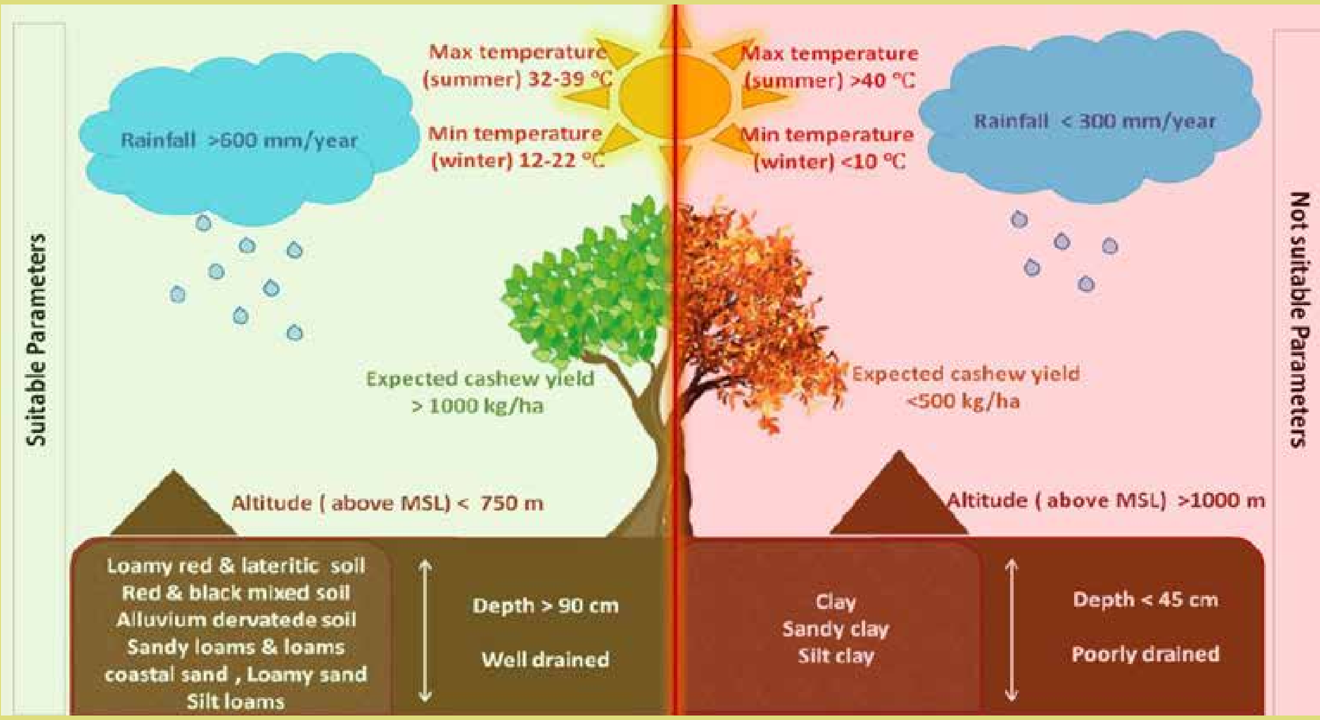
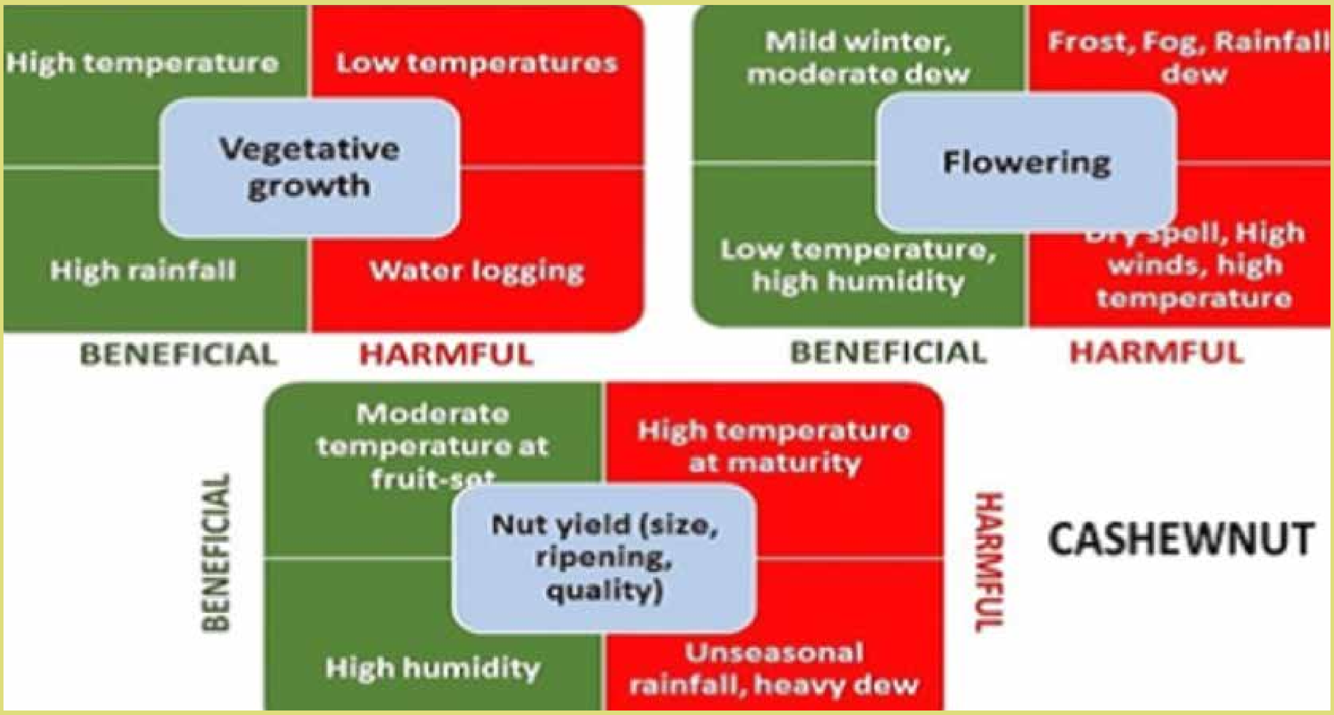


Fig. 3: Impact of climate change showing different climatic factors atvarious growth stages of Cashewnut(Taken from Bhattacharyya et al, 2021).



is highly sensitive to changes in climate and weather, especially during reproductive phase. High temperature (>34.4 °C) and low RH (<20%) during afternoon cause drying of flowers. The maximum temperature,humidity and rainfall are the major climatic factors that influence the productivity of cashew. The maximum temperature plays a crucial role on nut size and kernel weight of cashew during the nut development stage Prasada Rao et al. 2010). Haldankar et al. (2003) reported that there lative humidity during pre-flowering phase is the main factor which explains yield variation in cashew plantations.The unusual rains between November and December inordinately delay reproductive phase of the late flowering varieties. Unseasonal rainfall and heavydew during flowering and fruiting intensify the incidence of pests and diseases as well as deterioration of nut quality.

Cashew genotypes vary noticeably in their heat units (day °C) requirement. Early variety (Anakkayam-1) requires only 1953 heat units for reproductive phase while late variety (Madakkathara-2) requires 2483 heat units. Cashew kernel weight is positively correlated with heat units especially for mid and late varieties. Continuous rains without critical dry spells and late winter rains delay the budbreak in cashew. A dry spell of 7 days is usually necessary 30 days prior to the budbreak. Late and extended winter rains reduce the number of bright sunshine hours invariably which results in delaying of bud break and better availability of soilmoisture during flowering (December and January).

b). Effects on Insect Pest Incidence

Cashew is infested by numerous insect pests, thereby limiting the production considerably. One of the main reasons for reduction of cashew nut yield is the occurrence of an important sucking insect pest, tea mosquito bug (TMB) during the cropping season. The production loss from the TMB alone is estimated to be about 30 per cent.

The incidence and severity of the pest is highly dependent on climate and weather factors. The minimum temperature plays a vital role in the incidence of pest population and is negatively correlated with the TMB pest incidence (Godse et al., 2005). The favorable minimum temperature for TMB incidence ranges between 13-18 °C. Low temperature (12 °C) is antagonistic for pest build up.

c). Extreme Events of Weather Impacts

Changes in temperature and precipitation patterns together with occurrence of extreme events due to climate change are a major threat to future cashew sector. For instance, the Tsunami in coastal Tamil Nadu on 26 December, 2004 harshly affected cashew crop. Most of the standing crop was inundated with salty sea water ingression in the mainland. Salinity is a major environmental stress and is a substantial constraint to crop production. Most of the cashew varieties are sensitive to salinity. Rise in sea water level due to climate change conditions may adversely affect the cashew plantation. Electrical conductivity of 1.48 dS m^{-1}in irrigation water is a threshold tolerance for precocious cashew during the initial growth (Carneiro et al., 2002).

Adaptation and Mitigation Strategies

Adaptation strategies can work in two ways, by reducing vulnerability(susceptibility) to changing condition, or by increasing resiliency (to recovery) by reducing suffering during and immediately after the events (Bedsworth and Hanak, 2010). Some of the adaptation measures that the cashew sector can undertake to cope with future climate change include: Changing planting dates, planting different varieties, developing new drought and heat resistant varieties, salt tolerant varieties, adoption of intercropping, using sustainable fertilizer, weed management, more use of water harvesting techniques, supplemental irrigation, drip irrigation, fertigation, better pest and disease management etc.In order to mitigate the ill effects of climate change on soil quality and to protect the soil and land resource, it is important to give more focus on adoption of soil and water conservation practices, mulching, cashew leaf litter retention and recycling, addition of animal-based manures etc.

Way Forward:

Till date, several strategies such as soil and water conservation, mulching, drip irrigation, the association of the cashew trees with green manure, fertigation and carbon sequestration are attempted to reduce the vulnerability of the cashew trees to climate change.

Despite of all these strategies, the use of cultivars resistant to water deficit, temperature, salinity and floods seems to be one of the effective strategies to climate change. Unfortunately, cultivar resistant to climate change is yet to be identified since the introduction of cashew in India. Generally, Cashew is considered as a hardy crop and can survive in any environment with little care. Hence, the climate resilient traits need to be incorporated to cashew for maximum exploitation of it's potential. Climate change studies require huge datasets for the past and present scenarios to build the predicted incidences. There is huge data gap with special reference to cashew climatic data. Some data on climatic parameters of different AICRP centers as well as ICAR-DCR, Puttur are available but in scattered form. Primary data generation and filtering secondary data for modeling might help in accessing the multiple regional climate models for cashew. This will involve inter and trans disciplinary research experts, funding agencies, governments, and non-government organizations and private sectors to collaborate to promote climate resilient research in cashew.

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MORINGA
A Potential Miracle tree

[1]M.Ananthi
[2]S.Kavitha
[3]M.Anitha
[1]Teaching Assistant, Directorate of Planning and Monitoring, Tamil Nadu Agricultural University, Coimbatore
2Assistant Professor, Department of Seed Science and Technology, Tamil Nadu Agricultural University, Coimbatore
3Assistant Professor, Selvam Arts and Science College (Autonomous), Namakkal

Moringa, is a natural as well as cultivated variety of the genus Moringa belonging to family Moringaceae. It is native to India, grows in the tropical and subtropical regions of the world and commonly known as 'drum stick tree' or 'horse radish tree'. It is an edible, extremely safe plant. It can be easily and cheaply cultivated and can with stand both severe rough and mild frost conditions and hence widely cultivated across the world. It is an economically important, multipurpose tree with immense nutritional value, containing all essential vitamins and minerals.

Nutritional compositions and medicinal uses of

Leaves

Contains fiber, fat proteins and minerals like Ca, Mg, P, K, Cu, Fe, and S; Vitamin-A (β-carotene), vitamin B-choline, vitamin B1-thiamine, riboflavin, nicotinic acid and ascorbic acid. Various amino acids like Arg, His, Lys, Trp, Phe, Thr, Leu, Met, Ile, Val are present. Phytochemicals like tannins, sterols, saponins, trepenoids, phenolics, alkaloids and flavonoids like quercetin, isoquercitin, kaemfericitin, isothiocyanates and glycoside compounds are present. Leaves treat asthma, hyperglycemia, Dyslipidemia, flu, heart burn, syphilis, malaria, pneumonia, diarrhea, headaches, scurvy, skin diseases, bronchitis, eye and ear infections. Also reduces, blood pressure and cholesterol and acts as an anticancer, antimicrobial, Antioxidant, anti diabetic and anti-atherosclerotic agents, neuroprotectant.

Seeds

Contains oleic acid, antibiotic called pterygospermin, and fatty acids like Linoleic acid, linolenic acid, behenic acid, Phytochemicals like tannins, saponin, phenolics, phytate, flavanoids, terpenoids and lectins. Apart from these, fats, fiber, proteins, minerals, vitamins like A, B, C and amino acids. Help in treating hyperthyroidism, Chrohn's disease, antiherpes-simplex virus arthritis, rheumatism, gout, cramp, epilepsy and sexually transmitted diseases, can act as antimicrobial and anti-inflammatory agents.

Root Bark

Alkaloids like morphine, moriginine, minerals like calcium, magnesium and sodium. Root bark acts as a cardiac stimulant, anti-ulcer and anti-inflammatory agent.

Flower

Flowers act as hypocholesterolemic, anti-arthritic agents, can cure urinary problems and colds.
It contains calcium and potassium and amino acids. They also contain nectar.

Pods

Rich in fiber, lipids, non-structural carbohydrates, protein and ash. Fatty acids like oleic acid, linoleic acid, palmitic acid and linolenic acid are also present. Pods treat diarrhea, liver and spleen problems, and joint pain.

Nutritional Value

Moringa	100-gram Serving
Protein	9.4 grams (19% of Daily Value)
Potassium	400 mg
Calcium	450 mg
Fats	1.4 grams
Vitamin C	165 mg
Vitamin A	758 ¼ grams
Vitamin B6	19% of Daily Value
Fiber	2 grams
Carbohydrates	8.3 grams
Riboflavin	0.66 mg
Iron	4 mg (22% of Daily Value)
Magnesium	147 mg
Zinc	0.6 mg
Sodium	9 mg

It is a very valuable food crop (it is highly nutritive, grows very fast and drought resistant) and even beyond food it serves many benefits in developing countries. It is one of the richest plant sources of Vitamins A,B,C,D,E and K. The vital minerals present in Moringa include Calcium, Copper, Iron, Potassium, Magnesium, Manganese and Zinc. It has more than 40 natural anti-oxidants. It consist of various medicinal properties including wound healing, anti-tumor,

anti-hepato toxic, anti-fertility, hypotensive, diuretic, anti-ulcer, cardio vascular, anti-cancer. The leaves, pods, seeds, gums, bark and flowers of Moringa are used in more than 80 countries to relieve mineral and vitamin deficiencies. It has potential benefit in malnutrition and also used to make an efficient fuel, fertilizer and livestock feed. It is commonly referred as "The Miracle Tree" due to its extensive practical and nutritional benefits as well as a remedy to cure many fatal diseases. Besides, Moringa has a direct impact on agriculture, water, sanitation, biodiversity and environment.

Nutritional Importance

Every portion of Moringa is fully enriched with vital antinutrients and nutrients. The leaves portion of Moringa is very rich in minerals, vitamins and phytochemicals. The pods of Moringa are also very useful and fully enriched with fibers. These are good remedies for the diseases of thwart colons cancer and digestive problems. The pod and flower contain high amount of linolenic acid, linoleic acid and palmitic acid.

There is great abundance of minerals present in Moringa, of them the most important is calcium. Calcium is highly important for the growth and nourishment. The leaves of Moringa can give up to 4000 mg of calcium. The powder of Moringa leaves can be used as an alternative remedy for iron deficiency in disease of anemia. The amount of other different minerals depends on the climatic conditions, environmental conditions and locality conditions.

Nutritional Facts

1. Contain 4 times calcium than an equal amount of milk.
2. Twice the protein as compared to banana.
3. Moringa tree contains 92 nutrients and 46 antioxidants.
4. Have more Vitamin C than 7 oranges.
5. It is a better source of iron than spinach.
6.It contains 9 essential and non-essential amino acids

Malnutrition

Undernutrition and deficiency diseases are the serious public health problems among the third world countries. Poor accessibility to nutrient rich foods, low purchasing capacity, infection, ignorance are the major causes that thrust the at risk groups towards malnutrition. So a cheap and easily available food product which will be accepted by the mass is highly needed in those countries. Developing as well as the developed countries have now started to explore different species of Moringa and researches have been going on utilisation of this miracle tree " in different ways to tackle malnutrition and deficiency diseases.

Benefits/uses of Moringa

- Used as nutritional, industrial, medicinal, and agricultural advantage
- It is also used as a nutritional supplement.
- *Moringa oleifera* has great potential for prevention of different diseases like nutrient deficiency, cancer, anemia as well as for dirty water purification.
- It increase physical energy - Tune your body up with naturally occurring nutrients to make your energy last longer.
- The seed and leaves are advantageous sources of nutrients, medicines, clean ing dirty water and it can be used for alley cropping; because, it has lots of leafy material.
- The powder contains sufficient amount of vitamins, nutrients and chemicals. This makes the tree a medicine for many different diseases .
- Seeds are usually used for stabilizing blood sugar and improving sleep pattern.
- It is promoted by World Health Organization (WHO) as an alternative to imported food source to treat mal nutrition.

It is concluded that Moringa plant is a miracle plant. It has numerous health and medicinal benefits. It is used to cure more than 300 diseases. It is rich in minerals, vitamins, proteins, fats and phytochemicals. Moringa provides maximum amount of calcium. Moringa has also good activity when used by brain patients as it repairs the memory loss by stopping the release of reactive oxygen. Thus, Moringa has many health benifits and it should be cultivated widely and utilized daily.

Chaithra M. R.
Thava Prakash
Pandian Shivaji
Hausrao Tube
Elain Apshara
Priya U.K
C.T. Jose
Nagaraj N.R.
Bhavishyal
CAR-Central Plantation Crops Research Institute-CPCRI, Regional Station, Vittal-574 243, Karnataka

INTEGRATED MANAGEMENT OF PHYTOPHTHORA DISEASES IN COCOA

Introduction:

Cocoa (*Theobroma cacao L.)* is a shade loving crop mainly grown as a mixed crop in existing coconut, arecanut and oil palm gardens. In India, it is mainly grown in southern states viz., Kerala, Karnataka, Tamil Nadu and Andhra Pradesh. With the increase of cultivable area, the problem of pest and diseases are also increasing. Cocoa is known to be infected by many plant pathogens. Among them, diseases caused by *Phytophthora* are very important due to its economic loss. The oomycete pathogen *Phytophthora palmivora* is ubiquitous and polyphagus in nature.(Chee,1969). On an average the yield loss caused by *Phytophthora* in cocoa varies from 10 to 35 - 40 % but under favourable condition it may reach up to 100 % (Guest, 2007). To overcome this problem adoption of integrated management practices is very much essential. A list of diseases incited by *Phytophthora spp*. are listed below with symptoms and integrated management.

1. Seedling dieback/ Seedling blight

When cocoa beans are

sown during monsoon season we can observe pre and post-emergence damping off of seedlings. In both the cases seedling will die before the emergence from the soil the due to infection by *Phytophthora*. Seedling blight or seedling dieback disease is very severe in cocoa nurseries during monsoon season. Defoliation or dieback of seedlings is the characteristic symptom of this disease. It is also noticed in grafted and budded plants. The infection mainly starts from the grafted or budded region and proceeds upward and down wards causing seedling death.

2. Black pod rot

Black pod rot disease was first noticed in Guyana and West Indies and referred as black cocoa (Jenman and Harrison, 1897). At present it is prevalent in all the cocoa growing countries. In India the disease incidence has been found to vary from 12.93 to 29.78% depending upon locality and the garden (Chandra Mohanan, 1985). Black pod disease occurs during South - West monsoon season as a small circular water soaked lesion on pods, then turns into dark brown lesion. With in, four to seven days, the lesion enlarges and assumes elliptical shape. As the disease progresses, entire pod turns into black color with a white mycelial mat, containing sporangia.

3. Stem canker

In India stem canker disease was first reported in 1978 in cocoa plants grown as a mixed crop in arecanut garden in Karnataka state (Chandra Mohanan, 1978). Stem canker disease appears at different parts of the tree including bark of young seedling and old trees, jorquette and fan branches.

Cankerous symptoms are more pronounced during December i.e., after the rainy season. From infected pods disease spreads to peduncle and then to the cushion and bark causing canker. The external symptom appears as greyish brown water soaked lesion with a broad dark brown to black margin. A reddish brown liquid oozing out from such lesions dries up and forms a rusty deposit.

When the outer bark of the infected portion is removed we can see the greyish brown to black discoloration with black streaks running parallel to each other. When canker girdle the stem it causes dieback symptom due to blockage of vascular tissues, at last whole tree dies.

4. Chupon blight or twig blight

The infection starts as water soaked lesion anywhere on the leaf blade or petiole and extends backward into the stem and later it turns into brown to black colour. The lesion spreads to stem resulting in twig dieback or chupon blight. Lesion on leaves generally starts from the apex or margin of the leaves touching wet soil. Enlargement of lesions leads to blighting,

Fig 1. External symptoms of seedling dieback and seedling blight diseases (a) Die back (b) leaf blight symptom

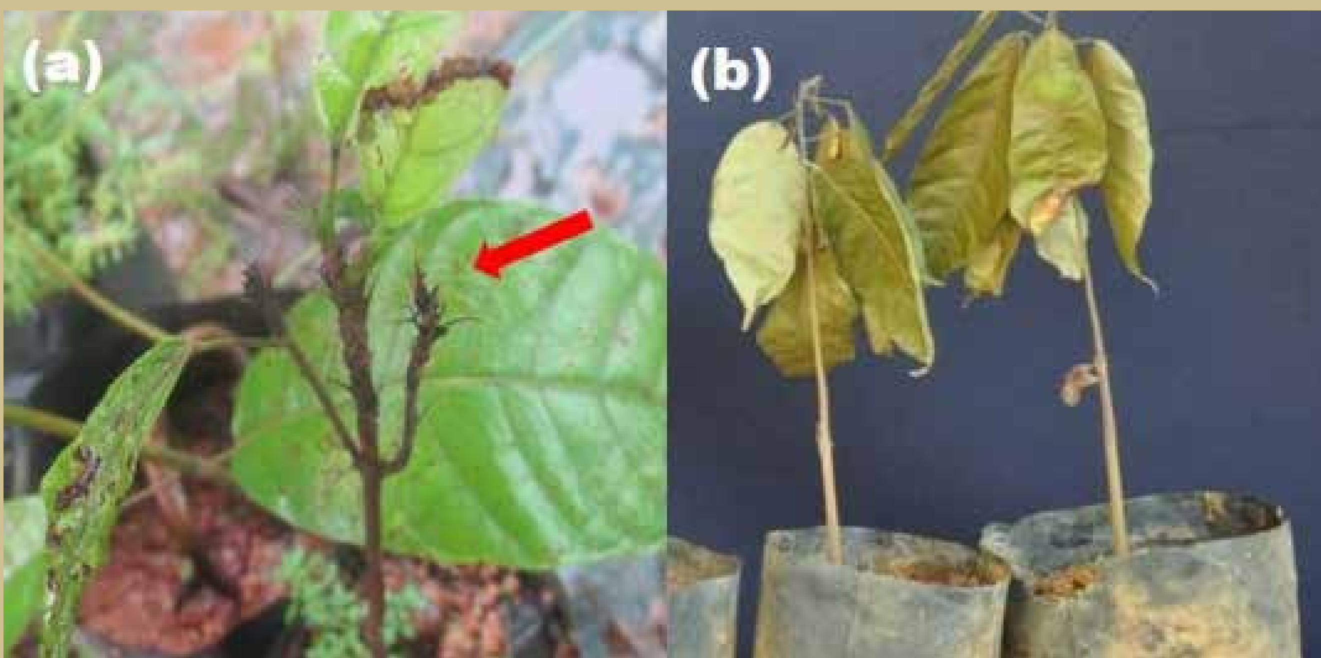


Fig 2. External symptoms of black pod rot disease (a) Chocolate brown colour discoloration on pod surface (b) White mycelial growth on infected pod

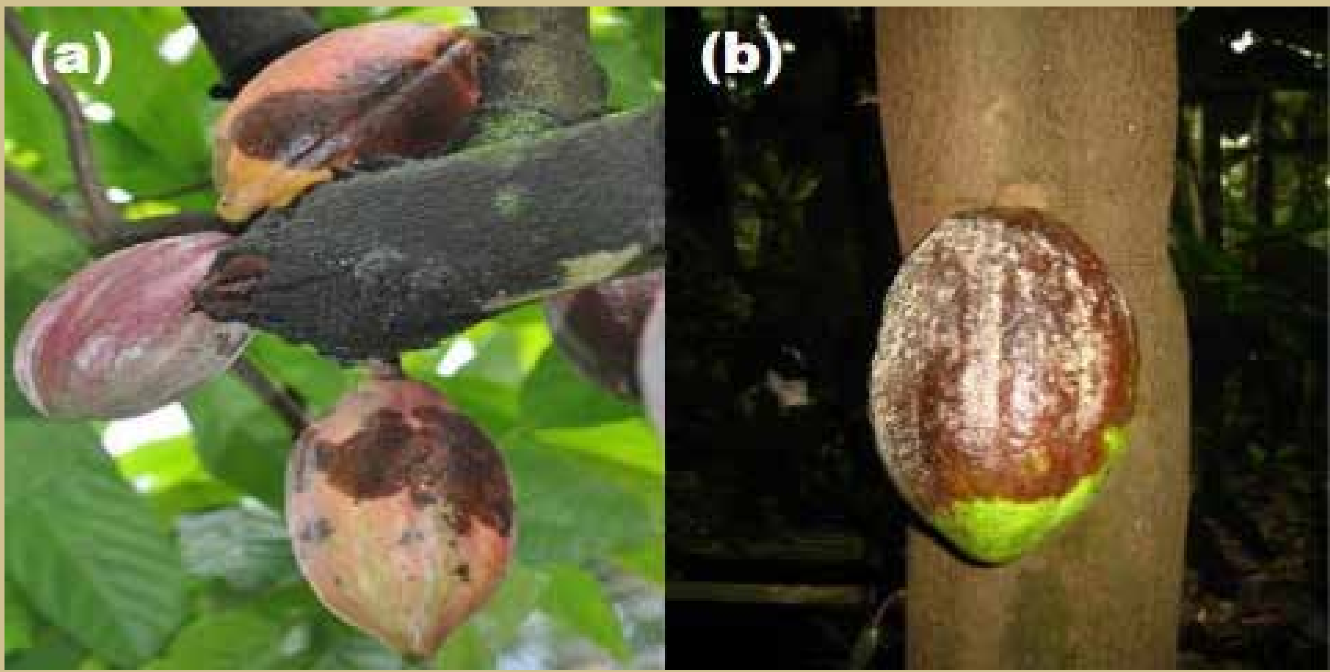
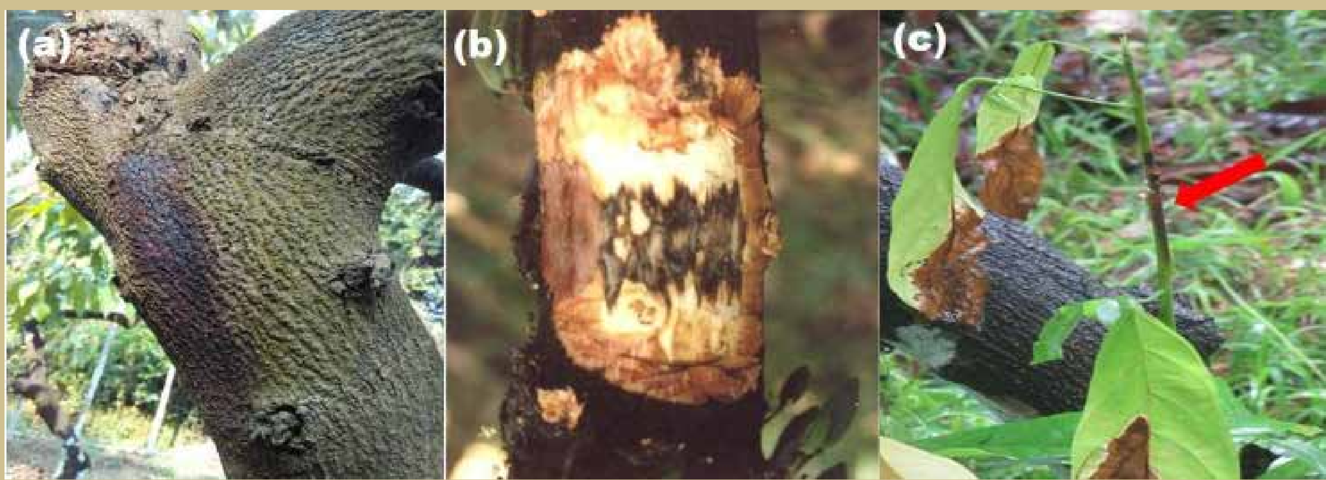


Fig 3. Stem canker symptoms (a) Dark chocolate brown to black discoloration of bark (b) black streaks noticed in cortical tissues (c) stem canker on young seedling bark.



defoliation and dieback of plants (Chandra Mohanan, 1994).

Integrated disease management:

Nursery diseases:

- Before preparing potting mixture, solarise the soil in sun or cover with black polythene sheet for 30 to 45 days during March to prevent nursery diseases.
- To protect germinating seeds from infection complete the sowing in April/ before 15th of May, in high rainfall zones like Kerala and Karnataka.
- Removal and destruction of infected seedlings from the nursery are very important.
- Management practices to check the secondary spread of the disease from nursery to main field.
- Improve the drainage facilities in the nursery to remove the stagnated water during heavy monsoon.
- ***Seed treatment:*** Treat the seeds with seed dressing fungicides i.e., Thiram @ 2g/ kg of seeds or Carbendazim @ 2 g/kg of seeds.
- Seed treatments should be done after removal of mucilage adhering/ surrounding the beans (seeds).
- Bio-priming or seed treatment with 25 g CocoaProbio or *Trichoderma harzianum* (isolate CPTD-28) microbial culture will improve the

Fig 4. Leaf blight symptoms seen on chupon

health of seedlings.

- ***Soil drenching:*** The disease incidence of seedling dieback/seedling blight can be reduced by improving drainage facilities and drenching seedlings with 1% Bordeaux mixture or 0.2% Copper Oxy Chloride before monsoon, then at 15 days interval will reduce the infection.

Black pod rot and stem canker:

- Timely pruning during the months of September-October to avoid self-shading. Self-shading creates microclimate congenial for the growth of Phytophthora.
- Phytosanitation i.e., removal & destruction of fallen leaves and rotten pods
- Preventive spray or pre-monsoon spray of 1% Bordeaux mixture may be given on developed cocoa pods during May month followed by post- monsoon spray after pruning, to the whole tree including main stem, canopy, branches and developing pods.
- With heavy monsoon and bumper bearing, spraying may be repeated at 45 days interval to protect the later/ off- season harvests.
- Stem canker disease can be reduced by, removing infected tissues and applying Bordeaux paste or treating the wounded plant part with Trichoderma coir pith cake and tying it with arecanut leaf sheath with regular watering to facilitate multiplication of bio-control agent.
- To reduce root infection, soil application of *Trichoderma* coir pith cake/ talc based formulation of *Trichoderma* is very useful which helps in reducing the inoculum level in the soil.
- Avoid dumping and heaping pruned branches near trunk/ main stem, clean the basin and improve drainage facilities in the garden.
- Sanitary pruning i.e., removal of chupons arising from trunk and removal of infected/ damaged pods remaining in the tree after main harvest will reduce the load of inoculum and spread of disease.

Chupon blight and twig blight

- It can be controlled effectively by pruning of chupons and infected fan branches.

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