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English journal

The First English farm journal from the house of Kerala Karshakan

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INSIDE

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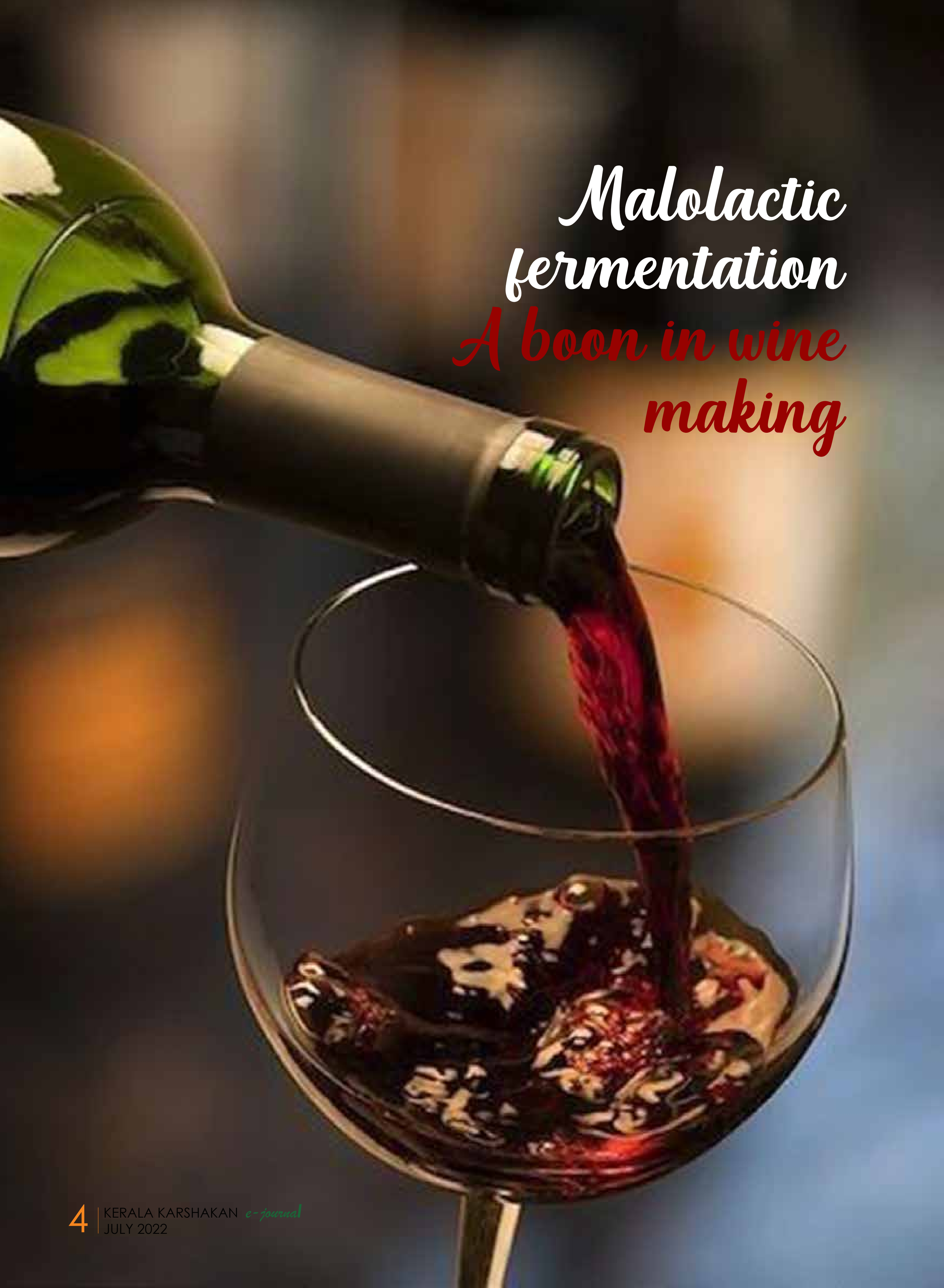

Malolactic fermentation A boon in wine making

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‘Wine is a bottle of poetry”, it is not just a bottle of beverage, it is a blend of art and science.Wine is an alcoholic beverage, made from the fermentation of fruit juices, preferably grapes, using yeast culture as an inoculant. The science of wine and winemaking is known as oenology. A winemaker may also be called a vintner and the process of wine making is called vinification. Wine making normally involves two fermentation processes: an alcoholic fermentation conducted by yeast and malolactic fermentation (MLF) performed by lactic acid bacteria (LAB) containing a malolactic enzyme (MLE). Alcoholic fermentation is a complex biochemical process during which yeasts convert sugars to ethanol, carbon dioxide and other metabolic by-products that contribute to the chemical composition and sensorial properties of the fermented food stuffs. Malolactic

fermentation (MLF) is a secondary fermentation conducted by lactic acid bacteria (LAB) and refers to the decarboxylation of L-malate to L-lactate.

Malolactic fermentation

Malolactic conversion (also known as malolactic fermentation or MLF) is a process in winemaking in which tart-tasting malic acid, naturally present in grape, is converted to softer-tasting lactic acid. Malolactic fermentation is most often performed as a secondary fermentation shortly after the end of the primary fermentation, but can sometimes run concurrently with it. The process is standard for most red wine production and common for some white grape varieties such as Chardonnay, where it can impart a "buttery" flavour from diacetyl, a by-product of the reaction. The fermentation reaction is undertaken by the family of lactic acid bacteria (LAB); *Oenococcus oeni* and various species of Lactobacillus and Pediococcus. Chemically, malolactic fermentation is a decarboxylation, which means carbon dioxide is liberated in the process. The primary function of all these bacteria is to convert L-malic acid, one of the two major grape acids found in wine, to another type of acid, L+ lactic acid. This can occur naturally. However, in commercial winemaking, malolactic conversion typically is initiated by an inoculation of desirable bacteria, usually *O. oeni*. This prevents undesirable bacterial strains from producing "off" flavours. Malolactic fermentation tends to create a rounder, fuller mouthfeel. Malic acid is typically associated with the taste of green apples, while lactic acid is richer and more buttery tasting. Grapes produced in cool regions tend to be high in acidity, much of which comes from the contribution of malic acid. Malolactic fermentation generally enhances the body and flavour persistence of wine, producing wines of greater palate softness. Many winemakers also feel that better integration of fruit and oak character can be achieved if malolactic fermentation occurs during the time when the wine is in barrel. A wine undergoing malolactic conversion will be cloudy because of the presence of bacteria and may have the smell of the buttered popcorn, as the result of the production of diacetyl. The onset of malolactic fermentation in the bottle is usually considered a wine fault, as the wine will appear to the consumer to still be fermenting (as a result of CO_2 being produced).

History

Malolactic fermentation is possibly as old as the history of wine, but scientific understanding of the positive benefits of MLF and control of the process is a relatively recent development. For many centuries, winemakers noticed an "activity" that would happen in their wines stored in barrel during the warm spring months following harvest. Like primary alcoholic fermentation, this phenomenon would release carbon dioxide gas and seem to have a profound change on the wine that was not always welcomed. It was described as a "second fermentation" in 1837 by the German enologist Freiherr von Babo as the cause for increased turbidity in the wine. Von Babo encouraged winemakers to quickly respond at the first sight of this activity by racking the wine into a new barrel, adding sulfur dioxide and then following up with another set of racking and sulfuring to stabilize the wine.

In 1866, LouisPasteur, one of the pioneers of modern microbiology, isolated the first bacteria from wine and determined that all bacteria in wine were a cause for wine spoilage. While Pasteur did notice an acid reduction in wine with the lactic bacteria, he did not link that process to a consumption of malic acid by the bacteria, but rather assumed it

was just tartrate precipitation. In 1891, the Swiss enologist Hermann Muller theorized that bacteria may be the cause of this reduction. With the aid of peers, Muller explained his theory of "biological deacidification" in 1913 to be caused by wine bacterium Bacterium gracile.

In the 1930s, the French enologist Jean Ribereau-Gayon published papers stating the benefits of this bacterial transformation in wine. During the 1950s, advances in enzymatic analysis allowed enologists to better understand the chemical processes behind malolactic fermentation. Emile Peynaud furthered enology understanding of the process and soon cultured stock of beneficial lactic acid bacteria was available for winemakers to use.

Role in winemaking

The primary role of malolactic fermentation is to deacidify wine. It can also affect the sensory aspects of a wine, making the mouthfeel seem smoother and adding potential complexity in the flavour and aroma of the wine. For these reasons, most red wines throughout the world (as well as many parking wines and nearly 20% of the world's white wines) today go through malolactic fermentation.

Malolactic fermentation deacidifies the wine by converting the "harsher" diprotic malic acid to the softer monoprotic lactic acid. The different structures of malic and lactic acids leads to a reduction of titrable acidity (TA) in the wine by 1 to 3 g/l and an increase in pH by 0.3 units. Malic acid is present in the grape throughout the growing season, reaching its peak at veraison and gradually decreasing throughout the ripening process. Grapes harvested from cooler climates usually have the highest malic acid content and have the most dramatic changes in TA and pH levels after malolactic fermentation.

Malolactic fermentation can aid in making a wine "microbiologically stable" in that the lactic acid bacteria consume many of the leftover nutrients that other spoilage microbes could use to develop wine faults. However, it can also make the wine slightly "unstable" due to the rise in pH, especially if the wine already was at the high end of wine pH. It is not unusual for wines to be "deacidified" by malolactic, fermentation only to have the winemaker later add acidity (usually in the form of tartaric acid) to lower the pH to more stable levels.

Conversion of malic into lactic

Lactic acid bacteria convert malic acid into lactic acid as an indirect means of creating energy for the bacteria by chemiosmosis which uses the difference in pH gradient between inside the cell and outside in the

wine to produce ATP. One model on how this is accomplished notes that the form of L-malate most present at the low pH of wine is its negatively charged monoanionic form. When the bacteria move this anion from the wine into higher pH level of its cellular plasma membrane, it causes a net-negative charge that creates electrical potential. The decarboxylation of malate into L-lactic acid releases not only carbon dioxide but also consumes a proton, which generates the pH gradient which can produce ATP.

Lactic acid bacteria convert L-malic acid found naturally in wine grapes. Most commercial malic acid additives are a mixture of the enantiomers D+ and L-malic acid

Sensory influences

Many different studies have been conducted on the sensory changes that occur in wines that have gone through malolactic fermentation. The most common descriptor is that acidity in the wine feels "softer" due to the change of the "harsher" malic acid to the softer lactic acid. The perception of sourness comes from the titratable acidity in the wine, so the reduction in TA that follows MLF leads to a reduction in perceived sour or "tartness" in the wine.

The change in mouthfeel is related to the increase in pH, but may also be due to the production of polyols, particularly the sugar alcohols erythritol and glycerol. Another factor that may enhance the mouthfeel of wines that have gone through malolactic fermentation is the presence of ethyl lactate which can be as high as 110 mg/l after MLF.

The potential influence on the aroma of the wine is more complex and difficult to predict with different strains of *Oenococcus oeni* (the bacterium most commonly used in MLF) having the potential to create different aroma compounds. In Chardonnay, wines that have gone through MLF are often described as having "hazelnut" and "dried fruit" notes, as well as the aroma of freshly baked bread. In red wines, some strains metabolize the amino acid methionine into a derivative of propionic acid that tends to produce roasted aroma and chocolate notes. Red wines that go through malolactic fermentation in the barrel can have enhanced spice or smoke aromas.

However, some studies have also shown that malolactic fermentation may diminish primary fruit aromas such as Pinot noir, often losing raspberry and strawberry notes after MLF. Additionally, red wines may endure a loss of colour after MLF due to pH changes that causes a shift in the equilibrium of the anthocyanins which contribute to the stability of colour in wine.

Conclusion

MLF is a traditional issue in enology that has continuing relevance in modern wine making. As it has been discussing, MLF plays a substantially beneficial role by reducing the wine total acidity (making wines more palatable as result of the loss of strong green taste), contributing to the stabilization and enrichment of aroma and flavour complexity (releasing of great amount of volatile compounds) and imparting microbiology stability to wines.

CLIMATE ADAPTATIONS

VITAL UNDER COCONUT BASED FARMING SYSTEMS OF KERALA

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One who watches the wind will not sow and one who looks at the clouds will not harvest

The proverb becomes meaningful in the changing climatic scenario and reminds on the need for adaptations in the farming sector to cope with the climate vulnerabilities. Farm level awareness on climate change and understanding of climate parameters, crop planning based on weather forecast and field level adaptations for climate resilience are the key factors to

be considered for successful farming under the challenging conditions.

Agriculture, mostly being rainfed in Kerala is influenced by the vagaries of climate. Changes in rainfall patterns play a greater role in crop production than temperature variations. We all witnessed the intensity of crop loss during the flood of 2018 and consequences of heavy rains in Northern Kerala during 2019. Reduction in summer rains to the tune of 50-60% also has been a regular phenomena, resulting in severe drought during summer months. Variations in the monthly availability and distribution of rainfall, mostly due to more number of depressions and cyclones also can affect the production of various crops. Even distribution of rainfall shows wide variations between districts also. Apart from rainfall and temperature, variations in humidity, sunshine and day and night temperature can also affect crops to a greater extent. Due to such extreme variations, regular occurrence of flood, water logging, drought, saline water intrusion, soil erosion and landslides became so common. Apart from crop loss, decrease in productivity to the tune of 15-20% also has been reported due to climate vulnerabilities.

Influence of Climate change on Agricultural Production

(a) Changes in the availability and distribution of rainfall

Drastic changes in the availability of rainfall and distribution are observed during the past 10-15 years, indicating a reducing trend and erratic distribution. The average rainfall during the past 10 year period has been reduced to 2300mm from the normal 3000mm. However increase in rainfall availability was recorded during 2018-2020. We were unfortunate to face the challenges of both water logging and drought almost every year during the past decade. Trend analysis of climatic variables during 2011-2020 revealed an increasing trend in rainfall and rainy days during August-December. But during 2017-2020, rainfall showed an increasing trend from May to August and November and rainy days showed decreasing trend except in September month. Increase in total rainfall and decrease in number of rainy days indicate high intensity rainfall for shorter periods resulting in frequent floods and heavy runoff to major water bodies without conservation in soils. Hence, awareness needs to be created to conserve water in ponds/rain pits/small watersheds so as to reduce frequent floods and also to conserve water for summer months as the droughts may be

severe during such years.

While the huge loss of annual crops due to erratic and untimely rainfall are being reported, the gradual loss in case of plantation crops like coconut remains unaccounted except for that of coconut seedlings.

(b) Variations in atmospheric and soil temperature

In case of temperature, maximum temperature showed a decreasing trend during 2011-2020 period except in February and November. During 2017-2020, increasing trend was observed during entire period except July and September. Minimum temperature showed increasing trend from February to November in 2011-2020 period except during June and October. During 2017-2020 period, increasing trend was noticed From March to December except in April, June and October. During the last decade, an increase in the average temperature to the tune of 1.5^{0}C with a maximum temperature above 36^{0}C and that of soil having 48^{0}C, resulting in low soil moisture level and low humidity. Even in high rainfall years too, we are experiencing water scarcity and drought from December to April/May, resulting in adversities. In case of coconut, this may influence development of inflorescence and buttons, in addition to the drooping of fronds and shedding of buttons and immature nuts. The effect of drought in terms of production loss may last for a period of 8-13 months. Reduction in monsoon rains and summer rains affect all crops including annuals, plantation crops and all other commercial crops, Analysis of weather parameters indicate a declining trend in total rainfall after 2010 and consequent reduction in number of rainy days except in abnormal years (2017-2020). Minimum temperature showing an increasing trend after 2010 which has potential to increase evaporation demand though at present values are about 3.5mm/day. With decreasing rainfall and steady evaporation chances of increased moisture deficit in the soil during non rainy season is increasing which can affect all the crops.With increase in temperature, volume of sea water increases. This may cause the sea waves to gain strength and height resulting in more erosive power. Coastal areas are becoming increasingly vulnerable to erosion by waves.

Coconut faces moisture deficit during December to April under rainfed cultivation. If summer rainfall is less, the situation aggravates. Diversification of crops and moisture conservation measures need to be encouraged to maintain optimum soil temperature, ensure ideal microclimate and to promote soil biodiversity. Moisture conservation activities like, summer ploughing, mulching with palm leaves/coir pith, husk burial, green manuring and green leaf manuring, application of composts for soil tilth and moisture conservation are recommended. Summer irrigation with increased water application efficiency (sprinkler,drip etc.) is most ideal in future water scarce scenario.

(c) Reduction in Relative humidity

Decreasing trend in rainfall and increasing trend in soil and atmospheric temperature results in reduction in relative humidity. This may result in more evaporation and transpiration losses, further adding to the consequences of drought. Reports indicate the impact of reduced relative humidity in terms of low germination levels and decreased storage period, pointing to the need for studies on the local methods followed by farmers for storage of seeds.

Measures of Adaptation to cope with Climate change

Farmers always practice some adaptive measures with changes in the weather conditions. Moreover technological advances helps farmers to tide over adverse conditions. Since climate change is a phenomenon experienced by farmers in their own fields, studies on adaptive capacity and related changes in the vegetative and reproductive behaviour of crops, and refinement for the local situations needs to be observed in the farmers field itself. The measures of adaptation as modified by field situations in different locations may be compiled and recommended for similar situations elsewhere. This field testing and refinement will improve the efficacy of technologies.

Changes occurring in Agriculture due to climate change and management practices required.

Climate change is increasing the frequency of climate vagaries like, flood, water logging, drought, sea

water inundation and increasing salinity of coastal areas, soil erosion resulting in crop loss and yield decline in crops. Hence crops and varieties suitable to the local climate needs to be selected to minimise losses. More over adjustments needs to be made in planting time to avoid periods of variability in climate parameters. Changes in management practices also need to be followed.

Cropping / farming systems suited to different Agro-ecological Units need to be planned based on recent weather events. In potential waterlogged areas, as an adaptive measure, fish farming may be promoted. The ponds for fish farming also need to be planned in such a way that water conservation is promoted avoiding water stagnation as a result of water storage and conservation. Raising duck and poultry in special cages built over water bodies are a viable option under such conditions to enhance farmers' income. In areas where salinity due to sea water inundation is prevalent, management practices needs to be modified with tolerant varieties and cultivation practices. To reduce the impact of salinity, soil moisture is very essential. Hence mulching and intermittent small irrigations can be practiced. Practices like, small mount formation in fields, Pokkali farming practices and other traditional farming methods based on farmers wisdom needs to be promoted.

In sloppy areas, slope may be broken by terracing to reduce accelerated flow of water and to help slow percolation into the soil. It is advisable to plant annuals and grasses with spreading root system (Like vetiver and fodder grasses) on the sides of slope to prevent soil erosion. Slops of waterways can be lined with carpet grass and geo textile mulches to reduce erosion and obstruction to flow of water.

In upland areas which are drought prone during dry season, practices like pits for rainwater harvesting, husk burial, coir pith mulching, mulching with biomass, multiple cropping for crop residue addition, water saving micro irrigation measures and such other measures may be adopted.

In areas with recurring floods, like kuttanad, there is always loss of nutrients and organic matter from the surface soil. Hence, it is better to apply the first split dose of nutrients to crops with the end of summer showers, before the onset of monsoon. Sowing green manure crops with the onset of monsoon will provide a green cover to

reduce the erosive power of rainwater and will help to reduce erosion. Use of slow release fertilizer compounds are ideal for flooded areas to increase the fertilizer use efficiency. Immediately after receding of floods, inter cultivation of soils/ ploughing needs to be done and dolomite/lime may be applied to reduce acidity. Then application of organic manures and other nutrients may be done to reduce soil hardening and surface crusting.

Protected cultivation is advisable under aberrant weather conditions to sustain the productivity and production of high value crops. Low cost rain shelters, poly houses and vertical farming are important for such conditions.

Pest and disease management

With gradual increase in mean temperature of atmosphere, sucking pests are becoming widely prevalent in crops. New pests are also emerging under this scenario. Emergence of new pests like Mite and White fly and flare up of Coreid bug in coconut plantations are the best examples. To tide over this, it is always advisable to follow multiple cropping and crop cafeteria approach, which can reduce the temperature in the crop lands and maintain an ideal micro climate for crops. Trap crops like marigold are useful in annual crops to reduce pest attack. To promote pollination, flower crops as intercrops may be promoted with honey bee farming. Due to water logging and increased acidity of soils, fungal diseases proliferates towards the end of rainy season. Application of dolomite/lime during the onset of monsoon, may reduce this incidence. Biological measures including utilization of native microbes for plant growth and pest and disease management needs to be explored.

Weed Management

Weeds cause huge loss in productivity of crops which farmer may not recognize during farming. Multiple cropping, inter cultivation, mulching, use of organic manures, split application of nutrients etc. may reduce the weed growth. Mechanical and biological control of weed and its incorporation in soil can improve organic carbon content in soil.

Social adaptation practices

Apart from adaptation practices followed by farmers, societal awareness and vigilance on climate change and its implications on farming and daily life needs to be created. Uncontrolled exploitation of natural resources and wastage of resources needs to be strictly avoided. Common property resources needs to be protected and its encroachment may be made punishable. Private and public water bodies should be protected and regular maintenance and upkeep may be followed. As far as possible, every person, households and farmers should conserve water falling in his compound/farm. Protecting our hillocks, trees and promoting social forestry should become the responsibility of every citizen. Only with a joint responsibility of our society, we can reduce green house gas emissions and improve its capture, ultimately leading to enhanced soil carbon content leading to favourable climate for sustainable farming and for benefit of humanity.

Conclusion

Climate change awareness is critical in bringing sustainability in agricultural sector as the vulnerability to climate change impacts is very high. Currently, the awareness on climate variability, vulnerabilities and its consequences in the agricultural sector are reported to be low to moderate with a high adaptation deficit among all stakeholders at grass root level. However, the feasibility and success of the adaptation measures vary from one location to another, even within the Agro-Ecolological Uints, necessitating the location specific standardization of technologies, further emphasizing the need to conduct climate related research under real field situations.

Scientific validation and refinements of local adaptation measures can be undertaken in multiple locations on a community approach so as to ensure faster delivery on a wider scale. The role of Government and related public and private sectors is crucial in creating public awareness on climate change and its impacts and in promotion of public participation in development of policies and actions to combat climate change.

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The UN's millennium development goals (MDGs) of 2000-2015 for a better world free from hunger were later on succeeded by 'The Agenda 2030' for Sustainable Development and India is a signatory to it. The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. At its heart are the 17 sustainable development goals (SDGs), which are an urgent call for action by all countries - developed and developing - in a global partnership. They recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education,

CLIMATE RESILIENT AGRICULTURE

FRAMEWORK AND WAY FORWARD FOR KERALA

reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests. The SDG 2 aims at ending hunger, achieving food security and improved nutrition and promoting sustainable agriculture. The United Nations summit for the adoption of the post-2015 development agenda was held from 25-27 September 2015, in New York and convened as a high-level plenary meeting of the General Assembly.

After decades of steady decline, the number of people who suffer from hunger – as measured by the prevalence of undernourishment – began to slowly increase again in 2015. Current estimates show that nearly 690 million people are hungry, or 8.9 percent of the world population – up by 10 million people in one year and by nearly 60 million in five years.The world is not on track to achieve Zero Hunger by 2030. If recent trends continue, the number of people affected by hunger would surpass 840 million by 2030.

Food Security

The World Food Summit, took place from 13-17 November 1996at FAO headquarters in Rome, was called in response to the continued existence of widespread undernutrition and growing concern about the capacity of agriculture to meet future food needs. This historic event comprised five days of meetings at the highest level with representatives from 185 countries and the European Community. According to World Food Summit, 1996 'food security is achieved 'when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life'. So originally, the term 'food security' was used to describe whether a country had access to enough food to meet dietary energy requirements. In 2001, The State of Food Insecurity Report redefined it as 'food security is achieved when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life'.This new emphasis on consumption, the demand side and the issues of access by vulnerable people to food, is most closely identified with the seminal study by Amartya Sen.A household is considered food secure if it has the ability to acquire the food needed by its members to be food secure.

India has experienced remarkable economic growth in recent years and remains one of the fastest growing economies in the world. However, poverty and food insecurity are still areas of concern in spite of many strides. In 2021, India ranked 101 among 116 countries according to the Global Hunger Index (GHI). The Global Hunger Index (GHI) is a tool that measures and tracks hunger globally as well as by region and by country, prepared by European NGOs of Concern Worldwide and Welthungerhilfe. The GHI is calculated annually, and its results appear in a report issued in October each year.Thus, while the food security situation is progressively improving, access to balanced food is problematic for the vulnerable population. India implements one of the largest food security measures in the world, the National Food Security Act 2013.

It addresses the availability, accessibility and affordability dimensions of food security. Enacted on July 5, 2013, the act legally entitles upto 75% of the rural population and 50% of the urban population to receive subsidized food grains under targeted public distribution system (TPDS).

Climate variability and extremes are one of the most important drivers of recent food security trends. Though India is the world's largest producer of milk, pulses and jute; second largest producer of rice, wheat, sugarcane, groundnut, vegetables, fruits and cotton; and also one of the leading producers of spices, fish, poultry, livestock and plantation crops, climate vagaries have been very seriously affecting the crop output. Fifty-one per cent of the net cultivated area in India is rainfed contributing 44% of annual food production. Hence our country's food security is closely linked with rainfall. Timely onset and spatial distribution of south west monsoon (June-September) rainfall is crucial for farming and kharif crops account for 85 percent of paddy, 71 percent of coarse cereals and 66 percent of oilseeds production in India. Our country is facing recurrent droughts in the recent past and during the period 1801-2019, there were 45 drought years of which eight years were the severe drought years and all these occurred during the past 50 years. It has been estimated that negative impacts of climate change would reduce crop yields by 4.5 – 9%. Since agriculture contributes about 15% of country's GDP, a 4.5-9% negative impact implies that the cost of climate change would be 1.5% of GDP per year.

Climate Resilient Agriculture

As climate aberrations have become a regular occurrence, developing practices to cope with such stresses has become very essential. Climate resilient agriculture (CRA) involves integration of adaptation, mitigation, and other practices in agriculture which increases the capacity of the system to respond to various climate-related disturbances by resisting or tolerating the damage and recovering quickly. Such perturbations and disturbances can include events such as drought, flooding, heat/cold wave, erratic rainfall pattern, long dry spells, insect or pest population explosions, and other perceived threats caused by changing climate. The CRA includes an inbuilt property in the system for the recognition of a threat that needs to be responded to, and also the degree of effectiveness of the response and focuses on judicious and improved management of integrated genetic resources along with natural resources namely, land, water, and soil through adoption of best management practices. Climate resilient agricultural practices are crop and location specific and can be tailored to fit into the agroecological and socioeconomic conditions and priorities of farmers. It is an integrative approach to address the interlinked challenges of food security and climate change that explicitly aims for three objectives: (1) sustainably increasing agricultural productivity to support equitable increases in farm incomes, food security, and human development; (2) adapting and building resilience of agricultural and food security systems to climate change at multiple levels, and (3) reducing greenhouse gas (GHG) emissions from agriculture (including crops, livestock, and fisheries) to the extent possible. It also consists of elements of preparedness such as documentation of aberrant weather conditions, weather-based agroadvisory, awareness about the impacts of weather, etc. In case of water, resilient practices consist of aquifer and groundwater recharge, in situ moisture conservation, farm ponds, efficient application system, etc. Some of the crop-based practices consist of drought- and flood-tolerant varieties, intercropping systems, etc. and interventions related to carbon, fertilizer, and institutions in the village.

CRA Frame work

Several improved agricultural practices evolved over time for diverse agro-ecological regions in India have potential to enhance climate change adaptation, if deployed prudently. The National Innovations in Climate Resilient Agriculture (NICRA), a mega project started by ICAR-CRIDA, Hyderabad in 2011 and being currently implemented in 100 districts involving over one lakh farm families across the country has set certain golden standards based on ground level data over the past ten years for successful CRA practices implementation. Village level interventions towards climate resilient agriculture can be grouped into ten major categories and this will form an ideal framework in developing a future CRA practice at village level. Since the village concept is different in Kerala state as the rural urban divide is vague, panchayat can be considered as the unit for preparation of contingency plans.

1. Building resilience in soil

Soil health is the key property that determines the resilience of crop production under changing climate. A number of interventions are made to build soil carbon, control soil loss due to erosion and enhance water holding capacity of soil, all of which build resilience in soil. Mandatory soil testing will have to be done to ensure balanced use of chemical fertilizers. Improved methods of fertilizer application such as site specific nutrient management (SSNM) following 4R nutrient stewardship and foliar nutrition using nano fertilizers matching with crop requirements reduce nitrous oxide emissions.

2. Adapted cultivars and cropping systems

Improved, early duration drought, heat and flood tolerant varieties for achieving optimum yields despite climatic stresses are important. For enabling this varietal shift, establishment of village level seed production systems and linking farmers decision-making to weather based agro advisories and contingency planning are most crucial.

3. Rain water harvesting and recycling

Farm ponds, restoration of old rainwater harvesting structures in dryland / rainfed areas, percolation ponds for recharging of open wells, bore wells and injection wells for recharging groundwater are to be given importance to enhance farm level water storage.

4. Water saving technologies

Since climate variability manifests in terms of deficit or excess water, major emphasis need to be given on introduction of water saving technologies such as direct seeded rice, zero tillage and other resource conservation technologies (RCT), which also reduce greenhouse gas (GHG) emissions besides saving of water.Laser levelling, drip and sprinkler irrigation and fertigation also need to be widely practised for increasing water and nutrient use efficiency and reduced GHG emissions.

5. Farm machinery (custom hiring) centres

Community managed custom hiring centres will have to be set up in each village to access farm machinery for timely sowing / planting. This is a very important intervention to deal with variable climate like delay in monsoon and inadequate rains requiring replanting of crops.

6. Crop contingency plans

ICAR-Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad has developed district agricultural contingency plans (DACP) for more than 650 districts of our country. These are technical documents containing integrated information on agriculture and allied sectors such as horticulture, livestock, poultry, fisheries and technological solutions for all the major weather related aberrations including extreme events viz., droughts, floods, heat wave, cold wave, untimely and high intensity rainfall, frost, hailstorms, pest and disease outbreaks and are aimed to be utilised by district authorities. The DACP documents are available for all 14 districts in Kerala and can be downloaded from their website. Operationalization of these plans during aberrant monsoon years through the district / block level extension staff helps farmers cope with climate variability.

7. Livestock and fishery interventions

Use of community lands for fodder production during droughts / floods, improved fodder / feed storage methods, feed supplements, micronutrient use to enhance adaptation to heat stress, preventive vaccination, improved shelters for reducing heat / cold stress in livestock, management of fish ponds / tanks during water scarcity and excess water are some key interventions in livestock / fishery sector.

8. Weather based agro advisories and AI enabled smart farming

Automatic weather stations need to be established in all villages to record real time

weather parameters such as rainfall, temperature, wind speed etc. and they need to be linked to artificial intelligence (AI) enabled smart farming devices such as electronic crop (e-Crop) designed by ICAR-CTCRI, Thiruvananthapuram, Kerala so that customized agro advisories as well as near real time agrotechniques can be communicated via SMS to the farmers.

9. Institutional interventions

We can either strengthen the existing institutions or initiate new ones relating to seed bank, fodder bank, commodity groups, custom hiring centre, collective marketing, introduction of weather index based insurance and climate literacy through a village level weather station can be introduced to ensure effective adoption of all other interventions and promote community ownership of the programme.

10. Village climate risk management committee (VCRMC)

A village level committee representing all categories of farmers including women and landless will have to be formed with approval of grama panchayat to take all decisions regarding interventions, promote farmers participation and convergence with ongoing government schemes relevant to climate change adaptation. This committee will have to participate in all discussion leading to finalization of interventions, selection of target farmers and area, and liaison with gram panchayat and local elected representatives and maintain all financial transactions.

Way Forward for Kerala

Problems related to climate change are location specific and issues vary from year to year, season to season and from village to village. Table 1 shows the seasonal rainfall received in Kerala during the past three years in comparison to the normal receipt which is the average of past 30 years. It has now become very clear that unpredictable weather aberrations have become a routine affair. The important climatic constraints facing Kerala state are increased rainfall, periodic flooding, increased intensity of rainfall, shifting seasonality of rainfall, more variable summer precipitation, decreased rainfall, increased drought, increased average temperature, increased minimum temperature and extreme high temperature events.

In order to address the issues related to impact of climate change on Kerala agriculture, following action points are

Table 1. Variations in seasonal rainfall in Kerala since 2020 vis a vis normal rainfall

Season	2019	2020	2021	2022	Normal
Winter (January-February)	13.1	9.6	114.1	14.9	22.4
Pre-monsoon (March-May)	169.6	387.5	750.9	668.5	361.5
South-west monsoon (June-September)	2309.8	2227.9	1718.0	-	2049.2
North east monsoon (October-December)	626.8	365.3	1026.3	-	491.6
TOTAL	3119.3	2990.3	3609.3	-	2924.7

suggested to be considered in future plan programmes.

1. AEU based agricultural contingency plans (AACP)

Detailed agricultural contingency plans for all 23 agro ecological units (AEUs) need to be prepared. These are technical documents that are ready reckoner for agriculture department and farming community. A standard template can be developed in detailed consultation with all stakeholders to cover prevailing agro-ecological situations towards preparedness and suggested adaptive strategies. The AACPs can be prepared by Kerala Agricultural University (KAU) as nodal point along with ICAR institutes in Kerala, KVKs and Department of Agriculture and Farmers Welfare. Five agro ecological zone (AEZ) based workshops can be conducted to nodal officers of each zone to sensitize them about the template developed. Later on at each AEZ level, vetting workshops involving all officials in the zone can be organized to scruitinize and finalize the plan.

2. Panchayat agricultural contingency plans (PACP)

As the physiography, topography and climate related issues are highly location specific in Kerala state, separate panchayat agricultural contingency plans (PACP) need to be developed to serve as a rule book for all possible climate related contingency plans for the panchayat. All these technical documents should be made available in public domain as is available for more than 650 districts of India at https://agricoop.nic.in.

3. Linking plans with action

In order to sensitize all line departments to respond to various weather aberrations affecting agriculture sector, interface meetings before commencement of cropping season will have to be regularly organized. A proper mechanism needs to be evolved for coordination among all departments for timely action.

4. Establishment of climate resilient villages (CRV)

Based on the major climate related issues and farming system typologies in each AEU, model climate resilient villages (CRV) should be established in selected villages across the state. This is very important to address the issues related to climate variability and to enhance the adaptive capacity of communities, extensive farmer participatory demonstrations of location-specific technologies need to be initiated on farmers' fields in all 23 AEUs.

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BIODIVERSITY COOLS EARTH'S AMBIENCE

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Draping a cotton wear, relishing a vanilla ice cream or an avocado milk shake refresh us on a warm summer day! Will that be an utopian dream for our future generations?

Apparently the facts appear so bleak, as per a 2021 research article published, in journal plants, people, planet by a collaborative team of scientists led by

Barbara Goettsch of IUCN, UK. According to their studies, the wild relatives of vanilla, cotton, avocado and potato rank the top positions in the red list of threatened plants and animals of the International Union for Conservation of Nature (IUCN). And the reason for their dwindling is climate change!

Among the 224 crop wild relatives analysed in Mesoamerica, 35% of all species are on the verge of extinction. Wild relatives of crop plants are rich sources of genetic diversity that help crops to adapt to extreme environmental conditions. Mesoamerica, cradle of crop domestication comprising Mexico, Guatemala, El Salvador and Honduras is the centre of origin of most staple food crops currently in use around the world.

Climate change and global warming

Climate change indicates the long term change in average weather patterns, locally and globally due to human mediated global warming and natural calamities like hurricanes,

volcanic eruptions, floods, wildfires or droughts. Scientists make use of the observations from Earth's surface, air and space along with theoretical models to monitor and study past, present and future climate change. The climate data records offer proof of key climate change indicators like rising sea levels, global land and ocean temperature hikes, loss of ice in Earth's poles and mountain glaciers. The Nobel Prize in Physics 2021 was awarded a half, jointly for Syukuro Manabe and Klaus Hasselmann "for the physical modelling of Earth's climate, quantifying variability and reliably predicting global warming".

Global warming refers to the long term heating up of earth's atmosphere since pre- industrial times (between 1850 and 1900). The emitted greenhouse gases (mainly carbon dioxide, methane, nitrous oxide, chlorofluorocarbons) due to unscrupulous human activities, gets trapped in and thereby increase the global surface temperature. These activities include burning of fossil fuels, commercial livestock production, agriculture, air travel, deforestation and unscientific land use practices. Since pre-industrial times the average increase in atmospheric temperature has been 1°C and currently the rise is at an alarming rate of 0.2°C in every decade, according to NASA reports.

Biodiversity: common concern for humankind

Convention of Biological Diversity/ CBD is an international treaty, first of its kind, meant for a sustainable future, through the conservation of ecosystems, species and genetic resources. In 1992, at the Rio Earth summit in Brazil, under the aegis of the United Nations Environment Programme, 196 nations signed the multilateral

treaty. CBD aims for preserving biodiversity, making sustainable use of the components, along with fair and equitable sharing of benefits to the custodian farmers, arising from the use of genetic resources. The latter was developed as a supplementary agreement in 2010, known as Nagoya Protocol on Access and Benefit Sharing. CBD's governing body is the conference of parties/ governments (COP) that ratified the treaty. The parties are legally bound to follow the

Carbon capture and storage unit in Iceland

Legally approved lab grown meat in Singapore

goals or provisions of CBD, in their respective nations.

National Biodiversity Authority & State Biodiversity Boards

India became a signatory of CBD in 1994 and the parliament passed Biological Diversity Act (BDA) in 2002. The act mandates implementation of CBD goals, established by the National Biodiversity Authority in 2003 as a statutory autonomous body under the Ministry of Environment, Forest and Climate Change. NBA with its headquarters in Chennai has been facilitating, advisory and regulatory functions to the Government of India on matters of biodiversity conservation, sustainable utilization of bioresources, access to genetic resources along with fair and equitable sharing of benefits arising from their utilisation (access benefit sharing-ABS). NBA advises state governments to choose and notify under the act, those areas of biodiversity importance as heritage sites along with their management.

As a decentralised channel of commitment to Biological diversity Act (BDA), state biodiversity boards (SBB) were established and they are functional in all the 29 states as statutory autonomous bodies. SBB advises the State government, subject to any guideline issued by the Central government, on matters relating to conservation of biodiversity, sustainable use of its components, fair and equitable sharing of benefits arising from use of biological resources. Besides, SBB regulates, by granting of approvals or requests for commercial utilisation of bioresources or conducting biosurveys by Indian applicants. The Kerala State Biodiversity Board was established with its headquarters at Thiruvananthapuram in 2005, based on BDA, Biological Diversity Rules 2004 and later implemented Kerala State Biodiversity Rules of 2008.

The BDA mandates every self-governing institution in rural and urban areas to constitute a Biodiversity Management Committee (BMC) within their area of jurisdiction. In consultation with local people, BMC must prepare a People's Biodiversity Register (PBR) consisting of all the traditional knowledge regarding flora and fauna of the area and act as the custodian of these rich bioresources by conserving them for future generations. The law pinpoints commercial utilisation of these plant, animal, microbial or aquatic resources only through prior consent, ensuring a fair and equitable share of the revenue reaping out of it, to the BMC.

Paris Agreement & IPCC report

The United Nations Climate Change Conference in 2015 near Paris framed the Paris agreement signed by 195 nations. The agreement aims at reducing the rise in global temperature since pre-industrial times below 2°C, preferably by 1.5°C by 2050. Carbon neutrality or net-zero emissions of carbon dioxide (CO_2) by removing or eliminating emissions from society is the only way to achieve the goal. More than 700 billion tonnes of CO_2 must be removed from the atmosphere to attain the 1.5°C rise in temperature by 2100. The sixth and recent report of the Intergovernmental Panel on Climate Change (IPCC) made it clear that the global temperature will exceed the ambitious 1.5°C within one or two decades in the current scenario!!

Global efforts for mitigating climate change

The largest carbon capture plant Ocra, is a patented innovation of direct air capture technique developed by a Swiss firm Climworks in association with its subsidiary Carbfix in Iceland. CO_2 sticks to the filter while passing air through it. The sucked CO_2 is dissolved in underground water and gets mineralised to carbonates known as calcites. The Ocra unit removes 4000 tonnes CO_2 per year while the firm aims for 10 billion tonnes by 2050. Currently this is a very costly affair as the company claims 1000 $ per tonne of CO_2 sequestered!

Industrialisation promoted the development of agriculture and livestock production as commercial entities. According to a 2021 study published in the scientific journal Nature foods by Xiaoming Xu the emission of greenhouse gases (GHG) from the food system contribute 35% of the total anthropogenic emissions. Among the plant based commodities rice made a share of 12% whereas beef contributes 25% of GHG in animal based food. Nowadays, lab grown meat and plant based mock meats are gaining momentum even in developing countries with an eye on carbon reduction. Singapore is the first nation to get a legal approval for the lab grown chicken nuggets in 2020.

India contributes one third (1.96 t CO_2) compared to the world per capita (6.55 t CO_2) GHG emission. Based on the data pooled for a period from 2000-2019, global risk index (2021) identified India as the 7th worst affected country that faced severe cyclones and prolonged monsoon rainfall due to climate change. Climate risk index (CRI) acts as a warning for countries to expect and get prepared for such extreme weather events in future as well. Post Paris agreement commitments of India includes an ambitious 450 GW renewable energy capacity launching mega solar and green hydrogen mission. Besides, NITI Aayog proposed "Shoonya" campaign for adopting and popularising electronic vehicles intending zero emission and curbing environmental pollution.

Nature based solutions for managing climate change include maintenance of natural carbon sinks like plants, animals and microbes in the ecosystem. They play a key role in natural nutrient cycling. Cultural practices like afforestation, agroforestry for conserving locally available breeds, landraces and varieties of plants, animals and microbes helps indigenous people earn benefit through ecosystem resilience.

Avoid unscientific land use patterns, monocropping and popularisation of water intensive crops, instead, include diversity of species that makes the ecosystem self reliant. Strong political will, open mindedness in policy making and uncompromising resolve for reducing CO_2 emission as an individual motto/social responsibility adds on combating climate change.

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Genome Editing

The new buzz word in the fight against insect pests

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The mention of gene editing may conjure up images of rampaging dinosaurs and mad scientists, but this image is far from the truth. But after all, it is not only about dinosaurs and Jurassic World.

The goal of a genome editing experiment is to convert a targeted DNA sequence into a new, desired DNA sequence (or sequences) in the native context of a cell's genome. The recent establishment of genome editing techniques provides the capacity for gene knock-out (KO), knock-in (KI), and/or knock-down (KD) in insects. A revolution in genome engineering was started by the application of the CRISPR/CAS system. In just over a decade after its invention, CRISPR/Cas9 technology has been widely used to modify genome sequences in diverse species ranging from microbes and plants to animals and even humans. Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) is a technology based on the natural functioning of bacteria. Bacteria defend against invading viruses by "remembering" the genetic codes of previous invaders. If attacked again, the "remembered" code allows the bacteria to target the viruses' DNA, whilst an enzyme like Cas9 cuts the targeted DNA, disabling the virus. The technology has been manipulated to allow scientists to alter DNA by adding to or changing targeted sections. By doing so, scientists hope to achieve many bizarre things like bringing back animals which have gone extinct. But one of those things is an option which seems attainable, i.e., to utilize genome editing to manage harmful insect pests.

Genome editing in insects to alter/attenuate them

Gene editing tools can be used to generate novel economic insect strains more rapidly and with greater efficiency than traditional breeding methods. For example, a new silkworm strain with a high degree of resistance to *Bombyx mori* nuclear polyhedrovirus (NPV) infection was developed using transgenic CRISPR/Cas9- mediated knock-out of NPV genes. Gene editing methods were also utilised to develop a male only strain of silkworm which is a desirable outcome as males produce silk of higher quality and of a greater quantity than females. This new technology has been applied to develop gene drive systems to target doublesex, causing complete population suppression in *Anopheles*

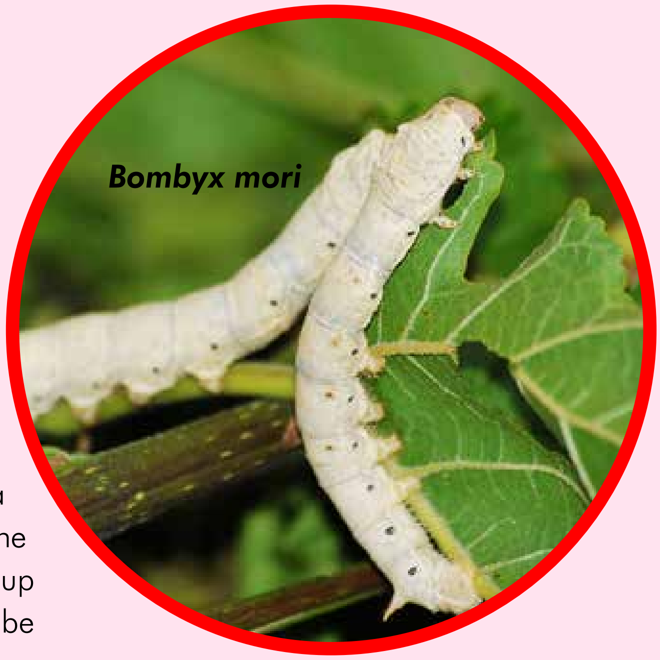
gambiae mosquito populations and all-male population collapse of the agricultural pest *Ceratitis capitata*.

The frequent and incorrect use of traditional chemical pesticides has led to high resistance in many of the major lepidopteran insects including *Plutella xylostella*, *Helicoverpa armigera*, *Spodoptera littoralis*, and *Spodoptera litura*, which makes them more difficult to control. Fortunately, over the past few years, CRISPR/Cas9-mediated target gene editing technology has been used in many insects, providing a new, environmentally friendly option for field pest control. Understanding the biology of insect pests is an important step towards developing appropriate control strategies. CRISPR/Cas9 gene knockout has been shown to enhance the efficiency of understanding and changing gene function. It is now possible in principle to target and modify any gene of interest in a controlled and efficient way.

An important approach to target insects for pest management is by knocking out developmental genes such as abd-A (Abdominal- A) gene, a transcriptional factor involved in downstream regulation of various target genes that are extensively involved in development. Loss of function mutants through CRISPR/ Cas 9 resulted in the generation of abd-A mutant phenotypes in various agricultural pests like *S. litura*, *Spodoptera frugiperda* and *Plutella xylostella*. Insects thus produced showed deformity in body segments, disarmed prolegs, anomalous gonads, and embryonic lethality indicating the success of gene editing tools. A pest management strategy induced via CRISPR/Cas9 technology was demonstrated to study the biology of Colorado potato beetle (CPB), *Leptinotarsa decemlineata*, an important pest of Solanaceae family, including potatoes. CRISPR/ Cas9 induced mutagenesis of vestigial gene (vest) developed wingless adults of CPB with no elytron formed. This study provides an excellent way forward to control the CPB in environmentally safe manner. Another level of insect management using genome editing is the ability to target genes that could disrupt chemical communication and mating partner identification. These two are among the very many factors that establish successful plant—insect interactions. In insects, olfactory receptors (ORs) are important for the recognition of host plant as well as mating partner odorant. Orco (olfactory receptor co-receptor) gene was disrupted in *S. litura* through CRISPR/Cas9, which resulted in impaired selection ability of host plant and distraction of insect from finding a mating partner. Adoption of such technologies will be a potential option to keep insect pests away from the crops and prevent insect damage. CRISPR/Cas9-based knock out of odorant receptor 16 (OR16) in *H. armigera* made males unable to receive pheromone signals from mature females, thus resulting in mating with immature females that subsequently led to dumping of sterile eggs. Knock out of OR16 receptor in lepidopteran pests can therefore be a novel and effective strategy to regulate mating time for pest management in agricultural crops.

Insects possess specialized detoxification enzymes responsible to overcome chemical defense response in various plant species. A strategy to target detoxification genes in polyphagous pests can be a promising option. Knockdown of insecticidal detoxification genes like gossypol-inducing cytochrome P450 resulted in insect susceptibility. CRISPR/ Cas9 knockdown of CYP6AE gene cluster in the polyphagous pest *H. armigera* proved the role of these enzymes in detoxification of various toxic phytochemicals. Although transgenic Bt technology has been well proven and exploited globally, resistance development against Bt insecticidal proteins (ICPs) has been the major fear. To evade this, efforts are being made to engineer receptors such that resistance management can be efficacious. Knockdown of cadherin receptors that are genetically linked to Cry1Ac toxin resistance is an evidence for successful genome editing in *H. armigera*. This strategy can also be adapted to modify target sites in midgut receptors responsible for resistance development against B tICPs or insecticidal proteins.

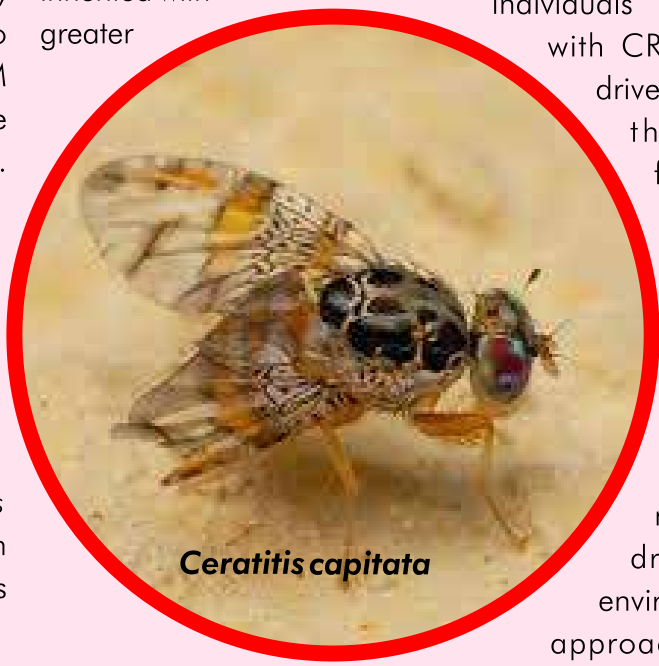
Researchers traditionally focused on vector control strategies to kill disease-spreading mosquitoes by using a variety of insecticides, in areas where diseases occur. The synthetic insecticides used for mosquito control includes organophosphates, carbamates, and pyrethroids, and mosquito repellents like DEET, DMP, DEM which could not control the mosquito species effectively. So, to overcome this problem, scientists, during the last few years have applied all kinds of genetic warfare by gene modifications against mosquitoes. CRISPR/Cas9 system was used to target FREP1 gene in *Anopheles gambiae* which is a plasmodium host factor so as to suppress malarial parasite infection.



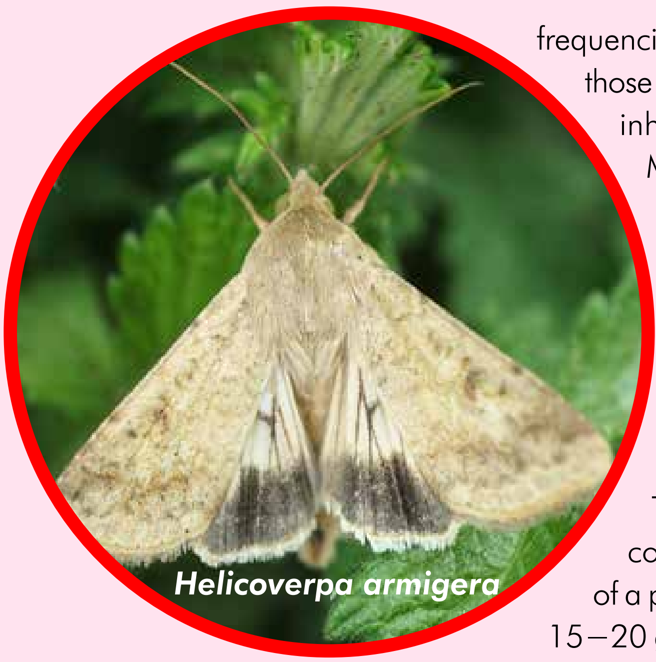
Bombyx mori

CRISPR-based gene drive in insects for crop protection

CRISPR editing creates a "gene drive" that is powerful enough for trans-generational spread of edited genes. In sexual reproduction, when one set of chromosomes contain a gene drive, it dominates over the other partner's genetic makeup and drives the gene flow to be inherited with greater frequencies than those predicted by Mendelian inheritance. This "super Mendelian inheritance" allows passage of such genes from one generation to another even when they reduce the fitness of the particular organism. This would result in the complete disappearance of a particular species within 15–20 generations even if few individuals with CRISPR-based gene drive are released into the environment for mating. In this direction, utilization of genome editing tools to target non Mendelian genes and genes that do not undergo gene drive would be an environmentally friendly approach. For instance, management of Bt resistance in *H. armigera* can be considered to be a sustainable approach when compared with other reported studies, since gene knock down in this case would only affect resistant populations of *H. armigera* against Bt toxins.



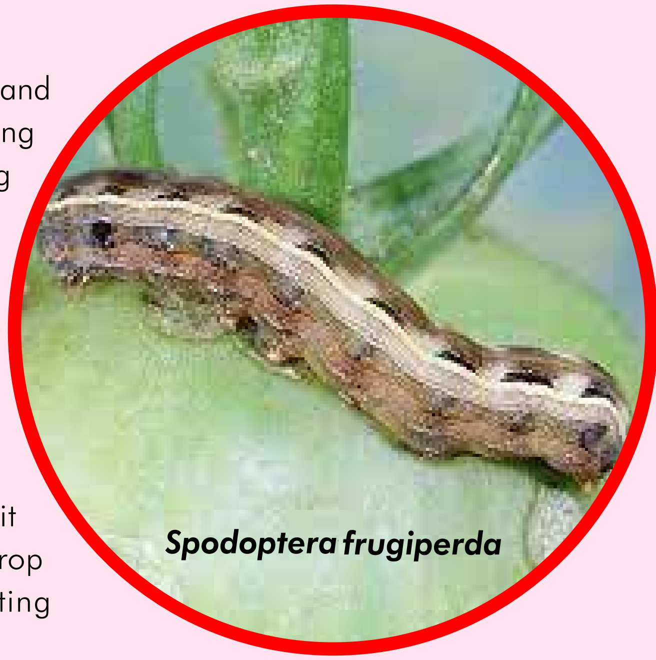
Ceratitis capitata



Helicoverpa armigera

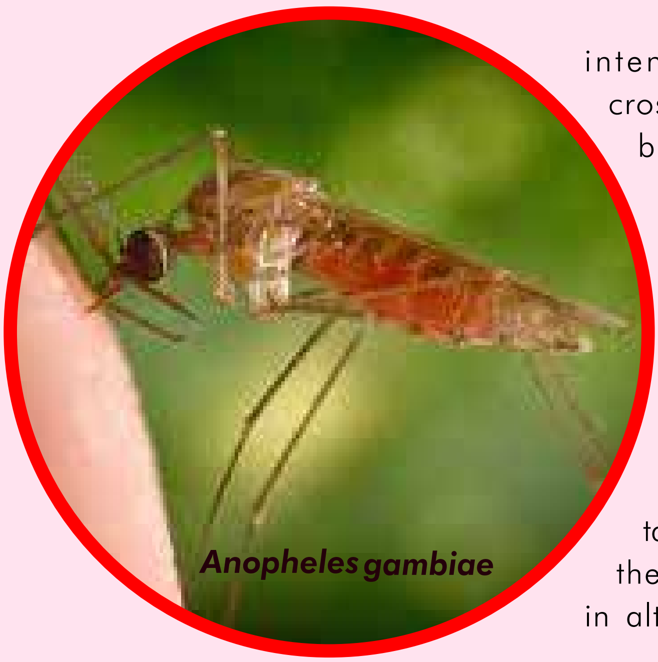
Genome editing in plants for insect pest management

Another area where genome editing is being used is to improve crop resistance against insect pests. Integrating genomics with modern breeding methods holds enormous potential in dissecting the genetic architecture of a complex trait like insect resistance and thus accelerating crop improvement. The use of molecular markers for identification and deployment of insect resistance quantitative trait loci (QTLs) can fastrack traditional breeding methods. Till date, several QTLs for insect pest resistance have been identified in field-grown crops, and a few of them have been cloned by positional cloning approaches. Genome editing technologies, such as CRISPR/Cas9, are paving the way to tailor insect pest resistance loci for designing crops for the future as they enable precise, efficient and targeted manipulation of target genes associated with insect resistance and agronomically important traits. QTLs do not follow a simple Mendelian pattern of inheritance and are extremely difficult to study and manipulate. Genome editing holds promise in overcoming these limitations by offering tools to associate genetic polymorphisms with phenotypic variations. CRISPR-based QTL editing can be utilized to incorporate numerous preferred quantitative trait alleles directly into elite crop varieties, thereby preventing the need for intensive crossing. This strategy will be particularly suitable for editing QTLs that are present in low recombination regions of the genome. Importantly, the CRISPR multiplex technique can be used to manipulate a blend of candidate QTLs or all target genes present within the QTL region, resulting in alterations to measurable phenotypes.



Spodoptera frugiperda

Leptinotarsa decemlineata



Anopheles gambiae

Plant genes can be targeted via CRISPR-based editing for insect management and highlight the possibilities of potential plant defenses that can be engineered for editing-based crop protection. Plants have devised a plethora of strategies in response to the attack of biotic stress factors. While the resistance genes (R genes) decide the ability of plants to resist pests / diseases, 3 susceptible genes (S genes) make them succumb to the stress. Editing of susceptible genes for the development of insect resistant plants is emerging as a reliable strategy. In some instances, insect behaviour, immunity and even development depend on vital chemical substances (VOCs, secondary metabolites, etc.) produced and secreted by the plants.This has been successfully reported in rice by mutating the CYP71A1 gene through CRISPR/Cas9 nucleases. This gene encodes tryptamine 5-hydroxylase that stimulates the production of serotonin from tryptamine and plays a crucial role in stunted growth of plant hoppers.The mutant population showed increased resistance against striped stem borer *(Chilo suppressalis)* and brown plant hopper (*Nilaparvata lugens*) in rice. The study was hypothesized on the fact that serotonin, a neurotransmitter from plants is essential for larval immunity and behaviour.

Most polyphagous pests recognize host plants using the plant's own volatile blends, visual appearance, gustatory clues, oviposition sites, and their interactions are coevolved. Any insect prefers to lay eggs on a host plant to confirm the availability of preferred feed for its young ones. Plant volatile blends are a mixture of volatiles, of which only a few are recognized by insects as clues for host selection and oviposition site detection. Studies have demonstrated that changes in volatile blends retract insects from host plants. In plants, aphid infestation leads to release of a sesquiterpene hydrocarbon (E)-β-farnesene (Eβf) which retracts feeding by other host populations and attracts a parasitic wasp *Diaeretiella rapae* that controls aphid population as seen in transgenic plants. Recent study demonstrates that a particular volatile blend can be utilized as a kairomone-mediated lure to attract the predator *Nesidiocoris tenuis*, for the biological control of major tomato pests, *Tuta absoluta* and *Trialeurodes vaporariorum*. Modifications of plant volatile blends via genome editing can serve as an effective strategy for insect pest management. That said, utmost care needs to be taken to ensure that the manipulation of volatile blends do not cause deleterious impact on beneficial insect/ natural enemy population.

Plant morphological features play an important role in the ability of insect pests to recognize and damage a particular host. For instance, modification in pigmentation of plants has been found to alter insect host preferences. This phenomenon was demonstrated in a study where upregulation of anthocyanin pigmentation produced red leaves in a transgenic tobacco plant. This alteration in leaf colour acted as a deterrent for the pests, *H. armigera* and *S. litura*, there by confirming the significance of leaf colour on host recognition in insect pests. Taken together, engineering of specific metabolic pathways in plants resulting in a change in plant visual appearance can be used as a plausible approach for CRISPR/Cas9-based editing for management of insect pests.

Exploitation of crop wild relatives for engineering resistance to insects

Crop Wild Relatives (CWRs) are ancestors or close relatives of cultivated crops and are resilient to various biotic and abiotic stress factors. Studies on CWRs have implicated the loss of resilience traits to have occurred during the crop domestication process (man-made selection), also referred to as "domestication syndrome". Though breeding for insect resistance using CWRs can be a viable strategy to increase genetic diversity of the primary gene pool, it has not been successful in most of the crops because of biological barriers, linkage drag, cross-incompatibility and sterile embryo production. Advancement in modern biotechnology tools has opened two horizons. First, de novo domestication of crop wild relative that possesses insect resistance and second, genome editing of cultivated crops utilizing insect resistant genes present in CWRs.

(a) De Novo domestication of CWRs for insect resistance

Wild relatives are bestowed with a large number of resistance traits but lack agronomic traits like high yield, fruit/ grain size, preferable plant structure, and so on. Knowledge available from breeding and genetics aid in the identification of genes responsible for desired agronomic traits that can be exploited by gene editing tools. Wild tomato *Solanum pimpinellifolium* is reported to be resistant to a wide range of arthropod pests including spider

mites. Multiplex CRISPR Cas9 editing of six different genes in *S. pimpinellifolium* in a single generation produced a high yielding tomato, restored with other resilience traits present in wild tomato. This strategy can be meticulously extended to other CWRs based on the traits and molecular mechanisms. De novo domestication of CWRs can there fore be a revolutionary strategy for the development of crops with improved traits.

(b) Genome editing of cultivated germplasm using genomic resources from CWRs for insect management

CWRs are known to be bestowed with resistance against various insect pests due to antixenosis and antibiosis. Editing of genes in the cultivated crops based on the respective variation in CWRs would be at angible approach to introduce variability.

This canbe feasible by initial assessment of variation in the sequences of relevant insect responsive genes between susceptible cultivated germplasm and the resistant wild relative using multiomic strategies. Upon validation of resistance genes against the relevant pest, they can be successfully utilized for genome editing.

These approaches provide opportunities to enrich the resistance in the cultivated gene pool to combat insect pests. The recent past has witnessed profound research activities in this area which can be a platform for genome editing for insect pest management.

Use of sequence variation for the development of a resistant phenotype has been demonstrated using either overexpression or silencing strategies in economically important crops. However, resistance through genome-editing-based sequence variation has not yet been proved.

Challenges of genome editing in insects

Despite a large amount of research effort, genome editing tools have still only been applied to a limited number of insect species, including the silkworm, butterflies, a few moths, mosquitoes and locusts. This is due to the difficulty of applying microinjection techniques in insect eggs. Many parameters need to be explored and optimized in each species, including appropriate penetration techniques, egg collection time, injection timing, injection placement, the method for sealing eggs after injection and incubation conditions. The embryos of many insects have a hard shell, which makes microinjection difficult. For example, a double-needle system, in which a tungsten needle pierces the egg shell and a capillary glass needle injects plasmids, is used for microinjection in the silkworm. Another obstacle is that it is not easy to select an edited insect from the brood population. Such screening problems can be resolved using transgenic based genome editing with select marker genes, such as fluorescent protein genes or body colour genes.

Way ahead

Future work should focus on the development of precise genome editing methodologies, with high efficiency and low probabilities of off-target effects. It will also be necessary for RNA function to be studied and novel techniques to be developed to edit non-coding RNA. Additionally, due to their ecological importance, the effects of transferring gene-edited insects from the laboratory to the wild will require further study, monitoring and the development of specific regulations.

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Groundnut

A legume or a nut ?

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Groundnut (*Arachis hypogaea L.*) is considered the 'king' of oilseeds. It is also known as peanut, earthnut, gobbers, pinders or manila nut (Beghin et al., 2003). It is a unique crop and has been aptly described as nature's master piece of food value (Nagaraj and Reddy, 1986). Groundnut is the world's thirteenth most important food crop, fourth most important source of edible oil and the third most important source of vegetable protein. While being a valuable source of all the nutrients, it is a low-priced commodity.Groundnuts are commonly sold roasted or boiled and are used to produce an edible oil with high smoke point. Peanuts are used also to make spreads, candies and other bakery products. Peanut is also used extensively as feed for livestock in some places, the tops of the plants, after the pods are removed, usually are dried and fed to livestock. The consumption of groundnut is associated with a reduced risk of coronary heart diseases, obesity, cancer inflammation etc. Groundnut is cultivated as a floor crop in coconut gardens, as an intercrop with tapioca and as a catch crop after paddy with irrigation in Kerala.

Nuts and legumes form a part of everyday food that contains a lot of nutrients needed for the body. Both nuts and legumes come with a dry fruit inside a pod but when examined closely there are a

lot of characteristic differences between them, for example, nuts often come with one or two seeds present inside the shell while legumes come with multiple seeds inside the pod or shell.

It is important to note that in cooking, the botanical definition of a nut is of less importance than its culinary definition. In culinary terms a nut is often considered as a large seed used in food which comes from a hard shell. Peanuts certainly fit this description and chefs often use them much in the same way as botanical nuts. The difference between nuts and legumes is much less important in the kitchen as long as they are used well within a dish.

Groundnut crop is characterised by indeterminate growth habit, its terminal meristem never becomes reproductive and there is no precise end to vegetative growth. In groundnut rapid vegetative growth starts only after flowering and it continues till maturity (Williams et al., 1975). Nitrogen is the key plant nutrient that stimulates root and shoot growth. Jana et al. (1994) reported that a pod yield of 1.48 t/ha was realized with 40 kg N t/ha compared to 0.90 t/ha with no nitrogen. Under optimum edaphic and climatic conditions groundnut can fix 222 kg N t/ha which was 50% of the N accumulated in plants. The response of groundnut to fertilizer application is not consistent and varies widely from field to field. It was observed that farmers generally do not apply sufficient fertilizers to groundnut crop. This may be probably due

to it being a leguminous crop can fix atmospheric nitrogen. However, experimental evidence clearly indicated that yield of groundnut can be improved considerably with application of nitrogen (Singh et al. 1997).

As a forage legume groundnut pods grow under the soil and the status of groundnut whether to be classified as a legume or a nut is a very hot debate; physiologically groundnut is a legume as it has the capacity to fix atmospheric nitrogen by the process of biological nitrogen fixation while in active symbiosis with specific rhizobial species and unlike tree nuts which grow above the ground, peanuts grow below the ground which makes it closely related to lentils. Being a member of fabaceae/ leguminosae family groundnut exhibit most morphological characters as exhibited by legumes, such as the presence of papilionacious flower (with one standard, two wing and a fused keel petal), tap root system with nodules infected by rhizobia.

Why groundnut should be considered a nut

Groundnut also differs from other legumes as the seeds/ ovules while developing are not attached to a central placenta as seen in the case of legumes.While legumes are dehiscent (bursting open on their own naturally), nuts usually are not and have to be cracked open to extract the kernel. At the same time the nutritional composition of groundnut is more similar to tree nuts such as almonds, cashews or walnuts, legumes being dense food, contains about 18-25 (except for soyabean) of proteins, dietary fibers and has low fat and oil content, but groundnut being a good source of edible oil has 40-46% oil content (based on variety), high fat content and low saturated fat content.

Unlike mungbean, blackgram and cowpea, groundnut was early to nodulate and maintained the nodules until late pod filling stage, which indicated its continued root system activity till later stages of crop maturity which is not commonly seen in other legumes. Nodule formation also differs in groundnut from that of other legumes; instead at sites of root hair formation, nodules in groundnut develop at the site of lateral root emergence.

Most plants (angiosperms) have distinctive reproductive mechanisms that allow them to form aerial fruits harboring seed. However, there are plants that have evolved to produce fruits beneath the soil. These species often exhibit a unique way of producing subterranean fruits, known as geocarpy, involving self-fertilizing subterranean-cleistogamous (fertilization occur within permanently closed flowers) flowers developed on underground shoots. Deviating from normal legume physiology, in groundnut, there is the formation and directional growth of a specialized reproductive organ called a peg,the peg develops from the meristematic cells present at the basal region of ovary. The peg has the capacity for positive gravitropism(to move towards earth) and penetrate the soil to form subterranean pods. This is why some people who are allergic to peanuts can still eat groundnut.Such characters influence the argument that groundnut is more closely associated with tree nuts rather than legumes.

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Suitable grass

Species for fodder production in temperate Hilly region

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Weepinglovegrass (*Eragrostis curvula*)

Introduction

Livestock population in India is 535.8 million, which is largest in the world (Bhaka r*et al.*, 2020). Approximately 20% of the world's livestock population and about 17.5% of the human population is sustaining on just 2.3% of the world's land area in India. The human inhabitants are increasing at a pace of 1.6% per annum, while the livestock population is escalating at a rate of 0.66% per year. India has a global position in highest milk production with large livestock population; though productivity of Indian cattle is low compared to the worldwide average. The reasons can be improper and inadequate nutrition to breeding and lack of adaptability problem (Bhakar*et al.*, 2020). The increasing population of both cattle and human are fighting tooth and nail for land resources for food and fodder production, respectively. India has a scarcity of 284 million tonnes of green fodder and 122 million tonnes of dry fodder. Demand of fodder is likely to grow further and India would require 400 and 117 million tonnes of green and dry fodder, respectively, by 2025. Owing to this, present study was taken up at ICAR-Indian Institute of Soil and Water Conservation Research Centre, Ooty, Tamil Nadu in special reference to find out suitable fodder species for temperate hilly region.

Hybrid Napier

S.N.	Common Name	Scientific Name
1.	Hybrid Napier (CO_4)	*
2.	Hybrid Napier(CO_5)	*
3.	Congo Signal grass	*Brachiaria ruziziensis*
4.	Guinea grass	*Panicum maximum*
5.	Weepinglove grass	*Eragrostis curvula*
6.	Guatemala grass	*Tripsacum laxum*
7.	Vettiver grass	*Chrysopogon zizanioides*
8.	Kikuyu grass	*Cenchrus clandestinum*
9.	Lemon grass	*Cymbopogon citratus*

Napier grass is an inter-specific hybrid between Napier grass *(Pennisetum purpureum)* and Bajra *(Pennisetum typhoides)*.

Present study

A study was conducted on different fodder grass species at Research Farm, ICAR-Indian Institute of Soil and Water Conservation Research Centre, Ooty, Tamil Nadu, India which is situated at 11°24'48.24"N latitude and 76°41'42.76"E longitude at an altitude of 2,240 metres above mean sea level, in temperate hilly region. Following grass species were planted using root cuttings except Congo Signal grass for which seeds were sown. In temperate condition stem cutting method gives only only 60 % success rate, hence root cutting method is prioritized over stem cutting. For root cutting, plant was uprooted with roots and bunch of roots were separated and single rootcutting was planted. Though vettiver, weeping love and lemon grasses are not fodder and widely used for soil conservation; they are planted to compare the biomass production with other fodder grass species.

Hybrid Napier grass

This is an inter-specific hybrid grass. It is widely known as Bajra-Napier Hybrid or Elephant grass. Hybrid Napier is a perennial grass which can be retained in the field for 2-3 years. Compared to Napier grass, Hybrid Napier produces larger and softer leaves. Stem or root cuttings are generally used for propagation of this crop with a spacing of 50 x 50 cm. While planting, two nodes are buried inside the soil and one node is exposed to outside. An average green fodder yield of 150 t/ ha per year can be taken. The excess fodder can be chaffed and converted to silage along with legume fodder in the ratio of 1:2. During summer this can


Congo Signal grass *(Brachiaria ruziziensis)*

be converted to hay.

Congo Signal grass

Congo grass is a forage crop that is grown throughout the humid tropics. With fast growth at the beginning of the wet season due to strong seedling vigour, ease of establishment, good seed production and yield and the ability to suppress weeds it has the ability to become developed into the most important forage crop planted in the tropics. The seeds should be drilled into a well prepared seed bed, sowing in rows that are spaced 60 cm apart and it can be grazed upon as soon as it is ready.

Guinea grass

It is a well known perennial grass adapted to tropical regions and is high yielding. The grass is a tall, densely tuffed perennial with numerous shoots arising from short, rhizomes. A full grown plant attains a height of 1.8-2.7 m under favourable conditions. The yield is about 120-150 tonnes of green forage in 4-5 cuttings. It is maintenance quality roughage containing 8-10% protein under ideal conditions and is propagated by roots.

Weeping love grass

Eragrostis curvula is native to Southern Africa. It is an introduced species on other continents. It is usually a long-lived perennial grass. Other common names include Boer love grass, curved love grass, Catalina love grass, and African love grass.The plant self-fertilizes or undergoes apomixis, without fertilization.In Lesotho, this grass is used to make baskets, brooms, hats, ropes, and candles, and it is used for food, as a charm, and in funeral rituals.

Guatemala grass

Guatemala grass is a fodder that grows well in areas where Napier grass and other fodders do well. It is an alternative fodder crop that withstands Napier stunt and head smut diseases. It can be fed to livestock to increase milk production. Well-managed grass produces 5-7 tonnes of dry

Guinea grass (*Panicum maximum)*

Vettivergrass *(Chrysopogon zizanioides)*

Table 1: Growth of above ground biomass by various grasses

Grass	Tillers/plant	Foliage Lateral Spread(cm)	Biomass (t/ha/year)
Hybrid Napier (CO_4)	68	146	266.7
Hybrid Napier (CO_5)	75	150	304.7
Guinea grass	54	126	191
Weeping love grass	115	138	110.2
Guatemala grass	46	142	136.6
Vettiver grass	66	120	117.8
Lemon grass	81	130	122
Congo Signal grass		90	82.3
CD p=0.05		22	56.8

matter per acre in a year. This is enough to feed one dairy cow per year. If it is in large quantity, silage making is done for dry season feeding.

Vettiver grass

Chrysopogon zizanioides, commonly known as vettiver and khus, is a perennial bunchgrass of the family Poaceae. The root system is finely structured and very strong. It can grow 3 metres to 4 metres deep within the first year. It has neither stolons nor rhizomes. Because of all these characteristics, the plant is highly drought-tolerant and can help to protect soil against sheet erosion. In case of sediment deposition, new roots can grow out of buried nodes. From the roots, oil is extracted and used for cosmetics, aromatherapy, herbal skincare and ayurvedic soap. Its fibrous properties make it useful for handicrafts, ropes and other items.

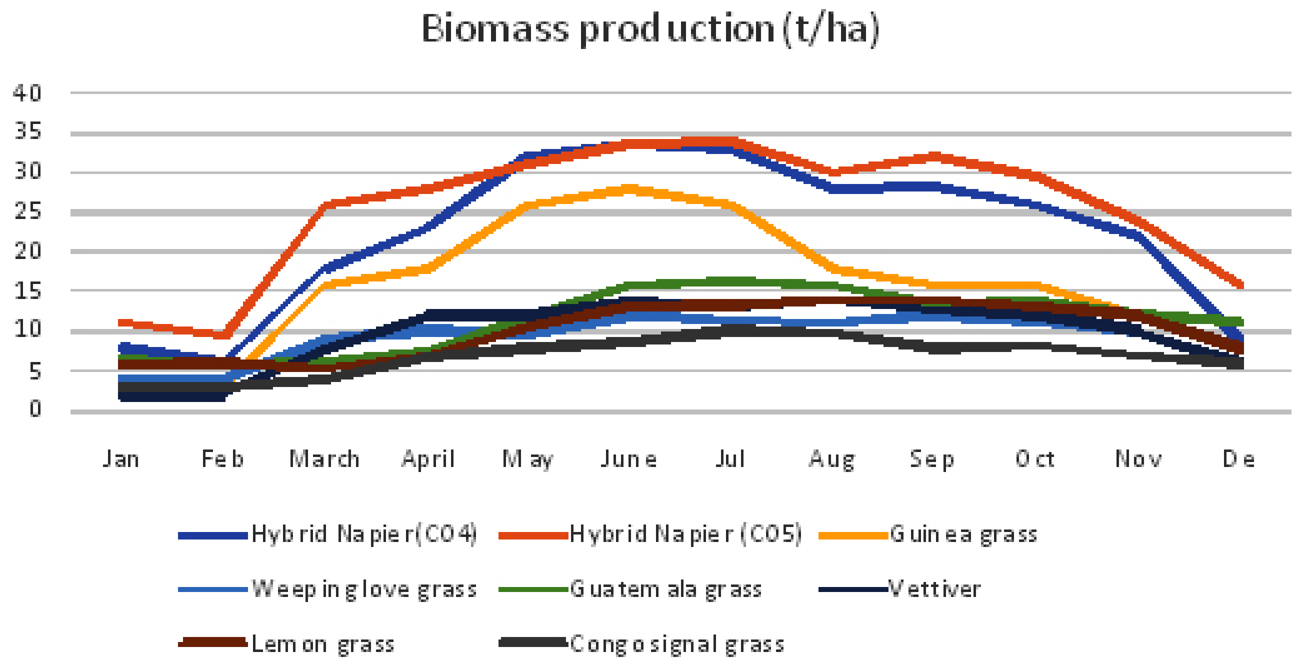

Fig. 1. Monthly Biomass Production of all fodder grasses

Guatemala grass *(Tripsacum laxum)*


Kikuyu grass *(Cenchrus clandestinum)*

Kikuyu grass

It is native to the highland regions of East Africa that is home to the Kikuyu people, so it is called as kikuyu grass. Because of its rapid growth and aggressive nature, it is categorised as a noxious weed in some regions. However, it is also a popular garden lawn species in Australia, New Zealand, South Africa and the southern region of California in the United States, as it is inexpensive and moderately drought-tolerant. The flowering culms are very short and "hidden" amongst the leaves, giving this species its specific epithet (clandestinus). It has high invasive potential due to its elongate rhizomes and stolons, with which it penetrates the ground, rapidly forming dense mats, and suppressing other plant species.

Lemon grass

Cymbopogon, also known as lemongrass, barbed wire grass, silky heads, Cochin grass, Malabar grass, oily heads, citronella grass or fever grass, is a genus of Asian, African, Australian, and tropical island plants in the grass family. The name cymbopogon derives from the Greek words kymbe (boat) and pogon (beard) which mean, the hairy spikelets project from boat-shaped spathes.

It is used for the production of citronella oil, which is used in soaps, as an insect repellent (especially mosquitoes and houseflies) in insect sprays and candles, and in aromatherapy. The principal chemical constituents of citronella, geraniol and citronellol, are antiseptics, hence their use in household disinfectants and soaps. Besides oil production, citronella grass is also used for culinary purposes, as a flavoring agent.

Performance

Growth performance (monthly yield and annual yield) of different grass has been explained after analysing the data collected in the field. Biomass of Hybrid Napier (CO_5) grass was maximum (304.7t/ha./year) followed by Hybrid Napier (CO_4) grass (266.7 t/ha/year). Apart from Napier species, Guinea grass was also giving biomass of 191 t/ha/year (Table1). Nilgiri being the temperate zone it is noteworthy to know the performance of grasses during winter.During winter (January-February) Hybrid Napier(CO_5) grass produced the maximum biomass of 10 t/ha (Fig.1). Better survival percent was found for the Hybrid Napier grass.

Conclusions

Highest fodder production was achieved with Hybrid Napier (CO_5) and Hybrid Napier(CO_4) and Guinea grass. Awareness was created with trainings, publications and camps which resulted in farmers'interest in using these grasses for fodder production. This study is with relevance to the National programme: SDG 15.3, INDC. Trainings and demonstration were conducted for Nilgiri farmers to create awareness about the fodder species suitability in Nilgiri region. Following successful establishment and growth of these grasses in temperate region especially Hybrid Napier(CO_5), many farmers are coming forward to cultivation of these grasses for fodder production and soil conservation in the hilly areas.

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Lemon grass *(Cymbopogon citratus)*

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