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KERALA KARSHAKAN

English journal

The First English farm journal from the house of Kerala Karshakan

Golden palm

Potential of oil palm farming

INSIDE KERALA KARSHAKAN

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APRIL 2024 Volume - 11 Issue - 10

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Phone: 0471-2314358

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Golden palm

Potential of oil palm farming

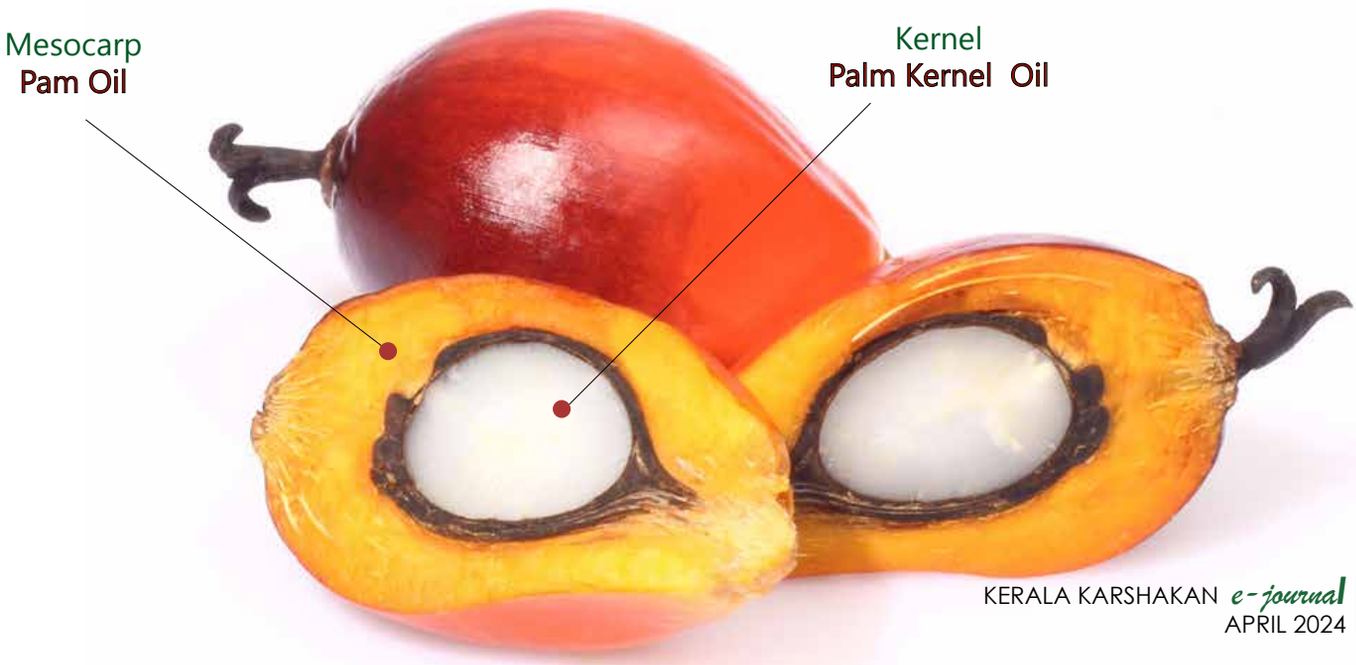
Palm oil is one of the major oils traded in global edible oil and fat market. This versatile oil is obtained from the fruits of oil palm tree.This is the only crop which produces two types of oil from the same fruit, that is palm oil and kernel oil. Palm oil comes from the mesocarp (flesh of the fruit) while the inside seed yields kernel oil

Dr. Rahana S N
Scientist, ICAR-Central Tuber Crops Research Institute (CTCRI), Sreekariyam, Thiruvananthapuram, Kerala

Scientific name	Elaeis guineensis
Family	Aracaceae
Centre of origin	West Africa

High oil yield per ha

Oil productivity	4 – 6 t/ha/year
Kernal oil	0.4 – 0.6 t/ha/year
Produces maximum	oil/area compare to other edible oil yielding crop



Oil palm varieties

Dura

Pisifera

Tenera

which is more or less similar to coconut oil. The palm produces 5 to 6 tonnes per ha of Crude Palm Oil (CPO) and 0.4 - 0.5 tonne per ha of Palm Kernel Oil (PKO) for a period of 25 to 30 years from third year of planting. It produces maximum oil per unit area in comparison to any other edible oil yielding crop species. In comparative terms, yield of palm oil is 5 times the yield of edible oil obtainable from traditional oilseeds. Due to its high yielding capacity, it is often referred as golden palm.

Oil palm is a tropical crop which is mainly cultivated in Asia, Africa and South America. It is comprised mainly of two species viz., *Elaeis guineensis* and *Elaeis oleifera*. Cultivated species is mostly dominated by E. *guineensis*. *Elaeis oleifera*, native of South and Central America. This species is under-utilized and considered to have tolerance to biotic and abiotic stresses, high oil quality, compact canopy and dwarfness.

Palm oil is an extremely important commodity all over the world. Unlike other edible oils, which are mostly used as cooking oil, both palm oil and kernel oil are used in many food and non-food applications and serve as the base materials for hundreds of products.Palm oil is used in the production of foods such as cake, chocolate, biscuits, margarine and frying fats. They are found in cosmetics, soap, shampoo, cleaning products, oleochemicals and can be used

Uses of palm oil

Cooking purpose

as a biofuel. Palm oil contributes 30.7% of total world production of edible oil. Consumption of palm oil is also the highest in the world (29.5%) followed by soybean oil (24.8%). Palm oil, being the cheapest among the edible oil, is widely consumed among the Indian households.

Oil palm is an introduced crop in India and it has come to the farmers few decades back. Oil palm is a uniquely productive tropical perennial oil yielding crop. Since its introduction, oil palm is now a leading agricultural crop. The palm oil contributes 33.35% of vegetable oil requirement of India.The consumption of edible oil in India is at 22 million ton per annum with a per capita consumption of 16 kg/ person. With the rapid increase in the per capita consumption, it is expected that by 2050 our country needs 40.5 million tonnes of vegetable oil. India is overly dependent on imports, mostly from Indonesia and Malaysia.The deficit of edible oil is being met through imports spending Rs.75,000 crores per year.Thus,Palm oil has become essential to India's food security in the past three decades.Moreover, being the richest source of vegetable oil, it has an immense potential to meet the future edible oil demand in India.

As the potentiality and prospects of oil palm cultivation have been recognised the Union

Cabinet approved the National Mission on Edible Oil-Oil Palm (NMEO-OP) scheme in August 2021 with an aim to promote oil palm cultivation and an overall increase in palm oil production of the country.In Kerala, Kollam based Oil Palm India Limited (OPIL) is the Nodal agency for undertaking area expansion programme of Oil Palm cultivation amongst the small holders in the state. The Central and State Government s are extending subsidy for the cultivation. The programme is successfully bring implemented in the state with the active participation of the farmers.

As a humid tropical crop, Kerala's climate andsoil is well suitable for oil palm cultivation.The only variety recommended for commercial cultivation is Tenera, which is a hybrid between Dura and Pisifera.Oil palm is planted in the main field in triangular system at spacing of 9 m.One hectare can accommodate 143 oil palm trees. Planting is preferably done at the onset of monsoon during May-June. Being hardy crop it has low pest and disease infestation. The crop assures monthly income and good market price throughout the year. First harvest can be taken 3.5 to 4 yearsafter planting. When a few ripe fruits are loose/fall off, the bunch is ready for harvest. Processing over-ripe fruits reduces quantityand quality of oil.A chisel is used for harvesting bunches fromyoung palms. The stalk of the bunch is struckhard with the chisel to cut off and push thebunch out. When the palms become taller(from 10 year onwards) a harvesting hook has to be used. When the palms are too tall, it isnecessary to climb the palms for harvesting.

The life span of an oil palm tree is 35 years, and it starts to yield 4.5kg per bunch in the fourth year, which goes up to 20kg per bunch the eighth year onwards, on an average.A tree is expected to yield 12 bunches, which makes it about 240-250kg per tree. In the initial four years, the farmers can go for inter-crops such as plantains, ginger, pineapple and vegetables. The state provides a subsidy of Rs 42,000/ha for the first four years. It also provides Rs10,500 per tonne of FFB as the base price to support the farmers. Now, the crop fetches Rs 17,000 per tonne.

Contact no for scheme related enquiry: Thajudeen S. (Mob. No. 9745766467)

Koova-Arrowroot/
West Indian
arrowroot
(Maranta arundinacea)

Arrowroot

A Potential Industrial Crop

Tuber crops are vital staples in the diets of small and marginal farmers, particularly among tribal populations, in tropical and sub-tropical countries. These crops serve as crucial subsistence foods, offering both nutrition and medicinal benefits. They enrich the daily diet, while also possessing medicinal properties that aid in treating various ailments and preventing their occurrence. Additionally, tuber crops contribute to the preparation of various medicine and health supplements.

Dr. Asha K. I.*
Dr. Suja G.
Dr. Sheela M. N.
Dr. Krishna Radhika N.
Aswin S. Kumar
ICAR - Central Tuber Crops Research Institute
Sreekariyam, Thiruvananthapuram-17

Manjakoova-
Yellow arrowroot
(Curcuma zedoaria)

India, with its rich genetic diversity of tropical root and tuber crops and their wild relatives, stands as a global hotspot for biodiversity, particularly in the Western Ghats and North Eastern Himalayan regions.

Arrowroot comes under the marantaceae family, is currently a less popular but commercially important tropical tuber crop. It is known in varied names such as West Indian arrowroot in English and Koova in Malayalam and scientifically as *Maranta arundinacea*. It has fibrous starchy rhizomes covered with fleshy scales. These white fleshy, cylindrical rhizomes are usually 2.5 to 5.0 cm thick and 20 to 45 cm in length. Apart from this, according to the colour of the rhizome, various arrowroot types namely Manjakoova-yellow arrowroot (*Curcuma angustifolia* and *Curcuma zedoaria*) and Neelakoova-blue arrowroot (*Curcuma malabarica*) varieties are also popular. In the National Active Germplasm Site,at ICAR-Central Tuber Research Centre, Sreekariyam, Thiruvananthapuram (under the Indian Council of Agricultural Research), about forty-five cultivars collected from different regions of India are maintained. Also, this institute focuses on collection, maintenance and research on various species of arrowroots.

Arrowroot originated in the tropical regions of America, later spread to Brazil, India, Sri Lanka, Indonesia and Philippines. St. Vincent in the West Indies is the world's largest producer of arrowroot. It contributes about 95% of the global commercial supply. In India it is cultivated in the rainfed areas of Uttar Pradesh, Bihar, Orissa, West Bengal, Assam and Kerala.

Average yield in Arrowroot is 20 to 31 tonnes per hectare.

These can usually be eaten boiled or baked. Arrowroot contains 8-16% starch and arrowroot starch are very fine and easily digestible. Arrowroot powder is an excellent food for both adults and children. In addition, it is an important ingredient in various food products (biscuits, bread, cakes, puddings, pasta, ice cream, jellies, sauces etc.). It is also a basic ingredient in the manufacture of special adhesives, pills, baby powder, face powder, moisturizing creams, hair dye and computer paper. Also, the rhizomes are used as chicken feed and the starch extracted Tuber residue is used as an organic manure.

Climate and soil

Arrowroot grows best in warm and humid climates. An ambient temperature of 25-30°C and an annual rainfall of 1500-2000 mm are suitable for arrowroot cultivation. It grows well in well-drained, fertile, sandy loam soils (pH 5-8). The key to optimal yield lies in evenly distributed rainfall, with a minimum annual requirement of 100-150 cm. High temperature and humidity and partial shade foster vigorous plant growth. In contrast, growth slows in colder regions, often leading to browning and withering of leaves. Nevertheless, mild frost may affect leaves, but not rhizomes and a short dry period in winter typically does not affect plant growth.

Advantages in arrowroot cultivation

The cultivation of arrowroot has some unique characteristics. It is a versatile plant, thriving under shaded conditions. Interestingly, it faces minimal threats from pests and diseases. Its tolerance to shade makes it a suitable companion crop/intercrop in coconut and arecanut plantations, with fresh rhizome yield of 20-30 tonnes per hectare. Remarkably, the extraction of starch from arrowroot rhizomes can be a simple household procedure, making it an attractive prospect for cottage industries, especially in rural areas.

Manjakoova-
Yellow Arrowroot/
East Indian arrowroot
(Curcuma augustifolia)

Neelakoova-Blue arrowroot *(Curcuma malabarica)*

Planting material

Arrowroot should be planted in the last week of May or early June with the onset of monsoon. Rhizome pieces of 4-10 cm length with 2-4 buds weighing 20-25 grams are used for planting. Also, suckers can be used for planting. If suckers are used, preparation of planting material should actually start from the time of harvest of the crop. The suckers are carefully separated from the clumps at the time of harvest and planted at a distance of 30-45 cm in the nursery during the offseason. These suckers give rise to new plants, which are uprooted, and the canopy cut off to retain 10 cm of the shoot intact with roots.

Land preparation and planting

The soil should be ploughed well before the onset of rain. Raised beds of convenient length, 1 m width, 15-20 cm height are to be prepared 50 cm apart. Plant 20-25 gram pieces of rhizomes at 30x15 cm spacing. About 4.4 to 5.5 tonnes of seed rhizomes will be required for planting one hectare.

Mulching

Mulching with green leaves, dried leaves, or coconut fronds immediately after planting helps to increase the yield by 60-65%. The plant commences its growth in 15-20 days.

Fertilizers

Arrowroot is a heavy feeder and replenishment of the soil with adequate amounts of nutrients is inevitable. Nutrient recommendation for arrowroot is farmyard manure (FYM) @ 10 tonnes and NPK @ 50:25:75 kg per ha. At the time of planting, FYM should be applied. Full dose of P is to be applied at the time of planting. Half the dose of N and K should be given one month after planting and the remaining doses of N and K should be given one month later. For this apply 125 kg Mussooriephos at the time of planting. Apply 55 kg urea and 63 kg muriate of potash one month after planting and the remaining 55 kg urea and 63 kg potash one month after the first dose for better yield.

Arrowroot as an intercrop in coconut gardens

Organic Farming

Before planting, seeds of green manure cowpea should be sown at the rate of 20 kg per hectare. After 45-60 days, it should be cut down and in corporated in to the soil. About 10-15 tons of green manure can be added to the soil in this way. At the time of planting, 10 tonnes of manure should be added per hectare. Along with this, biofertilizers such as *Azospirillum*, P solubilizer and K solubilizer should also be applied at the rate of 3 kg per hectare. Organically produced rhizomes weighing 20-25 grams can be planted at 30x15 cm spacing in beds of convenient length, one meter width and 15-20 cm height. Suckers of 30 cm length can also be used for planting.

Interculture practices and irrigation

It is essential to keep the field clean and free of weeds during the first 3-4 months. Earthing up should be done along with weeding. Flowers are to be nipped off as they appear. The crop is grown mainly as a rainfed crop. However, if dry spells occur during the initial 3-4 months, supplementary irrigation at weekly intervals becomes necessary. Sufficient moisture in the soil throughout the growing period ensures good yield. No major pests and diseases are noted except field rats, which tunnel and damage the roots. Poison baits using zinc phosphide is recommended to control rats.

Harvest

The crop attains maturity in 10-11 months after planting. Maturity is indicated by yellowing, wilting and drying up of leaves. At this stage, the plants are dug out and the rhizomes separated from the leafy stem. Under favourable conditions, rhizome yield of 20-25 tonnes per ha can be obtained. The amount of starch obtained is 16-20% of the fresh weight of the rhizome. Average production of starch per hectare is 3-3.5 tons.

Starch extraction and its nutritive value

The simple process of extracting starch from arrowroot becomes a source of income for cottage industries. The rhizomes typically contain about 16-20% starch on fresh weight basis. These are thoroughly washed, cleaned and separated from scales, followed by washing. The next step involves converting them into pulp using mortars, resulting in the extraction of milky liquid through continuous beating action. This liquid is filtered through cloth, separating the pure starch, which is insoluble. The starch is then left undisturbed to settle at the bottom of a container. Subsequently, the wet starch is dried either in the sun or in a drying house. The outcome is a starch powder that is packed for the market in airtight containers, packages, or cases. Apart from starch, arrowroot powder also contains various essential minerals including calcium, phosphorus, magnesium, zinc, iron, thiamine, riboflavin, vitamin A and energy. Commercially, high-quality arrowroot starch should be pure white, devoid of specks, with a moisture content not exceeding 18.5%. It should also possess low ash and fibre content, an initial pH of 4.5-7 and a maximum viscosity ranging from 512 to 640 Brabender units depending on the grade.

Traditional uses and health importance

Arrowroot has been utilized for many purposes since ancient times. It has been used to heal wounds from poison arrows and scorpion stings. The etymology of the name "arrowroot" in English is related to the belief that it can heal arrow wounds. It is considered a remedy to prevent birth defects, promote proper growth and development and improve circulation, blood pressure, cholesterol,

weight control and digestion. Arrowroot powder is notable for its effectiveness in treating diarrhoea in people with irritable bowel syndrome. Also, it has antiseptic benefits. It is a natural remedy for itching, cuts, rashes and scars. Arrowroot powder is rich in nutrients and is used as a breast milk substitute or as a weaning food. Arrowroot starch contains various components including alkaloids, cardiac glycosides, phenolic compounds, terpenoids, saponins and flavones. It is also valuable in the treatment of intestinal disorders. These compounds extend their utility to the nutraceutical and pharmaceutical industries by increasing their medicinal value. Tikhur or East Indian arrowroot, is eaten as food during fasting in the northeastern states.

Arrowroot market

The global arrowroot starch market was valued at USD 2.59 billion in 2022. Arrowroot is available in the market in both rhizome and flour form. The arrowroot market spans the food, pharmaceutical, nutraceutical, cosmetic and industrial sectors, both conventional and organic. Mainly the medicinal value increases the market potential of arrowroot species. The use of arrowroot species is widely found in Kerala and North Eastern states of India. After the West Indian arrowroot, the East Indian arrowroot also known as Tikhur is a medicinally valuable plant with high starch. Due to its anti-microbial properties similar to that of turmeric, it can be used as an alternative to nutritional health drinks available in the market today for health enhancement. It is also of great commercial importance as it is a tuber that is eaten during fasting. Due to its excellent medicinal properties, arrowroot powder is used as a raw material for many medicines and cosmetic products. It is also used in the production of cakes, puddings, fruit preserves and jams. The market for gluten-free arrowroot powder is booming as the health-conscious population prefers more nutritious food items. Research on arrowroot species is also gaining importance. The arrowroot market is expected to grow at a rate of 3.5% to reach a market size of $3.62 billion by 2032.

Arrowroot with its diverse types and varied applications, is a botanical treasure with immense economic significance. From its culinary uses to its medicinal properties this crop has the potential to impact various industries and improve livelihoods worldwide. Its resilience against pests and diseases, coupled with its adaptability to different climates and systems, underscores its value as a sustainable crop. As we continue to explore the potential of arrowroot, it may play an increasingly vital role in our diets, health and industries, offering us an arrow pointing towards a more sustainable and prosperous future.

Organic farming: Field view and harvested rhizomes

Vertical Medicinal Garden

Vertical garden is a special kind of garden suitable for small places, particularly for decorating walls in various styles. Vertical gardening is a suitable method for growers who experience shortage of land. It can be installed in almost all locations, even in indoor or balcony of apartments.

Medicinal plants, especially the medicnal herbs are ideal for growing in vertical fashion. It is an ideal choice for the people living in apartments/ flats and for balcony gardeners, especially at upper floors for whom the access to the ground is very limited.

Main advantage is that these medicinal plants can be

Dr. Pallot Sindhumole
Assistant Professor &Head (i/c)
AICRP on MAP & B, Thrissurcentre
Kerala Agricultural University

accessed very easily, at any time, to prepare fresh herbal home remedies for common ailments like cold, cough, cuts and bites etc.

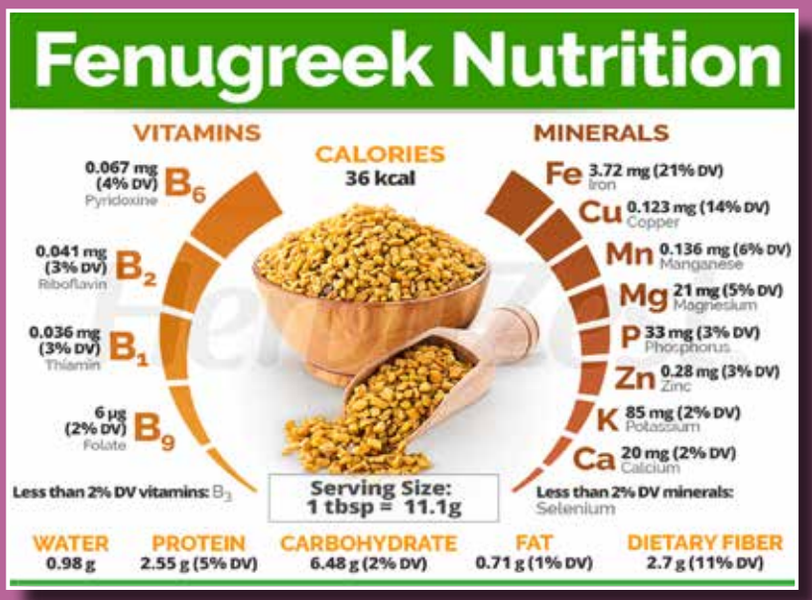
A vertical garden was installed at Thrissur centre of AICRP on MAP & B, at Vellanikkara, Kerala. The vertical stand with a square size of 75cm x75cm with 180 cmheight was constructed using 1.5inch square pipe legs and 1.5 inch square pipe frames. The sides were covered with wired mesh which was welded to the legs and frames. This vertical garden consists of 144 pots, filled with potting mixture, consisting of sand, soil and compost in the proportion of 1:1:1.On one side, six layers (rows) of pots are placed, with 6 pots placed in each layer and. Twelve different types of medicinal plants are planted, keeping same type of plants in all pots in a row.

The medicinal plants used in this unit are:

Tulsi *(Ocimum sanctum)*, Panikkoorkka or Indian borage (*Coleus aromaticus*), Vishamooli (*Pilea sp.*), Murikootti or Red flame Ivy (*Hemigraphis colorata*), Ayyappana (*Ayapana triplinervis*), Garudappacha(*Selaginella repestris*), Pazhutharachedi or Muehlenbeckia (*Homalocladium play clodium*), Vathamkolli (*Justicia gendrarussa*), Vishnukranthi (*Evolvulus alsinoides*), Kesavardhini or Brazilian button flower (*Centratherum punctatum*), Madhurathulasior Sugar leaf(*Stevia rebaudiana*) and Chathuramulla (*Myxopyrum smilacifolium*).

Other herbal medicinal plants which can be grown under shade/partial shade also are suitable for this purpose. Total expenditure for the construction of this vertical garden with medicinal herbs is approximately Rs. 15,000/-.The dimensions of this vertical structure can be modified according to the convenience and availability of space, either outdoor or indoor. Apart from serving as a ready source of fresh medicinal herbs for home therapies, the other major advantages of vertical medicinal garden are :

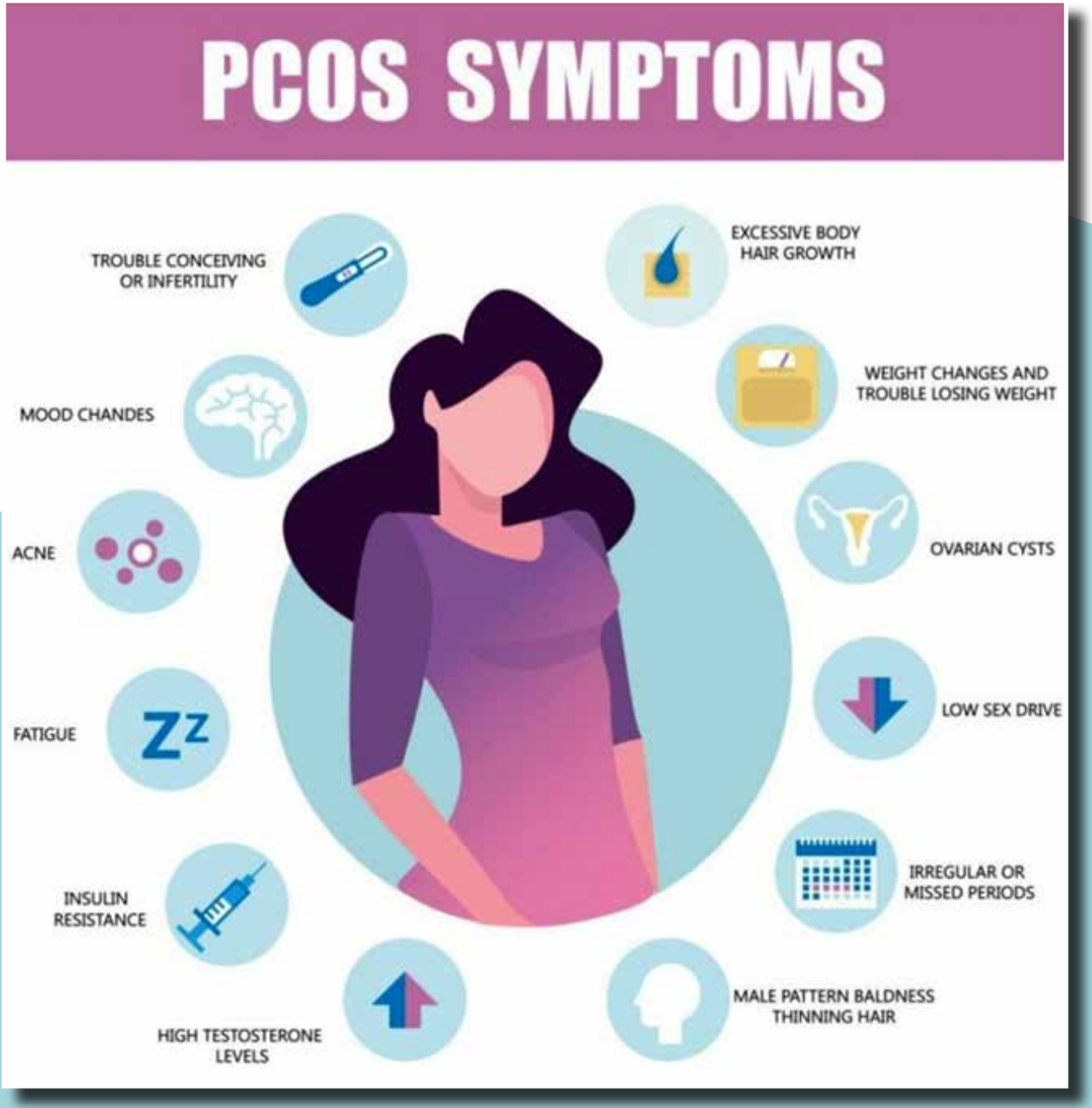
- Saves the space (horizontal) in the ground
- Effective use of vertical space in a healthy manner
- Reduces noise levels
- Acts as an air purifier
- Aesthetically pleasing
- Controls indoor temperature
- Easy maintenance
- Helps to improve mood by reducing stress
- Helps to ensure the purity of medicinal herbs for family use
- Helps to conserve the medicinal herbs at home level in the available space
- Reduces the carbon foot print

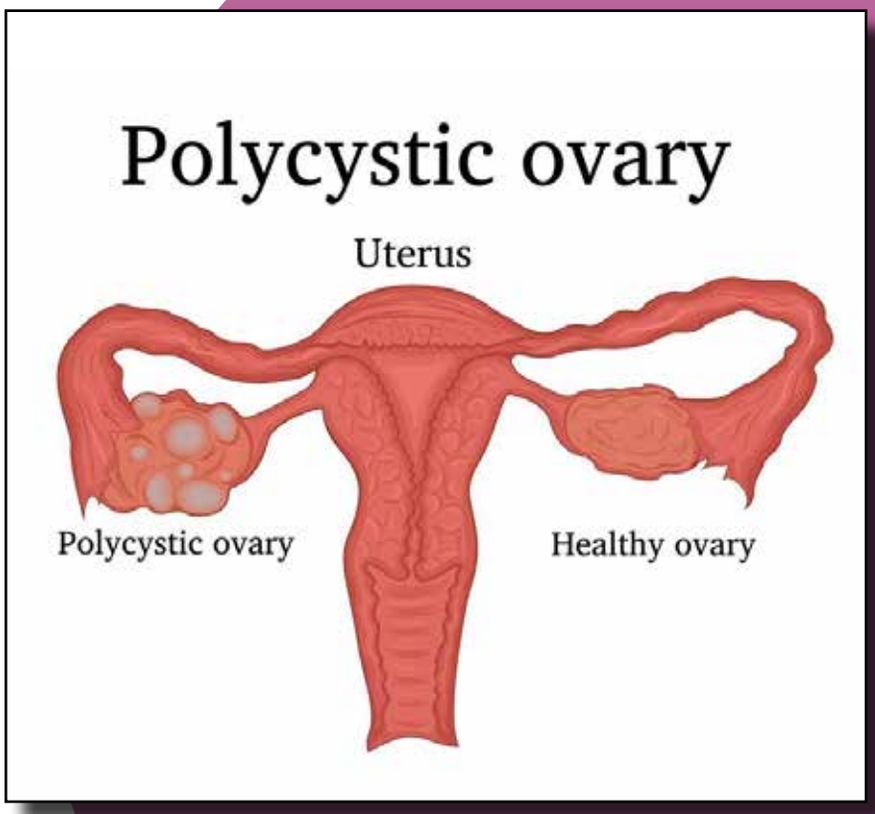


Fenugreek (*Trigonella foenum-graecum*) is an herbaceous plant belonging to the Fabaceae family, commonly found in Mediterranean regions, North Africa, and South Asia. It has been utilized for centuries in various culinary, medicinal, and even cosmetic applications due to its distinctive flavor, aromatic properties, and potential health

HARNESSING NATURE'S BOUNTY FENUGREEK'S SEED ROLE IN MANAGING PCOS

N. Vinothini
Assistant Professor (SST), SRM College of Agricultural Sciences , SRM Institute of Science and Technology, Chengalpattu - 603 201, Tamil Nadu, India.


PCOS SYMPTOMS
TROUBLE CONCEIVING OR INFERTILITY
EXCESSIVE BODY HAIR GROWTH
MOOD CHANDES
WEIGHT CHANGES AND TROUBLE LOSING WEIGHT
ACNE
OVARIAN CYSTS
FATIGUE
LOW SEX DRIVE
INSULIN RESISTANCE
IRREGULAR OR MISSED PERIODS
HIGH TESTOSTERONE LEVELS
MALE PATTERN BALDNESS THINNING HAIR



benefits.

Fenugreek Seeds: An Overview of Nutritional Elements

Fenugreek seeds are rich in various nutrients, including vitamins, minerals, and phytonutrients.

1. Protein: This makes them a valuable addition to vegetarian and vegan diets.

2. Fiber: Fiber is essential for digestive health, promoting regular bowel movements and aiding in weight management.

3. Carbohydrates: Fenugreek seeds contain carbohydrates,


HELPS
DIABETES
CONTROL
CURES
CONSTIPATION
STIMULATES
BREAST MILK
PRODUCTION
REDUCED
MENSTRUAL
DISCOMFORTS
FIGHTS
THE FLU
AND COLDS
CURBS
JOINT PAINS

primarily in the form of complex carbohydrates, which provide sustained energy release.

4. Fat: Fenugreek seeds contain fats, including both saturated and unsaturated fats. They typically provide about 6.4 grams of fat per 100 grams.

5. Vitamins: This is essential for metabolism and nervous system function.

6. Minerals: Supporting bone health, energy production, and immune function.

7. Phytonutrients: Contribute to the potential health benefits of fenugreek.

Fenugreek is a popular herb that has been used for centuries in traditional medicine, particularly in Ayurveda and traditional Chinese medicine. In recent years, it has gained attention for its potential benefits in managing polycystic ovary syndrome (PCOS), a hormonal disorder affecting women of reproductive age.

Symptoms of PCOS

PCOS is characterized by irregular menstrual cycles, excess androgen levels, and ovarian cysts, often leading to infertility, weight gain, and other metabolic complications. Treatment typically involves lifestyle changes, medications to regulate menstrual cycles and hormones, and sometimes surgery for cyst removal.

Research suggests that fenugreek may offer several potential benefits for women with PCOS:

1. Regulation of Menstrual Cycles

Fenugreek may help regulate menstrual cycles in women with PCOS. A study published in the "Journal of Ethnopharmacology" in 2015 found that fenugreek seed extract improved menstrual regularity and reduced ovarian volume in women with PCOS.

2. Improvement in Insulin Sensitivity

Insulin resistance is a common feature of PCOS, leading to elevated insulin levels, which can exacerbate symptoms. Fenugreek has been shown to improve insulin sensitivity and lower blood sugar levels. This effect may help in managing insulin resistance and reducing the risk of type 2 diabetes, which is often associated with PCOS.

3. Reduction of Androgen Levels

Excessive androgen levels contribute to many PCOS symptoms, including acne, hirsutism (excess hair growth), and irregular menstrual cycles. Fenugreek has been reported to reduce androgen levels in animal studies, though more research is needed to confirm this effect in humans.

4. Antioxidant and Anti-inflammatory Properties

Fenugreek contains compounds with antioxidant and anti-inflammatory properties, which may help reduce inflammation and oxidative stress associated with PCOS.

While these findings are promising, more high-quality clinical trials are needed to establish the efficacy and safety of fenugreek specifically for PCOS. It's also important to note that fenugreek may interact with certain medications and may not be suitable for everyone, particularly pregnant women and those with certain medical conditions.

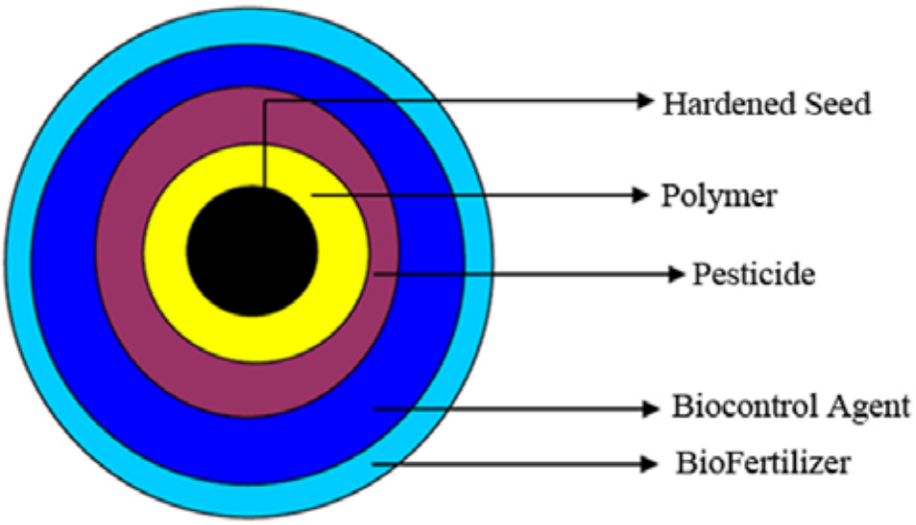
As with any herbal remedy, it's essential to consult with a healthcare professional before incorporating fenugreek into your treatment regimen, especially if you're managing a chronic condition like PCOS. They can provide personalized advice based on your medical history and help ensure safe and effective use.

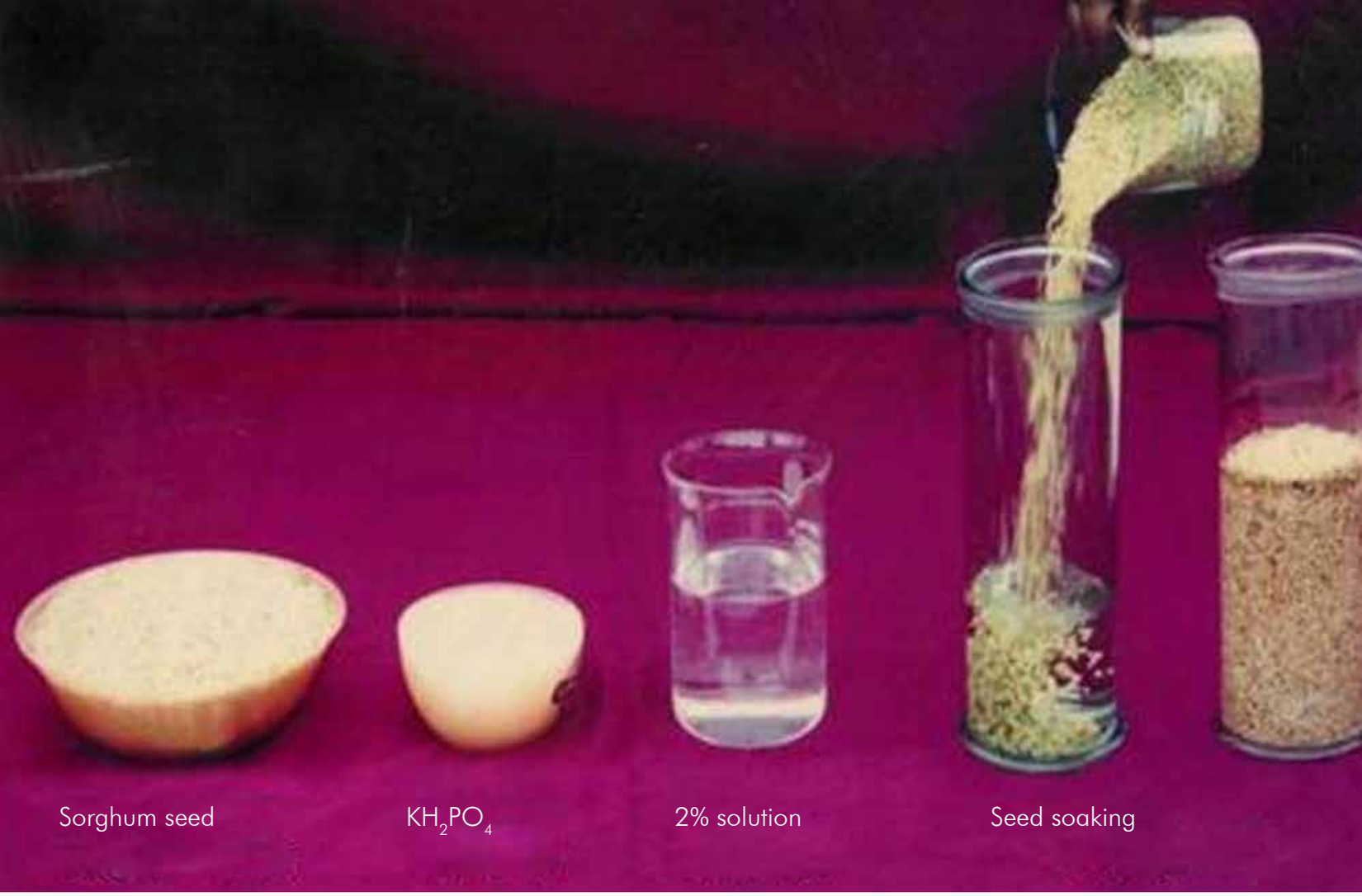
Unveiling the Future of Agriculture

The Fascinating World of Designer Seeds

M.Ananthi[1]
S.Umesh Kanna[2]
[1]Teaching Assistant,
Directorate of Planning and Monitoring, TNAU, Coimbatore
[2]Professor (Forestry),
Directorate of Planning and Monitoring, TNAU, Coimbatore

In today's rapidly evolving world, the agricultural industry is constantly seeking innovative solutions to meet the growing demand for food production. One such innovation that has gained significant attention is the concept of designer seeds. These specially treated seeds,





Crops	Chemicals and concentration	Soaking duration
Pearlmillet	2% Potassium chloride	10h
Sorghum	2% Potassium dihydrogen phosphate	16h
Maize, Varagu, Tenai and Samai	2% Potassium dihydrogen phosphate	8h
Cotton	2% Potassium chloride	10h
Sunflower	2% Potassium chloride	12h
Black gram	100ppm Zinc sulphate	3h
Green gram	100ppm manganese sulphate	3h
Ragi	0.2% Sodium chloride	6 h
Groundnut	0.5% calcium chloride	4 h
Redgram	100ppm Zinc sulphate	4 h
Bengal gram	1% potassium dihydrogen phosphate	4 h

equipped with advanced seed treatment techniques like seed hardening, seed coating, and seed pelleting, are transforming the way farmers approach planting and cultivation.

Designer Seed

Designer seed technology is an innovative approach in agriculture that aims to enhance seed quality and improve crop performance. Designer seed is an integrated pre-sowing seed treatment that involves addition of nutrients, plant protectants and bio inoculants to enhance seed quality viz., field emergence and yield attributing parameters. By incorporating designer seed technology into the agricultural practices, farmers can ensure that their seeds are equipped with the necessary elements for optimal growth and development.

Hardened Seed

Seed treatment, specifically seed hardening, plays a crucial role in ensuring successful crop establishment and optimal plant growth. Seed

Crop	Colour of polymer	Dose of polymer (g/kg)	Volume of water (ml)
Paddy	Yellow	3	3
Maize	Pink	3	5
Sorghum	Pink	3	5
Cumbu	Pink	3	5
Soybean	Yellow	4	5
Sunflower	Black	4	5
Tomato	Red	6	20
Bhendi	Green	5	5

hardening is the process of soaking seeds in chemical solution for specified time and drying to induce tolerance to drought. During seed hardening, seeds are subjected to partial hydration followed by dehydration before sowing. Seeds are soaked in chemical solutions of prescribed concentration. Soaked seeds are then dried in shade back to original moisture content. During soaking, seeds imbibe water and germination process is started but not completed. The hardened seeds are thus in a ready state for germination. When sown in moist soils, seeds germinate immediately.

Seed coating with Polymer

Seed coating with polymer involves applying a thin layer of protective material onto the seed surface. This coating serves multiple purposes, including improving seed handling, protecting against environmental stress and enhancing nutrient uptake.

Firstly, it provides a physical barrier that shields the seeds from external factors such as moisture loss and pathogens. Additionally, the polymer coating can regulate water absorption, ensuring optimal hydration for germination.

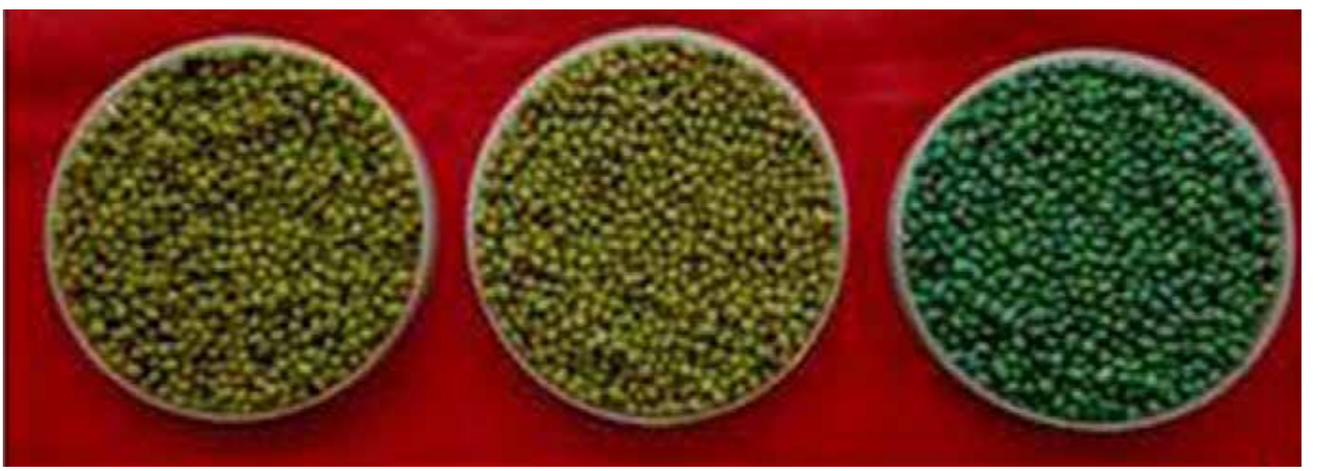
Seed treatment with Plant Protectants

Effective method of seed treatment is the application of plant protectants. These protectants are substances that are applied to seeds before sowing to safeguard them against various pests, diseases, and environmental stressors. It helps in preventing seed-borne diseases, which can significantly reduce crop yield and quality. Additionally, these treatments can provide protection against soil-borne pathogens and pests that may attack young seedlings during their early stages. By treating seeds with plant protectants, farmers can minimize the risk of disease transmission from one generation of plants to another.

Seed treatment with Biocontrol Agent

Biocontrol agents are naturally occurring organisms that can suppress or control plant pathogens and pests.

PRESOWING SEED TREATMENT



CONTROL **HARDENED SEED** **DESIGNER SEED**

Paddy	Seed soaking in 1% KCl for 16 hrs and drying back to original moisture content + polymer @ 3 ml/kg + imidacloprid @ 2 ml/kg + Bacillus subtilis @ 10 g /kg+ Azophos @ 120 g/kg.
Blackgram	Seed soaking in ZnSO4 100 ppm for 3 hrs and drying back to original moisture content + polymer @ 3 ml / kg + imidaclorprid @ 2ml / kg + Bacillus subtilis @ 4 g / kg + Rhizobium @ 20 g / kg.
Sunflower	Seed soaking in 1% KCl for 6 h and drying back to original moisture content + polymer @ 3 ml / kg + imidacloprid @ 2 ml / kg + Trichodermaviride @ 4 g / kg + Azospirillum @ 40+ g / kg.
Cotton	Seed soaking in 1 % KCl for 6 hrs and drying back to original moisture content + polymer @ 3 ml / kg + imidacloprid @ 2 ml / kg + Bacillus subtilis@ 10 g / kg +Azophos @ 120 g / kg

When seeds are treated with these agents, they provide an added layer of protection to the emerging plants, helping them establish a strong foundation for growth. It enhances plant health by preventing or reducing the incidence of diseases caused by pathogens such as fungi, bacteria, and viruses. By suppressing harmful organisms that attack seeds or young plants, biocontrol agents allow crops to develop without interference from pests or diseases.

Seed treatment with Biofertilizer

Effective method of seed treatment is utilizing biofertilizers, which have gained significant attention in recent years due to their eco-friendly and sustainable nature. Biofertilizers are natural substances that contain beneficial microorganisms, such as bacteria, fungi, or algae. These microorganisms establish a symbiotic relationship with plants, promoting nutrient uptake and improving soil fertility. Bio- fertilizers like Rhizobium, Phosphobacteria, Asozprillufn, Azatobactor etc., are utilized for seed treatment. The bio-fertilizer treatment helps in improving the activity of microorganisms in the rhizosphere (root environment) and help in nitrogen fixing. When used as a seed treatment, biofertilizers can enhance seed germination, root development, and overall plant growth.

Designer seed Treatment (Integrated Seed Treatment)

The combined effect of seed treatment ultimately leads to improved emergence and establishment of crops. By providing plants with the necessary resources and protection right from the start, they are better equipped to overcome environmental stressors, achieve uniform germination, and establish a strong root system. This early advantage sets the stage for healthier plants with increased vigor, ultimately translating into higher yields and improved overall crop performance.

Applications

- Enhanced germination and field emergence
- Improved seedlings vigour
- Sustained protection against pests and diseases during early growth period
- Reduced plant protection cost
- Increased yield

Designer seeds represent a significant leap forward in agricultural innovation, offering immense potential to address global food security challenges. By integrating these enhancement techniques into agricultural practices, farmers can optimize their crop production by improving germination rates, enhancing plant vigor and resilience against biotic and abiotic stresses. These advancements contribute towards sustainable agriculture practices while ensuring food security for a growing global population.

Table 1. Employing trap crops for insect-pests managementin vegetable crops (Panwar et al., 2021)

COMPANION PLANTING AND ITS ROLE IN SUSTAINABLE PRODUCTION OF VEGETABLES: A CURRENT PERSPECTIVE

Koku K. Tara*[1]
Sushmitha L C[1]
Kakali Das[1]
Pradeepkumara N[1]
1Division of Vegetable Science
ICAR-Indian Agricultural
Research Institute, New Delhi-12 India

Introduction

Companion planting is a form of polyculture, under which two different plant species are grown together to enhance each other's growth and provide mutual benefits. It is a system of crops that are planted in tandem as part of a management strategy. A successful companion plant can protect against predators, distract pests, attract

pollinators, enhance soil nutrients, or facilitate nutrient exchange.Additionally, it can be directly harvested, providing economic returns to farmers while supporting the growth of the main crop.This agricultural practice is rooted in the concept of "associational resistance," which encompasses strategies to increase agroecosystem diversity. Companion planting focuses on cultivating plants alongside cash crops to achieve benefits such as pest repellence through scent masking, confusion of adult pests, acting as decoy plants, and protection against soil-borne pathogens by releasing root toxins. By fostering positive interactions between plants, companion planting increases economic value per unit area, contributing to sustainable agricultural development. This article explores the role of companion planting in promoting sustainability in vegetable production.

History of companion planting

The history of companion planting is not well documented because it is likely a practice with ancient roots. For centuries, companion planting has been practiced by many tribal groups throughout the world. Three Sisters is one example of companion planting known to the Native American tribes comprising of corn, beans, and squash. The corn provided a support for climbing bean vines, the beans added nitrogen to the soil, and the leaves of squash plants provided a mulch to hold water in the soil. Owing to its manifold advantages, companion planting has taken a growing interest among today's conventional farmers.

Benefits of companion planting

Advantages of companion planting include-

- Functions as a nurse crop, providing shade, wind protection, and weed control.
- Acts as a bait crop that lures pests more effectively than the primary crop.
- Minimizes risk through increased crop diversity.
- Unites aesthetics and functionality, providing a pleasing and healthful environment.
- Conserves water through living mulch and shade.

SN	Main crops	Trap crops	Insect
1	Tomato *(Solanum lycopersicum)*	Marigold *(Tagetes erecta)*, *Solanum viarum,* Corn	Tomato fruit borer *(Helicoverpa armigera)*
2	Okra *(Abelmoschus esculentus)*	Cluster bean *(Cyamopsis tetragonoloba)*	Spotted bollworm (Earies vitelli)
3	Onion (Allium cepa)	Carrot (Daucus carota)	Thrips (Thrips tabaci)
4	Cabbage *(Brassica oleracea)*	Yellow rocket (Barbera vulgaris), Collard greens (Brassica oleracea var capitata)	Diamond back moth (Plutella xylostella)
5	Brinjal *(S. melongena)*	Coriandrum sativum) *(Helicoverpa armigera)*	shoot borer *(Leucinodes orbonalis)*
6	Garlic *(Allium Sativum)*	Tulsi, Marigold	Thrips
7	Potato *(Solanum tubersoum)* and Tomato *(Solanum lycopersicum)*	Marigold	Nematode

- Maximizes space with fast-growing companion plants.
- Boosts natural predator populations targeting pests.
- Exhibits allelopathic effect influencing the growth and reproduction of pests
- Improves soil health, reducing erosion, enhancing organic biomass, and moisture retention. Therefore, it enhances long-term soil fertility.
- Increases crop production.
- Reduces reliance on chemical pesticides for economic and environmental benefits.
- Provides habitats and food sources for beneficial insects.
- Offers physical protection or support between plants.
- Deters pests by emitting sexual attractants.
- Suppresses pests, diseases, nematodes and weed growth.
- Conserves biodiversity by providing an alternative habitat beneficial for beneficial insects and pollinators.

How does companion planting operate?

Companion planting is a strategic approach to cultivate plant partnerships that create a harmonious farming ecosystem. The goal is to establish a balanced environment beneficial to all organisms, from microscopic soil microbes to tall corn plants. The key is to pair plants in a way that each imparts specific benefits to the other, such as providing nutrients or controlling weeds. For instance, Plant A may offer food for Plant B, while also aiding in weed control around Plant B. Aromatic herbs like thyme, lavender, scented geranium, and chamomile emit strong odors and natural toxins, acting as repellents against plant-eating animals and insect pests (Reddy, 2017). African and French marigold release the biochemical thiophene from their roots, which is toxic to root-knot nematodes (Marotti et al., 2010).

A. Insect-pests management

Companion plants directly control insect pests by discouraging pest establishment, by trapping pest insects away from the target crop (also called trap crop) and indirectly, by attracting natural enemies that then kill the pest.

White mustard and marigolds can deter nematodes in greenhouse tomatoes (Tringovska et al., 2015). Introducing marigolds alongside tomato plants can effectively discourage these harmful pests from targeting the tomatoes (Fig. 1). Additionally, the volatiles from onion, garlic, and marigold can deter or confuse flying insect pests.

Certain companion trap plants are more attractive to pests than the desired crops. These trap crops are strategically planted alongside primary cash crops to divert and concentrate pests away, reducing the need for extensive pesticide use (Table 1). This approach helps manage pests through pesticides or other cultural/biological methods.

Companion planting and trap crops not only attract pests but also attract natural enemies that indirectly control pest attacks. For instance, introducing flowering plants like coriander, dill, fennel, and carrot can increase the presence of predators like green lacewings and ladybugs, effectively managing aphids. In dealing with caterpillars, predatory wasps can be utilized, and companion plants such as chamomile, lemon balm, dill, fennel, yarrow, and peppermint can control them. Overall, strategic companion planting in the entire field aids in managing insect pests, providing a more sustainable approach to pest control.

B. Disease management

Cultivating companion crops alongside specific crops is beneficial for crop diversity and helps reduce the risk of crop loss. Companion planting is effective in preventing the spread of diseases.For example, introducing barley as a companion crop significantly reduced the occurrence of Ascochyta blight in peas by altering the microclimate and limiting the spread of spores(May et al., 2009).Similarly, companion cropping with potato onion enhanced tomato resistance against Verticillium wilt, showcasing the effectiveness of this approach in reducing soil-borne diseases in vegetables.

C. Weed management

Certain companion plants, such as legumes and vining crops like cucurbits, have the ability to manage weed growth in a vegetable garden.

The inclusion of ground covers like clover and rapidly growing plants such as buckwheat in the main crop field can efficiently suppress weeds by covering available space and shading out competitors. According to Isik et al. (2009), hairy vetch, grain sorghum, and Sudan grass are highly effective cover crops for minimizing weeds in organic lettuce production.

D. Improves soil fertility or structure

Monocropping or continuous cropping presents challenges such as nutrient imbalance and disruptions in soil microbial communities. Companion planting addresses these issues by enhancing soil nutrients, increasing enzyme activities, diversifying microbial species, and lowering the incidence of soilborne diseases. For instance, cultivating green onions alongside cucumbers can enhance cucumber plants' potassium absorption. Various reports indicate that companion planting with garlic, cabbage, celery, and oats in pepper cultivation enhances microbial diversity and significantly alters soil microbial community structures and compositions.

E.Improved pollination

Incorporating companion plants into fields serves to attract a diverse range of pollinators, including honeybees, to crops. Two key considerations when selecting companion plants for this purpose are ensuring their flowering time aligns with the main crop and assessing their adaptability to specific growing conditions. In vegetable cultivation, studies have indicated that the use of companion plants can enhance fruit sets, consequently increasing overall yields.For instance, cultivating garden peas alongside beans attracts pollinators, facilitating bean flower pollination. The planting of both annual and perennial companion plants has been found to impact the total and marketable yield in cucumber and habanero peppers (Montoya et al., 2020).

Conclusion

Understanding how beneficial organisms leverage plant resources has the potential to enhance biological pest control by indirectly supporting their populations. Farmers employ companion planting as an in-field strategy for pest management, highlighting the importance of data for tailoring cropping systems to specific pests. This approach focuses on preserving plant diversity and reducing pesticide usage. However, achieving a thriving crop necessitates a comprehensive Integrated Pest Management (IPM) program that combines cultural, mechanical, biological, and chemical methods.

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Human–Wildlife Conflict Management in the Farms of Kerala

Hridya S[1]
Dr. Hans Ram Meena[2]
[1]PhD Scholar,
Dairy Extension Division,
ICAR-National Dairy Research Institute,
Karnal, Haryana
[2]Head, Extension Education Division,
ICAR-Indian Veterinary Research
Institute, Izatnagar, Uttar Pradesh

Reports of human–wildlife conflict (HWC) incidents are on the rise in Kerala. Agrarianfamilies living alongforest fringes are the most affected by frequent interactions with wildlife. Conflict emerges when the needs of humans and wildlife overlap, spatially and temporally, resulting in both protagonists bearing associated costs.Wildlife damages crops, preys on livestock, breaks their houses, and episodically causes casualties, thus posing a threat to livelihood, safety, and overall well-being of farmers. Farmers, as a result, develop intolerance and hostility towards wild animals. Habitat degradation, fragmentation, and changes in land-use practices are identified as some of the root causes of the problem.

Large mammals like elephants are reported to damage crops like plantain, coconut, arecanut, pepper,

Fig 1: Electric fence protectingpaddy field and nylon net covering plantain

Fig 2: Predator-proof cattle shed

rubber, and paddy either through their raiding behaviour or by trampling while moving through the farm. Wild boars sniff their way to raid tubers like tapioca and colocasia, which are widely cultivated in the state. Macaques cause significant loss, especially to coconut farmers, as tender coconuts get targeted by these animals. Cattle, buffaloes, goats, and poultry are predated by carnivores like tigers and leopards.However, often, farmers don't account for the losses caused by rodents and birds like peacocks, though they are significant. So, to reduce these losses borne by the farmers, management of HWC through farm-level interventions is a necessity.

Management of HWC through prevention

Preventive measures could be adopted to stop or prevent losses due to wildlife before they occur. The methods that are being widely promoted and implemented in the farmers' field are discussed below.

1.Barriers: This could be physical barriers or biological barriers. Physical barriers include fences made out of stones, barbed wire, wooden poles, arecanut sheaths, thorns, or nylonnets which could be effective against small mammals. Electric fences (which could be solar-powered too) have proven to be successful in reducing human–elephant conflict, provided maintenance is done routinely. Maintaining hedgerows comprised of plants like bamboo, cactus, hibiscus, or eucalyptus could act as a biological barrier, to a limited extent. To protect livestock from carnivores that enter the human settlement, predator-proofing of sheds with wire mesh or use of cages are advised.

2.Disruptive stimulus applications: Disruptive stimuli are undesirable stimuli that prevent or alter particular behaviour of the animals. These stimuliinclude light, sound, smell,or touch which may startle or frighten an animal.Such stimuli could be used to drive the animals away from the farmers' field. Use of spot lights, hanging bright coloured clothes or reflective materials, sirens,

crackers, burning chillies or tyres, and electric fence causing electric shock are examples of this method. The limitation of these applications lies in the possibility that most species get habituated to these methods over a period of time.

3.Changing cropping pattern: Crops like plantain, coconut, paddy, and jackfruit, among others, attract elephants. Tubers attract wild boars. Identifying the wildlife species that cause major damage and the crop that gets damaged and avoiding growing such cropsin each forest fringe area could reduce conflict. Though this is theoretically a viable solution, its practicability is debatable, considering economic viability and cultivation feasibility of alternate crops.

4.Altering grazing pattern: Grazing of livestock inside the forest or forest fringes should be avoided to prevent depredation by carnivores. This could also avoid interaction with wild animals and reduce the chances of spread of diseases from wild animals to livestock or vice versa. Grazing of livestock in the forests would also pose competition to herbivores for food. Ensuring the availability of fodder to farmers by promotion of growing fodder crops is crucial in this matter.

Management of HWC through mitigation

Mitigation, here, refers to lessening the impact of HWC after it has occurred.The methods listed below are used to manage HWC to reduce farmers' suffering following an event of wildlife damage.

1.Compensation: The government offers monetary support to those impacted by HWC to make up for their lost income, in the form of an ex-gratia payment. Determining a sufficient compensatory amount and ensuring timely verification of the losses and disbursement of the payments could potentially help reduce anti-wildlife sentiment among the people, thereby building or strengthening tolerance.

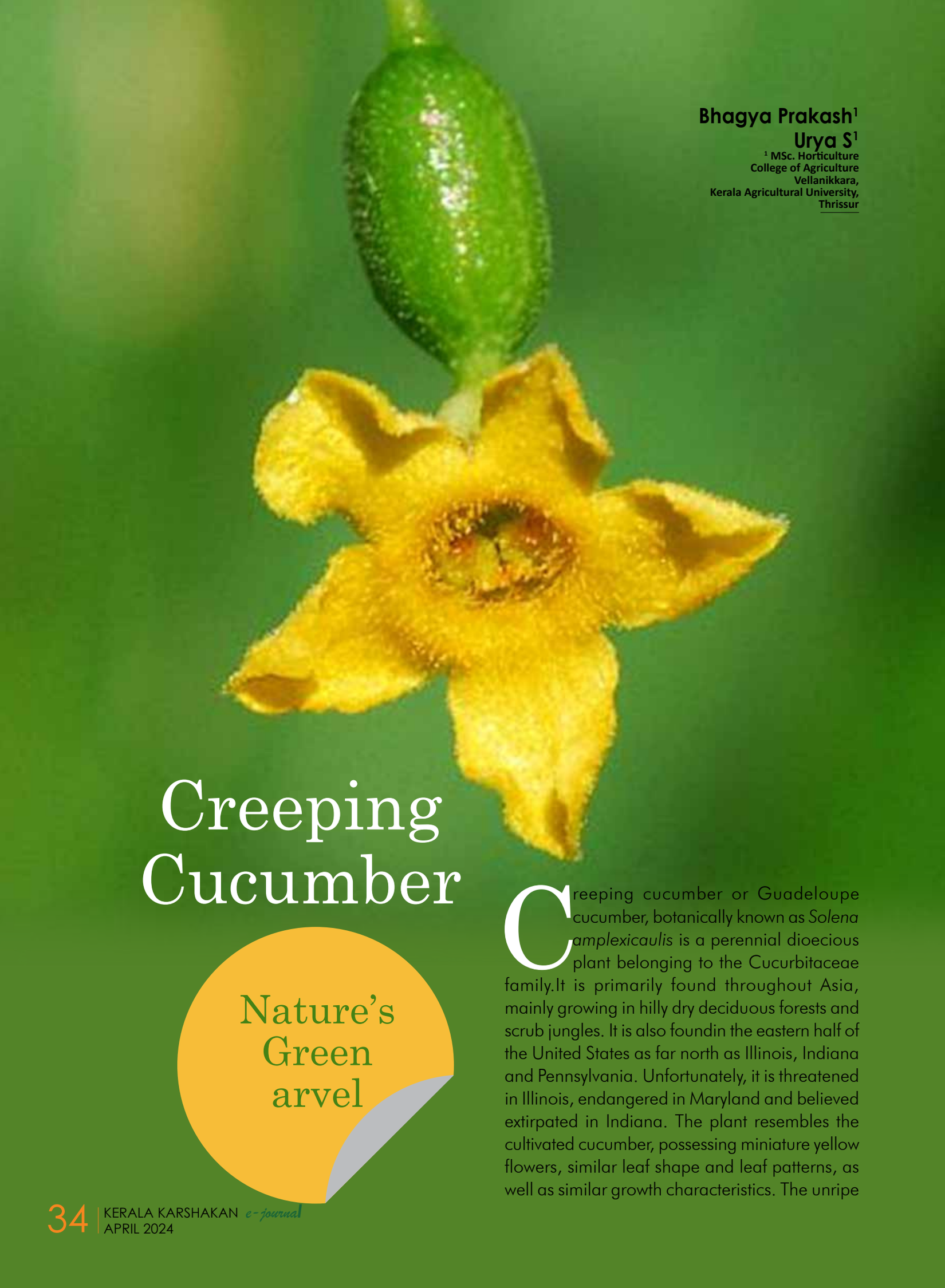
2. Insurance: Providing insurance coverage for farmers who face losses due to wildlife is under consideration by the government. In insurance schemes, farmers contribute a small amount as a premium to safeguard their crops and livestock against uncertain events in the future. Several existing insurance schemes do not account for wildlife losses, or cover only perennial crops. These require revision before proposing insurance as a conflict management option at larger spatial scales.

3.Providing alternative livelihoods: Providing opportunities like agrotourism or ecotourism is being suggested or promoted on trial basis, locally, among farmer communities in the forest fringe areas, there by helping them to generate additional income.The risk of income loss in the event that one crop gets damaged by wildlife can be mitigated by diversifying farm operations through beekeeping, fisheries, medicinal plant cultivation,and other ventures. Additionally, wildlife tourism being an income generation activity could aid in building tolerance for the species in the event of losses incurred.

Conclusion

Despite numerous HWC mitigation measures being experimented globally, no technique has been proven to be completely effective against driving wild animals. Site-specificity of mitigation measures need to be acknowledged, and blind replication of successful measures from one region to another to be avoided. It also needs to be conceded that conflict cannot be brought down to zero going forward.

Farmers need to be encouraged to trial the best preventive measures suitable for them and the region, and use a combination of those to ensure maximum safety. Financial assistance to implement these measures or incentives for those who do so, in order to offset the additional costs that forest fringe farmers must incur as a result of conflict, may also be considered.



Bhagya Prakash[1]
Urya S[1]
[1] MSc. Horticulture
College of Agriculture
Vellanikkara,
Kerala Agricultural University,
Thrissur

Creeping Cucumber

Nature's Green arvel

Creeping cucumber or Guadeloupe cucumber, botanically known as *Solena amplexicaulis* is a perennial dioecious plant belonging to the Cucurbitaceae family.It is primarily found throughout Asia, mainly growing in hilly dry deciduous forests and scrub jungles. It is also foundin the eastern half of the United States as far north as Illinois, Indiana and Pennsylvania. Unfortunately, it is threatened in Illinois, endangered in Maryland and believed extirpated in Indiana. The plant resembles the cultivated cucumber, possessing miniature yellow flowers, similar leaf shape and leaf patterns, as well as similar growth characteristics. The unripe

berries strongly resemble minuscule watermelons.

Botany

The plant consists of several spindle-shaped tuberous roots which are 1.5-2 cm in diameter and with slender branched furrowed stems bearing simple tendrils. Leaf stalks are slender, 4-10 mm, finelyvelvet-hairyatfirst, becoming hairless after some time. The leaves of *Solena amplexicaulis* are arranged alternately along the stem. Leaves are usually simple, ovate to cordate, measuring approximately 1 to 2 inches in length having palmate venation, with multiple veins running out wards from the base to the edges of each leaf. The leaf margin is typically entire or slightly toothed with medium green colour.

The flowers are small and yellow in colour. Male flowers are umbellate or sub-umbellate, flower-cluster stalk is very short, apically with10-20-flowered. Flower stalks are 2-8 mm in length, calyxtube is about 3-5 mm inlength and about 3mm indiameter. Flowers are yellow or yellow-white, petals are triangular in shape,1-1.5 mm in size, tip of petals are blunt or pointed, filaments are thread-like, about 3mm in length. Female flowers are usually solitary, flower-stalk is about 2-10 mm in length, finely velvet-hairy,calyx and flower of female flower is the same as male flowers. The ovary is ovoid in shape, 2.5-3.5 × 2-3 mm in diameter and stigmas are 3 in number.

The immature fruit is small, green, and ovoid, resembling miniature watermelons about 3cm in length. Ripe fruit is very dark purple and also about 3-4 cm long. Seeds of small, flat, and brown colour are present inside the fruits.

Creeping cucumber thrives well in warm climate. It is well-suited for tropical and subtropical regions. These plants prefer temperatures between 70°F to 90°F (21°C to 32°C). They are sensitive to frost and should be grown during the frost-free periods.

Soil

Creeping cucumbers prefer well-drained, fertile soil. A loamy soil that retains moisture but does not become water logged is ideal. Ensure the soil has a slightly acidic to neutral pH (around 6.0 to 7.0). Adding organic matter, such as compost, to the soil before planting can enhance its fertility and structure.

Propagation

1. Seeds

Sow the seeds in pots or seed trays filled with a quality seed-starting mix. Plant the seeds about 1/2 to 1 inch deep. Keep the soil consistently moist and maintain a warm temperature (around 70°F to 80°F or 21°C to 27°C) for germination.

2. Transplanting

Once the seedlings have developed a couple of true leaves and the danger of frost has passed, transplant them into the garden or larger containers.

Spacing

Space the creeping cucumber plants about 12 to 18 inches apart to allow for their spreading growth habit.

Care and maintenance

Provide support ortrellis for the vines to climb if it is necessary to control its spread or if space is limited. Regular watering is essential, especially during dry periods.

Uses

The unripe fruits of *Solena amplexicaulis* are used for making salads and in curries, and leaves, stems and tubers are used for edible purposes. In Chhattisgarh, the fruits and roots are consumed to assist in the digestion of bushmeat. Creeping cucumber can be gathered from the wild or can be cultivated as a field crop and given suitable supports over which to climb.

In traditional medicine, the tuberous roots of *Solena amplexicaulis* are used to treat anorexia, digestive problems, flatulence, asthma, gonorrhea and spermatorrhea, and extracts of the leaves are widely used to treat inflammation. The whole plant is used to cure jaundice. The tubers, leaves and seeds of the plant are extensively used in the traditional system for various ailments like gonorrhea, dyspepsia, asthma, appetizer, spermatorrhea, thermogenic, hepatosplenomegaly, cardiotonic, diuretics, hemorrhoids and invigorating. The whole plant is a potential source of natural antioxidant activity. Plant pacifies vitiated kapha, vata, anorexia, dyspepsia, colic, asthma, cough, renal calculi,

urinary retention and constipation. It is useful in paralytic disorders also.

Nutraceutical properties of Solena amplexicaulis

Chloroform and benzene stem extract of *Solena amplexicaulis* exhibited significant antibacterial activity. The ethanolic root extract of the plant showed promising results for both gram-positive and gram-negative bacteria.

In vitro antioxidant activity of *S. amplexicaulis* root was studied by using various alcoholic and aqueous extracts of tuber whose result showed good antioxidant activity and it was compared with synthetic (BHA and BHT) as well as natural antioxidants (rutin and quercetin). The aqueous extracts of the leaf have also shown significant anti-inflammatory activity.

The ethanolic extract of *S. amplexicaulis* showed a higher percentage of α-amylase inhibitory. The leaf and stem extracts possess anti-diabetic activity in terms of their α -amylase inhibition activity. Studies also show that the plant has hepatoprotective, analgesic, and urinary stone prophylaxis activity. The research on the nutraceutical value of this plant proves that it has valuable compounds for curing many diseases and thus it is a promising plant for future advanced medicine. The plant has good future prospects for the discovery of new molecules and pharmacological activities.

Pests and diseases

While creeping cucumbers are relatively hardy, they can be susceptible to common cucumber pests and diseases, such as aphids or powdery mildew. Providing proper spacing, good air circulation, and avoiding overwatering can help prevent these issues.

(Image courtesy: The Western Producer/Reuters/Erik De Castro)

Biofortification

A potential weapon to combat malnutrition

Hridya Biji[1]
Malavika N Shal[1]
Niranjana M[1]
Sasidharan N[2]

[1]Division of Genetics, ICAR-Indian Agricultural Research Institute, New Delhi
[2]BA College of Agriculture, Anand Agricultural University, Gujarat

Malnutrition or malnourishment is the lack of proper nutrition, caused by not having enough to eat, not eating adequate number of right things, or being unable to use the food that one does eat. Malnourishment may happen due to lack of sufficient calories or protein, carbohydrates, fats in the diet resulting in nutritional deficiency syndromes whose effects are obvious. "Hidden a from", form of malnutrition or undernourishment that occurs when intake and absorption

Table 1: Comprehensive list of biofortified crop varieties developed by transgenic technology worldwide.

Sl No.	Crop	Features	Mechanism/Target gene
1	Transgenic wheat	Increased protein content & antioxidant activity	Amaranthus albumin gene Maize regulatory genes
2	Transgenic maize content	Increased lysine &tryptophan	Antisense dsRNA targeting alpha zeins
3	Transgenic soybean	Rich in oleic acid	Antisense RNA mediated silencing of *FAD2-1*
4	Starch potato	Decreased amylose & increased amylopectin content	Downregulation of AGPase.
5	Transgenic carrot	Rich in calcium	Arabidopsis calcium transporter
6 7	Transgenic cassava Transgenic	Increased beta carotene in roots cauliflowerIncreased beta carotene content	Bacterial phytoene synthase gene(*crtB*) Insertion of copia like LTR retrotransposon in the *Or* gene.
8	Transgenic linseed	Rich in carotenoids	Bacterial phytoene synthase gene(*crtB*)
9	Transgenic mustard	Rich in gamma linoleic acid	*PiD6* encoding 6 fatty acid desaturase
10	Transgenic tomato	Enriched with lycopene, beta carotene, lutein, vitamin C, and antioxidants.	Overexpression of lycopene beta cyclase.
11	Transgenic banana	Enriched with Vitamin A	Overexpression of *PSY* gene

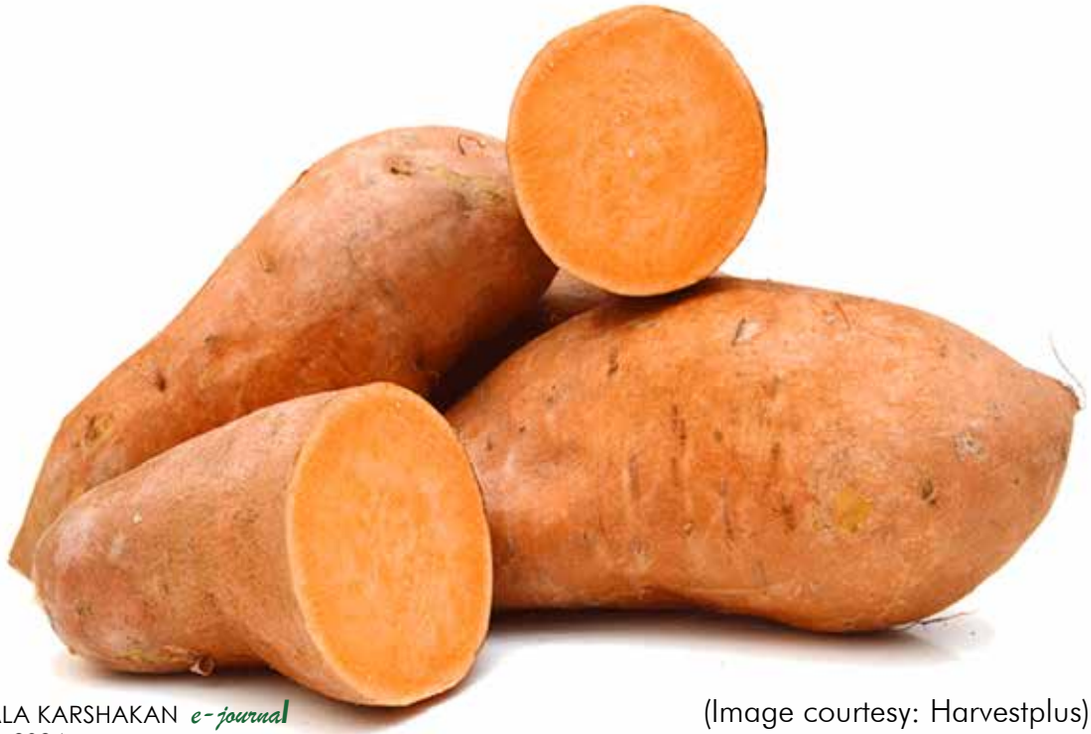
(Image courtesy: IRRI)

(Image courtesy: Mitra S. 2012. Nutritional Status of Orange-Fleshed Sweet Potatoes in AlleviatingVitamin A Malnutrition through a Food-Based Approach: Agricultural and Food Sciences. Journal of Nutrition and Food Sciences.DOI:10.4172/2155-9600.1000160)

of micronutrients are very less to maintain a good health and development. The term is coined because the effects of micronutrient deficiency are less obvious or invisible and the clinical signs of hidden hunger like night blindness due to vitamin A deficiency and goitre from inadequate iodine intake, become visible only once the deficiencies become severe (Gautam, 2014). Around 2 billion people across the world suffer from hidden hunger (FAO 2013). As per the 2019 UNICEF report, more than 80% of adolescents in India suffer from malnutrition, 44% of children under the age of 5 are underweight and 16% of India's population is undernourished. The trend was also evident from India's rank in Global Hunger Index (GHI, 2023) plummeting to 111 from 107 (GHI, 2022) out of 125 countries surveyed thus making it a front-runner in lack of nutritional security. Effects on children are more acute, especially during the first thousand days, leading to severe physical and cognitive consequences. At a time when more than 30% of the world is anemic, stunting and wasting are becoming frequent in infants; we need an antidote to combat this hidden hunger and deficiency diseases.

The nutritional dilemma-what do our diets lack?

One of the key reasons for undernourishment is the lack of diversity in the diet. Populations living under poverty line follow a diet dominated by staple cereal grains followed



(Image courtesy: Harvestplus)

(Image courtesy: Harvest Plus)

by pulses in miniscule quantity and tubers, the other potential sources of nutrients viz., vegetables, fruits, dairy and meat beyond the means of the poor and impoverished. Cereals are rich in carbohydrates which provides energy, nevertheless, lacking in micronutrients. Hence hidden hunger has serious implications particularly in developing and least developed countries. Micronutrients include vitamins like Vit. A, Vit. D and minerals like iron, iodine, copper, manganese, selenium, molybdenum, cobalt, nickel, and zinc. These micronutrients are present in fruits, vegetables, and non-vegetarian sources. Since there is limited availability of these food sources to socially and financially backward populations, the best way to improve their micronutrient intake is by improving the micronutrient content in cereal grains, pulses, and tubers.

What is biofortification?

Biofortification can be defined as the process of increasing the density and bioavailability of keymicronutrients of staple crops to improve the nutrition of populations whose diets are mainly based on staple crops. The term biofortification was coined by Steve Beebe in 2001. Biofortification is quite a cost-effective and feasible approach of delivering micronutrients to populations who may have limited access to diverse diets, supplements, or commercially fortified foods. It can be achieved by conventional plant breeding as well as transgenic technology. Crops are bred for higher levels of micronutrients using conventional breeding methods and have been released in several countries which are now being grown and eaten by farmers and consumers. The results of efficacy and effectiveness studies, as well as consumer acceptance studies, provide evidence that biofortification can be one of the way out to mitigate the problems arising among nutritionally incapacitated.

Different approaches to achieve biofortification

(1) Transgenic approach: In this method micronutrient content is increased by introducing foreign genes into the crop genome by genetic engineering

Table 2: Comprehensive list of biofortified crops developed through conventional plant breeding by ICAR institutes across the country.

Sl No.	Crop	Biofortified cultivar	Developed by	Released in and notified for	Features
1	Rice	CR Dhan 310	ICAR-NRRI, Cuttack, Odisha	Madhya Pradesh, Odisha, and Uttar Pradesh (2016)	Enriched protein (10.3%) in polished grain, matures in 125 days and average grain yield is 45q/ha.
		DRR Dhan 45	ICAR-IIRR, Hyderabad, Telangana	Tamil Nadu, Karnataka, Andhra Pradesh, and Telangana (2016)	Enriched zinc (22.6 ppm) in polished grain, matures in 125-130 days and average grain yield 50q/ha.
		DRR Dhan 49	ICAR-IIRR, Hyderabad, Telangana	Gujarat, Maharashtra, and Kerala (2018)	Enriched zinc (25.2 ppm) in polished grain and average grain yield is 50q/ha.
		CR Dhan 315	ICAR, NRRI,Cuttack	Odisha (2021)	Rich in protein (10.1%) and grain yield of 56.2/ha, matures in 140 days.
2	Wheat	WB 02	ICAR-IIWBR, Karnal, Haryana	Delhi, Punjab, Haryana, Rajasthan, Uttar Pradesh, Jammu and Kashmir, Himachal Pradesh, and Uttarakhand (2017)	Delhi, Punjab, Haryana, Rajasthan, Uttar Pradesh, Jammu and Kashmir, Himachal Pradesh, and Uttarakhand (2017)
		HPBW 01	PAU, Ludhiana under AICRP on wheat and barley	Delhi, Punjab, Haryana, Rajasthan, Jammu, Una of Himachal, and Tarai of Uttarakhand.	High iron (40 ppm), zinc(40.6ppm), matures in 141 days and average grain yield is 51.7q/ha.
		PusaTejas (HI 8759)	ICAR-IARI, R S, Indore, Madhya Pradesh	Madhya Pradesh, Chattisgarh, Gujarat, Rajasthan, and Uttar Pradesh	High protein (12%), iron(42.1ppm), zinc (42.8 ppm). Excellent durum wheat variety suitable for chapatti, pasta and average grain yield is 50q/ha.
		PusaUjala (HI 1605)	ICAR-IARI, RS, Indore, Madhya Pradesh	Maharashtra, Karnataka, and Tamil Nadu (2017)	High protein (13%), iron (43 ppm), zinc(35ppm). Excellent chapatti making quality and average grain yield is 30q/ha.

Sl No.	Crop	Biofortified cultivar	Developed by	Released in and notified for	Features
		MACS 4028	Agharkar Research Institute, Pune, Maharashtra under AICRP on wheat and barley	Maharashtra, Karnataka (2018)	High protein (14.7%), iron(46.1ppm) and zinc(40.33ppm). Matures in 102 days and average grain yield is 19.3q/ha.
		HI 8823(durum)	ICAR-IARI,RS,Indore	Madhya Pradesh, Chattisgarh, Gujarat, Rajasthan (2021)	High in protein 12.1% and zinc 40.1ppm.
		HUW 838	HUW 838 BHU under AICRP on Wheat & Barley	Punjab, Haryana, Delhi, Jammu &Kashmir, Himachal Pradesh,	High zinc (41.8 ppm), average grain yield 51.3 q/ha and matures in 148 days.
3	Lentil	Pusa Vivek QPM9 Improved	ICAR-IARI, New Delhi	Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu Jammu & Kashmir, Himachal Pradesh, Uttarakhand, andNorth Eastern states. (2017)	Early maturing hybrid(83-93 days) with 8.15ppm of provitamin A, 0.74% tryptophan and 2.67% lysine.
		Pusa HM4 improved	ICAR-IARI, New Delhi	Punjab, Haryana, Delhi, Uttarakhand, and western Uttar Pradesh (2017)	Medium maturing hybrid with 0.91% tryptophan and 3.62% lysine with average grain yield of 64.2q/ha.
		Pusa Vivek QPM9 Improved	ICAR-IARI, New Delhi	Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu Jammu & Kashmir, Himachal Pradesh, Uttarakhand, andNorth Eastern states. (2017)	Early maturing hybrid (83-93 days) with 8.15ppm of provitamin A, 0.74% tryptophan and 2.67% lysine.
		Pusa HM9 Improved	ICAR-IARI, New Delhi	Bihar, Jharkhand, Odisha, West Bengal and Uttar Pradesh (2017)	Medium maturing hybrid with high tryptophan (0.68%) and lysine (2.97%).
		Pusa HQPM 1 Improved	ICAR-IARI, New Delhi	Kharif season across the country (2021)	Rich in provitamin A(7.02 ppm), lysine(4.59%) and tryptophan(0.85%) with average grain yield is 81.9/ha and matures in 111 days.

Sl No.	Crop	Biofortified cultivar	Developed by	Released in and notified for	Features
4	Pearl Millet	HHB 299	CCHSAU with ICRISAT	Haryana, Rajasthan, Gujarat, Punjab, Delhi, Maharashtra, and Tamil Nadu (2017)	A hybrid with high iron(73ppm), zinc(41ppm) content and grain yield is 32.7q/ha and dry fodder yield is 73q/ha and matures in 81 days.
		AHB 1200Fe	VNMKV, Parbhani with ICRISAT	Haryana, Rajasthan, Gujarat, Punjab, Delhi, Maharashtra, and Tamil Nadu (2017)	A hybrid rich in iron(73ppm) and average grain yield is 32q/ha with dry fodder yield 70q/ha. Matures in 78 days.
		HHB 67 Improved 2	CCSHAU with ICRISAT	Rajasthan, Gujarat, Haryana (2021)	Rich in protein (15.5%), Iron 54.8 ppm, Zinc (39.6 ppm) with grain yield of 20q/ha, dry fodder yield 52.3 q/ha and matures in 76 days.
5	Finger millet	VR 929 (Vegavathi)	ANGRAU under AICRP on small	Kharif season across the country (2020)	Rich in iron(131.8ppm), matures in 118 days with dry fodder yield of 2 q/ha and grain yield of 36.1q/ha.
		CFMV1 (Indravathi)	ARS, ANGRAU, Vizianagaram under AICRP on small millets	Andhra Pradesh,Tamil Nadu, Karnataka, Puducherry and Odisha(2020)	Rich in calcium(428mg/100g), iron(58ppm) and zinc (44 ppm) with dry fodder yield of 4.4 q/ha and grain yield of 31.1 q/ha. Matures in 113 days.
6	Lentil	PusaAgetiMasoor	ICAR-IARI, New Delhi	Uttar Pradesh, Madhya Pradesh and Chattisgarh (2017).	Pureline variety with 65 ppm iron content, matures in 100 days and grain yield is 13q/ha.
		IPL 220	ICAR-IIPR, Kanpur	Uttar Pradesh, Bihar, Assam, West Bengal (2018)	High iron(73ppm) and zinc content(5199m). Average yield is 13.8q/ha and matures in 121 days.
7	Groundnut	Girnar 4	ICAR-DGR, Junagadh	Rajasthan, Karnataka, Gujarat, Tamil Nadu	Rich in oleic acid (78.5%), 53% in oil content,27% protein content, matures in 112 days and kernel yield of 21.3 q/ha.
		Girnar 5	ICAR-DGR, Junagadh	Rajasthan, Karnataka, Gujarat, Tamil Nadu	Rich in oleic acid (78.4%), 53% in oil content,26% protein content, matures in 113 days and kernel yield of 21.3q /ha.

Sl No.	Crop	Biofortified cultivar	Developed by	Released in and notified for	Features
8	Mustard	Pusa Mustard 30	ICAR-IARI, New Delhi	Uttar Pradesh, Uttarakhand, Madhya Pradesh, and Rajasthan (2013)	Low erucic acid (<2%), average oil content is 37.7% with seed yield of 18.2q/ha and matures in 137 days.
		Pusa Double Zero Mustard 31	ICAR-IARI, New Delhi	Northern states of India	Low erucic acid (<2%) in oil and glucosinolates(<30ppm) in seed meal with oil content 41% and seed yield of 23q/ha.
9	Soybean	NRC 127	ICAR-IISR, Indore	Madhya Pradesh, Uttar Pradesh, Rajasthan, Maharashtra, Gujarat (2018)	KTI-free pureline variety with 40% protein, 20% oil, average yield is 18q/ha and matures in 104 days.
		NRC 142	ICAR-IISR, Indore	Madhya Pradesh, Uttar Pradesh, Rajasthan, Maharashtra, Gujarat, Karnataka, Andhra Pradesh, Tamil Nadu(2018)	India's first double null variety for KTI and lipoxygenase-2, grain yield is 20q/ha and matures in 96 days.
10	Cauliflower	Pusa Beta Kesari 1	ICAR-IISR, Indore	NCR, New Delhi	Rich in provitamin-A(8-10ppm) and curd yield of 40-50 t/ha.
11	Potato	KufriManik	ICAR-CPRI, Shimla	Punjab, Uttar Pradesh, West Bengal, Bihar, Assam	Rich in anthocyanin(0.68ppm), matures in 90-100 days and tuber yield is 23t/ha.
		Kufri Neelkanth	ICAR-CPRI, Shimla	Punjab, Uttar Pradesh, Haryana (2020)	Rich in anthocyanin(1ppm) and antioxidants and matures in about 90-100 days and tuber yield is 36-38t/ha.
12	Sweet Potato	Bhu Sona	ICAR-CTCRI, Thiruvananthapuram	Odisha (2017)	Pureline variety with high beta carotene(14mg/100g). Average tuber yield is 19.8t/ha and dry matter of 27-29%, starch 20% and total sugar 2.4%.
		Bhu Krishna	ICAR-CTCRI, Thiruvananthapuram	Punjab, Uttar Pradesh, Haryana (2020)	High anthocyanin(90mg/100g), average tuber yield is 18t/ha with dry matter of 24-25.5%, starch of 19.5% and total sugar of 1.9-2.2%.

Sl No.	Crop	Biofortified cultivar	Developed by	Released in and notified for	Features
13	Pomegranate	Solapur Lal	ICAR-NRC on Pomegranate, Pune	Semi-arid regions of India (2017)	Hybrid variety with high iron (5.6-6.1 mg/100g), vitamin C(19.8mg/100g) and zinc(0.69mg100g) in fresh arils and average fruit yield is 27t/ha.
14	Greater Yam	SreeNeelima	ICAR-CTCRI, Thiruvananthapuram	Kerala (2020)	Rich in anthocyanin(50mg/100g), crude protein (15.4%) and zinc (49.8 ppm). It matures in 240-270 days and tuber yield is 35t/ha.
		Da 340	ICAR-CTCRI, Thiruvananthapuram	Kerala (2020)	Rich in anthocyanin (141.4mg/100g), iron (136.2 ppm) and calcium (1890ppm). It matures in 240-270 days and average tuber yield is 80t/ha.

to develop GM (Genetically Modified) crops. This method is considered when there is not enough variability for high micronutrient content in the gene pool of the concerned crop. The first and best example of biofortification is "Golden rice" in which the provitamin A(beta-carotene) content was increased by expressing genes encoding "phytoene synthase" and "carotene desaturase" in rice grains. The *psy* (phytoene synthase) gene was derived from daffodils (*Narcissus pseudonarcissus*) and crtI (carotene desaturase) from the soil bacterium *Erwinia uredovora* (syn Pantoeaananatis). Since there is no naturally occurring variation for provitamin A in grains in rice germplasm, biofortification was achieved by using genetic engineering, utilizing genes from across other species.Another example in rice is iron biofortification by increasing folate content to address the global challenge of anemia. Other examples of transgenic crops for biofortification are summarized in table1. The transgenic approach is still not much successful because of low acceptance among the masses and the regulatory processes are expensive and time-consuming.

(2) Conventional breeding approach: In case of crop plants where sufficient genetic variability is existing for high micronutrient content it can be utilized through conventional plant breeding techniques. It is the most widely accepted and trusted method to achieve biofortification. It involves screening of germplasm for sufficient variability and pre-breeding of parental genotypes if variability is not sufficient in the primary gene pool. Parent lines with rich nutrients are crossed with recipient lines of desirable agronomic traits in the conventional breeding approach.

HarvestPlus, a CGIAR Research Program on Agriculture for Nutrition and Health is operational in India and Africa. It focuses on the improvement of three nutrients Vitamin A, Iron and, Zinc in crops like rice, wheat, maize, beans, cassava, sweet potato, and pearl millet. BRRIdhan 62, BRRIdhan 72, and BRRIdhan 64(World's first zinc enriched ~ 20-22ppm in brown rice) were released by HarvestPlus along with Bangladesh Rice Research Institute in 2013.An improved line(IR6144-3B-2-2-3) was developed from the cross of IR72 and Zawa Bonday which

has high concentration of Fe (21ppm in brown rice). IIW & BR, Karnal has released WB2; a high zinc and iron-containing variety. ICRISAT has developed iron and zinc rich Bajra variety Dhanshakthi.Sunblack, a biofortified anthocyanin deep purple fruit peel variety of tomato has been developed under the TomAntho research project. Biofortified cultivars recently developed and released through the AICRP network are presented in the table no. 2.

Mineral biofortification is another term which is defined as when the micronutrient enrichment is done at the growing phase of agricultural crops (Dwivedi et al., 2012). This is not biofortification in the truest sense of meaning but can be called as biofortification by agronomic approach. It involves the physical application of mineral fertilizers and an increase in their mobilization and solubilization from soil to edible parts of plants. It includes foliar spray of iron, zinc oxide, and zinc sulphate on rice plants. Selenium biofortification in potato tubers is achieved by applying selenite/selenate along with humic acid.Iodine and selenium biofortification in lettuce leaves through the application of potassium iodate and sodium selenate.Zinc mobilization and biofortification in wheat through the application of Bacillus aryabhattai strains.Sorghum biofortification is achieved by using Azospirillumstrains blended with phosphorus solubilizing bacteria which has a profound effect on protein, nitrogen, and phosphorus. In chickpeas, manuring with actinobacteria can cause an increase in nutrient profile. However agronomic approaches face a lot of limitations as their success depends on mineral mobility, mineral accumulation among plant species, and soil compositions in specific geographical locations of each crop. It is a labor-intensive approach that needs continuous application of inputs and it's quite difficult to target these micronutrients to edible portions of plants. Moreover, mineral availability can be hindered by antinutrient compounds and fertilizer accumulation in soil and water causes pollution. However, if identifying the genes responsible for the uptake, transport, and integration of the nutrients in the grains can be achieved through mineral biofortification, then it can pave way in developing super nutritive cultivars.

Even though many varieties and hybrids have been developed through conventional breeding approaches, they face a lot of lacunas such as the limited amount of genetic variability in the gene pool, the time needed to develop crops with desired traits, and developed cultivars having heritability issues and linkage drag. With the newer and advanced approaches in hand as mentioned above, the researchers can bring up cultivars that are rich in nutrients. However, misconceptions and social anathema towards these modified varieties deprive the masses, access to cheap and healthy foods. Hence approvals at the government level along with an efficient extension network system which encourage farmers to take up the cultivation of biofortified crops are needed and incentives for masses to start consuming the biofortified crops should be envisaged to combat micronutrient deficiencies and embrace a healthy life.

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