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Growing seed

Editorial Board

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ACQUISITION OF DESICCATION TOLERANCE IN SEEDS

Email
n.veronica@angrau.ac.in
Veronica N
Acharya N G Ranga Agricultural University, RARS, Maruteru- 534122, India

Maturation drying is the normal terminal event in the development of many seeds, after which they pass into a metabolically quiescent state. Seeds remain viable in this dry state from several days to many years, and they germinate upon hydration if they are not dormant (Matilla, 2022).

Acquisition of Desiccation Tolerance in Crop Plants

Desiccation is the process of becoming completely dry. Seeds are not capable of withstanding desiccation at all stages during their development, but their acquisition of desiccation tolerance is usually considerably earlier than maturation drying itself. In the developing castor bean (*Ricinus communis*), seeds show germination 50-55 days after pollination (DAP), when maturation drying has commenced. But excised seeds do not germinate until they reach maturation drying. If excised seeds are first desiccated and placed on water, germination is achieved as early as 25-30 DAP. Seeds desiccated at 20 DAP will not germinate, nor will they survive, they have yet to reach the desiccation tolerant stage of their development. In some species desiccation-tolerance is achieved within 5 days during development (20-25 DAP) and similar rapid acquisition of tolerance occurs in developing seeds. Eg:- *Phaseolus vulgaris*, Mustard and Rape seed.In case of castor been survival upon desiccation occurs only if the seed is dried slowly over several days, later times of development tolerance of rapid desiccation is acquired. Thus the ability of seeds to tolerate desiccation improves progressively during development. This is consequence of physiological and morphological changes which take place gradually as development proceeds and synthesis of specific protective substances at later stages.In castor bean and soybean as seeds mature not only they become more tolerant of desiccation but also upon rehydration they increase capacity to form normal seedling. Drying leads to improved seedling quality following subsequent germination. Seeds of some graminae species may withstand rapid desiccation relatively early during their development. Eg:- *Avena fatua* (wild oat). The onset of desiccation tolerance in developing seeds may or may not coincide with their, or their embryos, ability to germinate, depending on the species. Eg:-barley.

Changes in Metabolism Associated with Drying

Several metabolic changes occur in seeds either just prior or during drying. These changes involve the appearance of oligosaccharides and sugars or specific types of proteins that have significant role in the protection of seed tissues against the rigors of dessication.

Sugars*:* In maturing seeds of several species, the concentration of several sugars and oligosaccharides increases in association with the onset of desiccation tolerance and in the early phase of water loss, they are the source of carbon and inducer of dessication tolerance (Mondal *et al*., 2002). .eg :- white mustard-sinapsis alba, soybean , brassica compestris, maize. In some cases disaccharise sucrose, oligosaccharides raffinose, and stachyose are relatively abundant. But these compounds generally occur at much lower concentrations when glucose, mannose, fructose and galactose predominant. In developing embryos like soybean, there is an increase in some sugars and oligosaccharides within embryos induced to become desiccation tolerant by slow drying. For example, the involvement of sucrose and oligosaccharides plays a role in desiccation tolerance in case of Arabidopsis thaliana.

Proteins**:** Proteins such as the dehydrins play an important key role in protection especially at very low moisture contents, they replace water and thus stabilize the cellular membranes and other sensitive systems (Savage, 2003). During seed development and maturation different groups of transcripts and their protein tranclation products arise at discrete times.In castor embryos one group of proteins accumulated relatively in high concentration at late embryogenesis, so these are named as LEA proteins (late embryogenesis abundant proteins) encoded by the lea genes.

LEA proteins: Their amino acid sequence has been deduced from the base composition of their respective cDNAs.These also found in other plant species and considered to have a highly homologous group. These are strongly hydrophilic proteins, highly stable in nature, not denaturated by boiling. Their ability to attract water water molecules maintain a water-enriched local environment. Even sometimes they act as substitutes for water. So at subcellular level they play an important role in protection against desiccation.

Conclusion

The process of desiccation tolerance is established during the later stages of seed development and is lost during the process of germination. Desiccation tolerance is a complex trait involves cellular protection and repair. Attaining levels of desiccation tolerance varies and is mainly dependent on progressive acquisition of specific tolerance mechanisms or accumulation of desiccation protectants. Proteins and sugars play a protective role by stabilizing the cellular membranes.

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EARTHWORM ECOSYSTEM: UNVEILING THE BENEFITS OF VERMICOMPOSTING

[1]Aadil Khan*, [1]Anisha Kalindi, [1]Rahul Mahto and [1]Jay Shankar Mishra

Email
aadilkhan7322@gmail.com

[1]Horticulture College, Khuntpani, BAU, Ranchi, India

Vermicomposting is a specialized form of composting that uses earthworms to break down organic materials into nutrient-rich compost. It's a biological process where earthworms consume organic matter, such as kitchen and plant waste and transform it into a valuable soil amendment called vermicompost. This type of composting is an effective way to recycle organic waste and used as an organic manure.

According to Dr. P.K. Mishraan Indian soil scientist who was also a pioneer in the field of vermicomposting states that “Vermicompost is a humus-like product obtained by the bioconversion of organic wastes by earthworms”. A Dutch soil scientist Dr. W.J.M. van Rhee states that "Vermicompost is a product obtained by the biological decomposition of organic matter by earthworms and their associated microorganisms”. Vermicompost is same as compost except that here earthworms are used to decompose the organic matter which accelerate the process of decomposition resulting ready in less time period in compare to compost. The process of making vermicompost is known as vermicomposting. Earthworm acts physically an aerator, crusher and mixer, chemically a degrader and biologically a stimulator in the process of decomposition. Vermicompost acts as an organic soil amendment- improves three-dimensional soil health’s (physical, chemical & biological properties). On application of vermicompost, it enhances the soil quality by improving its Physicochemical and Biological Properties.

Enterprises Associate with It

Vermiwash

It is drain out extract of vermicompost. The vermicomposting unit is set up with water trickling system to collect vermiwash. Water drops down over the vermicompost pit slowly and slowly. It contains more nutrients than vermicompost.

Vermiculture

It is simply defined as the rearing of earthworms by artificial means in order to use them in vermicomposting.

Advantages of Vermicompost

- Nutrient – rich compost
- Improved soil structure
- Enhanced plant growth
- Waste reduction
- Balance the pH level of the soil
- Safe for plants and environment
- Carbon sequestration
- Promotes beneficial microorganisms
- Cost – effective

Disadvantages of Vermicompost

- Odor issues
- Temperature and moisture control
- Slow process
- Pest attraction
- Initial investment
- Maintenance

Basic Requirements

Earthworms

Earthworm plays a key role in vermicomposting. The surface feeder earthworms, Epigeics are important for vermicomposting. The Epigeics used for vermicomposting are such as *Eisenia Foetida, Eudrilus eugeniae*.

Organic Substrates

Organic waste materials which are bio-degradable in nature which are not harmful for the earthworm are used as organic substrates. E.g., cow dung, kitchen wastes etc. Different organic substrates are used in vermicomposting. These may be classified as follows:

Table 1. Different sources of feedstocks for earthworm

Sources	Wastes
Agriculture wastes	Paddy straw, rice husk, wheat bran, wheat straw etc.
Food processing wastes	Sugar industry wastes, wine industry wastes, oil industry wastes etc.
Wood processing wastes	Wood chips, wood shavings, saw dust
Fruits and vegetable processing wastes	Peels, banana stems, rinds and unused pulp

Site Selection

Vermicompost production can be done in any place which is having shades, high humidity and cool. If it is to be produced in the open area, artificial shading should be provided. The waste heaped for vermicompost production should be covered with moist gunny bags

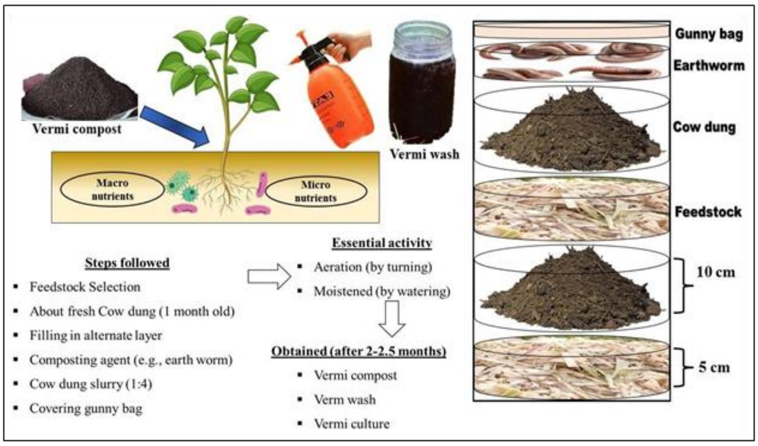

Plate 1. Steps followed in Vermicomposting

Procedure

There are different methods of vermicomposting but the most commonly used methods are pit method. Procedure followed in the vermicomposting:

Table 2. Recommended quantity and time of application of Vermicompost

Crop	Quantity to apply per acre	Time to apply
Rice	1 tonne	After transplanting
Sugarcane	1 ½ tonnes	Last ploughing
Chili	1 tonne	Last ploughing
Groundnut	½ tonne	Last ploughing
Maize	1 tonne	Last ploughing
Turmeric	1 tonne	Last ploughing
Citrus, Ber, Guava, Pomegranate	2 kg per tree	At planting time and before flowering 1-2 years old tree
Mango, Coconut	2kg per tree 5 kg per tree 10 kg per tree 20 kg per tree	At planting time 1-5 years old trees 6-9 years old trees Trees older than 10 years
Onion, Garlic, Tomato,	1-1 &1/2 tonnes	Last ploughing

Potato, brinjal, Okra, Cabbage, Cauliflower		
Grape	1 tonne	June-July
Sunflower	1 ½ tonne	Last ploughing

Problem Faced During The Process

- In the procurement of cow dung
- Excess moisture content due to rain in the pit
- High cost of earthworm
- Increase in millipedes population in the pit

Conclusion

Vermicomposting is a sustainable and environmentally friendly way to manage organic waste. It is a valuable product that can be used to improve soil quality, increase plant growth, and reduce the need for synthetic fertilizers. It is a simple and easy way to manage organic waste and improve your soil quality. As compared to other methods of waste management like waste disposal into landfills, vermicomposting causes no or less pollution and more benefits to the environment and economy of the country. If vermicompost can be used as a substitute to inorganic fertilizer for organic food production, it will be a major move towards achieving economic, social and environmental sustainability throughout the globe. The popularity of organic food is growing throughout the world, so the demand for vermicompost willalso be great in the future.

Plate 2. Working during vermicompost unit.

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NEEMASTRA: NATURE'S WARRIOR AGAINST PESTS

Email
juhisingh787037@gmail.com

[1]Kumari Arya*, [1]Juhi Kumari, [1]Pragya Suman and [1]Nidhi Tirkey

[1]Horticulture College, Khuntpani, BAU, Ranchi, India

NEEMASTRA offers a potential alternative to synthetic pesticides, with its perceived environmental safety and potential for sustainable pest control. However, it is essential to consider its effectiveness, environmental impact and resistance management. Incorporating neemastra into an integrated pest management approach can help maximize its benefits while minimizing any potential drawbacks.

What is Neemastra?

NEEMASTRA is an organic pesticide used as a major component of Zero Budget Natural Farming. It is environmentally safe, cost effective and non-chemical pest management option in modern day agricultural system.

Materials Used for Preparation of Neemastra

Neem leaves (Azadirachta indica; family- meliaceae): Importance

- Having amazing pesticidal property, they also act as fungicide as well as have anti-bacterial property and have been showing deleterious effect on insect.
- The leaf extract contains large portion of Azadirachtin steroid which shows anti attractant property moreover neem also acts as a fertilizer. Due to high medicinal and pesticidal property, this organic pesticide is highly effective in controlling wide range of pests, but mostly effective against sucker pests, rice weevil, caterpillar etc.
- Due to organic property, it also helps in improving the soil fertility and help in maintaining the C:N ratio and apart from these all it improves physical, chemical and biological property of soil.

- It is one of the major parts of ZBNF because all the material used in this is easily available without any cost or minimal paying. It is very rare to avoid the use of neem in organic farming due to its high importance in every aspect.

Table 1. Ingredients used in NEEMASTRA preparation

Ingredients	Quantity
Neem leaves	5 kilogram
Cow dung	2 kilogram
Cow urine	5 litres
Water	100 litres

PREPARATION

- 5 kg neem leaves crushed and mixed with water
- 5 litres urine and 2 kg cow dung added to it
- Ferment the prepared solution for 24 hours
- After 24 hour the mixture is filtered and diluted to 100 litres
- Use this bio-pesticide as foliar spray for 1 acre.

Neem leaves

Water

Cow dung

Cow urine

Plate 1. Materials used for NEEMSTRA preparation

Benefits of Neemastra

- Eco- Friendly
- Residue Free
- Non- toxic to non-target organisms
- Safe for farm workers
- Adaptable to various crop
- Sustainable Agriculture

Limitations of Neemastra

- As it is an organic insecticide, residual effect is less powerful as compared to chemical pesticides.
- Some pests may linger even after application of the treatment.
- It may take longer to show desired result.
- It should be applied more frequently which makes its use more labour intensive and more time consuming.
- It is more specific only for sucking pests and mealy bugs.
- After some time, pests may become resistant to Neemastra. So, it's best to use this biopesticide along with other cultural practices in IPM approach.
- Accurate pest identification and knowledge of pest life cycle is crucial while using organic insecticides.
- Shorter shelf life as compared to synthetic insecticides.
- One needs training to make it at home and use it effectively.

Conclusive Remarks

Neemastra is considered as broad-spectrum bio-pesticide. It disrupts the life cycle of pests by affecting their feeding, growth, and reproduction. While it may not provide instant or complete control, it can contribute to pest management strategies when used properly.

Neemastra is often considered a more environmentally friendly option compared to synthetic pesticides. It is biodegradable and generally has lower toxicity to non-target organisms, such as mammals, birds, and beneficial insects. However, it is still important to follow recommended doses and practices to minimize any potential negative effects.

Like any other pesticide, prolonged and indiscriminate use of neemastra can lead to the development of resistance in target pests. To mitigate resistance, it is important to incorporate integrated pest management (IPM) practices, including rotation with other pesticides, cultural controls, and monitoring pest populations.

Neemastra is often considered as part of an integrated pest management strategy rather than a standalone solution. It can be used alongside other pest control methods, such as biological control, cultural practices, and resistant crop varieties, to optimize pest management outcomes.

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Plates 2. Engaging in preparation of NEEMASTRA

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THE POWER OF WEEDS – PARTHENIUM AND CROTON

Email
sanyasinha525@gmail.com

[1]Riya Dutta, [1]Sanya Sinha*, [1]Deepshikha Gupta and [1]Nishi Priya Khalkho

[1]Horticulture College, Khuntpani, BAU, Ranchi, India

Weed composting is the process of turning unwanted weeds into nutrient-rich compost. It has several benefits, such as reducing weed growth and the need for herbicides, while improving soil fertility and plant health. However, there are challenges, such as persistent weed seeds and potential pathogens. Further research is needed to refine and expand its application in different agricultural, horticultural and gardening contexts.

Weed compost, also known as composted weeds or weed-based compost, is a type of compost that is made primarily from weeds. Composting is the process of decomposing organic matter, such as plant material, to create a nutrient-rich soil amendment known as compost. When it comes to weed compost, the weed plants are collected and allowed to decompose over time. During the composting process, the weeds break down and undergo microbial activity, resulting in the transformation of the organic matter into a nutrient-dense material. The heat generated during composting helps kill weed seeds and potential pathogens, making the final product safe to use. It enriches the soil with organic matter, improving its structure, moisture retention, and nutrient content. The compost releases nutrients slowly, promoting healthy plant growth. It also enhances the soil's ability to hold water, reducing the need for frequent irrigation.

Current Scenario of Composting In India

The Swachh Bharat Mission had committed to ensuring that all organic waste produced in Indian cities is processed into making compost by October 2019, but it doesn’t seem likely. To meet the ambitious target, the Ministry of Chemicals and Fertilizers had announced a policy on promotion of city compost to promote in February 2016. India currently produces close to 1.5 lakh tonnes of solid waste every day and its biodegradable fraction ranges between 30 per cent and 70 per cent for various Indian cities. This means there is a huge potential for compositing, the most natural form of processing wet waste. But, uncontrolled decomposition of organic waste in dumpsites and also leads to emission of potent greenhouse gases. So, it is imperative that necessary actions be taken to promote appropriate disposal mechanisms for solid waste management.

Utilization of Weeds to Make Compost

- We can make bio-fertilizer from abundantly occurred biomass of Parthenium. By making use of this weed, at one hand we can increase the productivity of our crop land by weeding out of this weed while at other hand we can even earn money by making compost on commercial basis from this waste material.
- Croton, also known as the rushfoil or sweatbush, is a plant species native to North and Central America. While it is primarily known for its medicinal properties, it can also be used in composting. Composting with Croton can help enrich the compost pile and improve the overall quality of the compost.

Materials Used In Weed Compost

Cow dung, Parthenium, Croton and Gunny Bags

Methods to Make Compost from Weed

- Make a pit of 3x 6x10feet (depth x width x length) at a | place where water dose not stagnate. Pit size can be increased or decreased but depth cannot be compromised.
- If possible, cover the surface and sidewalls of the pit with stone chips. It will protect absorption of essential nutrient of compost by the soil surface.
- Arrange about 100 kg dung, and one drum of water near the pit.
- Collect all the Parthenium andCroton plants from your field and nearby area.
- Spread about 50 kg of the weeds on the surface of pit.
- All the above constituents will make one layer.
- Like first layer make several layers till the pit is filled upto 1 fit high from the ground surface.
- Fill the pit in dome shape.
- While making layers, apply pressure by feet to make weed biomass compact.
- When pit is full with above-described layers then cover it with mixture of cow dung, soil and husk.

- After 4-5 months we can get well decomposed compost.
- We can get 37–45% of compost from 37-42 quintals of Parthenium biomass.

Benefits of Using Weed Compost

Nutrient-rich soil amendment:

When weeds are composted properly, they break down into a nutrient-dense material that can improve soil fertility and provide a balanced mix of macronutrients and micronutrients

Soil structure improvement:

When these weeds are composted and added back to the soil, they contribute to soil aeration and drainage. This improves water infiltration, root development, and overall soil health.

Weed suppression:

It helps suppress the growth of new weed seeds by creating a barrier that blocks their access to sunlight and nutrients. This can reduce the need for chemical weed control methods.

Environmental sustainability:

Composting weeds reduces waste and promotes a sustainable approach to gardening and farming.

Cost-effective solution:

Producing weed compost can be a cost-effective alternative to purchasing commercial fertilizers or soil amendments.

Limitations of Using Weed Compost

Weed Seeds:

Weed compost may contain viable weed seeds that can survive the composting process and potentially germinate when the compost is used in gardens or landscaping.

Persistent Weeds:

Some weed species have resilient characteristics that allow them to survive composting. As a result, these weeds can potentially reestablish themselves when the compost is used.

Chemical Residues:

If the weeds being composted have been treated with herbicides or other chemicals, there is a risk that residues of these substances may persist in the compost. These residues can potentially affect the growth of desired plants when the compost is applied.

Imbalance of Carbon and Nitrogen:

Weed material can be high in nitrogen, which can lead to an imbalance in the carbon-to-nitrogen ratio (C/N ratio) of the compost.

Precautionary Measures

However, it is crucial to follow proper composting techniques to ensure the effectiveness and safety of the weed compost. This includes maintaining the right balance of carbon and nitrogen, monitoring moisture levels, and ensuring the compost reaches adequate temperatures to kill weed seeds and pathogens. Additionally, it is important to use healthy weed plants and avoid including plants that have gone to seed or are infected with diseases or pests.

By adhering to these guidelines and being mindful of potential risks, weed compost can be a valuable tool for improving soil health, reducing weed growth, and promoting sustainable gardening and farming practices.

Conclusive Remarks

Weed compost offers several benefits for gardeners and farmers. By composting weed plants and other organic materials, it can provide a nutrient-rich soil amendment that improves soil fertility, enhances plant growth, and promotes environmental sustainability. Weed compost can help control weed seeds, reduce waste, and minimize the need for synthetic fertilizers, making it a cost-effective and eco-friendly solution.

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Coccinia indica: A NATURAL ANTIDIABETIC MARVEL

[1]Raju, C. A.* and [2]Harisha, S.

Email
rajuca80@gmail.com

[1]Department of Food Science and Nutrition, University of Agricultural Sciences, GKVK, Bengaluru, Karnataka- 560065, India

[2]Department of Agronomy, University of Agricultural Sciences, GKVK, Bengaluru, Karnataka- 560065, India

Numerous conventional medicines currently in practice are derived from medicinal plants, minerals, and organic substances. In recent years, there has been a growing inclination towards exploring the therapeutic potential of many botanical species derived from ancient medical practices, in order to address a wide range of health conditions. *Coccinia grandis* has been historically employed in traditional medicine as a domestic treatment for a variety of ailments. *Coccinia indica*, due to its many bioactive components, offers a natural and possibly efficacious approach for individuals seeking to control diabetes. The inclusion of this substance in diabetes care techniques is highly helpful due to its capacity to control blood sugar levels, enhance insulin sensitivity, and provide protection against oxidative stress. The natural world offers a promising resource in the battle against diabetes, and *Coccinia indica* might potentially serve as a valuable solution in this regard.

In a world where modern medicine reigns supreme, the age-old knowledge contained inside herbal treatments frequently takes a backseat. However, there is a rising interest in traditional medicinal plants, particularly in their potential to help control chronic illnesses such as diabetes. This interest has been on the rise in recent years. Medicinal plants are relied upon by an overwhelming majority of the people, particularly those who reside in rural regions, for the treatment of various ailments. India is home to over 7,000 unique types of flora. According to estimates provided by the World Health Organisation (WHO), roughly 80–85 percent of the population residing in underdeveloped nations relies almost entirely on traditional medicine for their basic health care requirements. *Coccinia indica* is one of the many plants that have been shown to significantly contribute to the preservation of human health and the enhancement of the overall quality of human existence. In addition, the plant has a long history of application in Ayurvedic and Unani medical practices across the Indian subcontinent.

Diabetes, a chronic metabolic condition characterised by hyperglycemia, is a highly widespread health concern in modern society. According to the International Diabetes Federation, an estimated 463 million individuals globally were affected by diabetes in 2019, with projections indicating a potential increase to 700 million by 2045 should present patterns persist. This condition is known to impact individuals across many age groups, ethnicities, and socio-cultural contexts, and if not well controlled, it can result in significant health issues, including cardiovascular disorders, renal insufficiency, and visual impairment. Major strides have been accomplished in the field of modern medicine with regard to the management of diabetes, including a diverse range of pharmaceutical interventions, insulin-based treatments, and innovative technology approaches. Nevertheless, the administration of these therapeutic interventions frequently entails adverse reactions, exorbitant expenses, and the perpetual supervision of a persistent ailment. Consequently, a considerable number of patients diagnosed with diabetes are actively pursuing complementary and alternative therapies as a means of treating their illness. This includes the use of medicinal herbs rooted in old traditional approaches. *Coccinia indica*, sometimes referred to as ivy gourd or crimson gourd, is a tropical vine that has potential as a natural treatment. In addition to its culinary use, this seemingly ordinary vegetable harbours a concealed characteristic - it possesses a wealth of bioactive chemicals that exhibit robust antidiabetic activities. This article examines the properties of *Coccinia indica* and investigates its potential in the management of diabetes.

Coccinia indica

Coccinia indica, commonly referred to as Ivy gourd or Scarlet gourd, is a tropical vine classified under the Cucurbitaceae family, among notable botanical specimens such as cucumbers and pumpkins. The plant in question has a wide range of adaptability and is indigenous to the Indian subcontinent. However, it may also be observed in various regions across Asia, Africa, and Australia. Its reputation stems from its multifaceted use in the realms of cuisine, medicine, and nutrition.

Pharmacological profile of *Coccinia indica*

The fruits of *Coccinia indica* exhibit a higher concentration of antidiabetic properties in comparison to other parts of the plant. However, the entire plant of *Coccinia indica* demonstrates a range of pharmacological activities, including antidiabetic, antioxidant, analgesic, antimicrobial, antimalarial, antidyslipidemic, antiulcer, hypoglycemic, hepatoprotective, anticancer, antitussive, antipyretic, anti-inflammatory, and mutagenic properties. The antidiabetic properties of *Coccinia indica* are attributed to its abundant presence of bioactive substances. The following individuals are considered to be significant contributors in this context:

Charantin: A molecule with a bitter taste, exhibits structural and functional similarities to insulin. One potential mechanism by which it may contribute to the reduction of blood sugar levels is by the facilitation of glucose absorption in cells, hence enhancing cellular utilisation of glucose. Additionally, it has been suggested that it may mitigate insulin resistance, a condition characterised by reduced responsiveness to insulin, which is crucial for glucose regulation. Furthermore, it has been proposed that it may impede the conversion of carbs into sugar inside the intestines.

Vicine and vicineine: These are chemicals that exhibit hypoglycemic characteristics, indicating their ability to reduce levels of glucose in the bloodstream. These medications function by inducing the pancreas to secrete insulin and enhancing its responsiveness.

Polypeptide-P: It has insulin-like properties and possesses the ability to lower blood glucose levels. Additionally, it facilitates the regeneration and restoration of pancreatic cells, which are pivotal in the synthesis of insulin.

Antioxidants: *Coccinia indica* possesses a notable abundance of antioxidants, including as flavonoids and polyphenols, which effectively counteract the detrimental effects of oxidative stress. There exists a positive correlation between elevated levels of oxidative stress and the occurrence of difficulties associated with diabetes. Consequently, the use of antioxidants has been found to be effective in mitigating the likelihood of such issues.

Table 1: Medicinal value of various parts of *Coccinia indica* (Pekamwar*et al.*, 2013)

Plant part	Medicinal value
Leaf	Antidiabetic, oxidant, larvicadal, GI disturbances, Cooling effect to the

	eye, Gonorrhea, hypolipidemic, skin diseases, urinary tract infection
Fruit	Hypoglycemic, analgesic, antipyretic, Hepatoprotective, tuberculosis, eczema, anti-inflammatory
Stem	Expectorant, antispasmodic, asthma, bronchitis, GIT disturbances, urinary tract infection, skin diseases
Root	Hypoglycemic, antidiabetic, skin diseases, removes pain in joint, urinary tract infection

Antidiabetic action of the bioactive compound of *C. indica* (Quercetin)

Quercetin has the potential to exert an influence on several anatomical components inside the human body, encompassing the liver, muscles, pancreas, and small intestine. Quercetin has been found to enhance the efficiency of glucose transporter 4 (GLUT 4) and insulin receptor activity inside muscle tissue. This mechanism facilitates enhanced glucose uptake by muscles from the bloodstream, hence contributing to the maintenance of normal blood sugar levels. Quercetin has been observed to enhance the enzymatic activity of glucokinase inside the hepatic tissue. This particular enzyme facilitates the storage of glucose, hence contributing to enhanced regulation of blood glucose levels. Quercetin has the potential to provide protection for the beta cells located in the pancreas, which play a crucial role in insulin production. The anti-inflammatory and antioxidant properties of quercetin may contribute to the maintenance of the overall health of these cells. Additionally, it has the potential to facilitate the regeneration of beta cells and induce the differentiation of stem cells into insulin-producing cells. Quercetin has been observed to exhibit inhibitory effects on the enzymatic activity of maltase and glucose transporter 2 (GLUT 2) within the small intestine. This phenomenon leads to a decrease in the uptake of glucose from ingested meals, hence contributing to the regulation of blood glucose within the physiological range. In general, quercetin exhibits many mechanisms that contribute to the regulation of blood glucose levels and the preservation of vital organs such as the pancreas.

Precautions and Side Effects

Although *Coccinia indica* is usually considered to be safe for use, it has the potential to interact with some drugs, particularly those prescribed for diabetes. It is advisable for those diagnosed with diabetes to get guidance from a healthcare expert prior to integrating ivy gourd into their dietary regimen or utilising it as a supplementary treatment.

Conclusion

In recent years, there has been a growing inclination towards exploring the therapeutic potential of several medicinal plants derived from traditional medicine for the management of various health conditions. Due to their purported efficacy, little adverse effects or toxicological impact, and relatively lower cost compared to manufactured pharmaceuticals, herbal remedies, particularly those derived from plants of the Cucurbitaceae family, are commonly recommended as a preferred treatment option for diabetes. *Coccinia indica* is commonly selected as the preferred botanical agent for managing diabetes, owing to its notable antidiabetic and hypolipidemic properties. The potential of this natural therapy in the treatment of diabetes is significant, however, further scientific investigation is necessary to fully exploit its therapeutic capabilities and establish its safety and efficacy in the management of diabetes.

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DYNAMIC SYNERGY: EXPLORING REAL-WORLD APPLICATIONS OF SAMUELSON'S MODEL WITH MULTIPLIER AND ACCELERATOR INTERACTION IN BUSINESS CYCLE ANALYSIS

[1]Arunima Konar*, [2]Piyali Dutta, [3]Arindam Ghosh and [4]Ananya Ghosh

Email
arunima.k@snuniv.ac.in

[1]Department of Agricultural Economics, School of Agricultural Sciences, Sister Nivedita University, Newtown, Kolkata, India

[2]Department of Horticulture, School of Agricultural Sciences, Sister Nivedita University, Newtown, Kolkata, India

[3]Department of Agricultural Extension, School of Agricultural Sciences, Sister Nivedita University, Newtown, Kolkata, India

[4]Department of Agronomy, School of Agricultural Sciences, Sister Nivedita University, Newtown, Kolkata, India

Samuelson's model of business cycles focuses on the interaction between the multiplier effect and the accelerator effect to explain the fluctuations in economic activity over time. This model combines elements of Keynesian economics and classical business cycle theories. The multiplier effect refers to the idea that an initial change in spending can lead to larger changes in overall economic activity, while the accelerator effect suggests that changes in investment can lead to proportional changes in output.

Keynes's economic theories did not address the cyclical and cumulative nature of economic fluctuations due to his omission of the accelerator, but Samuelson's influential paper demonstrated that the interplay between the multiplier and accelerator is essential for explaining these cyclical economic shifts.

Combining Accelerator with Keynesian Multiplier

How income and output will increase by even larger amount when accelerator is combined with the Keynesian multiplier.

$$\Delta \mathbf{I_a} \longrightarrow \Delta \mathbf{y} = \Delta \mathbf{I_a} \left(\frac{\mathbf{1}}{\mathbf{1}-\boldsymbol{MPC}}\right) \longrightarrow \Delta \mathbf{I_d} = \mathbf{v}\Delta \mathbf{y} \longrightarrow \mathbf{L}$$

Whereas, ΔI_a = Increase in Autonomous Investment

Δy = Increase in Income

ΔI_d = Increase in Induced Investment

$\left(\frac{1}{1-MPC}\right)$ = Size of Multiplier where MPC = Marginal Propensity to Consume

v = Size of Accelerator
L = Aggregate Demand and Income Increase by an Even Larger Amount

This equation illustrates how an initial change in autonomous investment (ΔIa) can lead to a series of cascading effects on income (Δy) and investment (ΔId) due to the multiplier effect and the accelerator effect. The result is an even larger increase in aggregate demand and income (L) than the initial increase in autonomous investment (ΔIa). This concept is fundamental in understanding how changes in investment can have a significant impact on the overall economic activity and growth of an economy.

Fluctuations in investment serve as the primary catalyst for instability within a free private enterprise economy, and this inherent instability is further exacerbated by the intricate interplay between the multiplier and accelerator effects. The model of interaction between multiplier and accelerator can be mathematically represented as under:

$Y_t = C_t + I_t$
$C_t = C_a + c\,(Y_{t-1})$
$I_t = I_a + v\,(Y_{t-1} - Y_{t-2})$

Whereas, Y_t = Income for a period t
I_t = Investment for a period t
I_a = Autonomous Investment
v = Capital-output ratio or Accelerator
C_t = Consumption for a period t
C_a = Autonomous Consumption
c = Marginal propensity to consume

This means that, $Y_t = C_a + c\,(Y_{t-1}) + I_a + v\,(Y_{t-1} - Y_{t-2})$
In static equilibrium, the level of income determined will be,
$Y = C_a + cY + I$
When $Y_t = Y_{t-1} = Y_{t-2} = Y_{t-n}$, the period lags have no influence at all and accelerator is reduced zero.

Interaction between Multiplier and Accelerator: Different Patterns of Income (Output) Movements of Various Values of C and V

Samuelson has delineated distinct economic trajectories determined by varying combinations of marginal propensity to consume and capital-output ratio values. Figure 1-5 illustrates five distinct patterns of economic activity, as measured by gross national product or income, based on diverse combinations of marginal propensity to consume (c) and capital-output ratio (v) values.

In Figure 1, when the values of marginal propensity to consume (c) and capital-output ratio (v) fall within region A, changes in autonomous investment result in gross national product or income moving up or down with diminishing speed, ultimately reaching a new equilibrium.

In Figure 2, when marginal propensity to consume (c) and capital-output ratio (v) values fall within region B, changes in autonomous investment or autonomous consumption lead to income fluctuations following a series of damped cycles, gradually diminishing in amplitude until the cycles eventually vanish.

In Figure 3, region C represents combinations of relatively high marginal propensity to consume (c) and capital-output ratio (v) values, leading to explosive cycles with progressively larger income fluctuations, while region D indicates combinations causing income to accelerate in its upward or downward movement, necessitating some form of restraint for cyclical fluctuations to manifest.

Figure 4 illustrates that, akin to region C, the values of multiplier and accelerator in region D lead the system to diverge significantly from the equilibrium state, causing it to explode with increasing deviation.

In Figure 5, under specific conditions where the values of C and V, and thus the magnitudes of the multiplier and accelerator, fall within region E, they generate income fluctuations with a constant amplitude.

Regions A and B share stability characteristics, leading to a stable equilibrium after disturbances, while regions C and D, despite similar multiplier and accelerator values, induce severe instability, causing the system to diverge significantly from equilibrium, and only combinations in regions B, C, and E give rise to business cycles; notably, while region B suggests damped oscillations, in reality, the cyclical movements persist due to frequent and random disturbances, resulting in irregular and non-uniform business cycles.

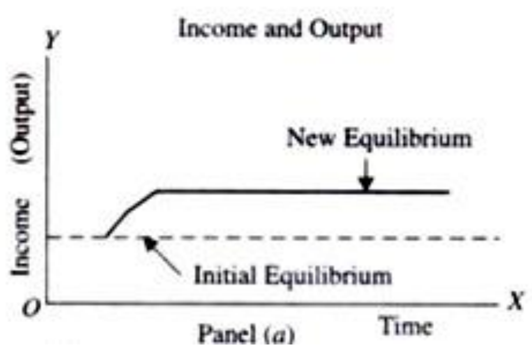


Fig. 1

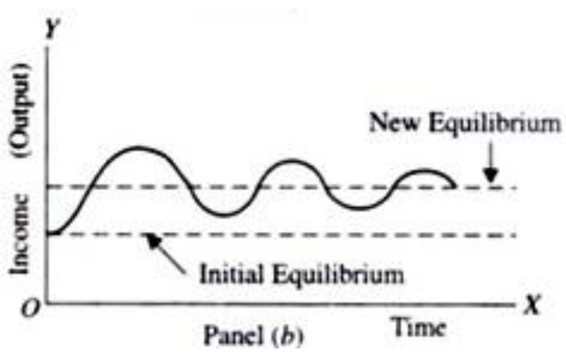
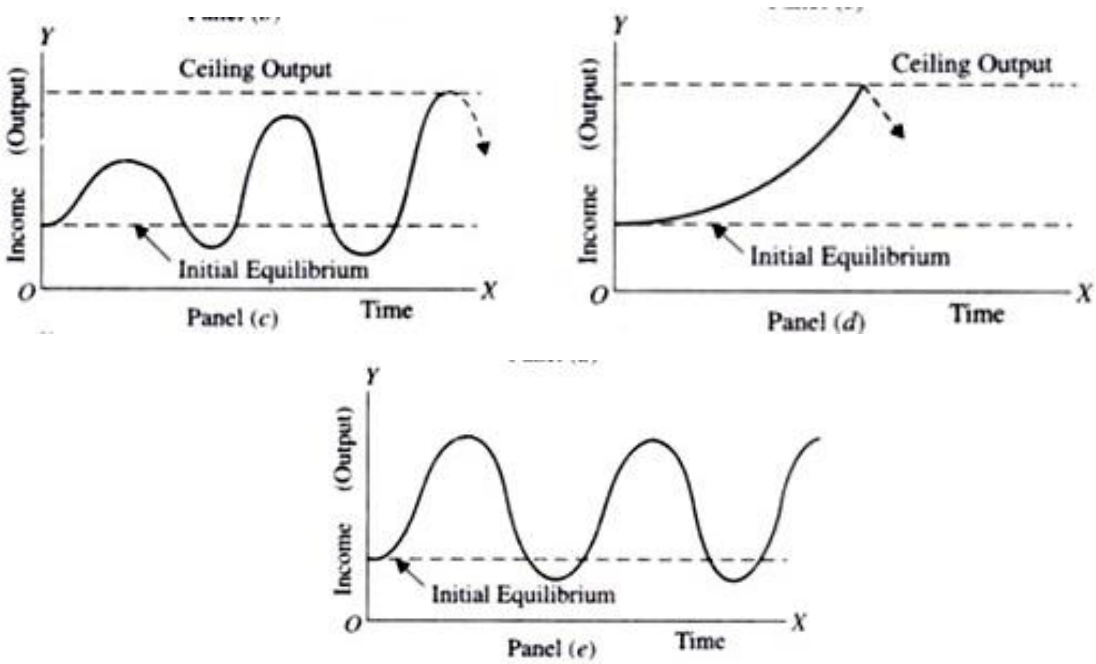


Fig. 2



Here are some applications of this model and how the interaction between the multiplier and accelerator effects plays a role:

1. **Explaining Economic Fluctuations**: Samuelson's model can be used to explain the cyclical nature of economic growth and contraction. When there's an increase in consumer spending (due to factors like government policies or changes in consumer confidence), the multiplier effect kicks in. This increase in consumer spending leads to higher demand for goods and services, causing businesses to increase production, which, in turn, triggers the accelerator effect. This positive feedback loop can lead to periods of economic expansion. Conversely, a decrease in consumer spending can set off a chain reaction of contraction.
2. **Investment and Business Confidence:** Changes in investment play a significant role in the business cycle. An increase in business confidence and expectations can lead to higher levels of investment spending. This initial increase in investment can have a multiplier effect, as it generates additional demand for goods and services, thus boosting economic activity. The accelerator effect amplifies this impact by increasing production levels in response to rising demand.
3. **Role of Government Policies:** Government policies, such as fiscal and monetary measures, can influence both the multiplier and accelerator effects. Expansionary fiscal policies (increased government spending or tax cuts) can stimulate consumer spending and investment, triggering the multiplier and accelerator effects and

fostering economic growth. Similarly, central banks can adjust interest rates to influence investment levels and overall economic activity.

4. **Amplification of Business Cycles:** The interaction between the multiplier and accelerator effects can amplify the magnitude of business cycles. During periods of economic expansion, the accelerator effect can lead to increased investment and further growth, while during downturns, reduced investment can exacerbate the decline in economic activity. This cyclical pattern of reinforcement can lead to booms and busts.
5. **Infrastructure Investment:** Large-scale infrastructure projects are often used as a means to stimulate economic growth. An initial injection of funds into infrastructure projects can create jobs and generate income for workers. This increase in income can lead to higher consumer spending, which sets off the multiplier effect. Additionally, the need for materials and equipment for these projects can trigger the accelerator effect, as businesses increase production to meet demand.
6. **Market Expectations and Confidence:** Positive or negative changes in consumer and business expectations can influence the interaction between the multiplier and accelerator effects. Optimistic expectations can lead to increased spending and investment, while pessimistic expectations can have the opposite effect, causing a downturn in economic activity.

Conclusion

Samuelson's model of business cycles, through its focus on the interaction between the multiplier and accelerator effects, provides insights into how changes in spending, investment, and expectations can drive the cyclical fluctuations in economic activity. This model helps economists and policymakers understand the dynamics of economic expansion and contraction and design effective strategies to manage business cycles.

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EMERGING TALENTS IN HORTICULTURE BREEDING AND GENETICS

[1]Rimpika*, [2]DP Sharma, [1]Shilpa and [2]Shubham

Email
rimpikathakur1989@gmail.com

[1]College of Horticulture and Forestry, Thunag, Mandi, Dr. YS Parmar University of Horticulture and Forestry Nauni, Solan, India

[2]Dr. YS Parmar University of Horticulture and Forestry Nauni, Solan, India

Horticulture is a vital sector of agricultural output that gives farmers essential financial assistance. A varied and healthy diet depends on horticultural plants, such as fruit, vegetable and ornamental plants. They also improve the comfort of our homes and preserve the environment. horticulture products are now regularly available as a result of the significant advancements achieved in horticulture plant development, cultivation, and postharvest treatment in the past few years. This has led to a year-round availability of a wide variety of high-quality fruits and vegetables. Despite this, the horticulture sector continues to encounter difficulties, such as biotic and abiotic stress, the time-consuming breeding of superior cultivars with favourable features, elevated labour and cultivation costs, low productivity and waste and loss associated with postharvest interventions (Liu *et al.* 2023). Due to a continuous rise in global population and the associated demand for more food, sustainable and rising fruit and vegetable farming is a significant issue for ensuring future food security. Although conventional breeding methods have significantly contributed to the development of important cultivars, new approaches are required to further increase horticulture production of crops.

Crop variety improvement techniques are developing quite at pace. A group of biotechnology-based techniques called "New Breeding Technologies" aim to swiftly yet accurately modify plant characteristics (Anon., 2018). These developments have given horticulture breeding programmes a way to decrease the number of cycles and improve the accuracy and efficacy of new cultivar development (Xiong *et al.* 2015). Genome-wide selection (GWS) is one of the techniques that is evolving at an unprecedented rate. Instead of the estimated breeding values (EBVs) that fruit breeders have always used, GWS uses genomic estimated breeding values (GEBVs) as selection criteria. GEBVs are developed employing dense genome-wide single-nucleotide polymorphism (SNP) markers for individuals in a phenotyped training population in order to demonstrate marker effects on complex phenotypes governed by a multitude of genetic loci. Then, in order to find those with outstanding qualities that may be considered "elite," individuals in breeders' selection populations are screened and their GEBVs are determined using genetic marker details. In order to outbreed woody perennial fruit crops, marker-assisted selection (MAS) for qualities governed by key genes or quantitative trait loci is now often used (Kumar *et al*. 2012; Van Nocker and Gardiner, 2014)

Genome Editing

This technique allows to make precise changes to the DNA of a plant. This can be used to improve traits such as yield, nutritional quality, and resistance to pests and diseases. It includes methods, based on recognising specific DNA sequences to direct where an enzyme will cut or modify a gene (Anon., 2018). These methods depend on engineered endonucleases (EENs), which break DNA according to a certain sequence owing to the presence of a specific DNA-binding domain or RNA sequence. These nucleases can efficiently yet accurately knock the targeted genes by identifying the relevant DNA sequence (Xiongand Ding. 2015). Due to cellular DNA repair processes including homology-directed repair (HDR) and error-prone non-homologous end joining breaks (NHEJ), the double-strand breaks (DSBs) of DNA ultimately lead to gene alteration at the targeted locations (Wyman and Kanaar, 2006).

- **Oligonucleotide-directed mutagenesis** adds a few additional bases into a gene resulting in a precise, specific mutation.
- **TALENs** (transcriptional activator-like effector nucleases) and **ZNF** (Zinc Finger Nucleases) use specially design proteins to identify the DNA sequence for the enzyme to cut. Until now, there have been no reports on ZFN applications in horticultural crops. TALENs, has rapidly emerged as an alternative to ZFNs for genome editing(Anon., 2018).
- **CRISPR:** Clustered regularly interspaced short palindromic repeats (CRISPR)- uses a short RNA guide sequence to identify the target. CRISPRs recognise and trim foreign DNA via a process similar to RNA interference. A novel breeding technique called CRISPR-associated protein-9 (Cas9) offers the ability to correctly and quickly

enhance a number of attributes in crops, including yield, quality, disease resistance, abiotic stress tolerance, and nutritional qualities. Due to its simple operation and high mutation effectiveness, this technology has been employed to get new germplasm resources through gene-directed mutation (Gaj*et el.* 2013; Mounika *et al.* 2022).

- **Ribonucleoprotein genome editing** is a novel technique to produce genome-edited plants without introducing foreign DNA at any stage (DNA is typically inserted at one stage and then removed). In this method, the DNA-cutting enzyme and the CRISPR guide RNA are combined before being delivered to plant cells.
- **Site-directed nucleases**: SDN1, SDN2, or SDN3 alterations are produced using TALENS, ZNF, and CRISPR. The DNA in the target gene is cut in SDN-1 and automatically repaired. A certain percentage of the restored cells will include a mistake, leading to a mutation. At the location of the break, one or more extra DNA nucleotides are specially inserted in SDN-2. The DNA that is inserted in SDN-3 is longer and can reach the size of a whole gene.

RNA Interference

The expression of particular genes may be turned down or off via RNA interference, also known as gene silencing. The target gene produces messenger RNA, which is bound by little RNA fragments that the cell is stimulated to generate. This prevents the gene from carrying out the function it was designed to perform. RNAi has been used to produce non-browning apples, as well as to lessen potato bruising and cold-sweetening.

- **Host-Induced Gene Silencing:** The interfering RNA used in HIGS is embedded into the plant and is intended to silence a critical gene in insect or pathogen. The interfering RNA causes the gene to be silenced when the pest or pathogen affects the plant. The host plant has therefore developed more resistance (Govindarajulu*et al.* 2015).

Marker Assisted Selection

With the fast development of molecular genetics and sequencing technology, scientists devised "marker-assisted selection" (MAS), a more efficient and accurate strategy, by incorporating DNA markers into phenotypic selection. Through marker-assisted selection (MAS), DNA markers offer a tremendous potential to increase the effectiveness and precision of conventional plant breeding. An abundance of DNA marker-trait connections has been produced by the numerous quantitative trait loci (QTLs) mapping studies conducted for several crop species (Hasan *et al.* 2021). Environmental factors and agricultural plant growth circumstances have no influence on the regulation of molecular or DNA markers, which are not visible during the plant's developmental phases. As more molecular markers and genetic maps have been available, MAS has become possible for traits controlled by substantial quality as well as for quantitative trait loci (QTLs) (Collard and Mackill, 2018). The usefulness of a particular molecular marker depends on its capacity to identify nucleotide polymorphisms that allow segregation between different molecular marker alleles. Molecular methods such as restriction fragment length polymorphism (RFLP), amplified fragment length polymorphism (AFLP), microsatellite or simple sequence length polymorphism (SSR), random amplified polymorphic sequences (RAPD), cleavable amplified polymorphic sequences (CAPS), single-strand conformation polymorphisms (SSCP), and single nucleotide polymorphisms (SNPs) are used to identify these polymorphisms.

Phenotyping

Plant phenotyping is the most important work of any plant breeding programme, and reliable assessment of plant attributes is required to choose genotypes with higher quality, higher yield, and greater climatic resistance. The bulk of phenotyping methods in use today are labor-intensive and harmful. The major method used in plant phenotyping investigations has recently been the development of numerous sensors and imaging systems for quick and accurate quantitative evaluation of plant features.

- **Image-Based High-Throughput Phenotyping**

In order to quantify morphological, physiological, biochemical, and performance parameters in a non-destructive manner, high-throughput phenotyping devices can photograph hundreds of plants every day utilising many different kinds of optical sensors (Chawade*et al.* 2019). The concept underlying image-based phenotyping is based on how electromagnetic radiation interacts with the surface of plants, causing changes in absorption, reflection, emission, transmission, and fluorescence between healthy and stressed plants as well as across genotypes (Abebe, 2023).

These are just a few of the emerging techniques in horticulture breeding and genetics. These techniques offer the potential to develop new crops that are more nutritious, resilient, and sustainable.

Here are some of the benefits of using these emerging techniques:

- They can be used to improve traits that are difficult to breed for using traditional methods.
- They can accelerate the breeding process, which can help to meet the growing demand for food.
- They can be used to develop crops that are more resistant to pests, diseases, and climate change.
- They can be used to develop crops that are more nutritious and have a better taste.

However, there are also some challenges associated with using these emerging techniques, such as:

- They can be expensive to develop and use.
- There are concerns about the safety of some of these techniques.
- There is a need for more research to understand the long-term effects of these techniques.

Conclusion

Despite these challenges, the potential benefits of using these emerging techniques are significant. As the field of horticulture breeding and genetics continues to evolve, these techniques are likely to play an increasingly important role in developing new crops that can help to feed a growing population and protect the environment.

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FARMERS DISTRESS INDEX: MAJOR INSIGHTS INTO RURAL ECONOMIC CHALLENGES

Email
wehars@gmail.com

Harshit Mishra

Department of Agricultural Economics, College of Agriculture, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.) – 224 229, India

This study identifies several critical factors contributing to farmer distress, including crop failures exacerbated by climate change, overwhelming debt burdens, volatile agricultural prices, and a dearth of income diversification options. The impact of this distress on rural communities is profound, with declining agricultural employment leading to increased migration to urban areas and causing social and psychological stress among those left behind. The article critically analyses both past and current government initiatives and policies designed to address farmer distress, evaluating their effectiveness and limitations. Finally, the article offers a set of comprehensive solutions and recommendations, emphasizing the importance of sustainable farming practices, increased access to financial services for farmers, rural skill development programs, and the necessity of market diversification to revitalize rural economies and alleviate farmer distress. This insightful analysis provides a holistic view of the challenges faced by rural farmers and suggests a path forward to create more resilient and prosperous agricultural communities.

In the heartland of nations around the world, where the fertile fields and rustic landscapes define the essence of rural life, a growing concern has been simmering for years. It's a concern that transcends borders and affects millions of lives, yet often remains hidden beneath the sprawling fields of grain and the idyllic scenery we often associate with the countryside. We are talking about farmer distress – a complex, multifaceted issue that lies at the intersection of agriculture, economics, and social well-being. The Farmer Distress Index, a comprehensive study and analysis, shines a spotlight on this pervasive problem, providing us with vital insights into the challenges faced by farmers and rural communities. This article delves into the critical aspects of this index, shedding light on the factors contributing to farmer distress, its far-reaching impact on rural communities, the initiatives and policies implemented by governments, and the solutions and recommendations that have emerged in the ongoing quest to alleviate this crisis.

At its core, farmer distress is not a singular problem but a result of a complex web of factors. Factors such as fluctuating crop prices, climate change-induced unpredictability, mounting debt burdens, and inadequate access to modern farming techniques have all played their part in exacerbating the woes of farmers. Understanding these factors is crucial to comprehending the depth of the issue and finding sustainable solutions. Farmer distress doesn't just affect individual farmers; it reverberates throughout rural communities. The backbone of rural economies, farmers are not only producers of food but also consumers of various goods and services. When they suffer, entire communities feel the strain. Rural schools, healthcare facilities, and local businesses all rely on the prosperity of the agricultural sector. The ripple effect of farmer distress can result in weakened social structures, reduced educational opportunities, and dwindling healthcare services, creating a vicious cycle that's difficult to break.

Governments around the world have recognized the gravity of farmer distress and have initiated various policies and programs aimed at alleviating it. From crop insurance schemes to subsidies and loan waivers, governments have taken measures to provide immediate relief to farmers. However, the effectiveness of these initiatives varies, and their long-term impact remains a topic of debate. To address the farmer distress crisis comprehensively, it's essential to explore potential solutions and recommendations that can offer lasting relief. These solutions range from modernizing agricultural practices, investing in rural infrastructure, promoting diversification of income sources, and ensuring equitable access to resources. Implementing these solutions requires a multi-pronged approach that involves not only governments but also civil society, private enterprises, and international organizations. The Farmers Distress Index provides us with a crucial lens through which we can understand and tackle this pressing issue. As we delve deeper into the chapters that follow, we will dissect each facet of farmer distress, providing valuable insights, real-life stories, and expert opinions that shed light on this ongoing rural crisis. By doing so, we hope to contribute to a broader conversation about the future of farming, rural communities, and the path towards a more sustainable and equitable agricultural sector.

Factors Contributing to Farmer Distress

Crop Failures and Climate Change

Crop failures and the adverse impacts of climate change are significant contributors to farmer distress. These challenges have become more pronounced in recent years due to unpredictable weather patterns, prolonged droughts, excessive rainfall, and the increased frequency of extreme weather events. Here's a detailed look at how these factors affect farmers:

- **Unpredictable weather patterns:** Modern agriculture relies heavily on predictable weather patterns. Farmers plan their planting and harvesting schedules based on historical weather data. However, climate change has led to erratic weather conditions, making it difficult for farmers to anticipate when to sow and reap crops. This unpredictability can result in poor crop yields and financial losses.
- **Prolonged droughts:** Droughts have become more frequent and severe in many agricultural regions. Prolonged periods of water scarcity can devastate crops and force farmers to use expensive irrigation methods, further increasing their operational costs.
- **Excessive rainfall and flooding:** On the other extreme, excessive rainfall and flooding can damage crops, cause soil erosion, and make fields inaccessible. This leads to the loss of valuable agricultural produce and reduced income for farmers.
- **Increased pest and disease pressure:** Climate change can also alter the distribution and behaviour of pests and diseases. Warmer temperatures may allow certain pests to thrive in regions where they were previously uncommon, leading to increased crop damage and the need for costly pest control measures.
- **Shifts in growing seasons:** Changing climate patterns can disrupt traditional growing seasons, affecting the suitability of certain crops for specific regions. This can force farmers to adapt to new crops or invest in expensive technology to maintain their livelihoods.

Debt Burden and Loan Waivers

Farmers often rely on loans to finance their agricultural activities, from purchasing seeds and equipment to investing in irrigation systems. However, the burden of debt can quickly become overwhelming, contributing to farmer distress. Here are some key aspects:

- **High-interest rates:** Farmers in many regions face high-interest rates on agricultural loans. These rates can significantly increase the overall debt burden, making it challenging for farmers to repay their loans.

- **Inadequate credit access:** Some farmers may not have access to formal credit institutions, leading them to rely on moneylenders who charge exorbitant interest rates. This can trap them in a cycle of debt.
- **Loan waivers:** In some cases, governments offer loan waivers as a short-term solution to alleviate farmer distress. While this provides temporary relief, it does not address the root causes of the problem and can have adverse long-term consequences on the financial sector and credit culture.

Fluctuating Agricultural Prices

Agricultural commodities often experience price volatility, which can severely impact farmers' income and financial stability. Here's how fluctuating prices contribute to farmer distress:

- **Price risk:** Farmers are exposed to the inherent volatility of agricultural commodity prices. Factors such as global market dynamics, changes in demand, and supply-side shocks can cause rapid price fluctuations.
- **Lack of price transparency:** In some regions, farmers have limited access to information about market prices, leaving them vulnerable to exploitation by middlemen who offer lower prices for their produce.
- **Storage and transportation costs:** Farmers may incur additional costs for storing and transporting their crops to market. When prices drop, these costs can erode their profits, leading to financial distress.

Lack of Diversification in Rural Income

Many farmers rely solely on agriculture for their income, which can be risky when faced with various challenges. The lack of income diversification contributes to farmer distress in the following ways:

- **Income vulnerability:** Relying solely on agriculture makes farmers highly vulnerable to crop failures and market fluctuations. A single bad season can push them into financial hardship.
- **Limited access to alternative opportunities:** In rural areas, opportunities for alternative sources of income can be limited. Lack of education and infrastructure can further restrict farmers from exploring other livelihood options.

- **Technological barriers:** The adoption of new income-generating technologies or diversification into non-agricultural sectors may require investment and access to information and resources, which some farmers lack.

Addressing farmer distress requires a holistic approach that considers the complex interplay of factors such as climate change, debt burden, price volatility, and income diversification. Policies and interventions that promote sustainable farming practices, improve access to credit, enhance market information, and encourage income diversification can help mitigate the challenges faced by farmers and ensure the long-term viability of agriculture as a livelihood.

Impact on Rural Communities

Rural communities around the world have experienced significant transformations due to various economic, social, and environmental factors. One of the most prominent influences has been the shift away from traditional agricultural practices towards modernization and urbanization. This transformation has had a profound impact on rural communities, leading to several interconnected consequences:

Declining Agricultural Employment

- **Shift to mechanization:** One of the primary reasons for declining agricultural employment in rural areas is the adoption of modern farming techniques and machinery. Farmers are increasingly turning to mechanized farming, such as tractors and automated equipment, which reduces the need for manual labour. As a result, traditional farming jobs, which were once a cornerstone of rural economies, are diminishing.
- **Economic uncertainty:** The decline in agricultural employment has led to economic uncertainty for many rural families. Those who depended on farming for their livelihoods may face income instability as they grapple with the seasonal and unpredictable nature of modern agriculture.
- **Generational shift:** Younger generations in rural communities are often less inclined to pursue farming as a career. The perception of farming as a labour-intensive and financially unstable profession has led many young people to seek alternative career paths, often in urban areas.

Migration to Urban Areas

- **Rural-urban migration:** The lure of better economic opportunities, improved infrastructure, and access to education and healthcare in urban areas has driven a significant rural-to-urban migration. This mass exodus from rural communities has contributed to the growth of urban centers.
- **Impact on rural population:** The outmigration of rural residents, especially young and educated individuals, can lead to a decline in the overall population of rural areas. This demographic shift can have far-reaching consequences, affecting the sustainability of rural communities.
- **Urbanization challenges:** Rapid urbanization can put stress on urban infrastructure and services, potentially leading to overcrowding, increased demand for housing, and strain on public resources.

Social and Psychological Stress

- **Social isolation:** As rural populations decline, those who remain in rural areas may experience increased social isolation. The close-knit, community-oriented nature of rural life may erode as more people leave for urban opportunities.
- **Mental health issues:** The changes in rural communities, such as declining employment opportunities and social isolation, can contribute to mental health issues. Rural residents may face higher levels of stress, anxiety, and depression due to economic uncertainty and social disconnection.
- **Loss of cultural heritage:** Rural communities often have rich cultural traditions and a strong connection to the land. The shift away from agriculture and rural life can result in the loss of cultural heritage and a sense of identity for these communities.

The impact on rural communities due to declining agricultural employment, migration to urban areas, and the associated social and psychological stress is complex and multifaceted. These challenges require a comprehensive approach that addresses economic diversification, social support systems, and the preservation of rural culture to ensure the long-term sustainability and well-being of rural communities in a rapidly changing world.

Government Initiatives and Policies

Analysis of Past and Current Policies

Government initiatives and policies play a pivotal role in shaping a nation's socio-economic landscape. Analysing past and current policies is essential to understanding their impact on various aspects of society, the economy, and governance. This analysis helps in refining existing policies and developing new ones to address emerging challenges. Here, we'll delve into the importance of assessing these policies, the methods used for analysis, and provide a few examples to illustrate the concept.

1. Importance of policy analysis: Policy analysis involves the systematic evaluation of government initiatives and policies to determine their efficacy, efficiency, and overall impact. This process is crucial for several reasons:

a. **Accountability:** It holds the government accountable for the decisions and actions it takes.
b. **Informed decision-making:** It provides valuable insights that can inform future policy decisions.
c. **Resource allocation:** It helps in allocating resources effectively by identifying areas where policies may need adjustments.
d. **Continuous improvement:** It promotes a culture of learning and adaptation in governance.

2. Methods of policy analysis: Policy analysis employs various methods and tools, including:

a. **Data analysis:** Examining quantitative data such as economic indicators, surveys, and statistics to assess policy outcomes.
b. **Qualitative research:**Conducting interviews, case studies, and focus groups to gather insights into policy implementation and its effects.
c. **Cost-benefit analysis:** Evaluating whether the benefits of a policy outweigh its costs.
d. **Comparative analysis:** Comparing policies across different regions or countries to identify best practices.
e. **Stakeholder engagement:** Involving stakeholders like citizens, experts, and interest groups to gather diverse perspectives.

3. Examples of policy analysis: Let's consider a few examples to understand the process better:

a. **Healthcare policy:** An analysis of a national healthcare policy might involve assessing the accessibility of healthcare services, the quality of care, and the impact on public health outcomes. Data on healthcare expenditures, disease prevalence, and patient satisfaction can be analysed to gauge policy effectiveness.
b. **Environmental policy:** Evaluating the impact of environmental regulations on air and water quality, wildlife conservation, and greenhouse gas emissions is crucial. Cost-benefit analysis can be used to determine whether the regulations yield a net positive environmental and economic impact.

Effectiveness and limitations

1. Effectiveness of policies: Assessing the effectiveness of government policies is essential to determine if they achieve their intended objectives. Some indicators of policy effectiveness include:

a. **Achieving goals:** Did the policy achieve its stated objectives, such as reducing poverty rates or improving education outcomes?
b. **Cost-efficiency:** Were the resources allocated efficiently to maximize the policy's benefits relative to costs?
c. **Equity:** Did the policy reduce disparities or inequalities within society?
d. **Public satisfaction:** Are citizens satisfied with the outcomes and implementation of the policy?

2. Limitations of policies: Policies are not without their limitations and challenges. Some common limitations include:

a. **Unintended consequences:** Policies may have unintended negative consequences or side effects that need to be addressed.
b. **Implementation gaps:** Policies may not be implemented as intended due to administrative inefficiencies, corruption, or lack of resources.
c. **Changing context:** Policies that were effective in the past may not be suitable for the current socio-economic or technological landscape.
d. **Resistance and opposition:** Policies can face resistance from interest groups, political opposition, or public backlash.

The analysis of government initiatives and policies is a critical aspect of governance. It helps in ensuring accountability, informed decision-making, and the continuous improvement of policies. Evaluating their effectiveness and acknowledging their limitations is essential for creating policies that better serve the needs of society and the economy.

Solutions and Recommendations

Sustainable Farming Practices

- **Promotion of organic farming:** Encouraging farmers to adopt organic farming practices can be a sustainable solution. This involves reducing the use of synthetic pesticides and fertilizers, which not only saves costs for farmers but also promotes soil health and reduces environmental pollution.
- **Crop rotation and diversification:** Promoting crop rotation and diversification can improve soil fertility, reduce pest and disease pressure, and enhance overall farm productivity. Government incentives and educational programs can encourage farmers to implement these practices.
- **Water conservation techniques:** Implementing efficient irrigation techniques, such as drip irrigation and rainwater harvesting, can help farmers optimize water usage. This is especially crucial in regions with water scarcity issues.
- **Training and education:** Providing training and education on sustainable farming practices through agricultural extension services can empower farmers to make informed decisions about their farming methods. This includes workshops on organic farming, pest management, and soil health.
- **Access to sustainable inputs:** Ensuring easy access to quality seeds, organic fertilizers, and biopesticides at affordable prices can further promote sustainable farming practices. Government subsidies and support can play a vital role in this aspect.

Access to Financial Services

- **Farm credit facilities:** Expanding access to credit facilities tailored to the needs of small and marginal farmers can alleviate financial distress. Low-interest loans, microfinance, and credit cooperatives can be promoted to provide farmers with the necessary capital for investments in their farms.
- **Crop insurance schemes:** Encouraging farmers to enroll in crop insurance schemes can mitigate the risks associated with crop failure due to unpredictable factors like

weather conditions and pests. Governments can subsidize premiums and simplify claim procedures to make these schemes more accessible.

- **Income diversification:** Promoting income diversification through non-farm activities and entrepreneurship can reduce the financial dependency on agriculture alone. Providing training and resources for establishing small businesses or agribusiness ventures can be beneficial.
- **Digital financial services:** Introducing digital banking and payment solutions in rural areas can enhance financial inclusion. Farmers can access their accounts, receive payments, and make transactions more conveniently, reducing the reliance on cash transactions.

Rural Skill Development Programs

- **Agricultural training centers:** Establishing agricultural training centers in rural areas can equip farmers with the skills and knowledge needed to improve their farming practices. These centers can provide hands-on training in modern agricultural techniques and technologies.
- **Vocational training:** Offering vocational training programs beyond agriculture, such as carpentry, welding, and mechanics, can help rural youth diversify their skill sets and find alternative employment opportunities.
- **Entrepreneurship training:** Providing training in entrepreneurship and business management can empower farmers to start their own agribusiness ventures or value-added processing units, reducing their dependence on middlemen.
- **Digital literacy:** In today's digital age, enhancing digital literacy among rural farmers is crucial. Training programs can teach farmers how to use smartphones and apps for accessing market information, weather forecasts, and financial services.

Market Diversification

- **Farmers' Producer Organizations (FPOs):** Promoting the formation of FPOs can help farmers collectively market their produce, negotiate better prices, and access larger markets. These organizations can also facilitate value addition and processing of agricultural products.
- **Access to e-Markets:** Connecting farmers to electronic marketplaces and online platforms can broaden their reach and eliminate intermediaries. These platforms can

provide real-time market information and enable direct sales to consumers and businesses.

- **Export promotion:** Encouraging the export of agricultural products can open up new markets and increase income for farmers. Support in meeting international quality and safety standards is essential for successful export initiatives.
- **Infrastructure development:** Investing in rural infrastructure, such as cold storage facilities, transportation networks, and market yards, can reduce post-harvest losses and enable farmers to access distant markets.
- **Market intelligence:** Providing farmers with market intelligence through agricultural extension services can help them make informed decisions about crop selection and timing of sales, ensuring better returns.

Farmer distress requires a multi-faceted approach that encompasses sustainable farming practices, improved access to financial services, skill development programs, and market diversification strategies. These recommendations aim to empower farmers, reduce their vulnerability to various risks, and enhance their overall livelihoods. Implementing these solutions with the active involvement of government, NGOs, and the private sector can lead to a more resilient and prosperous farming community.

Conclusion

The Farmers Distress Index sheds light on the multifaceted challenges faced by rural communities across the globe. The factors contributing to farmer distress, including crop failures exacerbated by climate change, overwhelming debt burdens, volatile agricultural prices, and a lack of income diversification, have created a web of economic woes for those dependent on agriculture. The impact of these challenges on rural communities is significant and far-reaching. Declining agricultural employment opportunities have led to an exodus of individuals and families to urban areas in search of alternative livelihoods. This migration, in turn, has placed additional strains on urban infrastructure and services. Moreover, the social and psychological stress endured by farmers and their families cannot be underestimated, as it affects the overall well-being of these communities. While governments have implemented various initiatives and policies aimed at alleviating farmer distress, their effectiveness has been mixed, often hindered by administrative limitations and gaps in implementation. A critical analysis of past and current policies is essential for crafting more impactful and sustainable solutions. To address these challenges, a multi-pronged approach is imperative.

Encouraging sustainable farming practices that are resilient to climate change, providing farmers with better access to financial services, and implementing rural skill development programs are crucial steps toward economic empowerment. Moreover, market diversification can help reduce vulnerability to fluctuating prices, offering rural communities greater stability and prosperity. In essence, the Farmers Distress Index underscores the urgent need for comprehensive and innovative solutions to tackle the complex issue of farmer distress. By addressing the root causes, offering support, and fostering resilience in rural communities, we can work toward a more equitable and prosperous future for those who feed the world.

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MECHANISMS OF SALT TOLERANCE IN RICE

[1]VaniPraveena M.* and [2]Venkata Ramana Rao P.

Email

vanipraveenamadhunapantula@gmail.com

[1]Genetics and Plant Breeding Department, ANGRAU, Agricultural College, Bapatla, India

[2]Plant Breeding Department, RARS, Maruteru, ANGRAU, India

India would need to produce about 311 million tonnes of food grains by 2030, to feed about 1.43 billion people, and by 2050, when the country's population is projected to reach 1.8 billion, this amount might rise to 350 million tonnes. Rice is a major cereal crop for more than 3 billion people globally and its demand is expected to increase by 38% by 2050. However, abiotic stresses critically limit the rice production, resulting in significant yield losses. Salt is a two edged sword and salinity is next major threat to rice production after drought. About 50% of world's arable land is predicted to be salt-affected and in India, salt-affected land covers 6.73 Mha, with the number anticipated to rise to 16.2 million by 2050. Rice is sensitive to salinity at seedling and reproductive stages. The first component of this stress is osmotic, and arises from NaCl induced reduction of the solute potential of the soil solution, which in turn reduces the water uptake by plants. The second component is ionic (ion toxicity), which arises from accumulation of noxious quantities of Na^+ in the cells and tissues of the plants which adversely affect its growth and development. Rice yield tend to decline when EC is more than 3 dSm^{-1} with 12% yield decrement per unit increase in EC (Munns and Tester, 2008). Hence, there is an urgent need to develop salt-tolerant rice cultivars to sustain rice production. Advancement in our understanding of abiotic stress tolerance mechanisms of crop plants and application of modern biotechnological techniques, marker-assisted selection (MAS) and genetic engineering are important to develop stress tolerant varieties.

Different Salt Tolerance Mechanisms in Rice

1. Sodium Homeostasis

Uptake of Na^+ at the root-soil boundary is believed to occur mainly through non-selective cation channels (NSCC), including the cyclic nucleotide-gated channels (CNGCs) and glutamate receptors (GLRs), as well as through some high affinity K^+ transporters (HKTs), K^+ channels including the Arabidopsis K^+ transporter (AKT1) and high-affinity K^+ uptake transporter (HAK). The Na^+ absorbed by the root then moves to the xylem with the aid of other transporters and channels which is delivered to the shoot, especially to the leaf blade, where its effects are most felt (Hanin *et al.*, 2016). In glycophytes, regulating this transport of Na^+ to the leaf is crucial and will be a determinant in their adaptation to salt stress. Therefore, transporters that operate to reverse the processes involved in Na^+uptake and translocation would be relevant, although Na^+ uptake, translocation and accumulation in the leaf is not always correlated with salt stress sensitivity (Munns and Tester, 2008). For example barley plants tolerate salt stress by accumulating salt in the leaves for osmotic adjustment.

2. Resistance to radial transport and xylem loading of Na^+

When Na^+ is taken up at the level of the root and moves radially to the stele, it is loaded into the xylem and taken up to the shoot in the transpiration stream. Restricting the radial movement of Na^+ across the root will greatly reduce the amount loaded into the xylem for delivery to the shoot. In addition to this observation, the SOS1 antiporter localized to the root epidermis offers the first line of resistance to Na^+ uptake, by extruding Na^+ to the external soil environment. At the cortical level, OsHKT2;1 has been shown to prevent radial transport of Na^+ at the root.

Maintaining minimal shoot Na^+/ K^+ ratios is an important stress tolerance trait in some halophytes and tolerant glycophytes (Katschnig *et al.*, 2015). To achieve this, the regulation of xylem loading at the root is crucial. SOS1 localized to the stele is believed to mediate xylem loading of Na^+ in both glycophytes and halophytes, especially under high salinity.

3. Restriction of Na^+ transport to the leaf

Once Na^+ is loaded into the xylem, it is transported via transpiration to the leaf. HKT and SOS1 found in the stem, mainly of dicots, and HKT (HKT1;4) in the sheath of monocots, participate in reducing the amount of Na^+ reaching the leaf, by retrieving Na^+ from the xylem into xylem parenchyma cells, thereby regulating Na^+ delivery to the leaf blade (Assaha *et al.*, 2017).

Class I HKT transporters are located at the xylem/symplast boundary and show high specificity for Na^+, thus mediating Na^+ unloading from xylem into xylem parenchyma cells of the shoot and root.

4. Regulation of toxic Na^+ accumulation in the leaf blade

The leaf blade is the central hub of most metabolic processes in plants and so needs to be protected from Na^+-induced damage. Therefore, under salt stress, Na^+ reaching the leaf needs to be rapidly redistributed in a way that will not hamper any metabolic processes. One such action was shown involving AtHKT1;1mediated Na^+ recirculation from the leaf to the root via the phloem (Fujimaki *et al.*, 2015).

5. Potassium homeostasis

The maintenance of constant intracellular concentration is crucial because K^+ is involved in a myriad of growth, developmental, reproductive and physiological processes, including germination, osmoregulation, stomatal regulation, nyctinastic movement of leaves, enzyme activation, loading and unloading of sugars in phloem, as a counter-ion for nitrate translocation, cytosolic pH regulation, stabilization of membrane potential and protein trafficking to protein-storage vacuoles.

Since salt stress often induces perturbations in the cellular K^+ homeostatic balance, with a consequential alteration in all these physiological processes, it has become increasingly certain that maintaining a high cytosolic K^+ / Na^+ ratio would constitute a stress tolerance strategy. This optimal K^+ / Na^+ ratio, especially under stress, can only be achieved if the root K^+ uptake, xylem loading for translocation to the shoot and cellular influx are enhanced, while detrimental cytosolic K+ efflux is restricted at the same time (Himabindu *et al.*, 2016).

6. Mechanisms favouring root K^+ uptake

The membrane potential is largely negative in order to maintain high intracellular K^+ concentrations. Maintaining more negative (inside) membrane potential is a key factor in salt stress tolerance.In fact, HAK is the only K^+ uptake transporter that is known to operate in this range of external K^+ concentrations, and this characteristic activity for high-affinity K^+ transport renders plants expressing the HAK transporter genes very tolerant to low K^+ conditions (Himabindu *et al.*, 2016).

7. Intracellular Na^+/ K^+ and pH homeostasis

Maintaining high cytosolic K^+/ Na^+ is a prerequisite for salt stress tolerance as this ensures optimal cellular metabolic functions. Under salt stress, the competitive inhibition of K^+ uptake by Na^+ often leads to the Na^+ interfering in many K^+dependent processes, thereby inhibiting them. For example Na^+ replaces K^+ in binding sites on enzymes resulting in enzyme deactivation and consequent interruption of the metabolic processes concerned. Also, the influx of Na^+ in cells depolarizes the membranes, leading to K^+ efflux through depolarization activated KOR, such as GORK. To counter this excessive Na^+ influx, SOS1 offers the first line of defense, by actively extruding the absorbed Na^+ back to the extracellular spaces (Anschutz *et al.*, 2014).

In xylem parenchyma cells, this extrusion will lead to the xylem Na^+ loading depending on external Na^+ concentration. Vacuolar sequestration of Na^+ is another very important strategy in the regulation of cytosolic Na^+ accumulation. However retention of the sequestered Na^+ has been proposed as a key stress tolerance mechanism, as Na^+ leakage back to the cytoplasm via the fast vacuolar (FV), and slow vacuolar (SV) channels, has been associated with salt sensitivity. Therefore, mechanisms that will favour the uptake and transport of K^+ and the maintenance of high cytosolic K^+/ Na^+ ratios should be relevant to the growth and tolerance of glycophytes

Rice plants mainly employ three mechanisms, ion exclusion, osmotic tolerance, and tissue tolerance to adapt in salt stress. These mechanisms are brought in to play during the various stages of Na+ uptake from soil and its translocation to shoot.

Conclusion

Understanding partly why halophytes are more salt-tolerant than glycophytes could constitute useful targets for engineering salt stress tolerance. In addition, novel regulatory pathways have been uncovered which, although augmenting the complexity of salinity, could also serve as important targets for improving salt stress tolerance.

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UNLOCKING THE ENIGMA OF ORPHAN GENES: THEIR SIGNIFICANCE, ORIGINS AND POTENTIAL APPLICATIONS IN MODERN AGRICULTURE

Email
hemanthbdvt2310@gmail.com

[1]Hemanth S*, [2]Dr. Laxmi C. Patil, [1]AavulaNaveen and [1]Bhargavi H A

[1] Division of Genetics, Indian Agricultural Research Institute, New Delhi, India

[2] Department of Genetics and Plant Breeding, AICRP on Groundnut, MARS, University of Agricultural Sciences, Dharwad, India

Recent advancements in agriculture have heightened the importance of orphan genes as a crucial tool for addressing the evolving demands and sustainability imperatives of contemporary food production. The urgency of modern agriculture arises from the need to sustainably feed a burgeoning global population while mitigating the environmental impacts of intensive farming practices. Orphan genes, with their unique attributes, play a pivotal role in addressing these challenges. They provide crop breeders with the means to develop varieties capable of thriving in changing climates, resisting emerging pests and diseases, and enhancing nutritional content. These genes contribute to the creation of resilient crops with reduced ecological footprints and lower chemical input requirements as environmental pressures escalate. Moreover, the conservation of orphan genes in wild crop relatives ensures the adaptability and sustainability of agriculture in the face of habitat loss and climate-induced disruptions.

Orphan Genes: A Mystery Unveiled

Orphan genes encompass a subset of taxonomically restricted or lineage-specific genes that are exclusive to a particular species. These genes possess coding sequences entirely unique to the species, resulting in the production of novel proteins that have not been previously observed in other organisms. They earn the "orphan" classification when their coding sequences exhibit no similarity to genes found beyond their specific species. This classification encompasses both genes that have newly emerged from non-genic sequences and descendants of ancient genes whose coding sequences have undergone such significant changes that they are no longer recognizable.

A Historical Odyssey: Unearthing Orphan Genes

The discovery of orphan genes began with the initiation of the yeast genome-sequencing project in 1996, where these unique genes accounted for approximately 26% of the yeast genome. Initially, it was hypothesized that as more genomes were sequenced, these genes would find homologous counterparts. This was a time when gene duplication was the prevailing model for gene evolution, and the limited availability of sequenced genomes was considered the likely reason for the absence of detectable homologues. However, as more genomes were sequenced over time, orphan genes persisted, leading to the realization that they are widespread across all genomes. Estimates of the percentage of orphan genes in different species vary widely in various studies, with figures ranging from 10% to 30% commonly cited (Domazet *et al*., 2007).

Novel Gene Formation from Ancestral Genes

1. **Duplication and Divergence:** After a gene duplication event, one of the copies gradually accumulates mutations and experiences relaxed selective pressure, leading to the acquisition of novel functions.

2. **Gene Fusion:** Gene fusion involves the merging of two previously separate genes to form a hybrid gene. Various mechanisms can lead to gene fusions, including interstitial deletions.

3. **Gene Fission:** In the process of gene fission, a single gene splits into two distinct genes. This separation occurs through gene duplication followed by the differential degeneration of the two copies.

4. **Horizontal Gene Transfer:** Genes acquired from other species via horizontal gene transfer undergo genetic divergence and neofunctionalization as they become integrated into the recipient organism's genome.

5. **Retro position:** During retro position, transcripts are reverse transcribed and subsequently integrated into the genome as intron less genes located elsewhere. These new genes may then undergo divergence.

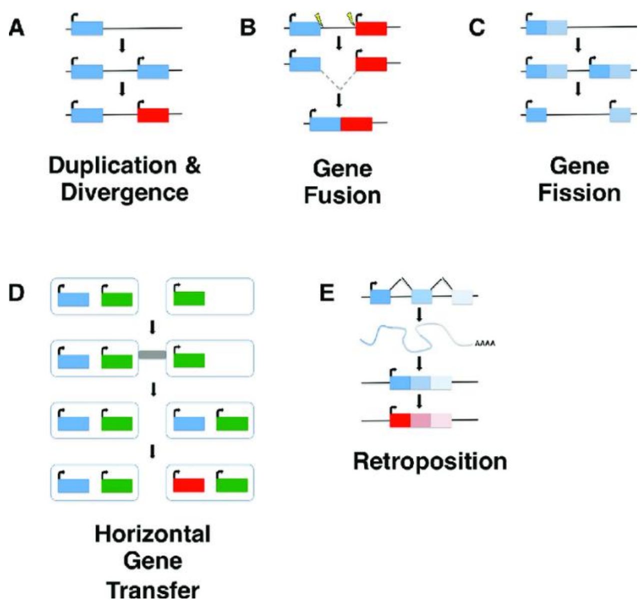

Fig 1: Novel gene formation from ancestral genes

How to Identify Orphan Genes?

BLAST(Basic Local Alignment Search Tool) is a computational algorithm employed for the comparison of fundamental biological sequence data, including protein amino acid sequences and DNA/RNA nucleotide sequences. BLAST identifies areas of localized similarity within these sequences and stands as the primary choice for detecting homologous genes in other species.

Phylostratigraphy is a technique used to categorize genes by their age, tracing their origins back to their ancestral founders. The general method involves selecting taxonomic groups in a hierarchical manner, moving up from the focal species, and for each gene, identifying the oldest taxon in which a homolog is found(Tautz and Loso, 2011).

The Evolutionary Tapestry of Orphan Genes

Duplication–divergence

A newly formed gene typically originates from a gene duplication or transposition event, followed by a rapid phase of adaptive evolution. This phase leads to the gene diverging significantly, ultimately resulting in the loss of any similarity to the original gene from which it was duplicated.

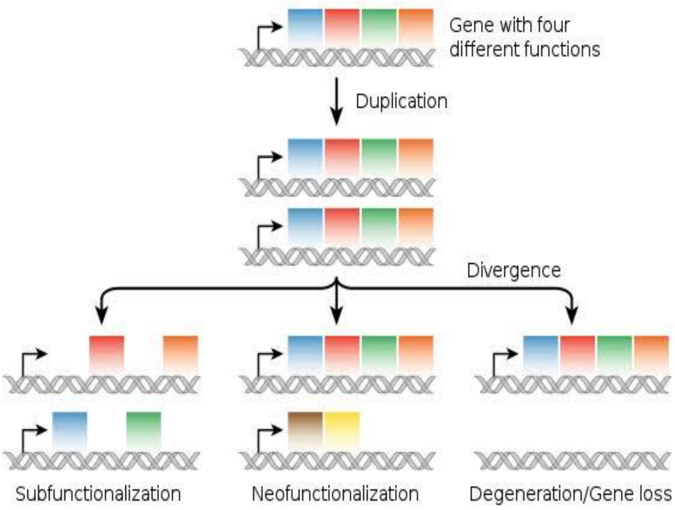

Fig 2: Gene duplication and divergence

De novo evolution

Protogenes, which encompass noncoding RNAs containing open reading frames (ORFs), overlapping gene ORFs, and regions found between genes, undergo transcription that leads to ribosomal association and message translation. The resulting peptides may offer a selective advantage due to potential but modest promiscuous activities. The mechanism outlined in the innovation-amplification-divergence (IAD) model operates to enhance the efficiency of protogenes through positive selection, facilitating the emergence of new genes. However, certain protogenes fail to ultimately gain long-term selective advantages and instead become pseudogenized.

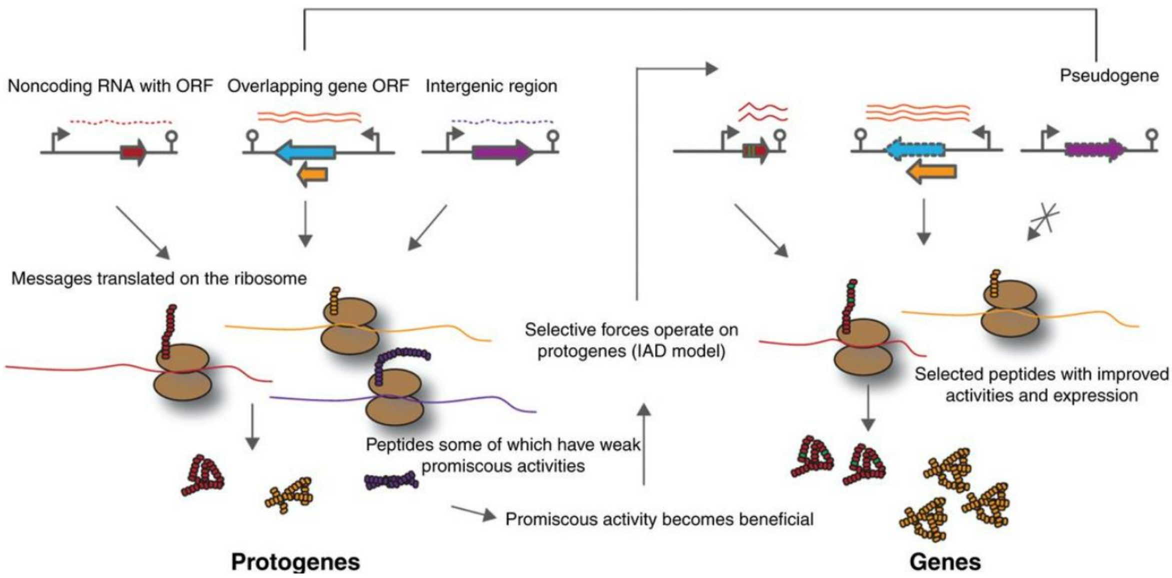

Fig 3: De novo gene evolution

Distinctive Traits of De Novo Genes:

I. Short Open Reading Frames (ORFs): De novo genes often have relatively short coding sequences compared to well-established genes. These short ORFs may initially encode small peptides with limited functions.

II. Low Expression Level: De novo genes typically exhibit low expression levels, meaning they are not actively transcribed and translated at high rates in the cell. This low expression may be due to their recent emergence and limited regulatory elements.

III. Higher Tissue Specificity: These genes are often expressed in a highly tissue-specific manner, meaning they are active only in specific cell types or under particular conditions. This tissue specificity may reflect their specialized or context-dependent roles.

IV. High Divergence Rates: De novo genes tend to evolve rapidly and have high divergence rates. Their sequences change relatively quickly compared to more conserved genes, which can result in functional diversity among different species.

V. Low GC Content: De novo genes often have a lower GC content (guanine-cytosine base pairs) compared to older genes. This lower GC content can affect the stability of the gene and its regulatory elements.

Orphan Genes in Action: Applications in Agriculture

The agricultural arena has witnessed a paradigm shift in recent years, with orphan genes playing a pivotal role in meeting the industry's evolving needs. Orphan genes offer a unique source of untapped genetic diversity, empowering crop breeders to develop resilient varieties capable of thriving in shifting climates and resisting emerging pests and diseases. These genes have the potential to confer traits like disease resistance, drought tolerance, and improved nutritional content, while simultaneously reducing ecological footprints and chemical inputs. Furthermore, the preservation of orphan genes in wild crop relatives ensures the long-term adaptability and sustainability of agriculture in the face of habitat loss and climate-induced disruptions.

Conclusion

As we navigate the intricate landscape of modern agriculture, orphan genes stand as indispensable tools for achieving increased food production, reduced environmental impact, and a more secure global food supply. Their role extends beyond the laboratory, encompassing marker-assisted and quality breeding, enhancing resistance, boosting economic yields, and fortifying crops against abiotic stresses. The study of orphan genes holds promise not only for agricultural innovation but also for our understanding of the dynamic mechanisms that underpin genetic diversity and evolution.

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UNVEILING THE OCEAN'S SECRET: HARNESSING SEAWEED AS A POWERFUL BIOSTIMULANT IN AGRICULTURE

[1]Rushali Katoch[*], [1]Varun Parmar and [1]Narender Kumar Sankhyan

Email
rushalikatoch19@gmail.com

[1]Department of Soil Science, CSK HPKV, Palampur, HP, India

The shift towards using seaweed-based biostimulants in modern agriculture is driven by the need for more sustainable and efficient farming practices. As conventional agricultural methods face challenges such as soil degradation, environmental impact, and regulatory constraints, biostimulants offer a promising alternative. Seaweeds, abundant in oceans, contain a rich blend of natural growth hormones, amino acids, and minerals that enhance plant growth, nutrient absorption, and stress tolerance. While their agricultural potential has been recognized since ancient times, the modern push for organic food production has sparked a renewed interest in using seaweed-based biostimulants in agriculture.

Over the past five decades, the agroindustry has achieved significant milestones by capitalizing on the chemical revolution, which gave rise to mineral fertilizers. This fruitful collaboration between agronomical and chemical sciences played a pivotal role in the remarkable increase in crop yields, effectively addressing the growing nutritional demands brought on by the post-World War II population surge. Today, in the context where environmental issues due to climate change are pervasive, modern agriculture is facing an array of formidable challenges with profound implications for global food production, sustainability and food security. In this quest for sustainable agriculture, we often find ourselves looking to the earth's fertile soils and the myriad of techniques to enhance crop production to meet nutritional demand of burgeoning world’s population. However, an often-overlooked treasure lies beneath the surface of our oceans i.e., seaweed.

Marine algal seaweed species are often seen as an overlooked natural resource. For centuries, they have been used as a source of food, raw materials for industry, and in medicinal applications. Today, as modern agriculture grapples with the need to reduce synthetic chemical inputs and minimize its environmental footprint, seaweed is emerging as a powerful biostimulant with the potential to revolutionize how we grow our crops. Biostimulants belong to the category of natural preparations that have the capacity to enhance overall plant health, vitality, and growth, while simultaneously provide them protection against environmental stress. Recently, biostimulants are recognized as a new category of products in "Fertilizer Amendment Order 2021", on February 23, 2021. These products are distinct from fertilizers and pesticides. These refers to the substances or microorganism or a combination of both whose primary is to stimulate physiological processes, to enhance nutrient uptake, growth, yield, nutritional efficiency, crop quality and provide stress tolerance when applied to plants, seeds or rhizosphere, regardless of its nutrient content. Harnessing seaweed as a biostimulant in agriculture is not only a story of innovation but also firmly grounded to the principles of sustainable agriculture. Seaweed extract based biostimulants contain many bioactive substances viz. polysaccharides, minerals, vitamins, amino acids, antioxidants, pigments and hormones (Craigie, 2011). Bioactive substances found in seaweeds work together to enhance plant growth by optimizing both physiological and biochemical processes within the plants. Numerous research investigations have unveiled the multifaceted advantages of seaweed-based biostimulants on plants. These natural extracts have been shown to facilitate early seed germination and robust seedling establishment, improved crop performance and thereby yields, increased resistance to environmental stress, and extended post-harvest shelf life of perishable agricultural products (Norrie and Keathley, 2006). Besides eliciting a growth promoting effect on plants, seaweed biostimulants also improve soil health thereby offers a sustainable alternative to synthetic fertilizers (Blunden, 1991).

Nurturing Plant and Soil Health: Positive Impact on Crops

Derived from various species of marine algae, seaweed based biostimulants offer a myriad of benefits for plants and the surrounding environment.

1. Enhanced nutrient uptake and crop yields

Seaweed-based biostimulants enhance plant nutrient uptake, and this improvement depends on how they are applied. These biostimulants can be administered either directly to the soil or sprayed onto the plants as a foliar application. When introduced into the soil, biostimulants encourage root growth and development through the presence of root growth-promoting hormones, ultimately enhancing the plant's ability to absorb nutrients more efficiently. Conversely, when applied as a foliar spray, certain compounds within the seaweed extract are directly absorbed through the plant's leaves, contributing to nutrient uptake and overall plant health. Seaweed extract @ 5% applied via a combination of corm dipping and foliar spray produced outstanding results in the development of saffron. This strategy resulted in a significant rise in corm production as well as noticeable improvement in growth parameters (Chaudhary *et al*., 2023). Deepana *et al*., (2021) found that applying seaweed extract @ 12.5 $kgha^{-1}$ to the soil, along with a 0.5% foliar spray during tillering and panicle initiation, significantly improved yield attributesvis-a-visrice productivity.

2. Imparted resistance to environmental stresses

Seaweed biostimulants contain natural growth regulators like cytokinins and auxins that help plants to cope with adverse environmental stress. Whether it's abiotic or biotic stress, plants treated with seaweed biostimulants tend to exhibit greater resilience and adaptability. Biostimulants obtained from the biomass of red seaweeds like *Kappaphycus* and *Eucheuma* species were found to provide protection against fungicide induced stress when applied to rice plants (Banakar *et al*., 2022).In a study conducted by Radwan *et al*., in 2023, seed priming of promising fodder and oil crop, *Citrullus lanatus*, in Egypt using extracts derived from the seaweed *Ulva lactuca* was observed to induce salt stress. This stress triggered the production of bioactive compounds, including betaines and phenolic compounds, which, in turn, facilitated successful seed germination, enhanced plant growth, and increased salt resistance.

3. Improved soil health

Biostimulants have a pioneering role in improving soil health by supporting a healthy environment beneath our feet. Through the stimulation of beneficial microorganisms, seaweed and their extracts actively participate in the processes of nutrient cycling and the decomposition of organic matter in the soil. In turn, the proliferation of microbial activity enhances the porosity and structure of the soil thereby improving water retention and aeration. Seaweed biostimulants also plays a crucial role in mitigating soil degradation and environmental pollution by reducing the need of synthetic fertilizers. Furthermore, the gelling and chelating abilities of polysaccharides found in seaweed extracts, alongside other active organic compounds, contribute to the enhancement of soil structure vis-à-vis soil health. Consequently, they contribute significantly to cultivating a more sustainable and ecologically balanced soil ecosystem. The application of seaweed as an organic amendment, coupled with the incorporation of pruning waste in grapevine fields, has proven to be a valuable strategy for enhancing soil fertility. This approach has demonstrated its superiority over inorganic fertilization by significantly increasing soil organic matter content, thereby improving the overall soil fertility status (L. de Sosa *et al*., 2023). Ngoroyemoto *et al*., 2020 found that the synergistic application of PGPR (Plant Growth-Promoting Rhizobacteria) and seaweed extracts enhanced the yield and mineral content of leafy vegetables like *Amaranthus hybridus* by encouraging the growth of beneficial microorganisms and increasing the bioavailability of essential nutrients.

Conclusions and Future Perspectives

In conclusion, seaweed's role as a biostimulant in modern agriculture is a crucial advancement in addressing global challenges related to food production, sustainability, and food security. Seaweed-based biostimulants have the potential to revolutionize agriculture by improving crop growth, yield, and resilience while also reducing reliance on synthetic inputs. As we confront environmental issues and the need for sustainable practices, harnessing the bioactive properties of seaweed offers a promising pathway towards a resilient food production system. This natural resource beneath the oceans represents an innovative and eco-friendly solution to meet the growing demands of a burgeoning global population. However, the mechanisms underlying the physiological responses triggered by seaweed extracts in plants are largely unknown. With the completion or near-completion of the genomes of many plant species, there is a possibility to look into the impact of seaweed extracts on the entire plant genome. This genomic approach holds the potential to unveil the precise mechanisms by which seaweed induces growth responses and alleviates stress in plants, offering valuable insights for optimizing their application in agriculture. Moreover, research and innovation in this field will continue to expand, unlocking new applications and formulations that maximize the benefits of seaweed based biostimulants for improved crop performance and overall agricultural sustainability.

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