AGRIALLIS

SCIENCE FOR AGRICULTURE AND ALLIED SECTOR

A Monthly "e" Magazine

VOLUME 5, ISSUE 8

AUG. 2023

Online ISSN 2582-368X

www.agriallis.com

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Editorial Board

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AGRIALLIS
Science for Agriculture and Allied Sector: A Monthly Magazine
Volume 5, Issue 8
www.agriallis.com

Article Id
AL04239

GENOME-WIDE ASSOCIATION STUDIES: A REVOLUTIONARY APPROACH TO UNDERSTANDING CROP GENETICS

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In recent years, the field of crop genetics has experienced a profound transformation with the advent of Genome-Wide Association Studies (GWAS). GWAS represents a powerful and innovative approach to deciphering the genetic makeup of agricultural crops, offering researchers an unprecedented window into the complex interactions between genes and traits. By analyzing vast genomic datasets from diverse crop populations, GWAS has become a game-changer in agricultural research, enabling scientists to identify key genetic variants associated with essential agronomic traits.

Unlike traditional breeding methods that often rely on phenotypic observations and controlled crosses, GWAS delves deep into the genomes of crops to uncover the genetic basis of specific traits. By scanning the entire genome for genetic variations, including single nucleotide polymorphisms (SNPs) and insertions/deletions (INDELs), GWAS identifies regions of the genome that are statistically associated with the expression of important traits such as yield, disease resistance, drought tolerance, and nutritional content. This fine-grained resolution allows for a more comprehensive understanding of the underlying genetic factors influencing crop performance. Furthermore, GWAS enables researchers to identify candidate genes associated with specific traits, leading to a better understanding of the underlying molecular mechanisms governing crop development. This knowledge opens the door to targeted genetic manipulation, precision breeding, and the development of genetically superior varieties with enhanced resilience, productivity, and nutritional content.

The application of GWAS is not limited to staple food crops; it has found success in horticultural crops, bioenergy crops, and other economically important plant species. By

shedding light on the complex genetic architecture of diverse crops, GWAS has the potential to revolutionize agriculture and address pressing global challenges, such as climate change, population growth, and food security.

Principles of GWAS

1. **Precise Genotypic and Phenotypic Data**: GWAS requires accurate genotypic and phenotypic data for identifying marker-trait associations. Next-generation sequencing technologies have made SNP genotyping efficient and powerful.
2. **Phenotypic Data Precision**: Phenotypic data collection should minimize experimental errors and ambiguity. Replication of experimental units and repeat observations can enhance data robustness. Phenotypic data can be binary (e.g., disease resistance) or quantitative (integer or real-valued), with quantitative data offering more statistical precision.
3. **Appropriate Analysis Methods (AM)**: Choosing the right AM for a plant species depends on factors like the extent of linkage disequilibrium (LD) in the population, population structure, pedigree information availability, trait complexity, and genomic resources.
4. **Association Testing**: GWAS involves testing the association between markers and traits. For quantitative traits, common methods include linear regression, analysis of variance (ANOVA), and general linear models (GLM). For discrete or binary traits, logistic regression, $\chi 2$, or Fisher's exact test are used, with logistic regression being robust for adjusting covariates.

In summary, GWAS relies on precise data, efficient genotyping technologies, careful phenotyping, appropriate analysis methods, and statistical tests to unravel marker-trait associations in crops, providing valuable insights for crop improvement and breeding strategies.

Understanding Population Selection for GWAS in Crop Plants: Leveraging Genetic Linkage Disequilibrium to Uncover Trait Influencing Regions

GWAS (Genome-Wide Association Study) is a method used to find genetic regions that influence specific traits in crop plants. It is performed on populations that have significant genetic linkage disequilibrium (LD) in the regions affecting these traits. LD refers to the non-random association of genetic variations close to each other on a chromosome.

GWAS is different from linkage mapping, another genetic mapping method, and is generally carried out in populations that cannot be used for linkage mapping. These populations can be natural or synthetic and are selected in a way that avoids distinct sub-populations or complicated ancestry information.

The populations used for GWAS include samples from natural populations, germplasm collections (collections of genetic resources), inbred lines or cultivars developed through breeding programs, and synthetic populations created from a group of inbred lines.

These populations can be categorized based on their kinship (familial relationships) and population structure:

1. Ideal populations: These have little population structure and few familial relationships among individuals.
2. Populations with moderate familial relationships but little population structure.
3. Populations with moderate population structure and moderate familial relationships.
4. Populations with little familial relationship but moderate population structure. Most plant materials belong to this category due to their adaptation to various local conditions, exposure to natural/artificial selection, and inbreeding.
5. Populations with strong population structure and variable familial relationships.

Inbred lines are particularly useful for GWAS because they can be maintained indefinitely, tested in replicated trials, and easily shared among researchers for repeated and diverse investigations. A diverse panel of inbred lines can be thoughtfully created to represent the maximum possible genetic diversity of the crop species.

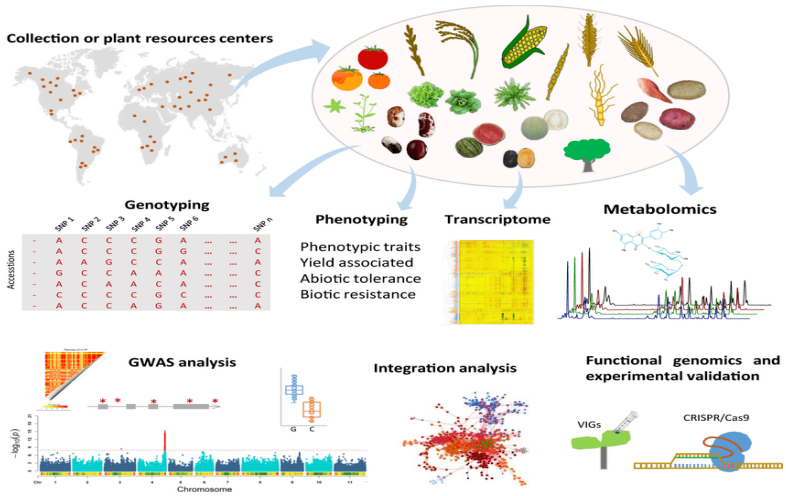

Fig 1: A schematic view of GWAS in plants, Source: Alseekh*et al*, 2021

Advantages of GWAS (Genome-Wide Association Study) for Crop Improvement

1. **High Resolution**: GWAS allows researchers to identify specific genomic regions associated with desirable traits in crops, providing a much higher resolution than traditional breeding methods.
2. **No Prior Knowledge Required**: GWAS does not require prior information about candidate genes or genetic markers, making it a powerful and unbiased approach to discover new genetic associations.
3. **Broad Trait Coverage**: GWAS can simultaneously investigate multiple traits across the entire genome, enabling the identification of genes related to various complex traits, including yield, disease resistance, and quality.
4. **Diversity in Populations**: GWAS can be performed on diverse populations, including natural, synthetic, and germplasm collections, allowing for the exploration of different genetic backgrounds and increasing the chances of finding valuable alleles.
5. **Speed and Cost-Efficiency**: Compared to traditional breeding approaches, GWAS is relatively quicker and more cost-effective. It reduces the need for time-consuming and expensive phenotyping and breeding trials.
6. **Precise Breeding Targets**: By pinpointing specific genomic regions linked to desirable traits, GWAS provides breeders with precise molecular markers to use in marker-assisted selection, leading to more efficient breeding efforts.
7. **Utilization of Untapped Genetic Diversity**: GWAS helps in harnessing untapped genetic diversity present in wild relatives or unexploited germplasm collections, which can be crucial for crop improvement and adaptation to changing environments.
8. **Accelerated Crop Breeding**: GWAS accelerates the crop breeding process by enabling breeders to focus on promising genomic regions, shortening the time to develop improved cultivars.
9. **Continual Improvement**: As genotyping and sequencing technologies advance, GWAS studies can be continuously refined and expanded, leading to a deeper understanding of crop genetics and the identification of even more beneficial traits.

Overall, GWAS has revolutionized crop improvement by providing valuable insights into the genetic basis of complex traits, accelerating breeding efforts, and promoting sustainable agriculture by utilizing the diversity of plant genetic resources.

Conclusion

In recent years, Genome-Wide Association Studies (GWAS) has transformed crop genetics, offering insights into gene-trait interactions. By analyzing diverse crop populations, GWAS identifies key genetic variants linked to agronomic traits such as yield, disease resistance, and nutritional content. Unlike traditional methods, GWAS scans entire genomes, providing a comprehensive understanding of crop genetics. This knowledge enables targeted genetic manipulation, precision breeding, and the development of resilient, productive, and nutritious crop varieties. GWAS's impact extends beyond staple foods to horticultural and bioenergy crops, addressing global challenges like food security and climate change. By leveraging precise data, appropriate analysis methods, and populations with significant genetic linkage disequilibrium, GWAS has become a powerful and unbiased approach for crop improvement. Embracing GWAS promises a sustainable and efficient pathway for advancing agriculture.

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Article Id
AL04240

SEED DORMANCY IN RICE WITH SPECIAL REFERENCE TO COASTAL ECOSYSTEM

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Seed dormancy is defined as the incapability of seeds to germinate in spite of prevalence of favorable conditions for the process of germination such as availability of water and oxgygen. (Finch-Savage and Leubner–Metzger, 2006). Dormancy in paddy seed is mainly imposed by chemical as well as physical factors of the hull and pericarp. It has been stated that the influence of the hull in imposing dormancy was stronger and more prolonged than that of the pericarp. Dormancy is also a genetically controlled trait but upto a certain extent also depends on the environmental factors especially at the time of harvest. The ratio of hormones such as Gibberellic acid (GA) and Abscisic acid (ABA) in the seed antagonistically control the processes of seed germination and seed dormancy (Chen *at al*., 2020).

Rice and Seed Dormancy

Rice (*Oryza sativa* L.) is the major food crop grown globally over a range of different ecosystems. In India, rice cultivation provides livelihood and is a major source of daily caloric intake. Seed dormancy is an important physiological trait for varieties cultivated in the wet season especially in the irrigated coastal ecosystem where monsoons coincide with the harvest time of the crop. In case dormancy doesn't exist, would prone the seed to preharvest sprouting especially when it reaches the maturity stage which is undesirable as it results in reduction in the production and grain quality as well (Marzougui *et al*., 2012). The loss of yield can go upto the extent of 80-85%. Hence, there is a need for seed dormancy. However, prevalence of higher seed dormancy in paddy results in poor seedling germination as well as establishment resulting in non-uniformity. Hence, suitable period of seed dormancy is needed and knowledge on the underlying molecular mechanisms that is required to improve seed quality for further utilization in plant breeding programmes.

In coastal regions, generally during the wet season the chances of coincidence of cyclonic storms at the time of harvest is high. During the dry season there are chances of occurrences of summer showers. Hence, dormancy period of the variety is one of the essential criteria while selecting the variety for cultivation. So, it is advisable to select varieties having minimum of 2-3 weeks of seed dormancy. In case it becomes imperative to use varieties with dormancy period of more than 3 weeks then it is essential to break dormancy before sowing in those varieties to attain good seedling percentage of atleast 80 per cent.

In case the standing crop or harvested seed on threshing floor get wet by rains, the standing crop can be sprayed with 5 percent of salt solution and in case the produce is on the threshing floor, one kg of salt mixed with 20kg bran can be broadcasted for one quintal of seed and should be piled up. By doing this germination can be arrested upto certain extent.

Breaking of Seed Dormancy

Seed dormancy can be broken by subjecting the seeds to a temperature of around 50^{o}C for 3-4 days. But this method is applicable only to laboratory conditions and not so readily available to farmers. In field, where dormancy has to be broken for a large amount of seed, chemical treatment with concentrated nitric acid solution can be adopted. It is recommended that in paddy varieties possessing 2-3 weeks dormancy, 0.63% concentrated nitric acid solution (i.e., 6.3 ml of concentrated acid in 1 liter of water) can be used by soaking the seeds for 24h and then incubated for a day and further use them for nursery. In varieties possessing strong dormancy as in the case of MTU 1001 (Vijetha), where dormancy can last upto 6-7 weeks, 1 percent concentrated nitric acid solution (10 ml of concentric nitric acid per liter of water) can be used. Breaking the dormancy will ensure a good germination percentage of the seed.

Conclusion

Seed dormancy is a vital trait of a variety. In coastal areas, it is advisable to select genotypes having minimum 2-3 weeks dormancy to avoid preharvest germination in case of rains coinciding during the maturity phase. If the gap between the seasons is less to ensure minimum 80 percent seed germination to break the seed dormancy it is advisable to treat the seeds with conc. nitric acid and then use the seed for sowing.

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Article Id
AL04241

NATURE'S NUTRITIONAL GEMS: HARNESSING THE POWER OF INDIGENOUS SEEDS AND THEIR HEALTH-BOOSTING COMPOUNDS

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India is rich in biodiversity and have varied types of flora and fauna. We have rich heritage of Ayurveda. Traditional knowledge of this system of medicine has gained its popularity globally. Today we will be discussing on health benefits of locally and easily available seeds. Seeds can offer various health benefits due to their rich nutritional content and active ingredients. The specific benefits will depend on the type of seed. Here are some common seeds and their potential health benefits:

Chia Seeds:

Active Ingredients: Omega-3 fatty acids, fiber, protein, calcium, magnesium, and antioxidants.

Health Benefits: Improved heart health, reduced inflammation, better digestion, enhanced bone strength, and regulated blood sugar levels.

Flaxseeds:

Active Ingredients: Omega-3 fatty acids, lignans, fiber, and antioxidants.

Health Benefits: Lowered cholesterol levels, improved digestive health, reduced risk of certain cancers, and potential anti-inflammatory effects.

Pumpkin Seeds:

Active Ingredients: Protein, healthy fats, magnesium, zinc, iron, and antioxidants.

Health Benefits: Promoted heart health, improved prostate health, better sleep quality, and potential anti-parasitic properties.

Sunflower Seeds:

Active Ingredients: Vitamin E, magnesium, selenium, copper, and antioxidants.

Health Benefits: Enhanced skin health, improved immune function, reduced risk of chronic diseases, and better thyroid function.

Sesame Seeds:

Active Ingredients: Calcium, magnesium, iron, zinc, fiber, and antioxidants.

Health Benefits: Strengthened bones, improved oral health, potential anti-inflammatory effects, and better blood sugar regulation.

Hemp Seeds:

Active Ingredients: Complete protein, omega-3 and omega-6 fatty acids, fiber, and antioxidants.

Health Benefits: Support for heart health, improved skin conditions, better brain function, and potential anti-inflammatory effects.

Pomegranate Seeds:

Active Ingredients: Vitamin C, antioxidants (especially punicalagins and anthocyanins).

Health Benefits: Boosted immune system, potential anti-cancer properties, improved heart health, and enhanced skin health.

Watermelon Seeds:

Active Ingredients: Protein, healthy fats, magnesium, iron, and antioxidants.

Health Benefits: Improved cardiovascular health, better digestion, potential diuretic properties, and a good source of essential nutrients.

It's important to note that while these seeds can be beneficial, they should be consumed as part of a balanced diet. Additionally, some people may have allergies or sensitivities to certain seeds, so it's always a good idea to consult with a healthcare professional or nutritionist before making significant changes to your diet.

Parts of Seeds to be Consumed

The parts of seeds that are typically consumed vary depending on the type of seed. Here are some common seeds and the parts that are commonly consumed:

Chia Seeds: Whole chia seeds are often consumed. They can be soaked in liquid to create a gel-like texture, which is commonly used in puddings and smoothies.

Flaxseeds: Whole flaxseeds are typically consumed, but they have a hard outer shell that is difficult to digest. To enhance digestibility and nutrient absorption, it's recommended to grind flaxseeds before consumption.

Pumpkin Seeds: Both the hulled inner kernels (pepitas) and the outer shells can be consumed. The outer shells are edible and can be eaten roasted, while the hulled seeds are often used in cooking and as snacks.

Sunflower Seeds: Sunflower seeds can be consumed in their hulled form as a snack, sprinkled on salads, or added to various recipes.

Sesame Seeds: Sesame seeds are usually consumed whole or ground, and they are often sprinkled on top of dishes for added flavor and texture.

Hemp Seeds: Hemp seeds can be consumed shelled or unshelled. The shelled seeds (hemp hearts) are more commonly used in foods like salads, smoothies, and yogurt.

Pomegranate Seeds: The arils (juicy seed sacs) of the pomegranate are the edible part, while the bitter white membrane is typically discarded.

Watermelon Seeds: Watermelon seeds can be roasted and eaten as a snack, similar to pumpkin seeds.

When consuming seeds, it's essential to be mindful of any allergies or sensitivities. Some people may have allergies to specific seeds, so it's a good idea to start with small quantities if you haven't consumed them before. Additionally, some seeds, like flaxseeds, are better digested and nutrient-absorbed when ground, so it's beneficial to consider the best form of consumption for each type of seed.

How to Keep or Store These Seeds for Round-The-Year Consumption?

To keep or store seeds for year-round consumption, it's crucial to protect them from moisture, light, and heat, as these factors can cause the seeds to go rancid or lose their nutritional value. Here are some general guidelines for storing different types of seeds:

Chia Seeds, Flaxseeds, and Hemp Seeds

Store in airtight containers: Place the seeds in sealed, airtight containers to prevent exposure to air and moisture.

Refrigerate or freeze: To extend their shelf life, consider storing them in the refrigerator or freezer. The cold temperatures help prevent oxidation and maintain freshness.

Ground seeds: If you grind flaxseeds, it's best to store them in the refrigerator or freezer to preserve their quality.

Pumpkin Seeds and Sunflower Seeds

Dry and roast: Before storing, make sure the seeds are thoroughly dried and roasted to reduce moisture content and increase shelf life.

Airtight containers: Store in airtight containers in a cool, dry place.

Sesame Seeds:

Dry roast: Dry roast sesame seeds before storing to remove any moisture and enhance their flavor.

Airtight containers: Store in airtight containers in a cool, dry place.

Pomegranate Seeds

Fresh or frozen: Pomegranate seeds can be stored in the refrigerator for a few days if fresh. For longer storage, consider freezing them.

Watermelon Seeds:

Dry and roast: Dry the watermelon seeds thoroughly and roast them before storage to remove moisture.

Airtight containers: Store in airtight containers in a cool, dry place.

Additional tips for Storing Seeds

Label containers: Ensure you label each container with the type of seed and the date of storage. This helps you keep track of their freshness.

Check for rancidity: Periodically check the seeds for signs of rancidity, such as an off smell or taste. If they have gone rancid, discard them.

Keep away from light and heat: Store seeds in a dark, cool place away from direct sunlight and heat sources.

Purchase in small quantities: Consider buying seeds in smaller quantities to ensure you can consume them before they go bad.

By following these storage guidelines, you can enjoy the health benefits of various seeds throughout the year, ensuring they remain fresh and nutritious for extended periods.

From Where We Can Procure These Seeds?

You can procure these seeds from various sources, depending on your location and preferences. Here are some common places where you can find these seeds:

Grocery Stores: Many well-stocked grocery stores and supermarkets carry a variety of seeds, especially popular ones like chia seeds, flaxseeds, pumpkin seeds, sunflower seeds, and sesame seeds. They are often available in the health food section or the bulk food aisle.

Health Food Stores: Specialty health food stores often offer a wider selection of seeds, including organic and bulk options. These stores may also have hemp seeds and other less common seed varieties.

Farmers' Markets: Local farmers' markets are excellent places to find fresh, locally produced seeds, especially watermelon and pomegranate seeds. Some vendors may also sell roasted pumpkin seeds.

Online Retailers: You can find a vast selection of seeds on various online platforms, including major retailers and specialized health food stores. Online shopping allows you to access a wider variety of seeds, and you can often find bulk options for more cost-effective purchasing.

Seed Suppliers or Nurseries: Some seeds, such as pumpkin seeds and watermelon seeds, can be purchased from seed suppliers or nurseries for gardening purposes. If you grow your own fruits or vegetables, you can harvest the seeds from ripe produce and save them for consumption.

Health Food Websites and Co-ops: Websites dedicated to health foods or co-operative buying groups often offer organic and sustainably sourced seeds.

Ethnic Grocery Stores: For less common seeds used in specific cuisines, consider visiting ethnic grocery stores that cater to specific regional foods.

When purchasing seeds, especially if you plan to consume them regularly, it's a good idea to look for reputable sources that offer high-quality and fresh products. If possible, opt for organic seeds to minimize exposure to pesticides and other chemicals. Always check the expiration date and look for signs of freshness, such as intact packaging and a pleasant smell. By being mindful of where you source your seeds, you can ensure you get the best possible products for your year-round consumption. Indigenous seeds, often referred to as traditional or heirloom seeds, are seeds that have been passed down through generations within specific indigenous communities. These seeds are adapted to local environments and have been cultivated and preserved by indigenous peoples for their sustenance and cultural significance. They offer a wide array of nutritional compounds that can be highly beneficial for health.

Here are Some Examples of Indigenous Seeds and Their Powerful Nutritional Compounds

Quinoa (*Chenopodium quinoa*): Quinoa is a seed native to the Andean region of South America and has gained popularity worldwide for its exceptional nutritional profile. It is a complete protein, meaning it contains all nine essential amino acids required by the human body. Quinoa is also rich in dietary fiber, vitamins (such as B-vitamins, vitamin E, and folate), minerals (including magnesium, iron, and phosphorus), and antioxidants like quercetin and kaempferol.

Chia Seeds (*Salvia hispanica*): Chia seeds were widely used by the Aztecs and Mayans in Central America. They are an excellent source of omega-3 fatty acids, particularly alpha-linolenic acid (ALA), which is beneficial for heart health. Chia seeds are also high in fiber, protein, calcium, magnesium, and antioxidants, making them a nutritious addition to the diet.

Amaranth (*Amaranthus* spp.): Amaranth is a grain-like seed that has been cultivated in various regions across the world for thousands of years. It is rich in protein, containing a higher amount compared to most other grains. Amaranth also provides essential minerals such as iron, magnesium, phosphorus, and potassium, as well as vitamins like B-vitamins and vitamin C.

Teff (*Eragrostis tef*): Teff is an ancient grain indigenous to Ethiopia and Eritrea. It is a good source of complex carbohydrates, dietary fiber, and protein. Teff is also rich in iron, calcium, and B-vitamins, particularly thiamin (vitamin B1).

Black Cumin (*Nigella sativa*): Also known as "Nigella" or "Kalonji," black cumin seeds have been used in traditional medicine systems in the Middle East and South Asia for centuries. These seeds contain thymoquinone, a potent antioxidant compound with potential anti-inflammatory and immune-enhancing properties.

Pumpkin Seeds (*Cucurbita pepo*): Pumpkin seeds have a long history of consumption in indigenous cultures, and they are a valuable source of various nutrients. They are rich in healthy fats, protein, dietary fiber, magnesium, zinc, iron, and antioxidants like vitamin E and carotenoids.

Sunflower Seeds (*Helianthus annuus*): Sunflower seeds were cultivated and consumed by Native American tribes long before European settlement. They are an excellent source of vitamin E, a powerful antioxidant, as well as protein, healthy fats, and minerals like magnesium and selenium.

Conclusion

It's important to note that the nutritional value of indigenous seeds can vary based on growing conditions, processing methods, and storage. Including a diverse range of foods, including these indigenous seeds, in one's diet can contribute to overall health and well-being. However, if you have any specific health concerns or dietary requirements, it's always a good idea to consult with a healthcare professional or a registered dietitian.

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Article Id
AL04242

ROLE OF NANO FERTILIZERS IN AGRONOMIC BIOFORTIFICATION: REVOLUTIONIZING CROP NUTRITION

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Malnutrition and vitamin shortages have caused serious problems for the global population in recent years. Traditional fertilizers have played a significant role in increasing crop yields, but they frequently fall short of improving the nutritional value of the harvested produce. The development of nano fertilizers, which present a novel method for agronomic biofortification, offers a viable alternative. These cutting-edge fertilizers have the potential to change crop nutrition through the use of nanotechnology, effectively addressing nutrient deficiencies and supporting the global effort to eradicate malnutrition.

Understanding Agronomic Biofortification

The practice of strengthening crops' nutritional value by increasing their nutrient content through targeted fertilizer application is known as agronomic biofortification. The concept of agronomic biofortification recognizes the role of agriculture in addressing malnutrition and nutrient deficiencies. By using biofortification techniques, crops can be enriched with key micronutrients during their growth stages, making them more nutritious when consumed by humans. (White and Broadley, 2009)

Introducing Nano Fertilizers

On the other side, nano fertilizers represent a paradigm leap in crop nutrition. These fertilizers use nanotechnology to develop effective, focused, and environmentally friendly nutrient delivery systems. The fertilizers can increase nutrient uptake, decrease nutrient losses, and increase the bioavailability of micronutrients to plants by encapsulating vital nutrients within nano-sized particles. (Khot *et al*., 2012)

Advantages of Nano Fertilizers in Agronomic Biofortification

1. **Enhanced Nutrient Uptake:** Nano fertilizers help plants absorb nutrients more effectively. Due to the nanoparticles' small size and large surface area, roots can penetrate them more easily and nutrients are more readily available for absorption. As a result, crop output is increased as is the efficiency of fertilizer use. (Hussain *et al*., 2016)
2. **Controlled Release Mechanisms:** Nano fertilizers may be designed with controlled release mechanisms to provide the plants with nutrients gradually and continuously. Through the use of this controlled release function, nutrient leaching is avoided and a consistent supply of vital micronutrients is provided to plants at all stages of their growth cycle.
3. **Increased Bioavailability:** The solubility and bioavailability of vital micronutrients can be increased by using nano-sized particles, which can overcome the drawbacks of conventional fertilizers. Thus, crops cultivated with nanoparticle fertilizers have greater nutrient contents, making them more wholesome for human consumption.
4. **Environmental Sustainability:** Nano fertilizers are environmentally sustainable substitutes for traditional fertilizers. Their exact targeting lessens the requirement for heavy fertilizer application, reducing the chance of nutrient runoff and water body pollution. This lowers production costs for farmers while simultaneously preserving the environment. (Kah and Hofmann, 2014)

Challenges and Future Directions

Although the potential of nano fertilizers in agronomic biofortification is intriguing, there are still a number of issues that need to be resolved. These include worries about the cost-effectiveness, toxicity, and mass production of nanoparticles. In-depth research and development efforts are being made to tackle these issues and guarantee the secure and long-lasting use of nanoparticle fertilizers in agriculture. Availability of micro-nutrient based nano-fertilizers in market is also a major problem.

Conclusion

Global malnutrition and nutrient inadequacies can be addressed through agronomic biofortification employing nano fertilizers. These fertilizers provide tailored nutrient delivery, higher bioavailability, and increased crop yields by utilizing the power of nanotechnology.

Nano fertilizers have the potential to change agriculture with additional research and development, resulting in a healthier and more secure global food supply.

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Article Id
AL04243

MARKET-LED EXTENSION- AN OVERVIEW

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Globalization and WTO regime have made the extension functionaries to play a major role in getting better price to farmers farm produce. Hence extension should extend focus from production to market led extension. Farmers must change their roles from domestic producer-sellers to producer-cum-sellers in a broader market sense in order to realise a return on their investment in light of market globalisation.

Farmer should sensitize on the production aspects like:

i. What to produce
ii. When to produce
iii. How much to produce
iv. When and where to sell
v. At what price and to whom to sell his produce.
vi. Various aspects of quality
vii. Consumer preference
viii. Market intelligence
ix. Value addition etc

Why

- Even after independence the quality, timely and cost-effective delivery of adequate inputs remains a dream.
- Farmers cannot profitably sell their excess product.
- Plenty of distress sales among farmers.

Concept

A market-led extension is a tool for effectively delivering sufficient and high-quality information to farmers so they can make decisions about production and marketing that will maximise their return on investment without endangering the needs of future generations. Farmers must change from being merely producers-sellers in the domestic market to producers cum sellers in a wider market sense in order to best realise the returns on their investments, risks, and efforts considering the market's globalisation. Along with production

technologies, extension workers now need to equip themselves with market knowledge, which necessitates teaching them new training techniques. This necessitates the adoption of fresh extension strategies that focus on productivity to profitability, subsistence to commercial agriculture, commodity-oriented to farming systems-oriented, local market to export markets, mono-cropping to crop diversity, and other issues. The extension functionaries' attention needs to go beyond production. The importance of quality, consumer preferences, market intelligence, processing, value addition, and other marketing information should be made clear to farmers.

- Market: - A market is a place for buyers and sellers where they can exchange goods and services.
- Market led: - Identification of customer needs and wants before giving a service.
- Extension: - Transfer of technology.
- Market led extension as a market ward orientation of agriculture through extension includes agriculture and economics and is the perfect blend for reaching at the door steps of farming community with the help of appropriate technology (Khaleel *et al.*, 2007).

Basics of Market Led Extension

- ❖ Market oriented production
- ❖ Updated knowledge of market
- ❖ Market intelligence
- ❖ Use of technology
- ❖ Appropriate extension approaches

History

- Before MLE there is mainly focus on production i.e., PLE.
- First it was started in Kerala in 1993.
- Experiment was conducted with the help of SHGs and Market oriented production.
- MANAGE started working on the concept of MLE and beginning was made through a three-day national workshop on MLE at MANAGE during 118th – 20th December 2001.

Advantages of MLE

i. Future marketing will diminish the role of middle men in the marketing system.
ii. MLE helps in reducing the scarcity of a product.

iii. It gives more income and guides them to decide regarding selection of crops as per farming situation.
iv. It helps to link farmers more closely to consumers.
v. It can regulate production based on consumer preferences for quantity, quality, variety and food safety.

Principle of MLE

i. If there is not a market, farmer should not be encouraged to produce a specific crop or product. The first task that must be done is to evaluate the prospective markets for various high-value crops or goods that may be effectively produced in various blocks around the district.
ii. If farmers cannot easily transport the products to market search for more promising products that can be easily marketed.
iii. If the crop or product cannot be successful grown or produced within the district due to unfavourable Agro-ecological conditions, then look for more promising crops or products crops or products that are well suited to the districts.
iv. Diversified into a range of high-value items and commodities that are ideal for the district's various farmers' or women's interest groups (FIGs). By preventing the market from becoming oversaturated with just one or two items, this strategy will reduce risk without lowering pricing. (Singh *et al.*, 2006)

Need

i. Conversion of P-L-E into M-L-E.
ii. Orientation of extension system with knowledge and skills related to the market.
iii. Minimization of production cost.
iv. Introduction of export-oriented product.
v. Modernization of wholesale markets or new markets with new Agricultural policy.

Objectives of MLE

i. To determine potential regions for extension or involvement in agricultural marketing.
ii. To build up and use effective extension methodologies for providing need-based support to farming community in marketing of their produce.
iii. The present linkage among Research-Extension-Farmers is extended by market linkage.

iv. To identify and communicate innovation for value addition practices and post-harvest technologies.

v. To develop network and action plans for extension to support marketing of the product at different level.

vi. Conversion of agricultural sector into profit-oriented business.

vii. Strengthening R-E-F linkages – between various department at various levels.

Types of information required in MLE

- Demand of Agro based products or crops under the present agricultural scenario.
- Technical options available in respect of crop or commodities.
- Requirement and availability of inputs.
- Credit facilities availability.
- Quality dimension of the product to ensure consumers acceptance.
- Availability of a network of warehouse and storage facilities.
- Transport facilities.
- Market structure in the neighbourhood and pricing variations amongst markets.
- Regular updating of market intelligence.
- Post-harvest management

Fig 1: Dimensions of MLE

Prospects of MLE

Market-led extension has a huge potential to pave the way for optimal production on a sustainable basis, especially considering the present worldwide trend of problems in the food production process. Over the years, "lab to land" had received a lot of attention in our nation; now, the emphasis should be on “farm to fork”. Countries that have a competitive advantage are eager to export their production to any country in the world. Future success for Indian Agricultural Development, however, can be ensured thanks to the new functionary role of extension staff under Market Driven Extension. Below are a few of the expected functional responsibilities of extension employees. Some of the expected functional roles for extension employees include the ones listed below. This includes SWOT analysis of the market, organizing commodity-based farmers’ interest groups and farm management capacity building, Backward and forward linkage, Farmers exposure to market intelligence and guidance for quality decision about market. Therefore, key answer to the above questions will empower farmers in both production market-oriented knowledge which is the sole responsibility of Extension functionaries through Market Led Extension

Challenges in MLE

- Rapid changes in the information tech and need for collection of relevant information.
- Market intelligence data generation through the integration of the line departments of agriculture and marketing.
- Reorganization of extension system.
- Strong communication skills with credibility

Challenges Ahead Related With Market Led Extension

- ❖ Training programme for extension worker
- ❖ Introduce market-oriented approach into extension.
- ❖ Development of local market and promoting local consumption.
- ❖ Entrepreneurial training to farmers.
- ❖ Linking farmers to markets.
- ❖ Market reforms- It includes partnership with KVK & ATMA for effective technological reach.
- ❖ Formation of Market-Led Extension policies and its implementation.

Constrains in MLE

1. **Production related**

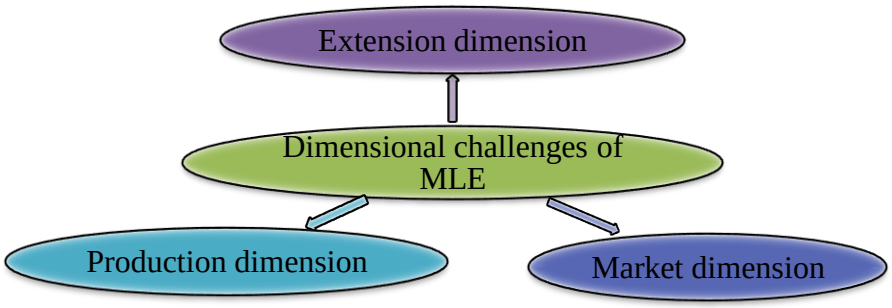
   a) Seasonality of production
   b) Perishability of the produce
   c) Bulkiness of the production

2. **Market related**

   a) Non availability of the market intelligence, which is one of the important issues.
   b) Existence of many middlemen is one of important problem.
   c) The inferior quality of produce is another issue in the market

3. **Extension related**

   a) Lack of communication skills of the farmers, who are the primary producers.
   b) Lack of credibility of the farmer.
   c) Insufficient information related to the market



Role / Strategies of Agricultural Extension in MLE

i. Identify the market demands in terms of produce for the present and the future.
ii. Creation of a strategy plan for market-led extension at the district, block, and village levels.
iii. SWOT analysis of the market
iv. Organization of Farmers' Interest Groups (FIGs) on commodity basis and building their capabilities regarding management of their farm enterprise.
v. Enhancing the interactive and communication skills of the farmers to exchange their views with customers and other market forces (middlemen) for getting feedback and

gain the bargaining during direct marketing ex. Rythu Bazars, Agri-mandi and Uzhavar Sandies etc.

vi. Supporting and enhancing the capacities of locally established groups under various schemes /programmers like watershed committees, users' groups, SHGs, water users' associations, thrift and credit groups.

Government initiatives- Steps taken by Government

- Central warehousing Corporation-1965
- MSP by CACP
- Food Corporation of India, NDDB, APEDA etc.
- Collaboration with KVK & ATMA to expand technology effectively (R-E-F-M)
- Networking with Banks
- MANAGE- One year diploma in Agricultural Extension Services for Input Dealers.

Marketing Extension Techniques

- Market Oriented Production
- Crop Budgets
- Input Supply
- Finance & Credit
- Investment Advice
- Harvesting
- Grading, Packing & Storage
- Transportation and Distribution
- Improved communication in the marketing chain
- Establishing collection centres, village and assembling markets
- Working with Farmers Groups or Associations
- Working with Agribusiness
- Using market information

Conclusion

Market Led Extension is perfect blend and synergy between Extension Education, Agricultural Economics, and Agricultural Marketing. Extension functionaries need to work more in the area of marketing using extension strategies in order to disseminate not only production but essentially marketing related information for holistic sustainable agricultural development. The focus of the extension functionaries needs to be extended beyond production. Farmers should be sensitized on various aspects of quality, consumer's preferences, market intelligence, processing and value addition and other marketing information. To provide farmers with information on production and markets, it is necessary to fully utilise the possibilities of electronic, print, and information communication technologies. This will help the farming community realize high returns for the produce, minimize the production costs, and improve the product value and marketability. Now it should focus on the market needs, the farmer's needs and with an objective of enhancing the income levels of the farmers, which is the focus of the established governments also.

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AGRIALLIS
Science for Agriculture and Allied Sector: A Monthly Magazine
Volume 5, Issue 8
www.agriallis.com

Article Id
AL04244

AGRITECH IN INDIA: AN OVERVIEW

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Agriculture is the primary source of income for almost 58% of India's population. Due to its enormous potential for value addition, particularly within the food processing industry, the Indian food industry is poised for huge expansion, increasing its contribution to the global food trade every year. One of the largest sectors in India, food processing contributes 32% of the nation's total food market and is rated fifth in terms of production, consumption, export, and expected growth. The Government of India is launching a new AGRI-UDAAN initiative to mentor start-ups and help them connect with potential investors in order to foster innovation and entrepreneurship in farming.

Due to its enormous range of agro-ecological diversity, India is considered to as a worldwide agricultural powerhouse. India's agriculture sector, which contributes approximately 16% of GDP and employs 44% of the labour force there, makes a considerable economic contribution to the nation. India is one of the top 15 exporters of agricultural goods worldwide. According to an Ernst & Young Survey, India's agri-tech startups represent a USD 24 billion opportunity, yet the market is still mostly untapped (with 1.5% penetration). The Agri-tech sector has been given priority by the Indian government, which has been working towards a comprehensive approach to sustainable development. Around 86.2% of all farmers in India are small or marginal farmers who continue to use outdated, unscientific farming practises. The agritech players in this region not only established new financial channels but also enhanced yields through data, real-time crop monitoring, analytics, digitisation, crop and soil health, and weather forecasts for better strategies, ultimately leading to more profitability and less waste.

The increasing demand for agri-tech products in India and the rest of the world makes it one of the most important pillars for creating a sustainable future. According to the Economic Report of India 2022–23, the country's agricultural industry has increased by 4.6% during the previous six years, and more than 1000 agri-tech start–ups have entered the market. Building a strong agri-tech sector depends in large part on the development of infrastructure. There are already more than 1,300 start-ups addressing the untapped potential of the agri-tech area as a result of the growth of transformative technological solutions in the agriculture industry. India will get the third-highest number of agri-tech investments globally until 2021, totalling over USD 1.6 billion. Neglecting technology in the agriculture sector is not a prudent move in the current technological era. The importance and difficulties of agri-tech in India must therefore be re - evaluated quickly.

Technology Play in Agricultural Changes

- **Drones:** Unmanned aerial vehicles (UAVs), commonly referred to as drones, have the potential to drastically change agriculture and bring about a number of changes. Aerial sowing, pesticide treatment, and remote data collection for study are just a few uses for drones.
- **Biotechnology:** Crops with higher yields, resistance to pests and diseases, and drought have all been developed using biotechnology. As a result, there has been a rise in productivity, a decline in crop loss, and an improvement in crop quality.
- **Food processing and preservation:** Due to technology, food processing and preservation methods have been developed that make food safe and have a longer shelf life. As a result, there is less food waste and crops may be transported and stored more effectively.
- **Market Access:** Due to technology, farmers now have improved access to both domestic and foreign markets. Farmers can now interact with customers and sell their goods directly, eliminating intermediaries and increasing earnings through the use of technology and e-commerce.
- **Agri-start-ups:** By integrating cutting-edge technology and modern farming methods, agri tech start-ups can significantly contribute to agricultural reforms. Agri tech start-ups can aid in agricultural transformations by enhancing farming methods, increasing productivity, increasing access to capital, etc.

- **Precision agriculture:** Crops, soil, and weather conditions are monitored using technology such as GPS, drones, and sensors. As a result, farmers can make data-driven decisions and manage resources like water and fertilizers more effectively.
- **Farm machinery:** Mechanization has been important in increasing the agricultural sector's productivity. Tractors, harvesters, and seed drills are just a few examples of the cutting-edge agricultural equipment that has helped farmers become more productive and spend less on labour.

Why are Agritech Startups Needed in India?

Farmers today encounter several difficulties in trying to make a living from farming. Indian farmers are growing increasingly concerned about fraud in the unorganised agricultural marketplaces and the lack of regulated marketing mechanisms for produce. They also have to face with inadequate storage and transportation options, among other issues. Because they have limited access to cutting-edge technologies, they are vulnerable and on their own without timely information and agricultural solutions.

Startups in the agritech sector have the ability to address these issues right away and consequently transform Indian agriculture. They are the shining knights of Indian agriculture.

Initiatives by Indian Government for Agritech

The Indian government has introduced Digital India to address these problems. In short, Digital India is a platform for offering the Indian people a various services via digitally enabled devices. It includes offering services over the internet via computers, phones, etc. The goal of digital India in the farming sector is to offer farmers in rural and urban areas digital access to government services. The benefits of digital India for Indian agriculture have been both predicted and demonstrated.

- **National Agriculture Market (e-NAM):** It offers a national e-marketing platform and supports the development of infrastructure to enable e-marketing. The improved price discovery provided by this cutting-edge market technique is transforming the agriculture markets. As we move towards a "One Nation One Market," it encourages competition and transparency to help farmers receive better compensation for their produce. The fact that farmers, merchants, and commission agents all face related problems makes it difficult for e-nam to expand nationally.

- **National Mission for Sustainable Agriculture (NMSA):** With the goal of increasing agricultural production through the adoption of sustainable technologies.
- **Community Radio (CR):** Using radio station facilities, Community Radio meets the information needs of farmers.
- **National e-Governance Plan in Agriculture (NeGPA):** For supporting cutting-edge technologies like blockchain, drones, and ML.
- **Digital Green:** It is another fantastic programme that uses films to disseminate agricultural information.
- **e-sagu:** One of the most recent digital initiatives offers advice from experts to farmers. Farmers are routinely advised about the many methods to boost agriculture productivity using the internet and audio-visual communication facilities.

Other programmes implemented as part of the Digital India initiative provide farmers with information on funding sources, the availability of warehouses, government subsidies, soil testing and irrigation facilities, preventive measures for droughts and floods, complaint redressal facilities, and many other similar services. The Digital India program's various initiatives have all assisted Indian farmers in raising their productivity levels and profit margins. The Indian government has also launched a lot of other programmes to assist the farmers.

Business Models in India's Agritech Sector

The following categories can be used to categorize business models in the agritech sector:

1. **Margin-based business model:** This model is used to operate segments such market linkage - farm inputs, supply chain technology, and output market linkage. The agritech player makes a profit by establishing market connections at the input or output side of the marketplace and by delivering the promised services.
2. **Subscription-based business model:** Agritech players in industries like precision agriculture, farm management, quality management, and traceability provide a mix of hardware, software, and services-based solutions all year long and charge their clients on a monthly or annual subscription basis.
3. **Transaction-based business model:** Based on the volume of loans or insurance policies provided, this model is used by agritech businesses operating in the financial services sector.

The agricultural sector is actually very promising for the digital India project. Farmers who lack access to such services should receive digital agricultural infrastructure and literacy from the Indian government. Farmers should provide feedback on a regular basis to determine whether the project is beneficial to them. To improve the facilities, farmers should be encouraged to offer ideas and proposals. The government is making a lot of efforts to ensure that all farmers can use the services provided by digital India. And very soon, the Agriculture sector will see the huge success of the digital India project!

How Agritech Boosts Agricultural Efficiency and Productivity in India

Agritech is generally used to describe an ecosystem of firms and startup ventures that are leveraging technological improvements to offer goods or services for boosting production, efficiency - both in terms of time and cost, and profitability for farmers across the agriculture value chain. The several agritech industry segments that support the full value chain include:

- Farming as a service: Agricultural machinery for rent on a pay-per-use basis.
- Farm inputs are linked to the market through physical infrastructure and a digital marketplace.
- Using geospatial or weather data, IOT, sensors, robotics, etc. to increase production; farm management solutions for resource and field management, etc. are examples of precision agriculture and farm management.
- Agricultural automation that uses machines, tools, and robots for planting, handling raw materials, harvesting, etc.
- Financial services: Loan facilities for input purchase, equipment, etc. as well as insurance or reinsurance of crop.
- Farm infrastructure includes farming techniques including drip irrigation, indoor-outdoor farming, greenhouse systems, and environmental controls like heating and ventilation.
- Produce monitoring, quality control and analysis, and traceability during storage and transit are all part of quality management.
- Linking the market for farm product and the supply chain requires a physical infrastructure and digital platform to manage the post-harvest supply chain.

Some Examples of How This Can Be Achieved Are

- The yield can be increased by up to 30% using precision agriculture.
- Adding quality control and traceability will enable farmers to produce higher-quality product and will encourage them to keep using current techniques.
- By removing inefficiencies, such as excessive farm produce wastage, from the post-harvest supply chain, it will be easier to connect output markets, which will benefit both farmers and consumers.
- The current problems associated with input price volatility and inadequate input selection can be resolved by enabling input market linkages supported by a strong physical infrastructure network.
- Farm management can increase operational efficiencies and reduce expenses by digitalizing documents.

Challenges with Agritech in India

- **High initial costs:** Many agri-tech solutions demand significant initial cost, which can be a main barrier for small-scale farmers who may not have the finances to invest.
- **Poorly formulated government policies:** The success of the government's agri-tech promotion policies and programmes is frequently hampered by their inadequacy, consistency, or poor implementation.
- **Absence of cooperation:** Lack of cooperation among stakeholders, such as farmers, businesses, and the government, may hinder the creation and implementation of efficient agritech solutions.
- **Confined market access:** Farmers may encounter difficulties accessing markets to sell their produce even if they use agri-tech solutions because of a lack of market connections and insufficient market expertise.
- **Unconsolidated land holdings:** Due to their small and distributed land holdings, the majority of Indian farmers find it challenging to use more affordable large-scale mechanized techniques.
- **Problem with drone regulation:** Since aerial vehicles are outfitted with advanced sensors and cameras, privacy is a big issue that hangs over the future of this sector.
- **Lack of infrastructure:** The adoption and efficacy of agri-tech solutions may be hampered by the lack of essential infrastructure, such as electricity and network connectivity.

- **Lack of digital literacy:** Despite India's advancements in digitalization, many farmers there lack access to technology and digital literacy, making it difficult for them to implement agri-tech solutions.

What Should Be

- **Encourage training and education:** Farmers, researchers, and other stakeholders should have access to agricultural education and training. In addition to facilitating the transfer of knowledge, this can assist in promoting the adoption of new technologies and practises.
- **Drone regulation reform:** To protect people's privacy and safety, drone regulation is a critical problem that needs to be carefully considered. A clear and uniform set of regulations, the implementation of privacy laws, and other measures are some ways to enhance regulation.
- **Increase technological access:** In India, small farmers sometimes lack access to cutting-edge equipment for crop management, automation, and irrigation. Research organisations should be focused on developing technologies that are accessible and affordable that can increase agricultural productivity.
- **Promote the use of modern technology:** The government should promote the use of modern technology in agriculture. This can be accomplished by offering financial aid and subsidies to encourage the purchase and use of latest devices and techniques.
- **Encourage farmer-centric research:** Research in agriculture should emphasis on the requirements and concerns of farmers. To create technologies and procedures that are appropriate for local conditions, scientists and farmers should collaborate closely.

Role of Technologies in Agritech

By minimising production waste, decreasing carbon footprint, and increasing agricultural productivity, technologies like artificial intelligence, machine learning, and blockchain are helping to improve agricultural and food production and improve sustainable development. According to a MarketsAndMarkets tech forecast survey, the AI in agriculture market is expected to reach $4 Bn by 2026.

1. Artificial Intelligence

Recently, artificial intelligence has shown that it can replicate human intelligence and increase agricultural productivity by streamlining tasks that are more important to stakeholder

interests than others, such as monitoring soil quality, managing pests and diseases in crops, standardising food quality, offering crucial procurement insights, and minimising labour. Farmers and businesses are using artificial intelligence to relieve the strain of discovering faults and redirect their efforts to other parts of agricultural and procurement operations.

AI is revolutionising the agritech industry in several ways:

- **Quality control:** To help reduce waste and enhance, monitor, and manage the quality of food from farm to fork, AI-powered cameras and sensors are automating crop inspection, real-time quality monitoring, and data traceability.
- **Supply chain management:** AI has the potential to increase supply chain efficiency through trustworthy transactions, improve data transparency, lower the risk of product spoiling, and optimise logistics and transportation.
- **Automation:** Automating labor-intensive activities like harvesting and cutting with AI-powered robots and drones can increase efficiency and lower expenses.
- **Predictive Maintenance:** Applications of AI have been useful in anticipating the repair of post-harvest machinery, minimising downtime, and extending its shelf life.
- **Predictive modelling:** AI can help farmers optimise their operations and enhance harvests by forecasting crop yields, detecting disease outbreaks, and determining the ideal time to harvest.

2. Regenerative Agriculture

Regenerative agriculture is an all-encompassing approach to farming that puts soil health first by restocking and strengthening resources rather than depleting them. Intercropping, providing various soil nutrients, crop rotation, cover crops, and reducing the use of synthetic fertilisers are some techniques that can help with this.

Regenerative agriculture will revolutionise the agritech business in various ways by 2023, because of increasing farmer interest:

- **Soil Health:** Regenerative agriculture focuses on enhancing the health of the soil and its capacity to absorb nutrients and water, which can result in higher crop yields and increased resistance to environmental stressors like drought.
- **Reduced use of synthetic chemicals:** By encouraging the use of natural inputs like compost, mulch, and cover crops while using fewer synthetic chemicals, this type of

modern farming helps to improve the overall health of the soil, lessen its negative effects on the environment, and enhance the quality and safety of the harvested goods.

3. Internet of Things

The use of Internet of Things (IoT) devices in agriculture is focused on the effective measurement and monitoring of data, such as soil health, food's chemical and physical composition, equipment efficiency, supplier analytics, and meteorological conditions.

Precision agriculture is one of the most significant applications of the IoT, which is revolutionising agritech. Data on variables like soil moisture, temperature, and nutrient levels, as well as crop growth and health, can be recorded using IoT-enabled devices like sensors, drones, and cameras

4. Blockchain Technology

With the increasing demand for traceability, data management, food safety, and supply chain transparency in the global food ecosystem, blockchain, a revolutionary technology that has recently upended global food chains, will continue to strengthen the dynamics of agro commerce.

Blockchain has the potential to revolutionise Agri trade while maintaining food safety and quality norms, from securing the validity of data to confirming the origins of produce and tracking transactions. According to MarketWatch's estimate for 2023, the technology is expected to expand at a significant rate as a result of a number of industry leaders implementing smart agriculture tactics.

Conclusion

The country currently needs agritech startups. More and more entrepreneurs are starting organisations in this area, recognizing the chance to revolutionize the market. These firms are receiving support from government programmes as well, making it easier for them to attract investors. Farmers may now embrace this new approach and look forward to higher price realisation at last. Due to the adoption of advanced technology and a supportive regulatory environment, the number of agritech firms emerging in India is rapidly increasing. This can only be viewed as the beginning of the infiltration of cutting-edge technologies like blockchain, IoT, AI, and machine learning in the Indian agricultural sector. The agriculture

industry, which is largely dependent on erratic meteorological circumstances, is greatly aided by this collaborative technology.

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Article Id
AL04245

CAN ANIMAL CLONING TECHNOLOGY BE BENEFICIAL TO INDIAN FARMERS

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Cloning can be defined as a number of different processes used to produce genetically similar copies of a biological entity, which are termed as clones. Since February 1997, when scientists in Scotland successfully cloned a sheep they named Dolly by using DNA from an adult ewe's mammary cell, cloning earned name and fame globally. There are two types of animal cloning i.e. reproductive cloning and, therapeutic cloning. Reproductive cloning can be performed further by two methods; (i) Somatic cell nuclear transfer which is a technique in which the nucleus (DNA) of a somatic cell is transferred into an enucleated metaphase-II oocyte for the generation of a new individual, genetically identical to the somatic cell donor (Tian *et al*., 2003). The Dolly was created by using reproductive cloning. (ii) Embryo splitting involves the fusion of male and female gamete(oocyte and spermatozoa) through in-vitro fertilization (IVF) to form a zygote. After the successful fusion of both the gametes the cell division follows which is termed as cleavage, in order to develop the zygote into an embryo. This zygote divides into two and further four genetically identical cells which can further be split into separate cell to develop individual blastocyst from each split cell from the same embryo. These fully developed blastocysts can be implanted into the uterus of mature females. Therapeutic cloning on the other hand is an another form of SCNT involving the transfer of nuclear material isolated from a somatic cell into an enucleated oocyte in the goal of deriving embryonic cell lines with the same genome as the nuclear donor (Kfoury *et al*., 2007). These cells can be cultured for in an indefinite period of time for further production of organs as well as the tissues that are accepted by the immune system of the patients**.**

Benefits of Animal Cloning Technology

Some of the advantages of Animal cloning technology are discussed below**:**

(i) It helps in multiplication of elite animals by producing their genetically identical copies. These elite animals can be the high milk yielder female or high fertility potential bulls with best semen quality parameters (Smith *et al*., 2000).

(ii) Animal cloning has a vast application in preserving the endangered species all over the globe. Some of the examples includes; successful preservation of Enderby Island cattle breedof New Zealand using the method of adult somatic cell nuclear transfer (SCNT) (Smith*et al*., 2000). Another example includes production of a clone of the only wild-buffalo in Chhattisgarh, India, through the 'Hand-guided Cloning Technique' at ICAR-National Dairy Research Institute, Karnal. The female calf named **'Deepasha'** was born on December, 12, 2014 (NDRI, Karnal, icar.org.in).

(iii) This technology along-with the Transgenesis, has helped in transgenic animal production which is a process of incorporation of foreign DNA into cellular genome. The first transgenic mammals were created by microinjecting gene constructs into the zygotes of fertilized mice (Brinster *et al*., 1985). A number of animals like Sheep and Cattle have been produced by using transfected cells and nuclear transfer technology (Cibelli *et al*., 1998).

(iv)Production of transgenic animals for the purpose of xeno-transplantation through nuclear transfer cloning is another great milestone led by animal cloning technology. Pigs have been chosen as study animals for xeno-transplantation research because of their physiological similarities to humans and lesser cost when compared to other primates (Piederahita*et al*., 2004). Production of Xeno-transplants by using cloning technology will help production of organs from immunogen triggering protein gene knockout pigs leading to reduced hyper-immune response in the recipient humans.

Shortcomings of Animal Cloning Technology

(i) Although the nuclear transfer method is more effective at producing transgenic domestic animals, the cloning method does not address the issue of random insertion and its related positional effect (Piederahita *et al*., 2004).

(ii)The percentage of early abortions is very high in case on cloned embryos.

(iii)Cloned animals shows a prevalence of respiratory distress syndromes which may be a sign of inadequate adrenal gland growth and function, low foetal cortisol levels, and consequently, insufficient lung surfactant (Hill *et al*., 1999).

(iv)The ratio of surviving offspring to transplanted embryos in cattle and pigs is very low i.e. about 6-15% and 6%, respectively (European Food Safety Authority. (2012) which is still more or less same.

(v) The chances of early as well as late pregnancy losses are more in cloned embryos transfer. In case of cattle, the early loss is found to be due to unsuccessful placenta formation and the late ones are because of reduction in placentome with an increase in placentome weight (Hill *et al*., 2000; Heyman *et al*., 2002; Hoffert *et al*., 2005; Kohan-Ghadr *et al*., 2008).

(vi) The animals with cloned embryo transfer face the problem of hydroallantois during the pregnancy period which further might induce perinatal mortality. (Heyman *et al*., 2002; Schmidt, 2007; Schmidt *et al*., 2010; Schmidt *et al*., 2011; Chavatte-Palmer *et al*., 2012).

(vii) The offspring born through the cloning technology are mostly bigger in size as compared to naturally conceived ones which increases the occurance of Dystocia, defined as a difficult calving due to prolonged parturition or severe assisted parturition

(viii) Because the cells have a very limited capacity for development so the animal cloning by embryo splitting method makes the process non-repeatable leading to production of only two identical mice/animals at a time.

Conclusions

Animal cloning has immense economic and societal potential, however, before this technology is widely used, several issues related to the generation of cloned animals must be properly examined through appropriate research. To increase this genetic diversity, it can recreate reproductively competent copies of animals that had perhaps been incompetent or made incompetent early in life. The genetic diversity in one way can be increased by cloning the rare, endangered breeds or species of animals, but the expanses of animal cloning are so high that it can be restricted only to the high yielders or elite animals which in turn will decrease the genetic diversity or genetic variation.

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AGRIALLIS
Science for Agriculture and Allied Sector: A Monthly Magazine
Volume 5, Issue 8
www.agriallis.com

Article Id
AL04246

AZOLLA AND ANABAENA: THE BENEFICIAL SOULMATES

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Azolla leaves harbour, an enclosed environment for anabaena. In return, anabaena sequesters nitrogen directly from the atmosphere making it available to Azolla. Thus, making Azolla survive in a soil less environment. This unique relationship between the floating fern and the diazotrophic cyanobiont together leads to an immense and efficient nitrogen factory. While azolla production has the potential to offer several socio-environmental benefits, there are also concerns and potential negative impacts that need to be considered.

Azolla (*Azolla pinnata*) is a nature's gift which has tremendous benefits. It is a free-floating and rapidly growing aquatic fern. It floats like a small, flat, compact green mass and appears as a velvety green mat over water surface. A thick mat of Azolla supplies 30-40kg N/ha. This is a fern with a triangular stem coated in tiny hairs which gives them a hairy velvety appearance and bear roots which hang down in the water. It thrives well at low temperatures. Under ideal conditions, it grows exponentially. The lobes of azolla leaves contain cyanobacterium *Anabaena azollae*, which helps to fix nitrogen from the atmosphere. It multiplies vegetatively and is applied to the main field as a green manure crop and as a dual crop. In rice, nitrogen is the limiting factor due to which the yield gets affected. Azolla is incorporated in the rice field for better yield and for its nitrogen fixing properties.

Mechanism

Each leaf of azolla is divided into dorsal and ventral lobe. In the dorsal leaf lobe, there is an ellipsoidal cavity. The cavity largely filled with gases is lined with mucilage which contains the *Anabaena azollae*. *Azolla* provides an enclosed environment for *Anabaena* within its leaves. In return, *Anabaena* sequesters nitrogen directly from the atmosphere which then becomes available for *Azolla's* growth and after incorporation these N will enrich the soil.

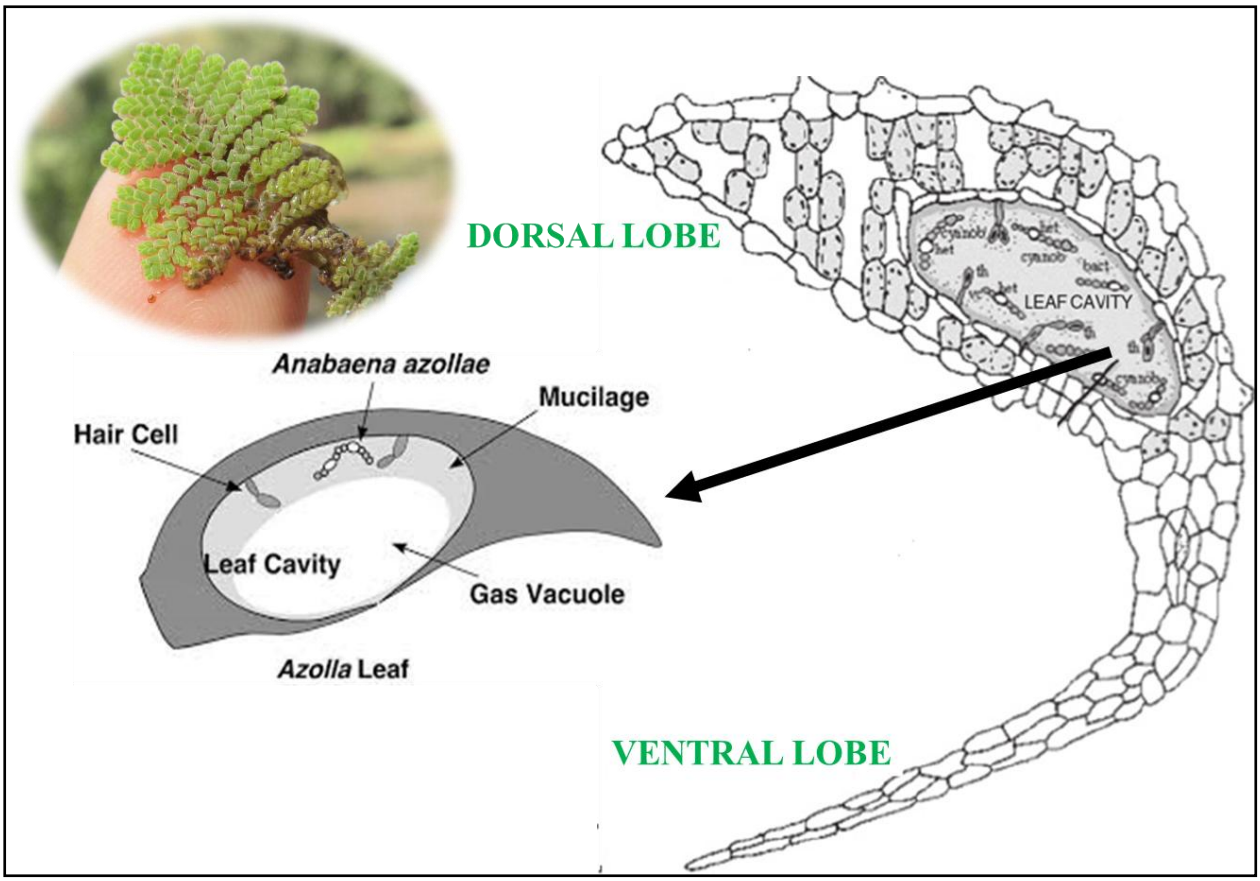

Fig. 1: Azolla – Anabaena symbiosis

Procedure

- Bed for Azolla production is prepared using bricks and concrete or any other types of artificial beds can also be used for this purpose.
- Plastic sheets are spread on the bottom to avoid leakage.
- Approximately 10-15 kg of sieved pond soil is spread over the pit.
- 3-5 kg cow dung is mixed with water and the slurry is spread over the bed.
- For nutrition 5g/sq m SSP is added.
- The tank is filled with sufficient water and the soil particles are allowed to settle down.
- Azolla is added to the pit as inoculum.
- The water level of the pit is maintained every day.
- It takes about two weeks for Azolla to get ready for the first harvest.

Exploring areas of Azolla Biofertilizer Use

Azolla is a small aquatic fern that holds significant potential for various applications due to its unique characteristics and properties. Here are some areas where Azolla has been explored and utilized:

Agriculture

Azolla is commonly used as a biofertilizer in rice paddies. It forms a symbiotic relationship with a nitrogen-fixing cyanobacterium called Anabaena azollae, which enriches the soil with nitrogen. When incorporated into rice fields, Azolla can reduce the need for synthetic nitrogen fertilizers, leading to more sustainable and eco-friendly agriculture.

Livestock Feed

Azolla can serve as a nutritious feed supplement for livestock such as poultry, pigs, and fish. It contains proteins, essential amino acids, vitamins, and minerals. When added to animal diets, Azolla can improve growth rates and overall health.

Wastewater Treatment

Azolla can be used in constructed wetlands and other water treatment systems to help remove pollutants from wastewater. Its rapid growth and ability to absorb heavy metals and nutrients make it effective in purifying water.

Bioremediation

Due to its ability to accumulate heavy metals and other pollutants, Azolla has been investigated for its potential in cleaning up contaminated water bodies and soil in polluted areas.

Bioenergy Production

Azolla can be used as a feedstock for bioenergy production, such as biogas and bioethanol. Its high growth rate and carbohydrate content make it a promising candidate for biofuel production.

Carbon Sequestration

Azolla can capture and store atmospheric carbon dioxide through photosynthesis. When it proliferates in water bodies, it can potentially contribute to mitigating climate change by removing CO2 from the atmosphere.

Limitations

It's important to note that while Azolla holds promise in these areas, there may also be challenges and limitations associated with its use. Factors such as local climate, water availability, and regulatory considerations can influence the feasibility of Azolla-based applications. Ongoing research is essential to fully understand and harness the potential benefits of Azolla in various fields.

Trust Areas

- Azolla is of interest to researchers studying plant-microbe interactions, nitrogen fixation, and sustainable agriculture practices. It is also used in educational settings to demonstrate ecological concepts and experiments.
- Azolla biomass can be used in various industries, including pharmaceuticals, cosmetics, and textiles. Extracts from Azolla have shown potential antimicrobial, antioxidant, and anti-inflammatory properties.

Precautions

- Harvesting of Azolla should be done on regular basis to avoid overcrowding.
- Temperature should be maintained at around 30-35 °C as it is an important factor for proper growth. Temperature above 35°C will lead to decrease in rate of multiplication.
- Bunds of the plot where Azolla is cultured should be lined with polythene sheet to avoid leakage.
- Nursery area should preferably be under tree and direct sunlight should be avoided.

Socio-Environmental Concerns

Here are some socio-environmental concerns associated with azolla production:

Invasive Species

Azolla has the potential to become invasive in certain ecosystems. If not properly managed, it can outcompete native plants and disrupt local biodiversity. Its rapid growth and ability to form dense mats on water bodies can alter aquatic habitats and negatively impact native species.

Water Quality

While azolla can absorb nutrients from water bodies, there is a risk of nutrient imbalances. If azolla overgrows, dies, and decomposes, it can lead to oxygen depletion in the water, which can harm aquatic life. Moreover, the release of stored nutrients from decomposing azolla can contribute to eutrophication, a process that leads to excessive nutrient enrichment and degraded water quality.

Habitat Alteration

The dense mats of azolla can alter aquatic ecosystems by shading out sunlight and reducing oxygen exchange between the water and the atmosphere. This alteration can affect the habitats and behaviors of various aquatic organisms.

Cultural Impact

Introducing azolla into traditional agricultural systems may require changes in farming practices and could impact local cultural practices and knowledge. Additionally, the introduction of non-native species like azolla could disrupt traditional ecological balances and relationships.

Genetic Contamination

The potential for genetic contamination exists when azolla is introduced into new areas. If not managed carefully, genetic mixing between cultivated and wild populations could lead to unintended consequences and impact native genetic diversity.

Disease and Pest Management

The dense growth of azolla can create favorable conditions for pests and diseases. If not managed properly, these issues could lead to the use of pesticides or other control methods that may have negative environmental consequences.

Resource Intensiveness

While azolla can reduce the need for some inputs like synthetic fertilizers, its production requires water and nutrient inputs. In areas with limited water resources, increased azolla cultivation could lead to competition for water resources with other uses or ecosystems.

Social Equity

The adoption of azolla-based practices may require changes in traditional agricultural systems and livelihoods. It's important to consider the potential impacts on local

communities, especially those who depend on existing agricultural practices for their livelihoods.

Regulatory and Policy Concerns

The introduction of non-native species, even with potential benefits, can raise regulatory concerns in some regions. Proper risk assessments and regulatory measures need to be in place to manage the introduction and cultivation of azolla.

Lack of Long-Term Research

Despite the potential benefits, there might be limited long-term research on the ecological, environmental, and socio-economic impacts of widespread azolla cultivation. This makes it important to proceed cautiously and gather comprehensive data on its effects.

Conclusion

The demand of organic agriculture is at its peak due to rising health and fitness awareness. The fact that Azolla is a Biofertilizer that possesses a rapid rate of multiplication and can be directly applied to soil in its living form is of utmost importance and usage. For small and marginal farmers, Azolla can be an economically feasible solution. The health hazards associated with chemical fertilizers can only be done away with by the use of potential biofertilizers in the fields. Rice being a major crop, Azolla can be a low input investment for farmers who are not economically strong. The positive environmental effects of the fern prove it to be a good choice.

Fig. 2: Azolla production unit

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AGRIALLIS
Science for Agriculture and Allied Sector: A Monthly Magazine
Volume 5, Issue 8
www.agriallis.com

Article Id
AL04247

DESIGNER EGGS

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Egg is considered as "nature's original functional food" (Hasler *et al.*, 2000). Eggs are considered the highest quality protein. Besides this, eggs also serve as the major source of dietary cholesterol, containing 213 mg cholesterol per egg. However, consumer awareness on the relationship between dietary lipid and the incidence of Coronary Heart Disease (CHD) and occurenece of *Salmonella* changed the attitude of people towards egg consumption. But, subsequent research suggests that dietary cholesterol in general and cholesterol in eggs in particular has limited effects on the blood cholesterol level and on cardiovascular disease. Despite this, a cholesterol scare exists among consumers which leads to a declining trend in egg consumption throughout the world especially in western countries (FAO, 2003). The poultry products like eggs have already gained a healthy image, so in order to curb the prevalence of chronic diseases several attempts were made to modify the eggs by adding ingredients which are beneficial for the health or by eliminating or atleast reducing the harmful components. In the backdrop of above facts, the concept of "designer egg" has been evolved with an approach to minimize the negative compunds (viz. cholesterol and triglycerides) and enriching it with health positive compounds viz. ω-3 fatty acids and antioxidants, vitamins and minerals.

Nutrient Composition of Eggs

The egg is one of the most complete and versatile food. Egg is a rich source of quality protein (high bioavailability i.e., more than 80%), important source of unsaturated fatty acids (oleic), iron, phosphorus, trace minerals, vitamin A, E, K and B complex vitamins, especially vitamin B. Traces of carbohydrates (1.0 per cent) are present in egg content. The lipid content in egg is 11.87 per cent of egg content and 32.8 per cent of yolk. Yolk is a complex milieu containing 68% low-density lipoproteins (LDL), 16% high-density lipoproteins (HDLs), 10% livetins and other soluble proteins, and 4% phosvitins. The egg white is a gel-like structure

that lacks lipids and is composed mainly of water (about 88%), fibrous structural proteins (ovomucins), glycoproteins (ovalbumin, protease inhibitors), antibacterial proteins (lysozyme), and peptides. Egg-white ovalbumin thus represents a valuable source of amino-acids for human nutrition. Besides ovalbumin, egg white is rich in antibacterial lysozyme that has potential as an anti-infectious agent in many pharmaceuticals and as food preservative. The total lipid content is relatively stable in the egg ranging from 8.7 to 11.2 per 100 g of whole egg. Egg does not contain any fibers and its content in carbohydrates is low (0.7%). The egg and, more precisely, the egg yolk, is a vitamin-rich food that contains all vitamins except vitamin C (ascorbic acid). The absence of vitamin C in the egg may result from the fact that birds are capable of satisfying their own vitamin C requirements, by de novo synthesis from glucose. The egg yolk contains high amount of vitamin A, D, E, K, B1, B2, B5, B6, B9, and B12, while egg white possesses high amounts of vitamins B2, B3, and B5 but also significant amounts of vitamins B1, B6, B8, B9, and B12. In addition to these vitamins, eggs represent a major source of choline, which is essentially concentrated in the yolk (680 mg/100 g in the egg yolk versus 1 mg/100 g in the egg white). Egg is rich in phosphorus, calcium, potassium, and contains moderate amounts of sodium (142 mg per 100 g of whole egg). It also contains all essential trace elements including copper, iron, magnesium, manganese, selenium, and zinc, with egg yolk being the major contributor to iron and zinc supply. The presence of such minerals and micronutrients in egg is quite interesting as a deficiency in some of these (Zn, Mg, and Se) has been associated with depression and fatigue and development of pathological diseases. Due to low caloric value and easy digestibility, egg is included in the diet of older people. In the egg, all the essential amino acids are present.

Designer Egg

Designer egg production can be defined as a pre-oviposition technology to exploit products (egg) beyond their traditional food value and is the enrichment of egg retaining their nutritional, functional and sensory qualities. Designer eggs can also be termed as enriched eggs or nutritionally enhanced eggs are called as, pre-ovipositor value added eggs or health promoting designer eggs. Research priority in poultry nutrition has been diversified into the field of enriching or fortifying eggs with certain nutrients of consumer's choice at pre-oviposition itself based on the basic concept that eggs accumulate nutrients if hens are subject to dietary and nutritional manipulations (Sujatha and Narahari, 2011). Eggs can be designed

through dietary approaches either through supplementation of specific nutrients, or certain herbs or specific drugs that have functional and therapeutic properties.

Need for Modifications in Eggs

The growing role of human nutrition in both the treatment and prevention of chronic diseases has led to the convergence of the consumer and governmental attention on the nutritional quality of foods. The food industry has responded to the demand for foods of superior health benefits by modifying the nutritional profile of popular foods like eggs and meat.

Egg is a cholesterol rich food. A large egg contains about 213 mg of cholesterol per yolk (USDA, 1991). Even though the nutritional superiority of the egg has been proven beyond doubt, the assumptions that egg consumption will increase the serum cholesterol levels directly, has resulted in reduced egg consumption. This "cholesterol phobia" scared the people in developed countries until 1990 and still continues to do so in developing countries including India due to ignorance. It was assumed that high cholesterol leads to atherosclerosis in vital arteries which may cause heart attacks and strokes and also is a major constituent of gallstone. Although the nutritionists and cardiologists have now established that there is only an insignificant correlation between dietary and serum cholesterol levels; the consumers are still scared of consuming cholesterol rich foods, hence there is an urgent need to reduce the egg yolk cholesterol levels as well as to incorporate several other health promoting components in the egg. Due to limited successful attempts to significantly reduce cholesterol content of eggs through genetic, nutritional, pharmacological tools, researchers have also turned towards using the egg as vehicle for delivering essential nutrients that were traditionally absent or in low concentration in those products. The industry is presently geared in production of speciality eggs that have higher or enriched levels of certain nutrients already present in the eggs or lower the levels of other nutrients, which are considered undesirable for some reasons. Such eggs are called “designer eggs", “functional eggs”, “diet eggs”, which are capable of safeguarding the health of the consumers.

History of Designer Egg Production

Cruickshank (1934) was one of the first researchers to document the ability to change the nutrient profile of the egg. In the late 80s, Sim, Jiang and their associates worked together to produce nutrient enriched eggs and developed designer egg, rich in n-3 fatty acids with

antioxidants and patented this egg as 'Professor Sim's Designer Egg'. Later in 1997, Van Elswyk developed eggs enriched with conjugated linoleic acid (CLA). In Australia, Farell (1998) enriched the eggs with folic acid and iron. Other available designer eggs in the market include eggs enriched with vitamins (Michella and Slaugh, 2000). In Canada, Leeson and Caston (2004) produced lutein and selenium enriched eggs which help in preventing eye disorders. In India, Narahari (2005) has also developed Herbal Enriched Designer Eggs (HEDE), which is not only rich in carotenoids, n-3 PUFA, selenium, trace minerals and vitamin E, but also rich in herbal active principles like Allicin, Betaine, Euginol, Lumichrome, Lumiflavin, , Lutein, Sulforaphane, Taurine and many other active principles of herbs, supplemented in the diets of hens. These eggs also contain natural sterols (phytosterols) like β-sitosterol, Brassicasterol, Campesterol, Stigmasterol etc. which are cardiac friendly in nature.

Methods for Designer Egg Production

- Inducing metabolic changes in the hen that can result in synthesis of compounds that essentially end up in the egg
- Change the characteristics of membrane transport to facilitate movement of compounds into the eggs
- Manipulate the diet of the hen such that the desired compounds level increase in the eggs

Dietary Manipulation for Designer Egg Production

Egg nutrients that can be manipulated by dietary manipulation are - Cholestrol , fatty acid profile: n-3 fatty acids Linoleic and Linolenic acid ;Vitamins : A,D, E, K, B12, Biotin, Folic acid and minerals- Cr, Se, Fe, Zn, I, Mn etc. Dietary mainipulation is an easy method for enrichment of eggs but there are certain factors that need to be considered before enrichment of eggs:

- Efficiency of nutrient transfer from feed to the egg
- Availability of commercial sources of effective feed forms of the nutrient
- Possible toxic effects of nutrients for the laying hens (Vitamin A and D are toxic for chickens at high levels)
- Amount of nutrient delivered with an egg in comparison with Recommended Dietary Allowance (RDA)

- Established health promoting properties of nutrients and their shortage in a modern diet.
- Possible interactions with assimilation of other nutrients from the egg
- Stability during cooking
- Effect of nutrient enrichment on appearance and taste (Vitamin E, carotenoids and selenium do not affect egg taste but help prevent fishy taste in ω-3 eggs)

Conclusion

Due to the cholesterol fear, egg consumers have developed certain taboos regarding egg consumption. This has resulted in the development of concept of designer eggs. Designer eggs provide varying nutritional benefits or properties compared to generic eggs. Dietary manipulation for designer egg production is dependent on several factors which must be considered while formulating the diets for laying hens. Designer eggs with new functional properties are highly demanding, however, still there is lack of knowhow for their commercial production.

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Article Id
AL04248

ADVANCES IN CAPRINE BREEDING MANAGEMENT

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Goats have always been the species of choice for in-house rearing for innumerable small, marginal and landless farmers because of their hardiness, versatility, feeding habits and prolificacy. Meat and milk of this species are accepted universally and there is ready liquidity cash value. Reproductive management of goat for increasing the profit is of utmost requirement therefore, advances in reproductive technology to accelerate goat production have been started since 1980s. Extensive investigation of the reproductive physiology of goats such as hypothalamic and pituitary control of the ovary related to estrus behavior and cyclicity have been conducted. Hormonal treatments for synchronization of estrus and ovulation in combination with artificial insemination (AI) or natural mating, embryo transfer (ET), multiple ovulation and ET (MOET) programme in goats combined with estrus synchronization (ES) and AI are evolving technologies being used in goat production.

Contribution of goat has an immense impact when it comes to the rural India, usually being associated with the poorest of the poor and goat has been the only source of income for some family. That is why; it has rightly been called "Poor Man's Cow" by Mahatma Gandhi, because of its contribution to the poor man's economy. They not only supply nutritious and easily digestible milk to their children but also regular source of additional income for poor and landless or marginal farmers. Being small-sized animals, goats can easily be managed by women and children as their feeding, milking and care does not require much capital investment, equipment and hard work. Four goats can be maintained as cheaply as one indigenous cow. Goats are the most prolific domesticated ruminant contributing. Farmers and pastoralists are increasingly relying on goat as means of survival and a way of boosting their income (Peacock, 2005). Returns on capital of up to 50% and recovery of 70% of retail price

are possible in goat farming. India contributes 16.1% to the world's goat population (FAO Statistics, 2013), making it among the highest livestock holding countries in the world. Based on the latest GOI statistics (19th Livestock Census, 2012), the number of goats in the country is 135.17 million. The state with the highest number of goats is Rajasthan (21.6 million), followed by Uttar Pradesh (15.6 million) and Bihar (12.1 million).

Breeding Management of Goat at a Glance

The male and female ratio for breeding goats should be 1:20. To avoid inbreeding, males should be replaced or exchanged once in two years. Indigenous breeds of goat can be put to breeding from 18to 24 months depending upon their body condition as too young animals result in more weaklings and higher kid loss. The body weight of the animal should be less than the adult body weight of that breed. Timely oestrous detection of all female goats above 1 year should be conducted using only approved or vasectomized bucks. September to October, February to March and May to June are considered as the normal breeding season. If any goat in a farm has no kidding for complete one year they should be removed from the flock. Day length (photoperiod) plays an important role in behavior of breeding goats. The nerve impulses received by eye signal the pituitary gland to secrete melatonin which promotes cyclical induction of reproductive processes in goats (Bearden and Furquay, 1984). Short days stimulate sexual activity, but prolonged exposure results in refractoriness and subsequent cessation of reproductive activity (Chemineau *et al*., 1992). Cyclic activity is observed in doe managed in tropical and subtropical climate as a result of exposure to equal or nearly equal lengths of day light and night.

Selection of Breeding Goat

For breeding, goats with 2 dental ages with a long, preferably low set body, roomy hind quarter, well-formed pliable udder, active foraging habit and good mothering instincts are the desirable breeding traits. The females having poor milking capacity, over shot or undershot jaw, broken mouth, blind teat and meaty udder should be disqualified. Females should be mated only when they reach 70% of the adult body weight. Male animals should be in good body condition, masculine, legs should be stronger and free from defects. The animal should have both testicles intact in the scrotum with good libido.

Preparation of Buck and Doe for Breeding

The breeding animals should be provided sufficient period of rest prior to initiation of the breeding season and examine6 to 8 weeks prior to the breeding seasonto determine the breeding soundness. Deworming and vaccination with tetanus toxoid before two to three weeks of breeding is important. Hairs from preputial sheath and around the eye of the buck, and from the perenial region and base of the tail of doe should be trimmed. Optimum BCS (body condition score) of the buck should be 5-6. Flushing (additional feed) is advised two months prior to the breeding season to improve body condition and ovulation rate. If required, the doe should be injected with vitamin E/Se to aid in ovulation.

Signs of Heat/Estrous

A female goat in heat exhibits reddening of the vulva and vulvar discharge, wagging of tail, mounting on other goat, seeking male, frequent bleating, push her back, and standing to be mounted (standing reflex).

Heat/Estrus Detection

Estrus detection can be done either by:

a) Using an intact male: Here, the male is allowed in the flock to identify the doe in estrus. Upon attraction by smell, sight and sound of the estrus doe the buck sniffs the vulva, extendsneck with curling of upper lip, and bites the side of the doe with wool pulling.
b) Use of intact male fitted with aprons: In this method, an apron made of a soft piece of cloth measuring 60x45 cm with strings on four sides is tied on the abdomen of the male tocover the penis to prevent mating. The apronized buck are allowed in the morning and evening for about 15 to 20 minutes for identification of estrous doe.
c) Vasectomized buck: vasectomized buck can be prepared by surgical intervention and allowed into the flock which follows the doe in estrous.

Artificial insemination (AI): AI is probably the most important biotechnology for significant genetic improvement used in the dairy goats. It entails semen collection, processing, and evaluation, with an emphasis on bucks. Nowadays, AI is extensively used in intensive dairy goat production systems. In the last decades, the sex-sorted sperm

technique has opened a new window to improve the reproductive efficiency of dairy goat to produce kids of the same sex (Jun Luo *et al*., 2019).

Embryo transfer (ET): The first ET in goat was reported by Warwick *et al*., in 1934(Warwick *et al*., 1934). Nineteen 2–16 cell embryos were transferred to 18 recipient ewes, and eight lambs were born (Hunter *et al*., 1955). Experiments have demonstrated the critical importance of the state of the uterine environment to embryo viability and the embryo must be present in the uterus in post-estrus does to prevent corpus luteum regression. The ET between breeds of differing gestational length has indicated conclusively that the genotype determines the duration of pregnancy (Jun Luo*et al*., 2019). The sequence of events leading to the ET usually starts with superovulation. Dairy goats of all breeds could ovulate 1 to 3 eggs per estrus cycle, but 10 to 20 available oocytes can be obtained from these goats after superovulation treatment with appropriate doses of FSHs (Melican*et al.,* 2008). The principle of superovulation is to artificially add exogenous gonadotropin so that more follicles have the opportunity to continue development. Finally these follicles will be able to complete the conversion from FSH-dependent to LH-dependent, and will establish the status of dominant follicle (Chang *et al*., 2006). PMSG and FSH are widely used for superovulation in the dairy goat industry.

Oestrous Synchronization

Large numbers of doe can be made to come in heat at one time through synchronization of oestrous. This reduces the cost of AI or natural breeding and subsequent care of kidding and also uniform flocks of kids are produced.

For synchronization of the female goats improved hormonal technology may be used or buck may be in a partitioned corral of woven-wire net so that the does and the buck may have full view of each other. This may be done a week or two before or during the breeding season. A 90% conception rate is ensured if one buck with one doe or more does (not exceeding 2 to 3) in heat are allowed to remain together for a whole day or whole night provided it is followed over period of 3 cycles. If two services are provided at an interval of 8 to 12 hours, improvement in conception is achieved. Goats which do not return to oestrus after 2 cycles are considered as pregnant and be kept in a group of not more than 15 to 20 does to avoid infighting.

Estrous Synchronization Protocol

During the mating season oestrus can be synchronized by intra-vaginal progestagen pessaries, progesterone implants or prostaglandin.

- Administration of progesterone hormones or their analogues through feed, as implant or as impregnated vaginal sponges which are removed after 14 days. The animal comes to heat within 3 days.
- Administration of two intra muscular injections of Prostaglandin F2 alpha or its synthetic analogues (10 mg each) at an interval of 10 days is effective to bring all the animals in heat within 72 to 96 hrs.
- Buck effect: Sudden introduction of buck in the does flock after prolonged separation leading to more number of does into oestrous is known as buck effect. Estrus can be induced with the strategic exposure of anestrus does to intact males, which is dependent on the depth of seasonal anestrus and associated with a first ovulation in two to three days. The first ovulation is usually silent and of low fertility. The second ovulation occurs after five days which is usually a fertile estrus.
- Light control: Goats are short-day breeders because they breed in the fall and when they are exposed to short periods of day light they are more receptive to breeding. This unique breeding behavior is used to program the cycle if they are kept in a building where the amount of day light exposure is controlled. Light exposure to the females can be reduced gradually over 8 to 12 week period and for the males the same lighting regiment improves sperm production, libido, semen quality and fertility (Gimenez, 2007).

Conclusion

The high nutritional quality and health benefits from consumption of goat milk in particular and also meat has become more widely acknowledged, with gradual realization of goat milk being higher in nutritional value than cow milk. However, the dairy goat industry has not yet become well developed in many developing countries, and there is great potential to produce more milk and meat and develop many high valued products. With the deepening understanding of the value of goat milk and meat, the market will gradually grow and expand, and goat industry will receive increasing attention and investment with more emphasis on dairy goat. The dairy goat industry also faces several challenges, such as lesser

number of large-scale intensive dairy farms, limited consumer market of milk products, and fewer high producing breeds of dairy goats etc. Therefore, it is necessary to formulate relevant breeding regulations to form a supporting breeding technique, and to accelerate the development of key technologies of reproduction, breeding, and feeding management in the goat industry. These measures could improve the production performance of goats to provide more excellent goat products for human consumption.

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AGRIALLIS
Science for Agriculture and Allied Sector: A Monthly Magazine
Volume 5, Issue 8
www.agriallis.com

Article Id
AL04249

CULTIVATING SUSTAINABILITY: BREEDING PERENNIAL GRAINS FOR A SUSTAINABLE AGRICULTURAL FUTURE

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Presently, perennial grain crops are not grown at large scale, mainly due to their early stages of domestication and current low yields. Perennial grains are a type of grain crop that differs from traditional annual grains, such as wheat, rice and corn in their growth and reproduction patterns as well as production capacity. Although still in the early stages of development, researchers and agriculturalists are working to breed and establish perennial versions of major grain crops to unlock their potential benefits.

Need for Perennials

While annual grains complete their life cycle within one growing season, perennial grains can live for multiple years, regrowing each year without the need for replanting. They continue to produce grains season after season, making them a promising option for sustainable agriculture and food security. Currently, discussions on breeding strategies for perennial grains have focused on distributing photosynthetic resources between seeds and vegetative structures. Nevertheless, as perennials are cultivated in more diverse agro-ecosystems, they will demand a wide range of traits that differ significantly from those typically addressed by annual crop breeders. While it might be feasible to expand food production to feed the projected 10 billion population by 2050, relying on agricultural methods that deplete soil and exhaust non-renewable resources could jeopardize the earth's ability to sustain sufficient food production in the 22nd century.

Key Characteristics of Perennial Grain Crop

Deep Root Systems: Perennial grains invest more energy in developing deep root systems, enabling them to access water and nutrients deeper in the soil profile. This adaptation makes them more drought-resistant and less reliant on irrigation.

Reduced Soil Erosion and weed suppression: The continuous growth and coverage of perennial grains help stabilize the soil, reducing erosion and nutrient runoff. This can contribute to soil health and conservation.

Enhanced Biodiversity: Perennial grain systems promote greater biodiversity compared to monoculture annual crops. The perennial growth habit provides a habitat for diverse plant and animal species.

Crop Resilience: Perennial grains have the potential to be more resilient to climate variability and extreme weather events compared to annual crops. Their deep root systems allow them to access water and nutrients from deeper soil layers, making them more tolerant of drought and better equipped to withstand fluctuations in rainfall patterns.

Soil Health and Nutrient Cycling: The extensive root systems of perennial grains increase organic matter in the soil, which improves soil fertility, nutrient cycling and carbon sequestration. This can contribute to sustainable agriculture and help mitigate climate change by reducing greenhouse gas emissions.

Reduced Chemical Inputs: With their deeper roots and persistent growth, perennial grains generally require fewer fertilizers and pesticides compared to annual crops.

Enhance pollinators: Perennial plants have the ability to produce more habitat for pollinators and extend the food resources for all beneficial insects.

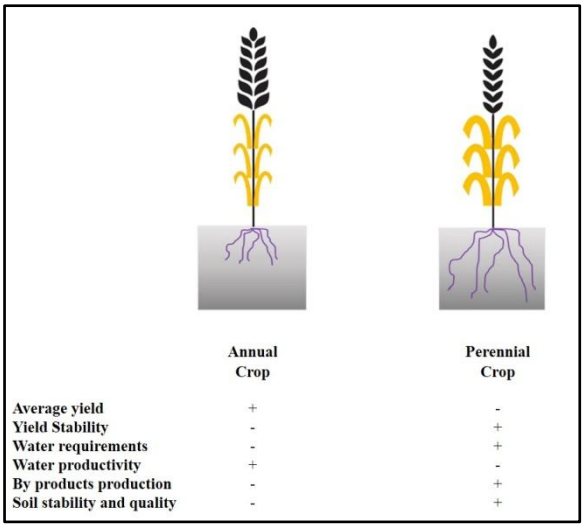

Fig. 1. Comparative diagram of perennial and annual crop characteristics and requirements

Breeding Determinants for Perennial Grains

1. Grain yield (seed size, seed weight, floret fertility, head weight)
2. Growing season
3. Plant architecture (Plant height, moderate tillering, erect leaves)
4. High regrowth ability, minimal shattering and low seed dormancy
5. Heading time, resistance to biotic and abiotic stress, food quality and nutrient use efficiency.

Major Approaches and Progress in Introducing Perennialism into Annual Grain Crops

- **Wide Hybridization:** Fortunately, the introduction of perennial characteristics into annual grain crops has seen significant achievements through wide hybridization. By crossbreeding perennial species with closely related annual crops, we can able to incorporate domestication genes much more rapidly compared to the methods used by our ancestors. Successful attempts have been made to combine the desirable traits of perennials with the high-yielding capabilities of annuals, with rice being the most advanced example. Perennial rice for instance, was created by hybridizing annual rice (*Oryza sativa* ssp. indica) with the rhizomatous perennial relative, *O. longistaminata* (Sacks *et al.*, 2003). Through backcrossing with annual rice and subsequent breeding, we now have perennial rice cultivars that offer grain yields comparable to annual rice while persisting for eight harvests. Nevertheless, challenges remain, such as ensuring the stability of the perennial trait, maintaining fertility among progeny and preserving perennialism while developing high-yielding lines. Similar efforts are being made for perennial grain sorghum, which involves hybridizing annual grain sorghum (*S. bicolor*) with perennial *S. halepense*. While hybrid progeny might struggle in cold temperate climates, it is feasible to produce high-yielding perennial varieties in warmer conditions. Other perennial grains, like rye (Daly *et al.*, 2022) and perennial wheat, are also under development through wide hybridization, with ongoing work to enhance perennial survival and genetic stability. Additionally, the breeding of perennials necessitates extended phenotyping over multiple seasons to assess yield stability and long-term climate resilience, which stands in sharp contrast to annual crops.

- **Domestication of Existing Grain Crops:** Another approach to achieving perennial grain crops is through the accelerated domestication of existing, low-yielding

perennial grain species (Osterberg *et al.*, 2017). This strategy mirrors the historical domestication process of annuals, where major domestication genes were repeatedly selected and breeding improvements were made over several years. These "domestication genes" play a crucial role in enhancing primary and harvestable grain yield for farmers, as well as regulating plant structure, dormancy and spike morphology, which includes traits like threshability, harvestability and lodging resistance. Plant breeding has been utilized to increase the productive capacity of perennial species, coupled with agronomic practice optimization. For example, wheatgrass (*T. intermedium*), traditionally used for forage purposes, is now undergoing de novo domestication to serve as a perennial grain crop. Nevertheless, this process comes with challenges, such as achieving chromosomal stability and perenniality while preserving the domestication traits. The direct domestication of wild perennial species offers the advantage of retaining perenniality but requires considerable time to enhance traits like shattering resistance, threshing ability, seed size, grain yield and other domestication-related characteristics.

- **Induced Random Mutagenesis**

To unlock the potential of perennial grains, it is essential to introduce beneficial alleles for these traits, be they naturally occurring, induced or edited (DeHaan *et al.*, 2020). Based on reverse genetic techniques, such beneficial genetic variants (induced mutant) can be identified using the recently developed method FIND-IT (fast identification of nucleotide variants by digital PCR) (Knudsen *et al.*, 2021).

In 2009, The Land Institute developed Kernza perennial grain, the first commercially available and economically viable perennial grain crop. It is a domesticated version of wild intermediate wheatgrass (*Thinopyrum intermedium*) and can be used as a substitute for annual wheat.

In perennial systems, intra and interspecific diversity must be deployed in space, through polycultures, for effective pest regulation and to increase stand structural complexity and floristic diversity which are associated with significant environmental benefits. Incorporation of perennial grains into polycultures may be additionally through increasing soil carbon sequestration (Sprunger *et al.*, 2020). Therefore, a future research could be aiming on the identification of leguminous perennial species for intercropping with perennial grains

to gain maximal environmental benefit, and, potentially, greater economic return through delivering two harvestable crops for human consumption as well as animal feed and other industrial purpose (Schlautman *et al.*, 2018).

Conclusion

Perennial grains can revolutionize agriculture with sustainable and eco-friendly alternatives to annual crops. Early-stage development shows promise in improving soil health, conserving resources and increasing agricultural resilience. Continued research, breeding and market efforts are vital for widespread adoption, creating more sustainable food systems. However, significant R&D investment and time are needed to achieve sufficient yield potential for mainstream use beyond niche health food markets. High seed yields are crucial for successful adoption and while challenges like nutrient supply and pest management can be overcome, achieving high-yielding perennial grains remains the primary focus.

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Article Id
AL04250

ONE HEALTH APPROACH IN AQUACULTURE

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The One Health plan acknowledges the connections between the health of people, animals, and the environment through an integrated and interdisciplinary approach (Mackenzie & Jeggo, 2019). This strategy becomes especially pertinent in the case of aquaculture because of the intricate relationships that exist between farmed aquatic creatures, human health, and the local ecosystem. The aquaculture business may move towards a more sustainable, effective, and responsible model by embracing the One Health theory, which prioritizes the health of aquatic animals, farmed animals, and human consumers (Stentiford et al., 2020).

Some of the Key Aspects of One Health Approach in Aquaculture

1. Disease Surveillance and Management
2. Antibiotic Use and Resistance
3. Environmental Impact
4. Sustainable Feed and Nutrition
5. Collaboration and Communication
6. Research and Innovation

Disease Surveillance and Management: An essential component of the One Health concept in aquaculture is the monitoring and management of diseases (CAVALLI, 2015). Because aquaculture is so intensive, it can facilitate the transmission of diseases among cultured aquatic animals. In addition, certain illnesses, known as zoonotic illnesses, can be passed from animals to people. In order to detect and control potential disease outbreaks and stop their spread to humans or wild aquatic species, continuous monitoring and surveillance are crucial. We can reduce financial losses, maintain ecosystem health, and safeguard human health by quickly addressing diseases in aquaculture.

Antibiotic Use and Resistance: In aquaculture, antibiotic usage and resistance are major issues. Infections caused by bacteria are frequently prevented and treated with antibiotics in aquatic farm animals. However, the uncontrolled use of antibiotics might result in the emergence of germs that are resistant to them, endangering both the health of humans and animals. To reduce the emergence of antibiotic resistance and safeguard human health, the One Health approach promotes responsible antibiotic use in aquaculture (Velazquez-Meza et al., 2022). The use of antibiotics can be decreased by using sound aquaculture techniques, enhancing hygiene, and investigating non-antibiotic disease management methods including probiotics and vaccinations.

Environmental Impact: Another important component of the One Health approach in aquaculture is the influence on the environment. Large-scale aquaculture activities have the potential to harm aquatic ecosystems and human societies that depend on healthy water bodies by contaminating water and destroying habitat (Bashir et.al.,2020). Sustainable aquaculture methods like integrated multi-trophic aquaculture, which combines species in a way that generates a more balanced and less polluting system, should be pushed in order to reduce these effects. Adopting sensible waste management procedures and making sure that aquaculture farms are located in the right places can also contribute to environmental protection and long-term sustainability (Ozbay et al., 2014).

Sustainable Feed and Nutrition: The significance of taking into account the origins of aquaculture feed are another point made by One health. Fishmeal and fish oil, which are common traditional feed ingredients for farmed fish, are frequently taken from wild fish stocks, which causes overfishing and ecological imbalances. To lessen the strain on wild fish populations and preserve the general wellbeing of aquatic ecosystems, sustainable and alternative feed sources like plant-based feeds and insects are being investigated (Hasan et.al.,2023).

Collaboration and Communication: The One Health strategy in aquaculture relies heavily on cooperation and communication to be successful. To design and implement integrated strategies and policies, stakeholders from multiple sectors, including aquaculture producers, public health officials, environmentalists, researchers, and policymakers, must collaborate. An effective response to the complex relationships between human health, animal health, and the environment can be developed through knowledge exchange, the identification of possible dangers, and effective collaboration (Machalaba et.al.,2021)

Research and Innovation: Research and innovation play a significant role in advancing the One Health approach in aquaculture. To provide diagnostic tools, vaccinations, and disease management techniques that are beneficial to both aquatic species and humans, investments in research and technology are required. Continuous research can also support adaptive management practises by identifying new threats and challenges to aquaculture.

Priorities of One Health included by FAO

- Enhancing early warning systems for zoonotic illnesses at the interface of humans, animals, plants, and the environment (HAPE).
- Enhancing biosecurity to better manage zoonotic diseases, pests, and invasive alien species as well as pest and disease management in animals and plants.
- Fostering efficient emergency preparedness and response for proactive action on and response to food-chain emergencies, food safety issues, and other health events at the interface of people, animals, plants, and the environment
- Strengthening one Health approaches to AMR in the food and agriculture sector to improve AMR risk management at the national, regional, and international levels
- Strengthening contributions to one health, biodiversity, ecosystem services, environmental health, soil/land, water, food safety, and the sustainability of agri-food systems would improve one health systems.

Conclusion

The One Health approach in aquaculture recognizes the intrinsic connections between human health, animal health, and the environment. By promoting disease surveillance and management, responsible antibiotic use, sustainable feed and nutrition, and environmental protection, the aquaculture industry can thrive while safeguarding the health of ecosystems, farmed animals, and human consumers. Collaboration, communication, research, and innovation are the pillars that support the successful implementation of the One Health approach, leading to a more sustainable and resilient aquaculture industry for the future.

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AGRIALLIS
Science for Agriculture and Allied Sector: A Monthly Magazine
Volume 5, Issue 8
www.agriallis.com

Article Id
AL04251

RANDOMIZED CONTROL TRIALS (RCTs): AN ANALYTICAL TECHNIQUE TO ASSESS THE IMPACT OF AGRICULTURAL TECHNOLOGIES AND POLICIES

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Three-quarters of the world's poor live in rural areas, and many rely on agriculture directly or indirectly. Agricultural technology has the ability to improve their lives by increasing yields, decreasing risk, and improving nutrition. However, adoption of these innovations, ranging from better seeds to financial products such as microinsurance, remains minimal. Extensive research is being conducted to encourage adoption, increase farmer income, manage the risks inherent in agriculture, and better connect farmers to markets. Impacts are defined by the OEDC-DAC as "positive and negative, primary and secondary long-term effects produced by a development intervention, directly or indirectly, intended or unintended. An impact evaluation can be conducted formative (improving or reorienting a program or policy) or summative (informing decisions about whether to continue, cease, replicate, or scale up a program or policy). RCTs were shown to be more trustworthy than other impact evaluation methods. Randomization is now an essential instrument in the repertoire of a development economist. Application of RCTs includes various fields such as Agriculture, Crime, violence & conflict, Education, Environment, energy & climate change, Finance, Firms, Gender, Health, Labour market and Political economy & governance etc.

Impact Evaluation Methods

1. Randomized Controlled Trials (RCTs) Also known as: – Random Assignment Studies, Randomized Field Trials, Social Experiments, Randomized Trials, Randomized Experiments, Randomized Controlled Experiments

2. Non or Quasi-Experimental Methods: these methods rely on being able to mimic the counterfactual under certain assumptions which at present are not testable

- Pre-Post

- Simple Difference
- Differences-in-Differences
- Multivariate Regression
- Statistical Matching
- Interrupted Time Series
- Instrumental Variables
- Regression Discontinuity

Randomized Controlled Trials (RCTs)

A randomized controlled trial (RCT) is a method of evaluating the impact of a program or policy intervention in which the population receiving the intervention is chosen at random from the eligible population, and a control group is likewise chosen at random from the same eligible population. It assesses the extent to which specific, planned effects are realized. RCTs can be used to assess both program interventions (for example, nutritional supplements delivered as part of a nutrition program) and policy interventions (for example, cash distributed as part of a cash transfer policy). RCTs are most suited for programs that aim to achieve clear, measurable outcomes that can be linked to a specific intervention or group of interventions and lend themselves to causal pathway analysis. RCTs are not well suited to programs that are emergent, or which seek to achieve results that are hard to measure.

Key Steps in Conducting a Randomized Evaluation: (White, 2013)

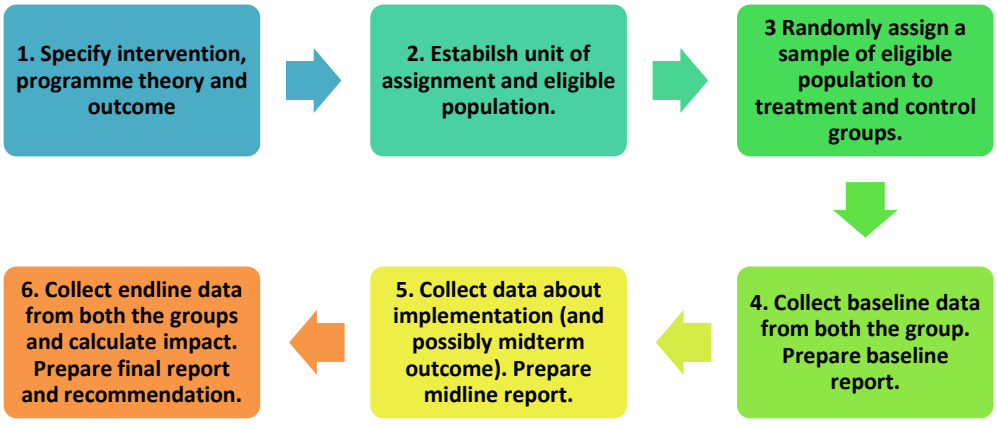

Fig. 1: Overview of conducting an RCT

Example: **Mobile Phone-Based Extension Services and Agricultural Advice for Cotton Farmers in Gujarat, India** conducted by **Cole and Fernando, J-PAL**.

- After China, India is the world's second-largest cotton grower. Despite this, Indian cotton productivity ranks 78th in the world, with yields just one-third of those of China. While financing limits, a lack of insurance markets, and poor infrastructure may explain some of this gap, a number of commentators have suggested that access to knowledge and awareness of agricultural technologies may also play a role (Jack, 2011). For decades, the Government of India, like most governments in developing countries, has run an agricultural extension system designed to disseminate information about new agricultural practices and technologies through a vast workforce of public extension agents. However, there is little evidence that these extension services are effective. In India, dispersed rural populations, monitoring challenges, and a lack of accountability limit the effectiveness of in-person extension systems: less than 6% of the agricultural population reports receiving information from these programs.

- In the absence of expert advice, farmers rely on word of mouth, generic broadcast programming, or agricultural input suppliers, who may be ignorant or have incentives to recommend the wrong product or overdose (Anderson and Birner, 2007). The development of mobile phone networks, as well as the rapid expansion of mobile phone ownership in South Asia and Sub-Saharan Africa, has given rise to the possibility of offering agricultural extension services in a fundamentally new way.

- This study examines whether the introduction of an information service that is able to deliver timely, relevant, and actionable information to farmers can meaningfully influence agricultural practices. Specifically, they evaluate Avaaj Otalo (AO), a mobile phone-based technology service that both pushes information to farmers via voice calls, and allows users to call a hotline, ask questions, and receive a recorded response from agricultural scientists and local extension workers. Callers can also listen to answers to questions posed by other farmers.

Particulars in case of mobile based extension service in Gujarat, India	
Intervention type	• Digital and mobile; Extension services; Information; Nudges and reminders; Training
Outcome of interest	• Technology adoption
Unit of assignment	• Farmers
Eligible population	• 1200 farmers across 40 villages having mobile phones

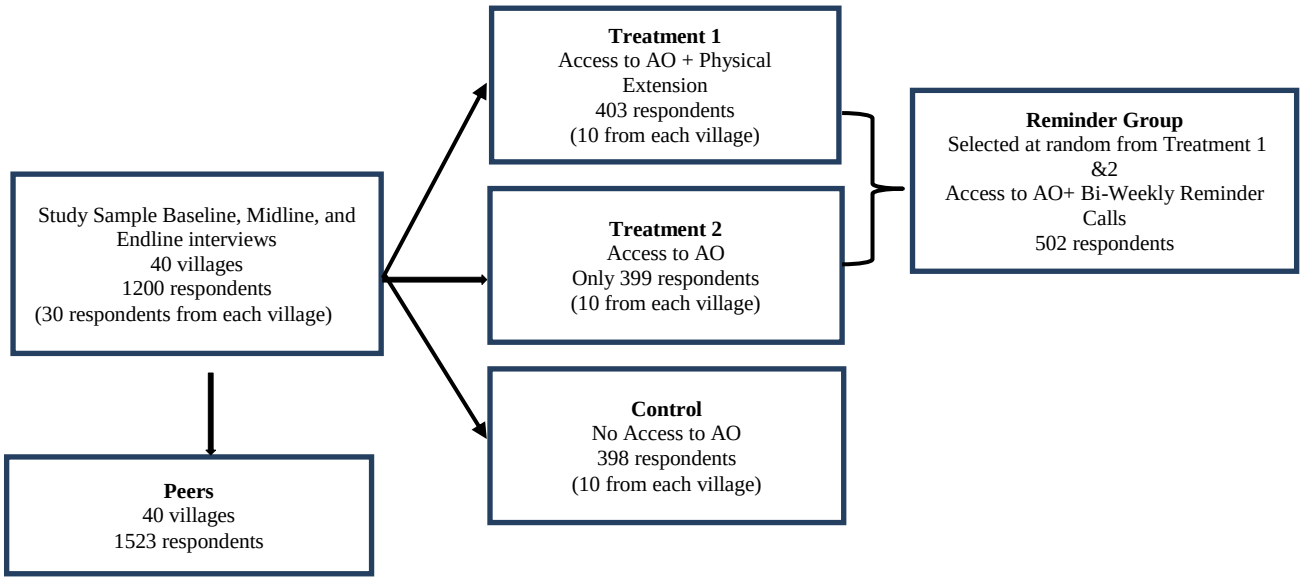

Fig. 2: Experimental design

Why Randomize?

There are many ways to estimate a programme's impact but i argued in favour of randomized experiments due to:

1. Conceptual Argument: -If properly designed and conducted, RCTs provide the most credible method to estimate the impact of a program

- Because the members of the treatment and control groups do not differ consistently at the start of the evaluation.
- Baseline data in the preceding example show that randomization was largely successful for the treatment groups across demographic characteristics (respondents are on average 46 years old and have approximately four years of education) and indices capturing information sources, crop-specific and general input use. At the baseline, there are no imbalances between treatment and control.
- Any difference that subsequently arises between them can be attributed to the program rather than to other factors.

Take-Up and Usage of AO

Cole and Fernando reported that nearly 90% of treatment respondents had called into the service by the end line (after two years), and the mean total usage for the combined treatment group (AO & AOE) - including both incoming calls and time

spent listening to push calls - was 7 hours (median 5.2 hours). By the end, 40% of treated responders had asked the system a question about their agriculture.

Agricultural Input Adoption

The therapy enhanced the cotton and seed management indexes by 0.12 and 0.09 standard deviations, respectively. They find no evidence of increased fertilizer adoption across all crops. Total input expenditure increased by about 8% relative to the baseline control mean across specifications, with irrigation and seeds spending increasing by roughly 15% and 20%, respectively, relative to the baseline control mean.

2. Empirical Argument: -Different methods can generate different impact estimates

Unit of Randomization:

- The RCT approach is adaptable enough to fit a wide range of situations and industries. The unit of analysis for the intervention and the random assignment is the same in a simple RCT. However, for practical and ethical reasons, a cluster RCT design, in which the unit of assignment incorporates multiple treatment units, is more commonly used.
- Randomizing at the individual level
- Randomizing at the group level "Cluster Randomized Trial"

Methods of Randomization

There are various approaches to implementing an RCT for a programme, such as phase in (pipeline), encouragement design, within-group randomization, oversubscription, and so on, but the RCT design should be chosen based on the programme characteristics (White et al., 2014).

Random Assignment

- There are various methods for randomly assigning population groups to treatment and control groups, including basic randomization, matched pair randomization, stratified random assignment, and so on.

• **Simple randomization**-It is listing individuals or sites and then assigning them to treatment and control groups using random numbers generated, for example, by a random number generator.

- **Matched pair randomization –** Individuals or clusters are divided into pairs based on observed similarities. Each pair has one unit assigned to the treatment group and the other to the control group at random. This first matching ensures balance and decreases the sample size required.
- **Stratified random assignment –** Participants are sorted into groups (strata) based on crucial variables that are likely to influence outcomes, such as income or education, and then randomization is performed for each group. This guarantees that essential variables are distributed equally throughout the treatment and control groups.

Statistical Power and Sample Size

An RCT may only be utilized when the sample size is large enough to detect program effects with adequate precision; the study design must have sufficient 'power'. The power of the design is the likelihood that we will be able to reject the hypothesis of no impact for a given effect size and statistical significance level (Duflo et al., 2006). According to the convention, 80% is a sufficient level of power.

Power: Main Ingredients

• **Effect Size**: A large effect may be distinguished from zero more easily than a tiny effect.
• **Variability**: Lower variability in the outcome variable makes distinguishing an effect easier.
• **Sample Size**: A higher sample size means that the treatment and control groups are more representative of the broader population, making it simpler to detect an effect.
• **Sample Split:**Equal proportions of treatment and control make it easier to discern an effect.

Minimal Detectable Effect Size

The smallest effect size that can be identified with a particular statistical power (e.g., 80% chance of accurate positive), statistical significance (e.g., 5% probability of false positive), and sample. We can alter the sample size based on the MDE to achieve a realistic experimental design. Bloom (1995) developed a formula to calculate MDE.

$$\mathbf{MDE_{\beta}} = (\mathbf{t_k} + \mathbf{t_{\alpha}}). \sqrt{\frac{\mathbf{1}}{\mathbf{P(1-P)}} \frac{\boldsymbol{\sigma}^{\mathbf{2}}}{\mathbf{N}}}$$

Where,

MDE_{β} = Minimal detectable effect,

$(t_k + t_{\alpha})$ = Critical values from Student t for power κ and significance level α

σ^2 = Variance

P = Proportion in Treatment

N = Sample size

The MDE will be smaller with llarger sample size N, smaller outcome variance $\sigma^2$and even proportion in treatment (P = 0.5).

Power in Clustered Designs

A number of factors influence statistical power, including sample size, the minimum detectable effect size (i.e. how sensitive the test must be), the underlying variance of the outcome variable, the proportion of participants in treatment and control, and, if the study is a cluster RCT, intracluster/intraclass correlation. When the number of clusters in a cluster RCT is raised, statistical power increases more than when the number of individuals or groups inside a cluster is increased.

Intraclass correlation (ICC): Intraclass correlation defines how similar - how correlated - units are within the same class or cluster. Kendall (2003) defines the ICC as the fraction of total variance accounted for by between-class variation.

Total variance(σ^2) can be divided into within-class variance (σ_n^2), and between-class variance (σ_v^2)

- **High ICC (close to 1):** subjects in the same cluster are similar; different clusters tend to be very different from each other.
- **Low ICC (close to 0):** Subjects in the same cluster are not particularly similar; other clusters are more similar to one another and more closely reflect the population as a whole.

The higher the intraclass correlation, the higher the required sample size.

MDE in case of clustered design is calculated as (Bloom, 1995):

$$\mathbf{MDE_{\beta} = (t_k + t_{\alpha}).\sqrt{\frac{1}{P(1-P)}\frac{\sigma^2}{N}} . \sqrt{1 + (m-1).\ ICC}}$$

Where,

m = cluster size

ICC = Intraclass correlation

The MDE will be smaller with larger sample size N, smaller outcome variance (σ^2),even proportion in treatment (P = 0.5) and lower ICC.

Power calculations step by step:

• Decide on your target power (e.g., 80%) and significance level (e.g., 5%).

• Determine the allocation ratio (sample split), for example, based on the cost of data collection (control and treatment) and intervention (just treatment).

• Inquire about the predicted treatment impact. Which effect sizes do we want to be able to detect? - This is used to configure the MDE.

• Calculate the variance and ICC.

• Calculate the sample size and project the study costs.

Threats Involved in Conducting RCTs

Even if random assignment is put in place, there are several potential challenges. These are:

- ✓ low take-up of the intervention;
- ✓ lack of compliance with intended procedures
- ✓ Contamination of the control group by other interventions affecting similar outcomes or through self-contamination; and
- ✓ Change in the design or location of the programme being evaluated, which are discussed under the following points.
- ✓ Partial Compliance and Sample Selection Bias: Intention to Treat & Local Average Treatment Effect
- ✓ Attrition
- ✓ Unexpected Spillovers
- ✓ Behavioral Responses to Evaluations
- ✓ Research Transparency

Generalizations of RCT Results

- Our focus has largely been on issues of internal validity up to this point, or whether we can infer that the intervention in the sample actually had the impact that was measured.
- Although crucial, internal validity is insufficient for external validity.
- The applicability of the influence we quantify to various populations or samples is known as external validity. Or, whether the results are replicable and transportable.

Application of RCTs to Indian Agriculture

- Mobile Phone-Based Extension Services and Agricultural Advice for Cotton Farmers in Gujarat, India by Shawn Cole and A. Nilesh Fernando
- Formal Rainfall Insurance for the Informally Insured in India by MushfiqMobarake and Mark Rosenzweig
- Diffusing new seeds through social networks in Indian village economies by Kyle Emrick
- Irrigation Tank Rehabilitation for Improved Agricultural Outcomes and Water Management in India by Aprajit Mahajan, Xavier Gine, Anup Malani and Manaswini Rao
- Group Incentives, Hygiene, and Milk Quality Among Dairy Cooperatives in Karnataka, India by J-PAL South Asia
- Targeted Information for The Adoption of Flood-Tolerant Rice in India by Manzoor Dar, Kyle Emerick and Elisabeth Sadoulett
- Marketing Rainfall Insurance in India by Shawn Cole, Sarthak Gaurav and Jeremy Tobacman
- The Impact of Drought-Tolerant Rice on Local Labor Markets in India by Alain de Janvry, Elisabeth Sadoulet, Kyle Emerick and Manzoor H. Dar
- Demand for Rainfall Insurance in India by Shawn Cole, Daniel Stein, Xavier Gine, Jeremy Tobacman, Petia Topalova, Robert Townsend and James Vickery

Conclusion

Since internal validity is an RCT's greatest strength, anything that could undermine it must be carefully taken into account. The capacity to overcome obstacles during the implementation phase is just as crucial as the design phase and power calculations. Making a

clear distinction between incomplete compliance, spillovers, and attrition and considering the effects of experiments is also crucial in RCTs and randomized evaluation can be done when there is time, expertise, and money to accomplish it well ,not too early or too late in the implantation stages of intervention. Programme is representational but not gold-plated - Or tests a fundamental notion we need to test By Creating a plan for prioritising evaluations and Seize opportunities as they arise RCTs can be conducted. Randomized evaluation cannot be conducted-when the project is too small to randomly divide into two "representative groups", the programme is premature and still needs significant "tinkering" to function well and when the programme is premature and still needs considerable "tinkering" to function well.

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