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Society of Green World for Sustainable Environment

NAAS Rating : 3.36
Indexed & Abstracted with:
Google Scholar, Summon
Proquest & CNKI Scholar
Ebsco Discovery

Internationally marketed by:
IndianJournals.com
www.Indianjournals.com

• Volume 14
• Number 1
• January - June 2024

Print ISSN 2319-2186
Online ISSN 2322-0996
www.biotechtoday.in
NAAS Accredited
A Peer Review Journal

International Journal of Biological Sciences

BIOTECH TODAY

In this Issue

An International Journal of Biological Sciences

Biotech Today

(A Peer Reviewed Journal)

Volume 14 **Number 1** **January-June 2024**

Published and Printed By

Prof. RS. Sengar
35, Akshardham, Roorkee Road, Modipuram, Meeut-250110 (U.P.)
E-mail : biotechtoday@gmail.com, Mob.: 9412472292, 8868868332
Website: www.biotechtoday.in Printed by: Society of Green World For Sustainable Environment, Meerut (U.P.) India

Online Submission of Manuscripts

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An International Journal of Biological Sciences

Biotech Today

Peer Review Journal

Volume 14 | Number 1 | January - June 2024

In This Issue — Page No.

REVIEW AND RESEARCH ARTICLE

An International Journal of Biological Sciences

Biotech Today

(A Peer Reviewed Journal)

Volume 14	Number 1	January-June 2024

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Biotech Today (January-June 2024) : 14 (1) : 1 - 7

DOI : 10.5958/2322-0996.2024.00008.X

REVIEW ARTICLE

Development of a scale to assess the Role Performance of Field Extension Functionaries

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Received: 21 April, 2023, **Revised**: 10 June, 2023, **Accepted**: 16 November, 2023, **Published**: 1 January, 2024

Abstract

This study aims to develop a valid and reliable scale to measure the role performance of field extension functionaries of the Dairy Development Department, Kerala. An exploratory research design was adopted. Non-stratified random sampling was adopted to select 120 Field Extension Functionaries, of which 60 were Dairy Extension Officers and 60 were Dairy Farm Instructors. Item-content validity index and scale-content validity index were used to measure the content validity of the role performance scale. Cronbach's alpha reliability coefficient was used to determine the internal consistency of the items. Cronbach's alpha was found to be very high and indicates strong internal consistency among the items.

Keywords: Role Performance, field extension functionaries, Dairy Development Department, Exploratory Research design, Non-stratified random sampling, Dairy Extension officer. Dairy farm Instructor, Cronbach's alpha reliability coefficient.

Introduction

The Dairy Development Department (DDD) of Kerala serves as a crucial entity delivering extension services in the dairy sector within the state. Despite recent adversities, Kerala is nearing self-sufficiency in milk production. The department's field extension personnel have significantly contributed to enhancing the state's dairy cooperative sector. Their responsibilities encompass executing dairy and fodder development initiatives, enhancing quality milk output via rural extension and advisory support and fostering collaborations with various stakeholders. According to Patel (2015), role performance refers to how effectively individuals fulfil various job responsibilities associated with their positions. Both a person's role and personality significantly impact their job performance. Over the past few decades, India has introduced numerous dairy development programs aimed at enhancing the nutritional security and socio-economic well-being of rural communities. These programs are predominantly devised and executed by governmental entities, with active involvement from local organizations such as farmer service cooperative societies, financial institutions and non-governmental organizations. The success of these developmental initiatives hinges upon the Field Extension Functionaries (FEFs) tasked with their implementation. FEFs must possess a thorough understanding of their roles and exhibit enthusiasm and innovation in executing their duties to ensure the goals of these programs are met.

Materials and methods

Role performance was operationally defined as the manner and extent to which various duties expected from Field Extension Functionaries (FEFs) were performed as perceived by them in terms of the frequency, level of importance,

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difficulty and effectiveness of performance.

During the initial phase of scale development, the identification of pertinent domains and the creation of items related to these domains were undertaken. This process was conducted with the assistance and guidance of Field Extension Functionaries (FEFs) and selected experts affiliated with the Dairy Development Department (DDD). Thus, a total of 65 items were enlisted under five major domains i.e., office management, field extension activities, management of cooperative societies, implementation of schemes and quality control activities to assess the role performance of the respondents.

Relevancy rating

During the second phase of scale development, a relevancy rating process was conducted. A total of 65 items were assessed by a panel consisting of 33 judges. Each judge was asked to rate the relevance of each item on a three-point scale: 'most relevant', 'relevant' and 'not relevant', corresponding to scores of three, two and one respectively. The highest possible score for a respondent was 99, while the lowest was 33. The midpoint of this scale, ranging from 33 to 99, was determined to be 66, serving as the cut-off point for item selection. Items scoring above 66 were included in the final scale, following this criterion (Kumar, 2003). Out of the initial 65 statements identified, 54 items met this criterion and were thus selected.

Content validation of the scale

In phase three of scale development, content validation of the scale was done. Content validity was conceptualised as the extent to which the items in the measuring instrument were appropriate enough to represent the domain of content, according to various researchers (Waltz *et al.*, 2005; Polit and Beck, 2006). Waltz and Bausell (1981) proposed the 'Content Validity Index (CVI)' as a quantitative assessment of content validity. The CVI is a measure of inter-rater agreement based on expert ranking of items on a scale of relevance to the variable being assessed.

Based on their experience and qualifications, a panel of nine subject matter experts comprised of professors from Dairy Science College, Mannuthy and Assistant directors from DDD were chosen to examine the content validity of the scale. The experts were asked to rank the relevance of the items on a four-point continuum, with scores of 4, 3, 2 and 1 for highly relevant, relevant, slightly relevant and not relevant, respectively.

Item Content Validity (I-CVI) for each statement was then calculated as follows:

I-CVI

$$\frac{\text{Number of experts giving a rating of 3 or 4}}{\text{Total number of experts}}$$

The items with I-CVIs of 0.78 and above were retained (Lynn, 1986), while the others were eliminated, based on the results of content validation. As a result, the scale retained 52 items. The I-CVI values for items that were retained ranged from 0.78 to 1.

The item validated scale was then subjected to content validation at the scale level. The formula for calculating the scale level Content Validity Index (S-CVI) was given below:

Sum of I-CVIs

$$\frac{\text{Sum of I - CVIs}}{\text{Number of items}}$$

As a result, S-CVI of the scale was calculated and determined to be 0.93. This demonstrated that the content validity of the scale was excellent according to Waltz *et al.* (2005).

Reliability analysis of the scale

The degree to which a phenomenon's assessment produces a consistent stable result is referred to as its reliability. Taherdoost (2016) defines reliability as being associated with repeatability. If a test measures the same thing repeatedly, it should produce close or identical results. The consistency with which the test measures what it does determines its reliability (Sarmah and Hazarika, 2012).

In phase four, a reliability analysis of the scale was done. Internal consistency was determined using Cronbach's alpha coefficient, which ensured the scale's reliability. The content validated scale was administered among the 30 FEFs who were selected randomly from the non-sampling area.

The item scores had been correlated with the total score in the subsequent item analysis. Items with correlation values less than 0.2 and greater than 0.8 were eliminated according to Di Iorio's (2005) guidelines. As a result, all of the items were selected from the content validated scale. Cronbach's alpha coefficient was then used to assess the scale's internal consistency. The subscale of perception of effectiveness obtained an alpha coefficient of 0.94, the level of importance obtained an alpha coefficient of 0.89 and the frequency of performance obtained an alpha coefficient of 0.77, all of which were deemed acceptable (Hair *et al.,* 2006). Since there was high internal consistency, all 52 items were selected for the final scale.

Administration of the scale

The final scale developed was administered to the respondents under study. The FEFs were asked to rate the statements of role performance in terms of their frequency of performance, level of importance, performance difficulty and perception effectiveness as follows:

Frequency of performance

It referred to how frequently each task was performed by the FEFs. The scoring pattern adopted was as follows

Category	score
Daily	5
Weekly (Once/twice)	4
Monthly	3
Occasionally	2
Seldom/never	1

Level of importance

It referred to the perception of the respondents about the importance of each task. The scoring procedure was as follows

Category	Score
Extremely important	3
Moderately important	2
Marginally important	1

Performance difficulty/learning

It referred to the degree of difficulty while performing/learning tasks as perceived by the respondents. The scoring was as follows

Category	Score
Very difficult	4
Difficult	3
Moderately difficult	2
Easy	1

Perception of effectiveness

It referred to the perception of the respondents about the effectiveness of each task. The scoring was as follows

Category	Score
Most effective	4
Effective	3
Somewhat effective	2
Not effective	1

The mean score of the respondent was calculated using the formula given below:

$$\text{Mean score of the respondent} = \frac{\text{Score of the respondent}}{\text{No. of items}}$$

The respondents were grouped into three categories based on the mean scores obtained i.e., low, medium and high.

Further, the mean scores of each item were calculated using the formula given below and the items were ranked based on the mean scores obtained:

Mean score of the item

$$\frac{\text{Score of the item}}{\text{Number of respondents}}$$

The mean scores of the major domains were calculated using the formula given below and the domains were ranked based on the mean scores of the major domain obtained:

Mean score of the major domain

$$\frac{\text{Sum of scores of all the items the domain}}{\text{Number of items in the domain}}$$

Table 1. Final scale to measure the role performance of field extension functionaries

		Frequency of performance					Level of importance			**Performance difficulty**				**Perception of effectiveness**			
		1.Seldom/ never 2.Occasionally 3. Monthly 4. Weekly (once/twice) 5.Daily					1. Marginally important 2. Moderately important 3. Extremely important			1. Easy 2. Moderately difficult 3. Difficult 4. Very difficult				1. Not effective 2. Somewhat effective 3. Effective 4. Most effective			
1. Office Management		1	2	3	4	5	1	2	3	1	2	3	4	1	2	3	4
1	Administration of dairy cooperative societies																
2	Office administration																
3	Maintenance of office records																
4	Supervision of office sub-ordinates																
5	Salary disbursement to office subordinates																
6	Financial assistance to scheme beneficiaries																
2. Field Extension Activities																	
1	Dairy farms and famer house visits																
2	Assisting farmers foravailing subsidies and loans																
3	Establishment of fodder demonstration plots and their periodical inspection																
4	Evaluation of various schemes of the department																
5	Consultancy services to dairy farmers regarding dairying activities																
6	Mass media publicity																
7	Conducting farmers contact programmes																
8	Demonstrations on innovative dairy farming practices and value addition																
9	Organising exhibitions, cattle-shows, seminars and study tours for farmers																
10	Enterpreneurship trainings for dairy farmers																
11	Project formulation for dairy start-ups																

12	Preparation of audio-visual aids																	
13	Technical advice for milk marketing																	
14	Organising consumer interface programmes																	
3. Management of co-operativesocieties																		
1	Attending the general body meetings of dairy cooperative societies																	
2	Monitoring the routine activities of milk collection centres and bulk milk chilling units																	
3	Verifying officer duty of pensions and insurance																	
4	Role as arbitrator in arbitration cases against the society or individual																	
5	Returning or electoral officer duty of milk cooperatives managing committee elections																	
6	Supervision of primary dairy cooperative societies																	
7	Periodical inspection of dairy cooperative societies																	
8	Registrationof dairy cooperative societies																	
9	Audit rectification																	
4. Implementation of schemes																		
1	Milk shed development programme																	
2	Assistance to dairy cooperative societies																	
3	Fodder development programmes																	
4	Modernisation of dairy cooperative societies																	
5	Mineral mixture/ Input distribution																	
6	Construction/Renovation of cattle shed																	
7	Subsidy for cattle feed and heifer purchase																	
8	Rural dairy extension and advisory services																	
9	Comprehensive insurance programme																	
10	Strengthening quality control labs																	
11	Implementation of schemes under KDFWFB (Pension to dairy farmers, Family pension, Cremation assistance, Marriage assistance, Education assistance)																	

12	Milk incentives																	
13	Implementation of schemes under local self-government (Cattle feed subsidy, cattle purchase, cattle shed construction, fodder cultivation)																	
5. Quality control activities																		
1	Monitoring milk quality at farmers level																	
2	Assessing milk product quality at the DCSs and quality control labs																	
3	Recommend dairy farmers about clean milk production																	
4	Supervision of quality control labs at the check post																	
5	Conducting intensive quality drive programmes during festival season																	
6	Microbiological evaluation of milk samples to ensure safety and well-being of individuals																	
7	Data collection regarding quality of milk at farmers level and DCSs level																	
8	Assessing and ensuring the quality of market milk available in local market																	
9	Providing necessary infrastructure and equipment's for testing the milk quality																	
10	Reporting any identified adulterated milk to the FSSAI																	

Conclusion

The items for this research were sourced from discussions with experts from DDD and the content validity of these items was assessed through judges' ratings. Reliability and internal consistency were evaluated using Cronbach's alpha coefficient, indicating the accuracy and consistency of the outcomes. Given the enhanced reliability and strong positive relationships among all items in the developed scale, there's no necessity to revise or re-examine individual statements for future research. This scale can effectively gauge FEFs' role performance in terms of performance frequency, importance level, performance difficulty and perceived effectiveness. Strategies for program implementation could be formulated based on the assessed level of role performance. With appropriate adjustments, the scale can extend its utility to assessing FEFs' role performance outside the study area.

Acknowledgment

The authors express their gratitude to the authorities of Kerala Veterinary and Animal Sciences University for their support and the facilities they provided. They also extend their appreciation for the cooperation and assistance received from the Dairy Development Department.

References

De-Iorio, C.K. (2005). Measurement in Health behaviour. *Methods for research and education* (1st Ed.). Jossey-Bass, San Francisco, pp. 336.

Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E. and Tatham, R.L. (2006). *Multivariate data analysis.* (6th Ed.). Upper Saddle River, New Jersey: Pearson University Press. pp. 74.

Kumar, N.V.R. (2003). Training needs of dairy farm instructors of the Dairy Development Department of Kerala. *M.V.Sc. thesis*, College of Veterinary and Animal Sciences, Mannuthy, pp. 140.

Lynn, M.R. (1986). Determination and quantification of content validity. *Nursing Research*. **35:** 382– 385.

Patel, D. (2015). Role performance of field extension functionaries in transfer of technology in dairy sector of Bangalore districts. *Doctoral dissertation thesis*, NDRI, Bengaluru, pp. 88.

Polit, D.F. and Beck, C.T. (2006). The content validity index: are you sure you know what's being reported? Critique and recommendations. *Research in Nursing and Health*. **29:** 489-497.

Sarmah, H.K. and Hazarika, B.B., (2012). Determination of Reliability and Validity measures of a questionnaire. *Indian Journal of Education and Information Management,* **1:** 508-517.

Taherdoost, H. (2016). Validity and reliability of the research instrument; how to test the validation of a questionnaire/survey in a research. *How to test the validation of a questionnaire/survey in a research. International Journal of Academic Research in Management*. **5:** 28-36.

Waltz, C.F. and Bausell, R.B. (1981). *Nursing research: Design, statistics, and computer analysis*. FA Davis company. Philadelphia. pp. 362.

Waltz, C.F., Strickland, O.L. and Lenz, E.R. (2005). *Measurement in nursing and health research*. (3rd Ed.). Springer Publishing Company. New York. pp 448.

Biotech Today (January-June 2024) : 14 (1) : 8 - 16

DOI : 10..5958/2322-0996.2023.00016.9

REVIEW ARTICLE

In vitro propagation protocol for ex situ conservation of *Pyrenaria khasiana* var. lakhimpurensis Odyuo and D. K. Roy - an endemic plant to Eastern Himalaya

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Received: 24 April, 2023, **Revised**: 21 June, 2023, **Accepted**: 10 August, 2023, **Published**: 1 January, 2024

Abstract

An agile and reproducible protocol for *in vitro* propagation of *Pyrenaria khasiana* var. *lakhimpurensis*, an endemic plant to eastern Himalaya was carried out successfully. The mature seeds of this tree were collected from semi-evergreen forest of Dullung Reserve Forest, North Lakhimpur district of Assam. *In vitro* seed germination, multiple shoot induction and *in vitro* rooting experiments were carried out in Woody Plant medium. Benzyladenine alone and Benzyladenine in combination with Gibberellic acid was tried for multiple shoot induction. Benzyladenine (8 mg/L) gave highest number of shoots (2.4) per explant with a maximum shoot length of 1.45 cm observed at BA (1 mg/L). The combination of Benzyladenine (1 mg/L) and Gibberellic acid (4 mg/L) gave highest number of shoots (5.2) per explant with a maximum shoot length of 4.43 cm. 1 node, 2 nodes and 4 nodes were used for multiple shoot induction studies and it was observed that 4 nodes gave optimum number of shoots (40.82) and shoot length (5.039 cm) after 4 weeks of experiment. Among the auxins investigated for root induction, indole butyric acid IBA at 2 mg/L gave the highest number of roots (10.3 per shoot) with root length of 2.35 cm. Survival rate of *in vitro* raised seedlings was found to be 70% when transferred from laboratory to land. This is the first scientific report on tissue culture of the genus *Pyrenaria* of Theaceae family.

Keywords: endemic, *Pyrenaria khasiana* var. *lakhimpurensis*, *in vitro* propagation, *ex situ* conservation

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Introduction

The family Theaceae is of great economic and medicinal significance, consisting of nine genera and potentially up to 460 species. Its highest diversity is found in subtropical and tropical forests, particularly in Southeast Asia (Prince, 2007; Odyuo and Roy, 2017a). One notable genus within this family is *Pyrenaria* Blume, which includes 31 species, one subspecies, and four varieties. This genus is distributed from northeastern India and northern Myanmar to the Malaysian region, spanning southwestern China and the Indochina Peninsula (Yang *et al*., 2000; Li *et al*., 2011; WCSP, 2016; Tropicos, 2016). *Pyrenaria* is a less-known genus in India with a narrow range of distribution and comprises five taxa so far namely *P. barringtoniifolia* Seem. (Assam, Arunachal Pradesh and Meghalaya), *P. cherrapunjeana* Mir. (Meghalaya), *P. diospyricarpa* Kurz var. *diospyricarpa* (Assam), *P. khasiana* R. N. Paul (Meghalaya) and *P. khasiana* R. N. Paul var. *lakhimpurense* N. Odyuo and D.K. Roy (Assam) (Chauhan and Paul, 1993; Odyuo and Roy, 2017a, b; Upadhaya *et al*., 2017; Sarma *et al*., 2017).

Pyrenaria khasiana var. *lakhimpurensis* Odyuo & D. K. Roy (Fig. 1a) is endemic to the eastern Himalayas, and was described by Odyuo and Roy in 2017. This discovery was based on collections from Dullung and Kakoi Reserve Forest in North Lakhimpur district, Assam. It was initially reported from the southern foothills of the Himalayas in the district of North Lakhimpur, Assam, bordering Arunachal Pradesh, at an altitude of 171 meters (N27°24´36´´, E94°11´42´´) in 2011. (Sarma *et al.*, 2017) came across the same Theaceae species while exploring the Sonitpur District of Assam.

It is a shrub or small tree up to 5 m, barks brown or brownish grey. Young branches sparsely pubescent. Leaves oblanceolate to spathulate, 22–25 × 8.5–10.5 cm, simple, alternate, leathery, serrate, glabrous above, sparsely pubescent below, margins serrate, midrib raised below, depressed above, secondary veins 17–22, depressed above and raised below, base attenuate to cuneate, apex long acuminate; petioles sparsely pubescent in young, later glabrascent to 0.7 cm long. Flower bisexual, axillary, solitary, *c.* 4.5 cm across; pedicel silky villous, 0.3 × 0.2 cm; bracteoles 2, ovate, 0.2–0.25 × 0.25– 0.3 cm, non-foliaceous, leathery, silky villous outside, glabrous inside, apex obtuse Sepals persistent, 7, ovate, orbicular to obovate, 0.5–1.5 × 0.7–1.2 cm, non-foliaceous, silky villous outside, glabrous inside. Petals 7, white, unequal, oblanceolate–obovate, 1.0–2.0 × 0.5–1.5 cm, silky villous outside, glabrous inside, apex rounded. Stamens numerous, basally connate; filaments glabrous, *c.* 1 cm long, outer whorl slightly adnate to petals; anther dorsifixed, bilobed. Ovary superior, globsose, 5-loculed, 0.3–0.4 cm long, axile placentation; style 5, free, *c.* 0.7 cm long. Fruit subglobose, 2.5–3.5 × 2.3–3.2 cm, glabrous, apex crowned with 5 stigmatic protuberances, with persistent calyx at base, 5-loculed, fleshy; pericarp yellowish, *c.* 0.4–0.6 cm thick, fleshy when fresh but becoming spongy when dry. Seeds 5–7, 0.8–1 cm, laterally compressed hemispheric, occasionally 2 per locule; testa bony. Flowering & Fruiting: February – August. This species is closely related to *P. khasiana* R.N. Paul but differs from it by pedicel silky villous (vs glabrous), bracteoles non-foliaceous (vs foliaceous), sepals ovate, orbicular to obovate, non-foliaceous (vs suborbicular, foliaceous) and petals oblanceolate-obovate (vs obovate to suborbicular).

Reviewing the protologue data and considering the current population, density, distribution area, and other factors in consultation with the IUCN categorization guidelines, this taxon can be classified as Critically Endangered- B1B2 (a, b); C2a (i); D category (Sarma *et al.*, 2017). Given that this species falls under the Critically Endangered category, its conservation is of utmost importance. To conserve this threatened Theaceous variety, both *ex situ* and *in situ* methods should be employed.

Species conservation primarily relies on the management of natural populations and their native habitats, known as *in situ* conservation. However, *ex situ* techniques can play a complementary role in conservation efforts (Maunder *et al.*, 1998; Ramsay *et al.*, 2000). In particular, *in vitro* propagation is a highly effective method for rapidly cultivating endangered plant species that have limited reproductive capabilities and are found in threatened environments (Fay, 1994). Plant tissue culture is an important propagation technique to reproduce plants on a superior scale in a short time (Singh, 2018). Micropropagation, which offers several advantages over traditional vegetative propagation, holds significant promise for supporting conservation initiatives and harnessing genetic diversity (Azad *et al.*, 2022). This technique is of particular importance for rare and endangered endemic plant species, as it enables the establishment of cultures from minimal initial plant material for subsequent multiplication (Benson *et al.*, 2000).

Till date, there have been no reports on *in vitro* propagation of *Pyrenaria* species. Consequently, the central aim of this research is to pioneer the development of a highly effective *in vitro* protocol for the mass multiplication of this species. This endeavour is poised to make a substantial contribution to the preservation of this distinctive plant species within its native habitat. Remarkably, this study represents the inaugural effort to establish a successful micropropagation technique for the conservation of this endemic species native to the eastern Himalayas.

Materials and Methods

Collection of explants

The mature fruits (Fig. 1b) were collected from Dullung Reserve Forest, North Lakhimpur district of Assam.

In vitro seed germination

Woody Plant Medium (WPM, Lloyd and McCown 1981) supplemented with 3% (*w/v*) sucrose and 0.8% agar (*w/v*) was used for *in vitro* seed germination studies. pH of the medium was adjusted to 5.8. About 50ml of the medium was dispended in 250 ml conical flask (Borosil Glass Works Ltd., Mumbai, India). Seeds (Fig. 1c) were disinfected with 10% (*v/v*) sodium hypochlorite solution (4% w/v solution, HiMedia Laboratories Pvt. Ltd.) with 2-3 drops of Tween®-80 liquid detergent per 100ml for 15-20 minutes, subsequently washed 4-5 times in sterile distilled water under laminar air flow chamber. Five seeds per 250ml conical flask were inoculated and all cultures were maintained in culture room under warm white fluorescent light at a 16h photoperiod and at 25±2°C. Initiation of germination was recorded after two weeks of culture.

Multiple shoot induction

Nodal segments from 2 months old aseptic seedlings were cultured on WPM containing various concentrations of 6-Benzylamino-purine (6-BAP) (0.5, 1, 2, 4, 8 mg/L) alone and in combination with Gibberellic acid (GA_3) (0.5, 1, 2, 4, 8 mg/L) were used for multiple shoot induction. pH was adjusted to 5.8 and gelled with 0.8% agar (*w/v*) before autoclaving at 121°C for 20 minutes at 1.05 kg/cm^2 pressure. Basal WPM was used as control and the experiments were repeated thrice with ten replicates per treatment. 1 node, 2 nodes and 4 nodes explants were also tested for better shoot proliferation. Cultures were maintained at 25±2ºC temperature under 16/8 hr (light/dark) photoperiod under white fluorescent light. Ten replicates were set up per experiment for comparing the effect of different concentrations of growth regulators and the experiments were repeated thrice. Observation for shoot initiation and number of shoots produced were recorded after 3 weeks and up to 12 weeks of culture.

Rooting

In vitro raised shoots of approximately 5 to 6 cm length isolated from healthy shoot clump were used for *in vitro* rooting. WPM gelled with 0.8% agar supplemented with different concentrations of auxins *viz.*, -Naphthalene acetic acid (NAA), Indole butyric acid (IBA) and Indole-3-acetic acid (IAA) were tested for root induction. Data for root initiation, number of roots and the root length were recorded after 8 weeks of culture. The experiment was repeated thrice with 10 replicates per treatment.

Data Analysis

Data analysis was conducted using OriginPro 8SRO v8.0725 (B725) software developed by OriginLab® Corporation based in North-ampton, MA. To compare the means of different treatments, a one-way ANOVA (Analysis of Variance) was performed. Tukey's test was then used to determine significant differences between treatment means at a significance level of P = 0.05.

Acclimatization

Healthy *in vitro* grown plants with well-developed roots (Fig. 1j) were carefully removed from the conical flask to avoid any damage to the plant. They were then washed with tap water to remove any residual media clinging to the roots. To minimize microbial infection, the plants were dipped in 0.1% Bavistin (w/v) solution for one hour. After the treatment, the plants were rinsed with tap water and transferred to polythene bags filled with a mixture of garden soil and leaf mould in a 1:1 ratio and kept in polyhouse (i.e., 25°C, RH 60%). The plants were watered on every alternate day and survival percentage was noted.

Results and discussion

In vitro seed germination

In vitro seed germination was found to be remarkably efficient on basal WPM (Fig. 1d), with the majority of seeds demonstrating signs of germination within a short time frame of just 2 weeks. This rapid response to the basal WPM indicates its suitability as a nutrient-rich substrate for initiating seed germination in *Pyrenaria khasiana* var. *lakhimpurensis*. However, an intriguing observation was the cessation of seed germination beyond the 8^{th} week of culture, which suggests a possible limitation or shift in the physiological state of the seeds as they progress in culture.

Multiple shoot induction

Effect of 6-BAP and GA_3 on shoot multiplication. In this study, the combination of 6-BAP at 1 mg/L and GA_3 at 4 mg/L proved to be the most effective treatment for promoting multiple shoot from nodal explants (Fig. 1e). This combination resulted in the highest number of shoots per explant, with a maximum of 5.2 shoots observed after 12

Table 1. Effect of different concentrations of 6-BAP alone and in combination with GA3 in multiple shoot induction

BA (mg/L)	GA3 (mg/L)	3^{rd} Week		6^{th} Week		9^{th} Week		12^{th} Week	
		No. of shoots	Shoot length (cm)	No. of shoots	Shoot length (cm)	No. of shoots	Shoot length (cm)	No. of shoots	Shoot length (cm)
0	0	0.6^{de}	0.19^{gh}	0.7^{fg}	0.26^{ef}	0.75^{e}	0.34^{g}	0.7^{g}	0.48^{g}
0.5	-	1.1^{cd}	0.25^{gh}	2.1^{ab}	0.56^{ef}	2.1^{bcd}	0.72^{efg}	2.3^{cdef}	0.83^{efg}
1	-	1.4^{bc}	0.36^{fgh}	1.8^{abcd}	0.82^{def}	1.8^{bcde}	1.21^{defg}	2.2^{cdefg}	1.45^{cdefg}
2	-	0.9^{cd}	0.22^{gh}	1.6^{bcde}	0.6^{ef}	1.5^{bcde}	0.8^{efg}	1.8^{defg}	1.09^{defg}
4	-	0.7^{d}	0.19^{gh}	1.7^{abcd}	0.38^{ef}	1.7^{bcde}	0.62^{fg}	2^{cdefg}	0.77^{fg}
8	-	0.9^{cd}	0.24^{gh}	1.7^{abcd}	0.25^{ef}	1.9^{bcde}	0.37^{g}	2.4^{cde}	0.81^{efg}
0.5	0.5	0.9^{cd}	1.37^{ab}	0.8^{efg}	1.95^{a}	1^{de}	2.41^{abcd}	1^{efg}	2.85^{bcd}
0.5	1	0.7^{d}	0.53^{efg}	0.7^{fg}	0.71^{ef}	0.7^{e}	1.44^{cdefg}	0.8^{fg}	2.41^{bcdef}
0.5	2	1.1^{cd}	1.24^{abc}	1.2^{cdef}	1.6^{abcd}	1.9^{bcde}	2.39^{abcd}	2.5^{cde}	2.46^{bcde}
0.5	4	1^{cd}	$.92^{bcde}$	1.3^{bcdef}	0.89^{cde}	1.8^{bcde}	1.77^{bcdef}	1.9^{defg}	2.35^{bcdef}
0.5	8	0.8^{cd}	0.66^{defg}	1^{def}	0.97^{cde}	1.7^{bcde}	1.73^{bcdefg}	2.7^{bcd}	2.03^{cdefg}
1	0.5	1.4^{bc}	0.98^{bcde}	1.7^{abcd}	0.89^{cde}	2.5^{abc}	1.64^{bcdefg}	3.5^{bc}	1.78^{cdefg}
1	1	1.8^{ab}	1.55^{a}	2^{abc}	1.86^{ab}	2.1^{bcd}	2.9^{ab}	2.7^{bcd}	3.96^{ab}
1	2	1.4^{bc}	1.14^{abcd}	2.1^{ab}	1.76^{abc}	2.7^{ab}	2.83^{abc}	4.1^{ab}	3.96^{ab}
1	4	2.3^{a}	1.54^{a}	2.5^{a}	2.12^{a}	3.7^{a}	3.75^{a}	5.2^{a}	4.43^{a}
1	8	0.6^{de}	0.78^{cdef}	0.6^{fg}	1.02^{bcde}	0.8^{e}	1.2^{defg}	1^{efg}	1.49^{cdefg}
2	0.5	0^{e}	0^{h}	0^{g}	0^{g}	1.9^{bcde}	0.89^{efg}	1.9^{defg}	1^{defg}
2	1	0^{e}	0^{h}	0^{g}	0^{g}	1.6^{bcde}	1.03^{defg}	1.6^{defg}	1.09^{defg}
2	2	0^{e}	0^{h}	0^{g}	0^{g}	1.9^{bcde}	1.12^{defg}	2.2^{cdefg}	1.32^{cdefg}
2	4	0^{e}	0^{h}	0^{g}	0^{g}	1.4^{cde}	1.34^{defg}	1.8^{defg}	2.21^{cdef}

weeks of culture. Moreover, these shoots achieved a maximum length of 4.43 cm, indicating their remarkable ability to enhance both shoot proliferation and elongation (Table 1). These results underscore the synergistic effects of 6-BAP and GA_3 on shoot organogenesis.

Cytokinins like 6-BAP are typically employed to stimulate growth and development, particularly promoting cell division. At higher concentrations, they can induce adventitious shoot formation while inhibiting root formation (Widhianata, 2019). Additionally, the presence of GA_3 played a crucial role in inducing shoot elongation, resulting in prominent nodal segments that could be used for further multiplication during subculture (Gonbad *et al.,* 2014).

On the other hand, gibberellins, such as GA_3, generally induce internode elongation and growth of plants or buds *in vitro* and they are known to break dormancy in isolated embryos or seeds. Gibberellins tend to inhibit the formation of adventitious roots. (Gana, 2010).

Furthermore, it was observed that 6-BAP alone produced only two-three shoots and higher concentrations of 6-BAP resulted in a reduction in the number of shoots, necrosis and shoot fasciations. This reduction in shoot numbers may be attributed to the inhibition of adventitious meristem elongation, possibly due to the use of higher 6-BAP concentration (Borchetia *et al*., 2009).

Data were statistically analyzed using one-way ANOVA and Tukey's test (P = 0.05) in Origin Pro 8SRO v8.0725 (B725). Each value is the average of three replications (*n* = 10). Different letters following numbers in the same column indicate significant differences, while means with the same letters are not significantly different.

Fig. 1. (a) *Pyrenaria khasiana* var. *lakhimpurensis* mother plant in its natural habitat (b) Mature fruits (c) Seeds inoculated for *in vitro* germination (d) *In vitro* seed germination on Woody Plant Medium (WPM) (e) Multiple shoot initiation on WPM with 6-BAP at 1 mg/L and GA_3 at 4 mg/L after 4 weeks in culture (f) Multiple shoots developed using 1 node (g) Multiple shoots developed using 2 nodes (h) Multiple shoots developed using 4 nodes (i) *In vitro* rooting after 12 weeks in culture on WPM containing 2 mg/L IBA (j) *In vitro* rooted plants ready for acclimatization (k) Six months old healthy plants grown in polythene bags for acclimatization (l) Established plant in office garden of BSI, Shillong.

Effect of node number on shoot multiplication

Node culture is a tissue culture method in which axillary shoot buds from shoots taken during active or resting period are transferred to artificial nutrient medium and developed into plants. A complete plant can be obtained from different organs of the plant such as buds, leaves, shoots and roots. These organs can be reproduced in a short time when they are cultured in artificial media under sterile conditions. A large number of plants are produced using micropropagation (Gulzar *et al.*, 2020).

The results of the multiple shoot induction experiment conducted over a 4-month period with different numbers of nodal explants revealed interesting results (Table 2). It is evident from the data that when using a single node explant, both the number of shoots and their length gradually increased from the first to the fourth month of culture. This observation implies that a single node explant can effectively generate multiple shoots over time, reaching its peak with 7.82 shoots in the fourth month, along with a significant increase in shoot length, which extended to 4.51 cm (Fig. 1f). These results underscore the impact of the number of nodal explants on multiple shoot induction, influenced by the varying physiological and developmental characteristics of these explants. The gradual increase in shoot numbers and length observed with single node explants over the 4-month period suggests that, although slower to initiate, they can serve as a sustained and reliable source of multiple shoots. This finding aligns with (Chen *et al.,* 2020) that have advocated for the utilization of single-node explants in long-term micropropagation protocols.

In contrast, when using two nodes or four nodes, the number of shoots and shoot length increased substantially. Explants with two nodes exhibited a remarkable surge in shoot numbers, with 24.3 shoots produced in the fourth month, and a steady increase in shoot length (5.66 cm) across the months (Fig. 1g). Similarly, explants with four nodes displayed an even more pronounced increase in shoot numbers, attaining 40.82 shoots in the fourth month. Although the shoot length fluctuated slightly, it remained relatively high (5.039 cm) (Fig. 1h). These findings indicate that explants with two or four nodes result in a rapid and robust response in terms of multiple shoot induction. On the other hand, explants with two or four nodes exhibited a more rapid and vigorous response in the early months of culture, producing a larger number of shoots. This may be associated with the presence of more meristematic regions and an increased potential for axillary bud outgrowth in multi-node explants. These results corroborate with the findings of (Buckseth *et al.*, 2017) and (Venkatasalam *et al.*, 2012) where they emphasize the rapidity of response associated with multi-node explants.

Table 2. Response of different nodal explants on shoot number and shoot length in 6-BAP at 1 mg/L and GA_3 at 4 mg/L combination

No. of nodal explants	1 month		2 months		3 months		4 months	
	No. of shoots	Shoot length(cm)	No. of shoots	Shoot length(cm)	No. of shoots	Shoot length(cm)	No. of shoots	Shoot length(cm)
1 node	2.39c	3.38a	4.47c	3.98a	5c	4.32a	7.82c	4.51a
2 nodes	11.04 b	3.45a	15.95 b	4.65a	21.21 b	4.91a	24.30 b	5.66a
4 nodes	17.34 a	3.8a	22.69 a	4.65a	35.21 a	4.25a	40.82 a	5.039 a

Data were statistically analyzed using one-way ANOVA and Tukey's test (P = 0.05) in Origin Pro 8SRO v8.0725 (B725). Each value is the average of three replications (n = 10). Different letters following numbers in the same column indicate significant differences, while means with the same letters are not significantly different.

Rooting

Among the auxins tested, IBA exhibited a dose-dependent effect on root development (Table 3). At lower concentrations (0.5 mg/L), IBA led to 2.3 roots with a root length of 0.85 cm, while at 1 mg/L, the number of roots increased to 9.2, and root length extended to 1.73 cm. The highest IBA concentration (2 mg/L) yielded the most promising results, with an average of 10.3 roots and a significantly enhanced mean root length of 2.35 cm (Fig. 1i). Similar results were reported in *Camellia japonica* L. (Wojtania *et al.*, 2011) where the best rooting response was observed in IBA. At higher IBA concentrations (4 mg/L and 8 mg/L), the number of roots and root length remained relatively stable, though slightly lower than the optimal 2 mg/L concentration.

In case of IAA and NAA, the effect on root development was less pronounced. Regardless of the concentration, IAA and NAA treatments resulted in only a limited number of roots, with IAA producing root lengths ranging from 0.865 cm to 1.125 cm and NAA inducing root lengths between 1.14 cm and 1.64 cm. Rooting was also observed in hormone-free WPM. But it was observed that the number of roots was less and root length was not comparable with hormone based medium results. This suggests that the presence of endogenous salicylic acid, an important compound for plant development and growth, including *in vitro* rooting, is the factor that causes adventitious roots to form on auxin-free basal media (Khan *et al.*, 2011).

Table 3. Effect of different auxins on root induction after 8 wk in culture

PGR	Concentration (mg/L)	Mean no. of roots	Mean root length (cm)
control	-	3.4[c]	0.96[ef]
IBA	0.5	2.3[c]	0.85[f]
IBA	1	9.2[ab]	1.73[bcd]
IBA	2	10.3[a]	2.35[b]
IBA	4	7.5[ab]	1.53[cdef]
IBA	8	7[b]	1.92[bc]
IAA	0.5	2.5[c]	1.125[def]
IAA	1	2.65[c]	0.97[ef]
IAA	2	2.05[c]	0.865[f]
IAA	4	3.15[c]	1.2d[ef]
IAA	8	2.5[c]	1.04[def]
NAA	0.5	2.6[c]	1.64[bcde]
NAA	1	2[c]	1.6[cde]
NAA	2	2[c]	1.32[cdef]
NAA	4	1.8[c]	1.14[def]
NAA	8	1.6[c]	1.26[cdef]

Data were statistically analyzed using one-way ANOVA and Tukey's test (P = 0.05) in Origin Pro 8SRO v8.0725 (B725). Each value is the average of three replications (n = 10). Different letters following numbers in the same column indicate significant differences, while means with the same letters are not significantly different.

Acclimatization and reintroduction

Approximately 70% (300 Nos.) of *in vitro* raised plantlets, which had developed roots, successfully adapted to greenhouse after twelve weeks of transplanting and were found to be growing well (Figure 1k). No abnormalities were observed and regenerated plants were morphologically similar to the mother plant.

Around 60 acclimatized plants were introduced to enhance the greenery at BSI, ERC office garden in Shillong and the Experimental Botanic Garden in Barapani, Shillong (Fig. 1l). Approximately 100 plants have been distributed to various organizations, institutions and stakeholders in Meghalaya for reintroduction. The remaining acclimatized plants have been preserved, with the intention of facilitating future reintroductions and distributing them to botanical gardens that share similar climatic conditions, thus contributing to their *ex situ* conservation efforts.

Acknowledgment

The authors are thankful to Director, Botanical Survey of India, Kolkata for the constant encouragement and facilities. The authors also extend their appreciation to the Head of Office, Botanical Survey of India, Eastern Regional Centre, Shillong for providing necessary resources and support throughout the study.

References

Azad M.A.K., Adhikari M., Sarker M.N.A., Hasan A.N.M. and Amin M.N. (2022). *In vitro* shoot regeneration from nodal and shoot tip explants of a threatened medicinal plant - *Smilax zeylanica* L. *Journal of Bio-Sciences*, **30(1):** 69-78.

Benson E.E., Danaher J.E., Pimbley I.M., Anderson C.T., Wake J.E. and Adams L.K.

(2000). *In vitro* micropropagation of *Primula scotica*: a rare Scottish Plant. *Biodiversity and Conservation*, **9:** 711–726.

Borchetia S., Das S.C., Handique P.J. and Das S. (2009). High multiplication frequency and genetic stability for commercialization of the three varieties of micropropagated tea plants (*Camellia* spp.). *Scientia Horticulturae*, **120:** 544–550.

Buckseth T., Singh R.K., Sharma A.K., Sharma S., Moudgil V. and Saraswati A. (2017). Influence of node number and orientation of explants on *in vitro* growth and development of potato. *Cytologia*, **83(1):** 19–22.

Chauhan A.S. and Paul T.K. (1993). Theaceae. In B.D. Sharma and M. Sanjappa (Eds.), Flora of India 3. *Botanical Survey of India*. (pp. 152–193)

Chen S., Xiong Y., Wu T., Wu K., Teixeira da Silva J.A., Xiong Y., Zeng S. and Ma G. (2020). Axillary shoot proliferation and plant regeneration in *Euryodendron excelsum* H. T. Chang, a critically endangered species endemic to China. *Scientific Reports*, **10,** 14402.

Fay, M.F., (1994). In what situations is *in vitro* culture appropriate to plant conservation? *Biodiversity and Conservation*, **3:** 176-183.

Gana, A.S. (2010). The role of synthetic growth hormones in crop multiplication and improvement. *African Journal of Biotechnology*. **10(51):** 10330–10334.

Gonbad R.A., Sinniah U.R., Aziz M.A. and Mohamad R. (2014). Influence of cytokinins in combination with GA_3 on shoot multiplication and elongation of Tea Clone Iran 100 (*Camellia sinensis* (L.) O. Kuntze). *The Scientific World Journal*. https://doi.org/10.1155/2014/943054

Gulzar B., Mujib A., Malik M.Q., Mamgain J., Syeed R. and Zafar N. (2020). Plant tissue culture: agriculture and industrial applications. *Transgenic Technology Based Value Addition in Plant Biotechnology*.

Khan M.I., Ahmad N. and Anis M. (2011). The role of cytokinins on *in vitro* shoot production in *Salix tetrasperma* Roxb.: A tree of ecological importance. *Trees*, **25:** 577–584.

Li R., Yang J.B., Yang S.X. and Li D.Z. (2011). Phylogeny and taxonomy of the *Pyrenaria complex* (Theaceae) based on nuclear ribosomal ITS sequences. *Nordic Journal of Botany*, **29(6):** 1–8.

Maunder M., Higgens S. and Culham A. (1998). Neither common nor garden: the garden as a refuge for threatened plant species. *Curtis' Botanical Magazine*, **15:** 124–132.

McCown B.H. and Lloyd G.B. (1981). Woody Plant Medium (WPM)—A mineral nutrient formulation for microculture of woody plant species. *HortScience*, **16:** 453-453.

Odyuo N. and Roy D.K. (2017a). *Pyrenaria khasiana* R.N. Paul var. *lakhimpurense* (Theaceae), a new variety from Assam, India. *Taiwania*, **62(1):** 29–32.

Odyuo N. and Roy D.K. (2017b). Recollection of *Pyrenaria khasiana* (Theaceae) in India after more than a century. In P. Medhi & H. Roy (Eds.), Compendium on *Botanical Research in Eastern India* (pp. 320–326).

Prince, L.M., (2007). A brief nomenclatural review of genera and tribes in Theaceae. *Aliso*, **24(1):** 105–121.

Ramsay M.M., Jackson A.D. and Porley R.D. (2000). A pilot study for the *ex situ* conservation of UK bryophytes. In *BGCI* (ed. *EuroGard*) *2000 – II European Botanic Gardens Congress* pp. 52–57.

Sarma J., Roy D.K., Sarania B. and Devi A. (2017). A note on extended distribution and IUCN status of *Pyrenaria khasiana* R.N. Paul var. *lakhimpurense* - an endemic Theaceous plant of Eastern Himalaya. *NeBIO: An International Journal of Environment and Biodiversity*, **8(2):** 108–110.

Singh, C.R., (2018). Review on problems and its remedy in plant tissue culture. *Asian Journal of Biological Sciences*, **11(4)**.

Tropicos. (2016). Facilitated by the Missouri Botanical Garden. Retrieved on May 20, 2015, from http://www.tropicos.org/

Upadhaya K., Mir A.H., Roy D.K. and Odyuo, N. (2017). A new species of *Pyrenaria* (Theaceae-Theoideae) from Northeast India. *Telopea*, **20:** 35–40.

Venkatasalam E.P., Singh B.P., Pandey K.K., Latawa J., Sharma S., Sood R. and Thakur, V. (2012). Effect of carbon sources and explants on *in vitro* multiplication of potato. *Potato Journal*, **39(2):** 166–172.

WCSP., (2016). World checklist of selected plant families. Facilitated by the Royal Botanic Gardens, Kew. Retrieved on May 20, 2015, from http://apps.kew.org/wcsp/

Widhianata, H. (2019). Organogenesis responses of tea (*Camellia sinensis* (L.) O. Kuntze) var. *assamica* and *sinensis*. *AIP Conference Proceedings*, **2099:** 020026. https://doi.org/10.1063/1.5098431

Wojtania A., Gabryszewska E. and Podwyszynska M. (2011). The effect of growth regulators and sucrose concentration on *in vitro* propagation of *Camellia japonica* L. *Propagation of Ornamental Plants*, **11:** 177–183.

Yang S. X., Gong X., Peng H. and Wu Z.-Y. (2000). A cytotaxonomic study on the genus *Pyrenaria* Complex (Theaceae). *Caryologia*, **53(3–4):** 245–253.

Biotech Today (January-June 2024) : 14 (1) : 21 - 29

DOI : 10.5958/2322-0996.2024.00002.1

RESEARCH ARTICLE

Standardization of growing media for cost effective production of Capsicum seedling under naturally ventilated polyhouse in Kumaon Region

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Received: 16 July, 2023, **Revised**: 8 August, 2023, **Accepted**: 24 August, 2023, **Published**: 1 January, 2024

Abstract

Production of healthy and vigorous capsicum seedling is most important factor in successful commercial production and yield and quality of capsium fruits. Moreover, germination of the seed is a critical, because the rest of the plant life is directly dependent upon the rate of its germination. Therefore, this experiment was conducted to investigate the effect of various locally available seedlings growing media on seedling growth of capsicum seedlings as well as growth and yield of capsicum inherent with the nutrients with seedling growing medium ball. Different cost effective growing media treatments were used viz., soil, FYM, vermicompost, forest litter alone or in combination in equal proportion to raise the seedlings of capsicum cv. California Wonder in portrays under naturally ventilated polyhouse at ICAR-CITH Regional Station, Mukteshwar, Nainital (UK) during 2016-17 and 2017-18. The objective of this study was to determine the best growing media (soil alone and its different combinations with farm yard manure, vermicompost and forest litter) in portray for healthy seedling and germination percentage of pepper cv. California Wonder under polyhouse conditions. The results of the study showed that mixture of media significantly increased length, diameter and weight of seedling. However, maximum seed germination (82.50 %) recorded in FYM+VC and VC+FL media. Whereas, highest seedling height (16.12 cm) and girth (2.61 mm) found in FYM media. The seedling raised in soil+vermicompost media produced maximum number of secondary roots/seedling (51.20). The plants of which seedlings were raised in soil+FYM+VC+FL media produced maximum average fruit weight (98.43g) whereas, maximum fruit yield/plant (1.42 Kg.) recorded with the plants of which seedlings were grown in FYM+VC+FL media. The maximum benefit: cost ratio (3.16) of seedling production of capsicum cv. California Wonder was found with seedlings produced in the FYM growing media.

Key word: Capsicum, growing media, growth, nursery, seedling, yield

Introduction

Sweet pepper (*Capsicum annuum* var. grossum) is an important vegetable crop of solanaceous group, used worldwide for domestic and commercial purposes (Khan *et al.,* 2012). One of the most important cultural inputs involved in greenhouse crop production, perhaps the most important is the type of growing media used (Angin *et al.,* 2011). Raising of seedlings is a foremost important aspect of capsicum production. Nursery is the place where young seedlings are raised and nurtured before planting them in the main field. For raising a good crop, it is utmost essential that seedling should be healthy, vigorous and disease-free. Seedlings are susceptible to a number of diseases due to

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its delicate, succulent and highly tender nature. To ensure high productivity and high quality of the produce, raising of high quality seedlings through use of good quality seeds at right time and at an appropriate place is one of the important aspects of vegetable farming. It is also a well-known fact that productivity of a crop plant is affected to the great extent with the care taken at its initial growth (Nicola and Basoccu, 1994).

Rapid evaporation under greenhouse due to high temperature causes salinity at upper layers of soil. It is suggested to improve soil characteristics the supplement of organic matter, soil disinfection and soil change (Sevgican, 1999a; Grangvist, 1981). For this reason, the most suitable media should be selected for capsicum. Different substrates have several materials which could have direct and indirect effects on plant growth and development. Therefore, selecting the best substrate between the various materials is imperative to plant productivity. This study was conducted to evaluate best growing media for length, diameter, weight of fruit, fruit number per plant, yield of fruit of pepper cultivars under greenhouse conditions.

Materials and Methods

The present investigation was carried out in the controlled greenhouse during summer Kharif 2017-18 at the ICAR-Central Institute of Temperate Horticulture, Regional Station, Mukteshwar (Uttarakhand), located in the Nainital district, (29°0'to 29°5'N; 78°80'to 80°14'E), has a sub humid to semiarid temperate climate. The area encompasses towering mountains (altitudes of 700–2400 m masl) and is dominated by rugged terrain and steep slopes (25–34%).The experiments was laid out in randomized complete block design (RCBD) consisting of fourteen treatments, three replications and one variety. The treatments were used for this experiment based on soil media alone and in combinations of FYM, vermicompost and forest litter. All nursery management practices were carried out as recommended. Seeds of Capsicum cv. California Wonder were obtained from ICAR-Central Institute of Temperate Horticulture Regional Station Mukteshwar. The following treatments were used:

- T_1-(Control): Soil alone,
- T_2-Farm yard manure alone,
- T_3-Vermicompost alone,
- T_4-Forest litter alone,
- T_5-Soil+FYM (1:1),
- T_6-Soil+Vermicompost (1:1),
- T_7-Soil+Forest litter (1:1),
- T_8-FYM+Vermicompost (1:1),
- T_9-FYM+Forest litter (1:1),
- T_{10}-Vermicompost+Forest litter (1:1),
- T_{11}-Soil+FYM+Vermicompost (1:1:1),
- T_{12}-Soil+FYM+Forest litter (1:1:1),
- T_{13}-Soil+FYM+Vermicompost+Forest litter (1:1:1:1),
- T_{14}-FYM+Vermicompost+Forest litter (1:1:1):1.

Seeds of pepper cultivar California Wonder were initially sown in pro trays filled with soil, FYM, Vermicompost, Forest Litter alone and different mixture combinations thereof. The seedlings were transplanted at the age of 40 days in naturally ventilated polyhouse. After the seedling stage, height of seedling above the top surface of the potting media was measured. Seedlings were carefully removed from all the protray. The mix adhering to the roots of seedlings was washed using tap water. Freshly washed seedling was placed in paper envelop and dried in an oven at 60°C for 24 hr (Thompson, 1985). The dry weight of each Seedling was recorded using an electronic weighing balance. Seed germination percent was calculated by dividing the total number of seeds sown in a tray with total number of seeds emerged and multiply it with 100. Similarly, leaf number was measured cumulatively at the time of transplanting stage of seedlings. The benefit cost ratio calculated on the basis of the entire nursery production and management components. under polyhouse. Data were subjected to analysis of variance (ANOVA) using Analytical Software to compare the effects of media and to test the significance of differences at P > 0.05.

Results and Discussion

Seedling characteristics

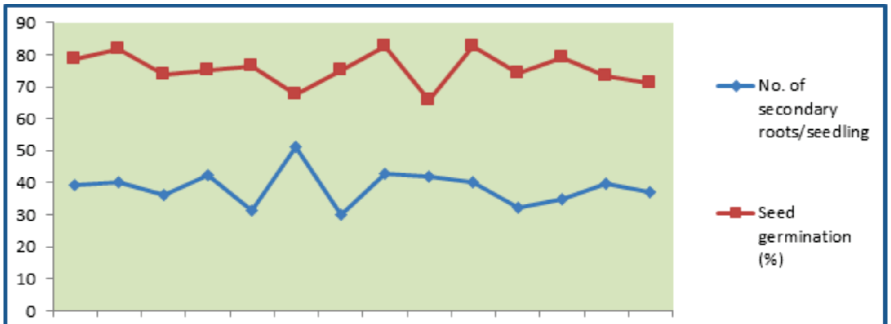
The effect of different growing media on seedling characteristics are given in Table 1. The data of length, fresh and dry weight of root and number of secondary roots, seed germoination showed that these were significantly affected by the growing media in tomato seedlings production. The seedling growing with Soil+FYM+VC media exhibited highest plant height (64.85 cm) followed by (61.84 cm) in forest litter media. The highest seedling length (16.12 cm) with FYM followed by (15.15 cm) in FYM+FL media. The maximum seedling girth (2.61 mm) recorded in FYM followed by 2.54 mm in VC+FL media. The seedling with soil+VC media produced maximum number of secondary roots (51.20) followed by (42.84) in FYM+VC. Vermicompost may also promote the proliferation of symbiotic organisms as a stimulator (i.e.) of mycorrhizal colonization of roots (Cavender *et al.* 2003) in the initial phases of the plant. The seedling fresh weight (1.15 g) recorded in soil+FYM+FL media. The seedling dry weight (0.26 g) recorded in soil+FYM+VC media. The maximum seed germination (82.50 %) in FYM+VC and VC+FL both followed by (81.88 %) in FYM media. Growing mediums influence seed germination and succeeding emergence and growth of seedlings in a nursery (Baiyeri and Mbah, 2006) because it is a reservoir of moisture and plant nutrients (Grower, 1987). In addition, it influences the performance of seedling before they are transplanted in the field (Adediran, 2005). It seems that vermicomposts provide some biological inputs as plant growth regulators (Atiyeh *et al.* 2001) as hormones and humates produced by microorganisms during vermicomposting that probably contribute to the germination and growth of plants (Arancon *et al.,* 2003 and 2008). The present findings are in agreement with studies conducted elsewhere using other plants which reported no significant effect of growing media on the number of leaves (Dolor, 2011; Khattak *et al*., 2011; Rajvanshi *et al.* 2011) found that potting mix of FYM, coarse sand and soil in the proportion of 2:2:1 as effective in enhancing the growth and flowering of Gaillardia (*Gaillardia pulchela* L.). (Narayan *et al*., 2021) also observed similar trend in respect of seedling traits of tomato in various growing mediums.

Growth and yield parameters

The effect of different growing media on fruit length, fruit diameter, fruit weight and fruit number of pepper cultivars are given in Table 2. The maximum fruit length (106.95 mm) and breadth (62.77 mm) recorded in FYM+vermicompost. The maximum number of fruits/plant (36.54) recorded in FYM+VC+FL. The seedling growing with soil+FYM+VC+FL media produced maximum average fruit weight 98.43 g followed by (94.11 g) with soil+FYM+FL media. The plant with media FYM+VC+FL produced average fruit yield (1.42 Kg). Composts can improve the physical and chemical properties of substrates and stabilize them microbiologically because of the large quantity of organic matter, available micronutrients and beneficial microorganisms (Mustin, 1987, Biala and Wymen 1998 and Fuchs, 2003). Hoitink *et al.,* 1997) reported that the use of compost (bark compost) in the nursery decreased production costs, improve plant growth and decreased losses caused by root rot diseases found in nurseries (*Phytophthora spp.*and *Pythium spp.*)

Table:1-Seedling characteristics of Capsicum var. California Wonder growing in different media

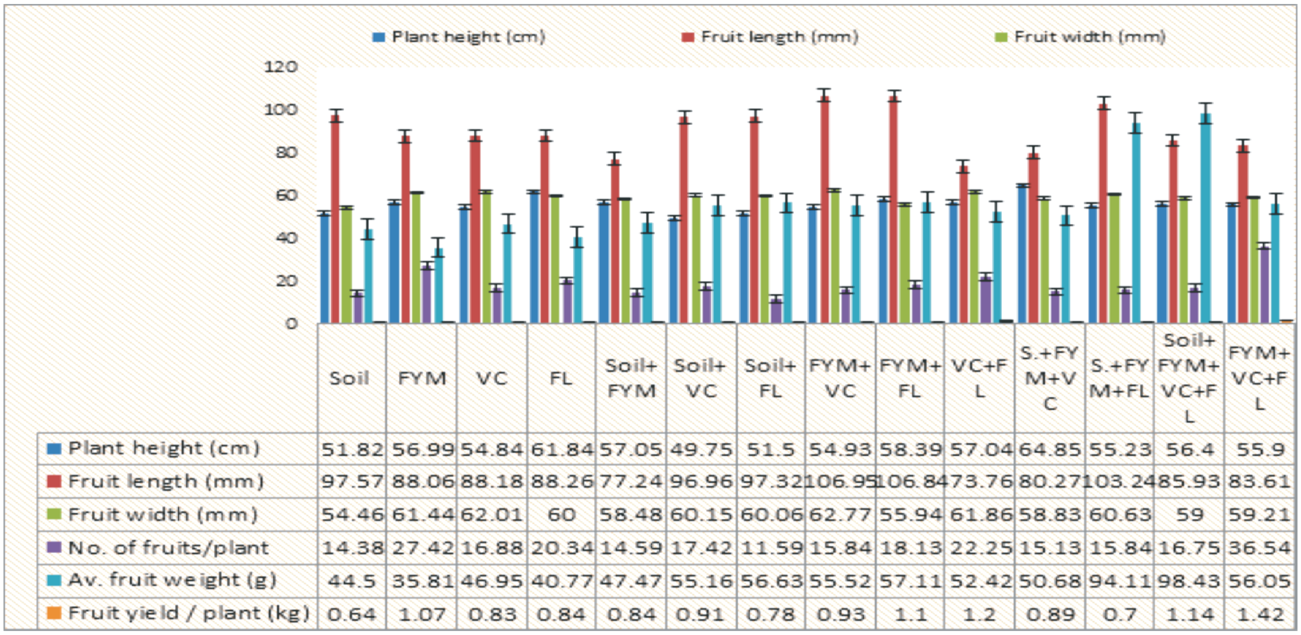
Treatments	Seedling length (cm)			Seedling girth (mm)			No. of leaves/seedling			Seedling root length (cm)		
	2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
Soil	7.33	6.77	7.05	2.21	1.72	1.97	6.33	5.67	6.00	10.80	9.00	9.90
FYM	16.53	15.70	16.12	2.94	2.28	2.61	8.33	8.00	8.17	9.20	8.13	8.67
VC	13.03	13.23	13.13	2.38	2.03	2.21	8.00	7.33	7.67	7.87	6.80	7.34
FL	10.50	9.40	9.95	2.21	1.91	2.06	6.67	6.33	6.50	10.10	9.67	9.88
Soil+FYM	12.37	10.63	11.50	2.23	1.89	2.06	8.00	7.67	7.83	4.43	7.67	6.05
Soil+VC	14.53	12.10	13.32	2.46	1.99	2.22	8.00	7.00	7.50	9.33	7.67	8.50
Soil+FL	11.37	10.03	10.70	2.61	1.99	2.30	7.67	6.67	7.17	5.87	5.30	5.59
FYM+VC	14.23	12.80	13.52	2.49	2.06	2.28	8.00	6.67	7.33	7.97	7.03	7.50
FYM+FL	15.77	14.53	15.15	2.58	2.05	2.32	8.67	7.67	8.17	8.77	7.67	8.22
VC+FL	12.73	11.87	12.30	2.81	2.27	2.54	7.67	7.00	7.34	7.07	6.47	6.77
S.+FYM+VC	13.07	12.33	12.70	2.30	1.92	2.11	7.67	6.33	7.00	5.57	4.37	4.97
S.+FYM+FL	13.50	12.37	12.93	2.41	1.91	2.16	8.00	7.33	7.67	7.87	6.30	7.09
Soil+FYM+VC+FL	13.30	12.57	12.93	2.12	1.92	2.02	7.33	7.00	7.17	8.63	7.27	7.95
FYM+VC+FL	13.23	12.13	12.68	2.28	1.99	2.13	7.67	6.00	6.84	7.47	6.53	7.00
Mean	12.96	11.89	12.43	2.43	2.00	2.21	7.71	6.90	7.31	7.92	7.13	7.53
CD 5%	1.85	3.25	2.55	0.08	0.25	0.165	0.26	0.42	0.34	0.78	0.26	0.52
Soil	40.33	38.00	39.17	0.50	0.47	0.48	0.09	0.06	0.07	85.00	72.50	78.75
FYM	42.00	38.00	40.00	1.05	0.87	0.96	0.13	0.10	0.12	85.00	78.75	81.88
VC	36.67	36.00	36.34	0.81	0.83	0.82	0.13	0.09	0.11	80.00	67.50	73.75
FL	39.33	45.33	42.33	0.59	0.97	0.78	0.11	0.13	0.12	80.00	70.00	75.00
Soil+FYM	29.67	33.33	31.50	1.03	0.85	0.94	0.16	0.11	0.13	85.00	67.50	76.25
Soil+VC	52.30	50.00	51.20	1.26	0.96	1.11	0.16	0.12	0.14	75.00	60.00	67.50
Soil+FL	33.00	27.33	30.17	0.77	0.64	0.71	0.10	0.08	0.09	80.00	70.00	75.00
FYM+VC	45.67	40.00	42.84	0.96	0.85	0.91	0.11	0.11	0.11	85.00	80.00	82.50
FYM+FL	44.00	40.33	42.17	1.29	0.80	1.05	0.13	0.10	0.12	70.00	61.25	65.63
VC+FL	37.00	43.33	40.17	0.87	1.06	0.97	0.11	0.14	0.13	90.00	75.00	82.50
S.+FYM+VC	31.33	33.00	32.17	0.97	1.06	1.01	0.11	0.40	0.26	80.00	68.75	74.38
S.+FYM+FL	39.00	31.00	35.00	1.17	1.13	1.15	0.20	0.17	0.18	85.00	72.76	78.88
Soil+FYM+VC+FL	38.33	41.00	39.67	1.12	0.94	1.03	0.15	0.10	0.13	85.00	61.25	73.13
FYM+VC+FL	37.33	37.33	37.33	1.12	1.03	1.07	0.11	0.11	0.11	80.00	62.50	71.25
Mean	39.00	8.88	23.94	0.97	0.89	0.93	0.12	0.13	0.13	81.79	69.13	75.46
CD 5%	4.41	3.03	3.72	0.29	0.21	0.25	0.03	0.009	0.019	5.06	3.50	4.28



Effect of different growing media on seedling germination & no. of secondary roots/seedling in California Wonder

Table:2-Growth and yield parameters of *Capsicum* var. California Wonder plants of which seedling's raised in different mediums

Treatments	Plant height (cm)			Fruit length (mm)			Fruit width (mm)		
	2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
Soil	54.27	49.37	51.82	115.10	80.04	97.57	61.28	47.63	54.46
FYM	47.27	66.70	56.99	113.51	62.61	88.06	72.76	50.11	61.44
VC	43.40	66.27	54.84	104.81	71.55	88.18	68.74	55.27	62.01
FL	55.80	67.87	61.84	97.25	79.27	88.26	64.18	55.82	60.00
Soil+FYM	33.97	80.13	57.05	84.94	69.53	77.24	64.91	52.05	58.48
Soil+VC	36.40	63.10	49.75	109.10	84.82	96.96	61.28	59.01	60.15
Soil+FL	36.93	66.07	51.50	130.88	63.75	97.32	57.01	63.11	60.06
FYM+VC	38.33	71.53	54.93	115.81	98.08	106.95	63.69	61.85	62.77
FYM+FL	45.30	71.47	58.39	128.49	85.18	106.84	56.86	55.02	55.94
VC+FL	54.80	59.27	57.04	70.56	76.95	73.76	67.74	55.98	61.86
S.+FYM+VC	46.43	83.27	64.85	82.16	78.38	80.27	65.87	51.78	58.83
5 S.+FYM+FL	34.53	75.93	55.23	122.29	84.19	103.24	64.82	56.43	60.63
Soil+FYM+VC+FL	33.87	78.93	56.40	93.41	78.44	85.93	61.80	56.20	59.00
FYM+VC+FL	53.30	58.50	55.90	92.85	74.37	83.61	56.86	61.56	59.21
Mean	43.90	68.46	56.18	104.37	77.65	91.01	63.41	55.84	59.63
CD 5%	4.41	3.50	3.95	31.16	5.19	18.17	1.92	2.62	2.27
Soil	22.75	6.00	14.38	50.10	38.89	44.50	1.14	0.14	0.64
FYM	47.50	7.33	27.42	38.73	32.88	35.81	1.84	0.30	1.07
VC	23.75	10.00	16.88	56.42	37.47	46.95	1.34	0.32	0.83
FL	31.00	9.67	20.34	40.01	41.53	40.77	1.24	0.44	0.84
Soil+FYM	22.50	6.67	14.59	67.55	27.38	47.47	1.52	0.16	0.84
Soil+VC	22.50	12.33	17.42	59.55	50.77	55.16	1.34	0.48	0.91
Soil+FL	16.50	6.67	11.59	58.18	55.07	56.63	0.96	0.60	0.78
FYM+VC	19.00	12.67	15.84	67.36	43.68	55.52	1.28	0.57	0.93
FYM+FL	22.25	14.00	18.13	67.41	46.80	57.11	1.50	0.71	1.10
VC+FL	31.50	13.00	22.25	54.28	50.55	52.42	1.71	0.68	1.20
S.+FYM+VC	25.25	5.00	15.13	63.36	38.00	50.68	1.60	0.18	0.89
S.+FYM+FL	14.00	17.67	15.84	65.71	122.50	94.11	0.92	0.49	0.70
Soil+FYM+VC+FL	16.50	17.00	16.75	70.90	125.96	98.43	1.17	1.11	1.14
FYM+VC+FL	31.75	41.33	36.54	53.22	58.88	56.05	1.69	1.14	1.42
Mean	24.77	13.02	18.90	58.05	55.03	56.54	1.37	0.52	0.95
CD 5%	5.10	0.86	2.98	0.89	2.09	1.49	0.26	0.36	0.31



	Plant height (cm)	Fruit length (mm)	Fruit width (mm)	No. of fruits/plant	Av. fruit weight (g)	Fruit yield / plant (kg)
Plant height (cm)	1.00					
Fruit length (mm)	-0.41	1.00				
Fruit width (mm)	-0.01	-0.14	1.00			
No. of fruits/plant	0.14	-0.32	0.16	1.00		
Av. fruit weight (g)	-0.13	0.22	0.01	-0.19	1.00	
Fruit yield / plant (kg)	0.20	-0.36	0.15	0.79	0.06	1.00

Fig. 2 Correlation matrix in growth and yield attributes

Cost benefit ratio

Data on cost benefit ratio are depicted in Table 3. The cost of seed used in protray was Rs. 1.20 in common. Percentage of germination varied in different media, ranging from a lowest of 65.63 in FYM+forest litter and highest (82.50) being in protray with FYM+vermicompost as well as Vermicompost+Forest litter growing media. Based on this, FYM+vermicompost as well as Vermicompost +Forest litter proved best medias and FYM+forest litter as poorest one. FYM is cheapest yet a better choice (81.88% germination). Soil+FYM+ FL closely followed (78.88%) with Soil almost similar (78.75%) and soil + FYM being close chasers (76.25%), Soil+ FL and FL were found clubbed (75%) and soil + FYM + VC with 74.38 percent seedling emergence also impressed as media. The gross income from sale of seedlings @ Rs. 1/- from 200 m^2 nursery was calculated and net return was obtained by substracting the total cost of seedling raising from gross income. Likewise, B:C ratio was calculated by dividing net returns by total cost. Based on B: C ratio criterion, seeds sown in FYM media proved best showing maximum of 3.16 B:C ratio and Soil media was chaser (3.09), other followers were found in descending order like soil + FYM+FL (3.00), Soil+FYM (2.86), FL (2.79), soil+FL (2.79) and, FYM+forest litter (2.33), Soil+FYM+VC+FL (2.28), VC+FL (2.19), and FYM+VC (2.14). The inclusion of vermicompost in growing media tends to decrease returns B:C ratio and consequently FYM alone as media gave the minimum benefit.

When compared to other mediums i.e. soil, FYM and forest litter, the cost of vermicompost in very high thus reduces the B:

C ratio in the vermicompost applied protrays. The rest of the treatments containing other media (T1, T2, T12, T5, T4 and T7) registered higher B: C ratio than other sole as well as medium combinations applied protrays. It is noted from above Table-3, at the overall level, it was 67584 to 84480 seedling productions of capsicum in 200 m^2 polyhouse. The net return for seedling production from 200 m^2 was highest (Rs. 64,185.92) in Farm yard manure growing media. However, the benefit cost ratio was highest (3.16), in case of (FYM). (Jeevitha *et al.*, 2019) indicated a finding indicated a finding similar to we have found in this study. Increased B: C ratio obtained by the addition of organic amendments was observed by the earlier workers (Chatterjee *et al.*, 2013; and Mal and Chatterjee 2016) in cabbage seedlings. Narayan *et al.*, 2021) also reported similar trend of BCR while raised capsicum seedling production in various growing mediums.

Table:3-Cost of seedling production in pro tray of capsicum

S. No.	Media	Media cost/ protray (Rs.)	For 1056 protrays	Pro tray rate (98 cells) (Rs.)	For 1056 protrays (Rs.)	Quantity of media /cell (g)	Media Kg / protray (kg)	For 1056 protrays (q)	Seed cost (Rs.) /protray	For 1056 protrays (Rs.)
1	Soil	0.81	855.36	11.00	11616.00	16.60	1.63	17.18	3.25	3432.00
2	FYM	1.18	1246.08	11.00	11616.00	9.60	0.94	9.93	3.25	3432.00
3	Vermicompost	13.52	14277.12	11.00	11616.00	9.20	0.90	9.52	3.25	3432.00
4	Forest litter	1.21	1277.76	11.00	11616.00	8.20	0.80	8.49	3.25	3432.00
5	Soil+FYM	1.12	1182.72	11.00	11616.00	13.10	1.28	13.56	3.25	3432.00
6	Soil+ VC	7.60	8025.60	11.00	11616.00	10.00	0.98	10.35	3.25	3432.00
7	Soil+FL	1.22	1288.32	11.00	11616.00	12.40	1.22	12.83	3.25	3432.00
8	FYM+VC	7.48	7898.88	11.00	11616.00	9.40	0.92	9.73	3.25	3432.00
9	FYM+FL	1.19	1256.64	11.00	11616.00	8.90	0.87	9.21	3.25	3432.00
10	VC+FL	7.03	7423.68	11.00	11616.00	8.70	0.85	9.00	3.25	3432.00
11	Soil+FYM+VC	6.56	6927.36	11.00	11616.00	12.00	1.18	12.42	3.25	3432.00
12	Soil+FYM+FL	1.21	1277.76	11.00	11616.00	11.46	1.12	11.86	3.25	3432.00
13	Soil+FYM+VC+FL	3.58	3780.48	11.00	11616.00	8.00	0.78	8.28	3.25	3432.00
14	FYM+VC+FL	5.21	5501.76	11.00	11616.00	9.00	0.88	9.31	3.25	3432.00

Table:4-

Labour & Other cost (Rs.)	Seed germination (%)	Total seedlings	Total seedlings of 1056 protrays	Total cost (Rs.)	Gross return (@ Rs. 1)	Net return (Rs.)	B:C ratio	Av. Yield/ plant (Kg)
4000.00	78.75	77.00	81312.00	19903.36	81312.00	61408.64	3.09	0.64
4000.00	81.88	80.00	84480.00	20294.08	84480.00	64185.92	3.16	1.07
4000.00	73.75	72.00	76032.00	33325.12	76032.00	42706.88	1.28	0.83
4000.00	75.00	73.00	77088.00	20325.76	77088.00	56762.24	2.79	0.84
4000.00	76.25	74.00	78144.00	20230.72	78144.00	57913.28	2.86	0.84
4000.00	67.50	66.00	69696.00	27073.60	69696.00	42622.40	1.57	0.91
4000.00	75.00	73.00	77088.00	20336.32	77088.00	56751.68	2.79	0.78
4000.00	82.50	80.00	84480.00	26946.88	84480.00	57533.12	2.14	0.93
4000.00	65.63	64.00	67584.00	20304.64	67584.00	47279.36	2.33	1.10
4000.00	82.50	80.00	84480.00	26471.68	84480.00	58008.32	2.19	1.20
4000.00	74.38	72.00	76032.00	25975.36	76032.00	50056.64	1.93	0.89
4000.00	78.88	77.00	81312.00	20325.76	81312.00	60986.24	3.00	0.70
4000.00	73.13	71.00	74976.00	22828.48	74976.00	52147.52	2.28	1.14
4000.00	71.25	69.00	72864.00	24549.76	72864.00	48314.24	1.97	1.42

Conclusion

The present investigation was intended to find out suitable and cost effective and locally available nursery raising mediums for capsium seedling production. It is noticed that most of seedling traits under study showed superiority while raising in organic substrate alone or in combination with and without soil over sole soil medium. Hence, admixture of organic medium with and without soil in equal proportion improved both germination and subsequent growth compared to soil media used alone. Many organic or inorganic ingredients have been used to obtain growing media for vegetable production. The raw materials used vary according to their local availability in the world. Different substrates have several materials which could have direct or indirect effects on plant growth and development. The present investigation was intended to suitable and cost effective growing media of capsicum. This experiment suggested that cost effective production of quality seedlings of capsicum cv. (California Wonder) gave best result in treatment farm yard manure alone in pro tray including highest B:C ratio (3.16).

Acknowledgement

The authors are grateful to Dr D.B Singh, Former Director, ICAR-Central Institute of Temperate Horticulture, Srinagar (J&K) for providing facilities and other resources to conduct this research work. Thank is also due to Dr J.P. Mishra, Director, ICAR-ATARI Zone II, Jodhpur for his kind support in preparation of this manuscript.

References

Adediran, J.A. 2005. Growth of tomato and lettuce seedlings in soilless media. Journal of Vegetable Science, **11(1):** 5- 15.

Angin, I., M. Kose and R. Aslantas. (2011). Effect of diatomite ongrowth of strawberry. *Pakistan Journal of Botany,* **43(1):** 573-577.

Arancon, N.Q., Edwards, C.A., Babenko, A., Cannon, J.,Galvis, P. and Metzger, J.D. (2008). Influences of vermicomposts, produced by earthworms and microorganisms from cattle manure, food waste and paper waste, on the germination, growth and flowering of petunias in the green house. *Applied Soil Ecology*, **39:** 91-99.

Arancon, N.Q., Edwards, C.A., Babenko, A., Bierman, P., Metzger, J.D. and Lucht, C. (2003). Effects of vermicomposts produced from cattle manure, food waste and paper waste on the growth and yield of peppers in the field. *Pedobiologia*, **47:** 731-735.

Atiyeh, R.M., Edwards, C.A., Subler, S. and Metzger, J.D. (2001). Pig manure vermicompost as a component of a horticultural bedding plant medium: effects on physicochemical properties and plant growth. *Bioresources and Technology,* **78:**11-20.

Baiyeri, K.P. and Mbah, B.N. (2006). Effects of soilless and soil-based nursery media on seedling emergence, growth and response to water stress of African breadfruit (*Treculia Africana* Decne). *African Journal of Biotechnology* **5(15):** 1405- 1410.

Biala, J. and Wymer, E. (2002). The value of Compost. The international magazine of IFOAM. *Ecology & Farming*. **29:** 17-17.

Cavender, N., Atiyeh, R.M. and Knee, M. (2003). Vermicompost stimulates mycorrhizal colonization of roots of *Sorghum bicolor* at the expense of plant growth. *Pedobiologia*, **47:** 85-89.

Chatterjee, R.; Jana, J.C. and Paul, P. K. (2013). Vermicompost Substitution Influences Shelf Life and Fruit Quality of Tomato (*Lycopersicon esculentum* Mill.). pp. 69-76.

Fuchs, J. (2003). Le compost de qualite au service de la santedes plants. *Alternative Agriculture*, **61:** 7-9.

Grangvist, G. (1981). Recent experience in the use of substratesfor vegetable production under glass in Sweden. *Acta Horticultural,* **126:** 259-262.

Grower, S.T. (1987). Relations between mineral nutrient availability and fine root biomass in two Costa Rican tropical wet forests. *Hypothesis Biotropica* **19(2):** 171-175.

Hoitink, H.A.J., Stone A.G. and Han D. (1997). Suppression of Plant diseases by composts. Hort Science. **32:** 184-187.

Khan, A.L., Shinwar Z.K., Kim Y., Waqas M., Hamayun M., Kamran M. and Lee I. (2012). Role of endophyte *Chaetomium globosum* lk4 in growth of *Capsicum annuum*by production of gibberellins and indole acetic acid. *Pakistan Journal of botany,* **44(5):** 1601-1607.

Mal, D. and Chatterjee, R. (2016). Residual effect of vermicompost and inorganic fertilizers of sprouting broccoli (*Brassicao oleracea* L. var. italica Plenck.) on succeeding cowpea (*Vigna unguiculata* L. Walp.) pod yield and soil fertility in eastern Himalayan region, *Green Farming* **7(1):** 148-151.

Mustin, M. (1987). Le compost. Gestion de la Matiere Organique Francois Dubuse (Fdn), Paris, pp. 954.

Narayan, R.; Debnath, S,; Kumar, A.; Kishor, A.; and Sharma, O.C. (2021). Effect of organic growing media for cost effective production of quality tomato seedlings in portrays under naturally ventilated polyhouse *Progressive Horticulture*, **53(2):** 176-182

Nicola, S. and Basoccu, L. (1994). Nitrogen and N,P,K relation affect tomato seedling growth, yield and earliness. *Acta Horticulture*, **357:** 95-102.

Sevgican, A. (1999a). Protected vegetable growing. I. EgeUniversity. Agriculture Faculty, No: 528. ISBN 975-483-384-2, Izmir, Turkey.

Thompson, B. E. (1985). Seedling morphological evaluation-what you can tell by looking. In: Proceedings of Evaluating Seedling Quality: Principles, Procedures and Predictive Abilities of Major Tests, eds. M. L. Durvea,Corvallis: Oregon State University.pp. 59–71.

Dolor, D. Effect of propogation media on germination and seedling performance of Irvingia wombolu (Vermoesen). American Journal biotechnology and molecular sciences, 2159-3698.

Biotech Today (January-June 2024) : 14 (1) : 26 - 30

DOI : 10.5958/2322-0996.2024.00003.8

REVIEW ARTICLE

Pre-harvest Fruit Drop in Darjeeling Mandarin: Its Causes and Strategies for Organic Management- A review

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Received: 21 July, 2023, **Revised**: 25 August, 2023, **Accepted**: 14 September, 2023, **Published**: 1 January, 2024

Abstract

Darjeeling Mandarin (*Citrus reticulata Blanco*) is one of the important cash crops of the hills. There are severe economic losses in yield of the crop just before harvest known as Pre-harvest fruit drop. These dropped fruits are unfit for human consumption. This article covers the reason behind preharvest fruit drops and also gives management for control of fruit drop. So that farmers and the scientific community can minimize or control the fruit drop.

Key words: Pre harvest fruit drop, Darjeeling Mandarin, abiotic factors, Biotic factors, Fungal pathogens, Chinese fruit fly

Introduction

After Banana and Mango, Citrus is the third most important crop in India. Among the citrus fruit Mandarin (*Citrus reticulata* Blanco) is the most common fruit grown in India. It occupies nearly 40% of the total area under citrus cultivation. In Darjeeling and Kalimpong hills of West Bengal, this mandarin crop is being cultivated since time immemorial. It is a native fruit of Sikkim and Darjeeling and is very popular all over the country. The valleys of Teesta and Rangit rivers and their tributaries of Sikkim and adjoining Darjeeling district of West Bengal offer an ideal Himalayan climate for the cultivation of mandarin. The crop blooms abundantly from February and continues upto April but only few blooms reach full maturity and harvest. Most commercially important citrus cultivars bloom prolifically producing as many as 1,00,000-2,00,000 flowers on a mature tree. However, fewer than 1-2 % of these flowers produce harvestable fruit. (Das *et al.*, 2023). In Kinnow, less than 1 per cent of flowers turn into harvestable mature fruit (Ratanpal *et al.*, 2019). Excessive fruit drop has contributed to low yield and has proven unprofitable in many mandarin growing countries around the world, despite adequate blooming and initial fruit set. All the fruits do not drop at one time but at different times also called waves, with more or less distinct periods or stages when significant shedding happens. Fruit drop in Mandarin occurs more or less in four distinct waves: Post- bloom drop, Summer or June drop, Rainy season drop, Pre-harvest fruit drop. In this article, Preharvest fruit drop is being discussed as this drop has economic importance for the farmers. The article provides the reason behind preharvest fruit drop and management and future strategies for its control and prevention.

Pre-Harvest Fruit Drop

Pre-harvest fruit drop is the drop of mature fruits before the harvest. This drop is of economic loss to the growers as in this drop nearly complete grown fruits are shed causing heavy losses to the grower. During this time, fruits may detach at the peduncle and calyx

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junction, resulting in fruit drop without the peduncle attached. Many biotic and abiotic factors are the reason behind preharvest fruit drop but the primary causes of pre-harvest fruit drop are fruit fly infestation.

Abiotic Factors/Physiological Fruit Drop

Many abiotic factors are associated for preharvest fruit drop such as age and health of the plant, poor orchard management, water stress, lack of nutrition during fruiting period etc. Ethylene gas production is triggered when plant is in stress, which causes the fruit to fall off by weakening the abscission layer between the branch and fruit. Therefore, it is necessary to maintain the optimum health of the tree and prevent stressful conditions.

Age and health of the orchard

The age of the orchard ranges from 40-60 years (Ghosh and Singh, 1993). Almost, most of the plants are old and senile. The old plants although bearing due to inability of transfer of nutrients from the soil to the fruits causes fruit drop. The bearing trees must be healthy and free from pest and diseases.

Poor orchard management

One of the reasons for fruit drop is poor orchard Management. The Mandarin trees are wildly grown without following proper spacing. The branches of one tree intermingle with the branches of other, resulting in competition for nutrition and light. As there is competition for nutrition therefore most of the fruit drop.

Water stress

Mandarin in the hills of West Bengal are grown as a rainfed crop. Dry spells occur from August and continues up to the harvesting. Water stress during the fruit period accelerates the synthesis of abscisic acid and which forms an abscission layer in the fruit leading to fruit drop.

Lack of nutrition during fruiting period

Mandarin is a nutrient demanding crop, optimum doses of both macronutrient and micronutrients helps develop sufficient foliage to support the developing fruits. Many reports suggest that applying nutrients to the soil or leaves of the plant improved fruit retention. Nutrients used in conjunction with growth regulators have shown to improve fruit quality, weight and reduce fruit drop (Dutta *et al.,* 2022).

Biotic Factors

Apart from Abiotic factors, fruit drop is also caused by diseases (Pathological) and insects-pest (Entomological).

Pathological fruit drop

The citrus fruits are attacked by number of pathogens from bloom to harvesting stage (Gade and Koche, 2019) and subsequently by post-harvest pathogens that affect the production of crop and considerably deteriorate the fruit quality. Among the citrus diseases, Huanglongbing (HLB) and *Citrus Canker* are found to be responsible for premature fruit drop. Stem end rot (SER) fungal pathogens viz. *Lasiodiplodia theobromae, Colletotrichum gloesporiodes* and in some cases *Alternaria* sp. cause the drop of mature fruits prior to harvest (pre-harvest drop) (Das *et al.,* 2023). Pathological fruit drop starts appearing from August and continues till harvest. The drop in the month of September to October is the most detrimental as the fruits are near maturity and have already drawn nourishment from the tree. Fruit drop has been reported to be higher in HLB-infected trees than in HLB tolerant tree. The infection causes oxidative stress leading to cell wall modification, cell separation and subsequent fruit drop.

Management

1. Removal of dead, diseased branches or twigs. Best time for pruning is after fruit harvesting to reduce the primary source of inoculum.

2. Collection and destroying the mummified as well as fallen fruits by deep burying. The fallen fruits must be removed from the orchard as they act as carrier of diseases.
3. After pruning, its is advisable to spray the trees with Bordeux mixture (2:2:250) or copper oxychloride 50 WP (3 g/litre) in March, July and September (Yasin Ashraf *et al.,* 2012).
4. Minimum fruit drop was observed in Nagpur mandarin (Ambiabahar) when spraying was done with Carbendazim 50 WP (0.1 %) starting from first week of July at one month interval (Mohod *et al.*, 2019).

Entomological fruit drop

In Kalimpong and Darjeeling districts of West Bengal, fruit flies are the notorious insects that causes pre-harvest fruit drop. When the dropped fruits from the orchard where examined it was found out that most of the dropped fruits were infected from fruit flies. The number of larvae per dropped fruit ranged from 7-15 per fruit which was quite high. (Pashi *et al.*, 2021) collected 600 dropped fruit samples from 323-1610 meters above sea level (MASL) out of which on an average 50.83% of the fruit samples were found to be infested by the fly. In a unmanaged citrus orchard at Takdah, West Bengal the infestation was 75.18% during harvesting season. Citrus hosts infested by *B. minax* include Darjeeling mandarin (*Citrus reticulata* Blanco), Sweet orange (*Citrus sinensis* Osbeck), Rough lemon (*Citrus jambhiri* Lush) and kinnow mandarin (*Citrus reticulata* Blanco). Rangpur lime (*Citrus limonia* Osbeck), had been found to be infested by *B. minax* along with Ptecticussp (Diptera: Stratiomyidae) from harvested and fallen fruits. The fallen fruits if left in the orchard later gets affected by fungal diseases. Majority of fruit drop during pre-harvest stage was due to fruit fly infestation followed by *Fusarium* sp and *Colletotrichum* sp infestation. (Dutta *et al.*, 2022a).

The fruit fly species causing fruit dropwas Chinese fruit fly (*Bactrocera minax*).These Chinese citrus fliesare a major citriculture pest species in China, Bhutan, India (Sikkim and West Bengal) and Nepal (Adhikari *et al.*, 2020; Gazmer*et al.*, 2023) stated that over the last 5-6 years, fruit drop in *C. reticulata* due to infestation of fruit fly is also increased with damage extent ranging from 50-70%. So far, *Bactoceraminax* is not reported to be the major pest for causing the fruit drop in the state of Sikkim. Evidence suggests that this species has originated in the high temperate Southern Yunnan-Guizhou Plateau and dispersed throughout China's waterway system (Xia *et al.*, 2018). Because of its flying capacity to great distances, this insect has made its way from China through Bhutan, Sikkim, India and, ultimately to Nepalese citrus orchards in the eastern middle mountain regime of the country. (Adhikari *et al.*, 2022).

Fig 1: a) Fruit drop in Darjeeling Mandarin due to Fruit fly infestation followed by fungal infection. b) Farmer collecting the infested fruits, cutting and dipping fruit in biopesticide solution

Adult female lays eggs on the immature fruit to deposit eggs on the surface of fruit with the help of needle like ovipositor. The eggs upon hatching become maggots and starts feeding the fruit pulp. Also, fungal and bacterial infections occurs due to the puncture hole resulting in fruit drop (Bishnoi *et al.*, 2023). Maggots feed inside the developing fruits causing rapid decay, which later becomes inedible and finally dropped prematurely (Wang and Zhang, 2009).

Management

1. Adopting good orchard management practices, clean culture, removal of rotten fruits etc.
2. Community collection of the fallen fruits should be done as these flies can fly to a wider range and deep burrowing of the fruits (below 60cm) to prevent fruit fly emergence from the soil.
3. Soil Racking around the orchard to expose the pupae and destroy them
4. An Area wide control programme is the only option for controlling this insect pest (Acharya and Adhikari, 2019).
5. A Selective bait application supplemented with protein .0and biopesticide can be effective.

Conclusion

Pre-harvest fruit drop is a complex problem in Citrus. It occurs in almost all citrus species. The article describes the detail report of preharvest fruit drop, enlisting not only one but more reasons for its causes. The causes or factors are grouped as abiotic (age, health of the plant, nutrition of the orchard, water stress and biotic (insect, pest etc), Poor orchard management. In order to address the issue of Pre-harvest fruit drop in mandarin with special reference to Darjeeling mandarin integrated approaches should be taken up staring with good orchard practices with special attention to proper nutrition, pruning, irrigation, pest and disease management.

References

Acharya, U.K. and Adhikari, D. (2019). Chinese Citrus Fly (*Bactroceraminax*) Management in mid hills of Nepal. *Journal of Agriculture* and *Environment*. **20:** 47-56.

Adhikari, D., Thapa, R.B., Joshi, S.L., Liang, X.H. and Du, J.J. (2020). Area-wide control program of Chinese citrus fly *Bactroceraminax* (Enderlein) in Sindhuli, Nepal. *American Journal of Agricultural* and *Biological Sciences*, **15:** 1-7.

Adhikari, D., Thapa, R.B., Joshi, S.L., Liang, X.H. and Du, J.J. (2022). Morphometrics of adult Chinese citrus fly *Bactroceraminax* (Enderlein) (Diptera: Tephritidae) in Nepal. *Journal of the Plant Protection Society*. **7:** 78-81.

Bishnoi, M., Parkash, J. and Khan, A., (2023). Citrus fruit drop: causes and management. *Just Agriculture*, **3(10):** 115-120.

Das, A.K., Sonkar, R.K., Thirugnanavel, A., Meshram, N.M., Bhattacharyya, S. and Ghosh, D. (2023). Management of Citrus fruit drop: a complex problem in central India. *Indian Citriculture*, **1(1):** 31-35.

Dutta, S.K., Das, S.K., Bhutia, T.L., Devi, E.L., Laha, R. and Mishra, V.K. (2022). Waves of flower and fruit drop in Mandarin: exploring the causes with a case study support of Sikkim Mandarin. *Food* and *Scientific Reports*. **3(3):** 30-34.

Dutta, S.K., Gurung, G., Yadav, A., Laha, R., and Mishra, V.K. (2022). Factors associated with citrus fruit abscission and management strategies developed so far: a review. *New Zeal*and *Journal of Crop* and *Horticultural Science*, **51:** 3822, 1–22.

Gade, R.M. and Mina D. Koche. (2012). Integrated disease management for root rot and gummosis in Nagpur Mandarin. *Indian Phytopathology*. **65(3):** 272-275.

Gazmer, R., Sharma, R.M., Bhutia, S.G., Laskar, N., Sharma, L. and Adhikari, D. (2023). Chinese citrus fly, *Bactroceraminax* (Enderlein) (Diptera: Tephritidae) in Sikkim: a study on its morphometrics. *Pest Management in Horticultural Ecosystems*. **29(1):** 77-81.

Ghosh, S.P. and Singh, R.P. (1993). Citrus in

South Asia. *Food and Agriculture Organization (FAO) RAPA* Publication No. 1993/24. Bangkok, Thailand. pp. 70.

Mohod, Y.N., Giri, G.K., Ingle, Y.V. and Koche, M. (2019). Management of preharvest fungal fruit drop in Nagpur Mandarin. *Journal of Plant Disease Science.* **14(2):** 129-132.

Pashi, R., Jha, S. and Barma, P. (2021). Survey of the Chinese citrus flies *Bactrocera* (Tetradacus) *minax* (Enderlein) (Diptera: Tephritidae: Dacinae) infesting Citrus in Darjeeling and Kalimpong districts of West Bengal. *International Journal of Current Microbiology and Applied Science.* **10(07):** 434-448.

Rattanpal, H.S., Singh, G., Arora, A. and Singh, S. (2019). Management of fruit drop in *Citrus*. Published by additional director of communication for Punjab Agriculture Univeristy. pp.1-22.

Wang, X.L. and Zhang, R.J. (2009). Review on biology, ecology and control of *Bactocera* (Tetradacus) *minax* Enderlein. *Journal of Environmental Entomology*. **31:** 73-79.

Xia, Y., Ma X.L., Hou, B.H. and Ouyang, G.C. (2018). A review of *Bactroceraminax* (Diptera: Tephritidae) in China for the purpose of safeguarding. *Advances in Entomology*. **6:** 35-61. https://doi.org/10.4236/ae.2018.62005.

Yasin, A.M., Yaqub, M., Akhtar, J., Khan, A.M., Khan, A.M. and Ebert, G. (2012). Control of excessive fruit drop and improvement in yield and juice quality of Kinnow through nutrient management. *Pakistan Journal of Botany*. **44:** 259-265.

Biotech Today (January-June 2024) : 14 (1) : 31 - 37

DOI : 10.5958/2322-0996.2024.00004.4

REVIEW ARTICLE

An overview of Structures and Function of Hydrogel

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Received: 16 September, 2023, **Revised**: 26 November, 2023, **Accepted**: 10 December, 2023, **Published**: 1 January, 2024

Abstract

A cross-linked water absorbing polymer, known as a hydrogel, essentially absorbs aqueous solutions through hydrogen bonding with water molecules. This synthetic polymer has ability to hold onto large amounts of moisture for a longer time. Thus, acting as a reservoir to store and release a steady stream of water and nutrients. It is an effective tool in conserving adequate amounts of water fastly in soil and providing water and dissolved nutrients slowly to the plants over an extended period when the rhizosphere zone starts drying up (Yazdani, *et al.,* 2022). Hydrogel can improve the soil's capacity to hold onto water by altering the physical properties of the soil, such as the apparent and actual densities and pore spaces. When moisture is scarce for an extended length of time, having more water available in the soil helps to prevent water stress. Hydrophilic functional groups attached to the polymer give the hydrogel its ability to absorb moisture, while the cross-links between network chains give it its resistance to dissolution (Kalhapure *et al.,* 2016). Hydrogel can also reduce irrigation frequency and water lixiviation, which helps plants that have less access to water survive.

Key words: Hydrogel, Hydrophilic functional groups, WUE

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Introduction

Water availability is one of the main ecological barriers to the viability of agriculture in arid and semiarid areas and under rainfed conditions. Agriculture is the important sector it consume large amount of water, Plants in arid and semi arid regions facing the problem related to low water availability for crop in dry land areas. Hydrogel is popularly known as 'root watering crystal', 'water retention granules', or 'raindrop', is a quasi-solid phase amorphous material. It is a 'smart and hungry network' which is current subject of scientific research due to its potential applications in modern agricultural system. The super absorbent polymer is water-absorbing and is cross-linked to aqueous solutions, The aqueous solutions are absorbed by forming bonds with water molecules. By lowering evaporation, deep percolation and runoff losses, this unique technique of water management, under water-stressed conditions helps to preserve soil moisture in the active rooting zone of crops.

Agricultural hydrogels, when in contact with water, they significantly swell and return to their previous size. It is able to absorb and hold 80–180 times its volume of water for a long time Wang.Y., & Gregg, L.L. (1990). Hydrophillic polymers-their response to soil amedments and effect on properties of a soiless potting mix. Journal of American society of horticulture and science. 115(6): 943-948. (Wang and Gregg, 1990). Hydrogel acts as a reservoir to store and release a steady stream of water and nutrients which plants need to grow. Plant roots are able to absorb water from the crystal bead of hydrogel. It is considered an effective tool in conserving adequate amounts of water quickly in soil and providing water and dissolved nutrients slowly to the plants over an extended period when the surrounding soil near the crop root zone starts drying up (Yazdani, *et al.,* 2022). Buck and Evans (2010) found that hydrogel could modify the physical properties of soils *i.e.* apparent and real densities, pore spaces and water retention capacity. Having more available water in the soil helps in avoiding water stress at the time of moisture scarcity when it occurs for a longer period.

The Super Absorbent Polymer (SAP) is water-absorbing and is cross-linked to absorb aqueous solutions through bonding with water molecules. It is a new method to water management under water-stressed conditions to conserve soil moisture in the active rooting zone of crops by reducing the evaporation, deep percolation, and runoff losses. Agricultural hydrogels are water retention granules which swell their original size to numerous intervals when they come in contact with water. It can absorb and retain a huge amount of moisture under plentiful rainfall and irrigation events and release it back to the soil for mitigating crop water demand when the rhizosphere zone dries up under drought conditions. It plays multifarious roles in agriculture including soil-water retainer, nutrient and pesticide carriers, seed coating, soil erosion reducer and food additives. It has the extraordinary ability in improving different physicochemical, hydro-physical and biological properties of soil, simultaneously decreasing irrigation frequency, increasing the water and nutrient use efficiencies and increasing the yield and quality of the field, plantation, ornamental and vegetable crops. These biodegradable materials are nontoxic to the soil, crop and environment. Hence, the addition of the hydrogel polymer will be a promising and feasible technological tool for augmenting crop productivity under moisture stressed conditions. The hydrophilic functional groups connected to the polymer backbone provide the hydrogel its ability to absorb moisture, while the cross-links between network chains give it its resistance to breakdown. Kalhapure *et al.*, 2016. When water is scarce, it results in massive loss of crops. Thus, hydrogel can be used as a solution to prevent such losses. Save *et al.*, (1995) recognized that hydrogel can decrease the frequency of irrigation and reduce water lixiviation. According to Santelices (2005), in *Eucalyptus goblulus,* harvested in the spring, hydrogel contributed to the survival of plants with less access to water.

Response to particular external stimuli like temperature, solvent quality, pH, electric field, etc., hydrogels may show abrupt volume changes (Tanaka, 1978). The synthetic polymers used to make agricultural hydrogels are typically derived from petroleum. They can be planted in dry areas to increase the soil's capacity to absorb water and they absorb water several times their weight. It is therefore referred to as Super Absorbent Polymer (SAP). Due to their exceptional qualities, these SAPs became successfully established in numerous applications, such as disposable diapers, hygiene napkins, cement, medicine delivery systems, sensors and agriculture. Water retention and absorption are the most crucial elements in these applications. When water is scarce, it results in massive loss of crops. Thus, hydrogel can be utlized as a solution to prevent such losses. (Save *et al.,* 1995) recognize that hydrogel can decrease the frequency of irrigation and reduce water lixiviation. According to Santelices (2005), in *Eucalyptus goblulus*, harvested in the spring, hydrogel contributed to the survival of plants with less access to water. The modifications also occurred after adding other soil improvers, for example peat, for this reason hydrogel is also known as a soil conditioner. Numerous studies have shown that hydrogels have a positive impact on soil moisture levels and rice yields, increasing them by 12–31% (Rahman *et al.*, 2011, Dar *et* *al*., 2017, Yangyuoru *et al*., 2011, and 17.4-24.7%) in wheat and maize, respectively. Similar to this, under deficit irrigated conditions, water productivity (WP) with hydrogels increased by 22.5% in Indian mustard and 97.1% in maize compared to no-hydrogel applied plots. It's interesting to note that hydrogels have been shown to increase the size and color of fruits and flowers, as well as the overall quality of agricultural produce. Despite offering several advantages, the use of hydrogels in agriculture remained very limited mainly because of high application rates (50–225 kg ha ^{1}) which incurred higher production cost (Narjary *et al*., 2017). Therefore, indigenous biopolymeric polyacrylate hydrogel, P-hydrogel (maximum water-absorbing capacity of 350 times, m/m) and its kaolin based derivative (water-absorbing capacity of 800 times, m/m) was developed for effective moisture conservation at a lower rate of application (2.5–5.0 kg ha ^{1}). Incorporating kaolin with cellulose based anionic polyacrylate as K-hydrogel exhibited higher water-absorbing capacity than P-hydrogel. Martyn and Szot (2001), after evaluating two commercially available hydrogel types, at different concentrations in soil, found variations, though without any clear trend. The same response was produced by other organic components such as peat and vermiculite. Rivera *et al*. (2015) indicate that hydrogel has an effect on the time the soil needs to dry up. On the other hand, when used in dry soil, hydrogel can moisten the soil in levels that vary depending on soil type. Arbona *et al.* (2005) reported an increase of 30% in soil moisture after using hydrogel. Authors such as Johnson (1990) have commented on the importance of using hydrogel on forest trees, especially during the sowing period. According to research, the soil's water volumetric content increases significantly when it is treated with water hydrogel composite and when the surrounding soil dries out, the water is slowly released back into the soil. Osmotic pressure difference will be used to remove water from these reservoirs in response to root demand. By encouraging the mobilization of few nutrient components, retaining them firmly and postponing their dissolution, the hydrogel also function as a controlled release system. Because the plant can still need some of the fertilizers, growth and performance rates are increased (Liang *et al.,* 2007).

Present scenario of climate change

According to research, when soil is treated with water hydrogel composite, its water volumetric content increases significantly. As the surrounding soil dries out, the water is slowly released back into the soil. Through an osmotic pressure difference, water will be drawn from these reservoirs in response to root demand. By encouraging few nutrient elements to be absorbed, holding them in place and postponing their dissolution, the hydrogels also function as a controlled release system. India ranks 41st out of 181 countries in terms of water stress, with an average score of 4.2 on a 0–5 scale. (Water Granules used for water retention called hydrogels expand significantly when they come into touch with water is withdrawn annually for domestic, agricultural and industrial uses from rivers, streams and shallow aquifers. Scores above 4 on a scale of 0 to 5 indicate that the average water user utilizes more than 80% of the available water annually.) India has a score of 4.2, which indicates that it is at high risk for water stress. As per the studies of the Intergovernmental Panel on Climate Change (IPCC, 2007), suggests that in the future climate change is expected to influence agriculture, raise the threat of hunger, water shortage and lead to the melting of glaciers.

Under this scenario, water scarcity in agriculture has impacted, as the agriculture sector holds the maximum water share (85%) when compared to the industry (10%) and domestic sector (5%) (Kalhapure *et al.,* 2016).

Types of Hydrogels have so far been found appropriate for agricultural use:

- Starch-graft copolymers
- Cross-linked Polyacrylates
- Cross-linked Polyacrylamides & Acrylamide-acrylate copolymers.

Potassium Polyacrylate is the principle material used in Super Absorbent polymer (SAP) industry and marketed as hydrogel for agricultural use because of its **longer retention and high efficiency in soil with nil toxicity issues.**

General properties of hydrogel

- Chemical constitution : Cross linked polyacrylate
- Appearance : Amorphous granules
- Particle size : 20–100 mesh (micro granules)
- pH : 7.0 –7.5
- Stability (50^0C) : Stable
- Absorbent capacity : absorbs 400 times its dry weight in water and gradually releases the same

Functional Characteristics of a Hydrogel

The features of the ideal hydrogel materials should include the following:

(i) The high water absorption capability

(ii) The desired rate of absorption and desorption capacity according to plant requirement

(iii) Soluble material and leftover monomer

(iv) Exceptionally strong and stable during swelling and storage

(v) High biodegradability and biocompatibility

(vi) High performance over a wide temperature range

(vii) After swelling, water becomes neutral in pH

(viii) Colourlessness, odorlessness, and nontoxic

(ix) Upscale the soil's physical, chemical, Including biological characteristics

(x) Photo stability, rewetting capability for a longer time, low-cost material and eco-friendly

Types of Super Absorbent hydrogel (SAH) SAH

- **Origin –** Natural, Hybrid
- **Porosity**- Non porous, Micro porous, Macro porous, Super porous
- **Ionic charge-** Non-Ionic, Ionic, Zwitter ionic
- **Cross linking**- Physical (Non covalent), Chemical (Covalent)
- The use of hydrogels results in higher soil moisture levels and higher yields by 5–11% in wheat (Dar *et al.*, 2017) 31–36% in maize (Yangyuoru, *et al.*, 2006).

Soil and water relationship

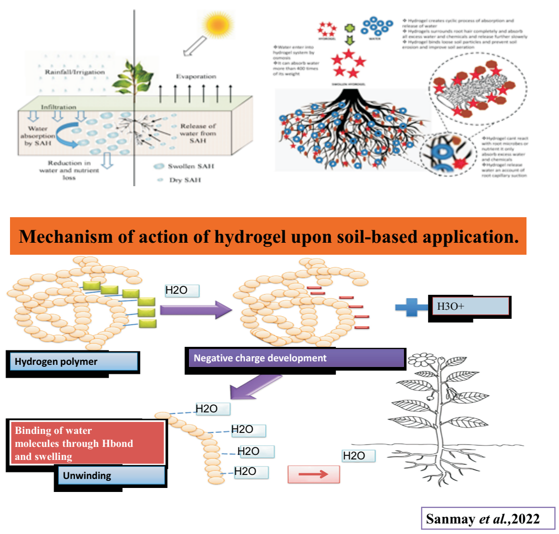

Fig: 1. Mechanism of action of hydrogel upon soil based application

(i) Water absorption in a hydrogel is caused by the hydrophilic groups of the polymer chain, including acrylamide, acrylic acid, acrylate, carboxylic acid, etc.

(ii) When water and the polymers come into contact, the water go through the hydrogel system by osmosis, and hydrogen atoms react and emerge as positive ions.

(iii) Along the polymer chain's whole length, this reaction leaves a number of negative ions. These opposing negative charges push the polymer chain to unwind and open up in order to attract and bind water molecules using hydrogen bonds.

(iv) The hydrogel can absorb more than 400-1500 times their dry weight of water in this process and act as a miniature water reservoir. When the surrounding around the root zone begins to dry up, the hydrogel gradually dispenses up to 95% of its stored water to plant absorption

(v) Rehydration begins when exposed to rewetting conditions, and the water-saving process continues.

(vi) This polymer can promote soil water retention, which encourages increased water intake and water usage efficiency. This reduces plant water stress and boosts crop development and production.

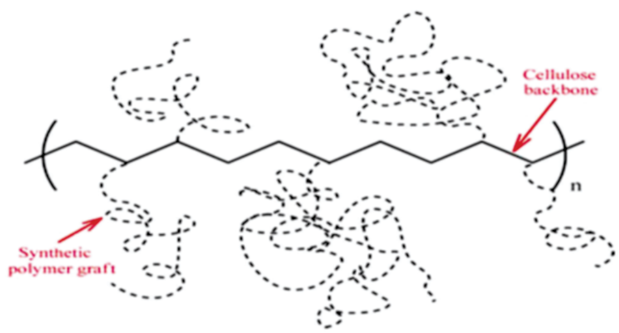

Fig.2 Agriculture hydrogel's atomic structure

(vii) Depending on the current environmental circumstances, they go through volume transition in response to physical and chemical stimuli.

(viii) After functioning in the soil for two to five years, the hydrogels decompose without changing the physicochemical makeup of the soil.

Preparation of hydrogel

Radiation exposure to cellulytic derivatives causes the breaking of part of the carbon bonds between the glucose molecules, forming free radical sites on the polymeric backbone molecules that make up the cellulose chain. The cellulose-acrylamide graft copolymer is created when cellulose radicals produced during irradiation combine with one side of the acrylamide.

Absorption capacity of hydrogels

Due to their exceptional qualities, these SAPs became successfully established in numerous applications, such as disposable diapers, hygiene napkins, cement, medicine delivery systems, sensors and agriculture

Status of commercialization in India

Pusa hydrogel has been licensed to six companies for commercialization.

- Earth International (P) Ltd., Delhi (Product: Vaaridhar G1)
- Carborundum Universal (P) Ltd., Bangalore (Product: Kauvery)
- Hunting Organics (P) Ltd., Faridabad (Product: Anmol)
- Nagarjuna Fertilizers (P) Ltd., Hyderabad
- The Sarpanch Samaj, Delhi
- Madhusudan and Company (P) Ltd., Jaipur

Limitations

- Water absorbed by the SAHs decreases drastically in the presence of salt or ions in the soil
- The natural polymer hydrogels are poor in mechanical strength
- If there is insufficient rainfall, the soil water will be depleted. Hence, in that case, hydrogel does not solve the problem
- There are many practical implementations of hydrogel technology. However, the most common use can be in plant agriculture as a slurry to coat bare rooted transplant which prevents roots from drying up

Salient findings

- For the majority of crops, a Between 1 and 2 kg/acre of low or minimal treatment rate is effective.

- Fertilizer and salt solutions have less of an impact on the hydrogel's swelling ratio.
- The hydrogel-amended sandy loam soil and medium without soil, such as sand, cocopit, etc., demonstrated a delay in the onset of permanent wilting point (2–6 days) when used to raise vegetable and flower nurseries.
- Reasons *Chrysanthemum* cuttings took less time in hi-tech horticulture to germinate and establish them (18 days) than the control crop did (28 days). Lessened the number of times drip fertigation was applied to horticultural crops grown in protected and open fields, respectively.
- In comparison to control, hi-tech cultivation significantly increased for the majority of the test crops, yield and water usage efficiency.

Future perspectives

- Preparation of hydrogels with low cost, that can show same time super absorption characteristics and good mechanical properties
- Develop eco-friendly and green hydrogels
- Producing SH in nanoscale (nanogels) with very high water (or aqueous solution) uptake capability (e.g. thousands fold)

Conclusion

Application of SAH in arid or semi arid areas improve the plant growth, yield & WUE

- 2.5 kg / ha of It is best for field crops to use hydrogel.
- SAH reduces water application rate and improve irrigation frequency.
- SAH performs best in loam soil to sandy soil with affordable.
- The aforesaid technologies has the capacacity to transform the situations like scarcity of irrigation, lack of fertilizer use efficiency, improving the soil fertility, productivity both crop and water in the Indian farming society, but the adaptation in real life by the farmers and research work carried out on these are at minimal level. So more research works and start up companies for commercialization of these may bring them to lime-light and increase the adaptation by farmers in turn improve the nations economy.

With an enhancement in the soil's hydrophysical, biological, and chemical environment, it also contributes to an an improvement in the size of the fruits and flowers, as well as the plant biomass, of agricultural products and color. In order to increase agricultural productivity while maintaining environmental sustainability in water-stressed areas, hydrogels may thus become a practically practical and financially viable option.

References

Arbona, V., Iglesias, D., Jacas, J., Primo-Millo, E., Talon, M. and Gómez, A. (2005). Hydrogel substrate amendment alleviates drought effects on young citrus plants. *Plant and Soil*, **270:** 73-82.

Buck, J and Evans, M. (2010). Physical properties of ground parboiled fresh rice hulls used as a horticultural root substrate. *Hort. Science.* **45(4):** 643-649.

Dar, S.B., Mishra, D., Zahida, R., and Afshana, B.B. (2017). Hydrogel: To enhance crop productivity per unit available water under moisture stress agriculture. *Bulletin of Environment Pharmecology and Lifesciences.* **6(10):** 129–135. http:// bepls. com/ sept_ 2017/ 22.

Johnson, M.S. (1984). Effect of soluble salts on water absorption by gel forming soil conditioners. *Journal of Science and Food Agriculture.* **35(10):** 1063– 1066.

Kalhapure, R; Kumar, Singh V. P. and Pandey D. S. (2016) 'Hydrogels: a boon for increasing agricultural productivity in water-stressed environment,' Current Science, **111(11):** pp. 1773–1779.

Liang, M., Zhan, R., Liu, F. and Niu, Z. A. (2007). Preparation of superabsorbent slow release nitrogen fertilizer by inverse suspension polymerization, *Polymer International* **56:** 729-737

Martyn, W. and Szo, P. (2001). Influence of superabsorbents on the physical properties of horticultural substrates. *Agrophysics*. 87-94.

Narjary, B. and Aggarwal, P. (2014) Evaluation of soil physical quality under amendments and hydrogel applications in a soybean–wheat cropping system. *Communication in Soil Sceince and Plant Analysis.* **45:** 1167–1180. https:// doi. org/ 10. 1080/ 00103 624. 2013. 875191

Rahman, A., Ahmad, R. and Safdar, M. (2011) Effect of hydrogel on the performance of aerobic rice sown under different techniques. *Plant Soil Environment* **57(7):** 321–325.

Rivera, R.; Navarrete, R. and Domínguez, J. (2015). Absorción de agua de hidrogel de uso agrícola y su humedecimiento de tres tipos de suelo. V Congreso Nacional y IV Congreso Iberoamericano de Riego y Drenaje. VII Exposición de Equipos de Riego y Afines. Lima-Perú.

Sanmay, K. (2022) Prospects of hydrogels in agriculture for enhancing crop and water productivity under water deficit condition. *International Journal of Polymer Science.*

Santelices, R. 2005. Desarrollo de una plantación de *Eucaliptulus globulus* establecida en primera con diferente tratamientos de riego. Bosque. **26(3):** 105-112.

Save R., Perry, M, Marfa, O. and Serrano, L. (1995). The effect of a hydrophilic polymer on plant water status and survival of transplanted pine seedlings. Hort-Technology. **5:** 141-143.

Tanaka, T. (1978). Collapse of gels and the critical end point. *Physical Review Letters,* **40:** 820–823.

Yangyuoru, M. et al. (2006). Effects of natural and synthetic soil conditioners on soil moisture retention and maize yield. *Journal of Applied Ecology*. **9:** 1–8.

Yazdani, I, Allahdadi and Akbari, G. A. (2022) Impact of superabsorbent polymer on yield and growth analysis of soybean (*Glycine max* L.) under drought stress condition, *Pakistan Journal of Biological Sciences,* **10(23):** 4190–4196.

Biotech Today (January-June 2024) : 14 (1) : 38 - 43

DOI : 10.5958/2322-0996.2024.00005.0

REVIEW ARTICLE

Hyperspectral Remote Sensing in Agriculture-A review

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Received: 1 April, 2023, **Revised**: 9 October, 2023, **Accepted**: 16 November, 2023, **Published**: 1 January, 2024

Abstract

The development of advanced remote capture devices with great spatial and spectral resolution and the ongoing development of more effective computing resources to handle the high volume of data, hyperspectral imaging has turned into a useful remote sensing tool. Hyperspectral image analysis has a significant implication in precision agriculture, where it is possible to access the health status of crops at different stages of the production process from their spectral signatures. The recent developments in hyperspectral remote sensing hold a major key in early diagnosis of abiotic stress over a broader area in non-destructive manner with less effort, expense and time as compared to direct field methods. Abiotic stresses *viz.* nutrient, cold, drought, salt, heavy metals have become a serious threat to food security. Plants can produce numerous molecular, biochemical and physiological responses to cope up and adapt to such stresses situation. Understanding these minute changes in crop plants in terms of biochemical and biophysical features and physiological processes, which are normally invisible in multispectral remote sensing, is possible with large continuous narrow waveband hyperspectral remote sensing. Many studies on potential applications of hyper spectral remote sensing in agriculture to assess abiotic and biotic stresses have been carried out by different researchers in India and abroad (Shobiga and Kumar, 2015). However, due to the low spectral resolution, multispectral broadband-based remote sensing is limited in its ability to quantitatively estimate biochemical properties. In this paper we have described about the principles and procedures of hyperspectral remote sensing in agriculture.

Key words: hyperspectral imaging, spectral resolution, abiotic stress, remote sensing, physiological processes, stressors.

Introduction

Remote sensing can be defined as science and art of acquiring information about an object without actually being in contact with it. Hyperspectral remote sensing commenced in 1983 with the first experimental hyperspectral sensor. It is called state of the art technique. This sensor has also been onboard Chandrayaan-1 for mapping the lunar surface. Hyperspectral imaging systems have gained a great amount of attention from researchers in the past few years. The sensors of these systems permit the simultaneous capture of several spectral wavelengths, hundreds per image pixel. The likelihood of more precisely differentiates objects, materials, or areas of interest increases with the availability of this extensive spectrum information. Furthermore, the fine spatial resolution of the sensors enables the analysis of small spatial structures in the image. The main property of the Hyperspectral images is the strong resolving power for fine spectra and

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then they have a wide range of applications in agriculture (Elmasry *et al.,* 2019). Hyperspectral imaging is a new technology used for acquiring high resolution data in terms of both the spatial and spectral properties of an object. It measures reflected light from plants in hundreds of narrow bands across the electromagnetic spectrum as hypercube. It is becoming increasingly available for agricultural applications and is used for a variety of purposes, such as disease detection, grading, classification and detection. HSI technology still faces a series of challenges, (fig. 3) mainly including the following problems that need to be solved. The high dimensionality of the hyperspectral data, for example, the spectral reflectance values of hyperspectral images collected by airborne or space-borne imaging spectrometers, is up to hundreds of dimensions. Moreover, factors such as sensors, atmospheric conditions, surrounding environment, composition and distribution of ground features affect the spatial variability of spectral information and interference (Bonettini *et al*., 2019).

Hyperspectral remote in agriculture

Monitoring of crop conditions at regular intervals is fundamental for implementing sustainable agriculture. It is axiomatic that high yields can only be obtained if plant stress is kept to a minimum. Abiotic stress such as nutrient, cold, drought, salt and heavy metals largely influences plant development and crop productivity. Due to anthropogenic climate change and environmental deterioration, abiotic stress has grown to be a significant threat to food security. Plants can start a number of molecular, cellular and physiological changes to react to and adapt to such pressures necessary for abiotic stress survival. Remote sensing approaches have been found to be timely, non-destructive and have the ability to offer spatial estimates for assessing and monitoring certain vegetation features in comparison to direct field techniques. However, the quantitative estimation of biochemical characteristics is constrained by the multispectral broadband-based remote sensing's low spectral resolution. The use of average spectral information across broadband widths, which results in the loss of crucial information present in certain narrow bands, such as, is a significant limitation of broadband remote sensing (Blackburn, 1998 and Thenkabail *et al*., 2000). The reflectance and absorption features in narrow bands are related to specific crop characteristics such as biochemical composition (Haboudane *et al*., 2002), physical structure, water content (Champagne *et al.,* 2003) and plant eco-physical status (Strachan *et al.,* 2002).

Hyperspectral cameras are commonly divided into spectral regions, including VIS (400–700 nm), NIR (700–1100 nm) and SWIR (1100–2500 nm). Photosynthetic pigments, xanthophyll, chlorophylls and carotenoids absorb strongly in the VIS region. SWIR can quantify properties of plant materials such as phosphorus, hemicelluloses, protein and mineral contents (Batten *et al*., 1998). The application of HSI to the evaluation of plant responses to biotic and abiotic stress conditions, such as fungal infection, water and nutrient deficits, is particularly noteworthy. Numerous physiological and biochemical reactions occur in plants as a result of the development of stress, including alterations in the functioning of the photosynthetic apparatus, plant organs, water content, leaf surface and internal structure. These changes affect the leaf's optical characteristics. (Sun *et al*., 2018) that can be measured by HSI.

The challenge of observing the early stages of this process noninvasively can be met by using hyperspectral sensors, which detect senescent changes in the spectral reflectance characteristics of leaves. These changes are mainly related to the aforementioned degradation of pigments (particularly chlorophyll), which alters the ratios between reflected, absorbed and transmitted radiation (Blackburn, 2007). Hyperspectral remote sensing is an automatic, quick and non-destructive method of assessing plant growth parameters and nutrient levels in crop plants (Hansen and Schjoerring, 2003). Drought stress, unlike the majority of plant diseases, does not show local symptoms. The reallocation of resources affects the entire plant and happens to a certain extent in all plants, even in those that receive plenty of water. Early and rapid leaf senescence is a characteristic of plants under drought stress (Munne-Bosch and Alegre, 2004). This creeping process must be detected and distinguished from spontaneous changes using spectral data with high degrees of temporal and geographical resolution. Our theory states that a set of hyperspectral images can be utilized to explanation.

Due to the urgent imminent requirement of supplying the growing world population with a sufficient volume of rice crop, it is important to know the development cycles of this plant, as well as the factors, both climatic and environmental, that limit its development and yield. In addition, it is important to study the influence of environmental factors, such as the presence of heavy metals or other contaminants, in the nutritional profile and potential toxicity of cultivated rice. It is also necessary to consider all the methodologies and technologies available for crop analysis such as the mechanisms of pollutants uptake and translocation in rice, phenology, canopy reflectance spectra, remote sensing, near-surface imaging spectroscopy and of particular interest to this work, hyperspectral imaging (Chen *et al.*, 2019). Several studies has made on crop separability using hyperspectral data to manage the agriculture field crop in a better way. To find out the relation between different agricultural crops types and hyperspectral data various methods like discriminate analysis, principal components analysis and partial least square regression analysis are used. The significant wave bands vary location to location and crop species however red edge and NIR region of spectra plays a major role in crop species discrimination as noticed by Jeffrey *et al., (*2014).

Working Principles and using of Hyperspectral radiometer

HSI is a non-invasive, fast, high-throughput and remote sensing plant phenotyping method. It captures both spectral (ë) and spatial (x, y) information and merges these into a 3D data matrix termed a 'hyperspectral data cube' (hypercube). A hypercube includes hundreds to thousands of contiguous images, narrow spectral bands and 2D images of spectral information in UV, VIS, near IR (NIR) and short-wave IR (SWIR) regions (250–2500 nm).

Hyperspectral data are much larger and more complex than multispectral data, posing significant challenges in data handling and analysis. They are collected over a large number of narrow bands in continuous spectral coverage. To handle high-dimensional datasets, it necessitates the development of new methods and techniques. The most frequent problem is information duplication caused by interband correlation, which necessitates understanding of application-specific 'optimal bands' that could effectively capture the majority of crop characteristic information (Thenkabail *et al.*, 2020). It has also been demonstrated that four principal components created from 76 bands 36 can account for 96% of the variability in the data. In addition, hyperspectral spectra are typically noisier than those obtained under controlled laboratory circumstances.

- Hyperspectral imaging works with the imaging of narrow spectral bands over a continuous spectral range and produces the spectra of all pixels in the scene.
- Hyperspectral sensors collect images as set

of images. These images are then combined and form into a 3D hyperspectral data cube for analyzing and processing.

- Hyperspectral imaging does not measure each pixel in the image, but also measures the reflection, emission and absorption of electromagnetic radiation.
- It provides unique spectral signatures for every pixel, which can be used by processing techniques, identify and discriminate materials.

Based on need hyperspectral image is divided into 3 types as given below

- **Small objects such as leaf lesions or seeds** HS can be mounted on a microscope – here if the object or image is small for example pollen structure, stigma, parts of flower etc for visualizing the hyperspectral image is fitted to microscope.
- **Monitoring plants in the laboratory** HS camera mounted to the side or above a conveyor belt or a translation stage- here the leaf or objects are laced on the rotator conveyor belt the image is taken by hyperspectral image.
- **Field trails** Vehicle- mounted HS camera are used-here the hyperspectral image is used in the drones. Example- UAVs-Unmanned aerial vehicle.

Procedure of handling hyperspectral instrument

I. Hyperspectral Sensor

- hyperspectral sensor, halogen light source, conveyor system, computer and photographic.
- The hyperspectral sensor utilized in the study was a V10E-B1410 sensor which contained visible and near infrared.
- (VNIR) bands with a spectral range from 380–1030 nm, a resolution of 5.5 nm.
- The distance between rice samples was 0.6 m.

II. Image Acquisition.

- Leaves were placed flat on the conveyor belt to scan the image at every 90 degree turn to enlarge the dataset.
- The exposure time for scanning was 5.495 ms

III. Calibration

- $R_c = R_0\text{-}B/W\text{-}B$
  Where R_0 = is the raw hyperspectral image
  R_c is the hyperspectral image after calibration

B is the standard black reference value obtained by covering t1he lens with a lens cap

W is the standard white reference value with a Teflon rectangular bar

Fig 1. Indicates calibrating of the instrument as seen below

IV. Spectral Information Extraction

- The background removal process performs binary segmentation through the **Otsu** method, including healthy, RLF-infested and other defective leaves.
- **An image showing the Pre-processing of Hyperspectral imaging**

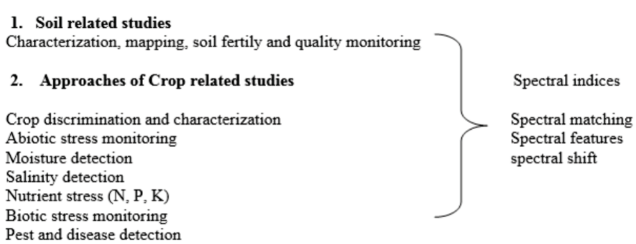
Hyperspectral imaging removing of noisy bands Segmentation Spectral curves Generation of spectral curves segmented hyperspectral cubes.

Fig. 2. Handling of hyperspectral radiometer/hyperspectral instrument in field condition

Applications of hyperspectral imaging

- Plant stress detection and monitoring
- Disease detection and diagnosis of the crops
- Soil analysis and nutrient management
- Crop phenotyping and yield prediction
- Weed detection and mapping
- Crop health indicators
- Grading and classification
- Surveillance of the agriculture and horticulture crops

Hyperspectral uses for soil and plant studies



Advantages and Disadvantages of Hyperspectral Imaging

Advantages	Disadvantages
Accurate identification of features	Cost of the instrument is high
Non-destructive	Complexity of the technology
Rapid data acquisition	Hyperspectral imaging requires fast computers
Detection of hidden features	Sensitive detectors
High spatial and spectral resolution	large data storage capacities for analyzing the data collected
Ability to capture the entire electromagnetic spectrum	It creates computational and statistical challenges due to multidimensionality of database

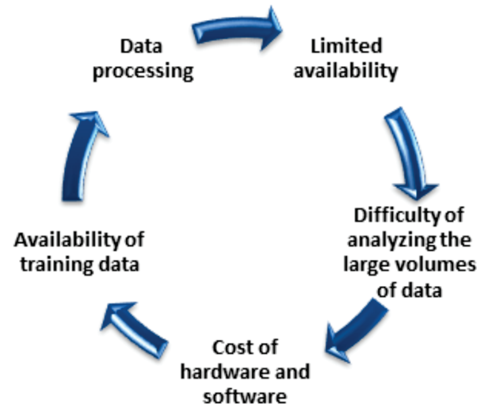


Fig. 3. Challenges in Hyperspectral Imaging

Future prospects

- The availability of hyperspectral images has enriched remote sensing research through better data quality.
- Interactions of biotic and abiotic stress as to be explored.
- impact of mixed infections on the optics properties has to be investigated

Conclusion

- Active area of research and development in hyperspectral remote sensing.
- The ability of HSI to provide integrated spatial and spectral information offers a perfect combination of rapid non-destructive assessment of plant traits.
- Requires an understanding of the nature and limitations of the data and of various strategies for processing and interpreting.
- Recent developments in hyperspectral remote sensing shows great promise for identifying a variety of crop biotic and abiotic stresses. However, any pressures impede the physical makeup of plants, photosynthesis and impact light energy absorption and reflectance hyperspectral

remote sensing was used to study the plant spectrum. But as remote sensing is not a standalone system, it must be verified using appropriate real-world data, combined with other collateral information to support decision-making

References

Batten, G.D. (1998). Plant analysis using near infrared reflectance spectroscopy: the potential and the limitations. *Australian Journal of Experimental Agriculture*, **38:** 697–706.

Blackburn, G.A. (1998). Hyperspectral remote sensing of plant pigments. *Journal of Experimental Botany*, **58(4):** 855–867.

Bonettini, S., Benfenati, A. and Ruggiero, V. (2019). Primal-dual first order methods for total variation image restoration in presence of poisson noise. In Proceedings of the *International conference of Information Photonics*.

Champagne, C.M., Staenz, K., Bannari, A., Mcnairn, H. and Deguise, J.C., (2003). Validation of a hyperspectral curve-fitting model for the estimation of plant water content of agricultural canopies. *Remote Sensing Environment*, **87:** 148-160.

Elmasry, G., Mandour, N., Al-Rejaie, S., Belin, E. and Rousseau, D. (2019). Recent applications of multispectral imaging in seed phenotyping and quality monitoring—an overview. *Sensors,* **19:** 1090.

Haboudane, D., Miller, J. R., Tremblay, N., Zarco-Tejada, P. J. and Dextraze, L. (2002). Integrated narrow-band vegetation indices for prediction of crop chlorophyll content for application to precision agriculture. *Remote sensing of environment*, **81(2-3):** 416-426.

Hansen, P.M. and Schjoerring, J.K. (2003). Reflectance measurement of canopy biomass and nitrogen status in wheat crops using normalized difference vegetation indices and partial least squares regression. *Remote Sensing Environment*, **86:** 542-553.

Pandey, P., Ge, Y., Stoerger, V. and Schnable, J.C. (2017). High throughput in vivo analysis of plant leaf chemical properties using hyperspectral imaging. *Frontiers in plant science*, **8:** 259439.

Rumpf, T., Mahlein, A., Steiner, U., Oerke, E., Dehne, H., Plümer, L. (2010). Early detection and classification of plant diseases with support vector machines based on hyperspectral reflectance. *Computers and Electronics in Agriculture*. **74(1):** 91–99.

Sahoo R.N., Ray, S.S. and Manjunath K.R. (2015). Hyperspectral remote sensing of agriculture. *Current Science*, **108(5):** 848-859.

Shobiga, R. and Kumar, J.S. (2015). Analysis of Biochemical and Biophysical Attributes of Plants Using Hyperspectral Imaging; *Karpagam Journal of Engineering Research* (KJER), **3:** 2393-994.

Strachan, I.B., Pattey, E. and Boisvert, J.B. (2002). Impact of nitrogen and environmental conditions on corn as detected by hyperspectral reflectance. *Remote Sensing Environment*, **80:** 213-214.

Sun, C., Gao, X., Chen, X., Fu, J., and Zhang, Y. (2019). Metabolic and growth responses of Thenkabail, P.S., Optimal hyperspectral narrow bands for discriminating agricultural crops. *Remote Sensing Review*, **20:** 257-291.

Thenkabail, P.S., Smith, R.B. and Pauw, E.D. (2000). Hyperspectral vegetation indices and their relationships with agricultural crop characteristics. *Remote Sensing Environment*, **71:** 158-182.

Munne-Bosch, S., & Alegre, L. (2004). Die and let live: leaf senescence contribute to plant survival under drought stress. Functional plant biology. 31(3) : 203 - 216.

Lang., Chem, X., Liang, L, Ren, S., & Qian, S. (2019). Geographic and climatic attribution of autum land surface phenology spatial pattern in temperature decidious forest of China. remote sensing. 11(13) : 1546.

Biotech Today (January-June 2024) : 14 (1) : 48 - 54

DOI : 10.5958/2322-0996.2024.00006.7

REVIEW ARTICLE

Iron Uptake, Translocation and Regulation in Higher Plants- A review

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Received: 4 November, 2023, **Revised**: 26 November, 2023, **Accepted**: 10 December, 2023, **Published**: 1 January, 2024

Abstract

For all plants to survive and grow, iron is necessary. The reduction strategy-I of nongraminaceous plants and the chelation strategy-II of graminaceous plants are two different ways that higher plants have evolved to obtain iron, which is only marginally soluble, from the rhizosphere. Both techniques' essential molecular elements, such as transporters, enzymes and chelators, have been elucidated. Many of these elements are now believed to also work inside the plant to promote internal iron transport. Also being clarified are the transporters involved in intracellular iron trafficking. The bulk of the genes that encode these components are transcriptionally regulated in response to iron availability.

Key words: accumulation; iron deficiency, phytosiderophores, mugineic acid family, transcription factor, toxicity; uptake mechanisms; iron.

Introduction

Iron (Fe) is the element that is needed most frequently. Iron is the third-most limiting nutrient for plant growth and metabolism because it has a restricted solubility in aerobic environments. (Zuo and Zhang, 2011; Samaranayke *et al.*, 2012). It is a part of heme, the Fe-sulfur cluster and other Fe-binding sites and is essential for a number of vital functions including photosynthesis, respiration and the creation of chlorophyll. Chloroplasts are rich in iron-sulfur (FeS) proteins, including Photosystem I, ferredoxins and a number of metabolic enzymes. Baulk and (Schaedler 2014); (Briat *et al.*, 2015). Respiratory complexes including Complex I&II and Complex III: A combination of FeS, heme and Complex IV: A mixture of heme and copper, are observed to include several FeS clusters. Fe's chemical properties, which make it suitable for redox reactions, also make it vulnerable to the development of reactive oxygen species when it occurs in free form and in large quantities. In order to obtain enough Fe without becoming poisonous, plants precisely control absorption, utilization and storage in response to environmental availability. Poor yields and nutritional quality are the results of iron deficiency, a common nutritional issue in many crop plants. Iron is necessary for the maintenance of chloroplast structure and function and for the production of chlorophyll in plants.

Despite being present in soils in substantial proportions as the fourth most common element in the lithosphere, iron has a low bioavailability in aerobic and neutral pH environments. Iron can be absorbed in considerable amounts in aerobic soils because it is largely present in the Fe^{3} state and is a component of oxyhydroxide polymers, which have a very low solubility. However, it poses a risk since it can promote the production of reactive oxygen-based radicals, which can damage membranes and induce lipid peroxidation. According to (Laan *et al.*, (1991),

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plants exposed to above-optimal iron levels display symptoms such bronzing (coalesced tissue necrosis), acidity and/or root blackening. Plants are unable to absorb iron under a variety of physiological conditions, including high soil pH in alkaline soils, where iron is mostly present in the soil as Fe [3] chelate forms. High-pH soils make it more difficult for plants to generate and stabilize chlorophyll, which leads to yellowing leaves, poor growth and decreased yields.

Iron uptake, translocation and regulation

Iron uptake from soil to root

In order to increase the root surface area for improved Fe uptake, plants respond to Fe deficiency by undergoing morphological changes in their root architecture, such as decreasing root growth and increasing the number of lateral roots and root hairs (Hindt and Guerinot, 2012). FeIII, which is not bioavailable to plants, is the type of iron that is present in the rhizosphere. Different plant species employ a variety of methods to get iron from the soil. Second, graminaceous plants, sometimes referred to as strategy-II plants, such as maize, barley and rice, adopted a chelation-based strategy. According to (Takagi *et al.*, 1984), these plants release phytosiderophores (PS), which have a high affinity for binding Fe (III) into the rhizosphere. The PS-Fe(III) complex is delivered to root cells by yellow stripe (YS) or yellow stripe-like (YSL) transporters (Curie *et al.*, 2001).

Numerous iron uptake-associated genes are activated when there is a lack of iron. For instance, AtAHA2 and AtAHA7 expression was elevated by an iron deficiency (Yuan *et al.*, 2008). AtAHA2 was found to be predominantly responsible for the acidification of root hairs under low iron circumstances and its absence revealed proton extrusion capacity. The AHA regulation mechanism, however, is still a mystery. Recent studies have demonstrated that cytochrome B5 reductase 1 (CBR1) expression is significantly increased in iron-deficient conditions and activates H1-ATPases by promoting the amount of unsaturated fatty acids. Organic acids, flavins, flavonoid and phenolic compounds are additional molecules associated with the acidity reduction technique for iron uptake. (Connorton *et al.*, 2017).

These substances take up apoplastic iron by chelation and diminish it in the soil. Few research have examined the role of coumarins, which plants release in situations with low levels of iron to help with iron uptake and Fe(III) availability (Jeong, Merkovich, 2017).

Additionally, the cell membrane-located root-expressed ferric reductase oxidase 2 (FRO-2) transforms the available Fe(III) to Fe(II) in the root apoplast (Mukherjee *et al.*, 2006).

According to (Robinson *et al.,* 1999), it has 725 amino acids, eight transmembrane domains and a hemes and NADPH binding motif. Two heme and flavin molecules carry the NADPH electron to the Fe(III) in the apoplast. (Schagerlo *et al.*, 2006). Additionally, FRO2 overexpression lines showed increased activity of FRO2 in iron-deficient environments. FRO2 is reported to be expressed in flowers and its regulation, either transcription or post-transcription, is controlled by iron concentration. (Connolly *et* al., 2003).

Fe(II) can be imported into cells by IRT1 with a high affinity for Fe(II) (km 5–6 M) following the reduction of Ferric to Ferrous in the root rhizosphere. The most important root transporter for absorbing Fe(II) from the soil is IRT1, which is a member of the ZIP family and has 8 transmembrane domains and 347 amino acids. IRT1 can also enhance the synthesis of many other metals, such as manganese, zinc, cobalt and cadmium (Vert *et al.*, 2002). IRT1 has previously been discovered in *Arabidopsis* and it has been discovered to be capable of saving the Fe absorption-deficient fet3-fet4 yeast mutants. IRT1 expression rises in low iron environments.

A particular kind of PS produced by the roots of rice, wheat and barley helps chelate the Fe(III) form and the resulting Fe-PS complex is then taken up by the plants by means of specialised transporters. Mugineic acid (MA) and other related PS are released into the rhizosphere as a first step by members of the main facilitator superfamily (MFS), such as the transporter of mugineic acid (TOM) and efflux transporter of nicotianamine (ENA) (Nozoye *et al*., 2011). The resulting PS-Fe(III) complexes are then transported into the root by yellow stripe 1 (YS1)/YS1-like (YSL) transporters (Curie *et al*., 2001; Inoue *et al*., 2009).

Originally discovered in maize, yellow stripe 1 (YS1) is aimed towards the plasma membrane where it is anticipated to transport Fe(III)-PS into root cells (Curie *et al*., 2001). As a chelated form complexed with MA, citrate and NA, iron is translocated inside the plant cell (Kakei *et al*., 2012; Kobayashi and Nishizawa, 2012; Takahashi *et al*., 2003). Under unfavourable circumstances, ZmYS1 expression is increased in maize roots and shoots (Curie *et al*., 2001; Roberts *et al*., 2004).

Contrarily, rice uses both Fe uptake pathways I and II (Ishimaru *et al*., 2006a). While barley and maize are two crops that have elements for both Strategies I and II, they are not the only ones (Morrissey *et al.,* 2009; Zanin *et al*., 2017). However, in a few plant species, like wheat, this region is still unexplored. Table 1 lists the number of genes used in both strategies in *Arabidopsis* and crop plants.

Young leaves develop chlorosis due to a Fe deficiency, which lowers grain quality and yield (Shi *et al*., 2012). In order to adjust to the iron-deficient state, plants drive a number of physiological processes in the root rhizosphere and other related processes like photosynthesis, root and shoot ratio and ferric reductase activity. Additionally, in order to maximise iron uptake, the root architecture changes based on the amount of iron in the soil. For example, the quantity of lateral roots increases, transfer cells are created and more root hair grows (Morrissey *et al.,* 2009)

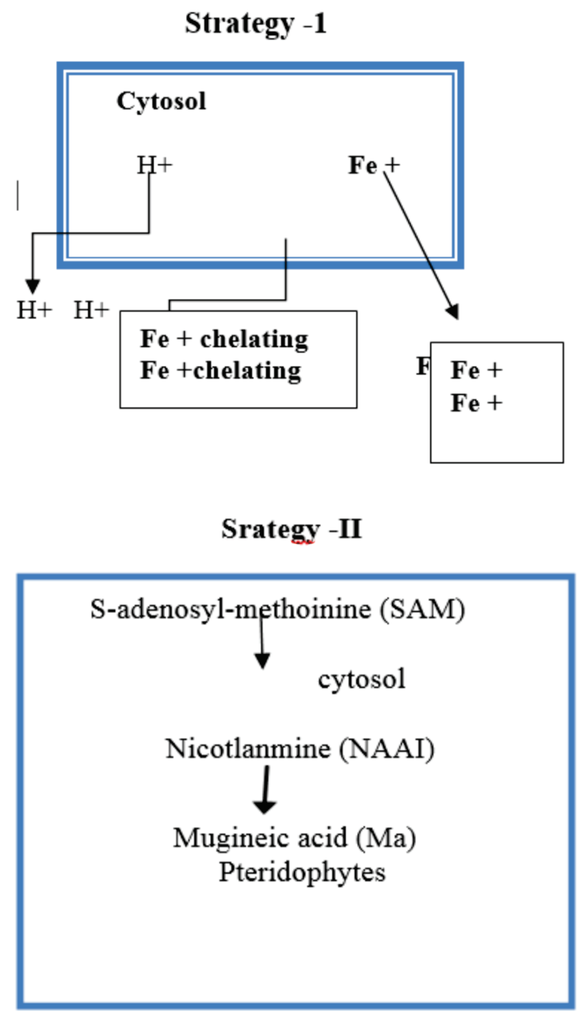

Fig. 1. Fe uptake strategies in plants. Technique I is a reduction-based technique in non graminaceous plants (left), while Strategy II is a chelation-based strategy in graminaceous plants (right). The reduction-based strategy-I entails acidifying the soil with a membrane-bound H1 ATPase proton pump and reducing Fe31-chelates with FRO. IRT transporters-1, which are membrane-bound, aid in further Fe21 trafficking. NA is synthesised from SAM by NAS and then transformed into DMA in two consecutive steps catalysed by NAAT and followed by DMAS in strategy-II. TOM proteins transport DMA into the rhizosphere. Plant roots include YS/YSL transporters, which produce PS, a chelating agent for Fe31 iron, which subsequently carries it across the plasma membrane.

Iron transportation mechanism

After entering the root endodermis from the epidermis, iron must be transported through the xylem to other parts of the plant. Citrate and succinate levels rose in the xylem with an iron deficiency (Ishimaru *et al*., 2010). While its rice homolog FRDL1 is essential for iron translocation, ferric reductase deficient 3 (FRD3) mediates the transfer of iron and citrate into the xylem in *Arabidopsis*. Even when iron levels are adequate, mutations of FRD3 exhibit a severe Fe-deficient phenotype because it is only present in the pericycle and cells surrounding the vascular tissue (Green and Rogers, 2004).

Despite the fact that iron intake processes vary between graminaceous and non-graminaceous plant species, iron transfer from root to shoot may be the same in both. Ferroportin1 (FPN1) is another protein that aids in iron loading into the xylem (Morrissey *et al*., 2009). Three FPN with different subcellular localizations are found in the *Arabidopsis* genome; for instance, FPN1, FPN2 and FPN3 are located in the chloroplast envelop, vacuolar membrane and plasma membrane, respectively (Morrissey *et al.,* 2009; Schaaf *et al*., 2005).

Additionally, Fe can move through the xylem in a complex containing MA and nicotianamine (Fe-NA and Fe-MAs). Nicotianamine synthase converts S-adenosyl methionine into NA, a nonprotein amino acid that serves as a metabolic precursor to PS (Inoue *et al*., 2009). In addition to being required for iron transport in the phloem (Curie *et al*., 2009), NA and DMA are found in xylem exudate. Iron must be carried from the apoplastic region to the leaf cells once it reaches the leaves, which calls for the employment of NA and DMA. Iron is transported from the apoplast to the symplast by a select few metal NA transporters, including AtYSL1, AtYSL2 and AtYSL3.

In addition, the oligopeptide transporter 3 (OPT3), which was found in *Arabidopsis*, belongs to another class of transporters and is involved in the recirculation of iron in the roots. In addition, OPT3 controls the movement of iron ions rather than iron ligand complexes from the leaves to the root and developing tissues (Mendoza-Co'zatl *et al*., 2014). A mitochondrial cochaperone called HSCB is involved in the transport of iron from the root to the shoot. While its mutant plants displayed iron accumulation in the shoot despite poor iron uptake in the roots, its overexpressing lines generated iron buildup in the root while reducing iron content in the shoot.

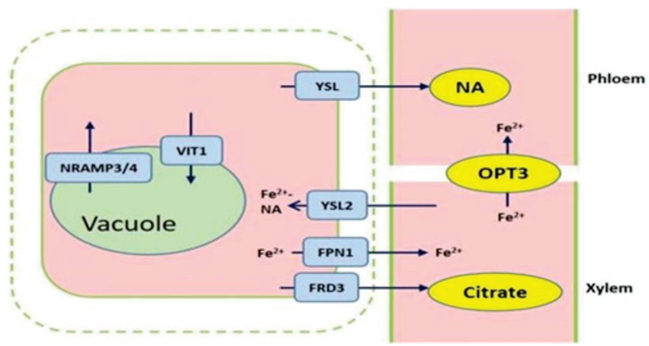

Fig. 2. A schematic depiction of iron transport to shoot from root. The combination of iron and citrate transported into the xylem by two enzymes: ferric reductase deficient 3(FRD3) and ferroportin1 (FPN1). YSL2 (Yellow stripe like 2) transports iron to neighbouring cells from the xylem. Furthermore, VIT1 mediates iron loading into the vacuole, while NRAMP3 and NRAMP4 carry out vacuolar iron outflow. Finally, OPT3 transports iron from the phloem to the sink tissues.

Note The figure was modified from (Zhang *et al*., 2019) and the journal's copyright and permission allowed open access to the information, as stated in their licence and permission.

Plant iron homeostasis regulation mechanism

Several genes and molecular components implicated in iron deficiency reactions have gone completely unnoticed. With bHLH being the most common, it has been revealed that many transcription factors are differentially expressed in iron deficiency. Six of the 26 different subgroups that make up the bHLH family in plants have been found in *Arabidopsis* due to their role in regulating iron homeostasis.

A large number of individuals in these groups or subgroups show iron deficiency-related reactions. FIT (Fer-Like Fe Deficiency-Induced Transcription Factor), a FER protein homolog, has been extensively studied to show its potential role in controlling iron uptake in *Arabidopsis* (Colangelo and Guerinot, 2004) Under Fe deficit, FIT interaction with the bHLH subgroup 1b members activates both proteins.

Numerous downstream genes involved in long-distance transport and absorption are activated as a result of this activation (Schwarz and Bauer, 2020). According to (Ogo *et al*. 2007), IRO2 functions as a master regulator in rice, favourably controlling the expression of root-specific genes related to the Fe homeostatic system. Additionally, it has been shown that the TFs of bHlH subgroups IVb, which includes bHlH121/URI and IVc, which includes bHLH034, bHLH104, bHLH105/ILR3 and bHLH115, control the homeostasis of iron in *Arabidopsis* and rice.

Furthermore, OsbHLH057/PRI4, OsbHLH058/PRI2, OsbHLH059/PRI3 and OsbHLH060/PRI1 bind to the promoter region of bHLH subgroup Ib genes such as OsIRO2, IRO3 and Plant iron homeostasis regulatory system Under iron-limiting conditions, cation transporters in plants PYE and lead to their activation (Zhang *et al*., 2020a, 2020b).

In *Arabidopsis*, PYE performs the role of an antagonist of genes involved in iron homeostasis. PYE ortholog OsIRO3 has been found in rice and was up regulated in iron deficient conditions. OsIRO3 was also discovered to be antagonist of iron homeostasis-related genes, downregulating OsIRO2 (Zheng *et al*., 2010). Overall, bHlH TFs seem to help build a regulatory network that may control the gene linked to iron regulation.

References

Balk, J. and Schaedler, T.A. (2014). Iron cofactor assembly in plants. *Annual Review of Plant Biology,* **65:** 125–153. doi: 10.1146/annurev-arplant-050213-035759.

Briat, J.F., Dubos, C. and Gaymard, F. (2015). Iron nutrition, biomass production and plant product quality. *Trends in Plant Sciences*, **20:** 33–40. doi: 10.1016/j.tplants.2014.07.005

Colangelo, E.P. and Guerinot, M.L. (2004). The essential basic helix-loop-helix protein FIT1 is required for the iron deficiency response. *Plant Cell*, **16:** 3400–12.

Curie, C., Panaviene, Z. and Loulergue, C. (2001). Maize *yellow stripe1* encodes a membrane protein directly involved in Fe(III) uptake. *Nature*, **409:** 346–349. https://doi.org/10.1038/350530

Green, L. and Rogers, E.E. (2004). FRD3 controls iron localization in *Arabidopsis*. *Plant Physiology*, **136:** 2523–31.

Hindt, M.N. and Guerinot, M.L. (2012). Getting a sense for signals: regulation of the plant iron deficiency response. *Biochimistry and Biophysics Acta*. **1823(9):** 1521-30. doi: 10.1016/j.bbamcr.2012.03.010. Epub 2012 Mar 28. PMID: 22483849; PMCID: PMC4008143.

Inoue, H., Kobayashi, T., Nozoye, T., Takahashi, M. and Kakei, Y. (2009). Rice OsYSL15 is an iron-regulated iron(III)-deoxymugineic acid transporter expressed in the roots and is essential for iron uptake in early growth of the seedlings. *Journal of Biological Chemistry*, **284:** 3470–79.

Ishimaru, Y., Masuda, H., Bashir, K., Inoue, H. and Tsukamoto, T. (2010). Rice metal-nicotianamine transporter, OsYSL2, is required for the long-distance transport of iron and manganese. *Plant Journal*. **62:** 379–390.

Ishimaru, Y., Suzuki, M., Tsukamoto, T., Suzuki, K. and Nakazono, M. (2006). Rice plants take up iron as an Fe3+-phytosiderophore and as Fe^{2} . *Plant Journal*, **45: 335–46**

James, M., Connorton, J.B. and Rodríguez-Celma, J. (2017). Iron homeostasis in plants – a brief overview. *Metallomics*, **9(7):** 813–823. https://doi.org/10.1039/c7mt00136c

Jeong, J., Merkovich, A., Clyne, M., and Connolly, E.L. (2017). Directing iron transport in dicots: regulation of iron acquisition and translocation. *Current opinion in plant biology*, **39:** 106-113.

Kobayashi, T. and Nishizawa. (2012). Regulation of iron and zinc uptake and translocation in rice. In: Biotechnology in Agriculture and Forestry 62 Rice Biology in the Genomics Era, 321–335.

Korshunova, Y.O., Eide, D., Gregg-Clark, W., Guerinot, L.M., and Pakrasi, H.B. (1999). The IRT1 protein from *Arabidopsis thaliana* is a metal transporter with a broad substrate range. *Plant molecular biology*, **40:** 37-44.

Laan, P., Smolders, A.J.P. and Blom, C.W.P.M. (1991). The relative importance of anaerobiosis and high iron levels in flood tolerance of *Rumex* species. *Plant Soil*, **136:** 153-16.

Morrissey, J., Baxter, I.R., Lee, J., Li, L. and Lahner, B. (2009). The ferroportin metal efflux proteins function in iron and cobalt homeostasis in *Arabidopsis*. *Plant Cell*, **21:** 3326–38.

Mukherjee, I., Campbell, N.H., Ash, J.S., and Connolly, E.L. (2006). Expression profiling of the *Arabidopsis* ferric chelate reductase (FRO) gene family reveals differential regulation by iron and copper. *Planta*, **223:** 1178-1190.

Nozoye, T., Nagasaka, S., Kobayashi, T., Takahashi, M., Sato, Y., Sato, Y., and Nishizawa, N.K. (2011). Phytosiderophore efflux transporters are crucial for iron acquisition in graminaceous plants. *Journal of Biological Chemistry*, **286(7):** 5446-5454.

Ogo, Y., Itai, R.N., Nakanishi, H., Kobayashi, T. and Takahashi, M. (2007). The rice bHLH protein OsIRO2 is an essential regulator of the genes involved in Fe uptake under Fe-deficient conditions. *Plant Journal*, **51:** 366–77.

Santos, R.S.D., Araujo, A.T.D., Pegoraro, C., and Oliveira, A.C.D. (2017). Dealing with iron metabolism in rice: from breeding for stress tolerance to biofortification. *Genetics and Molecular Biology*, **40:** 312-325.

Roberts, L.A., Pierson, A.J., Panaviene, Z., and Walker, E.L. (2004). Yellow stripe: Expanded roles for the maize iron-phytosiderophore transporter. *Plant Physiology*, **135(1):** 112-120.

Robinson, N.J., Procter, C.M., Connolly, E.L., and Guerinot, M.L. (1999). A ferric-chelate reductase for iron uptake from soils. *Nature*, **397(6721):** 694-697.

Samaranayake, P., Peiris, B.D. and Dssanayake, S. (2012). Effect of excessive ferrous (Fe 2+) on growth and iron content in rice (*Oryza sativa*). *International Journal Agriculture Biology*, **14:** 296-298.

Sattelmacher, B. (2001). The apoplast and its significance for plant mineral nutrition. *New Phytology*, **149:** 167-192.

Schaaf. G., Schikora, A., Haberle, J., Vert, G.and Ludewig, U. (2005). A putative function for the *Arabidopsis* Fe-phytosiderophore transporter homolog AtYSL2 in Fe and Zn homeostasis. *Plant Cell Physiology*. **46:** 762–74.

Schmidt, W. (1993). Iron stress-induced redox reactions in bean roots. *Physiology Plantarum*, **89:** 448-452.

Schwarz, B., and Bauer, P. (2020). FIT, a regulatory hub for iron deficiency and stress signaling in roots and FIT-dependent and-independent gene signatures. *Journal of Experimental Botany*, **71(5):** 1694-1705.

Song, W.Y., Mendoza-Cózatl, D.G., Lee, Y., Schroeder, J.I., Ahn, S.N., Lee, H.S. and Martinoia, E. (2014). Phytochelatin–metal (loid) transport into vacuoles shows different substrate preferences in barley and *Arabidopsis*. *Plant, cell and environment*, **37(5):** 1192-1201.

Takagi, S.I., Nomoto, K. and Takemoto, T. (1984). Physiological aspect of mugineic acid, a possible phytosiderophore of graminaceous plants. *Journal of Plant Nutrition*, **7(1-5):** 469-477.

Takahashi, M., Terada, Y., Nakai, I., Nakanishi, H. and Yoshimura, E. (2003). Role of nicotianamine in the intracellular delivery of metals and plant reproductive development. *Plant Cell*. **15:** 1263–80.

Vert, G., Grotz, N., Dédaldéchamp, F., Gaymard, F., Guerinot, M.L., Briat, J.F., and Curie, C. (2002). IRT1, an *Arabidopsis* transporter essential for iron uptake from the soil and for plant growth. *The Plant Cell*, **14(6):** 1223-1233.

Welch, R.M. and Graham, R.D. (2004). Breeding for micronutrients in staple food crops from a human nutrition perspective. *Journal of Experimental Botany*, **55:** 353–364.

Yuan, Y., Wu, H., Wang, N., Li, J. and Zhao, W. (2008). FIT interacts with AtbHLH38 and AtbHLH39 in regulating iron uptake gene expression for iron homeostasis in *Arabidopsis*. *Cell Research*. **18:** 385–97.

Zhang, X., Zhang, D., Sun, W., and Wang, T. (2019). The adaptive mechanism of plants to iron deficiency via iron uptake, transport and homeostasis. *International journal of molecular sciences*, **20(10):** 2424.

Zuo, Y. and Zhang, F. (2011). Soil and crop management strategies to prevent iron deficiency in crops. *Plant Soil*, **339:** 83-95.

Comolly, E.L., campbell, N.H., Gertz N., Pritchard, C.L., & Guerinot, M.L (2003). Overexpression of the FRO_2 ferric Chelate Reductase confers Tolerance to Growth on low Iron and uncovers Post transcription al control. Plant physiology. **133(3):** 1102-1110.

Mendoza-cozatl, D.G., Xie, Q, akmakjian, G.Z., Jobe, T.O., Patel, A., stacey, M.G., Song L., Demene, D.W., Jurisson, S.S., Stacey G., & Schroeder, J.I (201). OPT3 is a component of iron signalling Network between leaves and roots and Misregulation of OP3 leads to an over-accumulation of codinium in seeds. Molecular plant **(7)**: 1455-1469

Connorton, J.M., Balk, J., & Rodriguez-celma, J. (2017). Iron homeostasis in plants - A brief overview. Metallemics. **9(7):** 813-823.

Kakei, Y., Ishimaru, Y., Kobayashi, T., Nankanishi, H., & Nishizawa, N.K. (2012). OsYL16 plays role in the allocation of iron. Plant molecular biology **79:** 583-54.

Zanin, L., Venuti, S., Zamboni, A., Varanini Z., Tomasi, N., & Pinton, R., Venuti, S., Zamboni, A., Varanini Z., Tomasi, N., & Pinton, R. (2017). Transcriptional and physiological analyses of Fe deficiency response in maize reveal the presence of strategy I components and Fe/P interactions. BMC Genomics. **18:** 154.

Shi, R., Hao, H., Fan, X; zhang, F., & Zou, C., (2012). Responses of aerobic rice (oryza sativa L.) to iron deficiency. Journal of Integrative Agriculture. **11(6):** 938-945.

Zheng, L., Ying, Y., wang, L., wang, F., whelan, J., & shou, . (2010) Identification of novel iron regulated basic helix-loop-helix protein involved in Fe homeostasis in oryza sativa. BMC plant biology. **10:** 166.

Biotech Today (January-June 2024) : 14 (1) : 55 - 66

DOI : 10.5958/2322-0996.2024.00007.3

REVIEW ARTICLE

Effect of Level of Nitrogen and Weeding Regime on the Yield of Fine Rice

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Received: 2 August, 2023, **Revised**: 8 September, 2023, **Accepted**: 22 October, 2023, **Published**: 1 January, 2024

Abstract

The goal of this study was to find out how the fine rice cultivar BRRI dhan 34 production was affected by nitrogen levels and weeding techniques. The experiment included three nitrogen levels viz. 50, 100, and 150 kg N ha ^{1} as well as three weeding schedules *viz.* one hand weeding at 15 DAT, two hand weeding at 15 and 30, and three hand weeding at 15, 30, and 45 DAT. Three replications of the experiment were set up in a randomized full block design. The findings demonstrated important correlations between weeding techniques, nitrogen levels, and yield components. When the crop was fertilized with 50 kg N ha ^{1}, the best numbers of total tillers hill ^{1} (8.53), effective tillers hill ^{1} (7.51), grains panicle ^{1} (128.0), and grain yield (3.97 t ha ^{1}) were attained. Regarding weeding practices, two manual weeding carried out at 15 and 30 DAT reported the highest numbers of effective tillers hill ^{1} (7.62), grains panicle ^{1} (128.1) and grain yield (4.10 t ha ^{1}). The highest effective tillers hill ^{1} (8.33), the most grains panicle ^{1} (129.8), the grain yield (4.36 t ha ^{1}) and straw yield (6.40 t ha ^{1}) were found in two hand weeding combined with 50 kg N ha ^{1}, and the lowest grain yield (3.53 t ha ^{1}) was obtained from one hand weeding given at 15 DAT along with 150 kg N ha ^{1}. In order to get the best grain production of fine rice, cv. BRRI dhan34, two manual weeding at 15 and 30 DAT and 50 kg N ha ^{1} are thus recommended.

Keywords: BRRI dhan34, Fine Rice, Nitrogen Level, Weeding Regimes, Yield Components

Introduction

The majority of Bangladesh's agricultural production is produced through the cultivation of rice (*Oryza sativa L.)*. Rice comprises 91.1% of the country's total grain production, provides 74% of Bangladeshis' daily caloric needs. The demand for rice is expected to rise globally by 25% between 2001 and 2025 in order to keep up with population expansion (Maclean *et al.,* 2002). *Aman* is the second-largest rice crop in the country in terms of output volume. The average rice production in Bangladesh is 2.72 t ha^{-1}, which is incredibly small (BBS, 2022). In the next 20 years, it is anticipated that Bangladesh's population will increase by another 30 million, adding two million per year. On the other hand, the amount of arable land is decreasing every day. Bangladesh's growth region is unable to extend horizontally as a result of the country's high population pressure, rapid urbanization, and industrialization. Both for internal use and export, the demand for fragrant rice has grown dramatically in recent years. Fine rice is another name for fragrant or aromatic rice. It is tremendously well-liked across Asia, especially in Southeast Asia, and has recently gained increasing popularity in the US and Europe (Weber *et al.,* 2000). These are regarded as the highest quality rice and sell for substantially more money in overseas markets than high grade non-aromatic rice.

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These distinguishing traits include fineness, smell, taste, and protein content. Bangladesh has a bright prospect for export of fine rice thereby earning foreign exchange (Islam *et al.,* 2012; Sarkar *et al.,* 2014; Mushtaree *et al.,* 2022).

For better grain production, nitrogen, one of the necessary components, must be present in appropriate quantities during the early, middle, and panicle initiation periods of the rice plant. Nitrogen is a component that is commonly required for rice to generate a high yield (Saha *et al.,* 2012; Khatun *et al.,* 2023). Nitrogen fertilizer increases the yields of grain, straw, and vegetative growth. Too little nitrogen can make it difficult to grow rice, while too much nitrogen can induce lodging in plants and a decrease in production (Islam *et al.,* 1995). Therefore, nitrogen should be administered sparingly to get a respectable yield.

The capacity to grow and procreate in vast numbers despite difficult environmental conditions makes weed a nutrient absorbing, competitive plant that invades its native habitat on its own. It also possesses other characteristics that increase productivity. A heavy weed infestation is one of the reasons for low rice production (Mamun, 1988). According to (Mamun *et al.*, 1993), the competitive features of weeds have a considerable negative influence on agricultural productivity and are to blame for significant yield losses. The most popular and time-consuming method of weed management in our country is still manual weeding. Hand weeding is becoming more and more important when there is no pesticide that can successfully control a certain weed or when the expense of herbicides makes them prohibitive for farmers, especially small-scale farmers. Finding the ideal levels of nitrogen and weeding techniques for crops to achieve a respectable yield requires much research. The goal of the current study was to establish the perfect nitrogen level, the most effective weeding technique, and the effects of interactions between these elements in order to maximize the grain output of fine rice cv. BRRI dhan34.

Materials and Methods

Experimental site and experimentation

The experimental site was situated at latitude of 24°75' N and a longitude of 90°50' E, with an elevation of 18 meters above sea level. This location falls within the Old Brahmaputra Floodplain, specifically in the Sonatola Soil Series of Agricultural Ecological Zone 9 (AEZ-9) (UNDP and FAO, 1988). The soil in the experimental area was characterized by non-calcareous dark grey floodplain soil, which had a nearly neutral pH of 6.5, low organic matter content, and fertility. The soil texture was silty loam, and the land type was classified as medium high. The experiment consisted of various treatments, including three different nitrogen levels (50, 100, and 150 kg N ha^{-1}) and three different weeding schedules (one hand weeding at 15 days after transplanting (DAT), two hand weedings at 15 and 30 DAT, and three hand weedings at 15, 30, and 45 DAT). The experimental design followed a randomized complete block format with three replications of each treatment. Within each replication, there were nine unit plots, and the allocation of treatment combinations to these unit plots was done randomly. In total, there were 27 unit plots, each measuring 4.0 meters by 2.5 meters, with distances of 0.75 meters between unit plots and 1.0 meter between replications.

Crop husbandry

BRRI dhan34, a high-yielding variety of aman rice, was introduced by the Bangladesh Rice Research Institute (BRRI). This aromatic, fine-grain rice is typically cultivated during the Transplant *Aman* season. BRRI developed this variety in 1997 through the careful selection of the locally available Khaskani genotype from the Jessore region. The grains of BRRI dhan34 are characterized by their short and bold size, and they possess an aroma reminiscent of kalizira. This rice variety typically takes approximately 135 days to reach maturity, reaching a height of 117cm at that stage. The grains themselves are fine-textured, featuring a light golden husk and a white color. On average, this variety can yield around 3.5 tons per hectare.The seeds of this fine rice variety (cv. BRRI dhan34) were sourced from the Agronomy Field Laboratory at Bangladesh Agricultural University, Mymensingh, Bangladesh. The selection of healthy seeds was carried out using a specific gravity method. Afterward, the seeds were soaked in water for 24 hours, and the soaked seeds were then densely packed in gunny bags. Sprouting occurred within 48 hours, and the seedlings were transplanted 72 hours after soaking. These seedlings were nurtured in a medium-high land area, with a seedling nursery prepared through soil puddling. The sprouted seeds were sown in this wet nursery bed, and proper care was taken to ensure their healthy growth, without the use of fertilizer in the nursery bed. During transplanting into the main field, three seedlings were planted per hill. Land preparation involved several steps, including tractor-drawn disc ploughing, power tiller operation, thorough puddling, cross ploughing with a country plough, and laddering to achieve suitable soil tilth. Weeds and stubble were manually removed from the field before seedling transplantation, and field layout was designed accordingly after land preparation. In terms of fertilization, the experimental plots were treated with Triple Super Phosphate (TSP), Muriate of Potash (MoP), Gypsum, and Zinc Sulphate (ZnSO4) during the final land preparation at specified rates. Urea was applied as top dressing in three equal splits at 15, 30, and 45 days after transplanting, following treatment guidelines. Prior to uprooting the seedlings, the nursery bed was watered, and healthy, uniform-sized seedlings were carefully selected for transplantation. Intercultural operations, such as weeding, irrigation, and pest and disease control, were carried out as needed throughout the crop's growth cycle. Harvesting occurred when the crop reached full maturity, indicated by 90% of the grains turning a golden color. Data on crop characteristics and yield components were recorded by selecting five hills from each unit plot (excluding border rows and the central 1m × 1m area) in preparation for harvesting. The central 1.0 m^2 areas were harvested to record data on grain and straw yields. The harvested crop was threshed using a pedal thresher, and the fresh weights of grain and straw were recorded for each plot. Subsequently, the grain and straw yields per plot were recorded and converted to tons per hectare.

Data collection

To gather information on crop characteristics and yield components, five hills were randomly chosen from each unit plot, excluding the border rows and the central harvest area measuring 2.0 meters by 2.5 meters. These selected hills were uprooted. Subsequently, the crop from the central 2.0 meters by 2.5 meters area was harvested, and each plot's crop was tagged and bundled separately. These bundles were then taken to the threshing floor. After hand threshing, the grains were washed, and they were subsequently sun-dried to achieve a moisture level of 14%. Adequate drying was also ensured for the straw. The yields of grain and straw per plot were then measured and converted to t ha^{-1}.

Statistical analysis

The recorded data were compiled and organized for statistical analysis. The analysis of variance (ANOVA) technique was employed using the computer software package MSTAT-C. Mean differences among the treatments were assessed using Duncan's Multiple Range Test, as described by (Gomez and Gomez, 1984).

Results and Discussion

Infested weed species in the experimental field

The weeds that can be found in fragrant rice fields include broad leaved grasses and sedges. The same circumstances that allow for the cultivation of fragrant rice also allow for the wild proliferation and competition with agricultural plants of some weed species. Eleven weed species from five distinct family invasions were found in the test field (Table 1). The eleven weed species included four sedges, three with broad leaves, and three grasses.

Table 1: Infesting species of weeds in the experimental field of aromatic rice

S.No.	Local name	Scientific name	Family	Life cycle
1.	Shama	*Echinochloa crus-galli (L.) P. Beauv.*	Gramineae	Annual
2.	Arail	*Leersia hexandra Swartz*	Gramineae	Annual
3.	Panikachu	*Monochoria vaginalis (Burm. F.) C. Presl*	Pontederiaceae	Perennial
4.	Sabuj Nakphul	*Cyperus difformis L.*	Cyperaceae	Annual
5.	Chechra	*Scirpus mucronatus*	Cyperaceae	Annual
6.	Keshuti	*Eclipta alba L.*	Compositae	Annual
7.	Angta	*Panicum repens L.*	Gramineae	Perennial
8.	Panimorich	*Poligonum orientale L.*	Poligonaceae	Annual
9.	Anguleeghash	*Digitaria sanguinalis L.*	Gramineae	Annual
10.	Topapana	*Pistia stratioter*	Araceae	Perennial
11.	Chela ghash	*Parapholis incurva*	Gramineae	Perennial

Growth parameters

Plant height

In this study, nitrogen levels, weeding techniques, and their interactions at 45 and 60 days after transplanting had a substantial impact on plant height, a vital measure of crop development. The administration of nitrogen had a discernible effect on plant height at 60 DAT (Figure 1). A plot treated with 100 kg N ha^{-1} produced the tallest plants (115.1 cm), whereas a plot treated with 50 kg N ha^{-1} produced the shortest plants (111.2 cm). We found it that the latter was statistically similar to the plant height in the plots with 150 kg N ha^{-1}. This implies a distinct dose-response connection between the amount of nitrogen applied and the height of the plants, with the tallest plants growing at the intermediate rate of 100 kg N ha^{-1}. Similar to this, at 60 DAT, weeding techniques were obviously correlated with plant height (Figure 2). The plots with a single hand weeding at day 15 of the experiment had the tallest plants (114.24 cm), and the plots with three weeding at days 15, 30, and 45 of the experiment had the shortest plants (112.11 cm), which were statistically equivalent to plots with two hand weeding. Additionally, weeding methods and nitrogen levels interacted significantly to affect plant height (Table 2). The height of the plants ranged between 65.40 cm and 69.50 cm in different treatment combinations. One hand weeding at 30 DAT and 50 kg N ha^{-1} application resulted in the tallest plants (69.50 cm), demonstrating the favorable connection between nitrogen treatment and appropriate weeding time. In contrast, the plots with the shortest plants (65.40 cm) underwent two manual weeding at 30 and 45 DAT and received 100 kg N ha^{-1}, emphasizing the need of combining nutrient management with effective weeding methods. The stimulatory effect of nitrogen fertilizer on a number of physiological processes within the plant, including cell division and cell elongation, may be responsible for the relationship between nitrogen fertilizer application and plant height. This behavior is consistent with the observations made by (Zhilin *et al.,* 1997; Khatun *et al.,* 2023), who both found that nitrogen administration significantly increased plant height. In addition, (Chandra and Pandey, 2001) found that manual weeding was the most efficient strategy for lowering weed dry matter buildup and nitrogen depletion.

Table 2. Interaction effects of level of nitrogen and weeding regime on plant height at different days after transplanting of fine rice

Interaction (Level of N x weeding regime)	Plant height (cm)		
	Days after transplanting (DAT)		
	30	45	60
N_1 x W_1	69.50a	78.88	112.08
N_1 x W_2	65.92bc	82.25	111.42
N_1 x W_3	67.83ab	78.00	110.33
N_2 x W_1	67.58bc	85.67	113.58
N_2 x W_2	67.08bc	81.83	110.82
N_2 x W_3	65.40c	78.25	112.92
N_3 x W_1	67.42abc	84.25	117.07
N_3 x W_2	67.92ab	82.67	115.00
N_3 x W_3	66.33bc	81.38	113.08
Sx	0.661	1.30	0.98
Sig. level	*	NS	NS
CV (%)	1.70	2.76	1.51

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT) * =Significant at 5% level of probability NS = Not significant; N1 = 50 N kg ha ^{1}; N_2 = 100 N kg ha ^{1}; N_3 = 150 N kg ha ^{1}; W_1 = one hand weeding at 15 DAT; W_2 = Two hand weeding at 15 and 30 DAT; W_3 = Three hand weeding at 15, 30 and 45 DAT

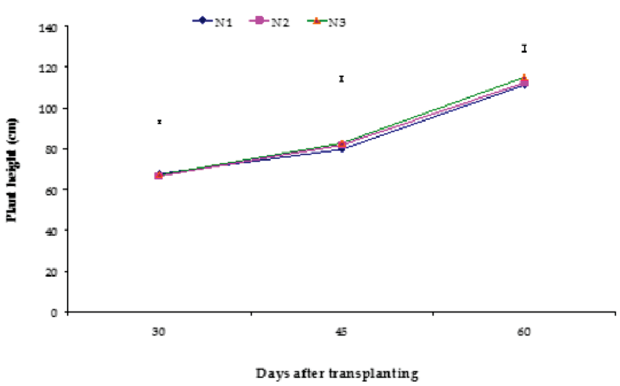

Figure 1. Effect of level of nitrogen on plant height at different days after transplanting

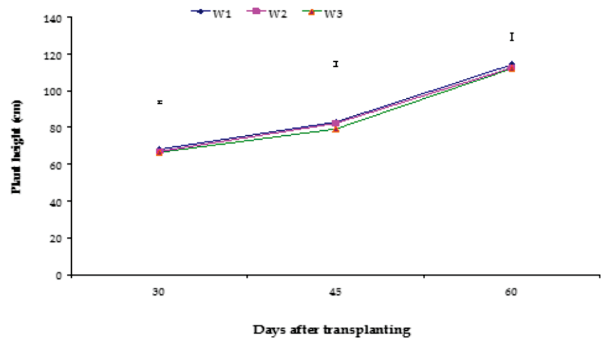

Figure 2. Effect of weeding regime on plant height at different days after transplanting

Number of total tillers hill^{-1}

The findings demonstrate that the number of tillers hill^{-1} was significantly influenced by nitrogen levels, weeding methods, and their interactions at 30, 45, and 60 days after transplanting (DAT). According to (Figure 3), the largest number of tillers hill^{-1} (13.86) was recorded at 45 DAT with 50 kg of nitrogen per hectare, whereas the lowest number (11.69) occurred at 45 DAT with 150 kg of nitrogen per hectare. The two hand weeding procedures at 15 and 30 DAT produced the highest number of total tillers hill^{-1} (15.03), as shown on (Figure 4). On the other side, the lowest count, which was achieved with just one hand weeding operation, was 15 DAT. Regarding the interactions between nitrogen levels and weeding methods, (Table 3) demonstrates that the conditions with the greatest number of tillers hill^{-1} (13.58) at 30 DAT also included two weeding at 15 and 30 DAT and 50 kg of nitrogen per hectare. The lowest number of tillers hill^{-1} (9.75) was seen when only one hand weeding was carried out at 15 DAT combined with 50 kg of nitrogen per hectare. A research was carried out by (Singh et al., 2007) to determine the effects of various weed management techniques on weed growth, crop production, and nitrogen uptake in transplanted rice. Their research showed that weeds removed a large amount of nitrogen, 12.97 kg ha^{-1}, when allowed to grow unfettered until they reached maturity. The grain and straw yields in this unweeded control setting were interestingly comparable to those achieved after three weeding cycles. According to research by (Kabiraj *et al.,* 2020; Dubey *et al.,* 1991), plots that had not been weeded had the highest numbers of worthless tillers and sterile spikelets.

Table 3. Interaction effects of level of nitrogen and weeding regime on number of total tillers hill^{-1} at different days after transplanting of fine rice (cv. BRRI dhan 34)

Interaction (Level of N x weeding regime)	Number of total tillers hill ^{1}		
	Days after transplanting (DAT)		
	30	45	60
N_1 x W_1	9.75g	12.08	9.50
N_1 x W_2	13.58a	16.25	10.83
N_1 x W_3	12.67b	13.25	9.92
N_2 x W_1	11.25e	11.38	9.08
N_2 x W_2	12.67ab	15.50	10.50
N_2 x W_3	11.75d	12.67	9.90
N_3 x W_1	10.58a	9.75	8.48
N_3 x W_2	12.33c	13.33	10.00
N_3 x W_3	10.83f	12.00	9.50
Sx	0.093	0.380	0.189
Level of sig.	**	NS	NS
CV (%)	1.38	5.10	3.35

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT) * =Significant at 5% level of probability; NS = Not significant; N_1 = 50 N kg ha ^{1}; N_2 = 100 N kg ha ^{1}; N_3 = 150 N kg ha ^{1}; W1 = one hand weeding at 15 DAT; W_2 = Two hand weeding at 15 and 30 DAT; W_3 = Three hand weeding at 15, 30 and 45 DAT

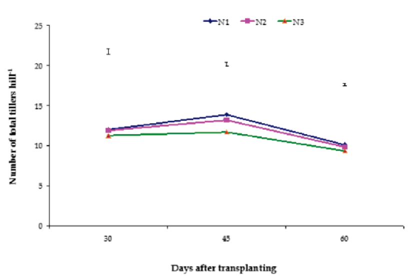

Figure 3. Effect of level of nitrogen of total tillers hill^{-1} at different days after transplanting

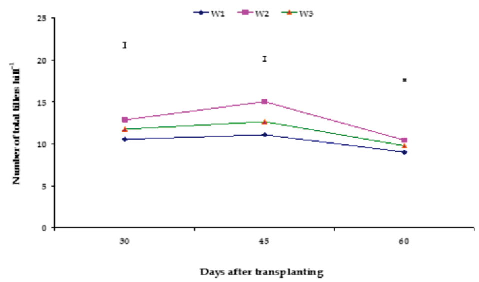

Figure 4. Effect of weeding regime on number of total tillers hill^{-1} at different days after transplanting

Crop characters, Yield components and Yield

Plant height

The nitrogen amount and interactions impact did not significantly affect plant height, but the weeding regimen did. The plant with the maximum height (147.72 cm) was identified in a 50 kg N ha^{-1} environment. In 150 kg N ha^{-1}, the lowest plant height (144.03) was discovered (Table 4). The lowest plant height (143.56 cm) was discovered in three weeding at 15, 30, and 45 DAT, while the maximum plant height (148.36 cm) was discovered in one hand weeding at 15 DAT (Table 5). The lowest plant height (141.50 cm) was discovered in two weeding operations at 15 and 30 DAT with 100 kg N ha^{-1}, whereas the maximum plant height (149.92 cm) was discovered in one hand weeding at 15 DAT with 50 kg N ha^{-1} (Table 6). It was found in research (Sahrawat *et al.,* 1999; Khatun *et al.,* 2023) that nitrogen levels had a significant impact on plant height. It has been shown that higher nitrogen levels cause plants to grow much taller. Additionally, studies by (Kabiraj *et al.,* 2020) showed that weeds have a suppressive effect on plant height, mostly through competing with plants for nutrients or other elements required to their growth.

Number of total tillers per hill

The overall number of tillers per hill was significantly influenced by nitrogen levels. The application of 50 kg of nitrogen per hectare resulted in the highest total number of tillers per hill (8.53), closely followed by 100 kg of nitrogen per hectare, and the lowest total number (7.99) was seen when 150 kg of nitrogen per hectare was used (Table 4). The overall number of tillers per hill also significantly varied depending on the weeding strategy chosen (Table 5). Due to their capacity to absorb more sun energy, two weeding operations at 15 and 30 DAT resulted in the largest total number of tillers per hill (8.75). On the other hand, simply one hand weeding at 15 DAT resulted in the lowest number of tillers per hill (7.77). Additionally, the total number of tillers per hill was significantly impacted by the interplay between the nitrogen level and the weeding schedule. The two weeding at 15 and 30 DAT along with 50 kg of nitrogen per hectare resulted in the largest number of tillers per hill (9.25). On the other side, when one hand weeding was done at 15 DAT with 150 kg of nitrogen per hectare, the lowest total tillers per hill (7.57) were found (Table 6). These results are consistent with earlier study, which showed that the application of nitrogen enhanced the total tiller count per hill (Sarkar *et al.,* 2017). This result is most likely attributable to the effective weed management implemented during critical crop-weed competition periods.

Number of effective tillers per hill

The nitrogen levels had a considerable impact on the quantity of productive tillers per hill. The maximum count of productive tillers hill^{-1}was obtained with a nitrogen application rate of 50 kg per hectare, followed by 100 kg per hectare, and the lowest count was obtained with a nitrogen application rate of 150 kg per hectare (Table 4). Similar findings were made regarding the number of productive tillers hill^{-1}, where it was discovered that the weeding schedule had a substantial impact on this figure. The number of productive tillers hill^{-1}increased the most when weeding with two hands at 15 and 30 DAT and decreased while weeding with one hand at 15 DAT (Table 5). Additionally, the quantity of productive tillers hill^{-1} was strongly impacted by the interplay of nitrogen levels and weeding practices. The results showed that using two weeding at 15 and 30 DAT along with 50 kg of nitrogen per hectare led to the maximum count of fruitful tillers hill^{-1} (8.33). However, utilizing one-handed weeding at 15 DAT and 150 kg of nitrogen per acre resulted in the lowest count (6.17) (Table 6). Given the high costs involved in using hand weeding as the only weed control technique in aerobic rice systems, it would be preferable to include hand weeding as part of a more comprehensive weed management strategy. In comparison to only utilizing pesticides, (Singh *et al.,* 2007) shows that this integrated technique not only significantly minimizes weed interference but also virtually doubles rice yields by boosting productive tillers. As a result, manual weeding is more cost-effective when used in conjunction with other methods, and it also performs better at controlling weeds.

Number of grains per panicle

Different nitrogen dosages caused a noticeable fluctuation in the number of grains per panicle. In particular, the application of 50 kilogram of nitrogen per hectare resulted in the highest numerical count of grains panicle^{-1} (128) and was comparable to the count at 100 kg N ha^{-1}. On the other hand, while employing 150 kg N ha^{-1}, the lowest count of grains panicle^{-1} (121.8) was observed, and this count statistically mirrored that of 100 kg N ha^{-1} (Table 4). Additionally, the weeding schedule caused a statistically significant change in the amount of grains panicle^{-1}. As shown in (Table 5), the two weeding treatments applied at 15 and 30 days after transplanting (DAT) resulted in the highest grain count panicle^{-1} (128.1), whereas the single hand weeding application at 15 DAT resulted in the lowest grain count per panicle (121.6). A noteworthy finding was that the interaction between the nitrogen level and the weeding schedule had no statistically significant impact on the number of grains panicle^{-1}. With two weeding at 15 and 30 DAT and 50 kg N ha^{-1}, the highest grain count panicle^{-1} (129.8) was noted. The lowest count (116.4), on the other hand, was achieved at 15 DAT with one handed weeding and 150 kg N ha^{-1} (Table 6). This observation is consistent with those made in earlier research by (Sarker *et al.,* 2017). These investigations, like the present one, produced results that were comparable, demonstrating a recurrent pattern or tendency in the findings across many study attempts.

1000-grain weight

The amount of nitrogen present significantly affected the weight of 1000 grains. While the lowest 1000-grain weight (18.59 g) was recorded when 150 kg N ha^{-1} was used, the highest 1000-grain weight (19.69 g) was seen when 50 kg N ha^{-1} was used, which was equal to the weight attained with 100 kg N ha^{-1} (Table 4). The 1000 grain weight was strongly influenced by the weeding schedule. At 15 and 30 days after transplanting (DAT), two rounds of hand weeding produced the maximum weight of 1000 grains (20.23 g), while just one cycle at 15 DAT produced the lowest weight (17.71 g) (Table 5). There was no discernible influence from the interplay of nitrogen levels and weeding practices. When two rounds of hand weeding were done at 15 and 30 DAT in addition to 50 kg N ha^{-1}, the maximum 1000-grain weight (20.89 g) was attained. However, one hand weeding cycle at 15 DAT with 150 kg N ha^{-1} applied resulted in the lowest 1000-grain weight (17.18 g) (Table 6). According to the statement, nitrogen's presence influenced the crop in a way that helped grains flourish. To be more precise, it helped the grains become plumper, which implies they were more completely formed and had superior overall size and shape. There was an increase in the total weight of grains produced as a result of this better grain growth (Jisan *et al.,* 2014; Pal *et al.,* 2018; Chowdhury *et al.,* 2016).

Grain yield

Grain yield was significantly affected by nitrogen levels. Application of 50 kg N ha^{-1} resulted in the highest grain production (3.97 t ha^{-1}), which was comparable to the output from 100 kg N ha^{-1}. In contrast, applying 150 kg N ha^{-1} resulted in the lowest grain yield (3.69 t ha^{-1}) (Table 4). A statistically significant relationship existed between the weeding schedule and grain yield (Table 5). The two hand weedings at 15 and 30 days after transplanting (DAT) produced the maximum grain yield (4.10 t ha^{-1}), while the single hand weeding at 15 DAT produced the lowest grain yield (3.55 t ha^{-1}). The more effective tillers per hill and grains per panicle in the two-hand weeding procedure are likely responsible for the enhanced grain output. Additionally, the nitrogen-weeding combination had a considerable impact on grain output. Two hand weedings at 15 and 30 DAT in addition to 50 kg N ha^{-1} were used to provide the maximum grain yield (4.36 t ha^{-1}). In contrast, utilizing one hand weeding at 15 DAT and 150 kg N ha^{-1} resulted in the lowest grain production (3.53 t ha^{-1}) (Table 6). (Alam *et al.,* 2014) reported that the application of a two-hand weeding approach resulted in the highest rice grain yield. Similar to this, (Malek, 2008) found that the maximum grain yield was obtained by conducting two rounds of weeding at 15 and 30 days after transplanting (DAT), whereas the lowest yield was produced when no weeding was done. According to (Neelam and Nisha, 2000), the seed production increased significantly linearly up to 80 kg N ha^{-1}. At a level of 120 kg N ha^{-1}, they saw a modest decline in seed production after this.

Straw yield

Nitrogen concentrations have a substantial impact on straw output. Up to 50 kg N ha^{-1} of nitrogen was shown to boost the production of straw. The maximum yield of straw (6.01 t ha^{-1}) and the lowest yield (5.81 t ha^{-1}) were both obtained with 50 kg of nitrogen per hectare (Table 4). The degree of weeding has a statistically significant impact on straw output. The results showed that two hand weeding at 15 and 30 DAT produced the best straw yield (6.08 t ha^{-1}), whereas one hand weeding at 15 DAT produced the lowest yield (5.71 t ha^{-1}) (Table 5). The interplay between nitrogen level and weeding practices had a big impact on straw output. The lowest straw yield (5.69 t ha^{-1}) was observed in one hand weeing at 15 DAT with 150 kg N ha^{-1}, whereas the maximum straw yield (6.40 t ha^{-1}) was reported in two hand weeing at 15 and 30 DAT with 50 kg N ha^{-1} (Table 6). The amount of straw produced was increased as a result of nitrogen's effects on the height and number of tillers $hill^{-1}$. Similar findings were found in regards to rice by (Sarker, 2012), who discovered that a two-hand weeding method resulted in the most rice straw.

Biological yield

On the biological yield, nitrogen level had a considerable impact. 50 kg N ha^{-1} had the largest biological yield (9.98 t ha^{-1}). In 150 kg N ha^{-1}, the lowest biological production (9.51t ha^{-1}) was discovered (Table 4). The biological yield was statistically significantly affected by the weeding regimen. The two hand weeding at 15 and 30 DAT produced the maximum biological output (10.19 t ha^{-1}), while the one hand weeding at 15 DAT produced the lowest biological yield (9.26 t ha^{-1}) (Table 5). The connection between the nitrogen level and the weeding strategy statistically affected biological yield. In a combination of two hand weedings at 15 and 30 DAT with 50 kg N ha^{-1}, the maximum biological yield (10.76 t ha^{-1}) was discovered. Using one hand weeding at 15 DAT and 150 kg N ha^{-1}, the lowest biological output was recorded (9.23 t ha^{-1}) (Table 6). Results that (Ahmed *et al.,* 2005) observed were in line with the conclusions being explored.

Harvest index

The harvest index was significantly impacted by the nitrogen dosage. With the increase in nitrogen level up to 50 kg N ha^{-1}, the harvest index rose. 50 kg N ha^{-1} had the greatest harvest index (39.74%), whereas 150 kg N ha^{-1} had the lowest harvest index (38.75%) (Table 4). The harvest index was significantly impacted by the weeding regimen. The two hand weeding operations at 15 and 30 DAT produced the greatest harvest index (40.27%), whereas the three hand weeding operations at 15 and 45 DAT produced the lowest harvest index (39.14%) (Table 5). The relationship between nitrogen level and weeding strategy did not significantly affect harvest index. In two weeding operations at 15 and 30 DAT with 50 kg N ha^{-1}, the greatest harvest index (40.54%) was discovered. With three hand weeding at 15, 30, and 150 kg N ha^{-1}, the lowest harvest index (38.05%) was discovered (Table 6). This implies that the earlier investigations were somewhat in agreement with or confirmed it (Khatun *et al.,* 2023; Sarkar *et al.,* 2017).

Table 4. Effect of level of nitrogen on crop characters, yield components and yield of fine rice

Nitrogen level	Plant height (cm)	Total tillers $hill^{-1}$ (no)	Effective tillers $hill^{-1}$ (no)	Grains $panicle^{-1}$ (no)	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
N1	147.72	8.53 a	7.51a	128.0a	19.69a	3.97a	6.01a	9.98a	39.74a
N2	145.31	8.08b	6.82b	124.9ab	18.98ab	3.76b	5.81b	9.57b	39.26ab
N3	144.03	7.99b	6.66b	121.8 b	18.59 b	3.69 c	5.82b	9.51b	38.75 b
Sx	1.25	0.059	0.071	1.33	0.265	0.021	0.038	0.043	0.198
Sig. level	NS	**	**	**	*	**	**	**	**
CV (%)	2.58	2.14	3.03	3.19	4.17	1.56	1.97	1.36	1.51

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT); ** =Significant at 1% level of probability; * =Significant at 5% level of probability; NS = Not significant; N_1 = 50 N kg ha^{-1}; N_2 = 100 N kg ha^{-1}; N_3 = 150 N kg ha^{-1};

Table 5. Effect of weeding regime on crop characters, yield components and yield of fine rice

Weeding regime	Plant height (cm)	Total tillers hill–1 (no)	Effective tillers hill ^{1} (no)	Grains panicle -1 (no)	1000-grain weight (g)	Grain yield (t ha ^{1})	Straw yield (t ha ^{1})	Biological yield (t ha ^{1})	Harvest index (%)
W_1	148.36 a	7.77c	6.42c	121.6b	17.71c	3.55c	5.71c	9.26c	38.33c
W_2	148.14 ab	8.75a	7.62a	128.1a	20.23a	4.10a	6.08a	10.19a	40.27a
W_3	143.56 b	8.19b	6.94b	125.1a b	19.32b	3.76b	5.85b	9.62b	39.14b
Sx	1.25	0.059	0.071	1.33	0.265	0.021	0.038	0.043	0.198
Sig. level	*	**	**	**	**	**	**	**	**
CV (%)	2.58	2.14	3.03	3.19	4.17	1.56	1.97	1.36	1.51

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT); ** =Significant at 1% level of probability; * =Significant at 5% level of probability; NS = Not significant; W_1 = one hand weeding at 15 DAT; W_2 = Two hand weeding at 15 and 30 DAT; W_3 = Three hand weeding at 15, 30 and45 DAT

Table 6. Interaction effects of level of nitrogen and weeding regime on crop characters, yield components and yield of fine rice

Interaction effect	Plant height (cm)	Total tillers hill ^{1} (no)	Effective tillers hill ^{1} (no)	Grains panicle ^{1} (no)	1000-grain weight (g)	Grain yield (t ha ^{1})	Straw yield (t ha ^{1})	Biological yield (t ha ^{1})	Harvest index (%)
$N_1 \times W_1$	149.92	7.83 cd	6.66c	126.3	18.42	3.58 d	5.75 bcd	9.33 d	38.39 c
$N_1 \times W_2$	145.83	9.25 a	8.33a	129.8	20.89	4.36 a	6.40 a	10.76 a	40.54 a
$N_1 \times W_3$	147.42	8.67 b	7.53b	127.9	19.77	3.97 b	5.88 bcd	9.85 b	40.29 a
$N_2 \times W_1$	148.58	7.75cd	6.45cd	121.9	17.53	3.54 d	5.70cd	9.24 d	38.31 c
$N_2 \times W_2$	145.83	8.50b	7.30b	129.2	20.00	4.00 b	5.91 bc	9.92 b	40.36 a
$N_2 \times W_3$	141.50	8.00c	6.73c	123.7	19.39	3.74 c	5.83 bcd	9.57 c	39.09 bc
$N_3 \times W_1$	146.58	7.57 d	6.17d	116.4	17.18	3.53 d	5.69 d	9.23 d	38.30 c
$N_3 \times W_2$	143.75	8.50 b	7.25b	125.5	19.81	3.94 b	5.93 b	9.87 b	39.91 ab
$N_3 \times W_3$	141.75	7.92 c	6.58c	123.6	18.80	3.59 d	5.85bc d	9.45 cd	38.05 c
Sx	2.17	0.102	0.123	2.30	0.459	0.037	0.066	0.075	0.343
Sig. level	NS	*	*	NS	NS	**	**	**	NS
CV (%)	2.58	2.14	3.03	3.19	4.17	1.56	1.97	1.36	1.51

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT); ** =Significant at 1% level of probability, * =Significant at 5% level of probability; NS = Not significant; N_1 = 50 N kg ha^{-1}; N_2 = 100 N kg ha^{-1}; N_3 = 150 N kg ha^{-1}; W_1 = one hand weeding at 15 DAT; W_2 = Two hand weeding at 15 and 30 DAT; W_3 = Three hand weeding at 15, 30 and45 DAT

Conclusion

The results of this experiment demonstrate the value of the cultivar BRRI dhan34 in the production of fragrant fine rice and the need for an all encompassing fertilizer and weed control plan. Two handed weeding in addition to the application of 50 kg of nitrogen per hectare has shown to be a highly successful and promising strategy in terms of growth and productivity. This comprehensive strategy aids in lowering weed competition, increasing the availability of nutrients for the rice plants, and boosting crop output. These findings provide rice farmers and other agricultural professionals with useful information and lead to a workable and long term plan for raising the output of fragrant fine rice.

Acknowledgments:

Swapan Kumar Paul extends his gratefulness to Ministry of Science and Technology, Bangladesh.

Conflicts of Interest: The authors certify that they have no financial or other competing interests to disclose with relation to the current work.

References

Ahmed, M., Islam, M. I. and Paul, S. K. (2005). Effect of nitrogen on yield and other plant characters of local T. *Aman* rice, var. Jatai. *Research Journal of Agricultural & Biological Science* **1(2):** 158- 161.

Alam, A., Paul, S. K., Sarkar, M. A. R. and Islam, S. M. M. (2014). Effect of row arrangement and nitrogen dose on the performance of transplant *Aman* rice. *International*

Journal of Sustainable Crop Productivity, **9(2):** 7-16.

Ali, M.I., Sarkar, M.A.R. and Paul, S.K. (2018). Influence of plant nutrient management on the yield performance of transplant Aman rice (*Oryza sativa* L.). *Archives of Agriculture and Environmental Science,* **3(1):** 49-53.

BBS, Bangladesh Bureau of Statistics (2022). Statistical Year Book of Bangladesh. Bangladesh Bur. Stat., Statistics Division, Ministry Planning. People's Repub. Bangladesh, Dhaka

Chandra, S. and Pandey, J. (2001). Effect of rice culture, nitrogen and weed Control on Nitrogen competition between scented rice and weeds. *Indian Journal of Agronomy,* **46(1):** 68-74.

Chowdhury, S. A., Paul, S. K. and Sarkar, M. A. R. (2016). Yield performance of fine aromatic rice in response to variety and level of nitrogen. *Journal of Environmental Science and Natural Resources*, **9(1):** 41-45. https://doi.org/10.3329/jesnr.v9i1.30289

Dubey, O. P., Upadhyaya, S. P., Dixit, J. P. and Grag, D. C. (1991). Response of short duration paddy varieties to nitrogen under rainfed condition. *Indian Journal of Agronomy,* **36(2):** 255-256.

Gomez, K. A. and Gomez, A. A. (1984). Statistical Procedures for Agricultural Research. 2nd Edn. A Wiley Interscience Publication, John Wiley and Sons, New York. pp. 207-215.

Islam, M. S. (1995). Effect of variety and nitrogen fertilizer application on the growth and yield of transplant *aman* rice. M. S. Thesis, Department of Agronomy., B. A. U., Mymensingh, pp. 26,29.

Ismail, U., Kolo, M. G. M. and Gbanguba, U. A. (2012). Efficacy of some weed control practices in upland rice (*Oryza sativa*) at, Badeggi, Nigeria. *American Journal of Experimental Agriculture,* **1(4):** 174-186. https://doi.org/10.9734/AJEA/2011/224

Jisan, M. T.; Paul, S. K. and Salim, M. (2014). Yield performance of some transplant Aman rice varieties as influenced by different level of nitrogen. *Journal of Bangladesh Agricultural University*, **12(2):** 321-324. https://doi.org/10.3329/jbau.v12i2.28691

Kabiraj, M.S., Rashid, M.M., Anwar, M.P. and Hossain, M.D. (2020). Performance of Boro rice cv. BRRI dhan28 as influenced by different plant establishment methods and weeding regimes. *Journal of Bangladesh Agricultural University*, **18(4):** 934–940. https://doi.org/10.5455/JBAU.129791

Khatun, M. R., Sarkar, M. A. R., Kabiraj, M. S., Sarkar, S. K., Harun, M. H. and Paul, S. K. (2023). Influence of nitrogen and phosphorus on the growth and yield of fine aromatic rice (cv. Binadhan13). *Journal of Agroforestry and Environment,* **16(1): 96-103.** https://doi.org/10.55706/jae1612

Maclean, J. L., Dawe, D. C., Hardy, B. and Hettel, G. P. (2002). *Rice Almanac.* Los Banos (Philippines): International Rice Research Institute, Bouake (Coted' Ivoire):West Africa Rice Development Association, Cali (Colombia International Center for Tropical Agriculture, Rome (Italy): Food and Agriculture Organaization , pp., 253.

Malek, A. (2008). Study the effect of spacing and weeding regime on the performance of transplant aus rice cv. BR26, M.S. Thesis, Dept. Agronomy Bangladesh Agriculture University Mymen Singh.

Mamun, A.A. (1988). Farmers concepts of weeds and weed control. Jawal village in Kishoregonj-Agricultural and Rural Development in Bangladesh. JS ARD Pub. No. 8. Japan Intl. Co-operation Agency Dhaka, Bangladesh.pp., 74-90.

Mamun, A.A., Karim, S.M.R., Begum, M., Uddin, M. I. and Rahman, M.A. (1993). Weed survey in different crops under three agro-ecological zones of Bangladesh. *BAURES Prog,* **8:** 41-51.

Mushtaree, A., Sarkar, M. A. R., Kabiraj, M. D., Sarkar, S. K., Rashid, M. H. and Paul, S. K (2023). Performance of Aman Rice Varieties Under Different Nutrient Management. *Bangladesh Agronomy Journal*, **25(2):** 89–96. https://doi.org/10.3329/baj.v25i2.65952

Neelam, K. C. and Nisha, C. (2000). Effect of row spacing and N level on growth, yield and seed quality of scented rice under transplanted conditions. *Indian Agricultural Research Institute* **45(2):** 304-308.

Saha, P. K., Islam, S. M. M., Akter, M. and Zaman, S. K. (2012). Nitrogen response behaviour of developed promising lines of T. *Aman* rice. *Bangladesh Journal of Agricultural research,* **37(2):** 207-213. https://doi.org/10.3329/bjar.v37i2.11222

Sahrawat, K. L., Diatta, S. and Singh, B. N. (1999). Nitrogen responsiveness of lowland rice varieties under irrigated conditions in West Africa. *International Rice Research Notes,* **24(2):** 30.

Sarkar, S., Sarkar, M., Islam, N., and Paul, S. K. (2014). Yield and quality of aromatic fine rice as affected by variety and nutrient management. *Journal of the Bangladesh Agricultural University,* **12(2):** 279–284. https://www.banglajol.info/index.php/JBAU/article/view/28683

Sarkar, M.A.R., Paul, S.K. and Paul, U. (2017). Effect of water and weed management in Boro rice (cv. BRRI dhan28) in Bangladesh. *Archives of Agriculture and Environmental Science*, **2(4):** 325-329, DOI: 10.26832/24566632.2017.020414

Sarker A.K. (2012). Effect of Variety and Nitrogen Level on Yield and Yield Performance of Transplanted Aman Rice. M. S. Thesis, Department of Agronomy, B. A. U., Mymen Singh, pp., 25.

Singh, S., Ladha, J., Gupta, R., Bhushan, L., Rao, A., Sivaprasad, B. and Singh, P. (2007). Evaluation of mulching, intercropping with Sesbania and herbicide use for weed management in dry-seeded rice (*Oryza sativa* L.). *Crop Protection,* **26:** 518–524. https://doi.org/10.1016/j.cropro.2006.04.024

UNDP, United Nations Development Programme and FAO, Food and Agriculture Organization. Land Resources Appraisal of Bangladesh for Agricultural Development. Report 2, (1988). Agro-ecological Regions of Bangladesh. *Bangladesh Agricultural Research Council*, Dhaka-1207. Pp., 212-221.

Weber, R., Charles W., Jeffrey, K., Lazo. and Kenneth. (2000). The economic impacts of agriculture-to-urban water transfers on the area of origin: a case study of the Arkansas River Valley in Colorado. *American Journal of Agricultural Economics*, 1200-1204.

Zhilin, L., Sarket, R. S., Nayak S. K., Ravi, L. and Li, J. L. (1997). Physiological effect of nitrogan application on aromatic rice. *Journal of South China. Agricultural University,* **18 (3):** 4,13-17,23.

Pal, D., Patra, P.K., & Mukopadhyay, D. (2018). Effect of tillage and organic residuce on yield of wheat (Triticum aestivum L.). Research on crops, 19(3): 373-379.

Biotech Today (January-June 2024) : 14 (1) : 67 - 73

DOI : 10.5958/2322-0996.2024.00009.6

REVIEW ARTICLE

KisanTech Companion: A Complete Guide for an agriculturalist using MERN Stack Development

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Received: 18 September, 2023, **Revised**: 28 October, 2023, **Accepted**: 17 November, 2023, **Published**: 1 January, 2024

Abstract

This research paper delves deeply into the integration of cutting-edge technologies aimed at bolstering small-scale farming practices. It meticulously examines a scenario wherein small-scale farmers partake in equipment sharing arrangements with their larger counterparts, incorporate a sophisticated e-commerce platform tailored for the seamless sale of seeds and fertilizers, and integrate a state-of-the-art weather application to access real-time meteorological updates. The principal aim of this study is to effectively tackle the pervasive challenges faced by small-scale farmers in accessing pivotal resources such as essential equipment, high-quality seeds, fertilizers, and timely weather forecasts. By capitalizing on the inherent synergies between equipment sharing, e-commerce functionality, and real-time weather data accessibility, the research endeavors to significantly enhance productivity levels, streamline operational efficiency, and augment decision-making processes within the agricultural sector. In this paper it allows them to book the equipment in advance. It also helps to get the track of equipment's that are on rent. The aim is also at developing analytic for the state heads to make better availability of equipment's and to keep track of the equipment's as well, which could help in providing better support for farmers. This paper undertakes a comprehensive examination of the potential ramifications of these technological integrations on diverse facets of small-scale farming operations, including but not limited to, profitability and sustainability metrics. Through the meticulous analysis and synthesis of findings, this study aims to provide invaluable insights into the formidable transformative potential of technology in empowering small-scale farmers and catalyzing a culture of innovation within the agricultural landscape.

Keywords—MERN, MongoDB, Express.js, React.js, Node.js

Introduction

It is where modern technology in farming assists small farmers. This paper discusses about small farmers who borrow tools from big ones, buy seeds and stuff online, check the weather with their smartphones, and so on. This could help solve a lot of problems small farmers have in getting what they need to farm properly. This work aims to make the work of farming a bit easier for small farmers and, at the same time, also create an avenue where they can increase their income. Sharing tools means that money is saved for community building. Buying things online makes it easier and cheaper for them to get good seeds and stuff they need for farming. It also helps in deciding planting the crop, crop watering, and giving protection to the crop with all real-time, really important stuff amid great changes in weather conditions. This research is looking at how these new ways of farming can help small farmers do better and make farming more sustainable. It connects

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resources to what a farmer needs to do. As highlighted by (Wu, 2022), the adoption of new agricultural technologies significantly increases farm productivity and income. Their study, published in PLOS ONE journal explains that the adoption of better machinery, improved fertilizers, as well as the best ways of controlling pests, has significantly improved the level of efficiency among farmers working on small pieces of land in China. Thus, the proposed model would indeed work to make small farms work better, thus growing and making more money. Sharing tools is a way of bringing people together and enabling wiser, cheaper use of resources. At the same time, having an online store makes it easier for them to buy good seeds and fertilizers at good prices. The weather app again will help the farmers know the weather in time. This will help the farmer to know the exact period for planting, watering, and protecting the crops. Real-time knowledge of the weather will enable such smallholder farms to better cope with changing weather and extreme weather events. This research paper seeks to find out how sharing equipment, using online stores, and having weather apps can make small farms stronger to produce more and thus make farming better for the environment in a world where technology is becoming more of a top priority.

A. Equipment Sharing

Make it easy for small farmers to borrow gardening tools. Have simple rules for borrowing, easy ways to book the tools, and make sure they are returned on time. also, set up a website or app where farmers can ask for tools, see where they are, and keep track of what they have borrowed.

B. E-commerce Website

Make a website where farmers can easily buy seeds and fertilizers:

- Clear Sections: Sort items neatly into categories like seeds and fertilizers so it easy to find what they need.
- Details About Products: Put lots of info about each product like what it's for and how to use it
- Safe Ways to Pay: Make sure there are safe ways to pay like using a credit card or online banking
- Easy Search: Make it easy to search for specific things farmers want to buy
- Personal Suggestions: Use info about what they have bought before to suggest other things they might like.

C. Weather Application

- Developed a simple weather app for farmers:
- Shows Local Weather: The app tells farmers what the weather's like where they are right now
- Alerts for Bad Weather: Farmers can set up alerts for things like rain or cold, so they know when to protect their crops
- Easy-to-Read Forecasts: The forecasts are easy to understand, so farmers know what's coming up
- Farming Tips: The app gives advice on farming tasks based on the weather like when to plant or water crops
- By making it easy to use, farmers can quickly check the weather and plan their farming jobs better.

Technological Integration In Farming

This review attempts to synthesize the insights of fifteen critical studies to address the integration of advanced technologies to support small-scale farming practices. These studies, therefore, combined, affirm the great potential that is held by technology in ensuring access to resources and in making agriculture more productive and sustainable. All reviewed works underpinned the central theme that technology could be used as an avenue for farmers to bridge the resource-gap that is associated with small-scale farming.

(Tippannavar *et al.*, 2023) propounded AGROPEDIA, the integrated platform of agricultural knowledge resources manifesting access to information, which is very important in the developmental process of agriculture. In equal measure, (Pagar *et al.,* 2021) considers the Android app, which links farmers to retailers and offers services in the hiring of agricultural machinery. It confirms further embodiment of the vital role that mobile technology plays in direct market linkages and sharing of resources. The sharing of equipment, an important aspect of shared resources with small-scale farmers, is further detailed in (Bagaitkar *et al.,* 2019 and Ner *et al.* 2023), who also include the sharing of digital platforms to rent out agricultural equipment. The platforms enhance the access to equipment and the introduction of efficiency and cost-effectiveness in the conduct of farming operations. (Shin *et al.,* 2014) continues this idea with a demonstration of a web-based rental business management system of agricultural machinery, which is another clear example of fruitful digital solution integration with traditional practices.

(Pressman *et al.,* 2005; Luo *et al.*, 2016) bring technical views to the discourse, especially tackling software engineering principles and the best scheduling models for available resources. This presents foundational knowledge within the technological context that may be very critical toward the development and implementation of successful solutions within the Kisantech domain. The review also includes newly opened research areas on the use of sustainable water resources in agriculture (Renzi *et al.*, 2024) and management of biotic stress through the use of nanotechnology and phenolic compounds (Rathore *et al.*, 2024). AI technology on the farm takes place in a future perspective (Jarinaa *et al.*, 2023). These are the studies that highlight different kinds of technologies that intervene for specified, narrow, and defined problems in agriculture, including water-saving, crop-health, and optimization of yield. Notwithstanding the above technological interventions, the literature review could indicate other effects of Kisantech implications on the agricultural supply chain and the market dynamics. (Adesiyan *et al.*, 2024) comes out with the next-generation supply chain of agriculture in America, while (Balasubramanian *et al.,* 2024) focuses on the transformational impacts of cutting-edge agriculture technology. Furthermore, (Yadav *et al.,* 2024) have focused on technological jolts regarding the value chain of agriculture and competitive dynamics of the Agritech firms in India. The authors make it possible to carry out further enrichment of the analysis with the help of the works by (Spalletti *et al.,* 2023), who point at the role digital agriculture is playing in the framework of sustainable development, and (Bloomer *et al.*, 2024), who studied innovations connected with weed control not requiring herbicides. All these studies collectively, conclusively try to put more emphasis on the critical connection that exists between technological advancement and the sustainable development goals, which call for the adoption of practices in farming that are alive to culture and taking care of the environment. From the foregoing, therefore, the integration of technology in small-scale farming provides a multifaceted tool that can be applied regarding the perennial challenges of resource accessibility, productivity, and sustainability. This involves easing access to shared facilities, increasing direct market access courtesy of e-commerce platforms, and use of real-time data in informed decision-making, technologies that the sector can deploy as a catalyst to spur change. This literature review seeks to underscore the far-reaching potential that comes with the empowerment of technology advances for small-scale farmers, the increase in operational efficiency, and the creation of a culture that encourages both sustainability and innovation within agriculture.

Research Gap

There is a great place for modern equipment in today's farming, it ensures better farms and doing work at a faster pace. But the problem is that the machines are very costly. This way, it becomes very hard for small farmers who do not have much money to buy them. Although this equipment could be of help to the farm, but fact remains that it is so expensive. It will always be a very big issue for farmers across the globe. Though many have tried to mend this, still a very big gap remains in small farmers getting quick, easy, and cheap solutions that work for them. Most of these works are grounded on rather old-style ways of solving this problem, and it might simply be that they miss considering new and out-of-the-box ideas that really could make quite a difference in getting farming equipment to the smallholder. This research paper tries to fill this void with a novel solution—to not only understand the financial pain small-scale farmers deal with but also to propose a pragmatic and efficient alternative. The introduction of an agricultural equipment rental service hopes to make modern farming tools more affordable to all and empower farmers in increasing their productivity without the worry of high upfront costs. Take, for example machines for planting potatoes; they have become essential in making planting easier and getting more crops, but they come with a huge amount hence many small-scale farmers were not able to afford purchasing them. While this equipment may be rented for much less by these machines, the proposed model not only allows easy facilitation for farmers in getting the correct equipment that they need but also relieves the financial problems they might face due to which they are unable to use new technology. Addressed one major gap in the current discourse around the access to agricultural equipment. The research provides a new and practical way that brings the affordability, convenience, and effectiveness of equipment to the smallholder farmer. It also demonstrates, using real-world data and case studies, that this strategy of implementing a rental service model specifically designed around the needs of small-scale farmers is not only feasible from the manufacturer's perspective but can truly make a substantial difference in the number of smallholders that are able to gain access to such machinery. At last, it is hoped that these efforts contributing to putting agriculture on a more sustainable course and increasing the value of its products to rural communities.

Methodology Software Requirement Specification

A. Introduction

The Software Requirement Specification (SRS) that describes the requirements and objectives of developing an Agricultural Technology Platform using the MERN stack. The platform developed should enable farmers in India to take equipment on rent and even purchase seeds whenever necessary.

B. Functional Requirements

- User registration and authentication
- Browsing the equipment and select as per the need
- Rental booking and scheduling
- Seed browsing and selection
- Secure payment gateway

C. Non-functional Requirements

- High performance and responsiveness
- Reliability and availability
- Security and data privacy
- User-friendly interface and ease of navigation
- Compatibility with various devices and browser.

D. System Requirements

- Development using the MERN stack (MongoDB, Express.js, React.js, Node.js)

- Cloud hosting for scalability and reliability.

E. Data Requirements

- Storage of user information, equipment listings, and seed inventory
- Manipulation of data for analytics and insights

F. Documentation Requirements

- User manuals for farmers and administrators
- Technical specifications for developers
- Training materials for platform users

G. Acceptance Criteria

- Successful completion of user registration, equipment rental, and seed purchase processes
- Positive feedback from pilot users and stakeholders

H. Risk Management

- Identification of potential risks such as data breaches or system downtime.

I. Proposed System

The “KisanTech” platform proposed herein synthesizes two pivotal workflows, as documented by the research.

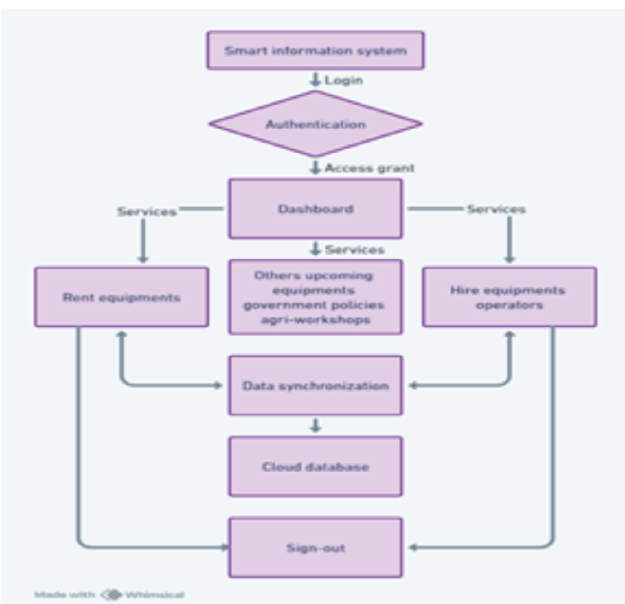


Fig. 1. User Interface Flowchart for Smart Information System.

According to the flowchart of the user interface, as described in reference by (Kumar *et al.*, 2022), bearing in mind the smart information system (Fig. 1) and the KisanTech Platform Interaction Workflow outlined in reference by (Ner *et al.*, 2023), (Fig. 2), it comes out to facilitate the increase in agricultural transactions. Farmers can upload their produce details on KisanTech most of the time after logging in, supported by the inclusion of geolocation data, which will help conduct location-centric search. This combined system would enable customers to search, select, and purchase agricultural products easily, and be compatible with existing functionalities in the farm equipment rental systems, further popularizing the existing current technological advances in the agricultural sector. Marrying the strengths of both systems—Kumar and Saravanamuthu’s design of the interface and Ner *et al.*‘s interaction workflow design—"KisanTech" is all set to change, in a sweeping manner, the way the digital marketplace takes place in the domain of agricultural equipment, taking agri-economy to a more connected and efficient future.

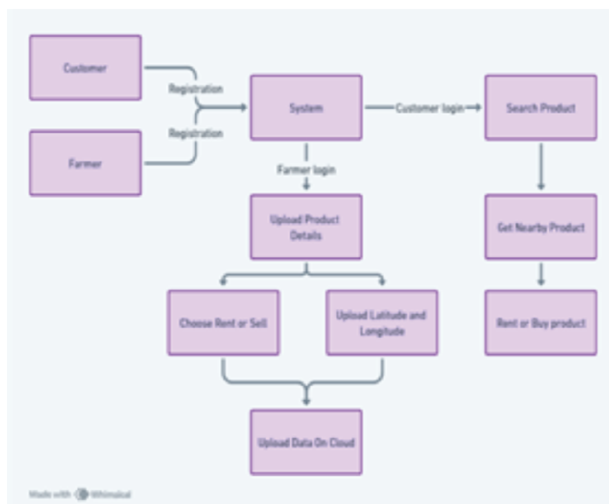


Fig. 2. KisanTech Platform Interaction Workflow

Conclusion

The integration of agricultural equipment rentals, e-commerce websites selling seeds and fertilizers, and weather apps for agriculture provides a way to improve the small farm. Small farmers can increase business and farming efficiency by using non-motorized equipment through credit. The use of e-commerce platforms can facilitate market access, product visibility and sale of agricultural products, thereby promoting sustainable trade. Additionally, integrated weather application allows farmers to make decisions based on accurate weather conditions, thus improving crop management, resource allocation and overall productivity. This combination emphasizes the importance of technological advances, resource pooling and decision-making in today's agriculture, ultimately contributing to sustainable and profitable agriculture. It also saves time. Furthermore, the information linked to the overall research is shown, and it should be in the knowledge of all and several so that needed changes can be made as per requirement. A lot of improvements can be made to the website, and it can be extended to all other devices. Possible extensions: the analysis can be extended to lead to a head of state where he can see machines needed in the area, then gets moved to a new location or may include GPS and maps to help track the device's current location.

References

Adesiyan, J. S. and Raffington, A. E. (2024). AgriTech Revolution: Next-Generation Supply Chain in America's Agriculture. *International Journal of Environment and Climate Change* **14(2)**: 254-272. http://asian.go4 sending.com/id/eprint/1991/

Bagaitkar, K. Lande, K., Welekar, A., Yadav, A., Tambe, A., and Chopade, A. (2019). Tractor Hiring application for Farmers. *International Research Journal of Engineering and Technology* **6(3)**: 2401-2409. https://www.academia.edu/download/60405858/IRJET-V6I346620190826-13953-hyp07d.pdf

Balasubramanian, G. (2024). Cutting-Edge Agriculture Technology: Transforming Farming for a Sustainable Future. *European Economic Letters (EEL)* **14(1)**: 463-473. https://eelet.org.uk/index.php/journal/article/view/1049

Bloomer, D. J., Harrington, K. C., Ghanizadeh, H. and James, T. K. (2024). Robots and shocks: emerging non-herbicide weed control options for vegetable and arable cropping. *New Zealand Journal of Agricultural Research* **67(1)**: 81-103. https://www.tandfonline.com/doi/abs/10.1080/00288233.2023.2252769

Kumar, C.A. and Saravanamuthu M. (2022). AGRARYANS: Farm Equipment Rental System/Based on Agriculture. *International Research Journal of Engineering and Technology (IRJET)*. https://www.irjet.net/archives/V9/i6/IRJET-V9I6152.pdf

Jarinaa, B. and Manida, M. (2023) A study on Pros and Cons of AI Technology Used Agri Farming in Tamil Nadu. Recent Trends in Data Mining and Business Forecasting **4(2).** https://www.matjournals.co.in/index.php/JTDMBF/article/view/4728

Luo, X. W. and Zhang, L. Y. (2016). The optimal scheduling model for agricultural machinery resources with time-window constraints. *International Journal of Simulation Modelling*, DAAAM International Vienna, **15(4)**: 721-731. http://www.ijsimm.com/Full_Papers/Fulltext2016/text15-4_721-731.pdf

Ner, M. C., Hire, M. V., Salunkhe, M. M., Patil, M. S. and Ahire, M. B. (2023). *Agriculture Equipement's Rental System*. https://www.irjmets.com/uploadedfiles/paper/issue_3_march_2023/34591/final/fin_irjmets1679567128.pdf

Pagar, M. M., Nehate, M. M., Godse, M. A. and Patil, M. S. (2021) Android App to Connect Farmers to Retailers and Agricultural Machinery Rental Business. Computer Engineering, Savitribai Phule Pune University, Late GN Sapkal College of

Engineering, Nashik, India, *International Journal for Research in Applied Science and Engineering Technology (IJRASET)* **45** https://www.academia.edu/download/65668818/32991.pdf

Pressman, R. S. (2005). *Software engineering: a practitioner's approach*. Palgrave macmillan. https://books.google.com/books?hl=enandlr=andid=bL7QZHtWvaUCandoi=fndandpg=PA1anddq=Pressman,+R.+S.+(2005).+Software+engineering:+a+practitioner%27s+approach.+Palgrave+macmillan.andots=O9udbOtI8eandsig=XFNKEHwdiGP1rD4WSxyunLwzXhw

Rathore, D., Naha, N. and Singh, S. (2024). Phenolic Compounds and Nanotechnology: Application During Biotic Stress Management in Agricultural Sector and Occupational Health Impacts. *In Plant Phenolics in Biotic Stress Management* (pp. 503-549). Singapore: Springer Nature Singapore. https://link.springer.com/chapter/10.1007/978-981-99-3334-1_21

Renzi, N., Pacetti, T., Lompi, M., Castelli, G., Caporali, E., Setti, A. and Bresci, E. (2024). Water footprint and water productivity analysis of an alternative organic mulching technology for irrigated agriculture (No. EGU24-8048). *Copernicus Meetings*. https://meetingorganizer.copernicus.org/EGU24/EGU24-8048.html

Shin, S. Y., Kang, C. H., Yu, S. C., Kim, B., Kim, Y. Y., Kim, J. O. and Lee, K. S. (2014). Web-based Agricultural Machinery Rental Business Management System. *Journal of Biosystems Engineering* **39(4):** 267-273. https://citeseerx.ist.psu.edu/document?repid=rep1andtype=pdfanddoi=e0ba3972020885344f9e6c439565d1db9334e3b8

Spalletti, S., Frontoni, E., and Paolanti, M. (2023). Digital agriculture for sustainable development-*AGRITECH EU*. https://u-pad.unimc.it/handle/11393/324373

Tippannavar, S. S., Yashwanth, S. D., Gagana, C., Meghana, M., Gautami, J. and Konnur, P. (2023). AGROPEDIA-One Stop for all Agricultural Needs. *IJIRAE: International Journal of Innovative Research in Advanced Engineering* ISSN, 2349-2163. https://www.researchgate.net/profile/Sanjay-Tippannavar/publication/369689479_AGROPEDIA_-One_Stop_for_all_agricultural_Needs/links/6427a59e92cfd54f8444e9aa/AGROPEDIA-One-Stop-for-all-agricultural-Needs. pdf

Wu, F. (2022). Adoption and income effects of new agricultural technology on family farms in China. *PLoS One*, **17(4):** e0267101. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0267101

Yadav, R., Jafri, A. and Awate, S. (2024). Technology turbulence in agricultural value chain: Evidence from India. *In Strategy in a Turbulent Era* pp. 251-269. Edward Elgar Publishing. https://www.elgaronline.com/edcollchap/book/9781802201482/book-part-9781802201482-22.xml

RECENT NEWS

E-Crop – An IoT Device for Smart Farming

ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram launched an IoT-based precision agriculture technology called 'e-crop' in Thiruvananthapuram. The precision agriculture technology was transferred successfully by signing the Technology Licensing agreement with M/s. Tech Visit IT Pvt. Ltd, Mumbai which was facilitated by Agrinnovate India Limited, New Delhi. Dr. G. Byju, Director, ICAR-CTCRI, Thiruvananthapuram, exchanged the Technology License Agreement with officials Shri. Bharat Patni, Director, M/s. Tech Visit IT Pvt. Ltd. Dr. Praveen Malik, CEO, AgIn, said that e-crop has a high potential market in the smart farming sector and can help the farmer to reap higher profits, than conventional farming. While exchanging the TLA, Dr. G. Byju, emphasized that licensing e-crop – a climate-focused and high-value technology on World Environment Day marks a significant milestone in the history of ICAR-CTCRI. Dr. V.S. Santhosh Mithra, Principal Scientist and inventor of the technology explained the key features of this "farmer-friendly" technology. Institute Technology Management Unit of ICAR-CTCRI managed the licensing process through M/S Agrinnovate India Private Limited, New Delhi. This technology helped farmers manage scarce natural resources by accurately measuring soil moisture, temperature and nutrient content, along with weather parameters. The system's crop growth models provide timely advice on irrigating crops, applying fertilizers and identifying pest and disease incidence. This eco-friendly alternative to regenerative agriculture maximizes input efficiency and reduces wastage. The technology also holds a significant share in India's $886.21 million market. About 120 scientists and staff of ICAR-CTCRI participated in the function.

Chinese Scientists Achieve First Healthy *Rhesus* Monkey Clone

A milestone has been reached in the field of primate cloning. Scientists at the Chinese Academy of Sciences have announced the successful birth of Zhong Zhong (meaning "Middle Middle"), the first healthy clone of a *Rhesus macaque* monkey. This breakthrough represents a significant leap forward in our ability to understand primate biology and holds immense potential for advancements in medical research.

Previously, attempts at primate cloning met with limited success. Dolly the sheep, famously cloned in 1996, sparked excitement about the possibilities of this technology. However, replicating the feat in primates proved to be a substantial challenge. The new research overcomes these hurdles, offering a refined technique for somatic cell nuclear transfer (SCNT), the same method used for Dolly. In SCNT, the nucleus of an egg cell is replaced with genetic material from a donor cell, essentially creating a genetic twin.

The key innovation in this research lies in the type of donor cell used. Previous attempts relied on adult skin cells, resulting in complications during development. The Chinese team employed a specific type of placental cell, leading to a significant improvement in the health and development of the cloned embryo. Zhong Zhong, born in 2020, serves as a testament to the success of this approach.

The implications of this breakthrough are far-reaching. *Rhesus macaques* are widely used in biomedical research due to their close genetic similarity to humans. The ability to create healthy clones opens doors to a multitude of possibilities. Scientists can now study the development of complex diseases like Parkinson's and Alzheimer's in genetically identical animals, providing valuable insights into disease progression and potential therapies. Additionally, creating clones with specific genetic modifications could allow researchers to model the effects of different genes on disease susceptibility or drug response.

The potential for organ transplantation is another exciting avenue. Creating organs compatible with a specific recipient through cloning could revolutionize transplantation medicine. However, significant technical hurdles remain before this becomes a reality.

Ethical considerations surrounding animal cloning remain a crucial discussion point. Issues of animal welfare and the potential unintended consequences of manipulating genetic information must be carefully evaluated. Open communication and collaboration between scientists, ethicists and policymakers are essential to ensure this technology is used responsibly and ethically.

The successful cloning of Zhong Zhong marks a pivotal moment in primate biology research. This achievement opens doors for a deeper understanding of primate health and disease, with the potential to revolutionize medical research and treatment in the years to come. As scientists move forward, the ethical implications surrounding this technology must be addressed to ensure its responsible and beneficial application.

IVF Spark of Hope: Scientists Attempt to Save Northern White Rhino from Brink

A glimmer of hope has emerged for the critically endangered northern white rhino. Scientists achieved it successfully using in vitro fertilization (IVF) to create a white rhino embryo. While the surrogate mother carrying the embryo sadly passed away from an unrelated illness, the very existence of a viable embryo offers a potential lifeline to this species on the brink of extinction.

The northern white rhino is a tragic conservation story. With only two females remaining, Najin and Fatu, at the Ol Pejeta Conservancy in Kenya, natural reproduction is no longer an option. This breakthrough by the BioRescue project, an international consortium dedicated to saving endangered species, demonstrates the feasibility of assisted reproduction techniques in rhinos.

The procedure involved harvesting eggs from the remaining females and fertilizing them with sperm collected from deceased northern white rhino males. The resulting embryos were then implanted into a southern white rhino, a closely related subspecies. While the first attempt ended tragically, the success of embryo creation paves the way for future attempts.

The BioRescue team is optimistic. They plan to refine the IVF process and implant embryos into southern white rhino surrogates again, aiming to eventually bring northern white rhino calves back into the world. This achievement not only offers hope for the northern white rhino but also sets a precedent for assisted reproduction in other critically endangered rhinos facing similar challenges.

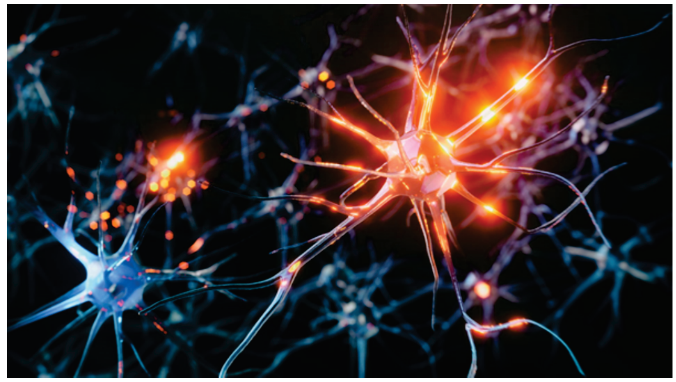
However, significant hurdles remain. The long-term success of IVF in rhinos requires further research and refinement. Additionally, ensuring the genetic diversity of future generations through the use of multiple sperm donors will be crucial for the long-term viability of a revived northern white rhino population.

Despite the challenges, this scientific feat offers a ray of hope. With continued research and collaboration, the combined efforts of scientists, conservationists and veterinarians could rewrite the story for the northern white rhino, bringing this magnificent species back from the brink.

Brain Cells Rehearse the Future During Sleep

We all have experienced a strange feeling of familiarity with a completely new situation. This phenomenon, known as *déjà vu*, has long puzzled scientists. A recent study sheds new light on brain activity during sleep, suggesting that neurons might not only replay past experiences but also rehearse potential future events.

Researchers focused on rats navigating a maze for the first time. By monitoring brain wave patterns, particularly "sharp wave ripples" associated with memory consolidation, they observed activity in the hippocampus, the brain's memory center. Interestingly, these ripples didn't just replay the maze journey after the fact, but also seemed to anticipate the upcoming turns and pathways even before the rats physically experienced them.



"It turns out some neurons end up doing something else," explained Dr. Daniel Kemere, a co-author of the study. "They activate in a sequence that suggests they're replaying not just the past experience, but also a potential future experience."

This "preplay" activity could be the brain's way of consolidating new memories and preparing for future encounters. Imagine practicing a presentation in your head before actually delivering it – this neural rehearsal might be happening during sleep for spatial tasks as well.

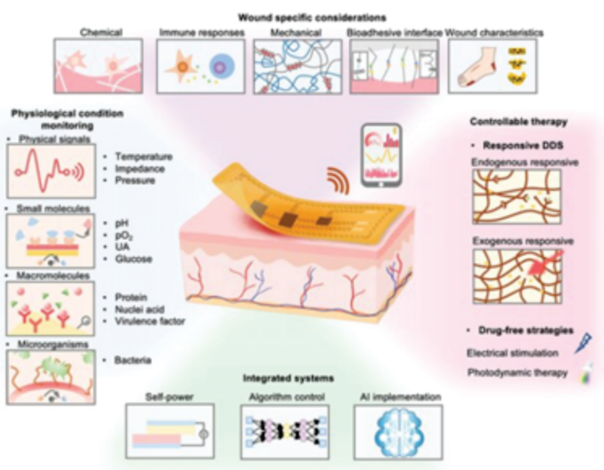
The study's lead author, Dr. Matthew Walker from Michigan University, emphasizes the importance of this discovery. "This is the first time we've seen evidence for the brain actively generating future events during sleep. It suggests sleep may not just be about consolidating the past, but also about preparing for the future."

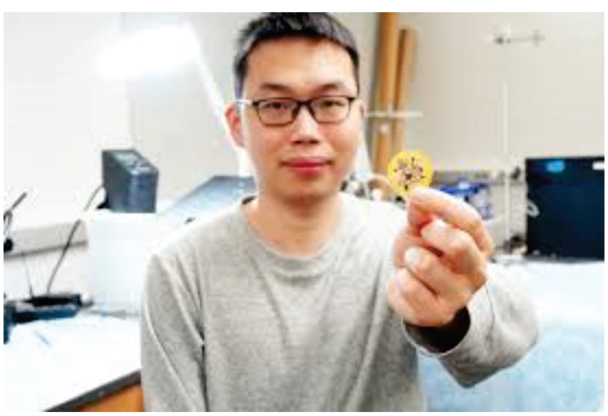
While further research is needed to fully understand the implications, this finding could have significant applications. Improved understanding of how the brain rehearses future experiences could inform training methods for complex skills or even rehabilitation strategies for individuals with memory impairments.

This discovery adds a fascinating new layer to our understanding of sleep and its role in learning and memory. It seems our brains might not simply be resting during those nighttime hours – they could be actively preparing us for what lies ahead.

Blurring the Lines: Living Bioelectronics Offer New Hope for Wound Healing

Imagine a future where medical devices seamlessly integrate with the body, not just monitoring health but actively promoting healing. This vision inches closer to reality with the development of "living bioelectronics." Researchers at the University of Chicago have created a prototype device that combines living cells, a biocompatible gel and electronic sensors, offering a ground-breaking approach to wound healing and diagnostics.





The brainchild of Professor Bozhi Tian's lab, this living bioelectronic patch is a marvel of bioengineering. A thin, flexible electronic circuit embedded with sensors sits atop a gel base made of tapioca starch and gelatin, mimicking the natural composition of human tissue. The final key ingredient? Live S. epidermidis bacteria, commonly found on healthy skin and known for their anti-inflammatory properties.

Early tests on mice with a condition similar to psoriasis yielded promising results. The living bioelectronic patch continuously monitored the wound and delivered real-time data on inflammation levels. More importantly, the patch's presence seemed to promote healing, with a significant reduction in symptoms observed in a week-long study.

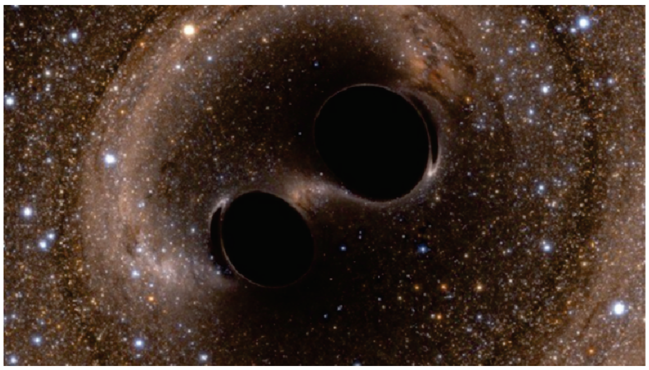
"We're excited because it combines multiple functionalities," explained Dr. Jiuyun Shi, a lead researcher on the project. "It can sense the biological signals, it can deliver therapeutic agents and it can potentially improve tissue regeneration."

This research represents a significant leap forward in biocompatible technology. Traditional electronic implants often suffer from rejection by the body, requiring rigid materials that can irritate surrounding tissues. Living bioelectronics, on the other hand, offer a more natural approach. The soft, flexible design and the incorporation of live cells minimize the risk of rejection, potentially leading to longer-lasting and more comfortable implants.

The potential applications of this technology extend far beyond wound healing. Imagine bioelectronic patches that monitor blood sugar levels in diabetics or deliver targeted pain relief. This research paves the way for a new generation of medical devices that work in harmony with the body, offering a more holistic and personalized approach to healthcare. While further research is needed to refine the technology and explore its full potential, living bioelectronics offer a glimpse into a future where technology seamlessly blends with biology to improve our health and well-being.

Dark Matter Mystery Deepens: Could Exotic Black Holes Hold the Key?

Dark matter, the invisible substance estimated to comprise 85% of all matter in the universe, remains one of science's greatest enigmas. However, a recent study by MIT physicists proposes a captivating link between dark matter and a new breed of black holes – "primordial black holes" formed in the universe's first fraction of a second.



"For fifty years, scientists have explored the possibility that dark matter could be black holes," explains Professor David Kaiser, co-author of the study. "Our research focuses on a specific type: black holes born in the very early universe, much smaller than the stellar black holes we typically observe."

These "primordial" black holes, theorized to be incredibly dense and harboring an exotic property called "color charge," could offer a novel explanation for dark matter's elusive nature. Color charge, a fundamental force in quantum chromodynamics (QCD), is typically only observed in quarks and gluons, the building blocks of protons and neutrons.

The MIT team proposes that these primordial black holes, formed amidst the quark-gluon soup of the early universe, might have swallowed these color-charged particles. If a significant population of such black holes exists, their immense gravity and unique properties could contribute to the invisible influence attributed to dark matter.

"The key here is the color charge," says Dr. Elba Alonso-Monsalve, the study's lead author. "By understanding how much color charge gets trapped in these primordial black holes, we can potentially calculate their abundance and see if it aligns with the amount of dark matter we infer from astronomical observations."

This research opens exciting new avenues for dark matter exploration. While further theoretical work and advanced astronomical observations are needed to validate this connection, it presents a fresh perspective on this cosmic mystery. The possibility of primordial black holes contributing to dark matter could lead to new strategies for detecting them, potentially involving the unique signature of their color charge.

"If we can demonstrate a link between these exotic black holes and dark matter," concludes Prof. Kaiser, "it would be a major breakthrough in our understanding of the universe's composition and evolution." The quest to unravel the nature of dark matter continues and this research on exotic black holes offers a compelling new thread to follow in this cosmic whodunit.

Avian Flu Jumps the Species Barrier: Elephant Seals Infected in Argentina

In a worrying development, scientists have documented the first confirmed case of a highly pathogenic avian influenza virus (HPAI) jumping from birds to mammals. The victim? Thousands of elephant seals in Argentina. Researchers at the UC Davis Wildlife Health Center, collaborating with Argentine colleagues, identified HPAI H5N1 as the culprit behind a mass die-off that devastated elephant seal pups on the Valdés Peninsula in 2023.

"This is the first multinational transmission of HPAI viruses in mammals ever observed globally," says Dr. marinho dos Santos, a lead author of the study. The outbreak resulted in a staggering mortality rate, with nearly all pups born that season succumbing to the virus. Adult seals were also affected, with significant population declines observed.

The virus likely originated from infected wild birds, with terns found near the seal colonies also testing positive. However, the high mortality rate in seals suggests a potential adaptation of the virus for efficient transmission among mammals. This raises concerns about the possibility of spillover events to humans or livestock populations.

"While the current HPAI strain appears low-risk for humans, this event highlights the potential for these viruses to evolve and adapt to new hosts," cautions Dr. Christine Wibble, another researcher involved in the study.

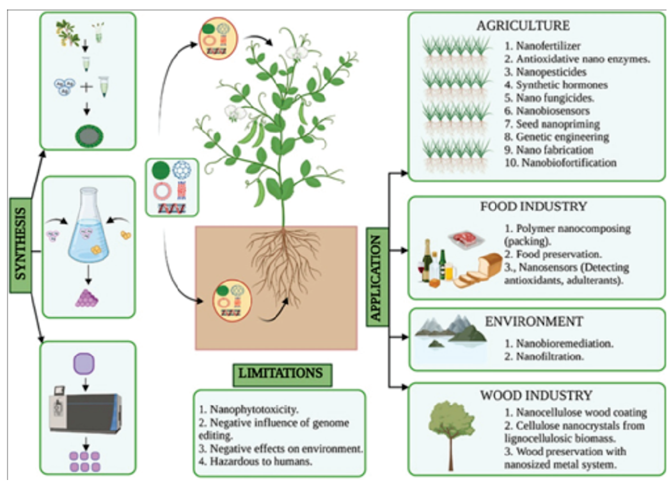
The unprecedented scale of the outbreak in elephant seals underscores the need for heightened surveillance. Monitoring HPAI strains in both birds and mammals, particularly those with close contact points, will be crucial in preventing further cross-species transmission events. Understanding how the virus adapted to thrive in elephant seals could also provide valuable insights for developing preventative measures.

The research team emphasizes the importance of international collaboration in combating this evolving threat. Sharing data and expertise across borders will be essential for mitigating future outbreaks and protecting both wildlife populations and human health. With the specter of zoonotic diseases looming large, this incident serves as a stark reminder of the interconnectedness of our world and the need for proactive measures to safeguard animal and human health.

Nanotechnology: A giant leap towards the new age agriculture

In a recent scientific hustle, scientists highlight some of the best-known strategies for improving agriculture with nanotechnology. Nanotechnology is an umbrella term for the study and design of microscopically small things. How small? A nanometer is one billionth of a meter, or about 100,000 times smaller than the width of a human hair. Using nanotechnology, drugs can now be delivered where they're most needed. But these insights have yet to be applied to plant science on a large scale.

"There are studies predicting we will need to increase food production by up to 60% in 2050 relative to 2020 levels. Right now, we are trying to do that through inefficient agrochemical delivery," said Juan Pablo Giraldo, UCR associate professor and paper co-corresponding author.



"Half of all the fertilizer applied on farms is lost in the environment and pollutes the groundwater. In the case of commonly used pesticides, it's even worse. Only 5% reach their intended targets. The rest ends up contaminating the environment. There is a lot of room for improvement," Giraldo said.

Currently, agriculture accounts for up to 28% of global greenhouse gas emissions. This, in addition to a range of other factors from extreme weather events to rampant crop pests and rapidly degrading soil, underlines the need for new agricultural practices and technologies.

In their review, the researchers highlight specific approaches borrowed from nanomedicine that could be used to deliver pesticides, herbicides and fungicides to specific biological targets.

"We are pioneering targeted delivery technologies based on coating nanomaterials with sugars or peptides that recognize specific proteins on plant cells and organelles," Giraldo said. "This allows us to take the existing molecular machinery of the plant and guide desired chemicals to where the plant needs it, for example the plant vasculature, organelles, or sites of plant pathogen infections."

Doing this could make plants more resilient to disease and harmful environmental factors like extreme heat or high salt content in soil. This type of delivery would also be a much greener approach, with fewer off-target effects in the environment.

Another strategy discussed in the paper is using artificial intelligence and machine learning to create a "digital twin." Medical researchers use computational models or "digital patients" to simulate how medicines interact with and move within the body. Plant researchers can do the same to design nanocarrier molecules that deliver nutrients or other agrochemicals to plant organs where they're most needed.

"It's like J.A.R.V.I.S. (Just A Rather Very Intelligent System) from the film Iron Man. Essentially an artificial intelligence guide to help design nanoparticles with controlled delivery properties for agriculture," Giraldo said. "We can follow up these twin simulations with real-life plant experiments for feedback on the models."

"Nano-enabled precision delivery of active agents in plants will transform agriculture, but there are critical technical challenges that we must first overcome to realize the full range of its benefits," said Greg Lowry, Carnegie Mellon engineering professor and co-corresponding author of the review paper. "I'm optimistic about the future of Plant Nanobiotechnology approaches and the beneficial impacts it will have on our ability to sustainably produce food."

A protein that enables smell—and stops cell death

While smell plays a considerable role in the social interactions of humans — for instance, signaling fear or generating closeness — for ants, it is vitally important. Researchers from New York University and the University of Florida found that a key protein named Orco, essential for the function of olfactory cells, is also critical for the cells' survival in ants.

Their study showed that mutating the *orco* gene in *Harpegnathos saltator* jumping ants dramatically decreased the number of olfactory neurons, suggesting that Orco is necessary for the development and life of these cells. The findings, published in *Science Advances*, offer insights into the cellular and molecular basis of how animals socialize.

"Understanding how the nervous system develops is among the most pressing challenges in modern neuroscience," said Bogdan Sieriebriennikov, a postdoctoral fellow in NYU's Department of Biology and the study's first author.

Sensing smell and mutant ants: Ants have evolved approximately 400 smell receptors — a number closer to humans than most other insects — thanks to their use of pheromone communication.

“Ants, like humans, are highly social and display cooperative social behavior and thus provide an ideal system to study sensory-mediated social behavior,” explained Hua Yan, assistant professor of biology at the University of Florida and the study’s senior author. “Expanded odorant receptor genes allow ants to ‘talk’ to each other in a large society with hundreds, thousands, or up to a million individuals.”

Even for humans, who rely on other senses for communication, smell is essential. “Loss of function of odorant receptor neurons leads to deficits in olfactory sensing and is often associated with social isolation, neurological disorders such as schizophrenia and social disorders such as autism,” added Yan. To better understand how ants’ sense of smell influences their social interactions, NYU researchers previously created the first genetically engineered ants by using CRISPR to edit the *orco* gene. These “mutant” ants, lacking the Orco protein, experienced changes to their smell organs and had difficulty interacting.

“We found that the antennae — which are the ‘nose’ of the ant — had very few cells. They were almost empty, suggesting that the cells that sense smell were absent from the mutant ants,” said Yan.

Neuron survival depends on Orco: In their new study in *Science Advances*, the researchers used single-nucleus gene expression profiling of ant antennae and fluorescence microscopy to analyze olfactory cell development. It emerged that mutant insects lacking Orco lose most of their olfactory neurons before adulthood.

“The cells appear to be made normally and they start developing — growing, changing shape and switching on certain genes they will need later, such as odorant receptors,” noted Sieriebriennikov. “Once the developing cells turn on the odorant receptors, very soon they start dying in massive amounts.”

This neuronal death may be because of stress. As the odorant receptors in the mutant ants cannot form a complex with Orco to travel to the cell membrane, the newly made receptors clog the organelles, leading to stress and death.

Such neuronal death may also show patterns particular to social insects. “So far, these unique processes have not been found in solitary insects and may provide important evidence of evolution of neural development to adapt to the expansion of odorant receptor genes,” said Kayli Sieber, a doctoral candidate at the University of Florida and the co-first author of the study.

Interestingly, some odorant receptors survived even without Orco. The cells in which they were present also expressed other types of receptors, suggesting that the activity they facilitate is essential for neuronal development.

“Some neurons must periodically ‘fire’ to develop properly. Without Orco, smell cells did not ‘fire’ and complete their development, leading to their death,” said Sieriebriennikov.

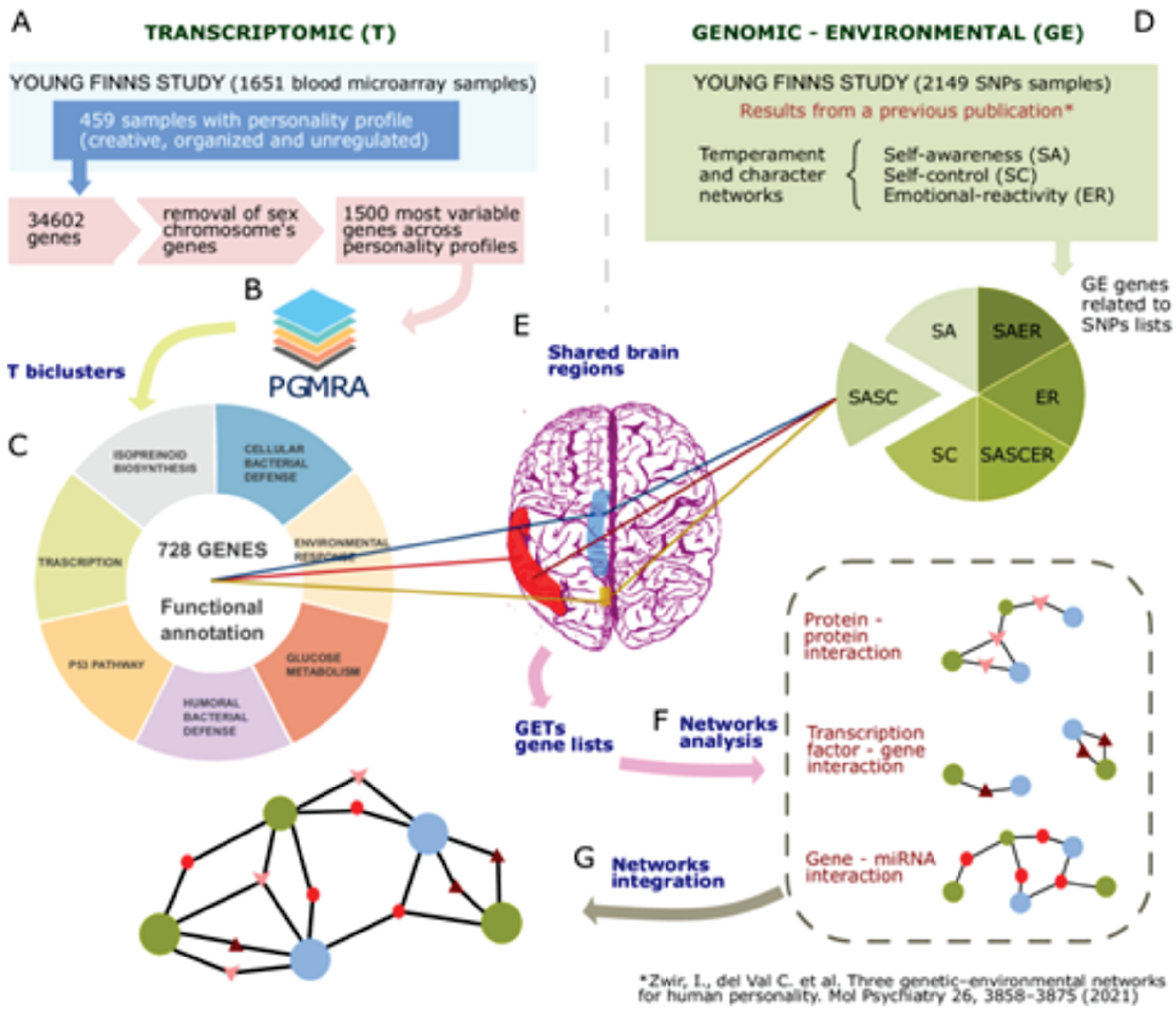
The researchers also found that some odorant receptors are present in non-smell cells, such as mechanosensory neurons that detect motion and glia, which wrap around neurons and help them function. This may be due to imperfect regulation of genes, which causes odorant receptors to be accidentally activated by nearby genomic regions that are normally regulating other genes in other cells. Alternatively, the receptors may have a new function in these cells, like the odorant receptors found in the glia of *C. elegans* worms or human sperm.

“Turning on odorant receptor genes in the cells that are not smell-sensing could be totally useless for the organism — but then again, evolution tends to make use of such mistakes to give existing genes new function, so perhaps there is some exciting new role of odorant receptors in non-smell cells that we will discover in the future,” noted Sieriebriennikov.

"Our findings enhance our understanding of social insects' sensory systems, including olfactory neural development that establishes a framework for social communication," said Yan.

Scientists map networks regulating gene function in the human brain

A consortium of researchers has produced the largest and most advanced multidimensional maps of gene regulation networks in the brains of people with and without mental disorders. These maps detail the many regulatory elements that coordinate the brain's biological pathways and cellular functions. The research, supported the National Institutes of Health (NIH), used postmortem brain tissue from over 2,500 donors to map gene regulation networks across different stages of brain development and multiple brain-related disorders.



"These groundbreaking findings advance our understanding of where, how *and* when genetic risk contributes to mental disorders such as schizophrenia, post-traumatic stress disorder and depression," said Joshua A. Gordon, M.D., Ph.D., director of NIH's National Institute of Mental Health (NIMH). "Moreover, the critical resources, shared freely,willhelp researchers pinpoint genetic variants that are likely to play a causal role in mental illnesses and identify potential molecular targets for new therapeutics."

The research report findings along several key themes:

- Population-level analyses that link genetic variants, regulatory elements and different molecular forms of expressed genes to regulatory networks at the cellular level, in both the developing brain and adult brain
- Single-cell-level maps of the prefrontal cortex from individuals diagnosed with mental disorders and neurodevelopmental disorders
- Experimental analyses validating the function of regulatory elements and genetic variants associated with quantitative trait loci (segments of DNA that are linked with observable traits)

The analyses expand on previous findings, exploring multiple cortical and subcortical regions of the human brain. These brain areas play key roles in a range of essential processes, including decision-making, memory, learning, emotion, reward processing and motor control.

Approximately 2% of the human genome is composed of genes that code for proteins. The remaining 98% includes DNA segments that help regulate the activity of those genes. To better understand how brain structure and function contribute to mental disorders, researchers in the NIMH-funded PsychENCODE Consortium are using standardized methods and data analysis approaches to build a comprehensive picture of these regulatory elements in the human brain.

In addition to these discoveries, the papers also highlight new methods and tools to help researchers analyze and explore the wealth of data produced by this effort. These resources include a web-based platform offering interactive visualization data from diverse brain cell types in individuals with and without mental disorders, known as PsychSCREEN. Together, these methods and tools provide a comprehensive, integrated data resource for the broader research community.

The papers focus on the second phase of findings from the PsychENCODE Consortium. This effort aims to advance our understanding of how gene regulation impacts brain function and dysfunction.

"These PsychENCODE Consortium findings shed new light on how gene risk maps onto brain function across developmental stages, brain regions and disorders," said Jonathan Pevsner, Ph.D., chief of the NIMH Genomics Research Branch. "The work lays a strong foundation for ongoing efforts to characterize regulatory pathways across disorders, elucidate the role of epigenetic mechanisms and increase the ancestral diversity represented in studies."

National and International Conferences

- 12th Genomics India Conference 2024, February 1st – 3rd 2024, Shiv Nadar Institution of Eminence, Delhi (NCR), India.
- 37th Annual Lorne Cancer Conference February 8th -10th, 2024, Mantra, Lorne, Australia,
- INTECH: The Israeli Industry & Technology Week; April, 2nd-3rd, 2024; Tel-Aviv University, Israel
- International Conference on Bioinformatics, Biomedicine, Biotechnology And Computational Biology, July, 15th, 2024, Gaza City, Palestinian Territories.
- International Conference on Environment, Agriculture a*nd Biotechnology*, July, 15th, 2024, Kolkata, West Bengal, India
- 4th World Conference On Multidisciplinary Research & Innovation (WCMRI) October 28th - 29th 2024, Singapore
- 45th World Conference on Applied Science, Engineering & Technology, 25th - 26th November, 2024, Malaysia.
- International Conference on Recent Trends in Multi-Disciplinary Research (ICRTMDR-24)
- Bio International Convention Boston, United States June 5th – 8th, 2024.
- Bio Spain Barcelona, Spain September 26th -28th, 2024.
- International Conference on Solar Power Technology (ICSPT) –August, 18th, 2024, Kyoto, Japan
- International Conference on Computational Biology and Artificial Intelligence- August 18th, 2024, Kuala Lumpur, Malaysia
- International Conference on Mechanical, Manufacturing, Industrial and Civil Engineering (ICMMICE) – August, 18th, 2024, Kuala Lumpur, Malaysia
- International Conference on Recent Advances in Science, Engineering, and Technology (ICRASET) August, 18th, 2024, Daegu, Korea (south)
- BPA — BioPharm America 2024, September 13th – 14th, 2024 Raleigh, United States
- The joint 15th European Congress of Chemical Engineering (ECCE14) & 8th European Congress of Applied Biotechnology (ECAB7). September, 17th – 21st, 2024, Berlin, Germany.
- 20 Jul-National Conference on BioTechnology and BioMedicines (NCBB) | National conference-Trivandrum,India
- 20 Jul-National Conference on BioTechnology and BioMedicines (NCBB) | National conference-Lucknow,India
- 21 Jul-National Conference on BioTechnology and BioMedicines (NCBB) | National conference-Indore,India
- 28 Jul-National Conference on BioTechnology and BioMedicines (NCBB) | National conference-Lucknow,India
- 03 Aug-National Conference on BioTechnology and BioMedicines (NCBB) | National conference-Visakhapatnam,India
- 03 Aug-National Conference on BioTechnology and BioMedicines (NCBB) | National conference-Pune,India
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- 04 Aug-National Conference on BioTechnology and BioMedicines (NCBB) | National conference-Mumbai,India
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- 08 Sep-National Conference on BioTechnology and BioMedicines (NCBB) | National conference-Lucknow,India

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- 15 Sep-National Conference on BioTechnology and BioMedicines (NCBB) | National conference-Lucknow,India
- 21 Sep-National Conference on BioTechnology and BioMedicines (NCBB) | National conference-Visakhapatnam,India
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- 07 Oct-Global Conference on Biosensors (Global Conference on Biosensors) | Displaycia-New Delhi,India
- Oct 18 International Conference on Science, Engineering & Technological Innovations - Alappuzha, India
- Dec 09 International Conference on Bioscience, Biotechnology, and Biochemistry (ICBBB) - Goa, India
- Dec 09 International Conference on Biotechnology and Bioengineering (ICBB) - Goa, India
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- Jan 28 International Conference on Molecular Biology, Biochemistry and Biotechnology (ICMBBB) - Bengaluru, India
- Jan 28 International Conference on Bioscience, Biotechnology, and Biochemistry (ICBBB) - Bengaluru, India
- Jan 28 International Conference on Biotechnology and Bioengineering (ICBB) - Bengaluru, India
- Feb 15 International Conference on Bioscience, Biotechnology, and Biochemistry (ICBBB) - Mumbai, India
- Feb 15 International Conference on Systems Biology and Bioengineering (ICSBB) - Mumbai, India
- Feb 15 International Conference on Biotechnology and Bioengineering (ICBB) - Mumbai, India

- Feb 15 International Conference on Molecular Biology, Biochemistry and Biotechnology (ICMBBB) - Mumbai, India
- Feb 22 International Conference on Bioscience, Biotechnology, and Biochemistry (ICBBB) - New Delhi, India
- Feb 22 International Conference on Biotechnology and Bioengineering (ICBB) - New Delhi, India
- Feb 22 International Conference on Molecular Biology, Biochemistry and Biotechnology (ICMBBB) - New Delhi, India
- Feb 22 International Conference on Agricultural Biotechnology and Food Security (ICABFS) - New Delhi, India
- Dec 09 International Conference on Bioscience, Biotechnology, and Biochemistry (ICBBB) - Goa, India
- Dec 09 International Conference on Biotechnology and Bioengineering (ICBB) - Goa, India
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Manuscripts that deal with clinical findings should be enclosed with a statement on informed consent of the patients under study. If humans and animals are the subject of a clinical study, it is essential for the study to have been carried out in accordance with the ethical standards of the country/ countries where the research described in the article has been conducted. A declaration to that effect must accompany the manuscripts.

Author conflict of interest statement

Authors must knowledge the organizations that have provided financial support for their work. Any other conflict of interest must be declared while submitting the manuscripts.

CATEGORIES OF MANUSCRIPTS

General articles not exceeding 5000 words, 8 display items (tables and figures)] discuss current trends in research in a field that would be of interest to readers outside the field. These include interdisciplinary topics, science policy and science administration, some aspects of the application of science and technology to human needs or the impact of science and technology on society/ecosystem/life. The articles should include an abstract, introductory paragraph, brief subheads at appropriate places, illustrations that will help a general reader and references .

Review articles (not exceeding 7000-8000 words, cited references to be limited to about 100 in number) are expected to survey and discuss current developments in a field. They should be well focused and organized, and avoid a general ..textbook' style.

Research articles (not exceeding 5000 words) report research result of major significance. They should include an abstract, an introductory paragraph and brief subheads.

News (not exceeding 1000 words) can cover important scientific events or any other news of interest to scientist in general.

MANUSCRIPT PREPARATION

Manuscripts should be typed/printed double spaced on one side of white paper (21×28 cm). The pages should be numbered consecutively, starting with the title page and through the text, reference list, tables and figures legends. The title should be brief, specific and amenable to indexing. Not more than five keywords should be indicated separately; these should be chosen carefully and must not be phrases of several words. Abstract and summary should be limited to 100 words and convey the main points of the paper, outline the results and conclusions, and explain the significance of the results. The full length paper should have the following headings.

SHORT TITLE : A short title, not exceeding 35 letters, should be typed at the top of first page in first letters capitals and underlined.

TITLE : The title should be short and informative, typed in first letters capital, Latin names underlined

AUTHORS : Names of authors to be typed in first letters capital.

ADDRESS : Address of the institution where the work was carried out. Footnote should indicate the authors for correspondence.

MAIN HEADINGS : Each full-length research paper should be divided into the following main headings which are to be bold and typed in first letters capitals on the left hand side of the pag: Abstract, Introduction : Materials and Methods, Results, Discussion, References.

SUB-HEADINGS : Typed flush left in first letter capital, bold and italicized.

Abstract : A brief abstract, not exceeding 200 words should be typed after address.

Key words : The Abstract should be followed by about five key words indicating the contents of the manuscript.

Introduction : Introduction should be brief and pertinent.

Materials and Methods : Materials and Methods should include the source and nature of material, experimental design and the techniques employed.

Result : Result should contain data which are essential for drawing main conclusion from the study. Wherever needed the data should be statistically analyzed. Same data should not be presented in tables and figure form.

Discussion : The discussion should deal with the interpretation of the results. Wherever possible, Results and Discussion can be combined.

Tables : Tables should be typed on separate sheets, each with a heading. Tables should be typed with the first letter capital, table number in Arabic numerals, followed by a period.

Figures : For each figure submit a glossy print or original drawing. Photomicrograph should have a scale bar. Line drawings should be roughly twice the final printed single column size of 7.5 cm width. Text figures should be numbered in Arabic numerals. Captions and legends to illustrations should be typed on a separate sheet of paper. Line drawings and photograph should contain figure number and authors' name, on the back with soft lead pencil. Colour photographs will be printed if author(s) pay Rs 600/- (or US $ 20) as processing charges.

References : References should be cited in Text Form. In brackets as (Sengar, et al., 2013). Listing of References should be alphabetically. References should not include unpublished source materials. The list of References at the end of the text should be in the following format.

Rynold, M.P. (1994). The Archaean grey gnesisses and the genesis of continental crust. In: Archean Crustal Evolution (ed. Candie, K.C.) Elsevier, Amsterdam, pp. 205–259.

Sengar,R.S. (2013). Estimation of population growth and extinction parameters from noisy data. *Ecol. Appl.*, **13**: 806–813.

Sirova, D., Adamec, L. and Verba,J. (2013). Enzymatic activities in trops of four aquatic pieces 3 of the Carnivorous genus Vlricularia, *New Phytology* **159(3)** : 669-675.

Sengar, R.S., Sharma, A.K., Chaudhary, R. and Kureel, R.S. (2009). Biodiesel plant Jatropha need for future. Procedings of ..5th World Congress of Cellular & Molecular Biology (WCCMB, 2012).., November 02- 06, School of Biotechnology, Devi Ahilya University Indore, India & World Society of Cellular & Molecular Biology, France. 142-143.

Abbreviations : Use standard abbreviations. Some of the common abbreviations are given below: A (absorbance); h (hour); min (minutes); sec (seconds); cpm (counts per minutes); Ci (Curie); molwt (molecular weight); kD (kilo Dalton); kb (kilo base); sp act (specific activity); wt (weight); SD (standard deviation); SE (standard err); DAF (days after flowering)

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Society of Green World for Sustainable Environment

An International Journal of Biological Sciences

A Peer Review Journal

Biotech Today

Corporate & Business Office: 35, Akshardham, Roorkee Road, Modipuram, Meerut-250110 (U.P.)

Editorial Office : Department of Ag. Biotechnology, College of Agriculture, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut-250110 (U.P.)

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