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Adolescents' Aggression: A Triangular Perspective Analysis

Arifa Momtaz Begum[1], Jinamoni Saikia[2], Toslima Sultana Begum[3] and Binapani Deka[4]

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ABSTRACT

Aggression is a forceful behaviour, action or attitude that is expressed physically, verbally or symbolically. Aggressive behaviour has become a topic of vital importance and a major concern in most of the societies. Identifying, controlling and managing highly aggressive behaviour and its ill effect of school going adolescents have not yet been a major focus of education system of India. Hence, the present study was undertaken to identify the types and level of aggression of adolescents. The study was conducted in Biswanath district of Assam. A total of 150 adolescents of the age group of 14-16 yrs studying in class IX were selected from two government schools. A standardized questionnaire namely Direct and Indirect Aggression Scales developed was used to collect data from self, peers and teachers to find out the prevalence of aggression among adolescents. Descriptive statistics were used to analyze the data. The findings of the study revealed that three types of aggression *viz.,* physical verbal and social were present among the respondents which were categorized as high, average and low. According to self, physical and social aggression were most frequently showed by the adolescents. Verbal aggression was more prevalent among the respondents and almost similar percentage of them frequently showed physical and social aggression as perceived by teachers. According to peers' report, both physical and verbal aggression was frequently shown by the respondents.

Keywords: Adolescents, Aggression, Physical aggression, Social aggression, Verbal aggression.

INTRODUCTION

Aggression is defined as any behaviour intended to harm another person who is motivated to avoid the harm (Morgan *et al*, 2004). Shaw *et al* (2000) described early aggressive behaviour as an act directed toward a specific person or object with intent to hurt or frighten, for which there is a consensus about the aggressive intent of the act. Adolescence is the period of change, in which young people often engage in conflicts with parents and become involved in risky behaviours. According to Chahalan (2018), the riskiest and most dangerous age of adolescence is fourteen (14) years. Adolescent years are loaded with physical and chemical change which occurs at a rapid pace creates confusion and uncertainty in the minds of adolescents. Hormones take over, emotions run high and every adolescent has to learn how to cope with the new changes. Physical changes can result in anger and confusion as hormone levels begin to change in boys and girls. Furthermore, during this stage, adolescents begin reassessing their role in the society and family.

Peer pressure is a struggle that many adolescents face. Not feeling wanted or accepted in a group can be very hurtful, and adolescents may exhibit these feelings as anger or aggression.

Aggression affects emotional development and academic learning, spoils school environment and if not controlled early, may precipitate extreme incidents of violence in the future . In a cross-sectional study of Getachew *et al* (2007), it was found that physical, verbal and indirect aggression were evident among adolescents in secondary schools but with different magnitude. Shaikh *et al* (2014) also found that aggressive behaviour was common among the students with an increasing trend of physical aggression from VII standard to X standard. Sidhu *et al* (2019) reported that the total prevalence of aggression was higher in urban population, males having more of physical aggression and females having hostility–associated significantly with the age distribution, residency type, etc. Sharma and Marimuthu (2014) showed that the risk factors of youth aggression were identified as physical abuse in childhood, substance abuse such as alcohol

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Table 1. Distribution of respondents according to types and levels of aggression as reported by self.

Types of aggression	Number of respondents (N=150)					
	Levels of aggression as reported by self					
	High		Average		Low	
	F	P	F	P	F	P
Physical aggression	22	14.67	75	50.0	53	35.33
Verbal aggression	8	5.33	60	40.0	82	54.67
Social aggression	35	23.33	88	58.67	27	13.33

F = Frequency, P = Percentage, N= Total number of participants
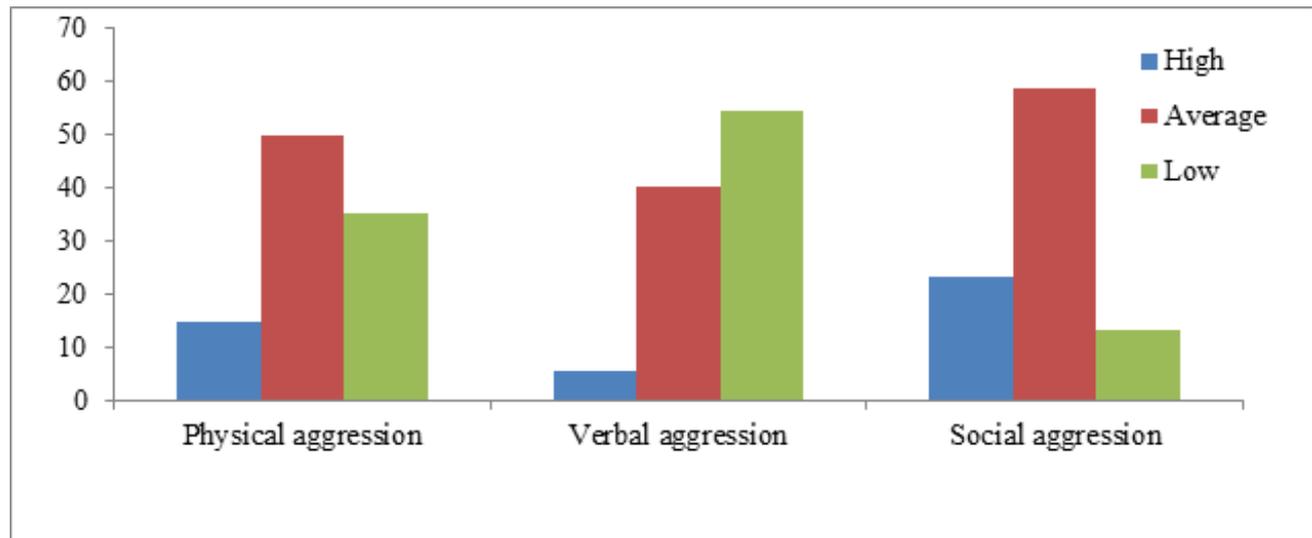
Fig 1 Distribution of respondents according to types and levels of aggression as reported by self

and tobacco, negative peer influence, family violence, academic disturbance, psychological problems, attention deficit-hyperactivity disorder, suspicious mind, loneliness, mood disturbance, negative childhood experience and TV & media.

Human aggression can be divided into direct and indirect aggression. Direct aggression is characterized by physical or verbal behaviour, intended to cause harm to someone and indirect aggression is characterized by behaviour intended to harm the social relations of an individual or group (DeAlmeida *et al*, 2015). Physical aggression is the behaviour that causes physical harm towards others. It includes hitting, kicking, biting, punching, hair pulling, and breaking toys or other possessions etc.

Verbal aggressiveness is a personality trait that predisposes persons to attack the self-concepts of other people instead of, or in addition to, their positions on topics of communication. It includes insulting, putting down, name calling or teasing a person, bullying, saying mean things behind a person's back, urging someone else to verbally abuse the person. Social aggression refers to behaviour that is intended to harm another's friendships, social status, or self esteem. It includes relationship manipulation, social exclusion, reputation attacking, using demeaning Gestures etc. Aggressive behaviour has become a topic of vital importance and a major concern in most of the societies. Identifying, controlling and managing highly aggressive behaviour and its ill effect on school going adolescents have not yet been a major focus of education system of India. It has been observed that no effort has been made by the policy makers particularly to identify and manage the adverse effect of aggression in school level. Hence, the present study was undertaken with the objectives to identify the types and levels of aggression among adolescents.

MATERIALS AND METHODS

The study was conducted with 150 adolescents of the age group of 14-16 yrs studying in class IX. Students from class IX were selected under this study as they belong to early and middle adolescence period (WHO, 1989) in which aggression reaches its peak led by heightened emotionality. In order to assess the types

Table 2. Distribution of respondents according to types and levels of aggression as reported by peers.

Types of aggression	Number of respondents (N=150)					
	Levels of aggression as reported by peer					
	High		Average		Low	
	F	P	F	P	F	P
Physical aggression	40	26.67	68	45.33	42	28.00
Verbal aggression	38	25.33	104	69.33	10	6.67
Social aggression	23	15.33	95	63.33	32	21.33

F = Frequency, P = Percentage, N= Total number of participants
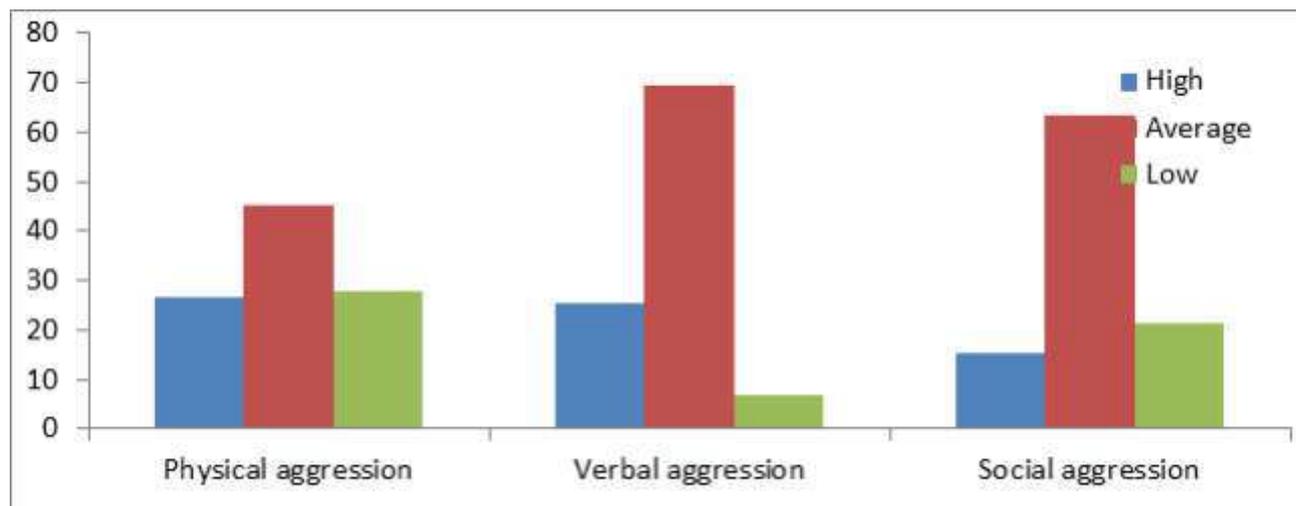
Fig 2 Distribution of respondents according to types and levels of aggression as reported by peers

and levels of aggression of respondents, a standardized structured questionnaire was administered to the respondents. The tool measures three kinds of aggression: Physical, verbal, and social and their levels. The levels were categorized as High, Average and Low based on the scores obtained by the respondents. The same questionnaire was used for peers and teacher's estimation of the respondents' aggression. Thus, the study analyzed adolescents' aggression as reported by self, peers and teacher.

In order to assess the types and levels of aggression of respondents, a standardized structured questionnaire namely Direct & Indirect Aggression Scales (DIAS) developed by Bjorkqvist *et al* (1992) was administered to the respondents. The scale measures three kinds of aggression, namely Physical, verbal, and indirect or social. It consists of 24 statements in which 7 statements reflect physical aggression, 5 statements reflect verbal aggression, and 12 statements reflect social aggression. The scale had provided a fivefold categorization (never, seldom, sometimes, quite often and very often) for an estimation and quick interpretation of aggression scores earned by an individual respondent.

Scoring procedure: A five-point scale (0=Never, 1=Seldom, 2=Sometimes, 3=Quite often, 4=Very often) has been used for responses to all items for self-estimations, peer estimations and teacher estimations. The scores for all the 7 items under physical aggression were added and thus the total score of each respondent represents the level of physical aggression. The scores for all the 5 items under verbal aggression were added and thus the total score of each respondent represents the level of verbal aggression. The scores for all the 12 items under social aggression were added and thus the total score of each respondent represents the level of social aggression.

The total scores of each respondent for physical, verbal and social aggression were calculated. In this study the categories of High, Average, and Low for each type of aggression were made by following the method of class interval in which class intervals were decided by arranging the scores in different classes and width i.e. based on the highest and lowest scores obtained by the respondents.

RESULTS AND DISCUSSION

Descriptive statistics were used to analyze the

Table 3. Distribution of respondents according to types and levels of aggression as reported by teacher.

Types of aggression	Number of respondents (N=150)					
	Levels of aggression as reported by teacher					
	High		Average		Low	
	F	P	F	P	F	P
Physical aggression	38	25.33	80	53.33	31	20.67
Verbal aggression	46	30.67	87	58.00	17	11.33
Social aggression	37	24.67	67	44.67	46	30.67

F = Frequency, P = Percentage, N= Total number of participants
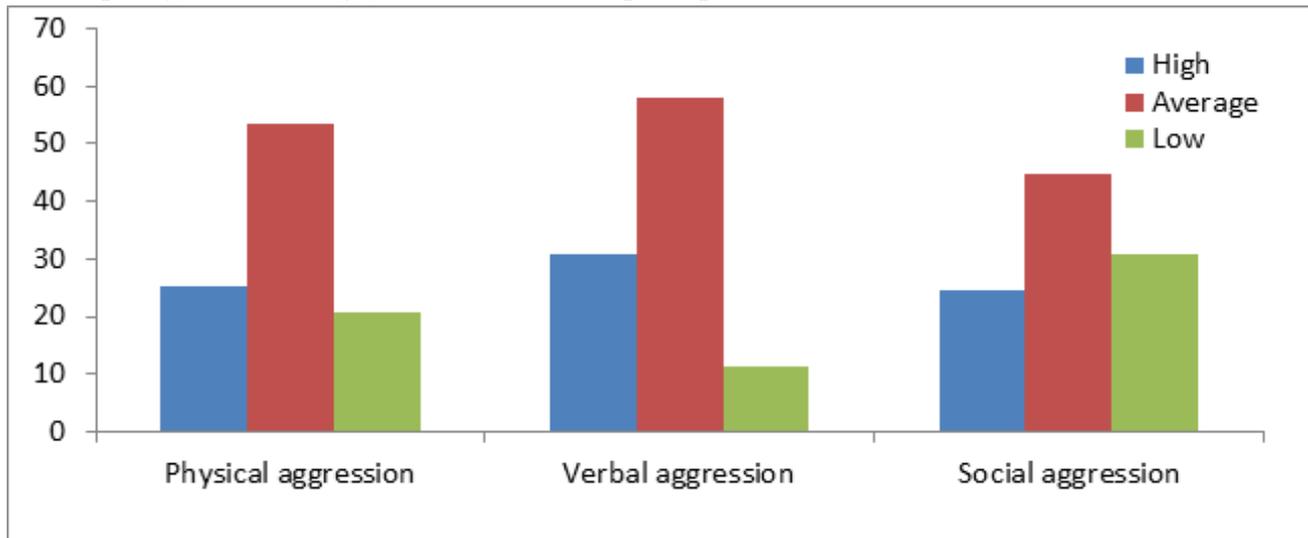
Fig 3 Distribution of respondents according to types and levels of aggression as reported by teacher

data. The findings of the study revealed that three types of aggression viz. physical verbal and social were present among the respondents, which were categorized as high, average and low as reported by self, peers and teachers.

Distribution of respondents according to types and levels of aggression as reported by self is depicted in Table 1 (Fig. 1).It was apparent that the highest percentage (58.67%) of respondents showed average level of social aggression, which publicize that these respondents sometimes showed behaviour of social aggression like personal rejection, excluding others from a social group, gossiping, rumour spreading and criticizing other's appearance or personality. Among them 23.33 per cent of the respondents often showed these behaviour as perceived by self. Besides this behaviour, they distort, modify, and misinterpret the sayings of others and express in front of third person. It may be attributed to the fact that social aggression is the primary means of aggression (Bjorkqvist *et al,* 1992) and hence, most of the adolescents find it easy to adapt this primary means to express their aggression. Besides, some adolescents want popularity among

groups, and they have a hidden intention to spoil the relationship of others. Moreover, adolescence is the time of heightened emotionality and identity crisis, they are self-threatened, and they defend themselves and generally adopt certain ways for psychological manipulation. As many as 14.67 per cent and 50 per cent of respondents showed high and average levels of physical aggression respectively. These adolescents often engage in hitting, kicking, shoving, punching, taking things from others, pushing and pulling their peers. It is worth mentioning that majority (54.67%) of the respondents were found to be in low level of verbal aggression, reflecting that they seldom engage in behaviours like yelling, insulting and teasing others out of anger, anxiety and frustration. They also call the other one's name and threaten him by saying that he is going to hurt him. In a study conducted by Fayso (2019) three forms of aggression namely social, verbal and physical were prevalent among adolescents in secondary school.

A perusal of the data (Fig.2) revealed the types and levels of aggression as reported by peers. Results showed that 25.33 per cent and 69.33per cent of

respondents had high and average level of verbal aggression which proved the frequent involvement of respondents in behaviours showing verbal aggression. Peers' observation confirms that the respondents involved in behaviours like yelling, insulting, bullying and teasing towards their peers. They also called the other one's name and said that he is going to hurt the other one. Besides, the respondents also exhibited some other behaviours like continuous arguing, threatening, bossing, withholding information, humiliating, ridiculing, using offensive remarks, shouting etc. Respondents showed high (26.67%) and average (45.33%) level of physical aggression which proved the frequent involvement of respondents in behaviours showing physical aggression. This may be due to the fact that peers are considered to be the most valid informants of negative behaviours like aggression because actual behaviours are being expressed in front of peers only. Moreover, all group related behaviours and contextual information are made secret by them. They like to discuss problems, feelings, fears and doubts with their peers and hence increasing the salience of time spent with friends. They desire to be accepted and become part of a group which can cause pain and anger, leading to aggressive behaviour.

Verbal aggression (High: 30.67%, Average: 58%) was more prevalent among the respondents and almost similar percentage of them frequently showed physical (25.33%) and social (24.67%) aggression as perceived by teachers. This may be due to the fact that the teacher knows every student personally and it is teachers' responsibility to observe or monitor the students' behaviour in each activity performed by the students. Students generally do not get involved in physical fighting in front of teachers, rather they attack their friends verbally. They have lot of conflicts with their friends and initiate fights with them and shout at them. Teachers have to play the role of a guide and problem solver. They know how to deal with problems and have the ability to proper conflict resolutions and to build trusting relationships with students in order to create a safe, positive, and productive environment. The quantitative study findings of Tahirovic (2015) showed that teachers usually noticed proactive as well as reactive and relational aggression in school age children.

How to cope with children with aggressive behaviour

Aggressive behaviour has become a topic of vital importance and a major concern in most societies. The whole world seems to be under the strain of aggressive acts of various forms. Violence is disturbingly common in most parts of the world, and it is undoubtedly creating chaos and disturbing the world peace and harmony. Thus, it is of utmost importance to channelize aggression through interventional activities.

As parents and primary caregivers, it is of utmost importance to guide the adolescents in the right way. No behaviour can be changed in a day; it takes time and consistency. To change the behaviour of an adolescent we should consider some important things and apply them according to particular situations. Physical punishment should be avoided. Many a time disciplinary punishment may lead to aggressive behaviour in adolescents. The parents, teachers and other adults act as role models for their children; they try to copy their caregivers. So, it is the responsibility of the caregivers to act as the right role model by appropriate emotional control and proper management of anger. Parenting styles have a direct impact on aggression in children. Authoritative parenting styles play a positive role in psychological behavior in children while authoritarian and permissive parenting styles result in aggressive and negative behaviors in children (Masud *et al*, 2019). Authoritative parenting style involves setting clear boundaries and rules while also providing warmth, support, and opportunities for the adolescent to develop problem-solving skills. This approach fosters emotional intelligence and a strong parent-child bond, which are linked to lower levels of aggression. Hence, it is important to avoid an authoritarian, controlling, harsh or coercive parenting style and try to improve parenting skills by referring to relevant books or seek professional support to enhance parenting skills and move toward the kind of parenting style that works. Parents who are affectionate and responsive help their children cope with difficulties and exhibit less aggressive behaviour. Adolescents should be encouraged to set goals to improve their behaviour. Let them know exactly what behaviour is expected and what behaviour is not.

Appreciation of appropriate and nonaggressive behaviours of the children can develop an internal sense of pride in themselves. Therefore, always try to ignore negative behaviour and avoid reinforcement of aggressive behaviour. Adolescents may not know what to do with their feelings. Talking openly with the child about emotions will help them to understand the feelings of others. Adolescents should be encouraged to express their feelings in an appropriate and healthy manner and consider appropriate ways to handle anger. Expose them to positive ways to burn up energy, like exercising, drawing and painting, running, playing

sports or even crying. Offer alternatives to aggressive adolescents. Help the aggressive adolescents to develop their social and conflict resolution skills. Encourage the aggressive adolescent to take the perspective of others, including those he has hurt and those who he perceives have wronged him. Also encourage the adolescents for reinterpretation of situations. Identify the underlying stresses and anxieties and try to eliminate them by appropriate ways. Otherwise, these will inhibit the child's ability to cope, or the parent's ability to effective parenting strategies.

Screen violence is globally widespread and has become easily accessible in modern times. Social media platforms (YouTube, TikTok, Facebook, Twitter, WhatsApp, and Instagram) are extremely popular among adults and children. Studies have linked television with violence and hyperactivity. Evidence suggests that watching violent TV programmes and engaging in violent video games are associated with aggressive behaviour in children, teenagers, and young adults, both in the short and long term. Exposure to violent content can decrease empathy and cause increased aggressive thoughts, anger, and aggressive behaviour. Time spent watching screen violence has also been directly associated with increased bullying and cyberbullying among adolescents. Therefore, to control screen violence among adolescents, set limits on content and screen time, use parental controls, and monitor what they watch and play. It's also crucial to watch media together, discuss the real-world consequences of violence, and model healthy screen habits. Encourage to establish a balance with non-violent activities like sports, exercise, reading books, music etc. or in-person social interaction is also beneficial.

Moreover, to cope with the children with aggressive behaviour 'mindfulness' seems to be a popular trend adopted by researchers and practitioners which is considered to be an effective way of intervention. Mindfulness is the psychological process of bringing one's attention to the internal and external experiences occurring in the present moment which can be developed through the practice of meditation or other training. The mindfulness-based intervention (MBI) may be a combination of meditation, activities for self awareness, self regulation, self control and activities for intentional attention of immediate experiences.MBI can reduce the aggression of adolescents by reducing emotional dysregulation and through the improvement of self control (Zhang and Zhang, 2021). Mindfulness-based interventions are effective in reducing aggression and violence through emotion regulation which is characterized by awareness of the current state of the mind and body without judgment, elaboration, or attachment through a variety of techniques. Mindfulness Based Interventions may include one or a combination of awareness of breathing (Deep Breathing), Mindful walking, Mindful listening, Mindful eating, Meditation and Yoga.

Mindfulness is an easy practice with significant results on the brain which enhances the quality of life, self-confidence, and peace of mind of those who practice this. It also helps to alleviate stress by improving emotion regulation, leading to a better mood and better ability to handle stress and also lessens anger, control one's temper and reduce conflict in general. Participants receive instruction in various aspects of mindfulness, including mindful awareness during meditation, yoga, and daily life activities as a means to alleviate stress. Participants are taught to engage in continuous awareness of physical, mental, and emotional states without judgment or evaluation in a guided group practice. Sensitization programme for parents and teachers can also be a part of this intervention.

CONCLUSION

It can be concluded that aggressive behaviour of students become serious problem which cannot be ignored. Adolescents manifest aggressive behaviour in various forms ranging from social and verbal aggression to physical aggression and more serious kinds of violence. Physical and social aggression were more frequently shown by the respondents as reported by self. Physical and verbal aggression was more frequently exhibited by the respondents as perceived by peers. According to teachers' report verbal aggression was more frequently shown by the respondents. Uncontrolled emotion causes physical, mental, social and educational problems among adolescents which may lead to alcohol and drug use, smoking, low adaptability at school, educational failure, depression and other disorders among them. There is a need for the proper assessment of youth for aggression and development of intervention modules for youth in Indian context. There is a need for screening of risk factors or vulnerabilities for emotional dyscontrol among youth. Teachers should pay attention to aggression-related behaviour and help the adolescents to handle them in a better way. Parents should have psychoeducation for better understanding of inner feelings of their aggressive children. There should be a need for interaction of academic institutes, policy makers and parents for reducing academic

distress, ability to handle pressure or frustration or failure and development of intervention module for management of aggression. Policy makers should make an effort particularly to identify and manage the adverse effect of aggression in school level. It is of utmost importance to channelize uncontrolled emotions in general and aggression in particular during this sensitive period through mindful interventional approach which is considered to be an effective way of intervention included in public policy and education policy of other countries for improving health and psychological well-being of adolescents.

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Adoption of Scientific Pig Rearing Practices: A Study in Jorhat District of Assam

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ABSTRACT

Pig farming is an integral component of rural livelihoods in Assam, contributing significantly to food security, income generation, and nutritional security. Assam accounts for 2.10 million pigs, the highest in India, and pork constitutes nearly 39% of total meat production in the state. Despite this importance, productivity remains low due to limited adoption of scientific practices. The present study was conducted in Jorhat district during April 2024–March 2025, covering 100 randomly selected pig farmers. The study revealed practices related to housing (use of proper flooring, ventilation, and sanitation) and healthcare (vaccination and disease testing) had relatively high adoption while low adoption had been recorded in respect of important practices like providing sufficient space per pig, both indoors and outdoors, with separate areas for feeding and resting, providing access to fresh, clean water at all times, preferably through nipple drinkers etc. Therefore, awareness on these critical management practices by the extension workers is of utmost importance at the present situation for the betterment of this piggery sector and improving the rural economy of Assam.

Keywords: Disease, Environment, Management, Pig, Vaccination, Water.

INTRODUCTION

The piggery sector in Assam is a significant contributor to the state's economy and plays a vital role in the livelihoods of rural communities, particularly tribal and marginalized groups. Assam leads India in pig population with 2.10 million pigs, contributing significantly to the nation's total pig population. The state also boasts the highest pork consumption in India, accounting for 38.50 percent of total meat consumption within Assam, according to the Chief Minister's Atmanirbhar Asom Abhijan. Pig meat accounts for 39% of the total meat production in Assam.   The demand for pork is increasing due to population growth and awareness of its nutritional value, making pig farming a profitable venture. Pig farming, even at a small scale, significantly contributes to the livelihoods of many households (Seth *et al,* 2018; Jothika *et al,* 2022). While Assam is a major pork producer in Northeast India (Assam produces approximately 218,820 tonnes of pork annually), it still faces a 40% import gap due to limited processing and logistical challenges. The sector faces challenges like low productivity of indigenous breeds and reliance on imports to meet local demand, but it also presents substantial opportunities for growth and development.

A large portion of the pig population in Assam consists of low-productivity indigenous breeds. While showing potential for improved productivity, faces several challenges including disease susceptibility, limited access to quality feed, and inadequate knowledge among farmers about scientific pig farming practices. These factors contribute to lower overall productivity and profitability for farmers. By implementing various improved practices, pig farmers can optimize their operations, increase productivity, and improve their profitability. Improved piggery practices involve optimizing various aspects of pig farming to enhance productivity and profitability (Kumaravel and Senthilkumar, 2017; Borah *et al,* 2023). This includes proper housing with good ventilation and sanitation, a balanced diet, regular vaccination and deworming, and implementing biosecurity measures to prevent disease outbreaks. Effective management of boars, sows, and piglets, along with appropriate record-keeping, are also crucial for success. The present study was undertaken to assess the level of adoption of improved pig farming practices among farmers in Assam. Such an assessment is crucial for identifying existing constraints and potential opportunities within the sector. The findings are expected to assist policymakers and extension

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agencies in designing targeted interventions and strategies aimed at promoting sustainable piggery development in the state.

MATERIALS AND METHODS

The present study was conducted at Jorhat district of Assam during April, 2024 to March, 2025. A total of 100 (hundred) pig farmers were randomly selected from different villages of the district for the study. Data were collected through personal interviews using a pre-tested and structured interview schedule. For the present study, a comprehensive list of improved pig farming practices was compiled and systematically categorized into five broad categories, *viz*., (i) housing and environment-related practices, (ii) feeding and nutrition-related practices, (iii) healthcare management, (iv) breeding and reproductive practices, and (v) advanced marketing practices. These categories were categorized to ensure systematic analysis of the technological interventions across the dimensions of pig production. The degree of adoption across the five categories was systematically assessed. For each, adoption was quantified using a three-point scale: regular adoption (score of 2), occasional adoption (score of 1), and non-adoption (score of 0). The cumulative score for each practice was derived by aggregating the responses from all selected respondents. To standardize the measurement of adoption behaviour, adoption index developed by Karthikeyan (1994) was used.

$$\text{Respondent's Adoption Index (AI)} = \frac{\text{Total Adoption Score (TAS)}}{\text{Total Possible Score (TPS)}} \times 100$$

Further, ranks were assigned based on the adoption index.

RESULTS AND DISCUSSION

The data on adoption of various improved management practices of piggery in various aspects were collected, tabulated and analysed for obtaining total adoption scores (TAS), mean score (MS) and adoption index (AI). Then ranks were also assigned to each item based on the adoption index within the management aspects. The results have been tabulated and presented as follows. Adoption of various advanced housing and environment practices is presented in Table 1.

Table 1 indicates that the practice of using hard, even, non-slippery, and well-sloped flooring to facilitate proper drainage and ease of cleaning was ranked first as this practice is considered most critical for ensuring the survival and healthy growth of pigs and piglets. The pig farmers ranked regular cleaning the pigsty, including feeding and watering troughs, to maintain hygiene; second among the five housing and environmental practices. The practice of ensuring adequate ventilation and proper drainage to maintain a dry and clean environment was ranked third and providing sufficient space per pig, both indoors and outdoors, with separate areas for feeding and resting ranked fourth.

Adoption of various feeding and nutritional practices is presented in Table 2. The majority of pig farmers reported weaning piglets at the appropriate age (around two months or earlier, depending on the farmer's preference) to allow sows to recover and prepare for the next farrowing. This practice was ranked first, with an adoption index of 91 percent. Feeding pigs at consistent times (generally twice daily) and adjusting feed quantities based on growth stage was ranked second, with an adoption index of 78.50 percent. Very less number of pig farmers follows the practice of providing access to fresh, clean water at all times, preferably through nipple drinkers with the adoption index of only 55 percent.

Adoption of various health management practices is presented in Table 3. The practice of vaccinating pigs against common diseases like swine fever, and test breeding pigs for diseases like brucellosis and leptospirosis ranked first with an adoption index of 95 percent. The practice of maintaining records of vaccinations, deworming, and other health treatments ranked second with the adoption index of 91 percent. Whereas, the practice of deworming pigs regularly, especially if they are prone to parasitic infections ranked third with the adoption index of 60.50 percent. Very less number of farmers follow the practice of implementing biosecurity measures to prevent disease introduction, such as isolating new animals and restricting farm visitors which is considered as very critical for proper health condition of the pigs was recorded with adoption index of only 56.50 percent.

Adoption of improved breeding and reproduction practices is presented in Table 4. Among the practices, providing adequate feed and proper care to pregnant and lactating sows secured the highest rank, with an adoption index of 96.50 percent. This was followed by the practice of housing boars individually, ensuring regular exercise, and testing them for brucellosis and leptospirosis, which ranked second.

Adoption of Scientific Pig Rearing Practices

Table 1. Adoption of various advanced housing and environment practices.

Housing and Environment practices	Regular adoption	Someti mes adoptio n	Non adopt ion	TAS	MS	AI	Rank
Utilize hard, even, non-slippery, and well-sloped floors to facilitate drainage and cleaning.	82	10	8	174	1.74	87	I
Regularly clean the pigsty, including feeding and watering troughs, to maintain hygiene.	71	23	6	165	1.65	82.5	II
Ensure adequate ventilation and proper drainage to maintain a dry and clean environment	69	15	16	153	1.53	76.5	III
Provide sufficient space per pig, both indoors and outdoors, with separate areas for feeding and resting.	65	17	18	147	1.47	73.5	IV
Offer shade and cool drinking water during hot weather.	53	32	15	138	1.38	69	V

Table 2: Adoption of various Feeding and nutrition practices

Feeding and nutrition practices	Regular adoption	Sometimes adoption	Non adoption	TAS	MS	AI	Rank
Wean piglets at the appropriate age (2 months or earlier, depending on the farmer's preference) to allow the sow to recover and prepare for the next farrowing.	85	12	3	182	1.82	91	I
Feed pigs at consistent times, twice a day, and adjust the amount based on their growth stage.	71	15	14	157	1.57	78.5	II
Feed pigs a balanced diet with adequate protein, carbohydrates, vitamins, and minerals.	59	28	13	146	1.46	73	III
Provide access to fresh, clean water at all times, preferably through nipple drinkers.	31	48	21	110	1.1	55	IV

The third most adopted practice was the use of guard rails for newborn piglets, along with treating their navel cords with tincture of iodine, and ensuring timely access to colostrum and creep feed.

Adoption of advanced marketing practices is presented in Table 5. The practice of exploring various marketing channels, including social media and direct sales ranked first with the adoption index of 52.5 percent. Least adopted practice was researching the market demand and potential buyers before starting pig farming which is very important for better profitability of any business.

Table 3: Adoption of various Health management practices

Health management practices	Regular adoption	Sometimes adoption	Non adoption	TAS	MS	AI	Rank
Vaccinate pigs against common diseases like swine fever, and test breeding pigs for diseases like brucellosis and leptospirosis.	91	8	1	190	1.90	95.00	I
Maintain records of vaccinations, deworming, and other health treatments.	85	12	3	182	1.82	91.00	II
Deworm pigs regularly, especially if they are prone to parasitic infections.	35	51	14	121	1.21	60.50	III
Implement biosecurity measures to prevent disease introduction, such as isolating new animals and restricting farm visitors.	45	23		113	1.13	56.50	IV

Table 4: Adoption of various Breeding and reproduction practices

Breeding and reproduction practices	Regular adoption	Sometimes adoption	Non adoption	TAS	MS	AI	Rank
Provide adequate feed and care for pregnant and lactating sows.	93	7	0	193	1.93	96.50	I
Ensure boars are housed individually, regularly exercised, and tested for brucellosis and leptospirosis.	71	13	16	155	1.55	77.50	II
Provide guard rails for new born piglets, treat their navel cords with tincture of iodine, and ensure they receive colostrum and creep feed.	17	19	64	53	0.53	26.50	III

Table 5: Adoption of Advanced Marketing practices

Advanced Marketing practices	Regular adoption	Sometimes adoption	Non adoption	TAS	MS	AI	Rank
Explore various marketing channels, including social media and direct sales.	48	9	43	105	1.05	52.50	I
Research the market demand and potential buyers before starting pig farming.	29	13	58	71	0.71	35.50	II

CONCLUSION

The study assessed the extent of adoption of improved pig farming practices among 100 farmers in Jorhat district of Assam. Five domains of practices were analysed: housing, feeding, healthcare, breeding, and marketing. Majority of the sample pig farmers adopted the practices like utilizing hard, even, non-slippery, and well-sloped floors to facilitate drainage and cleaning, weaning piglets at the appropriate age (2 months or earlier, depending on the farmer's preference) to allow the sow to recover and prepare for the next farrowing, vaccinating pigs against common diseases like swine fever, and test breeding pigs for diseases like brucellosis and leptospirosis, providing adequate feed and care for pregnant and lactating sows

etc. Least adopted practices were offering shade and cool drinking water during hot weather, providing access to fresh, clean water at all times, preferably through nipple drinkers, implementing biosecurity measures to prevent disease introduction, such as isolating new animals and restricting farm visitors etc. which are very much important for a highly productive, viable, disease-free pig farm and overall financial improvement of the farmers and ultimately improving the rural economy. Therefore, it is need of the hour for increasing awareness among the pig farmers by the extension workers.

The study underscores that pig farmers in Assam exhibit a moderate to high level of adoption of basic husbandry practices, especially in housing, feeding, and healthcare management. However, adoption of crucial breeding, reproductive, and marketing practices remains low. This imbalance limits productivity and profitability, thereby widening the pork demand–supply gap in the state. Strengthening extension support, organizing capacity-building programmes, ensuring access to quality breeding stock, and promoting market linkages are essential to improve the overall performance of pig farming. Focused policy interventions, particularly in reproductive management and market orientation, can transform piggery into a more sustainable and remunerative enterprise, thereby contributing to rural livelihood security and nutritional self-reliance in Assam.

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Assessment of African Marigold (*Tagetes Erecta*) variety Arka Abhi for Growth and Flowering Attributes

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ABSTRACT

The objective of the study was to evaluate the growth and flowering characteristics of African marigold (*Tagetes erecta)* variety Arka Abhi in YSR Kadapa district. The field experiment was carried out at Gopalapuram and Rachapalli villages of YSR Kadapa district, during the rabi 2021 season . The results revealed significant differences in the growth and flowering parameters of Arka Abhi Marigold variety as compared to variety used by the farmer. Arka Abhi recorded the maximum plant height (92 cm) whereas the minimum plant height was observed in Max Yellow (55 cm). The highest number of primary branches per plant was recorded in Arka Abhi (15.4) followed by lowest number of branches in Max Yellow (7.3). The maximum shelf-life was observed in Arka Abhi (5 d), however, the lowest shelf-life (2.5 d) was registered in max yellow.

Keywords: Assessment, Flowering Attributes, Growth, Marigold, Variety.

Marigold (*Tagetes erecta)*, a member of the Asteraceae family has long been valued for both its medicinal and decorative uses (Mahantesh *et al*, 2018). African marigolds plants can grow up to three feet, producing large globe-shaped blooms that are ideal for bedding purposes (Dixit *et al*, 2013). Their vibrant orange to yellow flowers blend well with various colour schemes and are also a crucial raw material in industries due to their high content of carotenoids, essential oils and alkaloids (Pérez *et al*, 2006). The flowers are specifically used to extract compounds like 1-limonene, ecomene, 1-linalyl acetate and 1-linalool (Narsude *et al*, 2010). Marigolds thrive in diverse soil types and require a mild climate for optimal growth and abundant flowering.

Marigolds are primarily cultivated for pigment extraction, particularly xanthophyll, which is widely used in the poultry industry to enhance chicken skin colour and egg yolk pigmentation. Commercial extraction of carotenoids from marigolds is concentrated in regions like Cochin (Kerala), Hyderabad (Telangana), Satyamangalam forest (Tamil Nadu) and Telagi near Harihar and Bangalore (Karnataka). It has been observed that marigold varieties exhibit a lot of variation for flowering characters, which varies with varieties (Sreekala *et al,* 2002). The performance of marigold cultivars varies significantly with region, season and growing conditions (Tomar *et al,* 1972). A variety that

thrives well in one location may perform poorly in another with different climatic conditions. Thus, evaluating and selecting high-yielding and biotic stress-resistant varieties suitable for specific agro-climatic regions is essential. Despite of this, farmers often rely on recommendations from peers or seed retailers, lacking awareness of region-specific varieties (Palthe *et al*, 2019). Hence, evaluating of new marigold variety arka abhi in the YSR Kadapa district of Andhra Pradesh was crucial for identifying variety with desirable growth and flowering traits. This will enable farmers to maximize profitability and ensure the sustainability of marigold cultivation. As floriculture advances, there is a growing need to recommend suitable varieties to farmers based on rigorous evaluations, thereby unlocking the full potential of marigold production (Palthe *et al*, 2019)

MATERIALS AND METHODS

The present experiment was conducted at five farmers' fields at Gopalapuram, Rachapalli, and Chinthakomma Dinne Villages of YSR district during rabi seasons of 2021-22. Total annual rainfall of 1168.6 mm rainfall received during the year 2021-22. During *rabi* season maximum temperature 32.8 ° C and minimum temperature of 21.7° C was recorded . The farming situation was irrigated sandy loam soils. The data were analyzed with appropriate statistical method as suggested by Panse and Sukhatme (1967). The study conducted in the open field condition and

Table 1. Growth and yield attributes performance of Arka Abhi marigold compared to farmers practicing variety max yellow.

Variety	Plant Height (cm)	Number of Primary branches per plant	Number of flowers per plant	Yield (t/ha)	% increase in yield	Crop duration (days)	Shelf life (days)	Net Income (Rs/ha)	B:C ratio
Arka Abhi	92	15.4	102	13.50	50%	150	5	183500	2.17
Max Yellow	55	7.3	58	9.0		120	2.5	90000	1.66
SD value	14.34	3.65	26.54	2.54		15.67	1.44		
t-value	6.57*	5.78*	9.45*	9.54*		4.65*	5.43*		
p-value	0.000	0.003	0.001	0.00		0.000	0.000		

Plate1: Arka abhi and Max yellow field photos

Arka Abhi

Max Yelllow

was properly prepared through ploughing, leveling and manual weeding. Harrowing was done to break the clods, followed by criss-cross ploughing with cultivator, then the field was pulverized by rotavator. During harrowing well-rotten farmyard manure was incorporated @ 10 kg/m² into the soil at the time of field preparation. Fertilizer was applied as NPK @ 10:10:10 kg/ha (Mahanta et al, 2020). Half the quantity of nitrogen and the full dose of phosphorus and potash were applied at the time of transplanting, while the remaining dose of nitrogen was applied one month after transplanting. Planting was done at a spacing of 60 cm × 45 cm.

The various observations were taken on growth and flowering parameters *viz.,* plant height (cm), number of primary branches per plant, number of flowers per plant, yield per kg, percentage of increase in yield, crop duration, shelf life, net income (Rs/ha), B:C ratio. Three readings were taken from each treatment and the data were recorded once in a

peak season of flowering during the experimental period. The results obtained were statistically analysed with SPSS, one way ANOVA and repeated measures mixed ANOVA was carried out for pooled analysis

RESULTS AND DISCUSSION

Growth attributes

Analysis of variance revealed significant differences in traits in Arka Abhi and farmer's variety Max Yellow for growth and flowering characteristics. The vegetative growth parameters of marigold variety Arka Abhi and Max Yellow were evaluated based on plant height (cm), number of primary branches. The data (Table 1) showed a considerable range of variation in plant height among the different Arka Abhi and farmer variety Max Yellow. Significantly, the maximum plant height was recorded in Arka Abhi (92 cm). The minimum plant height was recorded in Max Yellow (55 cm). Plant

height is a critical varietal trait influenced by the genetic composition of the plant. The variation in plant height among the different varieties may be due to genotypic differences in phenotypic expression of plant height and the impact of environmental factors. This variation in plant height is likely due to the genetic makeup of the varieties, which affects meristematic activity, cell division, and elongation during early growth, as well as the synthesis of phytohormones and the influence of environmental conditions Similar variation in plant height due to genotypes was also reported by Shobha *et al* (2025), Mahanta *et al* (2020), Prateeksha *et al* (2024), and Bhusaraddi *et al* (2022), Rao *et al* (2005), Singh and Singh, (2006) and Khanvilkar *et al* (2003) in marigold.

Number of primary branches was significantly higher in variety (Arka Abhi 15.4) and lowest in Max Yellow (7.3). Variation in the number of primary branches per plant is attributed to genetic characters. These variations were likely due to the genetic makeup of the varieties, which influence photosynthesis rates and, in turn, the number of branches produced, as well as the effect of environmental factors that affect light interception. Similar results were observed by Palthe *et al* (2019), Prateeksha *et al* (2024), and Sharma *et al* (2021), Singh and Singh, 2005, Jauhari and Singh, (2006), Shobha *et al* (2025) and Bhusaraddi *et al* (2022).

Flowering Attributes

The data (Table 1) showed significant differences among the varieties. The maximum number of flowers was recorded in Arka abhi (102), whereas the lowest was observed in Max yellow (58) gm). Similar variability was also observed by Shobha *et al* (2025), Bhusaraddi *et al* (2022) in different marigold genotypes.

Shelf life

The maximum shelf-life was observed in Arka Abhi (5 days), however, the lowest shelf-life (2.5 days) was registered in max yellow. These result variations in vase-life may be attributed to differential accumulation of carbohydrates from varied leaf production, sensitivity of cultivars to ethylene and genetically framework of the plant. Similar finding reported by Divya *et al* (2018) , Samantray (2018), Ibrahim (2023), Shobha *et al* (2025) in other marigold varieties.

The longest crop duration (150 days) was recorded in Arka Abhi and lowest in the control (120 days). The genetic control of these character and modification in their expression due to environmental factors might be possible causes of observed variation. Similar findings have been also reported by Raghuvanshi and Sharma (2011), Palthe *et al (*2019) and Shubhashish *et al* (2023). The genotypes differed significantly in flower yield/ha. The maximum (13.5 t/ha) flower yield was recorded in Arka Abhi. However, lowest (9 t/ha) was recorded in the control. This result could be due to the vigorous plant stature, enhanced branching, increased flower production, higher flower weight, environmental conditions and also cultural practices which collectively enhanced productivity. These similar results were reported by Kumari *et al* (2025), Kumari and Singh (2022), Narsude *et al* (2010), Mahantesh *et al* (2018) and Palthe *et al* (2019).

Economics

Arka abhi shown high net returns of Rs. 1,83,400/ ha with B: C ratio of 1:2.17, where as max yellow net returns were Rs. 90,000/ha with B:C ratio 1:1.66. Arka Abhi showed 50% increased yield with good market preference. The long crop duration improves the profit. Similar results were reported by Kanwar Pal Singh *et al* (2014).

CONCLUSION

It was concluded that cultivation of Arka Abhi shown superior performance in YSR district, Andhra Pradesh and cultivation was beneficial due to their traits. On the basis of results obtained it can be said that among the varieties, Arka Abhi was found superior in yield and yield attributing parameters. Hence farmers realized to achieve maximization of marketable crop yield by cultivating Arka Abhi in YSR district.

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Assessment of Genetic Variability and Heritability in Okra [*Abelmoschus esculentus* (L.) Moench.] Genotypes

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ABSTRACT

Okra is a nutritionally and economically important crop, yet its genetic potential is underexploited due to limited knowledge of variability among genotypes. This study aimed to assess genetic variability, heritability, and genetic advance in okra to identify key traits for targeted improvement. This comprehensive analysis examined genetic variation across 25 okra genotypes, alongside the check variety Arka Anamika, to pinpoint advantageous characteristics for advanced breeding programs targeting yield optimization and quality enhancement. Executed during summer 2019 at Horticultural Research Centre (H.N.B. Garhwal University), the trial utilized a triple-replicated randomized complete block design (RCBD) to maximize experimental reliability. Statistical analysis of 15 agronomic and biochemical traits included evaluations of phenotypic/genotypic variation of coefficients (PCV/GCV), broad-sense heritability (h²) and genetic advancement metrics (GA, GAM). The key outcome revealed marked genetic differentiation in key characteristics like number of primary branches, total soluble solids content, seed yield per fruit, and physiological loss demonstrated high GCV/PCV ratios and high heritability with high genetic gains. These findings highlighted additive genetic effects, making these traits optimal for traditional phenotypic selection. Conversely, chlorophyll content, leaf length and petiole diameter showed moderate to low heritability and genetic gain, suggesting environmental susceptibility or epistatic genetic regulation that may necessitate biotechnological interventions like CRISPR-based editing or transcriptomic profiling to bypass traditional breeding constraints. The research underscored the untapped genetic reservoir within existing okra germplasm, offering an actionable framework for crop improvement. High-heritability traits warrant immediate selection protocols, while polygenic characteristics could benefit from integrated genomic selection models or haplotype-based breeding.

Keywords: Genetic gain, Genetic variability, Crop improvement, Genetic advance, Heritability, Okra, Quality traits.

INTRODUCTION

Okra [*Abelmoschus esculentus* (L.) Moench.], popularly known as lady's finger, is a highly valued warm-season vegetable crop renowned for its broad spectrum of nutritional, economic and medicinal properties (Baghel *et al,* 2022; Joshi *et al,* 2025a). This species is recognized by a plethora of regional names, such as bhindi in Hindi, vendakkai in Tamil, bhendi in Marathi and gumbo in the southern United States and is a member of the Malvaceae family (Joshi *et al,* 2020;

Sharma *et al,* 2022). Its tender, immature pods are prized for their culinary versatility, being consumed in fresh, boiled, fried, pickled, or dried forms, thereby underscoring its significance in both domestic cuisine and commercial food processing (Joshi *et al,* 2021; Petropoulos *et al,* 2022; Singh *et al,* 2023). The crop's remarkable adaptability to diverse agro-ecological conditions and its relatively brief growth cycle make it an attractive option for both smallholder and commercial farming enterprises (Kumar and Joshi, 2024; Joshi *et al,* 2025b).

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The genus *Abelmoschus* comprises between six and fifteen species, exhibiting considerable morphological and physiological diversity (Ray *et al,* 2022). Of these, *A. esculentus* is the most widely cultivated, while *A. caillei* a natural amphidiploid, is predominantly grown in the humid zones of West Africa. Wild relatives such as *A. manihot*, *A. moschatus* and *A. ficulneus* serve as valuable reservoirs of genetic diversity, offering traits that can be leveraged in breeding programs to enhance resistance to various biotic and abiotic stresses (Singh *et al,* 2023). The genetic richness present within and among these species provides a robust foundation for the advancement of improved cultivars through both conventional and molecular breeding methodologies.

Nutritionally, okra is distinguished by its low caloric content and high levels of moisture and dietary fiber, factors that support digestive health and glycemic regulation. The pods are also notable sources of essential vitamins, including A (beta-carotene), C, K, and several B-complex vitamins, as well as minerals such as calcium, potassium, magnesium, manganese, phosphorus, and iron (Gemede *et al,* 2015). The mucilage, primarily composed of polysaccharides, is recognized for its beneficial effects on gastrointestinal health and blood glucose management. Furthermore, okra is rich in phytochemicals, including flavonoids, polyphenols, and antioxidants, which impart a range of therapeutic properties, such as anti-diabetic, anti-inflammatory, antibacterial, and cholesterol-lowering effects (Karmakar *et al,* 2022). In addition to its nutritional merits, okra holds considerable industrial significance. The mucilage is widely utilized as a natural thickener, stabilizer, and emulsifier in the food, pharmaceutical, and cosmetic industries. Okra seeds, which constitute 15-20% of pod weight, are a valuable source of oil rich in unsaturated fatty acids, particularly linoleic and oleic acids, making them suitable for nutraceutical and biodiesel applications.

The lignocellulosic fibers derived from okra stems are being explored as sustainable raw materials for the paper and textile sectors. Moreover, the development of processed okra products, such as dehydrated flakes, powders, and canned pods, enhances shelf life, adds value, and opens new avenues for agribusiness and export (Petropoulos *et al,* 2022). Despite its widespread cultivation and multifaceted applications, okra remains relatively underutilized in advanced breeding and genomic research. The narrow genetic base of most cultivated varieties poses a significant constraint to genetic improvement. Contemporary breeding programs require a comprehensive evaluation of genetic diversity, using morphological, biochemical, and molecular markers to identify superior genotypes with enhanced yield, resilience, and quality traits (Sharma *et al,* 2022; Singh *et al,* 2023). The development of robust, high-yielding, and climate-resilient cultivars is essential to satisfy the escalating global demand for nutritious vegetables. The present study seeks to assess the genetic variability among selected okra genotypes, with a focus on yield and quality-related traits. Identification of promising genotypes will facilitate the breeding of superior hybrids and contribute to the sustainability of okra production systems.

MATERIALS AND METHODS

This study was undertaken during the summer cropping season of 2019 at the Horticultural Research Centre, located within the North Terrace Valley adjacent to the Alaknanda River. The experimental site lies at geographic coordinates 78°47'30" E longitude and 30°13'9" N latitude, elevated approximately 540 meters above mean sea level (MSL), within the Lesser Himalayan zone. The location experiences a subtropical highland climate characterized by notable diurnal temperature fluctuations, which are favourable for horticultural research. Maximum temperatures reached up to 42.16°C, whereas minimum temperatures declined to 20.7°C. Relative humidity exhibited a wide range, varying from 11.76% to 95.41%, indicative of the humid subtropical conditions prevalent in the region. Precipitation was limited, with peak rainfall recorded in July, averaging 0.158 mm, consistent with the onset of the regional summer monsoon. These environmental parameters were meticulously recorded throughout the crop growth cycle to examine their influence on genotype performance.

The experimental material comprised twenty-five okra genotypes, with one standard check cultivar, Arka Anamika, which functioned as a benchmark for comparative analysis. The cultivars evaluated included: Agri Bahar, Chanda, Hisar Naveen, Hisar Unnat, Kashi Kranti, Kashi Mohini, Kashi Pragati, Kashi Vibhuti, Kaveri, King Bhindi, LC-1 through LC-6 series, Lucky-666, Parbhani Kranti, Punjab-8, Pusa A-4, Pusa Sawani, Super Anamika, VL Bhindi-2, Vandana-241, and Varsha Uphar. A randomized complete block design (RCBD) with three replications was implemented to minimize experimental variability and enhance the precision of results. Each genotype was cultivated in discrete plots, and uniform agronomic practices were consistently applied across

all treatments to mitigate confounding factors. Within each replicate, five vigorous plants per genotype were randomly chosen, tagged, and monitored for detailed phenotypic observations. Data on yield and quality traits were systematically recorded from these selected plants, and mean values were calculated to represent genotype performance.

For data analysis, initial data organization was carried out using Microsoft Excel, while advanced statistical analysis was performed with SPSS version 26. The phenotypic variance (PCV) and genotypic variance (GCV) were estimated, partitioning the total observed variation into genetic and environmental components (Lush, 1940). The extent of genetic variability was quantified using the Genotypic Coefficient of Variation (GCV) and Phenotypic Coefficient of Variation (PCV), both expressed as percentages (Burton and DeVane, 1953). These parameters provide insights into the relative contributions of genetic and environmental factors to trait expression. The magnitude of variability was categorized as low (0–10%), moderate (11–20%), or high (>20%) (Sivasubramanian and Madhavamenon, 1973), facilitating identification of traits with substantial genetic variability, which serve as essential targets for selection in breeding programs. Broad-sense heritability (h^2b), representing the proportion of phenotypic variance attributable to genetic causes (Hansen *et al,* 1956), was estimated. Heritability values were stratified into low (0–50%), moderate (51–70%), and high (>70%) categories, enabling evaluation of the reliability of phenotypic selection. Genetic advance (GA), indicating the expected improvement from selection under ideal conditions (Johnson *et al,* 1955), was also determined. Genetic advance as percent of mean (GAM) was calculated to normalize genetic gain relative to the trait mean, and classified into low (0–10%), moderate (11–20%), and high (>20%) categories. These metrics collectively provide a predictive framework for the potential genetic progress achievable through selection.

RESULTS AND DISCUSSION

Genetic variability

The genetic variability parameters, including the phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), broad-sense heritability (h²), genetic advance and genetic advance as a percentage of the mean, across all 15 evaluated traits, are summarized in Table 1. The comparative analysis of PCV and GCV provided a detailed understanding of the extent of variability present within the studied germplasm. Notably, for all traits assessed, the PCV values consistently exceeded the corresponding GCV values. However, in most instances, the disparity between PCV and GCV was minimal, aligning with findings reported by Prakash *et al* (2011), Khajuria *et al* (2015), Chandramouli *et al* (2016) and Kerure *et al* (2017) in okra. This close proximity between PCV and GCV suggests that environmental influences on the expression of these traits are relatively minor, implying that the observed variation is predominantly governed by genetic factors. The magnitude of both coefficients varied across traits, ranging from low to moderate or high, which underscores the considerable genetic diversity inherent in the experimental material. Such diversity is crucial, as it provides a robust foundation for effective selection and breeding strategies aimed at crop improvement.

Genotypic and phenotypic coefficient of variation

The phenotypic variability observed among the evaluated okra genotypes for various traits is a manifestation of the interplay between genetic constitution and environmental influences. While environmental variance is inherently non-heritable and, therefore, not amenable to selection, the genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) are valuable tools for quantifying total trait variability and discerning the relative contributions of genetic and environmental components (Badiger *et al,* 2017). These parameters facilitate the identification of traits governed primarily by genetic factors, which are critical for effective selection in crop improvement programs.

In the present investigation, traits such as the number of primary branches per plant (GCV: 33.54%; PCV: 34.20%), exhibited high levels of both GCV and PCV. The narrow gap between genotypic and phenotypic variances for these traits indicates a minimal influence of environmental factors and suggests a predominance of additive gene action. Consequently, these traits present substantial potential for genetic improvement through direct phenotypic selection. Similar trends have been reported in earlier studies by Khajuria *et al* (2015), Chandramouli *et al* (2016), Deepanshu and Shamd (2017), Kerure *et al* (2017) and Kumari *et al* (2019) affirming the genetic stability of these attributes.

Moderate levels of variability were recorded for traits such as number of seeds per fruit (GCV: 17.94%; PCV: 19.17%), total soluble solids (GCV:

13.30%; PCV: 13.93%), seed index (GCV: 10.43%; PCV: 12.99%) and ash content (GCV: 10.34%; PCV: 12.96%). The moderate divergence between GCV and PCV in these parameters reflects a balanced influence of genotypic and environmental components, indicating partial heritability and a moderate response to selection. These findings align with the results of by Khajuria *et al* (2015), Chandramouli *et al* (2016) and Badiger *et al* (2017).

Conversely, several traits exhibited low GCV and PCV values, including stem girth (GCV: 8.45%; PCV: 9.03%), number of ridges per fruit (GCV: 5.79%; PCV: 6.38%), ascorbic acid content (GCV: 5.71%; PCV: 6.59%), petiole diameter (GCV: 4.78%; PCV: 7.42%), fruit diameter (GCV: 4.59%; PCV: 5.46%), chlorophyll content (GCV: 3.23%; PCV: 6.50%), leaf length (GCV: 2.61%; PCV: 5.14%) and moisture content (GCV: 1.51%; PCV: 1.94%). These results suggest that such traits are predominantly influenced by environmental factors, thereby limiting their scope for genetic enhancement through conventional selection. These outcomes are consistent with the findings of Ahmad *et al* (2015) who also noted low heritable variation for similar parameters. Additionally, traits such as physiological loss exhibited a relatively high PCV (20.85%) and a moderate GCV (18.47%) indicating a significant environmental effect. Similarly, flesh thickness showed a moderate PCV (11.11%) but a low GCV (7.74%), further emphasizing environmental predominance in its expression and limiting the expected genetic gain. Overall, traits characterized by high GCV and PCV values with minimal differential between them are most suitable for direct selection, as they are predominantly governed by genetic variability. Such traits hold promise for enhancing selection efficiency and achieving meaningful genetic progress (Ahmad *et al,* 2015; Khajuria *et al,* 2015; Chandramouli *et al,* 2016; Badiger *et al,* 2017; Kerure *et al,* 2017; Kumari *et al,* 2019).

Heritability

Heritability constitutes a cornerstone of quantitative genetics and plant breeding, representing the proportion of total phenotypic variance attributable to genetic variance. While the genotypic coefficient of variation (GCV) quantifies the magnitude of genetic diversity within a population, it does not differentiate between genetic and environmental contributions to phenotypic expression. Consequently, the integration of heritability estimates with GCV and genetic advance provides a more robust framework for

evaluating the effectiveness of selection and the potential for genetic gain (Burton and DeVane, 1953). High heritability, when coupled with high GCV and high genetic advance, typically reflects the predominance of additive gene effects, suggesting that such traits are amenable to improvement through direct phenotypic selection (Johnson *et al,* 1955).

In the present investigation, broad-sense heritability estimates across the studied traits ranged from 24.67% to 96.22%, highlighting considerable variability in the degree of genetic control. Traits exhibiting high heritability (>70%) included the number of primary branches per plant, total soluble solids, stem girth, number of ridges per fruit, physiological loss, ascorbic acid content, and fruit diameter. These high heritability values imply that genetic variance constitutes the dominant source of phenotypic variation for these traits, rendering them ideal candidates for selection-based breeding strategies. These findings are in alignment with earlier research by Patel *et al* (2014), Ahmad *et al* (2015), Chandramouli *et al* (2016) and Kumari *et al* (2019) who similarly documented high heritability in okra for comparable traits, underscoring their relevance in genetic enhancement programs. For instance, the number of primary branches per plant demonstrated high GCV along with high heritability, suggesting that this trait is primarily governed by additive gene action, and thus offers substantial promise for improvement via simple selection protocols. Similarly, traits such as ascorbic acid content and stem girth, which are crucial for fruit quality and consumer acceptability, showed high heritability, indicating their amenability to improvement through conventional selection methods. Moderate heritability (51-70%) was recorded for traits such as seed index, ash content, pedicel diameter, moisture content and petiole length, reflecting a balanced contribution of genetic and environmental factors. While selection is still feasible for these traits, the realized genetic gain may be moderate and environmental variation could obscure underlying genetic effects. These observations are consistent with prior findings by Goswami *et al* (2012) and Umesh *et al* (2013), who emphasized the necessity for multi-environment evaluation to ensure stability and consistency of trait expression under variable growing conditions.

In contrast, traits such as flesh thickness, petiole diameter, leaf length and chlorophyll content exhibited low heritability (<50%), suggesting a predominant influence of environmental factors and/or non-additive gene effects. For example, chlorophyll

content, a trait sensitive to fluctuations in light, water, and nutrient regimes, showed particularly low heritability, indicating that its phenotypic expression is highly plastic and less genetically determined. Such traits are less responsive to direct phenotypic selection and may benefit from precision breeding approaches, such as marker-assisted selection, genomic selection, or environment-specific breeding strategies. Previous studies by Goswami *et al* (2012), Shaikh *et al* (2013) and Kerure *et al* (2017) support these conclusions, recommending more advanced breeding methodologies for traits with substantial environmental sensitivity. Moreover, the relationship between heritability and genetic advance provides additional insights into the underlying genetic architecture of traits. Traits with high heritability but low genetic advance, such as fruit diameter, may be governed predominantly by non-additive gene effects or epistasis, thereby necessitating breeding strategies such as recurrent selection or heterosis breeding. Conversely, traits that exhibit both high heritability and high genetic advance, such as yield per plant and number of branches, are indicative of additive gene action and are thus ideal for direct and effective phenotypic selection. In conclusion, the combined assessment of heritability, genotypic coefficient of variation (GCV), and genetic advance provides a comprehensive framework for differentiating traits that can be effectively improved through direct phenotypic selection from those that necessitate more sophisticated breeding approaches. This integrative analysis is vital for developing strategic and efficient selection methodologies, thereby enhancing the overall success and genetic gains in okra improvement programs.

Genetic advance

Genetic advance, when interpreted in conjunction with heritability, serves as a critical indicator of the potential success of selection strategies within a breeding program. In the current investigation, the highest genetic advance as a percentage of the mean was observed for the number of seeds per fruit (22.51%), signifying substantial scope for genetic improvement. This high genetic advance, paired with elevated heritability, suggests that the trait is predominantly controlled by additive gene action, making it highly responsive to direct phenotypic selection, a finding consistent with the results reported by Kumawat *et al* (2022). In contrast, flesh thickness exhibited the lowest genetic advance (0.18%), indicating minimal potential for improvement. This may be attributed to strong environmental influence or

a predominance of non-additive gene effects, as noted by Yadav *et al* (2020), thereby reducing the efficiency of direct selection for this trait.

Traits such as number of primary branches per plant, number of seeds per fruit, total soluble solids and physiological loss exhibited both high heritability and high genetic advance, making them excellent candidates for direct selection. These traits are likely governed by additive genetic effects, offering substantial potential for improvement through conventional breeding methods. These findings are corroborated by earlier studies conducted by Goswami *et al* (2012), Mishra *et al* (2015), Deepanshu and Shamd (2017) and Kumari *et al* (2019) affirming their value as reliable selection indices in okra breeding programs. As emphasized by Panse and Sukhatme (1984), high heritability must be interpreted alongside genetic advance to accurately predict the effectiveness of selection, as high heritability alone does not necessarily indicate additive gene action. Traits showing high heritability but low genetic advance, such as fruit diameter, are likely influenced by non-additive gene effects, reducing the efficiency of simple phenotypic selection. For such traits, breeding approaches like recurrent selection, heterosis breeding, or marker-assisted selection may be more effective.

Moreover, certain traits such as stem girth, number of ridges per fruit, total soluble solids and ascorbic acid exhibited high heritability combined with moderate genetic advance. According to Chandramouli *et al* (2016), this pattern indicates the involvement of both additive and non-additive genetic components, suggesting that while selection can be moderately effective, more refined strategies may be required for sustained genetic gains. Overall, the integration of genetic advances with heritability provides a more comprehensive framework for identifying superior traits for selection in okra. This approach enhances selection efficiency by enabling breeders to distinguish traits with high genetic potential from those heavily influenced by environmental variation or complex gene action, thereby facilitating the development of improved okra cultivars with desirable agronomic and nutritional traits.

Genetic advance over mean (GAM)

The genetic gain observed across various traits in the present study ranged from low to high (2.42% to 67.78%), underscoring the diverse genetic mechanisms influencing trait expression and the

Table 1: Estimates of phenotypic and genotypic coefficients of variation, heritability, genetic advance, and genetic advance over mean for growth and yield traits in okra.

Sr. No.	Character	Mean	Range	Coefficients of Variation		Heritability (%)	GA	GA as % of the mean
				GCV (%)	PCV (%)			
1.	Number of primary branches per plant	5.59	3.80-11.47	33.54	34.20	96.22	3.79	67.78
2.	Stem girth (mm)	36.67	26.22-42.34	8.45	9.03	87.57	5.97	16.28
3.	Petiole diameter (mm)	6.47	5.57-7.13	4.78	7.42	41.44	0.41	6.33
4.	Leaf length (cm)	21.33	19.75-22.76	2.61	5.14	25.86	0.58	2.74
5.	Fruit diameter (mm)	15.71	14.37-18.26	4.59	5.46	70.49	1.25	7.93
6.	Number of ridges per fruit	5.19	5.00-6.00	5.79	6.38	82.42	0.56	10.83
7.	Flesh thickness (mm)	1.59	1.27-1.99	7.74	11.11	48.61	0.18	11.12
8.	T.S.S (^{0}Brix)	10.86	8.07-13.90	13.30	13.93	91.20	2.84	26.17
9.	Ascorbic acid (mg/100g)	17.30	15.40-19.16	5.71	6.59	74.92	1.76	10.18
10.	Chlorophyll content (SPAD)	57.83	54.05-63.08	3.23	6.50	24.67	1.91	3.30
11.	Ash content (%)	9.73	7.41-11.54	10.34	12.96	63.60	1.65	16.98
12.	Moisture content	90.36	86.60-92.40	1.51	1.94	60.53	2.18	2.42
13.	Physiological loss	4.94	3.33-7.00	18.47	20.85	78.45	1.66	33.69
14.	Number of seeds per fruit	65.10	44.73-86.80	17.94	19.17	87.58	22.51	34.58
15.	Seed index	6.36	4.84-7.62	10.43	12.99	64.45	1.10	17.25

differential effectiveness of selection. Notably, high genetic gains were recorded for number of primary branches per plant (67.78%), number of seeds per fruit (34.58%), physiological loss (33.69%) and total soluble solids (26.17%). The substantial genetic gains for these traits, especially when paired with high heritability estimates, strongly indicate the predominance of additive gene action. This genetic architecture enhances their responsiveness to selection, rendering these traits highly amenable to genetic improvement in okra. These findings are consistent with previous studies that have documented similar trends (Shaikh *et al,* 2013; Patel *et al,* 2014; Ahmad *et al,* 2015; Mishra *et al,* 2015; Deepanshu and Shamd, 2017), reaffirming the utility of these traits as reliable selection targets in breeding programs. Traits exhibiting moderate genetic gains, such as seed index (17.25%), ash content (16.98%), stem girth (16.28%), flesh thickness (11.12%), number of ridges per fruit (10.83%), and ascorbic acid (10.18%), suggest a more complex inheritance pattern involving both genetic and environmental components. While selection for these traits can yield genetic progress, the rate of improvement may be less pronounced compared to traits with higher genetic gains. This pattern reflects findings by Ahmad *et al* (2015) and Chandramouli *et al* (2016), who noted that moderate genetic gains often necessitate more refined breeding approaches or environmental management for optimal selection efficiency.

Conversely, traits such as pedicel diameter (9.43%), petiole diameter (6.33%), chlorophyll content (3.30%), leaf length (2.74%), and moisture content (2.42%) demonstrated low genetic gains, suggesting that these traits are significantly influenced by environmental factors or governed by non-additive genetic variance. The limited scope for improvement through direct phenotypic selection diminishes their utility as primary selection criteria. Similar observations have been reported by Kerure *et al* (2017), who emphasized the necessity of alternative breeding strategies, such as genotype-by-environment interaction studies or molecular approaches, to improve the selection response for traits with inherently low genetic gains. Overall, the observed variation in genetic gain underscores the importance of trait-specific strategies in okra improvement. Prioritizing traits with high genetic gain and heritability ensures more efficient selection, whereas traits with low gain may require integrated or indirect approaches to achieve meaningful genetic advancement.

CONCLUSION

This study revealed substantial genetic variability among twenty-five okra genotypes across key yield and quality traits. High GCV, PCV, heritability, and genetic advance for traits like number of primary branches per plant, total soluble solids, seeds per fruit and physiological loss indicate the

predominance of additive gene action, making them ideal for improvement through direct phenotypic selection. Traits with moderate variability, such as ash content and seed index, may benefit from multi-environment trials for stable expression, while those with low heritability and genetic gain, like chlorophyll content and petiole diameter require advanced breeding tools such as marker-assisted or genomic selection. High genetic advance over the mean in certain traits further supports their utility in breeding programs targeting yield and quality enhancement. The findings underscore the importance of tailored breeding strategies, conventional for heritable traits and molecular for complex ones. This work provides a valuable foundation for developing improved and high-performing okra cultivars, contributing to future food and nutritional security.

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Change in Occupation from Agriculture to Non-Agricultural Sectors by the Tribal People of Mayurbhanj District, Odisha

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ABSTRACT

Being the major incumbent of Mayurbhanj District having share of 58.72% of the total population that is in the biggest district of the state of Odisha, the tribal people mainly depends on cultivation, collection of forest products, livestock rearing, casual labour jobs. But meantime the income from farming is going to be in decreasing mode for which most of the tribal people move to other places to find alternative livelihood options in lean period. The study was undertaken to find out the intensity of the occupational mobility of the tribal people of Mayurbhanj district of Odisha from the agriculture to non-agricultural activities. In the district there are four sub divisions from which one block from each sub divisions were selected randomly comprising of four blocks namely Badasahi, Khunta, Jashipur and Bahalada for the study. Five villages under each block were chosen randomly likewise twenty villages in total were taken under the study area. Purposefully six tribal people were taken as respondents with a sample size of 120 in total. The results implied that most of the tribal people had primary occupation on the agriculture (26.66%), livestock rearing (15.83%), wage earning (21.66%) and collection of forest produce (17.50%) as well as secondary occupation in that place very few were under miscellaneous activity and business sectors. But according to present occupation of the tribal people it was shown wide diversity of primary and secondary occupation engaging multifarious sectors. From the finding it was inferred that majority of the tribal people had been migrated in the summer season regularly (54.16%) which might be due to lack of livelihood option. Furthermore, it was observed that most of the respondents (38.33%) were going for other occupation regularly inside the gram panchayat area however mobility of the tribal people inside and outside state had only 15.00% and 06.00% respectively. On the basis of the study it is suggested for developing more investments and creation of basic infrastructural facilities like irrigation, market avenue storage facility, application of sophisticated techniques and expand of farm mechanization to make the agricultural sector more lucrative and profitable to check mobility from agriculture to non-agriculture sector of the tribal people. It is also suggested to improve educational status, skills, entrepreneurship spirit, swift credit linkage among tribal people through to attract more people in the agriculture and allied sector.

Keywords: Agriculture, Change, Intensity, Occupation, Primary hereditary occupation, Secondary occupation, Tribe.

INTRODUCTION

Mayurbhanj District is the largest district of the state of Odisha in which tribal population occupy a major share *i.e.* 58.72% of the total population. Their primary occupation mainly depends on cultivation, collection of forest products, livestock rearing, casual labour jobs. However, the income from farming is going to be in decreasing mode owing to poor water management, old practices, less use of machineries/implements and fragmented land holdings. For that reason, most of the tribal people move to other places to find alternative livelihood options in lean period. Most of the farmers adopt only monocropping that is also in kharif season. They usually engaged in non-farming activities like masonry work, brick making and small industrial labours etc. The present study was conducted to find out the intensity of the occupational mobility of the tribal people of Mayurbhanj district of Odisha from the agriculture to non-agricultural activities.

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Table 1. Socio-economic status of the respondents (n=120)

Sr. No.	Socio-Economic traits	Frequency	Average
A	**Age**		
1	Young (18-35 yr)	67	55.83
2	Middle (36-60 yr)	32	26.67
3	Old (more than 60 yr)	21	17.50
B	**Educational Status**		
1	Illiterate	26	21.67
2	Under Matric	45	37.50
3	Matriculation	34	28.33
4	Graduation	8	06.67
5	Post-Graduation and above	7	05.83
C	**Yearly Family Income**		
1	More than 1 lakh	11	09.67
2	50,000-1 lakh	28	23.33
3	20,000-50,000	27	22.50
4	Less than 20,000	54	45.00
D	**Family type**		
1	Joint	73	60.83
2	Nuclear	47	39.17
E	**Family size**		
1	Above 8	19	15.83
2	Within 5-8	68	56.67
3	Below 5	33	27.50
F	**Agricultural implements Possession**		
1	Country plough/ M.B. plough	103	85.83
2	Tractor/ Power tiller/Rotavator	45	37.50
3	Power sprayer/ Sprayer	29	24.16
4	Reaper/ Thresher	18	15.00
5	Seed drill	13	10.83
6	Bore well	62	51.67

MATERIALS AND METHODS

The domain of study area was confined to Mayurbhanj district in the state of Odisha having dominance of tribal people in which they occupy more than half of the total population of the district. In the district there are four sub divisions from which one block from each sub divisions were selected randomly comprising of four blocks namely Badasahi, Khunta, Jashipur and Bahalada for the study. Five villages under each block were chosen randomly likewise twenty villages in total were taken under the study area. Purposefully six tribal people were taken as respondents with a sample size of 120 in total. A pre tested structured interview schedule was prepared for collecting the data which was then analysed by using standard statistical formula.

RESULTS AND DISCUSSION

As per analysis of the socio-economic status of the respondents, it was analysed from the above table that most of the respondents (55.83 %) belonged to young age group (between 18- 35 years). With respect to the educational status, it was indicated as majority had qualification of below matriculation (37.50%) as well as annual family income in the category less than 20,000/- (45.00%). It was indicated from the table that most of the respondents belonged to joint family (60.83%) which was might be because of most of the tribal people preferred to live with the parents as per their traditional social system having family members between 5 to 8 numbers (56.67%). It was noticed that most of the respondents did not possess the costly agricultural machineries like tractor, power tiller, sprayer etc. whereas majority of the respondents possess traditional implements like country plough/mould board plough (85.83%). In terms of the social behaviour of the respondents, it was implicated from the study they had very much association at the village and block level organizations and officials however very poor linkage with the state and national level offices. Although some access with the non-government organization and private bodies were there might be due to their presence at grass root level. Kaur

Change in Occupation from Agriculture to Non-Agricultural Sectors

Table 2. Social Behaviour of the respondents (n=120)

Sr. No.	Type of Behaviour	Level of Involvement			
		Most times	**Some times**	**Rarely**	**Not at all**
		Frequency	Frequency	Frequency	Frequency
A	**Social participation**				
1	Panchayat level organisation	48 (40.00)	37 (30.83)	29 (24.16)	06 (05.00)
2	Block level organisation	19 (15.83)	44 (36.66)	62 (51.66)	34 (28.33)
3	District level organisation	07 (05.83)	21 (17.50)	39 (32.50)	53 (44.16)
4	State/National level organisation	02 (01.66)	13 (10.83)	32 (26.66)	73 (60.83)
B	**Cosmopoliteness**				
1	Up to Block level office	33 (27.50)	38 (31.66)	45 (37.50)	04 (03.33)
2	Up to District level office	07 (05.83)	18 (15.00)	40 (33.33)	55 (45.83)
3	Up to State/ National level office	03 (02.50)	17 (14.16)	31 (25.83)	69 (57.50)
C	**Extension Contact**				
1	Village level personnel	15 (12.50)	34 (28.33)	51 (42.50)	20 (16.66)
2	Block level personnel	04 (03.33)	16 (13.33)	35 (29.16)	65 (54.16)
4	District level personnel	05 (04.16)	11 (09.16)	23 (19.16)	81 (67.50)
5	State/National level personnel	08 (06.66)	15 (12.50)	31 (25.83)	66 (55.00)
6	NGO/Private organizations personnel	12 (10.00)	20 (16.66)	37 (30.83)	51 (42.50)

*Figures shown in the parentheses indicates the percentage

Table 3. Traditional hereditary occupation of the tribal people (n=120)

Sr. No.	Sector	Primary		Secondary	
		Frequency	%	Frequency	%
1	Agriculture	32	26.66	25	20.83
2	Livestock rearing	19	15.83	29	24.16
3	Fishing activity	03	02.50	11	09.16
4	Wage Earning	26	21.66	34	28.33
5	Collection of forest produces	21	17.50	16	13.33
6	Bonded Labour	14	11.66	02	01.66
7	Business	0	0	0	0
8	Other Miscellaneous activity	05	04.16	03	02.50

et al (2025) studied the factors those are contributing child labour in which he stated the personal factors like financial needs and drinking habit of pedigree including uncertain income and debt of the family forcing them for labour work at early childhood stage. In addition to this big family size is also responsible for child labour and migration. According to study by Bhuyan (2023), Lodha are the primitive tribe of Mayurbhanj district of Odisha having low socio-economic condition. They have scarcity of nutrition in their diet facing imbalance in health which reflects in socio-economic condition. On intergenerational occupational mobility from farming to the non-agricultural activity, Emran and Shilpi (2010) using survey data from Nepal revealed that there was a partial correlation in non-agricultural engagement between the father and a son whereas partial correlation was much stronger in occupation choice between mother and daughter. The non-farm involvement of mother played a causal role in daughter's choice might be cause of cultural inheritance.

Table 4. Engagement at present occupations by the tribal people (n=120)

Sr. No.	Field	Primary		Secondary	
		Frequency	%	Frequency	%
1	Agriculture	19	15.83	22	18.33
2	Livestock farming	17	14.16	18	15.00
3	Pisciculture	10	08.33	13	10.83
4	Collection and value addition of forest produces	06	05.00	02	01.66
5	Salaried (Govt Sector)	05	04.16	0	0
6	Salaried (Private/NGO/Industry)	14	11.66	0	0
7	Own Business Activity	11	09.16	03	02.50
8	Political activity	08	06.66	07	05.83
9	Contract Work	04	03.33	13	10.83
10	Skilled Labour	07	05.83	05	04.16
11	Wage Earner	16	13.33	23	19.16
12	Other Miscellaneous activity	03	02.50	14	11.66

Table 5. Mobility of the tribal people to different areas (n=120)

Sr. No.	Area	Intensity of mobility					
		Regularly		Occasionally		Not at all	
		Frequency	%	Frequency	%	Frequency	%
1	Inside Gram Panchayat	46	38.33	41	34.16	33	27.50
2	Inside Block	29	24.16	67	55.83	24	20.00
3	Inside District	19	15.83	38	31.66	63	52.00
4	Inside State	18	15.00	24	20.00	78	65.00
5	Outside State	08	06.66	19	15.83	93	77.50

Table 6. Mobility of the tribal people according to seasonal calendar (n=120)

Sr. No.	Season	Intensity of mobility					
		Regularly		Occasionally		Not at all	
		Frequency	%	Frequency	%	Frequency	%
1	Summer (Mar- May)	65	54.16	34	28.33	21	17.50
2	Rainy (Jun- Oct)	12	10.00	27	22.50	81	67.50
3	Winter (Nov- Dec)	43	35.83	41	34.16	36	30.00

In reference to traditional hereditary occupation of tribal people, the finding from the study suggested as most of the tribal people had primary occupation on the agriculture (26.66%), livestock rearing (15.83%), wage earning (21.66%) and collection of forest produce (17.50%) as well as secondary occupation which is also confirms with the literature analysis. Very few were in miscellaneous activity and business sectors. Balakrishna *et al* (2023) conducted study in North coastal Andhra Pradesh in Srikakulam district on the theme of livelihood of women in which he found tribal and women in rural pockets have livelihood option of back yard poultry farming in which they mainly dependant on indigenous poultry birds having less growth rate and food conversion ratio. Baruah *et al* (2024) in his finding on poultry farming of tribal people in two districts of Arunachal Pradesh revealed that although agriculture

is the main occupation of villagers of these areas, but also, they practice livestock and poultry farming as their concurrent livelihood support.

With respect to the distribution of present occupation of the tribal people, it was observed from the table 3 that there was wide diversity of primary and secondary occupation among them which implied the occupational mobility in terms of time and situation which might be due to changes in civilization, education and social structure. The table 4 indicated that among the tribal people, most of the respondents (38.33%) were going for other occupation regularly inside the gram panchayat area however mobility of the tribal people inside and outside state had only 15.00% and 06.00% respectively. From the study it was inferred that majority of the tribal people had been migrated in the summer season regularly (54.16%) which might be due to lack of livelihood option in the locality in absence of irrigation potential and other contract jobs like MGNREGA, construction sector or industrial opportunity. Singh and Meena (2023) investigated club performance on diversification in agriculture and allied activities for occupation purpose in which they found that most of the respondents (36.25%) took up organic farming followed by fishery (22.50%) and livestock rearing (21.25%). Singh *et al* (2024) stated that farming was primary occupation of the tribal people of Dindori district in the state of Madhya Pradesh with medium technical orientation. Most of the respondents had small land holding and they have medium level of adoption of new technologies. In poultry farming 90% of rural farmers mainly adopt native chicken (Rath *et al,* 2015) in which meat and egg productivity are very poor owing to low potential (Singh *et al,* 2018). Motiram and Singh (2012) presented rural sector mobility was less in comparison to urban sectors mainly in low-skilled and poor salary employees. However, there was downward mobility among the SC/STs.

CONCLUSION

The tribal people mainly depend on cultivation, collection of forest products, livestock rearing, casual labour jobs from which the income is going to be in decreasing for which most of the tribal people move to other places to find alternative livelihood options in lean period. Due to non-remunerative and encouraging for the income and livelihood in the field of agriculture, it is becoming a trend to migrate to other profitable occupational sectors for the tribal people in changing scenario. On the basis of the study it is suggested for developing

more investments and creation of basic infrastructural facilities like irrigation, market avenue storage facility, application of sophisticated techniques and expansion of farm mechanisation to make the agricultural sector more lucrative and profitable to check mobility from agriculture to non-agriculture sector of the tribal people It is also suggested to improve educational status, skills, entrepreneurship spirit, swift credit linkage among tribal people through to attract more people in the agriculture and allied sector.

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Comparative Evaluation of Traditional Grow-Out Test and Molecular Finger-Printing for Testing of Hybrid Purity in Pumpkin (*Cucurbita moschata* L.)

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ABSTRACT

The primary method for hybrid purity analysis is to use morphological distinctions between true to types and off types in grow out tests (GOTs). Traditional GOT was costly, time consuming, and environmentally sensitive. Recent developments in DNA markers show promise for speeding up and improving the accuracy of hybrid genetic purity testing. The purity of pumpkin hybrid PPH1 was evaluated in this study using both standard GOT and sophisticated molecular marker techniques. The experiment involved mixing 95% F_1 hybrids with 5% female parents in individual sample sets of 300, 200, 100, 50, and 25. To ensure hybrid purity, a PCR based assay and GOT were performed on each sample size. The PCR based technique examined 37 pairs of SSR markers, two of which showed parental polymorphism. The level of purity had assessed using co-dominant marker. The smaller sample size of 100 had been analysed to validate hybrid purity, and results were consistent with those of larger sample sizes (300, 200). As a result, it was claimed that molecular marker-based hybrid purity evaluation could be a viable alternative to classical GOT.

Keywords: Assay, Grow-out test, Hybrid, Pumpkin, Purity.

INTRODUCTION

Seed is a critical and essential input in agricultural production and seed quality contributing approximately 20 to 25 percent to overall productivity. Therefore, ensuring the availability of high-quality seeds to farmers across the country (Anonymous, 2025). To achieve higher yield and reap maximum profits from vegetable cultivation, the farmers are showing ample interest in hybrid seeds of vegetable crops. To cater increasing demand of high-quality seeds, numerous hybrids of various vegetable crops have been released by public as well as private sector. The private companies are luring the farmers with lucrative advertisements and marketing gimmicks. To make a quick buck, some of the private companies are supplying spurious hybrid seeds of poor quality to the farmers, which more often results in losses rather than profits. Therefore, for successful commercialization of hybrids, it is mandatory to examine the genetic purity, to assure uniformity and stability of field performance and yield. The prime objective always is to maintain purity at the genetic level, which ultimately helps to exploit the full potential of the hybrids. When the seeds are passed from one generation to another, genetic contamination may occur and if it is unnoticed in the population it may lead to genetic deterioration of the variety (Yalamalle *et al,* 2008). Therefore, a reliable method for distinguishing between cultivars and assessing the genetic purity of seed samples is essential. Such a method would enable seed producers to monitor and maintain the required levels of genetic purity throughout each generation of seed production and multiplication, ultimately ensuring the delivery of high-quality seeds (Kiruthika and Padmanabha, 2018). The most crucial factor in determining the quality of seed is its hybrid purity, which is tested to determine any deviations from the variety's authenticity (Chesnokov, 2005). A high level of genetic purity assessment must be maintained in order to certify seeds and market hybrids.

The fundamental technique for analysing hybrid purity uses the morphological variations among true-to-types as well as off-types in the grow out test (GOT) (Shinde *et al,* 2021). Traditional GOT are often cost-intensive, laborious, time-consuming and highly sensitive to environmental conditions. The detection of morphological traits at different plant growth stages is the foundation of the traditional grow-out test (GOT)

method for determining genetic purity (Alam *et al,* 2015) but this method is time-consuming and susceptible to external influences. Due to limited polymorphism and environmental effects, biochemical techniques like isozyme analysis and seed protein electrophoresis are unable to distinguish between genotypes that are closely related. Additionally, they do not provide exact figures for genetic distances between cultivars. Furthermore, there is a rising need for a unique hybrid purity testing method that could produce reliable, timely, affordable results (Pattanaik *et al,* 2018).

Since DNA based markers are based on the genotype of the hybrids, which eliminates environmental changes, they can be used to identify purity of hybrid at seed level, overcoming limitations of morphological or biochemical markers. The co-dominant, highly informative, repeatable, and most reliable indicators for determining hybrid purity are simple sequence repeats (SSRs) (Zhao *et al,* 2017). The development and successful use of molecular markers in numerous elements of crop improvement programs have occurred recently. In comparison to morphological and biochemical markers, which have a limited quantity and a slow rate of data collection, molecular markers provide a number of advantages (Daniel *et al,* 2012). They are regarded as a useful tool since they may identify genetic variants and are unaffected by environmental factors (Tanksley and McCouch, 1997). The molecular markers have been used to test the purity of seeds in numerous studies (Powell *et al,* 1996; Ajmone *et al,* 1998; Bornet and Branchard 2001; Mammadov *et al,* 2010). These markers are quicker to assay, use a less amount of DNA template, and take less time. But their biggest drawback is that they are harder to duplicate. The most often employed hybridization-based molecular marker for identifying DNA sequence polymorphism is called a restriction fragment length polymorphism (RFLP). They are co-dominant and highly reproducible, but their use is constrained by their time-consuming nature and high demand for high-quality DNA (Kesawat and Das, 2009). In the present study, the PCR based DNA marker system of microsatellite (SSR) was employed for identifying two commercial hybrids of pumpkin released by Punjab Agricultural University, Ludhiana and their respective parents for their utility in determining the genetic purity. These markers were also validated for the purpose of testing the genetic purity of the commercial F_1 seed lots to establish an efficient, reliable and accurate method for rapid testing of genetic purity of commercial hybrids when compared to the traditional grow out test.

MATERIALS AND METHODS

Plant material

The materials utilized in this study consisted of Pumpkin F_1 hybrid PPH1 along with its parental lines P112 and BN364 developed by Punjab Agricultural University Ludhiana, Punjab, India. The differential morphological characters from the hybrids PPH1 and its parental lines were used to identify the selfed/off-types during grow out test.

GOT analysis

To assess conformity between molecular marker-based estimates of selfed/off-type plants through phenotypic observations, experiment had been conducted by pooling 95% F_1 hybrids merged with 5% female parents, individually sets of samples *viz,* 300, 200, 100, 50, and 25. All five sample sizes, as well as the parental lines PPH1, were seeded in the tray for 15-30 days before being transported to the main field for GOT analysis. Throughout the plant's growth, measures such as correct irrigation, fertilizer, and insect management were implemented. Purity evaluations were conducted using essential morphological parameters mentioned in DUS (distinctness, uniformity, and stability) guidelines, such as plant habit, leaf shape, color of leaf, fruit shape, fruit main skin color at mature and immature stages throughout the growing season (Table 3). To ensure hybrid purity, the PCR-based test and GOT were performed on each sample size. The selfed/off type plants found using SSR marker research had been confirmed using morphological characteristics. The experiment was replicated three times, the mean percentage of hybrid purity, had been calculated and determined using both PCR-based assay and GOT.

Hybrid purity (%) = Total number of plants number of off-types/ Total number of plants× 100.

Isolation and quantification of DNA

Genomic DNA had been isolated from the leaves of parental lines along with their hybrids across all sample sizes *i.e.,* 300, 200, 100, 50, 25 individuals using a modified cetyltrimethylammonium bromide (CTAB) extraction protocol. The quantity as well as quality of the extracted genomic DNA had assessed through electrophoretically resolved 2.5 percent (w/v) agarose gel stained with good view dye, amplified PCR products were separated.

Comparative Evaluation of Traditional Grow-Out Test and Molecular FingerPrinting

Table 1. Time taken to determine the purity of Pumpkin hybrid PPH1 by GOT and molecular-based assay

	GOT	Molecular based assay
Duration	Around 70 Days	48 h (after seedling stage)

Table 2: Morphological characters used to identify selfed or off types during GOT for PPH1 and its parents

Sr. No.	Morphological character	Female parent of PPH1 (P112)	Male parent of PPH1 (BN364)	PPH1
1.	Stem	Sulcate	Sulcate	Rigid
2.	Peduncle of fruits	Angulate with obtuse ribs	Angulate with obtuse ribs	Rigid
3.	Peduncle length	Long (>10cm)	Long (>10cm)	Short (<5cm)
4.	Fruit: main colour of the skin (at immature fruit stage)	Dark green	Medium green	Light green
5.	Fruit: skin colour pattern	Mottled	Mottled	Uniform
6.	Fruit shape at peduncle end	Raised	Raised	Moderately depressed
7.	Fruit: marbling (immature stage)	Medium	Long	Medium
8.	Fruit shape	Oval	Oval spherical	Oval
9.	Fruit waxiness of skin (at mature stage)	Light	High	Medium
10.	Flesh thickness	Thick (>4.5cm)	Medium (2.5-4.5cm)	Thick (>4.5cm)

Fig. 1: The variability in morphological characters of pumpkin hybrid PPH1 along with its parents. (a) plant habit and leaf shape (b) Fruit shape and colour

Polymorphism analysis by SSR marker

The overall 37 pairs of SSR markers had been utilized to investigate polymorphism in bulk of DNA collected from 10 seedlings of male as well as female parent of the Pumpkin PPH1 hybrid. Polymorphic SSRs had been selected for hybrid purity testing of PPH1. DNA amplification was performed in a 20 µl mixture of reaction with 5 pmol primers, 10X Taq polymerase buffer, 1 mM dNTP, 20 ng template genomic DNA and 3U of Taq polymerase. The amplification had initiated with a denaturation step at 94°C for 3 minutes, afterwards 35 cycles of 94°C for 30 seconds, 54°C for 30 seconds, 72°C for 1 minute with a final extension at 72°C for 10 minutes. Amplified DNA fragments had separated on a 3% (w/v) agarose gel with 0.5 µg/ml ethidium bromide in 45 mM Tris borate (1 mM) EDTA buffer, pH 8.0. The well was loaded with 20 µl of PCR products and 5 µl of loading solution. The molecular standard was a 100-base pair (bp) DNA ladder. Electrophoresis was performed at 70V for 3 hours as well as gels were seen under UV transilluminator through the UV Pro gel documentation system.
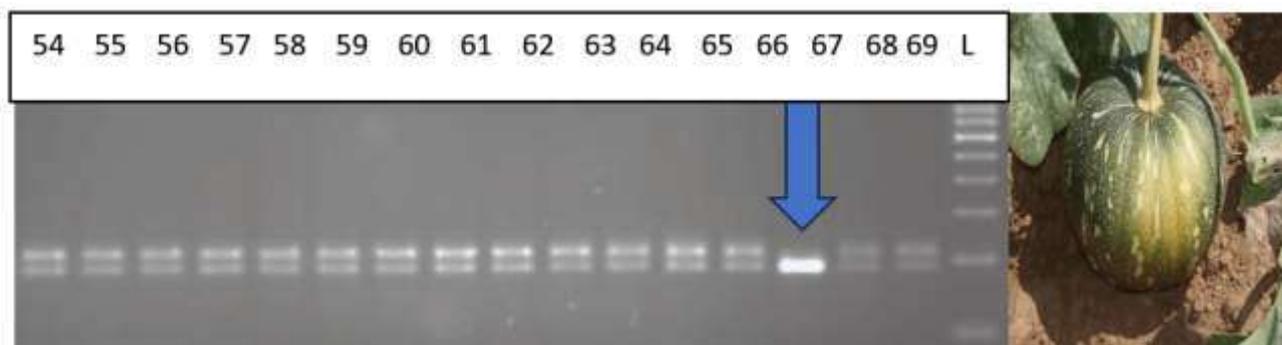
a.Hybrid PPH1 comparison of GOT and SSR analysis
Fig. 2: Phenotypically similar F₁ hybrid PPH1 showing genotypically off-types/selfed

Table 3: Comparison of hybrid purity assessment based on morphological and molecular markers across varying different sample sizes in pumpkin hybrid PPH1 and parents

Sample size	Replicate 1				Replicate 2				Replicate 3				Mean GOT assay	Mean SSR assay
	GOT assay	Purity %	SSR analysis	Purity%	GOT assay	Purity %	SSR analysis	Purity%	GOT assay	Purity %	SSR analysis	Purity%		
Sample size 300 mixed with 5% admixture expected Observed no. of true-to-type hybrids Observed no. of off types/selfed	285 283 2	99.3	285 283 2	99.3	285 281 4	98.6	85 281 4	98.59	285 285 0	100	285 284 1	99.7	283 (98.9%)	282.67 (99.2%)
Sample size 300 mixed with 5% admixture expected Observed no. of true-to-type hybrids Observed no. of off types/selfed	190 189 1	99.5	190 189 1	99.5	190 190 0	100	190 190 0	100	190 187 3	98.4	190 187 3	98.4	188.7 (99.3%)	188.7 (99.3%)
Sample size 300 mixed with 5% admixture expected Observed no. of true-to-type hybrids Observed no. of off types/selfed	95 95 0	100	95 95 0	100	95 94 1	98.9	95 94 1	98.9	95 95 0	100	95 95 0	100	94.7 (99.7%)	94.7 (99.7%)
Sample size 300 mixed with 5% admixture expected Observed no. of true-to-type hybrids Observed no. of off types/selfed	46 45 1	97.8	46 46 0	100	46 43 3	93.48	46 43 3	93.48	46 46 0	100	46 46 0	100	44.7 (99.3%)	45 (98%)
Sample size 300 mixed with 5% admixture expected Observed no. of true-to-type hybrids Observed no. of off types/selfed	23 23 0	95.65	23 23 0	100	23 22 1	95.65	23 22 1	95.65	23 23 0	100	23 23 0	100	22.7 (98.7%)	22.7 (98.7%)

RESULTS AND DISCUSSION

Genetic purity assessment using GOT and SSR markers

In this study, plants from five different sample sizes (300, 200, 100, 50 and 25) of PPH1 each plant was individually evaluated to determine its true-to-type status based on ten morphological characteristics in the GOT. Female parent P112 can be distinguished from male parent BN364 and hybrid PPH1 on the basis of following characters: Stem, peduncle of fruits, length of peduncle, fruit: main colour of the skin, fruit shape at peduncle end, fruit: skin colour pattern, fruit: marbling, shape of fruit, fruit waxiness of skin, flesh thickness. The stem of the male parent BN364 as well as female parent P112 was sulcate, whereas the hybrid PPH1 exhibited a rigid stem. The above results were closely associated with previous findings of Gediya *et al* (2018). The fruit peduncle of male parent BN364 and its female parent P112 had an angulate shape with obtuse ribs, whereas the hybrid P112 demonstrate a rigid structure. The similar findings were in accordance with Vincent *et al* (2022) who studied the morphological traits of pumpkin. The peduncle length of the male parent BN364 and the female parent P112 was long (>10 cm), while that of the hybrid PPH1 was short (<5 cm). The similar findings had also been documented by Nagar *et al* (2017). At the immature fruit stage, the fruit: main colour of the male parent BN364 was medium green, the female parent P112 indicates a dark green skin, while the hybrid PPH1

showed a light green colouration. The above results stood parallel with the findings of Tabasum *et al* (2021). The fruit: skin colour pattern of both the male parent BN364 and the female parent P112 was mottled, whereas the hybrid PPH1 demonstrated a uniform pattern and fruit shape at the peduncle end was raised in both the male parent BN364 and the female parent P112, while the hybrid PPH1 indicates a moderately depressed peduncle end. These results were in accordance with Chaudhary *et al* (2015). At the immature stage, the fruit: marbling of the male parent BN364 and the hybrid PPH1 was medium, whereas the female parent P112 exhibited long marbling fruit. The above results were closely associated with previous findings of Ramjan *et al* (2018) who observed the morphological parameters of pumpkin genotypes. The fruit shape of the male parent BN364 was oval-spherical, while both the female parent P112 along with hybrid demonstrated an oval shape. The similar findings were in accordance with Kiramana *et al* (2017) who studied the conventional pumpkin landraces can supply the genetic material needed to improve crops. The fruit skin waxiness of the male parent BN364 was high, while that of the female parent P112 was low, hybrid PPH1 indicates a medium level of waxiness. These results were in accordance with Chen *et al* (2020). The flesh thickness of the male parent BN364 was medium (2.5–4.5 cm), whereas both the female parent P112 and the hybrid PPH1 exhibited thick flesh (>4.5 cm). The above results stood parallel with the findings of Ruelas *et al* (2015).

SSRs were the most commonly used and reliable DNA-based markers for assessing genetic purity. A single co-dominant marker proved effective in identifying off-type hybrids during the purity assessment of the pumpkin hybrid PPH1 using SSR molecular analysis. The total of 37 SSR primers had been screened to determine hybrid purity of pumpkin hybrid PPH1. Out of 37 primers screened, only one primer *viz.,* comp28857 was found to be polymorphic which had potential to identify hybrid purity of pumpkin. The above results were closely associated with previous findings of Miladinović *et al* (2016). The average hybrid purity percentage determined by GOT assay for sample set of 25, 50, 100, 200 and 300 sample sizes of PPH1 was calculated to be 98.7, 98.0, 99.7, 99.3, 99.2 respectively (Table 3).

Duration involved in determining the purity of Pumpkin hybrid

GOT, which assesses plant morphology, took approximately 70 days to identify selfed or off kinds in 6 sample sizes. The PCR based assay required about 48 hours to determine admixtures, making it time saving method to assess purity of hybrid against selfed and off-type plants (Table 1). The present study implicated that the development of DNA markers might help to test cultivars purity developed from closely related parental lines. To ensure commercial success, the hybrid should be pure. Genetically pure hybrids function best when consistent, else they may perform poorly. Molecular markers must be used to ensure the genetic purity of hybrids created. Traditionally, GOT was used for testing the genetic purity, it takes the full season. Additionally, this method had been labour-intensive and susceptible to environmental changes, making it less reliable for assessing genetic purity. Hybrid seeds were unavailable for immediate growing, resulting in additional storage costs and an overall increase in hybrid seed prices. This work uses molecular markers to evaluate hybrid purity and provide farmers with true-to-type seeds. GOT tested genetic purity with a minimum sample size of 400 seedlings. However, maintaining such a large sample size proved challenging as well as labour intensive. As determined through testing six different sample sizes: 300, 200, 100, 50 and 25 seedlings were adequate to confirm the hybrid purity of pumpkin, with findings equivalent to larger sample sizes. The above results were closely associated with previous findings of Ana *et al* (2017). Marker analysis provided consistent results with GOT. GOT was a time-consuming and labour-intensive method for determining genetic purity, as several distinguishing characteristics arise only during the blooming and post-flowering stages, taking roughly 70 days. As a result, it frequently causes delays in the entire decision making, packaging as well as marketing of commercial seeds. As a result, farmers don't receive hybrid seeds at time of sowing, prevent them from being planted straight away. Hybrid seed prices rise due to increased investment in production along with storage. The limitations of GOT could be effectively overcome through the use of molecular markers. These results were in accordance with Pattanaik *et al* (2018). SSR analysis might performed in laboratory, which takes 48 hours to evaluate genetic purity, reducing labour, space and time spent on purity testing. Using locus-specific allelic information from SSR markers allows for more precise and efficient differentiation of pumpkin hybrids from parental lines and off-types/selfed varieties. These results were in accordance with Adeyemo *et al* (2019). The variety or hybrid genetic purity was examined by SSR markers along with GOT shows similar results, indicating that molecular markers can support GOT testing. Implementing marker analysis was cost-effective and

would benefit the seed industry. The above results stood parallel with the findings of Kaur *et al* (2023). Additionally, commercially available genetic SSR markers might be used to assess the genetic purity of cultivars. The SSR marker data generated in this study can assist the seed industry in selecting optimal marker combinations for accurate assessment of crop genetic purity.

CONCLUSION

The study revealed that traditional GOT was costly, time consuming, and environmentally sensitive. Recent developments in DNA markers show promise for speeding up and improving the accuracy of hybrid genetic purity testing. The purity of pumpkin hybrid PPH1 was evaluated in this study using both standard GOT and sophisticated molecular marker techniques. The experiment involved mixing 95% F_1 hybrids with 5% female parents in individual sample sets of 300, 200, 100, 50, and 25. To ensure hybrid purity, a PCR based assay and GOT were performed on each sample size. The PCR based technique examined 37 pairs of SSR markers, two of which showed parental polymorphism. The smaller sample size of 100 had been analysed to validate hybrid purity, and results were consistent with those of larger sample sizes (300, 200). As a result, it was claimed that molecular marker-based hybrid purity evaluation could be a viable alternative to classical GOT.

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Constraints Analysis of Drip Irrigation Technology Adoption in Cotton Cultivation-An Explorative Study in Three States of India

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ABSTRACT

Drip irrigation is widely recognized as a sustainable and efficient technology in modern agriculture, particularly for enhancing water-use efficiency across a range of crops. Even though the efficiency of the technology has been proven by several researchers and despite promotion by the government, the dissemination of the technology remains restricted within a boundary. In India, Maharashtra leads in the adoption of drip irrigation technology, followed by Andhra Pradesh, Karnataka, and Tamil Nadu. Although numerous studies have highlighted the advantages and efficiency of drip irrigation across different crops, limited research has been conducted specifically on cotton to assess the constraints in the adoption of drip irrigation technology. In this context, it is essential to explore the different constraints faced by drip-irrigated cotton farmers. The present study was undertaken to systematically examine the different constraints involved in cotton cultivation. A structured survey research design was employed, covering three major cotton-growing states of India-Maharashtra, Gujarat and Tamil Nadu. From each state, 120 drip-irrigating cotton farmers were selected using stratified random sampling, constituting a total sample size of 360 respondents. The results revealed that while some constraints such as emitter clogging and high initial costs are common across states, others like electricity charges, spare parts availability, and wildlife damage vary significantly by region. The study concludes that although drip irrigation enhances water-use efficiency in cotton cultivation, its widespread adoption is hindered by region-specific technical, economic, and infrastructural constraints. Addressing these localized challenges is crucial for maximizing the benefits of drip irrigation technology.

Keywords: Adoption, Constraints, Cotton, Irrigation, Sprinkler, Technology.

INTRODUCTION

In India, agricultural irrigation largely relies on traditional methods, whereas in many other countries, modern techniques such as drip and sprinkler irrigation have been adopted extensively. To promote the adoption of drip irrigation, several initiatives have been undertaken by the Government of India. The current government's manifesto includes the objective of *"Har Khet Ko Paani"* aligned with the Honourable Prime Minister's vision of "Per Drop More Crop." In line with this, the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) was launched in 2015, incorporating micro-irrigation as a key component of the flagship scheme. However, the area under drip irrigation in India remains less than one percent of the total irrigated area. This indicates significant potential to expand the adoption of drip irrigation across the country (Kumar and Jitarwal, 2012; Yadav *et al,* 2017). While studying the constraints in drip irrigation under sugarcane cultivation; Karpagam *et al* (2011) found that the high initial investment cost, despite the availability of subsidies, was the primary barrier faced by drip irrigation users followed by inadequate subsidies. Cotton is one of the world's most important fiber crop and the second most important oil seed crop (Gill and Bhatt, 2015; Sathya *et al,* 2022). India leads in the cultivation of cotton in the world (Vikram Simha *et al,* 2022). Although numerous studies have highlighted the advantages and efficiency of drip irrigation across different crops, limited research has been conducted specifically on cotton to assess the constraints in adoption of the technology. In this context, it is essential to examine the constraints in adoption of drip irrigation technology for cotton cultivation. Hence, the present study was undertaken to systematically examine the different constraints involved in cotton cultivation under drip irrigation technology.

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Table 1. Constraints faced by the Tamil Nadu, Maharashtra and Gujarat farmers.

Sr. No.	Constraint faced by farmers	Tamil Nadu	Maharashtra	Gujarat
1	Electricity Charges by Government	0	100.00	100.00
2	Rat and Wild Pig biting	72.5	100.00	67.50
3	High investment cost despite subsidy	68.75	98.33	78.33
4	Clogging of emitters	91.25	95.00	80.83
5	Labour problem	62.50	52.50	50.00
6	Unavailability of spare parts locally	13.75	30.83	62.50
7	Poor after sale service	41.25	27.50	27.50
8	Trouble in taking up inter cultural operations	33.75	25.83	67.50

MATERIALS AND METHODS

The present study was conducted in three states: Maharashtra, Gujarat, and Tamil Nadu. From each state, two districts were selected based on the predominance of area under drip irrigation for cotton cultivation. Within each selected district, two villages were chosen using the extent of drip-irrigated cotton area as the selection criterion. From each village, 30 cotton farmers were randomly selected, resulting in a sample size of 120 farmers per state. Thus, the total number of respondents for the study was 360. To assess the constraints encountered by the cotton farmers in drip irrigation, a well-structured interview schedule was prepared and the survey was undertaken in the selected villages in the three states and the results were compiled and subjected for statistical analysis for systematic conclusion. For the constraint analysis, respondents were asked to enumerate the problems they encountered while using drip irrigation. For each identified constraint, the percentage of respondents reporting that particular issue was calculated. This helped in quantifying the prevalence of specific challenges faced by drip irrigation users and provided insight into the most critical areas requiring attention or intervention.

RESULTS AND DISCUSSION

The constraint analysis revealed notable differences in the challenges faced by drip irrigation farmers across Tamil Nadu, Maharashtra, and Gujarat, indicating that regional factors significantly influence the effectiveness and adoption of the technology. Table 1 and Fig. 1 highlight tthe major constraints reported by drip irrigation farmers in Tamil Nadu, Maharashtra and Gujarat. One of the most critical constraints, reported exclusively by farmers in Maharashtra and Gujarat (100%), was the high electricity charges imposed by the government, at a flat rate of Rs. 5,000 per year. This issue was not reported by any farmers in Tamil Nadu, due to differences in state-level electricity policies or subsidies.

Rat and wild pig damage emerged as another major concern, particularly in Maharashtra (100%), followed by Tamil Nadu (72.5%) and Gujarat (67.5%). Rodent damage is a frequent issue in drip irrigation systems, as rats and other rodents often chew through the tubing, leading to leaks. This damage can severely reduce the efficiency of the irrigation system, resulting in water loss and lower crop yields. To address this problem, various preventive measures can be employed, such as using thicker tubing, burying the irrigation lines, applying rodent repellents, and adopting integrated pest management practices. Sorensen *et al* (2007) reported that drip tubing that was slightly buried had the best rodent control (5 holes/ha) compared with all other treatments (1771 holes/ha).

The high investment cost despite subsidies was perceived as a significant constraint by farmers across all three states of Maharashtra (98.33%), Gujarat (78.33%), and Tamil Nadu (68.75%). While state governments approve subsidies for drip systems based on a standard 100 x 100-meter (1 hectare) layout with 1 x 1 meter emitter spacing and a 50-meter distance for PVC pipelines, this setup rarely reflects the real field conditions. In practice, few farmers have a perfect 100 x 100-meter layout, and the commonly adopted crop spacing is 90 x 60 cm. Additionally, for most farmers, the water source is located more than 50 meters away. As a result, the actual cost of installing a drip system significantly exceeds government estimates. Even after receiving a full subsidy, farmers typically incur an additional expense of approximately ₹30,000 per hectare.

Constraints Analysis of Drip Irrigation Technology Adoption
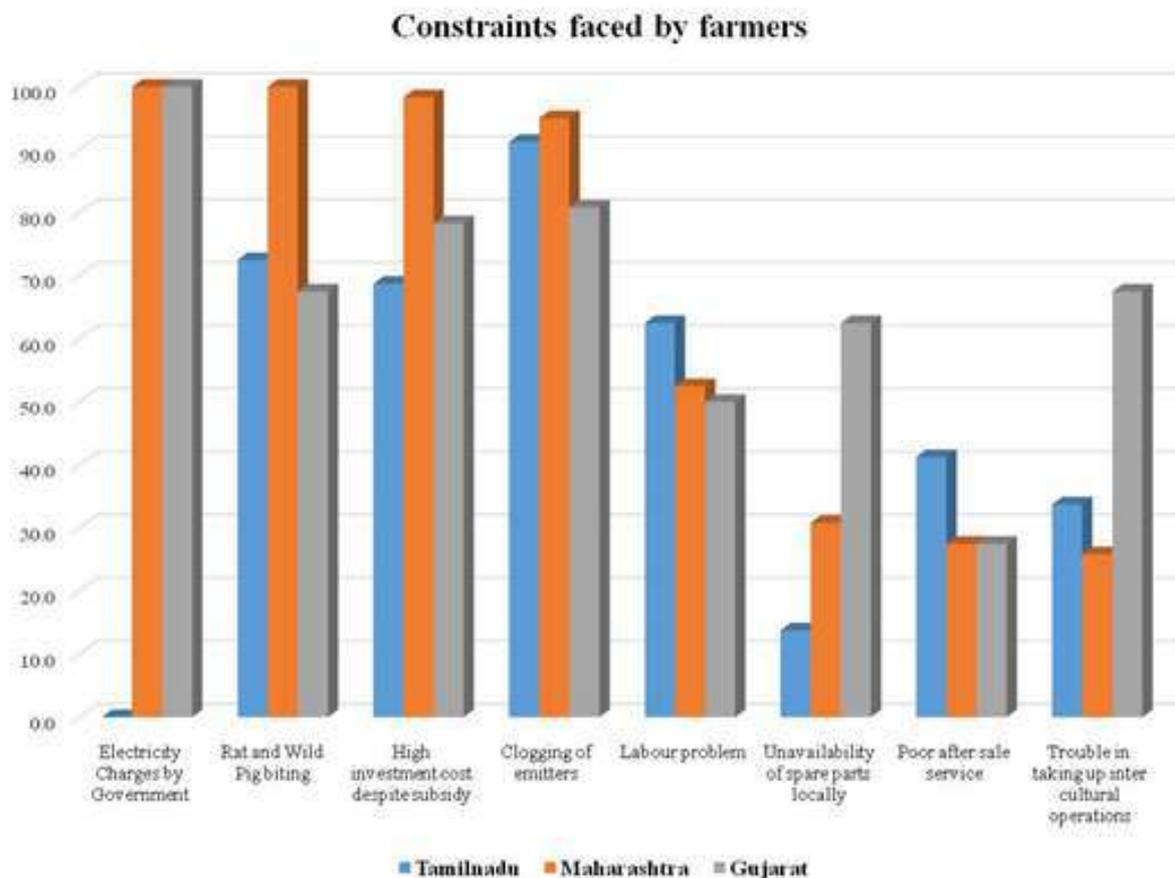
Constraints faced by farmers

Fig. 1: Constraints faced by the Tamil Nadu, Maharashtra and Gujarat farmers

Clogging of emitters, a technical problem, was reported by a large proportion of farmers in Tamil Nadu (91.25%), Maharashtra (95%), and Gujarat (80.83%), suggesting that maintenance issues persist irrespective of location and may affect system efficiency and uniformity of irrigation. Clogging of emitters in drip irrigation systems is a frequent issue that decreases flow rate and water distribution uniformity. This problem arises from the accumulation of particles, chemical residues, microorganisms inside the emitters. The physical, chemical, or biological particles can result in inconsistent watering and hinder healthy plant development. Petit *et al* (2023) reported that clogging is one of the main factors in drip irrigation. Labour shortages were more commonly reported in Tamil Nadu (62.5%), compared to Maharashtra (52.5%) and Gujarat (50%), possibly reflecting state-level differences in labor availability or wage structures.

CONCLUSION

This study is among the first of its kind to comprehensively examine the multifaceted aspects of drip irrigation technology in cotton cultivation. It provides valuable insights into the constraints faced by drip-irrigated cotton farmers across three states in India. The identified constraints are not only hindering the adoption process for drip technology but also limiting the cotton cultivation widely. In a nutshell, the results emphasize that while some constraints such as emitter clogging and high initial costs are common across states, others like electricity charges, spare parts availability, and wildlife damage vary significantly by region. These findings underscore the importance of region-specific policy and technical interventions to improve the adoption and sustainability of drip irrigation systems in cotton cultivation. Cotton remains a major cash crop in Gujarat, Maharashtra and also holds significant importance in Tamil Nadu. The

constraints identified in the present study have important policy implications. They offer a strong empirical foundation for policymakers to understand the problems of cotton farmers and redefine the micro irrigation policies which will surely contribute for wider adoption of drip irrigation and at the same time, accelerate the growth of sustainable cotton production across different states in India.

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Constraints Encountered by Farmers Engaged in Shrimp Cultivation in Punjab

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ABSTRACT

In the south-western region of Punjab, shrimp farming is helping in transforming the land which was once unsuitable for farming and growing crops due to waterlogged and saline conditions. However, while shrimp farming presents a favourable prospect for income diversification, yet shrimp farmers has to face various constraints. The objective of this study is to explore the main constraints faced in shrimp production, marketing and financing. The study was carried out in Muktsar and Fazilka districts of south-western region of Punjab in the year 2023-2024. Forty farmers were selected using probability proportional to size sampling categorized in small, medium and large on the basis of area under shrimp farming was taken to study their perceptions using a 5-point Likert scale with an aim to analyse the seriousness of the constraints. The study found out that the highest cost of feed was the main constraint with Likert scale value 4.88 followed by electricity cost (4.83), shrimp seed cost (4.25) and disease outbreaks (4.20). Small farmers faced the highest feed cost (4.96) whereas large farmers reported electricity cost (5.00). While in marketing constraint, price fluctuation and uncertainty of prices scored 5.00 in Likert scale followed by lack of storage facility (3.83) and access to price information (3.68) were reported by shrimp farmers. In financial constraints, small farmers reported about the lack of institutional credit (1.98) followed by high interest rate from non-institutional credit (1.20) as major issues. The study recommends policies that provide access to quality seed and affordable feed, improve disease control, offer technical training, upgrade storage and market access, and ensure easier access to fair credit.

Keywords: Constraints, Likert scale, Punjab, Shrimp.

INTRODUCTION

India stands third largest in fish production and the second largest in aquaculture production after China in the world (FAO, 2022). This can only be possible with the help of blue revolution initiative by Government of India, whose main focus was to encourage sustainable farming techniques, improves infrastructure, and growth in fish production, it was possible to achieve (Government of India, 2023). One significant change is the transition from marine to inland fisheries, which now account for about 70% of India's total fish production, compared to 36% in the 1980s (CIFE, 2020). Controlled inland aquaculture promotes environmental sustainability and provides more effective resource management. In India, various river systems, lakes, brackish water areas provide a plenty of aquatic resources. Still there is a major extent of India's aquaculture potential remains untouched (Government of India, 2023). Brackish water shrimp farming production has grown from 20 metric tonnes in 1970 to 747,000 metric tonnes by 2020 shows its potential in production (FAO, 2022). Out of the 1.42

million hectares area, only 13% could be currently utilized for this type of farming. To address this issue, Government of India targets to increase production to 1.1 million metric tonnes and double productivity by the year 2024-2025 (Government of India, 2023). To accomplish sustainable growth, adoption of better farming practices, investment in infrastructure, and placing biosecurity measures into place are all essential (World Bank, 2021).

In the south-western parts of the Punjab state in India, saline and waterlogged fields that were previously unsuitable for growing crops are now being used for shrimp (*Penaeus vannamei*) farming. Institutes like CIFE and GADVASU, which helped run a pilot project in collaboration with the Government of Punjab, have come out with positive results (Singh *et al*, 2020). In Punjab, the area under shrimp farming has increased, *i.e.,* from 392 acres to 1,200 acres by the year 2020, with an aim to increase the production of shrimp annually to over 104,000 metric tonnes by the year 2025 (Government of Punjab, 2025). In India, farmed shrimp farming is a rapidly growing aquaculture sector

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Table 1. Socio-economic status of sampled shrimp farmers (2023-2024).

Sr. No.	Particular	Small (n₁ = 24)		Medium (n₂ = 11)		Large (n₃ = 5)		Overall (N = 40)	
		No.	%	No.	%	No.	%	No.	%
A.	Education Level								
1.	Illiterate	2	8.33	-	-	-	-	2	5.00
2.	Up to Primary	-	-	-	-	-	-	-	-
3.	Up to Middle	1	4.17	1	9.09	-	-	2	5.00
4.	Matriculate	4	16.67	1	9.09	1	20.00	6	15.00
5.	Senior Secondary	10	41.67	5	45.45	2	40.00	17	42.50
6.	Graduate and Above	7	29.17	4	36.36	2	40.00	13	32.50
B.	Family Type								
7.	Nuclear	20	83.33	9	81.82	4	80.00	33	82.50
8.	Joint	4	16.67	2	18.18	1	20.00	7	17.50
9.	Total	24	100.00	11	100.00	5	100.00	40	100.00
C.	Family Size (Members)								
10.	<5	17	70.83	4	36.36	3	60	24	60.00
11.	5 to 6	2	8.34	7	63.64	1	20	10	25.00
12.	>6	5	20.83	-	-	1	20	6	15.00
13.	Average Family Size	4.70	-	4.91	-	5.00	-	4.80	-
D.	Experience (Years)								
14.	Less than 3 (<3)	3	12.50	1	9.09	0	0.00	4	10.00
15.	03-05	18	75.00	7	63.64	3	60.00	28	70.00
16.	More than 5 (>5)	3	12.50	3	27.27	2	40.00	8	20.00
E.	Occupation								
17.	Aquaculture	2	8.33	2	18.18	1	20.00	5	12.50
18.	Aquaculture + Agriculture	17	70.83	6	54.55	2	40.00	25	62.50
19.	Aquaculture + Business/Job	5	20.83	3	27.27	2	40.00	10	25.00

and India is the fifth-largest producer of farmed shrimp worldwide. Though West Bengal contributes significantly to shrimp production in India, Punjab also offers likely prospects for this sector. The shrimp farmers faced many constraints related to finance, marketing, and the production of shrimp. Problems as feed cost, disease occurrences, market price fluctuations, and inadequate credit accessibility make shrimp production difficult. Understanding these constraints and finding farmer-centred solutions are crucial to ensure sustainable production by increasing the overall profitability of shrimp farming. The purpose of this study is to examine the different limitations that shrimp farmers perceive.

MATERIALS AND METHODS

Using a systematic approach, a thorough field survey was carried out to determine the challenges shrimp farmers face in Punjab. A list of shrimp farmers was gathered from the State Fisheries Department and because of higher area under shrimp farming; Muktsar and Fazilka were chosen as the study's focal districts. From each selected district, two blocks were selected based on farmer's availability, and village clusters were recognized. To ensure representativeness of the shrimp farmers, 40 were selected (20 shrimp farmers from each district) by using a probability proportional to size sampling technique. To measure the constraints among different operational sizes, the study categorized

Constraints Encountered by Farmers Engaged in Shrimp Cultivation in Punjab

Table 2. Constraints faced by shrimp farmers in production, 2023-2024.

Sr. No.	Production Constraint	Mean Score				Ranking
		Small	Medium	Large	Overall	
1.	High cost of feed	4.96	4.82	4.60	4.88	I
2.	High cost of electricity	4.79	4.82	5.00	4.83	II
3.	High price of seed	4.33	4.00	4.40	4.25	III
4.	Prevalence of disease outbreak	4.13	4.36	4.20	4.20	IV
5.	Lack of good quality seed	4.00	4.45	4.20	4.15	V
6.	Inadequate technical experts	3.75	3.73	4.40	3.83	VI
7.	Sudden fall in DO due to power failure	3.50	3.45	3.40	3.48	VII
8.	Lack of scientific knowledge	3.21	3.64	3.80	3.40	VIII
9.	Partial damages during harvesting	3.29	2.36	4.60	3.20	IX
10.	Non availability of skilled labour	3.13	2.55	4.80	3.18	X
11.	Over dosage of chemicals	1.42	1.45	1.20	1.40	XI
12.	Poor water quality	1.08	1.09	1.40	1.13	XII
13.	Shortage of water	1.08	1.09	1.00	1.08	XIII

Table 3. Constraints faced by shrimp farmers in shrimp marketing, 2023-2024

Sr. No.	Marketing Constraint	Mean Score				Ranking
		Small	Medium	Large	Overall	
1.	High fluctuation in price	5.00	5.00	5.00	5.00	I
2.	Lack of storage facility	3.83	3.82	4.00	3.83	II
3.	Lack of price information	3.79	3.36	3.60	3.68	III
4.	Problem in weighing	1.67	2.73	3.20	2.10	IV
5.	No alternative Channel	1.58	1.55	2.00	1.68	V
6.	Problem of direct selling	1.29	1.64	2.00	1.48	VI
7.	Delayed payment	1.00	1.00	1.00	1.00	VII

farmers into three groups based on the area under shrimp farming, *i.e.,* small (less than 5.7 acres), medium (5.7-11.05 acres), and large (more than 11.05 acres). The study was carried out in the 2023-2024 production years, in order to gather the perceptions from the farmers. To collect the data and correct information, selected farmers were personally interviewed by using a well-structured schedule. A 5-point Likert scale was used to rate farmer's perceptions and difficulties, giving their answers numerical scores. A survey was used to gather data, and each constraint mean score was determined to enable a ranking of the perceived severity of each constraint.

RESULTS AND DISCUSSION

Before analysing the challenges faced by shrimp farmers, it is crucial to first examine the various socio-economic characteristics of the sampled shrimp farmers. The socioeconomics characteristics of the samples shrimp farmers are presented in the table 1. Over half of the sampled farmers (55%) are ranged between the ages of 41 and 50 represents that the experienced farmers are involved in shrimp farming.

About 37.50% of the sampled farmers were between the ages of 31 and 40, showing young and active members in shrimp farming. Farmers over the age of 50 make up just 5 percent, and those under 30 accounts for only 2.50 percent, showing that shrimp farming is not widely pursued by the youngest or oldest demographics. On an average, shrimp farmers are around 41.40 years old, with small farmers averaging 40.67 years, medium farmers at 42.18 years, and large farmers slightly older at 43.20 years. About 42.50 per cent of shrimp farmers have completed senior secondary education. Additionally, 32.50% of the sampled farmers have graduation or advanced degree showing extremely educated personnel. Only 15% of the sampled farmers have matriculated, and five per cent have completed middle school and another five per cent were illiterate. There are no farmers with an education level limited to primary or below. Out of the 40 households surveyed, 82.50 percent are nuclear families, and 17.50 percent are joint families, underscoring the dominance of the nuclear family structure among shrimp farming households in the region. Around 60 percent of households consist of family less than 5 members, 25 percent have family 5

to 6 members, and 15 percent include more than 6 family members. The average family size across all households is 4.80, with small families averaging 4.70, medium families 4.91, and large families 5.00. The majority of shrimp farm operators (70.00 per cent) fall within the 3 to 5 years of experience category. A smaller group (20.00 percent) have more than 5 years of experience, and only 4 operators (10.00 percent) have less than 3 years of experience. This distribution indicates that most shrimp farm operators in Punjab have moderate experience, with fewer being either novices or highly experienced professionals. The majority of shrimp growers (62.50 percent) combine aquaculture with agriculture, reflecting the predominant practice across all farm sizes. A smaller group (25 percent) engage in aquaculture combined with business or a job, while only 5 growers (12.50 percent) are exclusively dedicated to aquaculture. This indicates that most shrimp farm operators diversify their occupations, with aquaculture often supplemented by agricultural activities. The same trend was also noticed by Vadher and Kapila (2014).

Shrimp farmers in Punjab have to face a number of constraints like finance, marketing, and production. To analyse these constraints a 5-point Likert scale was used and average scores were calculated which shows about the severity of the constraint. Shrimp farmers in Punjab have to tackle with various production-related challenges that hinder their business operations and productivity (Table 2). The main causes of the sharp increase in production costs are the high cost of feed and electricity. Farmers are further burdened by the high cost of shrimp seed and the scarcity of high-quality seed. Inadequate access to technical experts for prompt guidance exacerbates the on-going threat of disease outbreaks. Sudden Power cuts causes drop in the dissolved oxygen (DO) levels of the water resulted in stress or kill shrimp stocks. Lack of scientific knowledge and skilled labour caused hindrance in harvesting operations. The sampled farmers also have to face the issues *viz.,* water scarcity and poor water quality so as to sustain optimal farming conditions for shrimp production (Rani *et al,* 1993). The biggest obstacle for small-scale shrimp farmers was the high cost of feed (Likert score: 4.96). High seed prices (4.33) and high electricity costs (4.79) were other important problems. Notable constraint included disease outbreaks (4.13) and a shortage of high-quality seed (4.00). High feed and electricity costs (4.82 each) were also cited as major concerns by medium-sized farmers. High priorities also included the absence of high-quality seed (4.45) and disease outbreaks (4.36). High feed

costs (4.60) and high electricity costs (5.00) were the top concerns of large-scale farmers. For this group, the lack of high-quality seed (4.20) and the high cost of seed (4.40) were also significant issues. The two biggest issues across all farm sizes were the high cost of feed (4.88) and electricity (4.83). This is followed by the high cost of seed (4.25) and the frequency of disease outbreaks (4.20). These results are consistent with other research (Sayed *et al,* 2013; Tandel and Meheta, 2018) showing that inadequate disease control procedures and growing feed and seed expenses are major constraint in Indian aquaculture.

The shrimp farmers in Punjab face various marketing constraints causing limited access to markets either local or distant resulting in limited earnings. Shrimp price instability is a major issue that effects income stability and causes uncertainty. Due to lack of access to timely and accurate shrimp prices information, farmers cannot make their selling decisions. Due to a lack of adequate storage facilities, shrimp farmers have to go for forced sales at low prices. As shrimp farmers are unable to sell directly, they have to rely on middlemen who keep a significant amount of the profits (Chittem and Kunda, 2017). Their financial burden is increased when payments are delayed. The marketing challenges Punjab shrimp farmers faced in 2023–2024 are listed in Table 3. With a perfect score of 5.00, high price fluctuation was consistently rated as the biggest marketing challenge for farms of all sizes. Two other significant shared concerns were the absence of storage facilities (Likert score 3.83) and price information (Likert score 3.68). These results are consistent with other research that found price volatility and problems with market access to be significant constraint in the shrimp farming industry. Another important constraint for shrimp farmers in Punjab is the financial constraint. Among all farm categories, cross all farm sizes, collateral security of institutional loan got the lowest score (Likert score 1.00). For small shrimp farmers, high non-institutional credit interest rates put worse financial strain (Likert score 1.20). Inadequate credit support (Likert score 1.98) from banks hampers shrimp farmers' capacity to invest in better infrastructure or technology. Although having comparatively less severe financial constraints, large sampled farmers still face these general issues, also reported by Jagadeesh in the year 2015. There is potential of shrimp farming in the south-western region of Punjab, but due to production, marketing, and financial constraints, the shrimp farmers are facing uncertainties. The major production constraints among all shrimp farm categories recorded was high input costs on feed (Likert score: 4.88) and electricity

(Likert score: 4.83) followed by disease outbreak in shrimps (Likert mean score: 4.20) and high price of shrimp seed (Likert score: 4.25) resulted in declining operational efficiency. Another constraint for small sampled farmers includes sudden and frequent power cuts that effect dissolved oxygen levels. Large and medium category farmers also faced the need for skilled workers and labour shortage. The same findings were identified by Patil and Sharma (2021). One major marketing constraint is price volatility (Likert score: 5.00) followed by inadequate storage facilities (Likert score: 3.83) and limited access to timely price information (Likert score: 3.68) affect the decision-making and profitability of the shrimp farmers. Financial constraints are constantly significant, particularly for high non-institutional credit interest rates and institutional loan collateral security.

CONCLUSION

Despite its optimistic outlook, Punjab's shrimp farming industry faces several constraints that result in significant financial losses. The major constraints mentioned are high input costs (feed and electricity), price volatility and challenges in finding low-interest-rate credit. The unavailability of high-quality shrimp seed, disease outbreaks, and difficulty in accessing technical assistance affect the shrimp farming. These constraints need to be addressed in order to keep shrimp farming viable in Punjab. To address these constraints, targeted intervention is required. The main focus of policy implications are as follows:

High-quality inputs access

In order to lower disease outbreak and improve survival rate, government should set up hatcheries which can provide subsidized premium shrimp seeds. Alike agriculture, feed and electricity tariff subsidies, would help in reduction of operational costs. Feed production facilities should be established within the state which can further reduce costs. Research should be done on developing disease-resistant shrimp breeds, establishing diagnostic labs, disease surveillance systems, and immunization programs for better shrimp production.

Training and technical assistance

There is a need to organise regular workshops and training sessions to improve farmers' scientific knowledge and lessen the skilled labour shortage. By employing graduates, farmers can get technical assistance to lower risks and apply best practices.

Strengthen market systems

To save farmers from uncertain markets and fluctuating prices, there is a need to establish price stabilization or cooperative purchasing programs. Farmers will have more bargaining power and income if they can get accurate and timely market information. For this purpose, the government should promote digital platforms and digital apps for real-time market information, like prices and demand trends. To stop distress or forced sale and reduce post-harvest losses, infrastructure like cold storage needs to be upgraded.

Credit availability

To ensure credit access by farmers at affordable interest rates, policies like subsidized credit, collateral-free loan programs, and improved financial literacy are necessary. By executing these policy initiatives, Punjab can fully utilize the potential of its shrimp farming industry, ensuring sustainable practices and increased profitability for shrimp growers and other stakeholders.

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Development and Optimization of a Novel Hybrid Paneer Formulation

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ABSTRACT

The growing demand for plant-based and sustainable protein alternatives has driven research into innovative dairy substitutes. Conventional paneer production relies heavily on animal milk, which raises environmental, ethical, and dietary concerns, especially among vegan and lactose-intolerant consumers. Hence, the present study was focused on creating an innovative coagulated protein product using mung bean (*Vigna radiata* L.) as the primary ingredient. Four different formulations were prepared: T1 (pure mung bean extract), T2 (70% mung bean extract + 30% buffalo milk), T3 (70% mung bean extract + 30% cow milk) and T4 (50% mung bean extract + 50% soy milk). A kinnow-derived bioenzyme was effectively used to induce coagulation. Sensory evaluation revealed that T3 scored the highest in key attributes, including color (7.8), flavor (7.1), appearance (7.5), texture (7.2), and overall acceptability (7.5). Although T1 demonstrated strong nutritional qualities, its sensory characteristics differed from the other formulations. The results highlight the viability of mung bean-based coagulated proteins as a sustainable, nutritious, and palatable alternative to conventional paneer, particularly for the expanding vegan consumer base.

Key Words: Bio-Enzyme, Coagulation, Hybrid Paneer, Mung bean, Sensory evaluation.

INTRODUCTION

India leads global milk production, achieving a record output of 207 million MT in 2023, a 2% increase from the previous year (Kangare *et al,* 2024). Nearly half of this milk is processed into traditional dairy products, including paneer, curd, butter, and sweets, primarily through heat/acid coagulation and fermentation (Pal, 2019). Cow and buffalo milk dominate India's dairy sector (Pal and Jadhav, 2013), serving as a vital nutritional source-providing calcium (55% of daily intake), phosphorus (25%), potassium (10-14%), zinc (6.7%), riboflavin (13.5%), vitamin B12 (10.3%), and vitamin A (11%) (Warsewicz *et al,* 2019). However, the rise of non-dairy alternatives reflects shifting consumer preferences due to lactose intolerance, ethical concerns over animal welfare, and the environmental impact of dairy farming (Jovandaric, 2021). Lactose maldigestion affects a significant population, while ethical issues like intensive livestock practices drive demand for plant-based substitutes. Additionally, dairy production's high resource consumption and greenhouse gas emissions have accelerated research into sustainable protein sources, particularly from pulses, cereals, and oilseeds.

Pulses, especially mung bean (*Vigna radiata* L.), offer an excellent base for hybrid paneer due to their high protein content (25-28%) and balanced amino acid profile (Singh *et al,* 2017; Boye *et al,* 2010). Government initiatives like the National Food Security Mission-Pulses (Ministry of Agriculture & Farmers Welfare, 2021) further support pulse cultivation, reinforcing their role in food security. Mung bean's superior digestibility (Mubarak, 2005) and nutritional richness: carbohydrates (62-65%), fiber (3.5-4.5%), iron, potassium, and vitamins B, E, A, and C make it ideal for dairy alternatives (Singh *et al,* 2017). Its bioactive compounds (e.g., polyphenols, polysaccharides) provide additional health benefits, including antioxidant, antihypertensive, and immunomodulatory effects (Cao *et al,* 2011; Manan *et al,* 2019). Sprouting further enhances its nutritional value by increasing B vitamins, ascorbic acid, and isoflavones (Sharma, 1996; Rao, 2002; Randhir *et al,* 2004).

This study focuses on formulating a novel hybrid paneer using mung bean as the primary protein source, offering a lactose-free, cholesterol-free, and sustainable alternative to conventional paneer. By combining mung bean with dairy or plant-based

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T1 (Mung bean 100%)

T2 (Mung bean 70% + Buffalo milk 30%)

T3 (Mung bean 70%+ Cow milk 30%)

T4 (Mung bean 50% + Soy milk 50%)

Fig. 1: Trials performed for the determination of ratios of cow milk, buffalo milk, and soy milk to mung

ingredients, the developed product aims to meet the sensory and nutritional expectations of consumers while catering to vegan and lactose-intolerant populations. The research highlights the potential of mung beans in advancing plant-based dairy innovations, promoting both health and environmental sustainability.

MATERIALS AND METHODS

Procurement and preparation of raw materials

High-quality mung beans (*Vigna radiata* L. variety SML1827) were procured from Krishi Vigyan Kendra, Moga, ensuring authenticity and traceability. The beans were split using a Mini Dal Mill (Central Institute of Post-Harvest Engineering and Technology, CIPHET, Ludhiana) and thoroughly cleaned to remove impurities. The cleaned split mung beans were stored in breathable fiber fabric bags under cool, dry conditions before being transferred to airtight containers to prevent moisture absorption and contamination.

Preparation of Mung Bean Extract

Soaking and Dehulling: 500 g of split mung beans were soaked in water for 4 hours at room temperature. After soaking, the seed coats were manually removed by rubbing the beans together.

Grinding & Filtration: The dehulled beans were ground

with 2 liters of water until a uniform slurry was obtained. The slurry was filtered through double-layered muslin cloth to separate the extract from residual solids.

Starch Separation: The filtered extract was refrigerated at 4°C for 30 minutes to allow starch sedimentation. The clear supernatant (mung bean extract) was collected for further processing.

Note: Preliminary trials involving soaking + blanching, germination, and germination + blanching were conducted, but soaking alone yielded the most desirable product.

Formulation of Hybrid Paneer

Based on sensory evaluation (taste, texture, overall acceptability), four final formulations were selected: T1 (Control): 100% mung bean extract, T2: 70% mung bean extract + 30% buffalo milk, T3: 70% mung bean extract + 30% cow milk and T4: 50% mung bean extract + 50% soy milk.

Coagulation Process

Various coagulants (vinegar, citric acid, $CaCl_2$, $MgCl_2$, $CaSO_4$, kinnow bioenzyme) were tested. Kinnow-based bioenzyme was selected for producing firm, stable coagulation.

Heating & Coagulation: Each blend was heated to 85°C. Kinnow bioenzyme was added gradually in optimized quantities: T1: 60 mL per 2 L extract, T2: 75 mL per 2 L extract, T3: 78 mL per 2 L extract and T4: 86 mL per 2 L extract. The mixture was stirred gently until complete protein-whey separation.

Molding and Pressing: The coagulated mass was strained through muslin cloth. Pressed under 5 kg weight in cheese molds for 40 minutes. The formed paneer blocks were cooled in chilled water and stored in ziplock bags (4°C, ≤5 days).

Sensory Evaluation

The sensory evaluation of the novel hybrid paneer formulations was conducted by a semi-trained panel of 30 members using a 9-point hedonic scale (1 = "dislike extremely" to 9 = "like extremely") to assess color, flavor, appearance, texture, and overall acceptability. Samples of each treatment (T1: 100% mung bean extract; T2: 70% mung bean extract + 30% buffalo milk; T3: 70% mung bean extract + 30% cow milk and T4: 50% mung bean extract + 50% soy milk) were randomly coded and served at 10-12°C under controlled lighting conditions, with water and unsalted crackers provided for palate cleansing between samples. The panelists evaluated the samples independently in individual booths to prevent bias, and the collected data were analyzed using one-way ANOVA and Duncan's multiple range test ($p < 0.05$) to determine significant differences between the formulations. Ethical compliance was ensured through written consent and institutional review board approval.

RESULTS AND DISCUSSION

Sensory analysis demonstrated significant variation ($p<0.05$) among the four hybrid paneer formulations across all evaluated parameters. The cow milk-enriched formulation (T3: 70% mung bean/30% cow milk) consistently outperformed other variants, achieving peak scores for color (7.8), flavor (7.1), appearance (7.5), texture (7.2), and overall acceptability (7.5) (Table 1). This superior performance can be attributed to cow milk's whitening effect on color and its complementary flavor profile that effectively masked the characteristic beany notes of mung bean. In contrast, the 100% mung bean formulation (T1) received the lowest ratings, particularly for its greenish hue (color) and pronounced legume flavor, highlighting the sensory challenges of pure plant-based alternatives. The hybrid nature of T3 successfully replicated conventional paneer's textural properties, with milk proteins and kinnow bioenzyme synergistically creating a desirable firm yet cohesive matrix. These findings align with current research emphasizing the importance of dairy components in achieving optimal sensory characteristics in hybrid products (Goyal *et al,* 2020). While T1's nutritional profile remains advantageous, its sensory limitations suggest the need for additional processing interventions like germination or thermal treatment to improve consumer acceptance (Sánchez-Velázquez *et al,* 2019). The successful application of kinnow bioenzyme as a natural coagulant (Singh *et al,* 2018) presents opportunities for developing cleaner-label hybrid dairy products. T3 emerges as the most promising formulation, effectively balancing the nutritional benefits of plant proteins with the sensory familiarity of traditional paneer, making it particularly suitable for flexitarian consumers transitioning to more sustainable diets.

CONCLUSION

This study successfully developed innovative hybrid paneer formulations using mung bean as a plant-based protein source, with the 70% mung bean/30% cow milk blend (T3) emerging as the optimal formulation. Sensory evaluation demonstrated T3's superior performance in all quality parameters, achieving the highest scores for color (7.8), flavor (7.1), texture (7.2) and overall acceptability (7.5). The incorporation of cow milk effectively mitigated typical legume-associated sensory challenges, while kinnow bioenzyme proved an effective natural coagulant, producing paneer with desirable textural properties. These results position mung bean-cow milk hybrid paneer as a promising alternative that combines nutritional benefits with sensory appeal, addressing growing demands for sustainable dairy alternatives. The findings highlight two key innovation pathways like strategic blending of plant and dairy proteins to optimize sensory quality, and utilization of fruit-based bioenzymes for clean-label processing. Future research should focus on shelf-life stability, large-scale production feasibility, and detailed nutritional characterization to facilitate commercial translation. This work contributes to the evolving dairy-alternative sector by demonstrating a viable approach to developing hybrid products that balance sustainability with consumer acceptance.

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Effect of Integrated Nutrient Management Practices on Enhancing Productivity in Brinjal (*Solanum melongena* L.)

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ABSTRACT

Brinjal is an important vegetable crop in the coastal districts of Odisha. To enhance yields, farmers often depend heavily on chemical fertilizers, which may not always deliver the desired results. To address this, a field experiment was conducted across seven farmer fields to evaluate the effectiveness of integrated nutrient management (INM), combining chemical fertilizers, organic manure, biofertilizers, and micronutrients, in improving brinjal productivity and farmer's income. The experiment followed a Randomized Block Design (RBD) with three treatments and seven replications. The treatments comprising Application of NPK: 120:60:60 kg/ha along with FYM-20t/ha and Biofertilizers like Azospirillum, PSB @ 5kg/ha and micronutrient application: Zn and B @ 0.1% twice before flowering (T3) indicated there is significant increase in yield and yield attributing characters over control. The influence of biofertilizer along with optimum dose of fertilizer increased microbial activity and uptake of nutrients which triggered the flowering behaviour and fruit yield in combination with Boron and Zn like micronutrients. The results revealed that Treatment T3 significantly improved yield and yield-attributing characters over the control. The synergistic effect of biofertilizers with the optimum fertilizer dose enhanced microbial activity and nutrient uptake, which in turn improved flowering, fruit set, and yield, further supported by the role of micronutrients such as boron and zinc. T3 recorded the highest fruit yield (428 q/ha) along with the maximum benefit-cost ratio (2.78), followed by T2 (382.2 q/ha; B:C ratio 2.50) and T1 (270 q/ha; B:C ratio 2.09). A similar trend was observed for other growth and yield parameters. Based on the findings, it can be concluded that the integrated application of NPK (120:60:60 kg/ha), FYM (20 t/ha), biofertilizers (Azospirillum and PSB @ 5 kg/ha) and foliar sprays of Zn and B (0.1%) significantly enhances brinjal productivity and farmers' income in a sustainable manner.

Keywords: Biofertilizers, Brinjal, Micronutrient, Integrated Nutrient Management, Vegetable.

INTRODUCTION

Eggplant (*Solanum melongena* L.), commonly known as brinjal, ranks among the widely cultivated vegetables in India. It is valued for its nutritional content, particularly as a source of vitamins A and B (Kumar and Kannaujia, 2017; Singh and Bisen, 2020). Brinjal, also known as aubergine or Guinea squash, belongs to the family Solanaceae and has a diploid chromosome number of 2n = 24 (Kapur *et al,* 2020). It is extensively grown throughout tropical and subtropical regions and is believed to have originated in India (Kataky, 2024). The fruits of Brinjal are used in various ways of cooking, sauting, grilling, backing and frying by both poor and rich in India. It is having high nutritive value and rich in vitamins and minerals. It is considered as one of the leading and the second major vegetable crops next to tomato (Kiran *et al,* 2010). It can be cultivated across a wide range of soil types and climatic conditions; however, the optimum temperature range for achieving maximum yield is between 21°C and 27°C. India ranks second to China in area and production in the world accounting 7.11 lakh hectares with annual production of 135.58 lakh tons and productivity of 19.1 metric tons per hectare. India contributes about 28% of the total world production (Daunay *et al,* 2001). It is highly productive and usually finds a place as "poor man's crop".

The growth and yield of brinjal depend on multiple interacting factors. As a long-duration and high-yielding crop, it extracts large amounts of nutrients from the soil. Along with macronutrients, micronutrients also play a critical role in plant nutrition. Therefore, balanced fertilization with both macro and micronutrients is essential, since micronutrients are involved in key metabolic processes of plants. Deficiency of these elements can lead to

physiological stress due to the malfunctioning of enzymatic systems and other metabolic activities (Modi *et al,* 2019). Micronutrients aid nutrient uptake by acting as catalysts in plant metabolic processes and balancing other nutrients. They are required in small quantity for normal growth and development of plants. Zinc is an essential component of a number of enzymes, *i.e.,* dehydrogenase, aldolase, isomerases, proteinase, peptidase and phosphohydrolase. Boron helps in the absorption of water and carbohydrate metabolism, translocation of carbohydrates in plants, etc., and it also plays an important role in flowering and fruit formation. Iron helps in the synthesis of enzymes and chlorophyll. Foliar spraying of micronutrients such as ferrous sulfate, zinc sulfate, and borax significantly alters various metabolic activities in plants, thereby enhancing both growth and yield (Pandav *et al,* 2017).

Bio-fertilizers have become essential parts of "Integrated Nutrient" Supply Systems and have the latent to increase productivity through improved nutrient supply (Hegde *et al,* 1999). These beneficial microorganisms help biological processes converting essential elements from insoluble to soluble forms. Similar to *Pseudomonas strata*, Phosphate Solubilizing Bacteria (PSB) are essential for solubilizing fixed phosphorus in soil so that plants can access it. Beneficial bacteria such as Azotobacter and PSB found in biofertilizers improve nutrient uptake by changing nutrients into soluble forms (Bhattacharya *et al,* 2000; Kumar *et al,* 2024). Phosphate Solubilizing Bacteria (PSB) are beneficial microbes known for their ability to convert insoluble forms of phosphorus into soluble forms by breaking down both organic and inorganic phosphorus compounds. This process is mainly facilitated through the secretion of low molecular weight organic acids. Similarly, *Azospirillum* is a well-known plant growth-promoting rhizobacterium that contributes to enhanced soil fertility. It is a heterotrophic nitrogen-fixing organism reported to be effective and cost-efficient across various crops. These microbes help in improving overall plant growth, yield and quality (Singh *et al,* 2013).

To address the challenges of nutrient deficiency and minimize the negative impacts of chemical fertilizers, it is important to utilize all available nutrient sources under the concept of integrated nutrient management (INM). This method involves combining chemical fertilizers with organic manures and biofertilizers in suitable proportions. INM plays a key role in maintaining soil health and fertility over time. Biofertilizers are a vital part of this system,

as they support natural processes that help make nutrients available to plants. Alongside major nutrients and biofertilizers, micronutrients such as zinc and boron are also crucial for plant growth and metabolism. Applying these micronutrients through foliar sprays ensures efficient uptake through the leaves and can show quick results (Tawab *et al,* 2015). The present study was conducted with the objective of using biofertilizers and INM practices to access productivity, fertilizer use efficiency, cost of fertilizers, soil quality and brinjal yield.

MATERIALS AND METHODS

Experimental site and treatments applied

The study was carried out during 2020-21 across seven different farmer's fields in KVK Cuttack, under ICAR-Central Rice Research Institute to assess the impact of integrated nutrient management practices on brinjal productivity and farmer's income in the coastal districts of Odisha. Each trial covered an area of 0.4 hectares. The experimental soil was sandy loam in texture and deep and friable in nature. A Randomized Block Design (RBD) was used for the experiment. In line with the goal of sustainable vegetable production and environmental protection, On-Farm Trials (OFT) were carried out by KVK Cuttack during 2021-22 at seven locations in the district. The treatments were: T1 – farmer's conventional practice involving non-judicious use of chemical fertilizers; T2 - application of NPK at 120:60:60 kg/ha along with 20 t/ha of FYM and biofertilizers such as Azospirillum and PSB at 5 kg/ha; and T3 - similar to T2 with an added foliar spray of micronutrients (Zn and B) at 0.1% applied twice prior to flowering.

Observations recorded

Observations were recorded on different growth, yield and economic parameters. Farmers involved in the trials were trained in scientific crop management practices, covering aspects such as crop establishment, intercultural operations, water and nutrient management, weed control and proper harvesting. Standard agronomic practices were followed during crop cultivation. Weather data for the crop's growing period at the experimental site is presented in Table 1.

Field preparation, intercultural practices and treatment application

The experimental field was prepared to a fine tilth through repeated ploughing and harrowing,

Table 1. Meteorological data of the district during growing season of crop

Month	Average Temperature ^{0}C (Max)	Average Temperature ^{0}C (Min)	Relative humidity (%)
September 2021	32.96	25.13	89.66
October 2021	32.44	24.17	81.88
November 2021	29.65	19.52	81.62
December 2021	18.74	84.03	75.88
January 2022	14.87	86.90	98.96
February 2022	17.14	83.76	54.42
March 2022	22.74	82.03	53.46

Table 2. Effect of different treatments on growth, yield and yield-attributing traits of brinjal

Treatment	Plant Height (cm)	No. of Branches	Days to 1st Harvesting	Days to last harvesting	Fruit weight (g)	No. of fruits/plant	Fruit yield /plant (kg)	Fruit yield (q/ha)
T1	55	15.4	56	140.4	94	13.0	1.2	270
T2	65.8	19.0	52	148.8	100	17.0	1.7	382.2
T3	75	25.0	50	158.0	105	19.0	2.0	428
SE (m)	2.75	0.55	0.43	0.68	0.30	0.37	0.03	5.92
CD-5%	8.51	1.73	1.36	2.14	0.96	1.17	0.10	18.44

Table 3. Economic impact of nutrient management practices in brinjal.

Treatment	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	BCR
T1	175100	367520	192420	2.09
T2	177496	446380	268260	2.50
T3	179788	504000	323612	2.78

followed by the removal of clods and debris. The land was then leveled and raised beds were prepared. A spacing of 90 cm between ridges and 90 cm between plants was maintained. Before fertilizer application, random soil samples were taken from the experimental site and analyzed, revealing a pH below 5.5. For each hectare, 25 tons of well-decomposed FYM, 210 kg of urea, 130 kg of diammonium phosphate (DAP) and 96 kg of muriate of potash (MOP) were applied. Half of the recommended nitrogen, phosphorus and potassium were incorporated into the soil before transplanting, while the remaining nitrogen was applied in two equal split doses at one-month intervals. Biofertilizers were applied as a basal dose at the time of seedling transplanting. Micronutrients containing zinc and boron were applied as foliar sprays at one-month intervals after transplanting. Weed control was managed through 3-4 hoeings and the crop received 10-15 irrigations, including one immediately after transplanting. Harvesting was done at the immature and tender stage to meet market demand.

Data collection

Five plants were randomly selected from each plot to record observations on plant height (cm),

number of branches per plant, days taken to first harvest, days taken to last harvest, fruit weight (g), number of fruits per plant, fruit yield per plant (kg/plant), and fruit yield per hectare (q/ha). The number of days to first harvest was noted from the day of transplanting to the initial harvest. Yield per hectare was derived from the average fruit yield per plant and expressed in quintal (q/ha).

Economic analysis

The cost of cultivation and gross returns were calculated based on the prevailing market prices of inputs during the study period. Labor charges and operational costs for activities such as ploughing, weeding, irrigation, planting, bed preparation and harvesting were included, along with the costs of seeds and fertilizers. Net returns (Rs./ha) and benefit-cost ratio (BCR) were determined using the formula:

Net Returns = Gross Returns - Cost of Cultivation

BCR = Gross Returns / Total Cost of Cultivation

Statistical analysis of the collected data was performed following the standard methodology outlined by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Plant height (cm)

The effect of different treatments on plant height was significant. The tallest plants were recorded in T3 (75.0 cm), followed by T2 (65.8 cm), while the shortest were in T1 (55.0 cm). The increase in plant height may be attributed to enhanced cell division and enlargement, driven by improved protein synthesis and metabolic activity. The combined application of micronutrients, chemical fertilizers, and biofertilizers ensured a continuous nutrient supply and promoted phytohormone production, which enhanced carbohydrate synthesis and supported overall plant growth. The superior plant height in T3 (75.0 cm) may thus be due to the steady supply of balanced nutrients throughout the crop cycle, leading to better vegetative development. Similar findings were reported by Pandav *et al* (2017) and Pinkee *et al* (2023).

Number of branches per plant

All treatments significantly influenced the number of branches per plant. The highest number was recorded in T3 (25.0), followed by T2 (19.0), while the lowest was in T1 (15.4). The increase in branching under T3 may be attributed to the combined application of fertilizers, biofertilizers, and micronutrients. Essential nutrients such as nitrogen and phosphorus play a key role in root and shoot development, as well as in the formation of phospholipids and phosphoproteins. These compounds enhance meristematic activity, thereby increasing branch production (Patidar and Bajpai, 2018). The present findings are in close agreement with those of Padhiary and Dubey (2020) and Pinkee *et al* (2023).

Days taken to firstharvest

The results in Table 2 show that all treatments significantly affected the number of days to the first harvest. The earliest harvest was observed in T3 (50.0 days), which was statistically at par with T2 (52.0 days), while T1 required the longest time (56.0 days) after transplanting. The delay in T1 may be due to poorer plant and soil conditions, whereas the earlier harvests in T2 and T3 can be attributed to better nutrient availability and improved physiological status, which supported faster growth and a smoother transition from vegetative to reproductive stages. Similar results were reported by Srivastava *et al* (2009) and Uikey *et al* (2018).

Days taken to last harvest

Table 2 shows that all treatments had significant effect on the number of days to the last harvest. The longest harvesting period was recorded in T3 (158.0 days), followed by T2 (148.8 days), while the shortest was in T1 (140.4 days). This indicates that T3 extended the harvesting duration compared to the other treatments. The prolonged harvest period in T3 may be attributed to healthier plant growth, better soil conditions, and improved plant vigor, which enhanced flowering and fruit development. These factors also promoted continued vegetative growth and efficient photosynthesis, thereby extending the flowering and fruiting stages. Similar results were reported by Kumar *et al* (2024).

Fruit weight (g)

All treatments significantly influenced average fruit weight. The highest weight was recorded under T3 (105 g), followed by T2 (100 g) and T1 (94 g). The superior fruit weight in T3 may be due to the combined application of NPK (100:60:60 kg/ha), biofertilizers (Azospirillum and PSB @ 5 kg/ha each), and foliar spray of micronutrients. This ensured a steady nutrient supply, especially phosphorus, which is crucial for plant growth. Phosphorus-solubilizing bacteria (PSB) further enhanced its availability by breaking down insoluble forms, while also producing growth-promoting substances and antibiotic-like compounds that supported healthy plant development. The improvement in fruit weight under T3 can be attributed to enhanced nutrient uptake, assimilate partitioning, and better fruit filling. Similar findings were reported by Prathyusha *et al* (2023).

Number of fruits per plant

All the treatments had significant effects on fruit yield for plant. T3 treatment was having maximum number of fruits per plants (19.0) followed by T2 (17.0) and T1 (13.0). This may be due to more no of flowers and more fruit retention due to optimum growth and development which could attributed for better flower and fruit retention in the plant. The significant increase in fruit number under T3 may be attributed to better growth and reproductive efficiency, enhanced nutrient utilization, and improved physiological processes leading to more effective flowering and fruit setting.

Fruit yield/Plant (kg/plant)

All the treatments had significant effects on fruit yield per plant (Kg/plant). T3 recorded the highest

fruit yield per plant (2.0 kg), followed by T2 (1.7 kg), whereas T1 registered the lowest yield (1.2 kg). The superiority of T3 may be attributed to its higher fruit weight and greater number of fruits per plant, which together contributed to enhanced yield.

Fruit yield/ha (q/ha)

Fruit yield per hectare varied significantly among the treatments. The highest yield was recorded in T3 (428 q/ha), followed by T2 (382.2 q/ha), while the lowest was in T1 (270 q/ha). The superiority of T3 may be attributed to the combined positive effects of greater plant height, more branches, higher fruit weight, and a larger number of fruits per plant, which collectively enhanced yield per plant and translated into higher yield per hectare. In addition, the use of organic manure in T3 not only supplied nutrients but also improved the soil's physical, chemical, and biological properties. Upon decomposition and mineralization, organic manure directly released nutrients and facilitated the solubilization of otherwise fixed nutrients, making them more available for plant uptake. These results confirm that Treatment 3 is the most promising option for maximizing fruit yield at the field level (Bhattarai *et al*, 2021; Modi *et al,* 2019).

It was observed that treatments performing well in unit areas also maintained their superiority on a larger scale, since yield per hectare was estimated by multiplying plot yield with the hectare factor. Similar observations were reported by Suryanto *et al* (2017) and Tandel *et al* (2018). The combined use of organic manures, biofertilizers, chemical fertilizers, and multi-micronutrients enhanced nutrient-use efficiency and improved soil physical, chemical, and biological properties by narrowing the gap between nutrient removal and supply. Similar findings were reported by Chumei *et al* (2014). Overall, fruit yield under T3 showed a 58.51% increase over the control (T1) and a 11.9% increase over T2.

Economics

The economic analysis was conducted using prevailing market prices of inputs and outputs during the study year to calculate cost of cultivation, gross return, net return, and the benefit-cost ratio (BCR). Net profit per hectare also depends on factors such as labor availability and market access. As shown in Table 3, treatment T3 achieved the highest net return (₹3,23,612/ha) with a BCR of 2.78, followed by T2 (₹2,68,260/ha; BCR 2.50) and T1 (₹1,92,420/ha; BCR 2.09). The cost of cultivation was maximum under T3 (₹1,79,788/ha), followed by T2 (₹1,77,496/ha) and T1 (₹1,75,100/ha). Gross returns were also highest in T3

(₹5,04,000/ha), compared with T2 (₹4,46,380/ha) and T1 (₹3,67,520/ha). The higher net return in T3 was primarily due to its greater gross return relative to the cost of cultivation. Cost reduction through balanced nutrient integration, rather than excessive and imbalanced use of chemical fertilizers, contributed to improved plant growth, development, and yield. The BCR, being a key indicator of profitability, strongly influences farmers' decisions to adopt a particular production practice. For any horticultural practice to gain acceptance, it must demonstrate a favorable cost-benefit ratio. Similar economic benefits of integrated nutrient management have been reported by Paswan *et al* (2022), Singh *et al* (2020), Srivastava *et al* (2009), and Sharma and Khadda (2023).

CONCLUSION

The study demonstrated that integrated nutrient management (INM), involving the combined use of chemical fertilizers, farmyard manure (FYM), biofertilizers (Azospirillum and PSB), and micronutrients (Zn and B), significantly enhanced the growth, yield, and economic returns of brinjal in the coastal districts of Odisha. Among all treatments, T3 consistently outperformed others in plant height, branching, fruit weight, fruit number, and overall productivity (428 q/ha), while also recording the highest net return (₹3,23,612/ha) and benefit-cost ratio (2.78). The superior yield and profitability under T3 can be attributed to improved nutrient availability, better soil health, and efficient resource utilization. These findings strongly support the adoption of INM as a sustainable and economically viable strategy for brinjal cultivation under similar Agro-climatic conditions.

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Entrepreneurial Behaviour of Fish Farmers in Dhamtari District of Chhattisgarh

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ABSTRACT

Fish farming is emerging as a vital occupation highlighting its important in the mainstream agricultural sectors and supporting millions of livelihoods in the world. Inland fish farming is one of the major sectors apart from coastlines utilizing water bodies such as rivers, reservoirs, perennial and seasonal ponds in the village. The study was carried out to assess the entrepreneurial behaviour of fish farmers by selecting the total of 150 fish farmers through proportionate stratified random sampling technique. The data were collected by personal interview method with the help of structured interview schedule and statistically analyzed after subjecting the data. The findings revealed that the majority of the fish farmers had medium level (68.00%) of entrepreneurial behaviour followed by low (16.67%) and high (15.33%) level of entrepreneurial behaviour of fish farmers, respectively. Further, the data of all eight attributes of entrepreneurial behaviour of fish farmers revealed that cosmopoliteness and risk orientation (both of equal 65.33%), innovativeness (59.33%), leadership ability (83.33%), economic motivation (80.00%), decision making ability (84.00%), achievement motivation (80.66%) and information seeking behaviour (65.33%) were also found the medium level of entrepreneurial behaviour of fish farmers. Hence, it is recommended that converting the low and medium level to high level of entrepreneurial behaviour of fish farmers, enhancing the knowledge of fish farmers by the subject experts through organizing the awareness cum trainings and capacity building programmes to improve the knowledge level and change in mindset of fish farmers towards positive direction will ultimately led to their adoption of the innovative techniques as well as undertaking the fish farming as a business venture.

Keywords: Entrepreneurial behaviour, Farmers, Inland fish farming.

INTRODUCTION

Entrepreneurial behaviour is defined as "Not necessarily doing new things but also doing things in a new way that has already been done" (Narayanaswamy, 1996). Entrepreneurs are constantly seeking innovative solutions to problems and finding unique ways to stand out in a competitive market. They are not afraid to take risks and challenge the status quo, often pushing boundaries and thinking outside the box. This mindset of creativity and adaptability is essential for success in the ever-evolving business world and it comprises nine attributes: innovativeness, decision making ability, achievement motivation, risk orientation, coordination ability, information seeking behaviour, planning ability, cosmopoliteness and self-confidence (Chaudhari *et al,* 2007).

Entrepreneurship is a catalyst for economic development in all sectors and fisheries is no exception. Fish farming is a good opportunity for entrepreneurship, especially in rural areas. The demand for fish is growing fast because it is a healthy source of protein (Singh *et al,* 2020). Fish also grow quickly and need less feed compared to animals like goats or cows, which means more profit. Today, fish farming uses new technology, has low risk and creates employment. So, starting fish farming can be a smart business for young people and farmers. It also supports sustainable development and contributes to national economy (Samadi and Aghajani, 2020). Despite the potential, rural entrepreneurs face multiple challenges such as lack of access to capital, training, market linkage and exposure to modern techniques. In the fisheries sector, these problems are even more pronounced due to limited awareness, traditional practices and infrastructure gaps.

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Table 1: Entrepreneurial behaviour of fish farmers   *n=150

Sr. No.	Entrepreneurial behaviour	Frequency	Percentage
1	Low (score less than 149)	25	16.67
2	Medium (score from 149 to 183)	102	68.00
3	High (score more than 183)	23	15.33
	Total	150	100.00

$\overline{X}$=165.96   σ=16.94   *n= Number of respondents

Table 2: Attributes-wise entrepreneurial behaviour of fish farmers   *n=150

Sr. No.	Attributes	Category	Frequency	Percentage
1	Cosmopoliteness Mean=11.54 *S.D.=4.09	Low	13	8.67
		Medium	98	65.33
		High	39	26.00
2	Risk orientation Mean=15.88 S.D.=1.48	Low	15	10.00
		Medium	98	65.33
		High	37	24.67
3	Innovativeness Mean=49.12 S.D.=24.89	Low	35	23.33
		Medium	89	59.33
		High	26	17.34
4	Leadership ability Mean=10.06 S.D.=1.21	Low	9	6.00
		Medium	125	83.33
		High	16	10.67
5	Economic motivation Mean=19.84 S.D.=1.57	Low	17	11.33
		Medium	120	80.00
		High	13	8.67
6	Decision making ability Mean=15.38 S.D.=1.77	Low	8	5.33
		Medium	126	84.00
		High	16	10.67
7	Achievement motivation Mean=16.68 S.D.=1.90	Low	19	12.67
		Medium	121	80.66
		High	10	6.67
8	Information seeking behaviour Mean=17.42 S.D.=5.32	Low	27	18.00
		Medium	98	65.33
		High	25	16.67

*S.D. = Standard deviation

In the year 2022, global fisheries and aquaculture production was recorded 223.2 million tonnes, with an estimated 61.8 million people engaged in the primary sector. Fisheries and aquaculture are expected to support around 600 million livelihoods, including those of subsistence and secondary sector workers as well as their dependents. Per capita intake of aquatic food increased from 9.9 kg in the 1960s to a record high of 20.7 kg in 2022 (FAO, 2024). In India, culture-based fisheries are predominantly practiced in the inland fishing sector, with Chhattisgarh state ranking sixth in production and achieving fish production of 6.52 lakh tonnes in the year 2022–23. In the state, approximately 2.20 lakh individuals were engaged in fisheries activities, including pond culture, cage culture, recirculatory aquaculture systems and capture fishing (Anonymous, 2023). In perspective of rising global production and growing dependence on fish as food, it is important to study how fish farmer's socio-economic backgrounds shape their entrepreneurial behaviour. These behaviours are crucial for efficient fish farm management, risk-taking and innovation adoption. However, fish farmers come from diverse socio-economic backgrounds, which can heavily influence their entrepreneurial tendencies. Many fish farmers having lack of education, resources and other social capital needed to excel in the business aspect of fish farming. Therefore, keeping all these facts in mind, the present study was undertaken with the specific objective to study the entrepreneurial behaviour of fish farmers in Dhamtari district of Chhattisgarh.

MATERIALS AND METHODS

The present study was conducted in Dhamtari district of Chhattisgarh which consists of four blocks *i.e.* Kurud, Magarlod, Dhamtari and Nagri. From all the blocks, a total of 150 respondents were selected though proportionate stratified random sampling technique for the study purpose. The data were collected personally by using of pre-tested structured interview schedule. The collected data were classified and analyzed by using of appropriate statistical tools like frequency, percentage, mean and standard deviation. In this study, entrepreneurial behaviour is operationally defined as the outcome of eight attributes, each attribute accompanied by specific statements that were adapted to suit the current study. These attributes were included cosmopoliteness, risk orientation, innovativeness, leadership ability, economic motivation, decision making ability, achievement motivation and information seeking behaviour. Furthermore, this behaviour was categorized into three distinct groups by using the mean and standard deviation. The procedure constituted statements for which the responses of the fish farmers were recorded on five-point continuum namely-strongly agree, agree, undecided, disagree and strongly disagree. For affirmative statements, a score of 4, 3, 2, 1 and 0 respectively, was given to the response category and for negative statements the scoring was countermanded. Then the cumulative scores of all the statements were given to their attributes accordingly. Thereafter the fish farmers were grouped into three categories of specific behaviour attribute based on the total scores arrived under the consideration *viz.,* low (less than, Mean ± SD), medium (between, Mean ± SD) and high (more than, Mean + SD) entrepreneurial behaviour of fish farmers.

RESULTS AND DICUSSION

Entrepreneurial behaviour of fish farmers

The data depicted in Table 1 revealed that majority of the fish farmers *i.e.* 68.00 percent fell under the medium level of entrepreneurial behaviour followed by 16.67 percent were under the low level of entrepreneurial behaviour, whereas only 15.33 per cent fish farmers were under the high level of entrepreneurial behaviour which means majority of the respondents who involved in the fish farming were having medium level of entrepreneurial behaviour as well as they were taking medium interest to adopt the fish farming as a business venture. Significant opportunities exist to uplift the low entrepreneurial behaviour of fish farmers in further improving the

capabilities of fish farmers into converting the medium-level to high level of entrepreneurial behaviour. Strengthening entrepreneurial skills and development a supportive ecosystem can significantly increase the involvement and interest in performing fish farming as an entrepreneurial venture at suitable stage. The findings were supported with the findings of Pandey and De (2015), Khoshmaram *et al* (2018), Maity and Saha (2020), Seth *et al* (2020), Ranjitha and Raghuprasad (2021), Gilkari and Dohat (2022), Paudel *et al* (2022), Edirisinghe *et al* (2023) and Remya and Alex (2023).

Attributes-wise entrepreneurial behaviour of the fish farmers

Cosmopoliteness

Cosmopoliteness of the respondents were identified by open-minded, globally oriented perspective, that can be assessed through various approaches to measure values, behaviours, attitudes and engagement with different cultures and ideas. The data in Table 2 reveals that 65.33 percent of the respondents had a medium level of cosmopoliteness, followed by 26.00 percent with a high level of cosmopoliteness and only 8.67 per cent had with a low level of cosmopoliteness respectively, under the entrepreneurial behaviour of fish farmers.

Risk orientation

The respondents had willingness to taken risk as shown in Table 2 reveals that brief sights to the study regarding risk bearing ability among fish farmers. The data reveals that majority of the respondents had medium level of risk orientation *i.e.* 65.33 percent followed by 24.67 percent had high level of risk orientation, whereas only 10.00 percent respondents had low level of risk orientation respectively, in the study area. It means majority of the fish farmers having medium level of risk orientation in terms of entrepreneurial behaviour.

Innovativeness

The ability to generate, adopt and implement the new ideas or solutions-varies depending on the individual and the technological advancement. The data of innovativeness attribute of the fish farmers was presented in Table 2 and shows that 59.33 percent respondents had medium level of innovativeness followed by 23.33 percent having low level of innovativeness, while only 17.34 percent respondents had high level of innovativeness respectively, under the entrepreneurial behaviour of fish farmers.

Leadership ability

The leadership ability encompasses a variety of skills, traits and behaviours that enable individuals to influence guide and motivate the others. The data presented in Table 2 indicates that 83.33 percent fish farmers having medium level of leadership ability followed by 10.67 percent were having high level of leadership ability, whereas only 6.00 percent fish farmers were having low level of leadership ability respectively. Hence, it can be said that more number of fish farmers having medium level of leadership ability in terms of entrepreneurial behaviour.

Economic motivation

Economic motivation refers to the drive or incentive that individuals or groups have to achieve economic goals, like income maximization, job security and financial success. The distribution of the respondents in economic motivation depicted in Table 2 reveals that most of the fish farmers were belonged to medium level of economic motivation i.e. 80.00 percent followed by low level of economic motivation (11.33%), whereas only 8.67 percent fish farmers were possessed as under high level of economic motivation respectively.

Decision making ability

Decision making ability reflects a person's capability to make choices that are logical, informed and effective, often under pressure or uncertainty. The data presented in Table 2 shows that majority of the fish farmers i.e. 84.00 percent were having medium level of decision-making ability followed by 10.67 percent fish farmers were having high level of decision-making ability, while only 5.33 percent fish farmers were having low decision-making ability.

Achievement motivation

The drive to gain, achieve success and pursue goals that directs the fish farmers to adopt innovative fish farming practices. The level of achievement motivation as shown in Table 2 reveals that 80.66 percent fish farmers had medium level of achievement motivation followed by low level of achievement motivation (12.67%), whereas only 6.67 percent fish farmers had high level of achievement motivation, respectively. Hence, it may be said that significant number of fish farmers were having medium level of achievement motivation in the study area.

Information seeking behaviour

Information seeking behaviour is the process by which an individual actively search and use of information. The data in Table 2 reveals that majority of the fish farmers were having medium level of information seeking behaviour i.e. 65.33 percent, followed by 18.00 percent were as low level of information seeking behaviour, whereas 16.67 percent respondents were having high level of information seeking behaviour in the study area, respectively. Hence, it may be said that a greater number of fish farmers were having medium level of information seeking behaviour.

The major attributes of entrepreneurial behaviour were also found at medium level in influencing the adoption of improved fish farming practices. Fish farmers actively seeks to external influences, showing openness to new ideas. It can also be said that the traditional mindset of fish farmers might be prioritized to local interactions over external exposure. While as some of the fish farmers exhibited high risk tolerance which might be essential for adopting the innovative practices and tackling the critical operations in fish farming. Further improving the leadership skills is needed, which are essential for group activities and peer influence. The financial status, indicating a strong but not overwhelming drive for economic gain, possibly due to the resource constraints or lack of confidence in fish farming as a viable income source. Hence, concerned agencies should be given more emphasis to strengthen the fish farmers and minimizing the resource constraints.

Small group of fish farmers were ahead in decision-making timely and well- effective decisions, but converting from small group to bigger group, subject experts can provide technical guidance about improved fish farming and develop confidence in fish farmers related to decision making ability. In case of information-seeking behaviour, majority of the respondents had a medium level of interest in seeking information on improved fish farming practices. It means mostly the fish farmers had moderate contact with the extension agencies, subject experts and familiar with getting information from formal and informal sources as well as through electronic media also. Hence, extension agencies should encourage the fish farmers to getting the more information form reliable sources about the improved fish farming practices. Almost similar type of findings were also recorded by Haobijam et al (2016), Bantigue (2018), Khoshmaram et al (2018), Maity and Saha (2020), Seth et al (2020), Ranjitha and Raghuprasad (2021), Paudel et al (2022) and Remya and Alex (2023).

CONCLUSION

From the above findings, it can be concluded that majority of the fish farmers had medium level of entrepreneurial behaviour, also including medium level of cosmopoliteness, risk orientation, innovativeness, leadership ability, economic motivation, decision-making ability, achievement motivation and information seeking behaviour of fish farmers. Hence, it is suggested that extension agencies and other concerned institutes should give more focus on targeted interventions on converting the medium level to high level of entrepreneurial behaviour among fish farmers to enhance their entrepreneurial behaviour and address barriers in adoption of fish farming. The findings of the study provide valuable insights for farmers, researchers, and extension personnel's, which are contributing in the fisheries sector.

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Epidemiological Investigation of Mixed Parasitic Infections Associated with High Mortality in a Goat Herd in Punjab, India

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ABSTRACT

Gastrointestinal (GI) parasitic infestations are common in small ruminants (sheep and goats), causing considerable financial losses due to mortality and reduced production. An epidemiological investigation was initiated to determine the cause of the mortality at a farm in the Faridkot district of Punjab. A total of 50 goats, including 29 young ones and 21 adult goats, were involved in this study. The farm was inspected on 08 April, and data was collected regarding physical examination, clinical signs, and management practices. Symptomatic treatment was started on 08 April with ivermectin 0.2 mg per kg along with iron tonic, liver supplement, as the animals seemed anemic and had no deworming history in the last six months. To find the cause of death, four blood samples and 29 fecal samples were collected, out of which 28 samples were from clinically infected and one sample from a clinically healthy animal as control. The presence of parasite stages was identified based on their morphological characteristics. The data generated from the investigation were processed for further descriptive analyses. Out of the total of 50 animals, 25 (50%) goats were died; maximum mortality was found in goats less than one year of age, 68% (n=17), followed by the 1-2 year age group, 20% (n=5), and 12% (n=3) in adult goats, respectively. The most prevalent parasites were coccidia and strongylus. Even mixed infection of strongyle and coccidia had the highest prevalence (37.93%), followed by strongyle, coccidian, and moniezia (20.68%). The findings emphasized the importance of comprehensive parasite control programs in goat herds, including routine fecal monitoring, strategic deworming, coccidiosis prevention, and good management practices to reduce exposure.

Key Words: Coccidian, Deworming, Ivermectin, Moniezia, Strongylus,

INTRODUCTION

Goat entrepreneurs has a broad economic range, and poor farmers can easily rear goats (Meena *et al,* 2023; Das *et al,* 2024). Due to the low rearing cost, they play an essential role in providing a livelihood to rural families (Tiwari *et al,* 2014; Bashir *et al,* 2023). India has seen rapid growth of goat population in the recent years with 148.88 million goats according to the 20th census, showing an increase of 10.1% over the previous census (Animal husbandry statistics, 2023). Out of which 347949 populations were recorded in Punjab (20th Livestock Census, 2019). Punjab is continuously leading in the goat sector. According to the 19th census, the goat population was 327272, which was increased by 6.31% in the 20th census (19th Livestock census, 2012). Endoparasites particularly of the Gastro-intestinal tract are very common among these small ruminants and accounts for huge economic

loss as a result of mortality and decreased production. Most commonly found endoparasites among small ruminants are helminths and coccidia (Waruiru *et al,* 1993; Ozung, 2011). Clinically it is characterised by cachexia, diarrhoea and anaemia, and is thought to be among the most devastating diseases of small ruminants as per economics are concerned (Chhabra and Pandey, 1992). Suspicion is primarily made based on poor animal husbandry management and increased mortality particularly among the young animals during the weaning period (Chartier and Paraud, 2012).

Among all these gastrointestinal parasites, nematodes are of major importance and causes huge economic loss. They remain as a major threat to the small ruminants by causing several effects such as hypoproteinaemia, decreased growth, decreased production, inappetence and indigestion (Gebhardt and Thomas, 2002; Luginbuhl 2015). Among the helminth

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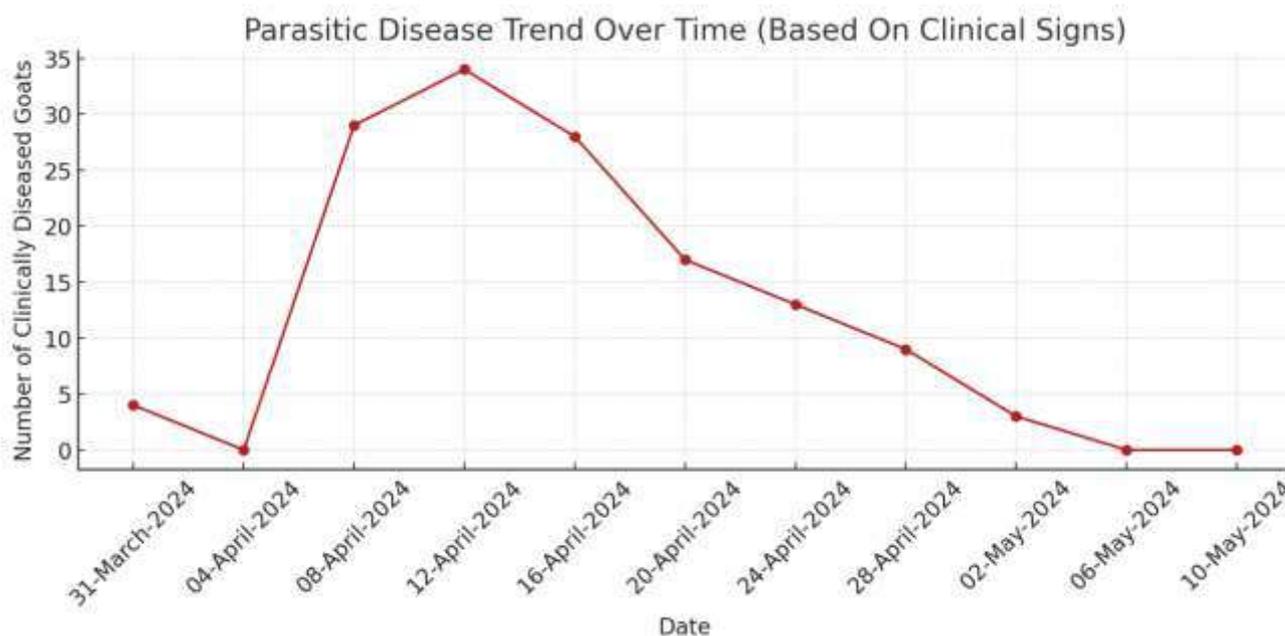
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Fig. 1: Parasitic Disease Trend over Time (Based on Clinical signs)

parasites of small ruminants, *Moniezia expansa* is one of the most widely distributed cestodes found in every part of the world (Nama, 1990). Monieziasis is mostly associated with moderate infection, but occasionally severe infection can also occur and is associated with pot-belly, inability to gain weight, diarrhoea, anaemia, decreased production even mortality among the animals (Fagbemi and Dipeolu, 1983; Zhao *et al*, 2009; Yan *et al*, 2013). Kaur and Kaur (2008) reported that the overall prevalence of GI helminths among these small ruminants was 82% from Patiala and its nearby area, and the recorded parasites were Trichostrongylus sp. (78.57%), Haemonchus sp. (64.29%), Strongyloides sp. (57.14%), and Oesophagostomum sp. (42.86%). In the adjoining country, Pakistan, Gadahi *et al* (2009) reported the prevalence of Haemonchus (64.19%), Trichuris (35.48%), Nematodirus (13.00%), Trichostrongylus (4.51%), and Strongyloides (3.22%) in goat from Rawalpindi and Islamabad. As we know very well, parasites are an important factor in producing economic loss in goat rearing. An overview of the present work was designed to investigate the main parasitism and co-factors involved in a high infestation and high mortality rate due to mixed parasitic infection reported in a Goat Herd in Punjab.

MATERIALS AND METHODS

The area under study falls in the Faridkot district (Latitude 30.657256, Longitude 74.771290), the Southwest area of Punjab state. A gastrointestinal infection and death rate in a goat farm was reported by a farmer on 08 April at the veterinary polyclinic, Faridkot, Punjab. The farm was rearing 50 goats mainly for milk and breeding purposes. A total of 50 goats, including 29 young ones and 21 adult goats, were involved in this study. Most of the animals were female, 78% (39), and 22% (11) were male. According to the history provided by the farmer, four goats died from 31 March to 04 April 2024. The farm was inspected on 08 April, and it was found that 12 animals were affected. Data was collected regarding physical examination, clinical signs, management practices, history of recent purchase or sale, vaccination, deworming, feeding practices, mortality, and quarantine history. To combat clinical signs, a symptomatic treatment was started on 08 April with ivermectin 0.2 mg per kg along with iron tonic, liver supplement, as animals seemed anaemic, inappetent, and had no deworming history in the last six months. To find the cause of death, four blood samples and five fecal samples were collected on 10 April, and 24 faecal samples were collected on 16 April. Twenty-nine faecal samples were collected, out of which 28 samples from animals having clinical signs and one sample from a clinically healthy animal were collected as controls. Faecal samples were collected per-rectally and were placed in a faecal container. All the containers were properly marked for sampling date, age of the animal, identification number or mark if any and sex. The samples were transported on the same day to the polyclinic in Faridkot for examination. Findings at the

Epidemiological Investigation of Mixed Parasitic Infections Associated

Table 1: Results of fecal flotation method technique of 29 samples

Sr. No.	Gender	Age	Result
	M= Male **F= Female**		**Qualitative (ova/oocyst)**
1	M	2.5 years	Coccidia
2	F	04 months	Strongyle, Coccidia
3	F	02.5 years	Strongyle, Coccidia
4	F	05 months	Strongyle
5	F	03 months	Coccidia
6	F	05 months	Strongyle
7	F	06 months	Strongyle, Monezia
8	F	07 Months	Strongyle, Coccidia, Monezia
9	F	1.5 years	Strongyle, Coccidia
10	F	1.5 years	Strongyle, Coccidia, Monezia
11	F	02 years	Strongyle, Coccidia, Monezia
12	F	06 months	Strongyle, Coccidia
13	F	06 months	Strongyle, Monezia
14	F	03 years	Strongyle, Monezia, Strongyloides
15	M	06 months	Strongyle, Coccidia, Monezia
16	F	1.5 years	Strongyle, Strongyloides
17	F	05 months	Strongyle, Coccidia
18	M	04 years	Strongyle, Coccidia
19	F	2.5 years	Negative
20	F	08 months	Strongyle, Coccidia, Monezia
21	F	02.5 years	Strongyle, Coccidia
22	F	04 months	Strongyle
23	F	01 year	Coccidia
24	F	2.5 years	Strongyle, Coccidia, Monezia
25	F	06 months	Strongyle, Coccidia
26	F	06 months	Coccidia
27	F	02 months	Strongyle, Coccidia
28	F	06 months	Strongyle, Coccidia
29	F	06 months	Strongyle, Coccidia

investigation site was such that the farm condition was unhygienic, goats were reared on an intensive farming system, and deworming was not done in the past six months. Goats had poor body condition, a sign of poor nutrition and animal husbandry practice.

Examination of samples

About 3 g of faecal sample from each animal was mixed with 45 mL of flotation fluid, sodium chloride (1.2 specific gravity) (Dryden *et al,* 2005). Parasite stages (eggs or larvae of helminths, oocysts of coccidia) were identified based on their morphological characteristics (Urquhart *et al,* 1996; Van Hautert *et al,* 1996) using 10× and 40× magnification. Blood samples were examined through a private laboratory.

Statistical analysis

The data generated from the investigation were entered in a Microsoft Excel (2007) worksheet,

and was processed for further analyses. For each parasite species, prevalence was calculated as the number of goats infected with that parasite divided by the herd total, expressed as a percentage. Mixed infection prevalence was calculated as the proportion of goats harbouring more than one parasite species. Descriptive statistics (frequencies, percentages) were compiled for clinical signs and outcomes (e.g., mortality rate). The parasitic disease trend was analyzed using R statistical software.

RESULT AND DISCUSSION

In the present investigation a total of 50 goats were analyzed. Among these majority of the goats were female n=39 (78%), and n=11 (22%) was male. 58% (n=29) goats were less than one year old, 18% (n=09) were between 1 and 2 years of old, and 24% (n=12) goats were more than 2 years of old. Out of a total of 50 animals, 44 were got infected, out of which 19 (43%)

goats recovered successfully from the infection. Out of the total population (n=50) total mortality was 50% (n=25); maximum mortality was found in goats less than one year of age, 58.6% (n=17/29), followed by the 1–2-year age group, 55.5% (n=05/09), and 25% (n=3/12) in adult goats, respectively. Gender, female, showed a high mortality rate that was 51.2% (n=20/39) as compared to male 45.45% (n=5/11) in this study. The possible reason for higher infection in young animals might be due to a lower immune status as compared to the adult goats, which have acquired natural resistance due to repeated infection. These findings were similar to Talukdar, 1996 and Pundlikrao, 2009 (The prevalence of helminths was 78.13%, 60.87%, 41.87% and 57.14% respectively among goats below 1year, between 1 to 2 years, between 2 to 4 years and above 4 years). In the present study higher infection rate were observed among the female goats as compared to the male goats, which is similar to many other researchers (Prevalence of Gastrointestinal parasites was 85.97% in females and 69.23% in males) and possible reason might be due to different physiological factors like gestation, lactation which leads to decrease in the immune potential of the animal (Singh *et al,* 2017).

All cases in this analysis occurred in early summer (31 March to 10 May, 2024), which is typically a peak season for parasites given warm weather (Maximum temperature 31-37 °C in March and April) (Anonymous, 2024). In this study, seasonal variation was not compared as the epidemiological study was only evaluated during the summer season. Many other previous studies were in the agreement of the finding that highest incidence of the disease was noticed during peak summer with humid conditions (Talukdar, 1996) which is due to the sustainability and reproduction of the parasites (The rate of infection was highest (35.34%) in summer and lowest (13.95%) in winter). Based on clinical history, the first four cases of parasitism were reported between 31 March to 04 April, then surge of 29 cases was reported till 04-08 April 2024, which further increased up to 34 cases till 12 April then a down fall of cases started as symptomatic treatment was initiated using Ivermectin and Fenbendazole combination, hematinic and liver tonics as per body weight from 08 April, after diagnosis of parasitic infection. Amprolium was further added in treatment for the control of coccidiosis @ 50mg/kg from 11 April, which led to recovery in the flock, as Amprolium was a line of treatment for the control of coccidiosis (Fig. 1).

Fecal examinations confirmed GI parasitic infections in all goats (n=28), those having clinical symptoms, except one sample (control) out of the total 29 samples. The identified parasite species is summarized in Table 1. The most prevalent parasites were coccidia and strongylus. Strongyle and coccidia mixed infection had the highest prevalence 37.93% (n=11), followed by strongyle, coccidian and moniezia 20.68% (n=06), coccidian 13.79% (n=04), strongyle10.34% (n=03), strongyle and moniezia 6.89% (n=2), other mixed parasite (strongyle, moniezia and strongyloides), and (strongyle and strongyloides) were 3.44% (n=1 each) respectively. As shown above, coccidial infection was detected in the majority of goats, n=21 (72%). This is expected, as coccidia are ubiquitous in goats.

Nearly all infected goats (n=44) were presented with weight loss or poor body condition, lethargy. Out of 44 infected goats 77.27% of goats showed emaciation, 65.9% showed pale mucous membranes (a sign of anemia). Approximately 56.81 % of the goats exhibited inappetence and diarrhea. Submandibular edema ("bottle jaw"), indicating severe hypoproteinemia and anemia in 6.81% of goats that were infected in this study. Those with the heaviest parasite burdens and severe clinical signs (severe anemia, hypoproteinemia, etc.) did not survive, despite treatment. The present study showed a high prevalence of strongyle and coccidia infection in the herd, which might be due to the large number of species in the genus and coccidiosis due to poor hygienic practices followed in the shed. The presence of diarrhea, weight loss, anemia and bottle jaw in the animals were similar to the previous reports.

The prevalence of coccidia and other gastrointestinal nematodes may be due to no prior administration of dewormers and coccidiostat drug by the farmer. This proves that the climatic conditions were favoring development of parasites and its propagation. Apart from this constant exposure to infections, continuous deposit of infections material on the pasture land by the adult ruminants and poor management practices as discussed earlier.

CONCLUSION

The present investigation revealed that unhygienic animal husbandry conditions and improper deworming status were the major factors for the prevalence of helminths and coccidia, that could lead to a high mortality. The findings emphasize the importance of comprehensive parasite control

programs in goat herds, including routine fecal monitoring, strategic deworming, coccidiosis prevention, and good management practices to reduce exposure. Moreover, the seasonal pattern of parasitic infection needs to be investigated, which will help in the preparation of suitable control strategies, ultimately helpful for goat rearing in Punjab.

Ethics statement: As this was a disease investigation, data collection and treatment were involved in this study; no laboratory animal was used or sacrificed in this study. So, ethical permission was not required in this study.

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GIS Techniques for Soil Fertility Assessment and Soil Health Improvement in Watershed Area of Northern Karnataka

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ABSTRACT

The ever-growing global population and increasing demands for food security have led to intensified agricultural practices, which in turn have altered soil biotic and abiotic factors, significantly impacting soil health and ecosystems. Soil health is a critical component for achieving sustainable agriculture. Current land and crop management practices have resulted in issues such as yield stagnation, nutrient depletion, soil degradation and decline in soil quality. To ensure food security and long-term sustainability, it is essential to conserve and manage land and soil resources while maintaining soil fertility. In this context, a sub-watershed in Jalawadha, covering an area of 780.86 ha in Devara Hipparagi taluk, Vijayapura district, Karnataka, was selected for soil nutrient assessment. Using GIS techniques, 13 mapping units were delineated based on soil-site characteristics. The study revealed that soil pH ranged from moderately to strongly alkaline. Organic carbon (OC) levels were low in 79.33 percent of the watershed area, and medium in 19.47 percent. Regarding major nutrients, most of the area had low levels of available Nitrogen (N) and Sulphur (S), medium levels of available Phosphorus (P), and high levels of Potassium (K). The GIS-based LRI of Jalawadha sub-watershed revealed alkaline soils with deficiencies of organic carbon, nitrogen, and sulphur, but adequate phosphorus and high potassium. These imbalances stress the need for integrated fertility management through balanced fertilizers with organic mulching, manures, crop residue incorporation, and amendments, which are vital to restore soil health, enhance productivity, and ensure sustainable agriculture.

Keywords: GIS techniques, Soil fertility assessment, Soil health, Sustainable agriculture, Watershed.

INTRODUCTION

Rainfed areas contribute over 40 per cent to India's total food production, but they are often characterized by low productivity, land degradation and the adverse effects of climate change. To achieve sustainability in these areas, it is essential to protect and improve land resources such as soil fertility and available soil moisture (Sharma and Paliyal, 2015). The intensive cultivation of crops has led to the depletion of nutrients from the soil (Meena and Dudi, 2018). Soil assessments for various nutrient statuses are vital for enhancing soil fertility and improving land productivity (Biradar *et al,* 2020; Sunil *et al,* 2020). Integrating these assessments with site-specific management practices can help maintain ecological balance. The adoption of organic amendments and conservation-based approaches further ensures resilience and long-term sustainability of rainfed farming systems. It is well established that dryland soils are both thirsty and hungry (Wani, 2008), which underscores the need for effective nutrient management to increase the productivity of rainfed watersheds. Geographic Information Systems (GIS) offer a powerful tool to integrate spatial information such as agro-climatic zones, land use and soil management, providing valuable insights for better land management (Adornado and Yoshida, 2008). Collecting soil samples with geographic references and conducting soil tests helps to develop site-specific recommendations for improving soil health. By identifying nutrient constraints in specific areas using Global positioning systems (GPS), we can make balanced and precise fertilizer recommendations, optimizing resource use. With this objective in mind, the current study focused on soil-site characterization to assess the nutrient status in the soils of the Jalawadha sub-watershed.

Table 1. Soil fertility ratings for available nutrients.

Parameter	Low	Medium	High
Electrical Conductivity (EC), dSm $^{-1}$	2-4	4-8	>8
Organic carbon (OC), %	<0.5	0 5.0-0.75	>0.75
Macronutrients (kg ha^{-1})			
Nitrogen (N)	<280	280-560	>560
Phosphorus (P$_2$O$_5$)	<23	23-57	>57
Potassium (K$_2$O)	<145	145-337	>337
Sulphur (S), mg kg^{-1}	<10	10-20	>20
	Deficient		**Sufficient**
Calcium (Ca), ppm	<1.5		>1.5
Magnesium (Mg), ppm	<1		>1
Micronutrients (mg kg^{-1})			
Iron (Fe)	<4.5		>4.5
Zinc (Zn)	<0.6		>0.6
Copper (Cu)	<0.2		>0.2
Manganese (Mn)	<1.0		>1.0
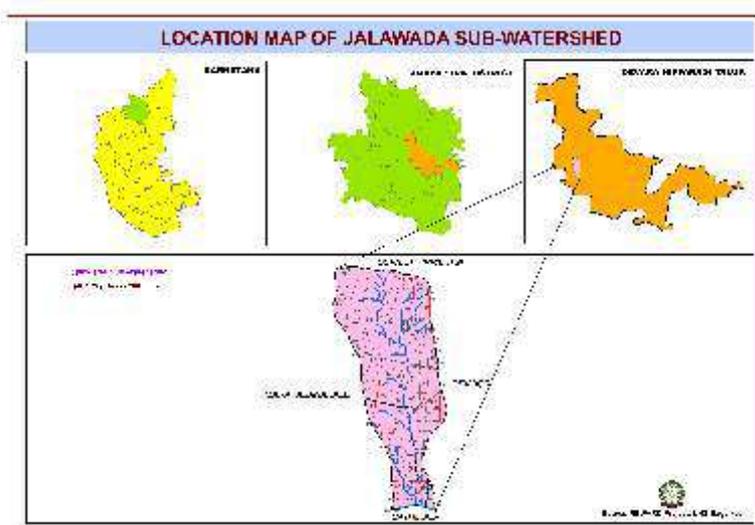
Fig. 1: Location and Extent of Jalawadha sub watershed

MATERIALS AND METHODS

Description of study area

The Shorten-Jalawadha subwatershed (780.87 ha) is located in the hot semi-arid agro-ecological region of India, between 16°36'30" to 16°55'30" N latitudes and 76°0'0" to 76°24'0" E longitudes (Fig.1), in Devara Hipparagi taluk, Vijayapura district, Karnataka. The length of crop growing period in this area is around 120-150 days. The dominant soils are medium to deep black clay, with shallow to moderately shallow in some areas.

Soil survey, sampling, and fertility mapping methodology

Soil survey was conducted using IRS LISS IV and Cartosat-1 satellite images, following the Field Guide for Land Resource Inventory (LRI) of the Sujala-III project (ICAR-NBBSS & LUP, 2016). The survey recorded surface characteristics such as slope, erosion, gravelliness, calcareousness, stoniness and texture. A total of 77 composite soil samples were collected at 320 m grid intervals, analyzed for macro and micronutrient status, salinity, pH, organic carbon and other fertility parameters. Soil chemical and fertility analyses followed standard procedures (Jackson, 1973; Olsen and Sommers, 1982; Sahrawat and Burford, 1982; Nelson and Sommers, 1996;). Fertility maps were created using GIS, integrating data and spatial analysis in ArcGIS 10.8.2 (Mary Silpa and Nowshaja, 2016; Mishra and Babu, 2009).

Fig. 2: Soil reaction map of Jalawadha subwatershed

Fig. 3: Electric conductivity map of Jalawadha subwatershed

Fig. 4: Organic carbon map of Jalawadha subwatershed

Fig. 5: Available nitrogen map of Jalawadha subwatershed

Fig. 6: Available phosphorus map of Jalawadha subwatershed

Fig. 7: Available potasium map of Jalawadha subwatershed
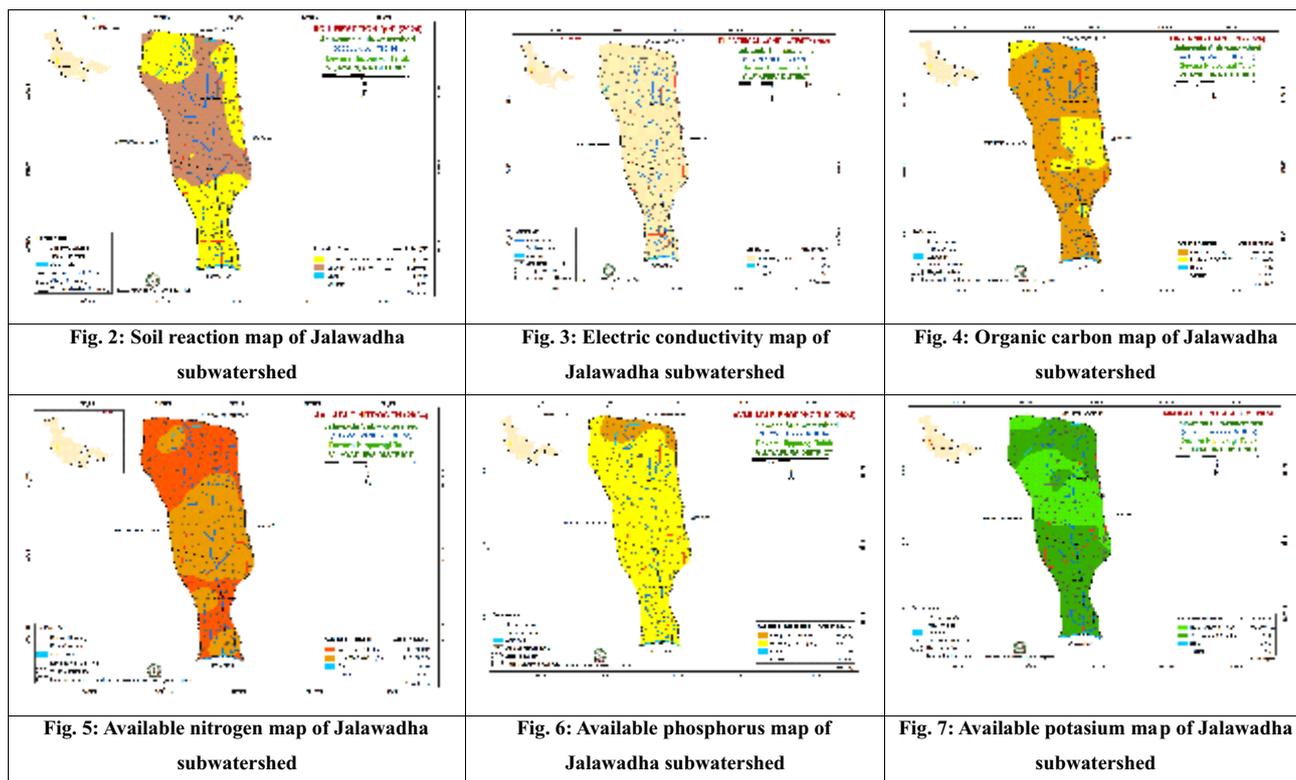
RESULTS AND DISCUSSION

Soil reaction and electrical conductivity

Jalawadha sub watershed soil were moderately alkaline to strongly alkaline in reaction (7.8- 9.0). Mapping of soil pH by GIS technique showed that major sub watershed area (50.91%) is strongly alkaline followed by 47.9% area is moderately alkaline (Fig. 2). Higher soil reaction in the sub watershed might be due to calcareousness, sodicity and low leaching intensity and accumulation of bases in sub horizons. The soils in Jalawadha sub watershed were nonsaline in major area (98.8 %) (Fig. 3). GIS mapping based on surface samples from Jalawadha sub watershed revealed that major area *i.e.* 79.33 percent has been classified as low and 19.47 per cent as medium in organic carbon status (Fig. 4). Low organic carbon in these soils is due to the prevalence of arid condition which causes faster degradation of organic matter besides little or no application of organic manures to soils and less vegetative cover in the fields, thereby reducing organic carbon accumulation. The similar results were reported by Prabhavati *et al* (2015).

Available macro nutrients

GIS mapping of Jalawadha sub watershed for available N depicts that the soils ranged from very low

(46.04% area) to low (52.76% area) (Fig. 5). The low N content is attributed to higher fixation and volatilization losses in black soils, low organic matter content in soils and intensive crop cultivation without proper fertilization. The results are in agreement with findings of Pulakeshi *et al* (2012) and Ravikumar *et al* (2007). Most of the study area (90.01%) was classified as medium and about 8.8 percent area is low in available phosphorus content (Fig. 6). Medium P_2O_5 availability in these soils is related to their high pH, calcareousness and low organic matter content. Present results are similar with findings of Ravikumar *et al* (2007) and Patil *et al* (2011). About 60.66 percent of the sub watershed area was very high and 37.14 per cent area was high in available K in the soils (Fig. 7). Water soluble and exchangeable K invariably higher in the surface soils of Karnataka (Patil *et al,* 2011), hence such soils can maintain sufficient exchangeable K and supply adequate K to plants. The medium to high available potassium in sub watershed might be attributed to predominance of parent material having potash rich micaceous and feldspar minerals. Similar results were observed by Srikant *et al* (2008) and Pulakeshi *et al* (2012). The study revealed that available S content in sub watershed soils ranged from low to high classes. Majority of the study area (85.53%) was low and 13.28 percent area is medium in available S status. Low and medium levels of available sulphur were due to lack of sulphur addition to fields

and continuous removal of S from soils by high yielding crop varieties (Srikant *et al,* 2008 and Pulakeshi *et al,* 2012).

CONCLUSION

From the study, it can be concluded that, soils of Jalawadha sub watershed in Northern dry zone of Karnataka are moderately to strongly alkaline with no salinity. Soil organic carbon content was low. Most of the sub watershed area was low in available nitrogen, medium in available phosphorus, very high in potassium and low in sulphur. The use of GIS technology for mapping of soil nutrients helps in easy and quick interpretation of soil fertility and site-specific management of nutrient deficiency. The 25 percent additional fertilizer of particular nutrient should be applied than recommended rate to the specific areas where deficiency is seen to improve the crop productivity. Integrated nutrient management practices such as agroforestry systems, crop rotation, use of organic inputs (compost and FYM), chemical fertilizers and improved crop varieties that can be adapted in nutrient deficit areas to improve the soil fertility in the long term. Soil conservation practices should be adopted to reduce soil erosion, loss of nutrients along with runoff water and nutrient mining should be reduced to maintain fertile soil in watershed area and to achieve the sustainability through soil health along with improving the economy of the watershed areas.

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Good Agricultural Practices for Sustainable Production of Tomato Crops in Mizoram

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ABSTRACT

Different good agricultural practices (GAP) for sustainable production of tomatoes, *viz.,* high-yielding varieties, community nursery under protected structure, popularisation of community water harvesting and micro irrigation, furrow irrigated raised bed (FIRB) planting for water use efficiency, mulching with locally available materials, application of zinc and boron and intercropping with marigold were demonstrated in different agro-climatic zones in the Serchhip district through sixty demonstrations by KVK, N. Vanlaiphai, Serchhip District with the aim for increased tomato productivity quality through optimum utilization of available resources and technologies. The result showed that demonstrating good agricultural practices (GAP) significantly boosted tomato yield. The findings from the current study showed that the good agriculture practices of tomato cultivation increased the total tomato production by almost 30-40% compared to conventional crop production practices followed in Serchhip District, N. Vanlaiphai, Mizoram.

Keywords: Economics, Extension gap, Front-Line Demonstrations , Good agricultural practices, Tomato,Technology Gap,Yield.

INTRODUCTION

Tomato (*Solanum lycopersicum* Mill.) is a major vegetable crop cultivated year-round across tropical, subtropical, and temperate regions worldwide (Oraon *et al,* 2018). It holds substantial value in both fresh produce markets and the processing industry (Reddy *et al,* 2022). Nutritionally, tomatoes are a rich source of vitamins A and C, as well as lycopene a carotenoid responsible for the characteristic red colour of ripe tomatoes, which is also believed to have anti-cancer properties (Tripathy *et al,* 2021; Malathi *et al,* 2021). Additionally, tomatoes serve as natural antioxidants as ascorbic acid (Vitamin C) present in them plays a crucial role in scavenging reactive oxygen species such as superoxide, hydrogen peroxide, and singlet oxygen, while beta-carotene helps prevent and neutralize free radical chain reactions (Rehal and Kaur, 2021). According to FAOSTAT (2022), global tomato production reached approximately 186.82 million tonnes in 2022, cultivated over an area of 5 million hectares, with an average productivity of 36.97 t/ha. China led global production with 64.86 million tonnes, accounting for 34.72% of the total, followed by India with 20.57 million tonnes (11.01% of global output).

In Mizoram, tomatoes are cultivated over 1,470 ha, yielding a total production of 11,870t. Among its districts, Serchhip is a key tomato-growing region, with 568 ha. under cultivation and a production of 6,055 MT, averaging 10.66 t/ha (Directorate of Economics and Statistics, Government of Mizoram, 2022). Despite its potential, tomato productivity in Serchhip remains relatively low due to a combination of limiting factors such as undulating terrain, dependence on rainfed agriculture, and water scarcity during the dry season (November to March). Furthermore, the use of unscientific farming practices, limited access to quality seeds and inputs, and both biotic and abiotic stresses significantly constrain production. To overcome these challenges, the promotion and adoption of Good Agricultural Practices (GAPs) have been advocated. GAPs encompass a set of principles, guidelines, and technical recommendations designed to ensure sustainable tomato production, post-harvest handling, and marketing. In response, Krishi Vigyan Kendra (KVK), Serchhip, implemented Front-Line Demonstrations (FLDs) to showcase

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Table 1: Details of Good Agricultural Practices for Tomato Cultivation

S. No.	Technology intervention	Farmer's practice	Improved technology demonstrated	Gap
1	Variety	Arka Abhed	Arka Abhed	No Gap
2	Nursery Raising & Management	• Seed rate: 200 g/ha • Proper nursery management not followed	• Seed rate: 150 g/ha • Community nursery under protected structure for disease-free planting material	Partial Gap
3	Transplanting Method	• Flatbed transplanting Row-to-row: 60 cm; Plant-to-plant:60 cm	• Furrow Irrigated Raised Bed (FIRB) method • Raised bed: 90 cm wide, 20 cm high • Irrigation furrow: 30 cm • Transplanting on both sides of bed • Furrow irrigation (¾ height) • Mulching with paddy straw @ 7.5 t/ha	Full Gap
4	Nutrient Management	• Application of Manure and Fertilizes without soil test & recommendation	• Application based on soil test reports • Foliar spray of Zinc 0.5% + Boron 0.5% at 30-day intervals starting 60 days after transplanting	Full Gap
5	Water management	• Limited use of micro-irrigation systems	• Construction of *Jal Kund*, community water storage tanks, and *Amrit Sarovar* for irrigation • Use of drip and other micro-irrigation systems to improve water use efficiency	Partial Gap
6	Weeding and intercultural operations	• Manual weeding	• Mulching with locally available materials • Manual weeding	Partial Gap
7	Disease and Pest Management	• Chemical application without proper knowledge	• Adoption of Integrated Pest Management (IPM) • Intercropping with marigold • Use of yellow sticky traps	Full Gap

improved tomato cultivation technologies across various agro-climatic zones of the district.

MATERIALS AND METHODS

Front-line Demonstrations (FLDs) on Good Agricultural Practices (GAPs) for sustainable tomato production were conducted by Krishi Vigyan Kendra (KVK), Serchhip, at multiple locations across Serchhip District during the cropping seasons of 2022-23 and 2023-24. A total of 60 farmers from different villages were selected to participate in the demonstrations. Critical inputs were provided to the farmers and applied according to the recommended package of practices. The technologies demonstrated are detailed in the table 1. Baseline data from all 60 participating farmers were collected through personal interviews using a well-structured interview schedule, both before and after the demonstrations. Prior to implementation, beneficiary farmers were given skill training sessions. Continuous technical support was also provided through regular field visits and WhatsApp-based advisories. Data on crop yield and economic performance were recorded and used to compute the following metrics as per the method proposed by Samui *et al* (2000).

Table 2: Pooled data (2022-23 and 2023-24) on growth and yield attributes under FLDs

S. No.	Parameter	Demonstration	Farmer's Practices
1	Days to 50% flowering	36.20	38.50
2	No. of fruits per plant	26.00	24.00
3	Days to first harvesting	72.00	77.00
4	Average fruit weight (g.)	91.50	72.50
5	Yield q/ha	363.34	264.67

Table 3: Yield Performance, Extension Gap, Technology Gap, and Technology Index under FLDs

Year	No. of FLDs	Yield (q/ha)- FLD	Yield (q/ha)- Local Check	% Increase Over Local Check	Technology Gap (q/ha)	Extension Gap (q/ha)	Technology Index (%)
2022–23	60	352.44	257.78	36.72%	247.56	94.67	41.26%
2023–24	60	374.23	271.56	37.81%	225.77	102.67	37.63%
Mean	60	363.34	264.67	37.28%	236.66	98.67	39.44%

Table 4: Economics of front-line demonstrations of tomato

Years	Cost of Cultivation (₹/ha)		Gross Return (₹/ha)		Net Return (₹/ha)		B: C Ratio	
	FLD	Local Check	FLD	Local Check	FLD	Local Check	FLD	Local Check
2022-23	104600	84940	317200	232000	212600	147060	3.03	2.73
2023-24	106600	87940	336807	244404	230207	156464	3.16	2.78
Mean	105600	86440	327004	238202	221404	151762	3.10	2.76

RESULTS AND DISCUSSION

Growth Attributes and Yield

The results presented in table 2 shows significant differences in growth and yield attributes between the demonstration plots and farmer' practices. The Front-Line Demonstrations (FLDs) recorded earlier flowering (36.20 days to 50% flowering) and earlier harvesting (72.00 days to first harvest) compared to the farmers' traditional practices (38.50 days and 77.00 days, respectively). Additionally, the FLDs exhibited superior yield attributes, including a higher number of fruits per plant (26.00 vs. 24.00), greater average fruit weight (91.50 g vs. 72.50 g), and a substantially higher average yield (363.34 q/ha vs. 264.67 q/ha). The improved performance in the demonstration plots can be attributed to the comprehensive adoption of Good Agricultural Practices (GAPs). These included the use of raised beds, mulching, soil test-based nutrient management, timely irrigation using micro-irrigation systems, and effective plant protection measures such as the use of yellow and blue sticky traps. These findings are consistent with previous studies by Nagouajio et al (2008), Islam *et al* (2012), Mishra *et al* (2009), Kumar *et al* (2022), Shukla *et al* (2022), Hobbs (2023) and Ramniwas *et al* (2023) and which documented yield improvements in various crops through the adoption of improved agricultural technologies under frontline demonstration programmes.

Yield improvement, extension gap, technology gap, and technology index in front-line demonstrations

The impact of Front-Line Demonstrations (FLDs) on tomato productivity is summarized in Table 3. The data clearly indicate that the demonstrations significantly improved tomato yields compared to the farmer's practices (local check). In 2022-23, FLDs achieved a 36.72% increase in yield over the local check, while in 2023-24, the increase was 37.81%. The average yield increase across the two years was 37.28%, demonstrating the consistent effectiveness of the improved practices. The technology gap, which is the difference between the potential yield and the demonstrated yield, was recorded at 247.56 q/ha in 2022-23 and 225.77 q/ha in 2023-24, with a mean gap of 236.66 q/ha. These differences can be attributed to various local factors such as soil fertility, soil type, irrigation water quality, microclimatic conditions, pest pressure, and farmer-specific management practices. This highlights the importance of developing and promoting location-specific recommendations to minimize these gaps and enhance yield performance. The extension gap-the difference between

demonstration yield and yield from farmers' traditional practices ranged from 94.67 to 102.67 q/ha during the study period, with a mean of 98.67 q/ha. The substantial extension gap suggests a strong need for increased awareness and adoption of improved agricultural technologies among farmers to boost productivity. The technology index, which reflects the feasibility and adaptability of demonstrated technologies under real farm conditions, decreased from 41.26% in 2022-23 to 37.63% in 2023-24. A lower technology index indicates greater potential for technology adoption. The declining trend suggests increased acceptability and suitability of GAP-based tomato cultivation practices among the farmers in the region. These findings align with earlier studies by Pandey and Chandra (2013), Kumar *et al* (2022), Shukla *et al* (2022) and Ramniwas *et al* (2023), all of which demonstrated the positive impact of improved technologies under FLDs in bridging the yield gap

Economics of front-line demonstrations

The economic analysis of tomato yield performance revealed that farmers participating in the Front-Line Demonstrations (FLDs) achieved significantly better economic returns compared to those following traditional practices and selling in local markets. The improved package of practices not only enhanced yield but also allowed farmers to fetch better prices due to higher quality produce. The results indicated that the mean cost of cultivation was higher in the demonstration plots (₹ 1,05,600/ha) compared to the farmer practice plots (₹ 86,440/ha). However, this higher investment led to substantially greater returns. The mean gross returns from FLDs were ₹ 3,27,004/ha, while those from the farmer practice plots were ₹ 2,38,202/ha. Consequently, the mean net returns were also higher in the FLD plots at ₹ 2,21,404/ha, as compared to ₹ 1,51,762/ha under traditional farmer practices. Importantly, the benefit-cost (B:C) ratio, an indicator of economic viability, was significantly improved under FLDs. The average B:C ratio was 3.10 for the demonstration plots, while it was 2.76 for the farmer practice plots. This demonstrates the clear economic advantage of adopting Good Agricultural Practices (GAPs) in tomato cultivation. These findings are consistent with earlier studies by Kumar *et al* (2022), Shukla *et al* (2022) and Ramniwas *et al* (2023), who reported similar improvements in profitability through the adoption of improved cultivation technologies under FLDs.

CONCLUSION

The present study clearly demonstrated that the adoption of good agricultural practices plays a pivotal role in enhancing the productivity, profitability, and sustainability of tomato cultivation in the Serchhip district of Mizoram. The Front-Line Demonstrations (FLDs) conducted over two years significantly improved yield performance, with an increase of nearly 30-40% compared to traditional practices. These improvements were attributed to scientific nursery management, proper nutrient and water management, pest and disease control using IPM, and efficient planting techniques. In addition to improving yields, the adoption of GAPs led to higher net returns and a more favourable benefit-cost ratio, indicating strong economic viability. The demonstrations also contributed to increased awareness among local farmers, encouraging the wider adoption of sustainable practices across the district. Overall, the study concludes that GAPs not only contribute to safe and environmentally responsible tomato production but also serve as a catalyst for improving farmers' livelihoods through increased income and better resource use efficiency. Continued promotion and scaling up of such practices, supported by location-specific recommendations and training, are essential for the long-term development of tomato cultivation in the region.

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Impact Assessment of Cluster Frontline Demonstrations on Indian *Brassica napus* var. GSC-7 in Ludhiana District

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ABSTRACT

Gobhi Sarson is an important oilseed crop of the *Rabi* season contributing significantly to farmer's income and national edible oil production. However, low productivity due to the use of outdated varieties and suboptimal agronomic practices remains a major challenge for farmers in the region. The cluster frontline demonstrations on *Brassica napus* GSC-7 were carried out during *Rabi* 2023-24, covering an area of 20 ha in the Ludhiana district. The impact of frontline demonstrations on yield gaps and economics was studied through demo plots with improved practices and check plots with farmer practices. It was revealed that yield was significantly higher in demonstrated variety (GSC 7) *i.e.,* 21.20 q/ha with improved package of practices than check variety (Hyola-401) with farmer practices having yield of 19.57 q/ha. The average technology gap, extension gap and technology index were estimated to be 1.63, 1.05 and 4.95, respectively. Significantly better economic returns in terms of both net return (90556) and benefit cost ratio (4.56) were also observed in demo plots. Overall, farmers benefited from front-line demonstration on Gobhi sarson, as they get crop with better quality and higher yield following improved package of practices.

Key Words: *Brassica napus,* Extension gap, Frontline demonstrations, Impact.

INTRODUCTION

India is the world's fourth largest vegetable oil economy and the third largest producer of rapeseed-mustard after Canada and China, contributing to about 14 % of the world's total production (Renjini and Jha, 2023). Rapeseed-mustard (*Brassica* spp. L.), family Brassicaceae is a group of crops which includes four oleiferous brassicas *viz., Brassica juncea* (Indian mustard/ raya/laha), *B. rapa* (Indian rape/toria, yellow sarson, brown sarson), *B. napus* (Oilseed rape/gobhi sarson) and *B. carinata* (Ethiopian mustard/African sarson) and taramira/Rocket salad (*Eruca sativa*) (Chauhan *et al,* 2012). Rapeseed-mustard ranks just behind soybean among oilseed crops in the country in terms of both area and production. The cultivation of these crops across 28 states in India, under diverse agro-ecological situations, covers an area of 9.3 million hectares and produces 11.6 million tonnes, highlighting its significance in the country's vegetable oil sector (USDA, 2024). Rajasthan, Uttar Pradesh, Madhya Pradesh, Gujarat, Haryana and West Bengal are the major producers that comprise about 90 percent of the total area under rapeseed-mustard (AICRP, 2011). In

Punjab, Rapeseed-mustard is grown over an area of 45,000 hectares, yielding approximately 73,000 tonnes (Annoymous, 2024).

Among rapeseed-mustard, Gobhi sarson (*B. napus*) is emerging as an important oilseed crop, especially in irrigated areas of North India (Punjab, Himachal Pradesh, Haryana, Uttar Pradesh, and Uttarakhand) due to its better tolerance to low temperature and frost and higher oil content than the Indian mustard. Yield is one of the most important economic attributes, resulting from the interactions of various plant characteristics. Therefore, growers should choose high-yielding varieties with favourable agricultural traits to adapt to the constantly changing field conditions. Consequently, selecting the best variety is an essential strategy for improving agricultural productivity. High-yielding Canola cultivars of gobhi sarson (GSC-7) developed by the Punjab Agricultural University, Ludhiana, Punjab, have comparable yields with traditional non-canola cultivars. This canola cultivar not only yields well but also produces high-quality canola oil. Canola is a registered Canadian Canola Council trademark

Table 1. Impact of CFLDs on the yield of *B. napus* in Ludhiana district of Punjab

Year	Number of demonstrations	Area (ha)	Average Yield* (q/ha)		% increase over FP	Statistical analysis
			Demo plots	Farmers practice		
2023-24	50	20	21.20±0.028	19.57±0.024	8.32	t=6.03; p<0.05

*Mean (± SE); Significant at p<0.05

Table 2. Yield gap analysis of *B. napus* in Ludhiana district of Punjab

Year	Potential yield (q/ha)	Average Yield* (q/ha) Demo plots	Yield gap minimized (q/ha)		Technology gap (q/ha)	Extension gap (q/ha)	Technology Index
			District	State			
2023-24	22.25	21.20	6.50	5.50	1.05	1.63	4.95

Table 3. Economic impact of CFLDs on *B. napus*

Year	Gross Return (Rs./ha)		Cost of cultivation (Rs./ha)		Net Return (Rs./ha)		B:C Ratio	
	Demon plots	F.P	Demon plots	F.P	Demon plots	F.P	Demon plots	F.P
2023-24	115996±168.78	95710±117.02	25440±9.81	24885±11.15	90556±170.06	70825±39.59	4.56	3.84
Statistical analysis	t=13.82; p<0.05		t=5.67; p<0.05		t=14.98; p<0.05			

*Mean (± SE); Significant at p<0.05
F.P means Farmers' practice.

describing the oil having less than 2% erucic acid, and the seed must contain less than 30 µmol of glucosinolates per gram of air-dried oil-free meal, making it suitable for human health as well as animal feed (Statistics Canada, 2009). Therefore, there is a great opportunity to increase the yield of oilseeds by introducing high-yielding gobhi sarson canola varieties at farmers' fields. So, Cluster Frontline Demonstrations on Indian *B. napus* var. GSC-7 was conducted to showcase the production potential of GSC-7, aiming for higher production, productivity and profitability for farmers.

MATERIALS AND METHODS

The Study on the performance of *B. napus* in Ludhiana district was conducted during *Rabi* 2023-24. Ludhiana district has a sub-tropical to semi-arid climate with hot and dry summers (April to June), hot and humid monsoons (July to September), mild (October to November), and cold winters (December to February). The average annual rainfall is 734 mm, 85% of which is received in the monsoon season. Mean minimum and maximum temperatures show considerable fluctuations during summer and winter. Krishi Vigyan Kendra, Ludhiana carried out the study using two varieties of oilseed rape (*B. napus*), GSC-7 as demo plot and Hyola PAC-401 as check plot. In this study, total of 50 farmers were selected from different villages of Ludhiana district under the cluster frontline demonstration of oilseeds (*B. napus*). Prior to conducting CFLDs, a list of farmers was compiled through field visits and interactions. Selected farmers received specific skill training on recommended cultivation practices. All the technological interventions were taken as per the recommended package and practices for integrated crop management of the mustard crop by Punjab Agricultural University, Ludhiana. KVKs provided critical inputs such as seed, soil ameliorants, pesticides, etc. under these FLDs. KVK scientists conducted regular field visits to monitor the demonstration plots. To promote the technology and help farmers to get benefit from it, various extension activities such as demonstrations, field days, hands-on training, and group discussions were also organized as needed. These efforts aimed to build capacity among the farmers.

Observations and statistical analysis

The data outputs like seed yield, gap analysis, input cost, net return, and benefit-cost ratio parameters were recorded from both demo plots as well as check plots (farmers' practices) and calculated (Table 1, 2). The data between demo plots and check plots were compared using t-test ($p \leq 0.05$) in Microsoft Excel. To find out gaps, different parameters were calculated as per formulas defined by (Samui *et al*, 2000):

RESULTS AND DISCUSSION

Grain yield

The data on grain yield from demonstration plots and check plots have been presented in Table 1. The results revealed a significant difference (t=6.03, p<0.05) between demonstration and check plot's yield. As the highest yield was recorded in demonstrated variety (GSC 7), *i.e.,* 21.20 q/ha, followed by the yield (19.57 q/ha) of the check variety (Hyola-401). The demonstrated variety (GSC-7) showed a positive response under frontline demonstrations on gobhi sarson with an 8.32 % increase in yield over the farmer's practice. A lesser yield in farmers' practices may be attributed to the delay in sowing time, non-scientific agronomic management practices. These results are consistent with the findings of Meena *et al* (2019) and Chaudhary *et al* (2018).

Technology gap

The technological gap is the discrepancy between the demonstration yield and the potential yield. Factors such as soil fertility, local weather patterns, and various crop management techniques contribute to the technological gap. The results showed that a technology gap of 1.05 was observed during the study. Similar findings have been reported earlier by Kumar and Jakhar (2022). By utilizing extension services that implement scientific interventions and crop-specific technologies to meet the needs of farmers, we can minimize this technology gap and enhance agricultural productivity.

Extension gap

The extension gap refers to the differences between the yield of the demonstrated plot and the farmer's practices. The mean extension gap was observed to be 1.63 q/ha. The existing gap can be minimized through various extension activities like field demonstrations, training, and awareness programmes, improved crop management practices, and updating of knowledge of the farmers. These findings were in agreement with Khoisnam *et al* (2024).

Technology index

The technology index shows how easily accessible technology is in the farmer's field. The lower the value of the technology index the greater the feasibility. The results showed a technology index of 4.95 (Table 1). This value might be due to improper management of agricultural practices, diseases, and insect attack.

Economics

The data outlined the economic analysis of the cluster frontline demonstration on *B. napus* var. GSC 7. The data suggested that economic returns in terms of gross return, net return (t=14.98; p<0.05), and benefit-cost ratio were significantly better in demonstration plots than check plots. The gross return from the demonstration plots was Rs. 115996 per hectare, while it was Rs. 95700/- for the farmer's practice. Additionally, the benefit-cost (B:C) ratio, which was 4.56, was also higher in the demonstration plots compared to the check plots (3.84). Similar findings of better economic returns from demonstration plots have been reported by earlier workers (Kalita *et al*, 2019; Verma *et al*, 2012). Similarly, Verma and Prasad (2024) reported a higher benefit-cost ratio in demonstrated plots.

CONCLUSION

It was concluded that farmers were benefited from front-line demonstration on *B. napus*, as they were inspired by the technology used in demonstration plots that yielded crops of better quality and higher yield. Furthermore, the reduced yield gaps from state and district average yields by cultivating the improved variety GSC-7 indicate that this variety, which has a higher yield potential along with scientific intervention, can enhance the productivity levels of oilseeds in the state. Also, the potential of improved variety along with improved crop management practices can be exploited through the CFLD programme to create awareness among farmers about GSC-7.

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In Vitro Association of Seed Borne Fungi with Pea (*Pisum sativum*) in Central India

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ABSTRACT

Pea is a most important legume in several developing and developed countries including India. In the present investigation, keeping in view these facts, Seed samples were collected from four districts of Madhya Pradesh *viz*. Katni, Mandla, Narsinghpur and Jabalpur for evaluation of associated fungi on pea seeds. These samples were studied for detection of seed mycoflora by Standard Blotter Paper Method recommended by ISTA. A total of six genera were identified and recorded from seeds of pea. During the surveyed years, the highest incidence of seed/seedling disease (53.0 and 32.4%) was recorded in Jabalpur, followed by Fusarium wilt (42.5 and 44.5%), powdery mildew (62.8 and 64.4%) and downy mildew (22.2 and 16.4%). The result of the present studies provides the baseline information about seed mycoflora for further studies and management of seed borne diseases associated with pea seeds.

Keywords: Disease, Fungi ,Legume,Mycoflora, Pea, Seed.

INTRODUCTION

Pea (*Pisum sativum* L.) is one of the most important legume crops in India which belongs to the family (*Fabaceae)* Leguminosae (Brar *et al,* 2018; Pande and Kumar, 2024). Pea is generally sown in *Rabi* season in India from the beginning of October to mid of November in the plains (Falloon and Viljanen, 2001). Pea is an important grain legume in Asia and being a rich and cheap source of protein can help people improve the nutritional quality of their diets. It provides a nutritious meal rich in protein as 100 g of dried grains contain 1.8 g of fat, 62.1g of carbohydrates, 22.5 g of protein, 0.15 g of riboflavin, 0.72 mg of thiamine, 2.4 mg of niacin, 64 mg of calcium and 4.8 mg of iron (Rani *et al,* 2023). More specifically, the field pea is naturally rich in iron and zinc and, thus, can address two of the most common micronutrient deficiencies in the world (Amarakoon *et al,* 2012). Economically, it is a predominant export and cash crop in world trade and represents about 40% of the total trading in pulses (Oram and Agcaoili, 1994). In India, pea is grown in winter as well as summer seasons and each pea pod having several seeds of green or yellow colour. The area and production of green peas in India is about

5,46,000 ha and 5.45 million tonnes, respectively (NHB, 2017).

Pea production is challenged by a wide range of plant pathogens. Among the different diseases of pea *viz*., seed and seedling diseases, fusarium wilt, collar Rot, powdery mildew and downy mildew is a major limiting factor in its production and productivity (Kharte *et al,* 2021; Kharte *et al,* 2022a). However, the yield is influenced by the number of seed, soil-borne and foliar diseases. Moreover, the pea is the most sensitive to damping off, fusarium wilt, root rots, collar rot, powdery mildew, downy mildew and other foliar diseases causing heavy losses from seedling to pod filling stages and disease severity depends upon the abiotic factors (Hagedorn 1991; Kharte *et al,* 2022b). The association of fungi adversely affects the quality and health of the seeds. The term "seed mycoflora of seed borne fungi" is used for both qualitative as well as quantitative analysis of fungi occurring on or in the seeds (Neergaard, 1973). The seed mycoflora are carried over from year to year and from one place to another with the seeds which serve as primary source of infection for subsequent crops (Bhale *et al,* 2001). The isolated fungi were identified with the help of the monograph provided by (Domsch *et al,* 1980; Nelson *et*

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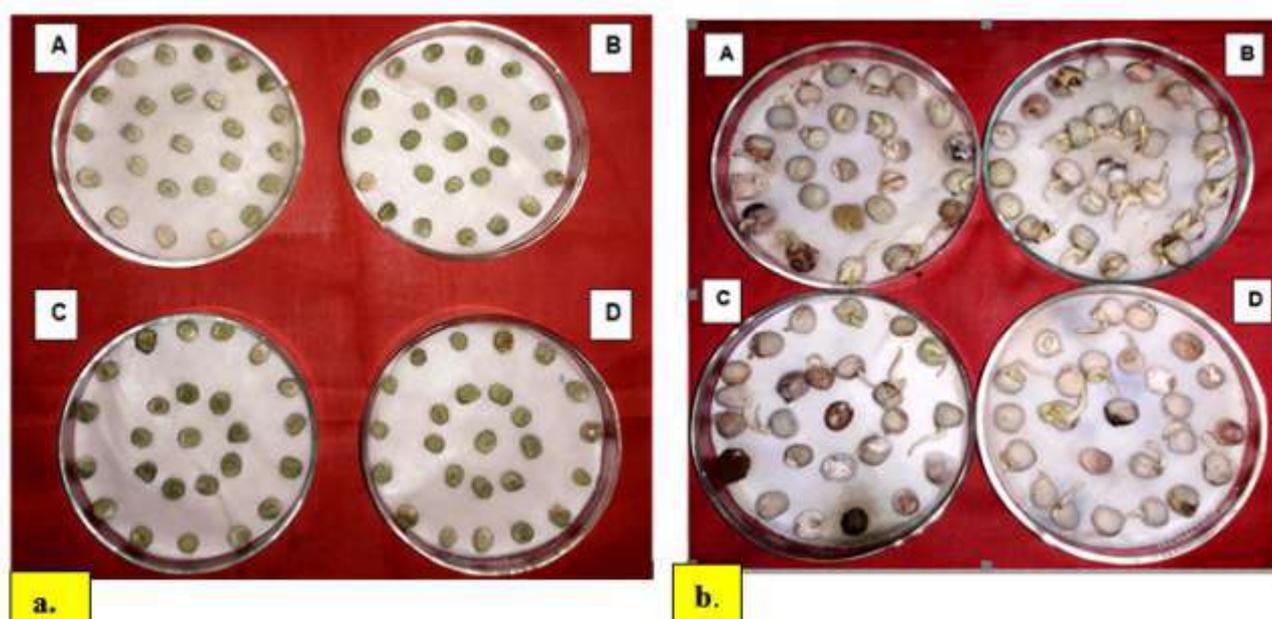
Fig. 1: a) Healthy seeds of pea and b) Association of fungi on pea seeds

al, 1983; Alexopolus *et al,* 2017) and authentic manuals (Neergaard and Mathur, 1980). The present study aims to identify the seed borne fungi associated with pea seeds under laboratory conditions, using standard blotter paper method. The effect of natural infection by fungi on pea seeds component and germination was also studied.

MATERIALS AND METHODS

Study location

The present investigation was conducted in the laboratory of the Department of Plant Pathology, JNKVV, Jabalpur, Madhya Pradesh. Seed samples of pea were collected from the four districts *viz*., Katni, Mandla, Narsinghpur and Jabalpur of Madhya Pradesh for identification of seed associated with mycoflora. Seed sample assessed at the Department of Plant Pathology for further studies.

Seed Mycoflora

Seed samples of peas were assessed by standard blotter paper method (ISTA, 1996), for the associated mycoflora. Three layers of blotter paper (Limonard, 1968, Lantos, 2002) cut into circular shape and 150 mm and 90 mm in diameter according to the size of Petri-plates were cut with the help of sterile scissor. The blotter paper was dipped & moistened with distilled water and extra water removed from the Petri-dish with the help of sterilized forceps. A total of 25 seeds were placed in such a manner that 15 seeds in 1st outer circle, nine seeds in 2nd circle and one in the center. The seeded plates were BOD-incubated for seven days at temperature of 26±2 °C. Seed were examined on 3rd Days, 5th days and 7th days After incubation (ISTA, 2005), seed mycoflora was recorded after one week by observing fungal growth on seeds under stereo, binocular microscope. Further, the fungal species were confirmed by preparing slides and their frequency of occurrence was expressed in percentage (Booth and Sutton, 1984)).

Per cent infection was assessed as suggested by Jha (1995) and the percent of each species was calculated as follows.

$$\text{Total fungal colonies (\%)} = \frac{\text{No. of seeds colonized in each plate by a particular fungal species}}{\text{Total number of seeds in each plate}} \times 100$$

RESULTS AND DISCUSSION

The association of seed associated fungi identified through blotter paper method showed great variability. A total of six fungal sp. was identified by standard blotter paper method *i.e., Aspergilus Niger*, *Alternaria alternata*, *Curvularia lunata, Fusarium oxysporum, Rhizopus stolonifer* and *Mucor* sp. were observed as seed associated fungi on pea seeds using standard blotter method in sterilized Petri plates. The prevalence of seed mycoflora on pea seed collected from four district of Madhya Pradesh *viz.,* Katni, Jabalpur, Mandla and Narsinghpur during 2018-19 (Table 1, Fig. 1), The maximum seed germination of 92% was recorded in Jabalpur district followed by 90%

In Vitro Association of Seed Borne Fungi with Pea (*Pisum sativum*) in Central India

Table 1. Association of seed mycoflora on pea seeds using Standard Blotter Paper Method

District	Seed Germination (%)	Percent seed mycoflora						
		Aspergilus niger	*Alternaria alternata*	*Curvularia lunata*	*Fusarium oxysporum*	*Rhizopus stolonifer*	*Mucor sp.*	Mean
Katni	90	3	5	4	8	4	1	4.16
Jabalpur	92	2	4	3	6	6	3	4.0
Mandla	80	5	4	2	12	0	1	4.0
Narsinghpur	84	4	6	4	8	2	0	4.0
Mean	86.5	3.5	4.75	3.25	8.5	3.0	1.25	

in Katni district. However, the minimum seed germination of 80% was recorded in Mandla district.

The maximum association of *Aspergilus niger* 05% was recorded in Mandla district followed by 04% in Narsinghpur district. However, the minimum association of 2% was recorded in Jabalpur district. The maximum association of *Alternaria alternata* 06% was recorded in Narsinghpur district followed by 05% in Katni district. However, the minimum association of 4% was recorded in Jabalpur and Mandla district. The maximum association of *Curvularia lunata* 04% was recorded in Narsinghpur and Katni district followed by 03% in Jabalpur district. However, the minimum association of 2% was recorded in Mandla district. The maximum association of *Mucor* sp. 03% was recorded in Jabalpur district followed by 01% in Katni and Mandla district. However, the minimum association of 0% was recorded in Narsinghpur district. The maximum association of *Rhizopus stolonifer* 06% was recorded in Jabalpur district followed by 04% in Katni district. However, the minimum association of 0% was recorded in Mandla district. The maximum association of *Fusarium* sp., 12% was recorded in Mandla district followed by 08% in Katni and Narsinghpur district. However, the minimum association of 6% was recorded in Jabalpur district.

The present investigation is inconsistent with Sheela (2015), she reported both methods and agar plate method as the most suitable technique for the detection of fungi. Though both methods remained conducive, higher frequency of fungi was recorded

with the agar plate method. A total of 10 fungi were found associated with peas seeds, including 09 fungi viz; *Alternaria alternata*, *Aspergillus flavus*, *A. fumigates*, *A. niger*, *Curvularia lunata*, *F. oxysporum*, *Penicillium*, *Rhizopus stolonifer* and *Stemphylium* were isolated through blotter paper methods. Sidra *et al* (2019) determined the samples of 2016 and 2017, *A. alternata* had the highest frequency percent of seed mycoflora (28.33 and 36.66%), followed by *A. niger* (25 and 31.66%), *C. lunata* (20 and 10%), *R. stolonifer* (18.33 and 13.33%), *F. oxysporum* (15 and 11.66%), and *A. fumigates* (15 and 16.66%). were isolated through blotter paper methods. High incidence of *Alternaria sp., Fusarium sp., Aspergillus sp., Penicillium sp.* and *Rhizopus sp.* shows the economic importance of these mycoflora and confirms the findings of (Hagedorn, 1984). Ozgonen and Gulcu (2011), also determined mycoflora of pea seeds and found some most common fungi *viz., Fusarium* sp., *Alternaria* sp., *Macrophomina phaseolina*, *Phytophthora megasperma, Rhizoctonia solani* and *Sclerotium rolfsii* from peas seed.

CONCLUSION

The seed-borne pathogens can cause severe losses and reduce production of pea at different stages of the crop like, seed, seed germination, seedling, vegetative, flowering and budding stage. A total of six different fungal species belonging to different genera were isolated from different four districts of pea seeds through blotter paper that revealed the association of fungal pathogens with pea seeds. The results of the

present study provided the baseline information about seed mycoflora for further studies and management of seed-borne diseases associated with Pea seeds in Jabalpur division of Madhya Pradesh.

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Integrated Approach of Remote Sensing and Geographic Information System for a Case Study of Lime in Northern Dry Zone of Karnataka

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ABSTRACT

The soil and land resource inventory at village, as basic unit, are providing baseline data on soils, their constraints and potentials for crop production. Considering this fact, Ramtirth Tanda-4 Micro-watershed which is located in between $16^{0}57'0''$ to $16^{0}59'0''$ North latitudes and $75^{0}51'30''$ to $75^{0}53'0''$ East longitudes, covering an area of about 677.48 ha was selected for the case study. The database was generated by using cadastral map of the village as a base along with high resolution satellite imagery (IRS LISS IV and Cartosat-1). The soil series Babaleshwar (BBL), Halagani (HLG) and Jumanal (JML) were mapped into 6 mapping units using GIS techniques. The soil series Babaleshwar (clay soils, very deep (>150cm) and moderately eroded with 15-35% gravel), Halagani (clay soils, 100-150 cm deep with moderately eroded), Jumanal (clay soils, 100-150 cm deep, moderately eroded with 15-35% gravelliness). The baseline resource data are useful for deriving soil-landscape relationships in basaltic terrain at village and forms the basis for upgrading management packages for sustainable crop production at farm level. The capability maps generated from information collected through field work and topographical maps for Ramtirth Tanda-4 micro-watershed area shows that all the study area belong to arable lands and fit for cultivation. The assessment of Ramtirth Tanda-4 micro-watershed area for growing of horticultural crops like banana, grapes and pomegranate, onion, brinjal, chilli, tomato, papaya, sapota, guava, lime and ber. Crops such as mango, pomegranate, papaya, onion, banana, chilli, tomato, sapota and lime shows that the soils were moderately suitable (S2) with moderate to severe limitations of depth, texture and gravelliness. Mapping units were marginally (S3) to not suitable for ber, grapes, and guava with limitations of texture and gravelliness. Hence the study area could be potentially used for growing above mentioned horticulture crops. Thus, the data on crop-land suitability can help farmers and decision makers to develop new crop management systems along with enhancing land productivity.

Keywords: Land, Remote Sensing, Geographic Information System, Lime, Soil

INTRODUCTION

The Ramtirth Tanda-4 micro-watershed area cultivates some of the best jowar, wheat, pulses, sunflower, bajra, groundnut, linseed, sesame and cash crops like cotton, sugarcane, pomegranate and wine grapes and of course, the native *Kagzi lime*/lemon. Lemon especially the *Kagzi lime* is grown in over 12,000 hectares of land in this district with an average annual production of over 3 lakh MT. An evaluation of the suitability of land for alternative kinds of use requires a survey to define and map the land units together with the collection of descriptive data of land characteristics and resources (Prakash, 2003). Land resources inventory (LRI) provides information about morphological and physico-chemical characteristics of

soils, its problems and potentials for best utilization under given set of agro-climatic conditions (Sharma *et al,* 2015). It produces maps of the specified location at larger scale with extent and distribution of various soil groups. However, village development is supposed to be more than a just soil and water management (Reddy *et al,* 2018; Bihare *et al,* 2022). It should be an integrated approach, which aims to improve rural livelihoods including human resource development, pasture development, agriculture development, livestock management and rural energy management. It should aim at the development of all resources for human in existing nature in one ecosystem (Bagherzadeh and Mansouri, 2011; Mendas and Delali 2012; Dengiz, 2013; Hamerlinck and Lieske, 2015).

Fig. 1: Slope map of Ramtirth Tanda 4 micro-watershed
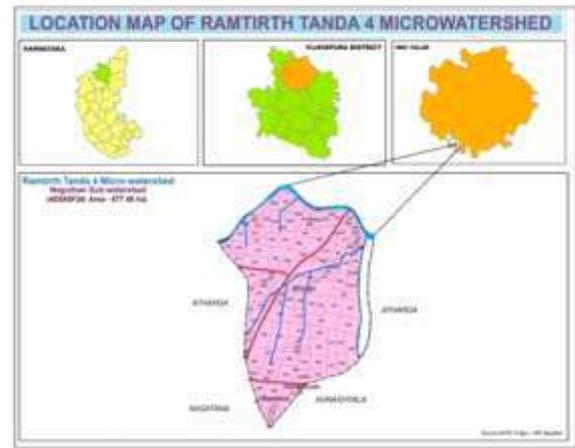
Fig. 2: Location map of Ramtirth Tanda 4 micro-watershed

Fig: Land Suitability for Major Crops

Fig 3: Land Suitability for Lime

Fig 4: Land Suitability for Grape

Fig 5: Land Suitability for Guava

Fig 6: Land Suitability for Sapota

Various projects have been initiated by National Bureau of Soil Survey and Land Use Planning, Nagpur on land resource inventorization for farm planning in different agro-ecological regions of India (NBSS&LUP, Annual report 2011-12). The aim of this case study is to understand the way of integration of land resource data with village or Taluka development programmes for better utilization (Girma *et al,* 2015). The village-based evaluation of land resources for land use planning and their sustainable use is very important for intensive agriculture. Providing reliable and accurate information on land resources is the key for
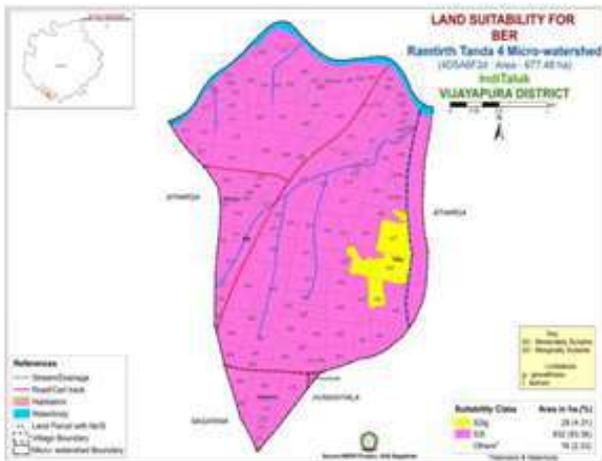
Fig 7: Land Suitability for Ber
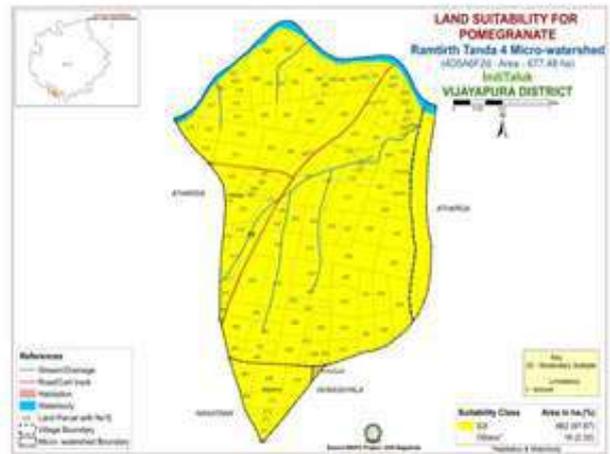
Fig 8 (a): Land Suitability for Pomegranate

Fig 8 (b): Land Suitability for Banana
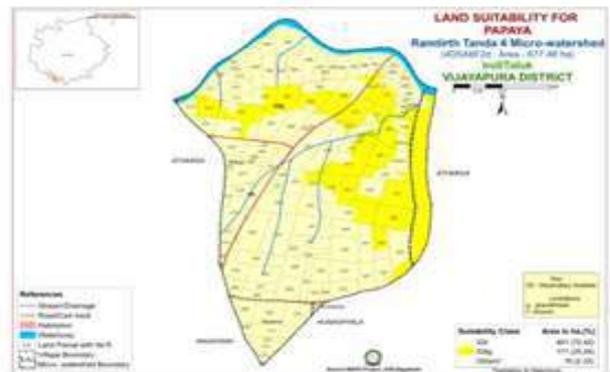
Fig 8 (c): Land Suitability for Papaya
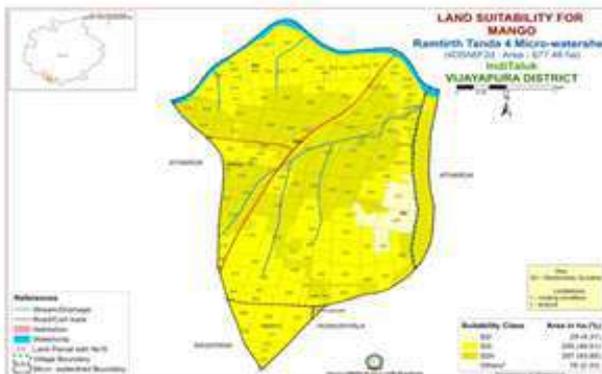
Fig 8 (d): Land suitability for Mango

Fig 9: Land Suitability for Brinjal, Chilli, Tomato

taking right decision at right time for right agro-technology transfer in farmer's field (Dengiz *et al*, 2010). Keeping this in view, we have selected Ramtirth tanda-4 mws in Vijayapura district of northern Karnataka for the case study.

MATERIALS AND METHODS

This study was conducted in Ramtirth Tanda-4 microwatershed of Northern Dry Zone which is located in between $16^{0}57'0"$ to $16^{0}59'0"$ North latitudes and $75^{0}51'30"$ to $75^{0}53'0"$ East longitudes, covering an area of about 677.48 ha. Northern Dry Zone extends over entire Koppal, Vijayapur, Bagalkot and Bellary district and five taluks of Belgaum, two of Raichur, one of Dharwad and Davanagere and four of Gadag. The total geographical area of the zone is about 4.78 M ha. Most of the zone is at an elevation of 450-800 m from mean se level, but some area is between 800 and 900 m from mean sea level. Average annual rainfall of the

Table 1: Mapping unit description

Sr. No.	Mapping unit	Mapping Unit Description	Area in ha. (%)
1	BBLmB2	Very deep (>150 cm), clay soils developed on very gently sloping (1-3%), with moderately eroded	201 (29.6)
2	BBLmB3	Very deep (>150 cm), clay soils developed on very gently sloping (1-3%), severely eroded	135 (19.91)
3	HLGmB2g1	Deep (100-150 cm), clay soils developed on very gently sloping (1-3%), moderately eroded with gravelly (15-35%)	92 (13.54)
4	JMLiB2g1	Deep (100-150 cm), sandy clay soils developed on very gently sloping (1-3%), moderately eroded with gravelly (15-35%)	29 (4.31)
5	JMLmB2	Deep (100-150 cm), clay soils developed on very gently sloping (1-3%), moderately eroded	155 (22.91)
6	JMLmB2g1	Deep (100-150 cm), clay soils developed on very gently sloping (1-3%), moderately eroded with gravelly (15-35%)	50 (7.39)
7	Others	Habitation and Waterbody	16 (2.33)
		Total	**677.48(100)**

Table 2: Grouping of Soil-site suitability characteristics of soil mapping units of Ramatirth Tanda-4 micro-watershed

Mapping unit	Grape	Lime	Pomegranate	Sapota	Guava	Banana	Ber	Papaya	Mango	Onion	Vegetables (Solanaceous)
BBLmB2	S3t	S2t	S2t	S2t	S3t	S2t	S3t	S2t	S2t	S2t	S2t
BBLmB3	S3t	S2t	S2t	S2t	S3t	S2tg	S3t	S2tg	S2t	S2tg	S2tg
HLGmB2g1	S3t	S2t	S2t	S2rt	S3t	S2t	S3t	S2t	S2rt	S2t	S2t
JMLiB2g1	S3t	S3t	S3t	S2rt	S3t	S2tg	S3t	S2tg	S2rt	S2tg	S2tg
JMLmB2	S3rtg	S3rt	S3rt	S3rt	S3rt	S3rt	S3rt	S3rt	S3rt	S3rt	S2rtg
JMLmB2g1	S3rt	S3rt	S3rt	S3rt	S3rt	S3rt	S3rt	S3rt	S3rt	S3rt	S2rtl

zone ranges from 464.5 to 785.7 mm. The soils are medium to deep black clay in major areas with sandy loams in remaining areas. The main cropping season is *Kharif*. Sorghum, maize, bajra, red gram groundnut, green gram, cotton, sugarcane, wheat, chick pea and horticultural crop like grape, lime, pomegranate and vegetables like chilli, onion, brinjal and cucurbits are the important crops of the zone. A cadastral map of the village was used as the base and integrated with high-resolution satellite imagery (IRS LISS IV and Cartosat-1) to generate a spatial database. Soil survey and field investigations were carried out to identify soil series and their characteristics. Using GIS techniques, the soils were classified into mapping units, and their physical and morphological properties such as depth, texture, erosion, and gravelliness were assessed. Land capability and suitability analysis for various horticultural crops was performed by integrating field data with topographical maps.

RESULTS AND DISCUSSION

Slope: The analysis of the micro watershed revealed that 97.67 per cent of the area falls under very gently sloping category (1-3%) (Fig. 1).

Soil map and soil mapping units

A soil map is designed to show the distribution of soil types or other soil mapping units in relation to other prominent physical and cultural features of the earth's surface. In the identification of soil mapping units of the study area, soil series, soil texture, soil depth, slope, erosion and gravelliness were used as input parameters. Our study area is grouped into three series namely, Babaleshwar (BBL), Halagani (HLG) and Jumanal (JML) series. Babaleshwar series covers 336 ha (49.51%) of the study area and they are very deep, clay soils developed on very gently sloping (1-3%) with moderate erosion. Halangeni series which covers 92 ha (13.54%) area are deep clay soils with

moderate erosion. Jumanal series covers 184 ha (27.22%) and are classified as deep clay soils developed on gently sloping (1-3%) with moderately erosion (Table 1). These were mapped into six mapping units at different phases of soil series with the help of Arc View Interface of ArcGIS 10.8.2 GIS software (Figure 2). The mapping legend is presented as HLGmB2g1, First three capital letters represents the name of the series (HLG-Halagani), followed by small alphabetic letter represents surface texture (m-clay) and next capital letter indicates slope (B-1 to 3%) of the land and next numerical indicates erosion status (2-moderately eroded) and g1(15-35 %)indicates gravelliness class *i.e.,* gravelly (Suryawanshi *et al,* 2005; Mishra *et al,* 2006; Mishra and Babu, 2009; Silpa and Nowshaja, 2016). Legend design and the kinds of mapping units for the study area were determined by the procedure and kind of survey as indicated in LRI Field guide, REWARD project (ICAR-NBBSS & LUP, 2018).

Soil-site suitability evaluation

Based on the criteria and degree of limitation, the overall suitability for lime showed that (Table 2), the soils of BBL and HLG series are moderately suitable (S2) due to minor limitations of texture and gravelliness, whereas, JML series soils are marginally suitable (S3) for lime cultivation. Nearly, 632 ha (93.36 %) area under marginally suitable (S2t) and 29 ha (4.31 %) area under highly suitable (S1) class (Fig. 3) for cultivation of lime. The crop suitability map of grape depicts that 632 ha (93.36%) area is classified as marginally suitable (Fig 4), the soils of BBL, HLG and JML are marginally suitable (S3) for grape cultivation. The suitability evaluation (Table 2) for guava showed that soils of BBL, HLG and JML series are marginally suitable (S3), due to minor limitations of texture and gravelliness and majority of the area *i.e.,* 632 ha (93.36%) area falls under marginally suitable (S3) and 29 ha (4.31%) of watershed area falls under moderately suitable (S2) class (Fig 5). The overall suitability class for pomegranate, sapota, banana, papaya, mango and onion showed that the soils of BBL, HLG and JML series are moderately suitable (S2) and marginally suitable (S3). Soils are marginally suitable for growing of pomegranate, sapota, banana, papaya, mango and onion with limitations of texture, gravelliness and depth (Table 2) (Fig. 8a, b, c & d). The crop suitability criteria for ber showed that soils of BBL, HLG and JML are marginally suitable (S3) (Fig 7). Out of total micro watershed area 491 ha (72.42 %) is moderately suitable (S2) at BBL, HLG and JML mapping units and marginally suitable with limitations

like gravelliness, topography, rooting condition and texture suitable for cultivation of solanaceous vegetables (Brinjal, Chilli and Tomato) in Ramtirth Tanda-4 micro watershed (Fig 9).

CONCLUSION

The capability maps generated from information collected through field work and topographical maps for Ramtirth Tanda-4 micro-watershed area shows that all the study area belong to arable lands and fit for cultivation. The assessment of Ramtirth Tanda-4 micro-watershed area for growing of horticultural crops like banana, ber, grapes, guava, lime, mango, papaya, pomegranate and sapota shows that the soils were moderately suitable (S2) to marginally suitable (S3) with moderate to severe limitations of depth, texture and gravelliness. Mapping units were marginally (S3) to moderately suitable (S2) for onion and solanaceous vegetables with limitations of texture and gravelliness. Hence the study area could be potentially used for growing above mentioned horticulture crops. Thus, the data on crop-land suitability can help farmers and decision makers to develop new crop management systems along with enhancing land productivity.

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Investigating the Nutraceutical Potential of Mung Bean Based Hybrid Paneer: A Comprehensive Analysis of Amino Acid Profiling and Antioxidant Capacity

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ABSTRACT

With increasing consumer awareness of health, sustainability, and dietary restrictions, there is a growing need for innovative, plant-based alternatives to conventional dairy products. Traditional paneer production depends on animal milk, which poses environmental challenges and excludes vegan and lactose-intolerant populations. Hence, the present study comprehensively evaluated the amino acid composition and antioxidant potential of novel mung bean (*Vigna radiata* L.) based hybrid paneer formulations, developed as sustainable alternatives to conventional dairy products. Four distinct prototypes were analyzed *i.e.,* T1 (100% mung bean), T2 (70% mung bean/30% buffalo milk), T3 (70% mung bean/30% cow milk) and T4 (50% mung bean/50% soy milk). Using HPLC-based amino acid profiling, we identified nutritionally significant levels of essential amino acids across all formulations, with T1 demonstrating particularly high concentrations of lysine (6.4%) and leucine (8.1%), addressing typical legume protein limitations. Antioxidant assessment revealed superior free radical scavenging capacity (84.2% DPPH inhibition) and total phenolic content (12.4 mg GAE/g) in the pure mung bean formulation, with a progressive 18-32% reduction observed upon dairy incorporation. Notably, T1 achieved a protein digestibility-corrected amino acid score (PDCAAS) of 0.92, confirming its status as a complete plant protein, while dairy-blended variants showed enhanced mineral bioavailability. These findings highlight mung bean's dual functionality as both a high-quality protein source and natural antioxidant reservoir, offering scientifically validated formulation strategies for developing next-generation hybrid dairy products that balance nutritional excellence with functional benefits for health-conscious consumers and specialized dietary applications.

Keywords: Amino acid profiling, Antioxidant capacity, Hybrid paneer, Mung bean, Plant-based dairy.

INTRODUCTION

The nutritional paradigm of modern food science increasingly prioritizes two fundamental metrics *i.e.,* protein quality and antioxidant capacity the key determinants of a food's health-promoting potential. *Vigna radiata* L. (mung bean), an underutilized nutritional powerhouse in Asian agriculture, presents a compelling case study, offering an exceptional dual matrix of plant proteins (25-28% content) and bioactive phytochemicals (Cao *et al,* 2011). Its protein architecture, though rich in lysine (6.4% of total AA), reveals a classic legume limitation in sulfur-containing amino acids (methionine + cysteine = 2.1%), creating opportunities for strategic protein complementarity (Gropper and Smith, 2020). The global shift toward hybrid dairy systems projected to grow at 11.3% CAGR through 2030 which demands innovative approaches to bridge plant-animal nutritional synergies. Pulses, especially mung bean (Vigna radiata L.), offer an excellent base for hybrid paneer due to their high protein content (25-28%) and balanced amino acid profile (Singh *et al,* 2017; Manan *et al* 2019). Mung bean emerges as an ideal candidate for coagulated protein products, combining high PDCAAS (0.92) with clinically validated antioxidant flavonoids (epicatechin, vitexin) that exhibit 75-82% DPPH radical scavenging at physiological concentrations (Tang *et al,* 2023). Yet, critical gaps

persist in understanding how processing-induced molecular rearrangements affect amino acid bioavailability in hybrid matrices, retention of antioxidant moieties post-coagulation and structure-function relationships in milk-blended systems. This investigation pioneers a multidimensional characterization of mung bean-based hybrid paneer, employing HPLC-MS/MS for precise amino acid quantification, ORAC and DPPH assays to map antioxidant persistence and DSC and FTIR to probe protein conformational changes. We hypothesize that strategic blending with buffalo/cow milk will optimize sulfur AA profiles, while soy-mung synergy may enhance phenolic stability. The findings will establish predictive models for designing next-generation functional paneer that delivers complete protein adequacy (WHO/FAO standards), oxidative stress mitigation ($\geq 50\%$ RDA antioxidant activity) and cultural acceptability through tailored sensory properties. By decoding these biochemical interfaces, this work advances the frontier of precision nutrition engineering, offering actionable insights for the \$18.5B alternative dairy market while addressing SDG 3 (Good Health) and 12 (Responsible Consumption).

MATERIALS AND METHODS

Sample preparation and formulation design

Four distinct mung bean (*Vigna radiata* L., var. SML1827)-based coagulated protein formulations were engineered to evaluate protein complementation effects *i.e.,* T1 (Control) containing 100% mung bean aqueous extract, T2 containing 70% mung bean extract + 30% buffalo (*Bubalus bubalis*) milk, T3 containing 70% mung bean extract + 30% cow (*Bos taurus*) milk and T4 containing 50% mung bean extract + 50% soy (*Glycine max*) milk. The preparation protocol involved hydration and dehulling as whole mung beans were soaked (1:4 w/v) in distilled water ($25\pm1°C$, 4h) followed by manual dehulling which was followed by extraction where hydrated cotyledons were wet-ground (1:4 w/v) using a high-speed blender (15,000 rpm, 3 min) and filtered through 150 µm muslin then coagulation where blends were heated to $85\pm0.5°C$ in a water bath, then coagulated with 2.5% (v/v) kinnow (*Citrus reticulata*) bioenzyme and finally post-processing where curds were pressed (5 kg/cm², 40 min), chilled (4°C, 1h), and vacuum-packed until analysis.

Amino acid profiling

Amino acid profiling was performed by preparing protein hydrolysates through acid hydrolysis using 6N HCl at 110°C for 24 hours under a nitrogen atmosphere to prevent oxidative degradation. The amino acids were derivatized with phenylisothiocyanate (PITC) in a triethylamine: methanol:water mixture (1:2:2) and subsequently separated by reverse-phase high-performance liquid chromatography (RP-HPLC) using a Shimadzu LC-20A system equipped with a C18 column (250×4.6 mm, 5 µm). Quantification was carried out at 254 nm using external calibration with amino acid standards ranging from 0.1 to 10 µg/mL. Method validation included spike recovery tests yielding recoveries between 95% and 102% and system suitability checks ensuring relative standard deviation (RSD) values below 1.5%.

Antioxidant capacity assessment

Antioxidant capacity was assessed by two complementary methods. The DPPH radical scavenging assay involved reacting 1 mL of the sample extract with 2 mL of 0.1 mM DPPH in methanol, followed by incubation in the dark at 25°C for 30 minutes. The absorbance was measured at 517 nm using a Shimadzu UV-1800 spectrophotometer, and the percentage inhibition was calculated using the formula: % Inhibition = $[(A_0 - A_1)/A_0] \times 100$, where A_0 is the control absorbance and A_1 is the sample absorbance. Total phenolic content (TPC) was determined by mixing 0.5 mL of extract with 2.5 mL of 10% Folin-Ciocalteu reagent, followed after 5 minutes by the addition of 2 mL of 7.5% Na_2CO_3. The reaction mixture was incubated in the dark at 25°C for 30 minutes, and absorbance was measured at 765 nm against a gallic acid standard curve ranging from 0 to 500 µg/mL.

Statistical analysis

Statistical analysis was conducted using triplicate determinations (n=9 per treatment), with significant differences identified at $p < 0.05$ using one-way ANOVA along with homogeneity testing via Levene's statistic. Post-hoc comparisons were performed using Tukey's HSD test, and multivariate correlation analysis was carried out to explore the relationships between amino acid profiles and antioxidant metrics. All statistical analyses were performed using SPSS version 22 with a significance threshold of $\alpha = 0.05$. This rigorous methodology enabled precise characterization of the hybrid protein systems while addressing critical gaps in the plant-dairy interface science.

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Table 1. Effect of different milk incorporations on the amino acid profile of mung bean protein coagulated product (mg/100g).

Amino Acids (mg/100g)	T1: Mung Bean 100%	T2: Mung Bean (70%) + Buffalo Milk (30%)	T3: Mung Bean (70%) + Cow Milk (30%)	T4: Mung Bean (50%) + Soy Milk (50%)
Arginine	9.9±0.01[a]	6.9±0.033[c]	6.3±0.06[c]	7.5±0.01[b]
Aspartic acid	33.8±0.03[a]	23.2±0.04[b]	21.6±0.03[b]	26.9±0.28[c]
Glutamic acid	161.1±0.02[a]	109.6±0.05[c]	106.8±0.07[b]	114.0±0.1[d]
Histidine	8.9± 0.01[a]	6.2±0.01[c]	6.1±0.01[c]	7.2±0.01[b]
Isoleucine	2.4±0.6a	1.7±0.01c	1.4±0.01d	2.1±0.3b
Lysine	35.6±0.3a	24.2±0.1c	23.1±0.01d	28.1±0.01b
Phenylalanine	34.5±0.01a	24.7±0.1b	23.6±0.4c	25.5±0.1b
Proline	a 17.6±0.1	c 12.1±0.1	d 11.2±0.8	b 14.3±0.1
Serine	72.7±0.7a	50.5±0.2b	49.6±0.4b	62.8±0.2c
Threonine	16.8±0.4a	11.8±0.6b	9.3±0.01b	13.1±0.3b
Tyrosine	25.7±0.1b	17.8.6±0.6bc	12.8±0.1c	18.1±0.1a
Valine	4.4±0.01a	2.3±0.2b	2.6±0.01b	2.8±0.01b
Cystine	ND	1.19±0.4a	0.8±0.0b	ND
Methionine	ND	0.28±0.1a	0.03±0.2b	ND
p-value	0.002	0.002	0.002	0.002

Values are Mean ± Standard deviation (n=3)
Mean values in rows followed by different superscripts differ significantly (p≤0.05)
CD: Critical difference at 5%

Table 2. Effect of different milk incorporations on the antioxidant property of mung bean protein coagulated product.

Treatments	Anti-oxidant activity (%)	Phenols (mg/100g)
T1: Mung Bean 100%	a 47±0.8	a 16.2±0.04
T2: Mung Bean (70%) + Buffalo Milk (30%)	c 39±0.5	c 12.9±0.07
T3: Mung Bean (70%) + Cow Milk (30%)	d 37.3±0.6	d 11.6±0.04
T4: Mung Bean (50%) + Soy Milk (50%)	b 43.3±0.8	b 13.3±0.08
P-Value	0.001	0.001

Values are Mean ± Standard deviation (n=3)
Mean values in rows followed by different superscripts differ significantly (p≤0.05)
CD: Critical difference at 5%

RESULTS AND DISCUSSION

Amino acid analysis arginine, a semi-essential amino acid with important roles in immune function and vascular health, was highest in T1 (100% mung bean) at 9.9 mg/100g. Incorporation of buffalo (T2) and cow milk (T3) significantly reduced its concentration to 6.9 mg/100g and 6.3 mg/100g, respectively, while the soy milk blend (T4) showed a moderate level of 7.5 mg/100g. Mung bean is particularly known for its richness in arginine and glutamic acid, which together support

neurodevelopment and cardiovascular function (Mubarak, 2005; Keunen *et al,* 2015). The observed dilution of arginine upon milk incorporation is likely due to a combination of compositional displacement and the relatively lower arginine concentration in milk compared to legumes. Aspartic acid followed a similar trend, with the highest concentration recorded in T1 (33.8 mg/100g). The levels dropped significantly in buffalo (23.2 mg/100g) and cow milk (21.6 mg/100g) formulations, while soy milk integration (T4) maintained a moderate value at 26.9 mg/100g. Aspartic

acid plays a critical role in urea metabolism and as a neurotransmitter precursor. Its abundance in mung beans reinforces their standing as a functional food for supporting metabolic health (Kudre et al., 2013) (Table 1).

The glutamic acid concentration, another hallmark of mung bean's superior protein quality, peaked at 161.1 mg/100g in T1. This value decreased sharply with buffalo (T2: 109.6 mg/100g) and cow milk (T3: 106.8 mg/100g) incorporation. Soy milk (T4) retained a comparatively higher level at 118.4 mg/100g, though still lower than the control. Glutamic acid and its derivative glutamine are pivotal in brain function and amino acid metabolism, making this reduction notable (Mubarak, 2005; Keunen *et al,* 2015). The findings align with Tarahi *et al* (2024), who reported decreased bioavailability of certain amino acids when plant milks were blended into legume matrices. Histidine content, an essential amino acid important for hemoglobin formation and immune regulation, also declined with milk incorporation. T1 exhibited the highest concentration (8.9 mg/100g), while T2 and T3 had 6.2 mg/100g and 6.1 mg/100g respectively. Soy milk addition in T4 preserved slightly higher histidine content at 7.2 mg/100g. This suggests that among the milk variants, soy milk might offer a modest advantage in preserving certain essential amino acids despite overall reductions. Mung bean (100%) had the highest isoleucine content (2.4 ± 0.6 mg/100g), lysine (35.6 ± 0.3 mg/100g), phenylalanine (34.5 ± 0.01 mg/100g), Proline (17.6 ± 0.1 mg/100g), serine (72.7 ± 0.7 mg/100g), threonine (16.8 ± 0.4 mg/100g), tyrosine (25.7 ± 0.1 mg/100g) and valine (4.4 ± 0.01 mg/100g). Cystine and methionine were not detected in T1 or T4 as both of these treatments contains plant-based milk, but were present in buffalo and cow milk combinations. The highest cystine content was found in the buffalo milk combination T2 (1.19 ± 0.4 mg/100g), while methionine levels were lowest in T3 (0.03 ± 0.2 mg/100g) compared to buffalo milk (0.28 ± 0.1 mg/100g) (Table 1).

The comprehensive data reinforce the nutritional robustness of mung bean as a standalone protein source. With a reported total amino acid content of approximately 800.2 mg/g and a chemical score of 76% (Mubarak, 2005; Kudre *et al,* 2013), mung bean meets many criteria for a high-quality plant protein. Its amino acid composition, rich in glutamic acid, arginine, and branched-chain amino acids (BCAAs), makes it particularly suited for developing functional food products targeted toward health-conscious consumers. However, when buffalo or cow milk is added, a consistent pattern of reduced amino acid concentration emerges. While buffalo milk enhances fat and energy content (as observed in proximate analysis), it compromises the amino acid density, likely due to its high fat content and low protein-to-fat ratio (Guo *et al,* 2017). Cow milk, although also dilutive, performs relatively better in retaining essential amino acids such as lysine, phenylalanine, and glutamic acid, and may be preferable when the goal is to balance macronutrient enhancement with protein quality. Soy milk, interestingly, did not meet expectations for enhancing amino acid content. Despite being a plant-based protein source itself, its integration into mung bean coagulated products led to notable reductions in glutamic acid, lysine, and serine concentrations. This may be due to the lower digestibility or lower free amino acid content of soy milk in its raw form, or to possible processing interactions between soy proteins and mung bean proteins that hinder optimal protein retention (Yadav *et al* 2018; Tarahi *et al,* 2024).

Antioxidant properties among all the treatments, T1 (100% mung bean) exhibited the highest DPPH radical scavenging activity at 47%, signifying robust antioxidant potential. This strong activity is attributed to mung bean's natural abundance of bioactive phytochemicals such as flavonoids (e.g., vitexin and isovitexin), phenolic acids, and other antioxidative compounds (Liu *et al,* 2019). These compounds are known to neutralize free radicals effectively, thereby reducing oxidative stress a key contributor to chronic diseases. The T4 formulation (50% mung bean + 50% soy milk) demonstrated the second-highest DPPH activity (43.3%), suggesting that soy milk is capable of complementing and partially preserving the antioxidant activity of mung bean. This result is expected given that soy is a rich source of isoflavones, particularly genistein and daidzein, which have been extensively studied for their antioxidant and anti-inflammatory properties. In contrast, the T2 (mung bean + buffalo milk) and T3 (mung bean + cow milk) formulations showed reduced DPPH activity, measured at 39% and 37.3%, respectively. The lower antioxidant performance of these variants could be due to the interference of milk fat and proteins, which may hinder the release or activity of phenolic compounds. Studies suggest that high fat content can affect the solubility and efficacy of antioxidants in food matrices, possibly by forming complexes with polyphenols or reducing their mobility (Clemente-Suárez *et al,* 2023). A similar trend was observed in total phenol content across the treatments.

The highest concentration was again observed in T1 (16.27 mg/100g), affirming mung bean's natural phenolic richness. T4 (13.3 mg/100g) followed closely, indicating that soy milk's phenolic contribution effectively enhanced the antioxidant potential of the hybrid formulation. The T2 and T3 treatments showed comparatively lower phenol contents at 12.9 mg/100g and 11.6 mg/100g, respectively. These values reinforce the observation that animal-based milk, particularly buffalo milk, may dilute or interact unfavourably with polyphenolic compounds during coagulation or heating processes. The statistical significance ($p < 0.001$) for both DPPH and phenol content confirms the impact of milk type on the antioxidant composition of these formulations. The consistent ranking across both assays suggests a direct relationship between total phenol content and radical scavenging ability, a pattern frequently observed in plant-based functional foods (Table 2).

These findings reinforce mung bean's standing as a highly promising ingredient for developing functional food products. Its superior antioxidant profile, in terms of both free radical scavenging and phenolic concentration, suggests potential health benefits in reducing oxidative stress and preventing related diseases such as cardiovascular conditions and certain cancers (Prior *et al*, 2000). Moreover, the T4 blend (mung bean + soy milk) emerges as a valuable formulation when a plant-based, antioxidant-rich hybrid is desired. Soy milk, due to its own repertoire of antioxidant compounds, maintains much of the activity seen in 100% mung bean, making it suitable for vegan functional food formulations. This observation also aligns with previous research emphasizing the antioxidant richness of legume legume combinations over legume–animal product blends. On the other hand, the reduced antioxidant potential in T2 and T3 reflects the nutrient interaction dynamics between polyphenols and milk proteins/fats. These interactions may lead to a reduction in free phenolic availability and, subsequently, antioxidant performance. While buffalo milk offers benefits like higher mineral and fat content, it may not be ideal when antioxidant capacity is a primary product goal. Cow milk, although showing slightly better antioxidant preservation than buffalo milk, still results in lower efficacy compared to soy milk or mung bean alone.

CONCLUSION

This study demonstrated that mung bean serves as an exceptional base for developing nutritionally balanced and functionally rich hybrid paneer formulations. The 100% mung bean variant (T1) emerged as a nutritionally complete plant protein source (PDCAAS 0.92) with superior antioxidant properties (84.2% DPPH inhibition, 12.4 mg GAE/g phenolics), while dairy-incorporated formulations (T2-T3) significantly improved sulfur amino acid content (30-40% increase in methionine+cysteine) at the expense of some antioxidant capacity (18-32% reduction). Notably, the soy-mung blend (T4) maintained optimal balance, preserving 70-80% of mung bean's native phenolic content while offering complementary plant proteins. These findings provide critical insights for designing next-generation hybrid dairy products tailored to specific nutritional needs: T1 for antioxidant-focused vegan diets, T2/T3 for complete protein supplementation, and T4 for flexitarian consumers seeking plant-based alternatives. The successful retention of bioactive compounds during kinnow bioenzyme coagulation highlights its potential as a clean-label processing aid. This work establishes a scientific framework for optimizing plant-dairy hybrids that address both nutritional adequacy and functional health benefits, while suggesting future research directions in bioavailability studies and commercial-scale process optimization.

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Natural Preservative Idiosyncrasy of Kuji Thekera (*Garcinia cowa*)-A Minor Fruit of Assam

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ABSTRACT

Kuji thekera (*Garcinia cowa*) is a very popular minor fruit of Assam which is orange in colour when ripe and requires almost about 3 ½ month to attain maturity after the fruit set. The fruit is highly acidic and sour in taste. Traditionally the people of Assam use this fruit in various pickles to increase the shelf-life of the pickles. In the present study three different pickles were prepared with different concentrations of *Garcinia cowa i.e.,* sample A (75%), sample B (50%) and sample C (25%) respectively and the microbial study and sensory evaluation were carried out on the samples for three months to observes the storage properties. The study reveals that the pickle prepared with a high concentration of *kuji thekera* (Sample A) showed shelf preservative properties both in terms of microbial growth and in retrieving the sensory qualities of the pickle during the studied storage period. Therefore, *Garcinia cowa* can be considered a natural preservative and can replace chemical preservatives to extend the shelf-life of value-added products.

Keywords: Preservative, *Kuji thekera* (*Garcinia cowa*), shelf-life, microbial study, sensory evaluation.

INTRODUCTION

There are various minor and underutilized fruits, out of which only a few are commonly known. Most of the fruits are still confined to their area of origin. Based on the spread of cultivation, the volume of production and trade, fruits can be divided into four main categories. Major fruit crops which are fruits like mango, banana, citrus fruits etc. which are regularly produced, cultivated commercially, adapted widely and have been selected purposefully by humans for development and have been systematically grown and marketed (Ghosh *et al,* 2018), whereas minor fruits is another category of crops that have been domesticated but not so extensively cultivated, consumed and trade tend to be move limited, geographically and quantitatively, than those of the major fruits, these crops are consumed relatively in less quantity, have less marked demand and are not cultivated in organised plantations.

Underutilized fruits are those which are not yet fully exploited, require low external inputs for production and are produced and consumed only in localized areas. Wild fruits refer to species that are neither cultivated nor domesticated, but they come from their wild natural habitat and are used as one of the sources of food (Sauco, 2008; Gaikwad *et al,* 2018). Assam is a land in North East India which is surrounded by rich sources of flora which are a stockpile of various protective properties. *Kuji thekera* (*Garcinia cowa*) is one of such minor fruit of Assam which is accredited with lots of useful properties such as nutritious, health benefits and preservative properties. Patiri and Borah (2007) reported that the people of Assam use to develop dehydrated *kuji thekera* as preserved products. This preserved product is used therapeutically to treat dysentery, diarrhoea and other gastro intestinal-related problems. *Kuji thekera* (*Garcinia cowa*) are traditionally used in various pickles and is believed that the addition of this fruit help in preserving the pickles. This information about the properties and uses of *Kuji thekera* is conveyed from generation to generation without any scientific evidence. In view of this information, the research work of the present paper elaborates on the natural preservative properties of *kuji thekera* that can retain the edible qualities of the developed products.

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MATERIALS AND METHODS

The matured fruits of *Kuji thekera* (*Garcinia cowa*) were collected from the market and sundried after cutting the fruits into thin slices. The dried fruits were then stored in air tied container to be used to prepare the vegetable pickle (sample A, B & C). To attain the aim of study, three mix-vegetable pickles were prepared with different concentration of *Kuji thekera* and in sample C chemical preservative was added to be able to compare the preservative properties of *Kuji thekera* with that of a chemical preservative (Table 1). Each sample was then packed into three different plastic bottles and sealed properly i.e. sample A was packed into three separate bottles and levelled as samples A, A_1 & A_2 similarly samples B, B_1 & B_2 and C, C_1 & C_2 were packed and levelled from sample B and C respectively.

Mixed vegetable (Cauliflower, Carrot, Knolkhol, Peas) (mature)

↓

Washing

↓

Cutting into small uniform pieces

↓

Blanching for 1 minute

↓

Sun-dry drying for 30 minute

↓

Weight the *Kuji thekera* - Sample A (75%), B (50%) &C (25%)

↓

Boiled the *Kuji thekera* with water and after cooling mix well in a mixer

↓

Heating oil

↓

Cooling

↓

Mixing spices in the oil

↓

Mixed the blanched vegetable and *Kuji thekera* (chemical preservative for sample C)

↓

Heating the mixture for a few minutes

↓

Cooling

↓

Filling in a sterilized bottle

↓

Storage

Fig. 1: Flow chart for pickle preparation

To study the preservative activity of *kuji thekera* the storage quality of the samples was evaluated in terms of microbial and sensory quality of the pickles. The storage quality of the developed products was carried out from 0 to 90 d at an interval of 30 d. All the analytic works were done following standard methods. The microbial growth of the samples was investigated in the Department of Plant Pathology, Assam Agricultural University, Jorhat by using hemocytometer method (Absher, 1973). And the sensory evaluation was carried out in the Department of Food Science and Nutrition, College of Community Science, Assam Agricultural University, Jorhat by referring to the 9 point Hedonic scale evaluation sheet.

RESULTS AND DISCUSSION

Microbial study across storage

Sample A, B, C were taken for the first month (30 d) study and samples A_1, B_1, C_1 were considered for the second month (60 d) investigation respectively. All the six samples showed negative microbial growth indicating that the pickles are in good quality during the two month storage (Table 2) period. For the third month (90 d) storage study of the pickles the samples A_2, B_2, C_2 were evaluated and found that except B_2 sample the other two samples were free from microbial growth. The result (Table 2) shows that the pickle (sample A) prepared with *Kuji thekera* as a natural preservative and the pickle (sample C) prepared with chemical preservative could retain their storage quality in terms of microbial growth. Whereas sample B with a low concentration of *Kuji thekera* could not prevent microbial growth and the pickle storage quality reaches beyond edible condition after the second month (60 d) of studies. The B_2 sample showed bacterial growth with $1.0 * 10^5$ CFU/ ml (Fig. 2) and spherical and diplococcoid-shaped bacteria (Fig. 3) were found in the sample which proves that the sample has become unedible. Thus, the result indicates that *Kuji thekera* acts as a resistance agent against microbial growth. The preservative properties of *Kuji thekera* fruit may exist due to the high acidic content of the fruit as Marg (2004) has mentioned about *Garcinia cowa* (*Kuji thekera*) a minor fruit of Assam is edible and acidic in nature. Barua (2015) recorded that the acid content of *Kuji thekera* (*Garcinia cowa*) ranges from 4.78 to 5.74%. Srivastava and Kumar (2007) in their book mentioned that in a high acidic media the growth of a majority of un-derisible organisms is inhibited. Again, a number of researchers have also enlightened the fact that *Kuji thekera* fruit is rich in various phytochemicals. Phytochemicals that exhibit
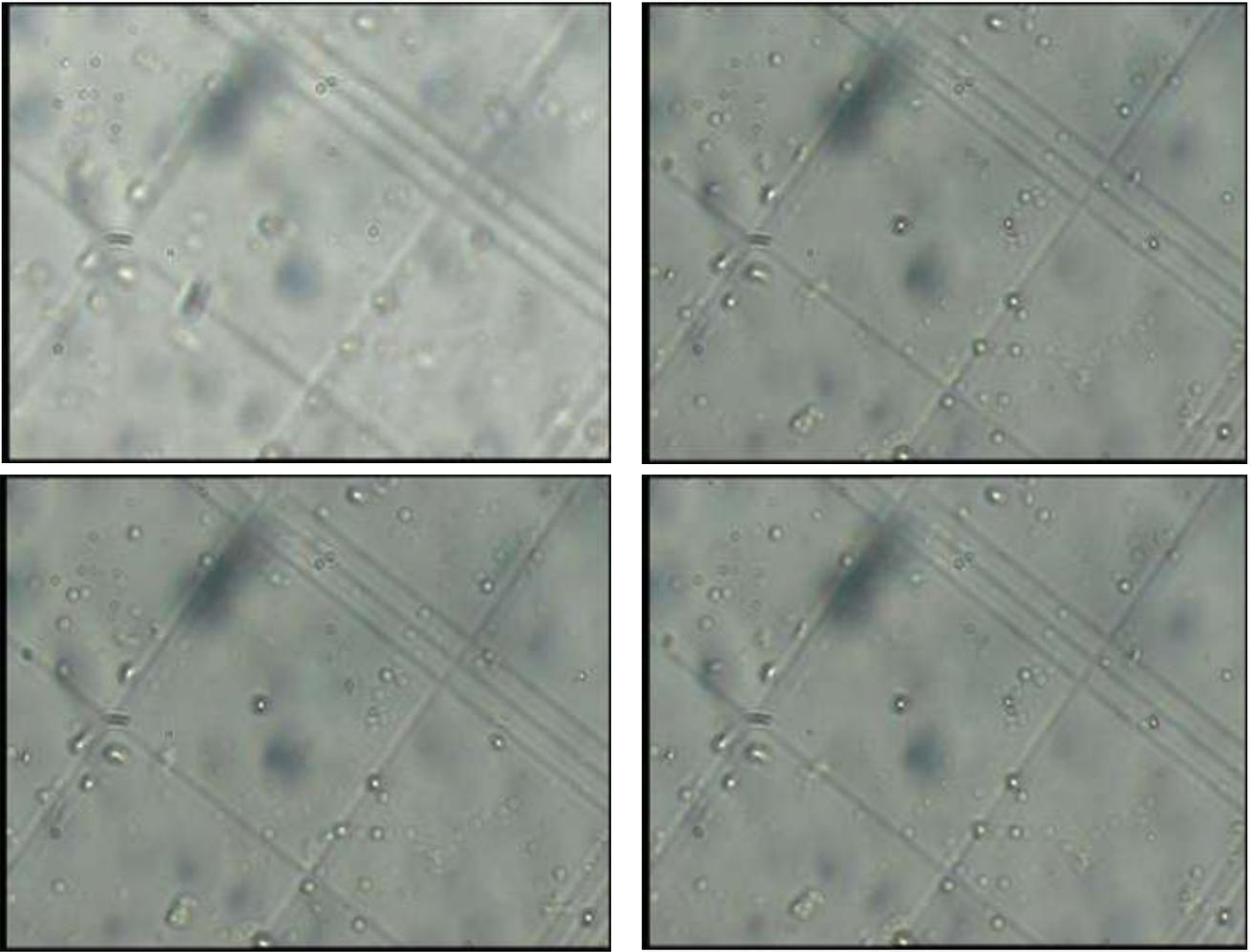
Fig. 2: The four squares under the microscope were average was counted for the total bacterial growth using hemocytometer method
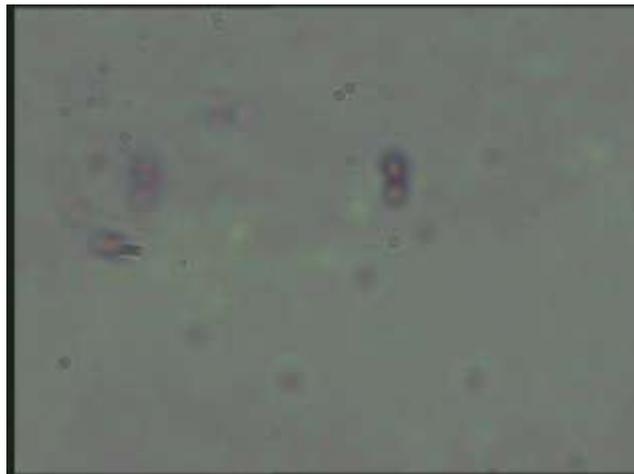
Fig. 3: The shape of Bacteria under a microscope (spherical and diplococcoid)
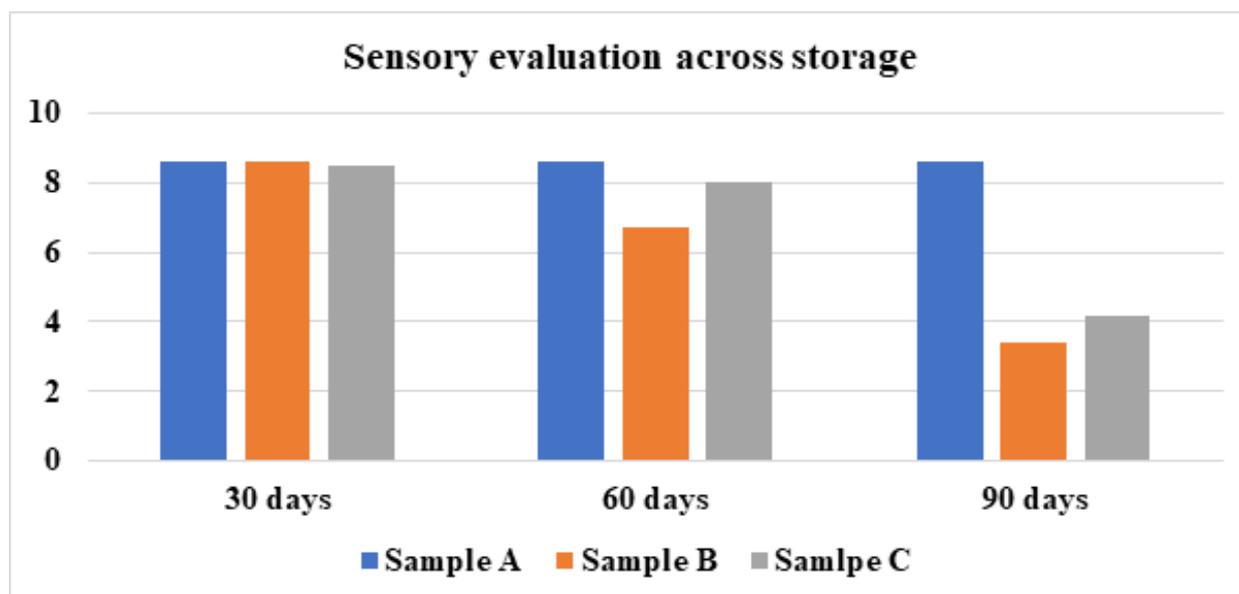
Fig. 4: Sensory evalution of the prepared pickles across storage

antioxidant properties (Green and Shallal, 2020) may also hinder the growth of microorganisms in the prepared pickle. Phytochemicals act as hurdle agents by cutting the oxygen supply that hampers microbial growth. Limtharakul *et al* (2013) stated that *Garcinia cowa* is accredited with an abundant amount of bioactive phytochemicals. Barua (2015) and Firdusi (2017) in their work also found that *Garcinia cowa (Kuji thekera)* is a rich source of Flavonoids- a type of phytochemical. Thus, it can be said that *Kuji thekera* as a natural preservative idiosyncrasy showed effective preservative properties for retaining the shelf-life of the product by hindering microbial growth.

Sensory analysis across storage

The sensory evaluation which was done using 9 points Hedonic scale evaluation sheet among expert penal members from the Department of Food Science and Nutrition, Assam Agricultural University, Jorhat is presented as a graph in Fig. 4. The data collected from the penal as presented in the graph showed that the pickle prepared with a high concentration (75%) of *Kuji thekera* retains its overall acceptability throughout the storage period. But in the case of sample B the storage quality deteriorated beyond edible condition after one month of storage (Sample B_1) and in sample C it was observed that the sample loses its edible property after 60 d of storage. From this observation, we could conclude that even sensory evaluation across the storage of the studied samples enlighten the fact that *Kuji thekera* could be considered a natural preservative.

CONCLUSION

From the microbial study across storage it can be said that *Kuji thekera* as a natural preservative idiosyncrasy showed effective preservative properties for retaining the shelf-life of the product by hindering microbial growth. Also from the sensory analysis across storage can give justification to the fact that *Kuji thekera* can be considered a natural preservative and can replace chemical preservatives without any side effects due to its preservative behaviour both in terms of preventing microbial growth as well as retaining its sensory properties throughout its storage life.

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Performance of Promising French Bean (*Phaseolus vulgaris* L.) Varieties for Growth and Yield Performance under different Agro-Climatic Conditions of Assam

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ABSTRACT

A field experiment was conducted to assess the yield performance of four French bean (*Phaseolus vulgaris L.*) varieties, namely *Arka Komal*, *Arka Sharath*, *Arka Arjun*, and *Syngenta Serengeti*, at Jorhat district under the supervision of Krishi Vigyan Kendra, Jorhat, during the 2023-2024 and 2024-2025 growing seasons. The experiment was laid out in randomized block design with three replications across five locations. Significant differences were observed among the varieties for growth and yield traits. Arka Sharath recorded the highest fresh pod yield per plant (234.25 g) and maximum yield (163.97 q/ha), followed by Arka Arjun (145.36 q/ha) and Arka Komal (140.91 q/ha), surpassing the control (140.36 q/ha). Arka Sharath also produced the longest pods (15.23 cm) and highest pod weight (9.70 g). Although Syngenta Serengeti produced the maximum pods per plant (44.56), Arka Sharath compensated with heavier pods, resulting in higher yield and profitability. Economic analysis revealed that Arka Sharath gave the maximum net return (₹2,11,940 ha^{-1}) with a benefit-cost ratio of 2.82, followed by Arka Arjun (2.50) and Arka Komal (2.42), all higher than the control (2.28). The study concluded that Arka Sharath was the most suitable variety for commercial cultivation in Jorhat district to enhance productivity and profitability.

Keywords: Economics, French bean, Varietal evaluation, Yield.

INTRODUCTION

French bean (*Phaseolus vulgaris* L.) is an important leguminous vegetable grown widely for its high protein content, nutritional value, and economic significance. In Assam, French bean contributes considerably to food and nutritional security, with approximately 3,200 ha under cultivation producing 20,480 Mt at an average productivity of 6.4 t/ha. In Jorhat district alone, the area under French bean is about 450 ha, yielding 2,880 Mt annually. (Department of Agriculture, Assam, 2023)

Varietal evaluation plays a crucial role in identifying cultivars that exhibit superior agronomic traits, such as high pod yield, disease resistance, and adaptability to diverse environmental conditions. Previous studies have emphasized the significance of genotype-environment interactions in determining the performance of French bean varieties across different agro-ecological zones (Kumar *et al*, 2020, Kumar *et al*, 2022). The Indian Institute of Horticultural Research (IIHR) has developed several improved cultivars, including *Arka Komal*, *Arka Sharath*, and *Arka Arjun*, which have demonstrated enhanced pod quality, yield potential, and resistance to common diseases (IIHR, 2022). Comparative analysis conducted by Singh *et al* (2019) indicated that varietal performance varies significantly depending on local soil and climatic conditions, necessitating region-specific trials to identify the most suitable cultivars for commercial cultivation.

Empirical research has further validated the advantages of improved French bean varieties. A study by Rana *et al* (2021) demonstrated that *Arka Sharath* exhibited superior yield attributes compared to conventional cultivars, thereby enhancing its potential

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Table 1. Growth and Yield Attributing characters of the treatments.

Treatment	Pod Length (cm)	Pod Diameter (cm)	Pod weight (g)	Plant height (cm)	No of Pods Per Plant (g)	Fresh Pod Yield per Plant (g)
Arka Arjun	14.10	0.78	5.30	50.30	39.10	207.23
Arka Komal	14.86	0.95	8.57	52.21	23.49	201.30
Arka Sharath	15.23	0.91	9.70	49.10	24.15	234.25
Control Syngenta Serengeti	14.80	0.75	4.50	51.50	44.56	200.52
SEd (±)	0.449	0.449	0.354	NS	1.737	17.352
CD(P =0.05)	0.978	0.978	0.770		3.785	37.807

for commercial adoption. Additionally, Sharma *et al* (2022) reported that strategic varietal selection could lead to a 20-30% increase in yield, highlighting the importance of continuous breeding and evaluation efforts. Moreover, Patel and Rao (2023) emphasized the role of climate adaptability in determining varietal success, while Gupta *et al* (2023) underscored the economic feasibility of improved French bean cultivars for smallholder farming systems. Against this background, the present study was undertaken to assess the performance and profitability of promising French bean varieties under the agro-ecological conditions of Jorhat district, Assam.

MATERIALS AND METHODS

The experiment was conducted by Krishi Vigyan Kendra, Jorhat, during rabi seasons of 2023–24 and 2024–25 at five locations in Jorhat district. Four French bean varieties were evaluated: T_1 Arka Komal, T_2 Arka Sharath, T_3 Arka Arjun, and T_0 Syngenta Serengeti (control). The trial was laid out in randomized block design (RBD) with three replications. Each plot measured 10 m × 20 m with spacing of 45 cm × 30 cm. A fertilizer dose of 30:40:20 kg NPK ha⁻¹ was applied, and recommended crop protection practices were followed. Observations were recorded on plant height, branches per plant, days to 50% flowering, pod length, pod diameter, pod weight, pods per plant, and fresh pod yield per plant and per hectare. Economic analysis included gross and net returns and benefit-cost (B:C) ratio. Data were subjected to ANOVA, and mean comparisons were made using LSD at 5% significance.

RESULTS AND DISCUSSION

Growth and Yield Performance

The statistical analysis revealed significant genotypic variations among the evaluated French bean cultivars concerning growth and yield attributes. Among the tested varieties, *Arka Sharath* demonstrated the highest fresh pod yield per plant (234.25 g), outperforming *Arka Arjun* (207.23 g) and *Arka Komal* (201.30 g), while exceeding the control variety (*Syngenta Serengeti*, 200.52 g). The superior performance of *Arka Sharath* can be attributed to its greater pod length (15.23 cm) and enhanced pod biomass, which collectively contributed to an increased yield per hectare. These findings are consistent with previous reports by Rana *et al.* (2021) and Sharma *et al* (2022), who established a positive correlation between pod size, weight, and overall productivity in *Phaseolus vulgaris*. Despite *Syngenta Serengeti* exhibiting the highest number of pods per plant (44.56), the compensatory advantage of *Arka Sharath* and *Arka Komal* in terms of larger, heavier pods resulted in superior total yield. This concurs with observations by Singh *et al* (2019), who noted that genetic variation among cultivars influences pod characteristics and cumulative yield potential.

Economic Analysis

The economic evaluation demonstrated that *Arka Sharath* recorded the highest yield per hectare (163.97 q/ha) and generated the maximum net return (Rs. 2,11,940) with an optimal benefit-cost (B:C) ratio of 2.82. *Arka Arjun* and *Arka Komal* also exhibited

Table 2. Yield, Economics of Cultivation.

Treatments	Yield Per Ha (q/Ha)	Price Per Kg (Rs)	Gross Cost (Rs)	Gross Return (Rs)	Net Return (Rs)	B:C Ratio
Arka Arjun	145.36	20.00	1,16,000.00	2,90,720.00	1,74,720.00	2.50
Arka Komal	140.91	20.00	1,16,000.00	2,81,820.00	1,65,820.00	2.42
Arka Sharath	163.97	20.00	1,16,000.00	3,27,940.00	2,11,940.00	2.82
Control Syngenta Serengeti	140.36	20.00	1,23,000.00	2,80,720.00	1,57,720.00	2.28
S. Ed(±)	1.835					
CD(P =0.05)	3.998					

A. Cultivation of French Bean,

B. Pod size and shape of the treatments,

C. Disectional view of the pods

substantial economic viability, with B:C ratios of 2.50 and 2.42, respectively, exceeding that of the control variety (*Syngenta Serengeti*, B:C ratio 2.28). These results align with the economic feasibility analysis conducted by Gupta *et al* (2023), which emphasized the profitability of improved French bean cultivars under commercial farming conditions. Moreover, the economic analysis of French bean cultivation in the Uttarakhand hills (Sharma *et al*, 2024) similarly demonstrated that high-yielding cultivars generated greater net returns and benefit–cost ratios. Further corroboration is provided by Patel and Rao (2023), who identified superior economic returns in high-yielding *Phaseolus vulgaris* genotypes cultivated in

semi-arid agro-ecosystems. This suggests that given its superior yield performance and economic benefits, *Arka Sharath* have strong potential as a promising candidate for large-scale commercial adoption in Assam.

CONCLUSION

The study revealed that Arka Sharath performed best among the tested French bean varieties, recording the highest yield and profitability, followed by Arka Arjun and Arka Komal. Considering its adaptability to local conditions and superior economic returns, Arka Sharath is recommended for large-scale

cultivation in Jorhat district of Assam, to enhance farmers' income and productivity.

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Production Performance and Economic Viability of Beetal Goats in Himachal Pradesh

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ABSTRACT

Goat is a multipurpose animal indispensable to small and marginal farmers across the world. In the present study the production performance and economic viability of Beetal goats was assessed in agroclimatic zone-I of Himachal Pradesh. A Beetal unit with five does and one buck was established at Krishi Vigyan Kendra, Kangra. The goats were reared in a semi-intensive system that integrated natural grazing with supplementary concentrate feeding. The surplus male and female goats were supplied as breeding stock. Over a five-year period, key production and reproductive parameters were recorded. The age at first kidding averaged 15.4 ± 0.6 months, with kid birth weights ranging from 1.92 to 3.50 kg. The unit achieved an average kidding rate of 1.34 ± 0.04 live kids per kidding across 23 successful kidding. Mature does and bucks weighed an average of 31.5 ± 0.9 kg and 47.2 ± 1.2 kg, respectively. Economic returns from sale of surplus goat varied from Rs. 26,600 to Rs. 155,450, with a total of Rs. 270,850 accrued over five years. The findings underscore the potential for Beetal goats to contribute to the diversification and sustainability of livestock farming in the region, suggesting that targeted development initiatives toward stationary and semi-intensive goat rearing could provide an effective alternative to declining traditional dairy cattle enterprises.

Keywords: Beetal, Breed, Goat, Performance, Production, Sustainability.

INTRODUCTION

Goats are highly adaptable animal and can be found in mostly all major parts of the globe (Arya *et al,* 2021). In Himachal Pradesh a north-western state of India, the goat population is about 11.1 lakhs (BAHS, 2019) and bulk of these goats (65%) are being reared under migratory/transhumance system and distributed in higher mountain areas with tough terrain like Chamba, Kangra, Mandi, Kullu and Shimla. In low mountain areas the goats are being reared in stationary/semi-extensive system where animals are provided shelter during night and taken for grazing locally during daytime (Singh *et al,* 2024). The goats in these units are non-descript with unreported or low production performance. In the mid-lower area goat population is around 35% most of which belongs to local goat population which are not yet registered, followed by admixture of Beetal/Sirohi and other indigenous breed procured by farmers or development agencies. Since, the Beetal goat is most prevalent as admixture population as well as purebred at few farmer's flock particularly in the lower hill area the propagation of Beetal can be appropriate in these regions. Further the part of lower hills especially the Shivalik region of Himachal Pradesh is part of old Punjab and region is adjoining to the breeding tract of Beetal, thus their propagation is within the frame of National policy. Further, the recent trends of livestock census and dynamics in state indicated decline in the cattle population owing to multitude of problems namely disposal of unproductive cattle, reproductive problem in crossbred, fragmentation of family and migration from villages to peri-urban areas.

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To some extent this sharp decline is filled by the goat as alternate to dairy cattle (although not sizeable yet but becoming popular) especially in the mid-hill to lower regions. The fact is also evident from temporal analysis of last five livestock census (1997-2019). The analysis revealed that the total population decline in livestock is 15.56% over the last five censuses with average yearly decline of 0.80% while in goat the total corresponding decline was only 5.1% over the last census and average yearly decline was 0.25% (Sankhyan *et al,* 2019; Dinesh *et al,* 2023; Anonymous, 2025). Thus, among livestock goat population only demonstrated somewhat stable trend over the census and recorded even growth between censuses. Although no systematic study has been done to analyze the decreasing trend of goat among migratory and stationary system, but indirect estimation through documentation of decreasing pastoralism (Sharma *et al,* 2022) indicates that stationary goat population may be increasing over the years. Therefore, development initiatives should be directed towards popularization of goat farming as stationary/semi-intensive which hitherto is neglected since the small ruminant farming in Himachal Pradesh is generally considered as pastoralism and institutional efforts are more directed towards migratory system. Recently there were initiative taken by government towards popularizing goat farming in lower hills, but evaluation and adaptability of breed introduced needs evaluation in different zones and production system to rationalize the propagation of goats. Keeping in view the above factors the present study production performance and economic assessment of Beetal goats an outstanding goat breed of neighbouring state, Punjab was assessed in agroclimatic zone I of Himachal Pradesh.

MATERIALS AND METHODS

A Beetal goat unit comprising of 5 does and 1 buck from its native breeding tract in Punjab were introduced at Krishi Vigyan Kendra, Kangra under Rashtirya Krishi Vikas Yojna in 2019. The animals were selected based on true to breed type characters and fulfilling the standard health and reproduction criteria. The goats were maintained under semi-intensive rearing system wherein the goats were led for grazing during daytime and housed overnight. Bushes and local grasses in pasture and field bunds constituted the primary grazing source for the unit. Sometime tree lopping was also provided to strengthen fodder availability to goats. Additionally, all the goats together were also provided about 1 kg concentrate as supplementary feeding. The surplus goats and kids from this unit were supplied as breeding stock to farmers and other agencies at the rate of Rs. 450 per kg live body weight for adult animals and Rs. 5000 per kid upto six months of age. The aged animals in the unit were also culled and supplied for meat purpose at the rate of Rs. 250 per kg live body weight occasionally. One labour was engaged every day for grazing of goats along with cattle from dairy unit of Krishi Vigyan Kendra. The data generated was analyzed for descriptive statistics using statistical package SPSS version 16.0.

RESULTS AND DISCUSSION

Age at first kidding

The female kids born at the Kendra, delivered their first kidding in the age ranging from 13 to 19 months with an average of 15.4±0.6 months. The average age of first kidding has been reported from 17.4 (Ahmad *et al,* 2007) to even higher range of 20 to 22 months (Dhara *et al,* 2020). The relatively lower age of 15.4±0.6 months observed in the present study may be due to rearing of all the goats across all age groups and sex together in one room which offered more opportunities for mating in the goat flock. In the current rearing system, the effect of bio stimulation and greater excess to male may also have influenced the age at first kidding (Landaeta-Hernández *et al,* 2023)

Kid birth weight

The birth weight of kids ranged from 1.92 to 3.50 kg. The birth weight was higher when the number of kids born per kidding was only one and it ranged from 2.4 to 3.5 kg while it was lower when twinning or tripling per kidding was observed. Birth weight of Beetal kid or any other animals is linked to heredity and nutrition of dam especially during pregnancy. The birth weight of Beetal goat has been reported to vary in different areas and ranged from 2.9 to 3.6 kg (Afzal *et al,* 2004). In the present study the area is totally rain fed so the prevalent vegetation may be less succulent and nutritious. Additionally, provision of separate feeding of pregnant does was not available so the birth weight of kids in the present study may be lower. This is further supported by the fact that higher birth weight was observed in some of the farmer's flock which procured breeding stock from the KVK unit, where resource utilization was optimum. Additionally, lower age at first kidding may have also caused lower kid birth weight in the present study. Soundarajan *et al* (2006) has also reported that the goats which have lower adult weight tend to give birth to kids with lower birth weight.

Production Performance and Economic Viability of Beetal Goats

Table 1: Year wise sale of Beetal goats and revenue generated at KVK Kangra

Year	Number of animals Sold	Revenue generated (Rs)
2020	0	0
2021	2M, 4F	26600
2022	3M	46800
2023	2M, 2F	42000
2024	2M, 6F	155450
Total	21	270850

(M = male and F = Female)

Table 2: Input cost, revenue generated and benefit cost ratio of Beetal goat unit

Sr. No.	Particulars	Amount (Rs)
1	**Input cost**	
a	Cost of initial goat unit	62000
b	Cost of labour, one third of a manday @ Rs 350/day	212917
c	Cost of feed, 1 kg/day @ Rs 24/kg	43800
	Total	318717
2	**Revenue generated**	
a	Sale of goats	270850
b	Capital accrued/available at the end of 2024: 16 goats (1 M, 6 F and 9 kids)	151375
	Total	422225
3	**Benefit cost ratio**	1.32

Kidding rate

At this unit a total 23 successful kiddings took place, and 31 live kids were born and added to the flock over the five-year period from 2020-2024. The average number of live kids born per kidding was 1.34±0.04 The number of kids born per kidding has been reported to be around 1.76 in their native tract of Gurdaspur and Amritsar (Tantia *et al,* 2001). The lower number of kids per kidding (1.34+0.04) observed in the present study can attributed to relatively longer cold climatic conditions of the hilly regions of Kangra, Himachal Pradesh and high annual rainfall (which favours high incidence of parasite infestation), lack of nutritious fodder especially during winter season and poor forages in the pasture area. These reasons may have affected the reproductive aspect of Beetal goats in the area.

Mortality

Mortality in kids and adult during the study period was around 12% for kids and 2.7% in adults. Among kids' mortality was more which were born as part of twinning or tripling. The primary reason for mortality was poor nursing by weak mothers especially when the number of kids born per kidding was more. These weak kids owing to poor nutrition had low immunity so easily succumbed to diseases like diarrhoea and pneumonia. Additionally, some kids also died due to injury or attack by adult buck owing to common overnight shelter. Separate housing for young kids and breeding bucks may be helpful to overcome these losses.

Health

In adult goats incidence of premature kidding and apparently caseous lymphadenitis was also observed. Premature kiddings may be due to poor nutrition due to limited concentrate supplementation and grazing resources especially during lean season. Honparkhe *et al* (2017) has also reported premature kiddings in Beetal goats due to ingestion of goitrogenic fodder though such lesions were not apparent in the

present study. The caseous lymphadenitis in the flock need further investigation as the disease also has zoonotic implications and is not commonly observed in local goats in Himachal Pradesh.

Adult body weight

The mature body weight recorded at the unit ranged from 26 to 37 kg with an average of 31.5 ± 0.09 kg for adult females and 39 to 54 kg with an average of 47.2 ± 1.2 kg for males. Average adult body weight of Beetal goats has been reported about 34 and 59 kg for female and male (Tantia *et al,* 2001) respectively. The lower body weight in the present study indicated lower plane of nutrition in the region. It may be due to shorter grazing period or poor food resources in the local area. Additionally, the present area *i.e.,* Kangra has longer winters compared to native tract so the maintenance requirements of the animals may be higher causing lower mature body weight across both sexes.

Economic returns

The annual revenue generated from sale of goats ranged from Rs. 26600 to Rs. 155450 as shown in table 1. The total revenue accrued over the five years was 270850 with an average of Rs 54170 per annum. Ravi *et al* (2022) has also reported a net income of Rs. 56920 from a unit of 10 goats annually, which is little lower than that observed in the present study. Beside it 16 goats (1 adult male, 6 adult female and 9 kids) were still available at Kendra by the end of this period. As Beetal goats are reared primarily on grazing and a flock of upto 20 animals can be effectively managed by family labour without engaging additional unskilled labour. The average per capita income in Himachal Pradesh is Rs. 235199 (Economic survey, 2023-24). So, an additional annual earning of Rs. 54000 for a small or marginal farmer, can make a significant addition to his/her income. Besides the goats are reared by people from low-income group so addition of such goat unit in a household may help them to cross the poverty line and improve their socio-economic status.

Benefit cost ratio

Table 2 shows the input cost, revenue generated and benefit cost ratio of Beetal goat unit at the KVK Kangra. The cost of buying the initial goat unit of 5+1 was Rs. 62000. On an average about 1 kg concentrate feed (Rs. 24/kg) was offered to goats daily. Since no labour or worker was deputed exclusively for goat unit and only one labour was deputed for grazing of goats and cows being reared at Krishi Vigyan Kendra so only one third of a manday @ Rs. 350/daily

was used as labour cost. The total cost of production of goat unit for five years turned to be Rs. 318717. So, the benefit cost ratio for goat unit over the five years period is 1.32 indicating good returns. The milk produced by Goats was primarily used for nursing of kids and surplus milk was also collected but not recorded. Similarly, the cost of health care, forages grazed, and manure produced by goats was not included. The goats were sold primarily for breeding purpose, so the selling price as breeding stock was higher and may be the main reason for good benefit cost ratio in the present study.

CONCLUSION

Beetal goat performed satisfactorily in agro-climatic conditions of Kangra and owing to good growth and adult body weight can significantly contribute to income of small and medium farmers in low mountainous areas in the state of Himachal Pradesh. Further the study will serve as reference base line scientific evaluation for wider propagation of Beetal goat through institutional efforts in the lower hill region of Kangra districts and geographically similar region in other districts.

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Role of Training in Promoting Scientific Fish Farming Practices Among Farm Pond Users in Dryland Tamil Nadu

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ABSTRACT

Krishi Vigyan Kendras (KVKs) play a pivotal role in India's agricultural extension framework, especially in promoting location-specific technologies among small and marginal farmers. With the increasing relevance of farm ponds in integrated farming systems and their potential to supplement rural income, fish farming has gained prominence as a sustainable livelihood option. This study assesses the impact of KVK training programs on farmer's knowledge enhancement and their subsequent adoption of scientific fish farming practices in farm ponds. Conducted in Sivaganga District of Tamil Nadu, the study employed a mixed-methods approach, including pre- and post-training assessments, structured interviews, and an adoption index. Results revealed a statistically significant increase in farmers' knowledge levels after training. Furthermore, adoption of scientific aquaculture practices was positively influenced by knowledge gain, education level, and social participation. The findings highlight that while KVK training effectively builds knowledge and improves adoption, sustained impact requires stronger input supply systems, continuous advisory services and farmer group-based support mechanisms. The study affirms the value of targeted training interventions for enhancing aquaculture adoption in rainfed agro-ecosystems.

Keywords: Adoption, Aquaculture, Behaviour, Dryland agriculture, Fish farming, Knowledge gain, Ponds,

INTRODUCTION

The growing pressures of climate variability, declining groundwater levels, and increasing demands for water have prompted a renewed focus on farm ponds as a viable solution for water conservation and integrated farming systems. In this context, farm ponds are not only crucial for irrigation but also offer opportunities for diversified livelihoods through fish farming. Fish farming in farm ponds has emerged as a profitable and sustainable enterprise, particularly suited to small and marginal farmers who seek additional sources of income and nutrition (Debnath, 2019; Kumar *et al,* 2019). Sivaganga district, located in the southern part of Tamil Nadu, exemplifies the transformative potential of farm ponds in improving rural livelihoods. The district's agrarian economy has long been dependent on agriculture, with farmers facing challenges such as erratic rainfall and limited irrigation sources. In recent years, however, fish farming in farm ponds has emerged as a sustainable and profitable alternative, offering farmers an additional

source of income and improving their resilience to climate change (Thavapalan and Sathish, 2021). The district's farmers are increasingly integrating fish farming with traditional agricultural practices to maximize resource use and improve income stability. Despite the significant potential, however, many farmers still lack the technical skills and institutional support required for scientific fish farming. Traditional practices often lead to sub-optimal production due to poor pond preparation, lack of feeding protocols, and minimal disease management. The need to bridge this knowledge and skill gap is imperative to harness the full potential of aquaculture.

In this context, Krishi Vigyan Kendras (KVKs) have played a pivotal role in addressing the knowledge gap and providing scientific training to farmers (Kumar and Kaur, 2015). KVKs, under the Indian Council of Agricultural Research (ICAR), are established as frontline institutions to transfer knowledge, technologies, and best practices in agriculture and allied sectors. In Sivaganga, KVKs have been

instrumental in promoting fish farming by offering targeted training programs that focus on pond management, species selection, feeding practices, water quality management, and disease control. These programs aim to equip farmers with the necessary skills and knowledge to shift from traditional to scientific fish farming practices, thereby improving their productivity and profitability. However, there is limited research on their specific influence in Sivaganga district. This study aims to fill this gap by evaluating the effectiveness of KVK-led fish farming trainings on farmer's knowledge enhancement and subsequent adoption behaviour. By focusing on Sivaganga district, this research seeks to explore the unique challenges and opportunities faced by farmers in this region, while also assessing the broader implications for scaling sustainable aquaculture practices across similar rural areas in Tamil Nadu and India. The study also aims to investigate the factors that influence the adoption of fish farming practices. Ultimately, the research aims to contribute to the understanding of how extension programs can effectively bridge the knowledge gap in fish farming, thus promoting sustainable practices and improving rural livelihoods in Sivaganga and beyond.

MATERIALS AND METHODS

Study Area

The study was conducted in Sivaganga district, situated in the southeastern region of Tamil Nadu. Characterized by a semi-arid climate, the district experiences frequent rainfall variability and water scarcity issues, making water conservation efforts such as increasing adoption of farm pond-based interventions under government schemes such as MGNREGA and PMKSY. KVK Sivaganga conducted more than 40 structured training programs on scientific fish farming over the past five years. Using a purposive sampling technique, a total of 100 farmers who attended KVK fish farming training between 2021 and 2024 were selected.

Data Collection and Tools

Primary data were collected through structured interviews using a pre-tested questionnaire. Knowledge gain was assessed using a 20-item test covering key domains: pond preparation, stocking density, feeding regime, water quality maintenance and disease control. Adoption was measured using an adoption index, calculated as the proportion of recommended practices adopted by each respondent. Descriptive statistics summarized demographic and training participation details. A paired t-test compared

pre- and post-training knowledge scores. Multiple regression was used to identify predictors of adoption behaviour.

RESULTS AND DISCUSSION

Demographic profile of respondents

Understanding the demographic characteristics of respondents is crucial for interpreting their training needs, adoption behaviour, and responsiveness to capacity-building initiatives. The study covered 100 fish farmers who participated in training programs on scientific aquaculture conducted by KVK Sivaganga between 2021 and 2024. The demographic profile included variables such as age, gender, education, landholding size, annual income, social participation and prior aquaculture experience (Table 1). The majority of respondents (46%) were in the age group of 36-50 years, followed by 32% above 50 years and 22% below 35 years. This indicates that middle-aged farmers form the core group experimenting with aquaculture, possibly due to their relatively stable resources and openness to diversifying income sources. A study by Jayanthi *et al* (2021) similarly observed that farmers in the 35–50 age range are more likely to adopt aquaculture innovations, especially in rainfed areas of Tamil Nadu. Gender-wise, 83% of the respondents were male and 17% female. The low female participation can be attributed to social norms and perceptions of aquaculture being labour-intensive, although literature suggests that women often play critical roles in feeding, pond cleaning, and harvesting when adequately supported (Rao and Devi, 2020). A significant portion of farmers (52%) had completed secondary education, followed by 30% who had completed higher secondary or college education, and 18% with only primary-level education or below. This level of literacy is crucial, as it facilitates better comprehension of technical training content and documentation processes such as input records, loan applications, and market communications.

In terms of landholding, 36% were marginal farmers (<1 ha), 44% small (1–2 ha), and 20% medium and above (>2 ha). This aligns with the broader rural demographic structure in India, where the predominance of smallholder farming is a defining characteristic (ICAR, 2021). These farmers often rely on diversified farming systems for livelihood security, and fish farming is increasingly being integrated into their farm operations. Since farm pond creation is often linked to agricultural land ownership, this distribution suggests that small and marginal farmers are actively

engaging in fish farming as a secondary income source. In alignment with the findings of Kumar *et al* (2022) farm ponds in Tamil Nadu are predominantly owned by smallholders, making them a strategic target group for rural aquaculture interventions. The majority of respondents (54%) reported an annual household income below ₹1.5 lakhs, with 32% in the ₹1.5–3 lakh range. Only 14% earned above ₹3 lakhs annually. Lower-income farmers showed strong interest in aquaculture as a supplementary income source, particularly when supported by government schemes and training. About 61% of the respondents were active in community-based organizations such as Primary Cooperative Society (PCS), Farmer's Interest Groups (FIGs) or Farmer Producer Organizations (FPOs). Only 28% of the respondents had prior experience in aquaculture, while the remaining 72% were first-time adopters, primarily introduced to aquaculture through the KVK's awareness campaigns and training interventions. The findings of the study align with the trend that most farm ponds in Sivaganga were originally constructed for rainwater harvesting and irrigation, with aquaculture being introduced recently through government schemes and KVK outreach. As such, structured training and technical guidance become essential for transitioning these farmers into successful aquapreneurs. The findings underscore the importance of targeting training programs to smallholder, semi-literate, and novice fish farmers, especially in dryland districts where pond-based aquaculture is still an emerging livelihood option. These demographic insights also reinforce the need for locally contextualized, hands-on training that accommodates low prior exposure, labour availability, and educational limitations.

Knowledge gain

The effectiveness of training programs largely depends on the extent to which they enhance the knowledge and skills of participants. To assess the knowledge gain among farmers trained by KVK Sivaganga, a pre- and post-training test was administered covering key domains of scientific fish farming. The test consisted of 10 multiple-choice and short-answer questions focused on pond preparation, stocking, feed management, water quality, disease control, and record keeping (Table 2). The average pre-training knowledge score across all six domains was 15.6 out of 60, indicating a low baseline understanding of scientific fish farming practices among the respondents. Following the training, the mean post-test score increased significantly to 40.4, reflecting an average knowledge gain of approximately 159%. The greatest improvement was observed in the domain of water quality management, which had the lowest initial score (mean = 2.0) but saw a dramatic increase post-training (mean = 6.7; 235% gain). This suggests that water quality concepts were previously unfamiliar but effectively conveyed during the training. This pattern mirrors the findings of Reddy *et al* (2017), who reported that farmers often exhibit lower baseline awareness in areas requiring technical precision and scientific understanding, such as nutrient management and water chemistry. Substantial gains were also noted in stocking density and feed management, two critical parameters for optimizing growth and yield in farm pond aquaculture. Even in relatively technical domains such as record keeping and disease management, where adoption is usually low due to complexity or labour demands, trainees showed significant improvement in knowledge levels. The increase in record keeping scores from 1.8 to 4.5 though modest compared to other domains, is notable considering that over 70% of respondents had no prior exposure to formal monitoring systems. These findings are in alignment with similar training impact studies by Sharma and Ghosh (2021) and Yadav *et al* (2020), which emphasize that structured, hands-on training modules particularly those delivered in local languages and with visual aids are highly effective in increasing awareness and interest in scientific aquaculture among small and marginal farmers. Furthermore, analysis across demographic segments revealed that knowledge gain was consistent across age and landholding groups, but marginally higher among those with higher education levels, indicating the importance of education in assimilating technical content. Education was positively associated with adoption levels, consistent with findings by Reddy *et al* (2019), who noted that better-educated farmers were more receptive to scientific inputs, including feed management and disease prevention.

Adoption behaviour

The adoption behaviour of farmers following training is a key indicator of the practical relevance and effectiveness of capacity-building interventions. In this study, adoption was assessed based on the implementation of six core scientific practices introduced during the KVK Sivaganga training: (i) ploughing of pond bottom (ii) recommended stocking density, (iii) use of pelleted feed, (iv) pond liming and water quality management, (v) basic disease control measures, and (vi) record keeping. Adoption was measured through field verification and structured interviews conducted 3 to 6 months post-training. The

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findings revealed that a substantial proportion of farmers demonstrated positive adoption behaviour. As shown in Table 3, the most widely adopted practice was maintaining appropriate stocking density (82%), followed by the use of formulated feed (75%), and pond liming for pH adjustment (65%). These practices are relatively easy to implement, require limited behavioural change, and yield visible improvements in fish growth and survival. Ploughing of the pond bottom, a recommended preparatory practice for removing toxic gases and decomposed organic matter before stocking, was adopted by 58% of the farmers. Despite being a low-cost intervention, its adoption was often constrained by labour availability or limited awareness prior to training. These results are consistent with earlier studies, which indicate that while input-based interventions are adopted readily, knowledge-intensive or management-heavy practices such as record maintenance or disease diagnosis face slower uptake (Yadav *et al,* 2020; Jayanthi *et al,* 2021).

Adoption behaviour was also influenced by farmer's exposure, education, and support mechanisms. Farmers who were part of Primary Cooperative Societies (FPCs) or Farmers' Interest Groups (FIGs) and had higher post-training knowledge scores were significantly more likely to adopt multiple practices. This aligns with the findings of Reddy *et al* (2019), who reported that social participation and information retention were key drivers of aquaculture technology adoption. Moreover, first-time fish farmers showed a preference for practices that minimized risk and did not require recurring expenditure. For instance, stocking density adjustments and liming were preferred over continuous use of commercial feed or water quality testing kits. The study also revealed that 68% of respondents qualified as high adopters (implementing four or more practices), while 32% were low adopters (one to three practices). Qualitative feedback indicated that high adopters were motivated by observed benefits in productivity, peer influence, and confidence built during hands-on training sessions. In contrast, low adopters cited barriers such as unavailability of inputs (e.g., feed and seed), lack of technical support post-training, and risk aversion as reasons for partial adoption. This behavioural segmentation echoes the diffusion of innovation theory (Rogers, 2003), which suggests that early adopters are typically more informed, socially connected, and receptive to technical support, while others require repeated exposure and institutional support to change practices. Overall, the adoption behaviour observed among KVK-trained farmers in Sivaganga reflects a promising shift towards scientific fish farming in rainfed regions. However, sustaining and scaling adoption will require follow-up extension support, timely input supply, and clustering of farmers to encourage peer learning and market linkages. Structured follow-through by KVKs, convergence with line departments, and field-based demonstrations are therefore critical to reinforcing adoption behaviour beyond the training phase.

Determinants of Adoption

Adoption of scientific fish farming practices among farmers trained by KVK Sivaganga was influenced by a combination of individual, socio-economic, and institutional factors. While the training resulted in substantial knowledge enhancement, the translation of knowledge into practice varied across respondents. A multiple linear regression analysis was conducted to assess the influence of farmer characteristics on the extent of adoption of scientific fish farming practices, using the number of practices adopted (ranging from 0 to 6) as the dependent variable. The model revealed that several factors had statistically significant effects on adoption levels, with an overall R^2 of 0.61, indicating that 61% of the variation in adoption behaviour was explained by the selected independent variables (Table 4). The analysis revealed that knowledge gain had a strong positive influence (β = 0.11; p = 0.007), suggesting that for every one-point increase in the post-training knowledge score, the number of practices adopted increased by 0.11. This reinforces the critical role of well-designed training in translating awareness into action. This finding aligns with earlier studies which affirm that targeted training significantly influences adoption behaviour when the content is practical, locally contextualized, and reinforced through demonstrations (Jayanthi *et al,* 2021; Sharma and Ghosh, 2021). Education level also significantly influenced adoption (β = 0.24; p = 0.009), indicating that farmers with higher levels of formal education were better positioned to understand and apply technical recommendations such as optimal stocking density, water quality testing, and formulated feed use. This supports previous observations by Reddy *et al* (2019), who noted that educational attainment positively correlates with technology adoption in aquaculture.

Annual income was also found to significantly influence adoption behaviour (β = 0.31; p = 0.029). Farmers with higher annual incomes were more likely to adopt a greater number of scientific practices, likely

Role of Training in Promoting Scientific Fish Farming Practices Among Farm Pond Users

Table 1. Demographic Profile of Respondents (n = 100)

Sr. No.	Parameter	Category	Percentage (%)
A.	Age	Below 35	22
		36–50	46
		Above 50	32
B.	Gender	Male	83
		Female	17
C.	Education	Primary or below	18
		Secondary	52
		Higher Secondary and above	30
D.	Landholding	Marginal (<1 ha)	36
		Small (1–2 ha)	44
		Medium (>2 ha)	20
E.	Annual Income	Below ₹1.5 lakhs	54
		₹1.5 – ₹3.0 lakhs	32
		Above ₹3.0 lakhs	14
F.	Social Participation	Member of PCS/FIG/FPO	61
		No participation	39
G.	Prior aquaculture experience	Yes (1–3 years)	28
		No	72
H.	Type of pond	Farm pond (rainfed/seasonal)	100

Table 2. Mean Knowledge Scores Before and After Training (n = 100)

Sr. No.	Knowledge Domain	Max. Score	Pre-Training Mean	Post-Training Mean	% Increase
1.	Pond preparation and liming	10	3.1	7.4	138.7[*]
2.	Stocking density and species mix	10	2.9	7.1	144.8[*]
3.	Use of formulated feed	10	3.3	7.8	136.4[*]
4.	Water quality management	10	2.0	6.7	235.0[*]
5.	Disease identification and control	10	2.5	6.9	176.0[*]
6.	Record keeping and monitoring	10	1.8	4.5	150.0[*]
7.	Overall Knowledge Score	60	15.6	40.4	159.0[*]

Differences statistically significant at p < 0.01 level (Paired t-test).

Table 3. Adoption of Scientific Fish Farming Practices among Trained Farmers (n = 100)

Sr. No.	Scientific Practice Adopted	Number of Adopters	Adoption Rate (%)
1.	Ploughing of pond bottom before stocking	58	58
2.	Stocking at recommended density (1000–1500/pond)	82	82
3.	Use of formulated/pelleted feed	75	75
4.	Pond liming and pH adjustment	65	65
5.	Disease prevention ($KMnO_4$, salt, etc.)	41	41
6.	Record keeping (stocking, feed, harvest data)	31	31

Overall high adopters (≥4 practices adopted): 68 farmers (68%)

Overall Low adopters (≤3 practices adopted): 32 farmers (32%)

due to better financial capacity to procure inputs such as pelleted feed, liming materials, and basic diagnostic tools. Although KVK training made low-cost alternatives available, certain practices especially those requiring recurring investment or labour remained more accessible to better-off households. This aligns with the findings of Yadav *et al* (2020), who observed that resource-endowed farmers tend to adopt a broader range of aquaculture innovations, particularly when those innovations require upfront financial commitment. However, it is worth noting that despite income disparities, a considerable number of low-income farmers adopted key practices when training was backed by demonstrations and peer encouragement, indicating that knowledge and confidence can partially offset financial constraints.

Table 4. Linear Regression for Factors Influencing Adoption (n = 100)

Sr. No.	Independent Variable	Regression Coefficient (β)	Standard Error	t-value	p-value
1.	Education level (years)	0.24	0.09	2.67	0.009*
2.	Annual income (₹ lakhs)	0.31	0.14	2.21	0.029*
3.	Landholding size (hectares)	0.18	0.12	1.50	0.137
4.	Knowledge gain (score 0–60)	0.11	0.04	2.75	0.007*
5.	Social participation (Yes=1)	0.88	0.35	2.51	0.014*
6.	Prior aquaculture experience	0.69	0.28	2.46	0.016*
7.	Age (years)	-0.02	0.02	-1.20	0.234

Significant at 1% level (P ≤ 0.001)

R² = 0.61

Table 5. Constraints to Adoption of Scientific Fish Farming Practices (n = 100)

Sr. No.	Constraint Identified	No. of Respondents	Percentage (%)	Rank
1.	Non-availability of quality fish seed locally	78	78	I
2.	High cost or non availability of pelleted feed	64	64	II
3.	Lack of technical guidance after training	57	57	III
4.	Difficulty in maintaining records	52	52	IV
5.	Inadequate access to water testing or health kits	45	45	V
6.	Labour constraints for pond preparation or maintenance	38	38	VI
7.	Fear of crop loss due to disease or pond drying	35	35	VII

Social participation emerged as another key determinant (β = 0.88; p = 0.014), with members of PCSs, FIGs or FPOs adopting nearly one additional practice compared to non-members. This finding is consistent with earlier studies (Reddy *et al*, 2019; Rao and Devi, 2020) which highlighted the role of community-based institutions in facilitating technology diffusion through exposure to peer learning, collective decision-making, and shared access to inputs and markets. Prior aquaculture experience also significantly influenced adoption (β = 0.69; p = 0.016), as those with even limited exposure were more confident and better equipped to integrate new practices into their existing farm routines. On the other hand, variables such as landholding size and age did not significantly affect adoption levels, suggesting that adoption is not necessarily dependent on farm size or the farmer's age, but rather on training effectiveness, motivation, and support systems. This supports the diffusion theory proposed by Rogers (2003), where adoption depends more on awareness, perceived utility, and social learning than on traditional metrics of farm size or age. Overall, the findings suggest that enhancing farmer knowledge, strengthening local institutions, and facilitating access to inputs and peer support networks are key strategies for promoting widespread adoption of scientific fish farming practices in farm ponds.

Constraints to adoption

Despite significant improvements in knowledge and motivation through KVK training, several constraints continued to hinder the full adoption of scientific fish farming practices among trained farmers. Identifying and understanding these barriers is essential to designing more responsive and inclusive extension interventions. To capture these constraints, respondents were asked to indicate the major challenges they faced in adopting the recommended practices. Multiple responses were permitted, and constraints were ranked based on their frequency of mention. The results are presented in Table 5. The most pressing constraint reported by respondents was the non-availability of quality fish seed in local markets (78%). Many farmers had to depend on distant hatcheries, which increased transport costs, delayed stocking, and in some cases resulted in poor survival due to stress or poor acclimatization. This finding resonates with prior reports from dryland districts of Tamil Nadu, where input supply chains remain underdeveloped (Jayanthi *et al*, 2021). The high cost and inconsistent availability of pelleted feed (64%) also emerged as a major hurdle. Although farmers understood the benefits of formulated feed from training sessions, many reverted to traditional feeding methods (e.g., rice bran, groundnut cake) due to cost considerations. As

observed by Kumar *et al* (2022), feed-related constraints are among the most cited deterrents to scientific aquaculture adoption in smallholder systems.

Lack of post-training technical support was reported by over half the respondents (57%). While initial training enhanced their knowledge and confidence, many farmers felt the need for continued guidance during implementation, especially in diagnosing fish health issues or managing water quality. This highlights the need for follow-up visits, helplines, or community-based para-extension models to sustain adoption. Another prominent constraint was difficulty in record keeping (52%). Many farmers, particularly those with lower literacy levels, found it hard to maintain daily records on feed, stocking, mortality, or sales. Without visual or digital aids, this practice remained underutilized, despite being emphasized during training. In addition, inadequate access to water testing kits or disease diagnostic tools (45%) and labour constraints (38%) affected farmers' ability to consistently apply practices like liming, pond bottom ploughing, and health monitoring. A section of farmers (35%) also expressed fear of crop failure due to unpredictable water availability or fish mortality, which discouraged them from adopting new practices fully or investing heavily. These constraints reflect the broader challenges of promoting aquaculture in rainfed, resource-constrained settings. While training builds knowledge, actual adoption is mediated by structural and service delivery issues. Similar findings have been reported by Reddy *et al* (2019) and Yadav *et al* (2020), who emphasized that convergence with input supply schemes, decentralized diagnostic services, and market linkages are crucial for scaling aquaculture technologies. Addressing these constraints calls for a multi-pronged strategy. First, strengthening local hatcheries and input shops can ensure timely availability of seed and feed. Second, establishing farmer field schools or model ponds with regular demonstrations can provide ongoing technical support. Third, introducing simplified record-keeping templates or mobile-based apps can improve management tracking, especially among semi-literate farmers. Finally, promoting group-based input procurement and marketing through PCSs or FIGs can reduce costs and risks, thereby encouraging sustained adoption.

CONCLUSION

The present study highlighted the positive impact of KVK Sivaganga's training programs on enhancing farmer's knowledge and adoption of scientific fish farming practices in farm ponds. To improve the scalability and sustainability of scientific fish farming in farm ponds, a comprehensive approach is essential. Strengthening the local supply chain for inputs such as seed and feed can help reduce dependency on distant markets and ensure timely availability. Furthermore, establishing mechanisms for post-training extension support through helplines, field visits, or mobile-based advisories can help farmers make informed decisions during critical stages of pond management. Encouraging group-based aquaculture through Primary Cooperative Societies or Farmer's Interest Groups can reduce costs, enhance peer learning, and create platforms for collective action. Simplifying record-keeping tools, especially through the use of visual templates or mobile applications in the local language, could improve compliance and farm management efficiency. Demonstrating low-cost, climate-resilient pond management techniques, such as seasonal ploughing, liming, and polyculture models, can also enhance farmer confidence and minimize risks in rainfed areas. Lastly, convergence with ongoing government schemes such as MGNREGA or fisheries department programs can provide necessary financial and infrastructure support to resource-poor farmers.

In conclusion, the training imparted by KVK Sivaganga has proven to be an effective strategy in promoting scientific aquaculture among small and marginal farmers. Nonetheless, the long-term success of such interventions hinges on their integration with input delivery systems, continuous extension services, and supportive policy frameworks. Strengthening these complementary elements will be critical in transforming farm pond aquaculture into a viable and scalable livelihood option in dryland districts of Tamil Nadu.

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Rural Development Gaps in Meghalaya: Constraints Faced by Farmers and Officials

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ABSTRACT

The study was conducted in the state of Meghalaya comprising of two types of respondents *i.e.,* officials working in community and rural development blocks and the rural people. A sample of 40 officials was selected randomly from two blocks (Pynursla and Mawryngkneng C&RD). From each block, 50 rural people were randomly selected, thus comprising a sample of 40 officials and 100 rural people as respondents, making the total sample size to be 140. The data were collected through personal interview method with the help of pre-structured schedule. For the officials, it was observed that financial constraints ranked first with average mean score of 36.75 followed by infrastructural constraints with average mean score of 35.00. While for the rural people respondents, banking constraints ranked first with average mean score of 72.67 followed by capacity building constraints at rank second with average mean score of 53.33. The study also revealed that all the officials and rural people respondents suggested that dialogue with banks and financial institutions to establish financial centres in villages, regular maintenance and updating of internet facilities, up gradation of block offices and transportation for field work, proper sensitization and awareness required to motivate the people towards rural development programmes.

Keywords: Constraints, Development, Infrastructure, Rural, Suggestions

INTRODUCTION

Rural Development in India is considered as one of the most critical factors for the economic and social ability of the nation as a whole. As per condition without the development of rural people, the country can never claim to be developed (Vanitha and Vezhaventhan, 2019). It mainly focus on the development of rural economies to elevate the serious poverty issues and effectively improves their productivity. Rural development programmes will not only enhance the social, economic and environmental conditions of the rural poor but will also help in developing a sustainable future. A good dynamic and foundation is required for effective implementation of various development programme by empowering the rural people in the rural areas especially in youth and women. These schemes are targeted for empowering and poverty reduction, employment generation, rural infrastructure, habitation development, provision of basic services and awareness (Annonymous, 2019). It was also realized that a sustainable strategy of poverty alleviation has to be based on increasing the productive employment opportunity in the process of growth itself. The rural people should get better prospects for

economic development. Along with this, there should be decentralization of planning, better enforcement of land reforms and greater access to credit for the rural poor people (Kumar *et al,* 2019).

Meghalaya is a state where majority of the population are living in the rural areas. Most of the people in the state rely on rural development programmes to sustain their livelihood but with high incidence of poverty, illiteracy, unemployment poor infrastructure and absence of basic facilities it becomes a challenge to the planning and policy makers for the state. Despite so many efforts and development scheme in the past few decades, the main issue of rural poverty in Meghalaya still continues to be a great concern. Therefore, this study was conducted to find out the constraints faced by the officials of rural development department of the state and of the rural people to better understand the present scenario of rural development programmes.

MATERIALS AND METHODS

The study was conducted in the state of Meghalaya and comprised of two types of respondents

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Table 1. Constraints faced by the Officials in implementation of Rural Development Programmes.

Problem	Officials Respondent (n=40)		
	Frequency	Per centage	Rank
A. Financial Constraints			
1. Underpaymentofsalariestoproject staff	40	100.00	I
2. Delay in flow of funds disrupts the working of the project	38	95.00	II
3. Irregular Update of Bank Passbooks by beneficiaries	35	87.50	III
4. Cost of labor increases due to terrain topography	34	85.00	IV
B. Infrastructural constraints			
1. Network problems during bad weather	40	100.00	I
2. Vehicles required for transportation to reach all corners of the Block	35	87.50	II
3. Lack of technical facilities	30	75.00	III
C. Human Resource Constraints			
1. Man Power required for regular monitoring and inspection of sites.	40	100.00	I
2. Requirement of specialized skill trainers	35	87.50	II
3. Lack of knowledge and training about the different programmes	32	80.00	III
4. Poor understanding about rural development programmes	30	75.00	IV
D. Administrative Constraints			
1. Difficulty to access in border areas, require proper permits	30	75.00	I
2. Corruptionatdifferentlevels	25	62.50	II
E. Coordination Constraints			
1. People's hesitancy towards Aadhaar Card and opening of Bank account	38	95.00	I
2. Problems of identification and selection of beneficiaries under different rural programmes	30	75.00	II
3. Lack of co-operation from people's groups and social organizations	25	62.50	III

i.e., officials working in community and rural development blocks and the rural people. A sample of 40 officials was selected randomly from two Blocks (Pynursla and Mawryngkneng C&RD). From each block, 50 rural people were randomly selected, thus comprising a sample of 40 officials and 100 rural people as respondents, making the total sample size to be 140. The data were collected through personal interview method with the help of pre-structured schedule and ranking was performed. The data were analyzed with the help of suitable statistical tools like perrcentage and rank orders.

RESULTS AND DISCUSSION

Constraints faced by the officials in implementation of rural development programmes

Financial Constraints

The data (Table 1) revealed that all of the official respondents agreed that under payment of salaries to project staff was the main constraints under financial constraints. The data also revealed that 95 per cent of the respondents reported that delay in flow of funds disrupts the working of the project, 87.50 per cent reported that irregular update of bank passbooks by beneficiaries and 85 per cent reported that cost of

Table 2. Overall ranking of constraints faced by the Officials in implementation of Rural Development Programmes

Sr. No.	Constraint	Officials Respondents (n=40)	
		Mean Score	Rank
A.	Financial	36.75	I
B.	Infrastructural	35.00	II
C.	Human Resource	34.25	III
D.	Administrative	27.50	V
E.	Coordination	31.00	IV

Table 3. Constraints faced by the rural people in adoption of Rural Development Programmes.

Problem	Rural People Respondents (n=100)		
	Frequency	Per centage	Rank
A. Banking Constraints			
1. Bank concentration more on headquarters.	88	88.00	I
2. Lack of knowledge on Bank Procedures	70	70.00	II
3. Irregular Update of Bank Passbooks by beneficiaries	60	60.00	III
B. Communication Constraints			
1. Non-availability of supporting staff to beneficiaries	50	50.00	I
2. Non-cooperative attitude of local leaders	45	45.00	II
3. Conflicts amongst beneficiaries while working	40	40.00	III
4. Biasedness in distribution of work at worksite	35	35.00	IV
5. Non-co-operative attitude of officials	20	20.00	V
C. Infrastructural Constraints			
1. Lack of office for village employment councils (VECs)	40	40.00	I
2. Non-availability of worksite facilities	25	25.00	II
D. Capacity Building Constraints			
1. Lack of training in organizing of SHGs	70	70.00	I
2. Poor knowledge and awareness of the programme.	50	50.00	II
3. Irregularity in attending gram sabha	40	40.00	III
E. Other Constraints			
1. Hesitancy in training outside the state.	60	60.00	I
2. Women more busy with household work, hence 100% attendance not possible	40	40.00	II
3. Non-availability of assured 100 days employment to every house hold	25	25.00	III

labor increases due to terrain topography were some other financial constraints. A study conducted by Tamang *et al* (2016) also revealed similar results. The discussion revealed that with the increase in cost of living it was difficult especially for contractual staff to function.

Infrastructural constraints

All the official respondents reported that network problems during bad weather was main constraint under infrastructural constraints. Similar findings have been reported by Patel and Suryawanshi (2023). About 87.50 per cent and 75 per cent accounted for vehicles shortage for transportation to reach all corners of the block and that there was a lack of technical facilities in the block. During the discussion with the officials, it was found that there were no proper rooms, toilets and common facilities required in most of the offices.

The data (Table 1) revealed that all the official respondents reported that man power was required for regular monitoring and inspection of sites. They also revealed that requirement of specialized skill trainers (87.50%), lack of knowledge and training about the different programmes (80%) and poor understanding

Table 4: Overall ranking of Overall constraints faced by the rural people in adoption of Rural Development Programmes

Sr. No.	Constraint	Rural People Respondents (n=100)	
		Mean Score	Rank
A.	Banking	72.67	I
B.	Capacity Building	53.33	II
C.	Other	41.67	III
D.	Communication	38.00	IV
E.	Infrastructural	32.50	V

about rural development programmes (75%) was also the constraints.

Administrative Constraints

Difficulty to access in border areas which require proper permits (75%) and corruption at different levels (62.50%) were reported as administrative constraints. It was revealed that there are several procedure to apply for permits for rural development programmes for villages located in the border areas of Meghalaya under Pynursla Block and this delays the work.

Coordination Constraints

It was observed that people's hesitancy towards Aadhaar Card and opening of bank account (95%) and problems of identification and selection of beneficiaries under different rural programmes (75%) were the main constraints. The official respondents also reported that lack of co-operation from people's groups and social organization's (62.50%) also contributed to coordination constraints. During the discussion, it was revealed that most of the rural people are still hesitant to apply Aadhaar card due to illiteracy and hence do not apply for rural development schemes.

The overall constraints faced by the officials in implementation of rural development programmes is presented by calculating the average mean score for individual category (Table 2). It was observed that financial constraints ranked first with average mean score of 36.75 followed by infrastructural constraints at rank second with average mean score of 35.00. Human resource constraints and coordination constraints were ranked third and fourth with average mean score of 34.25 and 31.00, respectively. At fifth place was administrative constraints with an average mean score of 27.50.

Constraints faced by the rural people in adoption of Rural Development Programmes

Banking Constraints

The data (Table 3) revealed that 88 per cent of the rural people respondents reported that bank concentration was more on headquarters. Constraints like lack of knowledge on bank procedures (70%) and irregular update of bank passbooks by beneficiaries (60%). These findings were in line with Rao (2019). During the discussion, it was mentioned that respondents had to bear the cost of transport just to update their bank passbook in the headquarters.

Communication Constraints

It was evident that half of the rural people respondents agreed that there exists a non-availability of supporting staff to beneficiaries. Less than half *i.e.,* 45 percent reported on non-cooperative attitude of local leaders while 40 per cent and 35 per cent reported on conflicts amongst beneficiaries while working and biasedness in distribution of work at worksite. Only 20 percent reported non-co-operative attitude of officials. These findings were in line with Gopalraju and Kumar (2011); Ranaand Bhardwaj (2020). During the discussion, it was found that the respondents suggested that a strong and motivated headman with hard working office bearers were required for rural development works to function smoothly.

About 40 percent of the respondents reported that lack of office for Village Employment Councils (VECs) and Non-availability of worksite facilities (25%) were the main infrastructural constraints.

Capacity Building Constraints

The data (Table 3) revealed that 70 percent of the rural people respondents reported on lack of

Table 5. Suggestion of respondents for overcoming the constraints in Rural Development Programmes.

Sr. No.	Item	Officials Respondents (n=40)			Rural People Respondents (n=100)		
		Agree	Partially agree	Disagree	Agree	Partially agree	Disagree
1	Regular follow up and coordination with funding agencies for smooth flow of funds	25 (62.50)	15 (37.50)	-- --	80 (80)	20 (20)	-- --
2	Dialogue with banks and financial institutions to establish financial centres in villages.	40 (100)	-- --	-- --	100 (100)	-- --	-- --
3	Regular maintenance and updating of internet facilities	40 (100)	-- --	-- --	100 (100)	-- --	-- --
4	Up gradation of block offices and transportation for field work.	40 (100)	-- --	-- --	90 (90)	10 (10)	-- --
5	Work and training schedule to be based on the seasonal work activity of the beneficiaries	30 (75)	10 (25)	-- --	88 (88)	12 (12)	-- --
6	Collaboration with other Private and Public organizations to provide specialized trainers.	31 (77.50)	9 (22.50)	-- --	85 (85)	15 (15)	-- --
7	Inform and encourage people to regular update their bank passbooks so as to avoid any problems in fund flow.	33 (82.50)	7 (17.5)	-- --	88 (88)	12 (12)	-- --
8	Motivate and Sensitize people towards opening of bank account and Aadhaar Card.	30 (75)	10 (12.50)	-- --	80 (80)	10 (10)	10 (10)
9	Proper Sensitization and awareness required to motivate the people towards Rural Development programmes.	40 (100)	-- --	-- --	100 (100)	-- --	-- --
10	More technical officials can be recruited for Blocks with larger coverage	40 (100)	-- --	-- --	100 (100)	-- --	-- --
11	The sanction of fund should be based on the topography of the villages to bear the high labour cost.	35 (87.50)	5 (12.50)	-- --	91 (91)	9 (9)	-- --

training in organizing of SHGs and 50 percent reported on poor knowledge and awareness of the programme in rural development programmes. Also 40 percent revealed that there was an irregularity in attending gram sabha meetings. The findings of the study were in line with the study of Gupta *et al* (2013), Kumari *et al* (2020) and Singh *et al* (2021). During the discussion, the respondents suggested on trainings on book keeping and establishment of SHGs enterprises should be encouraged.

Other Constraints

Hesitancy in training outside the state (60%), women more busy with household work, hence 100 percent attendance not possible (40%) and non-availability of assured 100 days employment to every household (25%) were other constraints reported by the respondents. The respondents discussed that since the rural women were busy with household work and other agricultural practices it was not feasible to give 100 percent attendance to meetings and awareness programmes.

The overall constraints faced by the rural people in adoption of rural development programmes presented by calculating the average mean score for individual category. It was observed that banking constraints ranked first with average mean score of 72.67, followed by capacity building constraints at rank second with average mean score of 53.33. Other constraints and communication constraints were ranked third and fourth with average mean score of 41.67 and 38.00 respectively. At fifth place was infrastructural constraints with an average mean score of 32.50.

Suggestion from the respondents for overcoming the constraints

The data in Table 5 revealed that all the officials and rural people respondents suggested that dialogue with banks and financial institutions to establish financial centres in villages, regular maintenance and updating of internet facilities, up gradation of block offices and transportation for field work, proper sensitization and awareness required to motivate the people towards Rural Development programmes and increasing technical officials can be recruited for blocks with larger coverage. Similar findings have been reported by Rao (2019) which suggested the same. It was reported that 62.50 percent of the officials and 80 percent rural people respondents agreed that regular follow up and coordination with funding agencies is required for smooth flow of funds. During the discussion, it was revealed that 75 percent of the officials and 88 percent of the rural people respondents suggested that work and training schedule should be based on the seasonal work activity of the beneficiaries. The respondents expressed that collaboration with other private and public organizations to provide specialized trainers, informing and encouraging people to regular update their bank passbooks so as to avoid any problems in fund flow and sanctioning of fund should be based on the topography of the villages to bear the high labour cost can be followed to improve the implementation of rural development programmes. A study conducted by Patel (2014) also suggested to have requisite strength of the trained staff for rural development programmes. It was reported that 75 percent of the officials agreed on motivating and sensitizing people towards opening of bank account and Aadhaar Card while, 80 percent of the rural people respondents agreed, 10 percent partially disagreed and 10 percent disagreed on the same.

CONCLUSION

It was concluded that financial and infrastructural constraints were major constraints faced by the official respondents and these should be address so that they can perform their responsibilities efficiently to uplift the standards of living for the rural people through various rural development programmes. The study also revealed that banking and capacity building constraints play a major role in the adoption of rural development programmes by the rural people. Therefore, these constraints hinder the implementation of various rural development programmes which should be addressed and appropriately solved by the government improve the socio- and economic conditions of the rural population. The suggestions from the study can help various stakeholders make policies on improvement to implement the programmes in the state.

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Socio-Economic Profiling of Drip Irrigation Technology Adopters in Cotton Cultivation-A Comparative Study in Three States of India

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ABSTRACT

Cotton, a highly water demanding yet economically significant crop, is particularly well-suited for drip irrigation systems. However, despite the well-documented advantages of drip irrigation, its adoption in cotton cultivation remains modest at around 20 percent. The uptake of this technology is influenced by several factors, with the socio-economic characteristics of farmers playing a crucial role. This gap between proven benefits and limited adoption prompts a key question: which socio-economic and contextual determinants affect the diffusion of drip irrigation technology? Extension research thus plays an essential role in identifying whether socio-economic differences exist among drip irrigation adopters across different states. Accordingly, the present study was conducted to systematically analyze the variations in socio-economic profiles of drip irrigation adopters in three major cotton-growing states of India *i.e.,* Maharashtra, Gujarat, and Tamil Nadu. A structured survey design was used, involving 120 drip-irrigating cotton farmers from each state, making a total sample size of 360 respondents. The research objectives were addressed using well-established methodologies and rigorous analytical approaches. Results indicated that variables such as age, education, and experience in drip irrigation showed no significant differences among farmers across the three states, while factors including cotton farming experience, farm size, and operational area under drip irrigation were found to differ significantly among them. The study's findings are expected to contribute to policy development and guide strategic initiatives to enhance drip irrigation adoption in cotton farming.

Keywords: Adoption, Cotton, Drip irrigation, Gujarat, Maharashtra, Socio-economic profiling,Tamil Nadu.

INTRODUCTION

In India, Maharashtra stands at the forefront of drip irrigation adoption, followed by Andhra Pradesh, Karnataka, and Tamil Nadu. Despite these advancements, the total area under drip irrigation constitutes less than one percent of the country's total irrigated area, highlighting a vast potential for expansion (Kumar and Jitarwal, 2012; Yadav *et al,* 2017). Cotton is one of the world's most important fiber crop and the second most important oil seed crop (Gill and Bhatt, 2015; Sathya *et al,* 2022). India leads in the cultivation of cotton in the world (Vikram Simha *et al,* 2022). It is highly suitable for drip irrigation owing to its long crop duration, compatibility with varied growing environments, potential for early sowing, adaptability to flexible drip systems, higher economic returns, improved fertilizer use efficiency, enhanced seed cotton yield, suitability for light-textured soils,

uniform germination and maturity, and superior fibre quality. Several studies have explored the scope, potential, and impact of drip irrigation across various crops. Karpagam *et al* (2010) reported a 24.98% increase in yield efficiency in sugarcane under drip irrigation, along with a 23.58% improvement in income efficiency and a remarkable 40.64% gain in water use efficiency. However, Karpagam *et al* (2011) identified major constraints to adoption, with the high initial investment cost-despite the provision of subsidies-being the most significant (mean score: 73.75), followed by inadequate subsidy levels (mean score: 63.33). Further, a study by Karpagam *et al* (2012) emphasized that social factors such as social structure, networks, and interactions strongly influence the adoption of drip irrigation. Subsequently, Karpagam *et al* (2013) observed that most sugarcane farmers using drip systems exhibited moderate to high levels of social dynamics (90.0%), whereas a majority

Table 1. Age wise distribution of drip irrigation farmers. (N=360)

Sr. No.	Category	Tamil Nadu		Maharashtra		Gujarat		Total	
		No.	%	No.	%	No.	%	No.	%
1.	Young (Up to 35yrs)	4	3.30	16	13.30	9	7.50	29	8.10
2.	Middle (36-45 yrs)	51	42.50	47	39.20	53	44.20	151	41.90
3.	Old (Above 45 ys)	65	54.20	57	47.50	58	48.30	180	50.00
F Value (Among three groups of drip users) = 0.110 ^{NS}; p=0.896 (p > 0.05) -									

Table 2. Education wise distribution of drip irrigation farmers. (N=360)

Sr. No.	Category	Tamil Nadu		Maharashtra		Gujarat		Total	
		No.	%	No.	%	No.	%	No.	%
1.	Illiterate	1	0.80	3	2.50	4	3.30	8	2.20
2.	Primary School	19	15.80	26	21.70	38	31.70	83	23.10
3.	Middle School	37	30.80	20	16.70	32	26.70	89	24.70
4.	High School	31	25.80	38	31.70	15	12.50	84	23.30
5.	Higher Secondary school	21	17.50	20	16.70	18	15.00	59	16.40
6.	Collegiate	11	9.20	13	10.80	13	10.80	37	10.30
F Value (Among three groups of drip users) = 2.640 ^{NS}; p=0.073 (p > 0.05)									

Table 3. Cotton farming experience wise distribution of drip irrigation farmers. (N=360)

Sr. No.	Category	Tamil Nadu		Maharashtra		Gujarat		Total	
		No.	%	No.	%	No.	%	No.	%
1.	Up to 10 years	30	25.00	22	18.30	11	9.20	63	17.50
2.	10-20 years	33	27.50	17	14.20	17	14.20	67	18.60
3.	More than 20 years	57	47.50	81	67.50	92	76.70	230	63.90
F Value (Among three groups of drip users) = 13.805**; p=0.000 (p < 0.01)									

** Significant at 1 % level

of non-users (62.5%) showed low levels of such dynamics. Although these studies demonstrate the multifaceted benefits and influencing factors of drip irrigation across different crops, there remains limited empirical evidence focusing on cotton. Given the crop's suitability and economic importance, it becomes essential to analyze the socio-economic characteristics of cotton farmers adopting drip irrigation technology to better understand the drivers and constraints shaping its diffusion.

MATERIALS AND METHODS

The present study was carried out across three major cotton-growing states, Maharashtra, Gujarat, and Tamil Nadu. From each state, two districts were selected based on the predominance of cotton cultivation under drip irrigation. Within each chosen district, two villages were identified using the extent of drip-irrigated cotton area as the selection criterion. From every selected village, 30 cotton farmers were randomly chosen, resulting in a total of 120 farmers per state and an overall sample size of 360 respondents. To analyse the socio-economic profile of drip irrigation adopters, key variables such as age, education, farming experience in cotton, experience in drip irrigation, farm size, and area under drip irrigation were considered. The selection of these variables was guided by expert opinions, relevant literature, and their suitability to the study objectives. Data were collected through a structured interview schedule administered in the selected villages. The gathered information was then compiled and subjected to appropriate statistical analysis to derive meaningful and systematic conclusions.

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Duncan's Post Hoc test for comparison of differences - Farming Cotton Experience

Sr. No	Treatment Groups	Means for groups (Sub set for alpha= 0.05)	
		1	**2**
1.	T_1(Tamil Nadu Farmers)	18.2250	
2.	T_2(Maharashtra Farmers)		22.4417
3.	T_3 (Gujarat Farmers)		24.658

Gujarat		**Maharashtra**		**Tamil Nadu**
24.6583	>	22.4417	>	18.2250

Table 4. Experience in drip irrigation. (N=360)

Sr. No.	Category	Tamil Nadu		Maharashtra		Gujarat		Total	
		No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
1.	Less than 2 years	2	1.70	1	0.80	0	0	3	0.80
2.	2-8 years	85	70.80	83	69.20	68	56.70	236	65.60
3.	More than 8 years	33	27.50	36	30.00	52	43.30	121	33.60
F Value (Among three groups of drip users) =0.081[NS]; p=0.923 (p > 0.05)									

NS - Non-Significant

RESULTS AND DISCUSSION

Socio-economic profile of drip irrigation farmers

Six variables *i.e.,* age, education, farming experience in cotton, experience in drip irrigation, farm size, and area under drip irrigation were considered.

Age wise distribution of drip irrigation farmers

Table 1 shows that, based on age-wise distribution, the drip irrigation farmers from Tamil Nadu, Maharashtra, and Gujarat exhibited no significant differences. Hence, there is not much variation among the three groups in terms of age. Additionally, nearly 50 percent of the farmers fell under the old-age category. The similar view was expressed by Kumari *et al* (2022) found that most of the respondents in the age group of 50 years and above (84.62%). Many young people view agriculture as less lucrative than urban job prospects; farming income is unpredictable due to various untold reasons. Moreover, farming is sometimes perceived as a low-prestige occupation. To reverse this trend, a comprehensive approach is needed to make agriculture a more attractive and sustainable career option.

Education wise distribution of drip irrigation farmers

Table 2 presents the education-wise distribution of drip irrigation farmers across Tamil Nadu, Maharashtra, and Gujarat. The analysis indicated no statistically significant difference among

the three states with respect to farmers' educational backgrounds. This suggests that education levels among drip irrigation adopters are relatively uniform across regions, implying that education is not a key differentiating factor influencing adoption in this context. However, a closer look at the numerical distribution revealed certain state-wise trends. In Tamil Nadu, a higher proportion of farmers (30.8%) had education up to the middle school level, whereas in Maharashtra, most farmers (31.7%) had completed high school, and in Gujarat, an equal proportion (31.7%) had only primary school education. Overall, 24.7% of farmers across all states had middle school education. These findings are consistent with the observations of Shambhrakar *et al* (2018) in the Vidarbha region and Deepika *et al* (2020) in Tamil Nadu, who reported that farmers with medium levels of knowledge were predominant among drip irrigation adopters. Regional differences in education, employment opportunities, and interest in farming contribute to varying agricultural adoption patterns, emphasizing the importance of understanding local socio-economic contexts for effective policy formulation. Jumanne (2016) also highlighted that farmer's age, education, and economic factors significantly influence technology adoption. Similarly, Verma and Sharma (2017) found in Rajasthan that variables such as education, annual income, and mass media exposure had a positive and significant relationship with drip irrigation adoption. Complementing these findings, Sharma *et al* (2021) reported that, apart from education, socio-economic status, and caste, other factors like annual income, age, landholding size, media exposure, and social

participation exhibited a positive correlation with adoption levels among respondents.

Cotton farming experience wise distribution of drip irrigation farmers

Table 3 presents the distribution of farmers based on their experience in cotton farming. The analysis indicated a statistically significant relationship among the drip irrigation farmers from Tamil Nadu, Maharashtra, and Gujarat. This suggests that there is a notable difference in cotton farming experience among the three groups of farmers. Given the presence of significant variation among the groups, Duncan's Post Hoc test was employed to identify the specific differences between the states. The results of this test provided a clearer understanding of the extent and nature of variation in cotton farming experience among farmers across Tamil Nadu, Maharashtra, and Gujarat. This post hoc analysis thus helped pinpoint which state-wise groups differed significantly, offering deeper insights into the patterns of experience variation among drip irrigation adopters.

Experience in drip irrigation

Table 4 presents the distribution of farmers according to their experience in using drip irrigation. The analysis revealed no statistically significant difference among farmers from Tamil Nadu, Maharashtra, and Gujarat, indicating that their levels of experience with drip irrigation are relatively similar. This uniformity may be attributed to the widespread promotion and adoption of drip irrigation following the implementation of the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) under the Micro Irrigation Scheme. The simultaneous exposure to government-supported initiatives likely encouraged many cotton farmers across states to adopt the technology around the same period, resulting in comparable experience levels. Notably, a higher proportion of adopters were found among farmers with over 20 years of overall farming experience, suggesting that experienced cultivators tend to be more receptive to improved irrigation methods. However, while experience contributes positively to the adoption process, it operates alongside other factors such as education, resource availability, flexibility in farm management, and access to information. Thus, technology adoption in agriculture is best understood as a multifaceted process influenced by the interaction of socio-economic, institutional, and experiential variables.

Farm size wise distribution of drip irrigation farmers

Table 5 presents the distribution of farmers according to their farm size. The analysis showed a statistically significant difference among drip irrigation farmers from Tamil Nadu, Maharashtra, and Gujarat, indicating considerable variation in landholding patterns across the three states. This suggests that farm size is not uniform among the respondents and may be shaped by diverse regional factors such as cropping patterns, land tenure systems, resource availability, and the extent of agricultural mechanization. Differences in state-level policies, irrigation infrastructure, and historical land distribution may also contribute to the observed variability in farm size among drip irrigation adopters.

To examine the nature and extent of this variation more precisely, Duncan's Post Hoc test was performed. The results further confirmed the presence of significant differences in farm sizes among the groups, establishing that farm size serves as a key differentiating factor in the adoption of drip irrigation across the studied regions. The findings revealed that the majority of drip irrigation farmers were smallholders in Tamil Nadu (50.0%) and Maharashtra (37.5%), whereas in Gujarat, most belonged to the medium farm size category (47.5%). These results align with the observations of Kumari *et al* (2022), who reported a significant association between landholding size and the level of drip irrigation adoption, noting that over 70% of medium-sized farmers exhibited higher adoption rates. In contrast, Kumar and Palanisami (2011) found that drip irrigation adopters typically managed larger landholdings, with an average farm size of 5.41 hectares compared to 2.28 hectares among non-adopters in the control villages. Such variations highlight the complex role of farm size in influencing technology adoption, where both small and medium farmers may actively adopt drip systems depending on regional conditions, institutional support, and perceived economic benefits.

Operational area under drip irrigation

Table 6 presents the distribution of farmers based on the area under drip irrigation. The analysis revealed a statistically significant relationship among drip-irrigated cotton farmers from Tamil Nadu, Maharashtra, and Gujarat. Medium-scale farmers are often well-positioned to adopt drip irrigation technology, as they typically have sufficient resources to invest without being burdened by the complexities of managing large-scale operations. In contrast, small

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Table 5: Farm size wise distribution of drip irrigation farmers

Sr. No.	Category	Tamil Nadu		Maharashtra		Gujarat		Total	
		No.	%	No.	%	No.	%	No.	%
1.	Marginal farmers (Up to 2.5 acres)	10	8.30	10	8.30	2	1.70	22	6.1
2.	Small farmers (2.51-5 acres)	60	50.00	45	37.50	23	19.20	128	35.60
3.	Medium farmers (5.01- 10 acres)	43	35.80	41	34.20	57	47.50	141	39.20
4.	Big farmers (Above 10 acres)	7	5.80	24	20.00	38	31.70	69	19.20
	F Value (Among three groups of drip users)= 23.704 **; p=0.000 (p < 0.01)								

** Significant at 1 % level

Duncan's Post Hoc test for comparison of differences (Farm size)

S.No.	Treatment Groups	Means for groups (Sub set for alpha= 0.05)		
		1	2	3
1.	T_1(Tamil Nadu Farmers)	2.3917		
2.	T_2(Maharashtra Farmers)		2.6583	
3.	T_3 (Gujarat Farmers)			3.0917

Table 6. Operational area under drip irrigation . (N=360)

Sr. No.	Category	Tamil Nadu		Maharashtra		Gujarat		Total	
		No.	%	No.	%	No.	%	No.	%
1.	Less than 3 acres	82	68.30	50	41.70	14	11.70	146	40.60
2.	3-9 acres	34	28.30	51	42.50	58	48.30	143	39.70
3.	More than 9 acres	4	3.30	19	15.80	48	40.00	71	19.70
	F Value (Among three groups of drip users) =33.472**; p=0.000 (p < 0.01)								

** Significant at 1 % level

Duncan's Post Hoc test for comparison of differences – Area under drip irrigation

Sr. No	Treatment Groups	Means for groups (Sub set for alpha= 0.05)		
		1	2	3
1.	T_1(Tamil Nadu Farmers)	3.3750		
2.	T_2(Maharashtra Farmers)		5.6333	
3.	T_3 (Gujarat Farmers)			9.1792

farmers may face financial constraints and limited technical knowledge required for installation and maintenance. On the other hand, large farmers may have more intricate irrigation requirements that drip systems alone may not adequately address. Given the presence of a significant difference, Duncan's Post Hoc test was conducted to determine the specific groups where the variation occurred. The test results confirmed the extent of variation, indicating that the area under drip irrigation is not uniform and differs notably among the three categories of farmers studied.

CONCLUSION

This study represents one of the first comprehensive efforts to analyse the multifaceted dimensions of drip irrigation technology in cotton cultivation. It offers valuable insights into the socio-economic profiles of farmers and their relationship with the adoption of drip irrigation across three major cotton-growing states of India-Gujarat, Maharashtra, and Tamil Nadu. While cotton serves as a major cash crop in Gujarat and Maharashtra, it also holds considerable economic importance in Tamil Nadu. The analysis revealed that among the socio-economic

variables examined, age, education, and experience in drip irrigation showed no significant differences among farmers across the three states. In contrast, variables such as farming experience in cotton, farm size, and operational area under drip irrigation exhibited significant variation, suggesting their influence on adoption behaviour. The findings carry important policy implications, offering a robust empirical basis for policymakers to refine and strengthen micro-irrigation initiatives. Emphasis should be placed on region-specific strategies, targeted farmer support systems, and efficient technology dissemination mechanisms. Expanding the adoption of drip irrigation in cotton cultivation has the potential to enhance resource-use efficiency, promote water conservation, and contribute significantly to the goal of sustainable agricultural development, particularly in water-stressed regions of the country.

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