An Analysis of Farmer Awareness for Banana Production from a Technological and Geographic Perspective in Indapur Tahsil of Pune District, India

ABSTRACT

The Indapur tehsil an arid climate region is gaining recognition as a prime location for banana cultivation. The identification of water sources, fertile soil, favourable climate, and income resulted in a shift towards cultivating bananas. This research identified a gap between the practices of farmers and modern agricultural techniques. The study is the first to survey farmers' understanding of geography, farming techniques, challenges faced, and factors for successful production in the region. Data was gathered from 270 banana farmers in various villages using qualitative and quantitative research methods, official documents, and on-site observations. The findings indicated that the farmers displayed a good understanding of drip irrigation and the use of liquid fertilizer through this method. Farmers showed a moderate understanding of soil quality, organic farming, tissue culture plantlets, banana variety selection, year-round farming, and crop protection. Factors such as land ownership, gender of the family head, family size, age, education, farming experience, subsidies, crop insurance, and access to information influence modern agricultural practices which is evident in the perception index. The perception index also highlights the necessity for focused attention on aspects such as application of agrochemicals to leaves, bunch feeding, the use of humidity sensors in irrigation, mulching, crop rotation, diseases caused by fungus, intercropping, cold storage, and ISO certification. Dry environments and the adoption of plantlets grown through tissue culture can reduce the risk of pest and disease issues. Rise in fertilizer and raw material cost, price fluctuations, commissions, middlemen's dishonesty, domestic and export market support and labour costs are major issues. It is recommended to offer awareness programs and training on modern farming techniques and banana export, along with strengthening of farmers organizations and communication channels. The findings will provide important information to support sustainable banana farming for researchers, farmers, policymakers, and agricultural services.

Kew words: *Arid climate. Agricultural practices. Banana. Socioeconomic. Sustainable farming. Technological adoption.*

1. INTRODUCTION

Fruits are vital for health and the economic stability of farmers and nations. Among various fruits, bananas are the most consumed globally, appealing to all demographics. The international banana market is worth over 10 billion dollars annually, and bananas have consistent demand worldwide (FAO, 2023). In India, bananas are a key economic crop, with the country being a global leader in cultivation, production and domestic consumption (FAO, 2023). However, with current population growth rates, projections indicate that the global population will reach 8. 5 billion by 2030 and 9. 7 billion by 2050, necessitating a 70 percent rise in food production (Anonymous, 2024; FAO, 2024). Currently, India is the most populous country, with a population of 1. 486 billion (UN, 2024). On a global scale and within India, the Green Revolution in the mid-20th century played a major role in enhancing food security. However, climate change and excessive chemical fertilizer use pose risks to crop production, including bananas (Varma and Bebber,2019). These chemicals also negatively impact soil health, soil microorganisms, and the environment (Onyeaka et al., 2024). The heavy use of chemicals in farming raises concerns about safety for producers, consumers, and the environment. Furthermore, rising awareness and WTO agreements concerning sanitary and phytosanitary measures and technical trade barriers have led to increased rejection of chemically contaminated products in domestic and international markets (Aryal and Aryal, 2023). Addressing environmental and socio-economic challenges is crucial in modern agriculture practices. Awareness and safe methods are needed

to meet the growing demand for bananas (FAO, 2024, Gelaye and Negash, 2024).

The Indapur tehsil, located in the Pune district of Maharashtra, India, is characterized by its arid climate and has recently emerged as a significant producer of bananas. This fruit is becoming increasingly important as an economic crop in the area. The success of banana cultivation largely depends on the farmers' capacity to utilize modern agricultural technologies and comprehend geographic factors, including soil composition, water resources, and climatic conditions (CDAP, 2017, FAO,2024). Historically, the farmers in this region have had limited exposure to banana farming techniques. The implementation of modern agricultural practices is essential for the cultivation of bananas, as these practices enhance production sustainability and reduce environmental impacts (FAO,2024). Additionally, these techniques are crucial for maintaining hygiene standards during harvesting, packaging, and transportation, ensuring that consumers receive safe and high-quality bananas (Gelaye and Negash, 2024). To date, there are no research studies that focus on the growing of bananas in this region, although economic benefits are more and more related to activities based on knowledge and are quickly becoming globalized. This can be made easier by using advanced technologies. It is important to recognize the current gap between traditional farming techniques and modern agricultural practices. In light of this, the present paper aims to examine the levels of socioeconomic, technological, and geographic awareness among banana farmers in Indapur tehsil and the influence of these factors on their agricultural practices.

Objectives:

- To assess farmers' knowledge of growing bananas in relation to geographical factors, socioeconomic considerations, and the adoption of modern agricultural practices
- To know the challenges faced by farmers in achieving sustainable banana production.
- To provide recommendations for the sustainable cultivation of bananas.

2. METHODOLOGY

STUDY AREA

Indapur tahsil is one of the tahsils in the Pune district consisting of 143 villages along with one urban centre in the study area (CDAP, 2017). There are eight revenue circles in the tahsil. Indapur lies approximately between 17°50' N to 18°10' N latitude and 74°40' E to 75°10' E longitude. The terrain is predominantly flat with gentle slopes, characteristic of the Deccan Plateau. The average elevation is approximately 530 meters (1,739 feet) above sea level (Bhore et al., 2021). The Bhima River and its tributaries, such as the Nira River, play a significant role in shaping the local topography and supporting agriculture. Tropical semi-arid climate (hot and dry). The region receives an average annual rainfall of 500–700 mm, with most precipitation occurring during the monsoon season (June to September) (Ogale, 2022). High fertility and water retention, suitable for crops like sugarcane, cotton, and bananas. The Bhima River is the lifeline of Indapur, providing water for irrigation, drinking, and other needs (CDAP, 2017; Dhobale, 2020).

3.1. Research design and collection of data

The study used a mixed research design, combining surveys and interviews. Both qualitative and quantitative techniques were adopted to collect data using structured questionnaires and thorough discussions that was focused to banana farmers. Secondary data such as number of villages, soil, climate, water sources, crops, villages with banana crop was obtained from official records and reports from the Agriculture Department of Indapur Tehsil, the horticulture section of Pune district, Maharashtra state, and the Directorate of Economics and Statistics.

3.2. Selection of Study Area

The Indapur tehsil was purposively selected being arid region where banana farming has been recently introduced and is becoming a banana production hub in Pune district of Maharashtra, India.

3.3. Sample Size and Procedure

The technique of simple random sampling was utilized to select the banana growers who took part as respondents. The tehsil consists of 143 villages (CADP,2017). A list of banana growers was created, and data were gathered from 270 randomly selected banana farmers across various villages in Indapur tehsil. Information on modern techniques adoption, technology challenges, geographic awareness, water management practices, and the impacts of challenges was gathered. The parameters and variables were detailed in Fig. 1, 2, 3, and table 1 and 2.

3.4. Data analysis

The information obtained from surveys, both through questionnaires and interviews (primary data), along with secondary data, was checked for accuracy and entered into Excel spreadsheets using SPSS (Statistical Package for the Social Sciences) version 24.0.0 (SPSS, 2016) for analysis. Descriptive statistics were used to examine quantitative data and assess the level of implementation. Tables, charts, and graphs were used as visual aids to display and explain the data.

3.5. Likert scale and Index of awareness:

The awareness level of banana farmers on various factors was assessed using a 5-point Likert scale (z-score), of strongly agree(well-known) (1), agree(known) (2), partially agree (partially known) (3), not agree (not known) (4), and unable to decide (neutral/unsure) (5) (Table 2) (Likert, 1932). To calculate the awareness index, the frequency of farmers knew (agreed) with the variable was calculated by summation of the frequencies of responses mentioned as well-known and known (strongly agree and agree). The frequency of responses indicating not new (disagreement) was determined by adding together the frequencies of partially known(agree), unknown (disagree), and undecided (neutral) responses. Awareness index was calculated using formula: Awareness Index = (frequency of known - frequency of unknown)/n, with n being sample size 270. An index value above 0.5 indicates awareness, while below 0.5 indicates unawareness. The average perception index was determined by adding up the perception indices for all variables and dividing the sum by the total number of variables. This evaluation followed World Banana Forum guidelines (FAO, 2024), covering soil management, fertilization, climate conditions, modern techniques adoption, technology challenges, water management, crop production, waste and energy management, harvesting and processing, and health and safety measures.

4. RESULTS AND DISCUSSION

4.1 Gender and Banana Farm Size

In the tehsil region, there is a growing trend of farmers switching to banana cultivation, with a total land area of 2,333 hectares used for this purpose in 2023. The identification of water sources, fertile soil, favourable climate, and income resulted in a shift towards cultivating bananas. The demographic characteristics of the farmer illustrated in Fig. 1 indicated that, most banana growers in the area use their own land, and all surveyed farmers family head were men. This trend reflects the traditional land tenure system that favours men in property transfer and resource control. Family sizes are balanced among banana growers, with many living in joint families. Women also participate in labour-intensive tasks such as planting, applying inorganic

fertilizers, and intercultural tasks, in banana farming, but men prioritize modern technology. Respondents own cows, other livestock, and engage in dairy farming (Fig.1). Some have multiple sources of income, and most banana growers had medium incomes. Research shows that farm size influences the adoption of modern techniques in banana cultivation and suggests improvements in the banana agribusiness system (Hamdani and Santoso, 2023).

Fig.1: Demographic profile of respondent banana growers Source: field survey, 2024

IL=illiterate; PS= Primary school; SSC, school; HSC= higher secondary school, Gd= graduate; PG= post graduate; J= joint; N= nuclear; F= farming; D= dairy; S= service; B= business; R=Relatives; FSA= fertilizer shop agriculturist; FG=farmers group; A= agents; SM=social media; GS= government staff; M= marginal; L=low; Me= medium; H=high; A=available; NA= not available; FS=small; FM= medium; FL=large.

4.2 Age of Respondents

The majority of banana farmers in the study area are aged 36 to 55 years, with a significant proportion being over 56 years old (Fig. 1). Older farmers may resist modern technology due to their farming experience and financial concerns. In contrast, younger farmers show interest in advanced technologies and aim to increase production quality and income. This age distribution is essential for understanding how social traits affect the adoption of modern technology in banana farming. Based on research and prior findings (Van Thanh and Yapwattanaphun, 2015; Hamdani and Santoso, 2023), it has been observed that young, educated farmers are more likely to introduce innovative methods in banana cultivation.

4.3 Formal Education

Banana growers in the region have strong educational backgrounds, ranging from primary to postgraduate levels (Fig.1). This is evident in their successful use of modern technologies and expansion of banana farming land, even without prior experience in banana cultivation. Formal education was found to influence farmers' decisions to adopt new technologies and enhance productivity in multiple studies (Abedin and Bose, 2023). The results revealed that, farmers' education levels were important in determining their adoption of banana production technology.

4.4 Access to Subsidies, Credit and Crop insurance

All the banana growers in the area took part in subsidy programs for drip irrigation and crop insurance (Fig.1). Government subsidies of substantial amount for drip irrigation and crop insurance scheme for a nominal one-rupee fee, greatly benefit banana farmers. These programs help farmers transition to banana cultivation and protect against damage from weather events such as unpredictable cyclones, strong winds, and heavy rainfall. Many banana farmers were able to access loans (Fig.1), enabling them to implement modern agricultural methods and make investments in labour and farming machinery, all of which necessitate financial resources in cash. The current study, as well as prior research (Kumari et al., 2018), suggest that the ability of banana farmers to manage risks and adoption of modern technology is greatly impacted by their access to credit.

4.5 Access to Information on Technology Adoption

Banana growers claim that having access to information plays a significant role in influencing their decision to proceed and adopt modern banana farming methods. They primarily acquire information about the benefits and technological aspects of banana farming through conversations with friends, family members, experts at fertilizer shops, fellow farmers,

exhibitions, and social media. Some farmers transitioned to banana cultivation after participating in seminars and workshops organized by various government agricultural departments, banana tissue culture company representatives, non-governmental organizations, and innovative farmers. The current study and earlier research (Abedin and Bose, 2023; Hamdani and Santoso, 2023), indicated that improved access to information from different sources contributes to advancements in banana farming techniques.

4.6 Understanding of Soil, Climate and Fertigation

The data in Table 1 shows farmers' understanding of soil traits, weather conditions, monsoon timing and adequacy, and fertigation requirements for banana farming.

Table 1: Modern agriculture practices (MAP) followed by banana growers

Sr. No.	Activity	Modern agriculture practice (MAP)	% of follower
•	Banana propagule used	Suckers	5.2
		Tissue culture plants	94.8
•	Banana variety preferred	Grnad Naine (G-9)	91.9
		Shrimanti	5.2
		Gross Michael	3.0
•	Planting season	June to September	51.5
		October to January	32.6
		February to May,	15.9
•	Planting distance and density	1.65 x 1.65 m	30.0
		1.7 x 1.75 m	28.1
		1.82m x 1.52m	24.1
		Newly own specified	17.8
•	Mulching	polythene,	13.7
		Banana leaves, crop straw, sugarcane trash	45.6
		No mulching	40.7
•	Irrigation	Flood/ Sprinkler	0.0
		Drip	100.0
•	Solar energy	Solar pump utilization	28.1
•	Nutrient management	Green manuring	14.4
		Bio fertilizers	19.3
		Liquid fertilizer through drip irrigation	100
		Liquid fertilizer through foliar spray	15.9
		Nutrient granule feeding through leaves	92.2
•	Bunch feeding	Nutrient and growth promoters	12.2
•	Intercropping	Vegetable.	14.1
		Fruit	11.5
		Flower	6.7
		No inter cropping	67.8
•	Prevention of damage due to sunlight, wind and weight,	Bunch covering	47.4
		Use sleeves to encase bunches	32.6
		Crop border covering and frequent watering	93.7
		Propping using bamboo/wooden sticks	36.3
		Propping by tape/string	60.0
•	Pest, disease and weed management and health precautions	Recommended Chemicals used	78.1
		Synthetic chemicals not used	21.9
		Use of recommended weedicides, hand weeding and spading	100
		Farmers take precaution during synthetic chemical applications	89.3

		Safe management of agricultural waste	100
•	Ratoon crop and removal of suckers	Ratoon crop taken by farmers	4.2
		Removal of unwanted suckers	100
•	Crop rotation	Crop rotation followed	91.9
•	Fruit storage	Use of cold room storage	17.4

Source: field survey, 2024

4.6.1 Soil type:

The best soil for growing bananas has a pH level between 6 and 7.5 (Abhishek, 2021) and is found along the Bhima and Nira River corridor in Indapur tehsil. This area has different types of soil like black, red, alluvial, sandy, and sandy loams (Bhore et al., 2012; CDAP, 2017). Farmers in the region are aware of the soil type and its water retention capacity. Sixty-three (63%) of farmers tested banana field soil for pH and minerals with help from banana and fertilizer related companies and government organizations. Some farmers didn't test their field soil because other crops grew well in their fields. Earlier reports (Bhore et al., 2012; CDAP, 2017) also show that the soil in the region is slightly acidic or alkaline and has good drainage and organic matter, nitrogen, phosphorus, and potash, which are good for growing bananas in Indapur tehsil.

4.6.2 Climate

Bananas thrive in warm and humid climates, with wind speeds below 80 km/hr. They can tolerate temperatures ranging from 13°C to 44°C (Reay, 2019). These conditions align with the geography and weather of the Indapur tehsil region (Dhobale, 2020; Salunkhe, 2023). Most respondents were unable to describe these weather conditions scientifically (Fig.2). The region experiences a hot tropical climate with mild summers, gentle winters, and dry conditions except during the southwest monsoon (Dhobale, 2020; Bhore et al., 2021). It falls into a dry and semi-arid agro-climatic zone with limited and irregular rainfall. Temperatures range from 6.8 °C to 42.3 °C (Ogale, 2022)., occasionally hindering banana growth in extreme conditions. However, the Grand Naine variety of banana is preferred by local farmers crop shows resilience due to adequate water resources and the limited duration of adverse conditions (kvk. icar.gov. in, 2023).

Fig. 2: Understanding about soil, climate and application of fertilizers among the banana growers. (a. Soil testing carried out before banana plantation b. Farmers understanding about climate c: Application of manure and fertilizers. Source: field survey, 2024.)

The main factor affecting banana cultivation is rainfall. A study in Indapur found a negative correlation between rainfall and banana cultivation over 24 years due to low rainfall (CDAP, 2017; Ogale, 2022). Despite this, banana cultivation is increasing using water from various sources such as Ujani dam's backwater, fed by the Bhima River, and from the Nira River, along with the Nira left canal and Khadakwasla canal system (Bhore et al.2021; Ogale, 2022).

4.6.3 Fertigation

Plant growth relies on mineral nutrients in the soil, which may be abundant in some minerals but

deficient in others (Ogale, 2014: www. shehrikisaan. in; 2023). Supplementing the soil with nutrient minerals from sources like compost, farmyard manure, or chemical salts is necessary (Santosh et al., 2024). Bananas require higher nutrient levels compared to other plants (www. shehrikisaan. in; 2023), and most farmers follow suggested fertilizer application rates for banana crops (Fig.2). This is often due to the presence of domestic animals owned by the majority of farmers and availability of manure. However, a small percentage of farmers use inorganic fertilizers and farmyard manure instead (Fig. 2).

4.7 Adoption of Modern Techniques in Banana Farming

The data in table 2 demonstrated the usage of tissue culture plantlets (seedlings), drip irrigation, liquid fertilizers via drip or foliar methods, and pest management technologies among farmers. It examines how access to these technologies differs based on farm size, education level, and government support.

Table 2: Farmers' perspective on modern agricultural practices (MAP) and growing bananas.

Sr. No.	Statement related to implementing and benefits of MAP applications	Perspective decision by the % of the respondent (Likert scale)					Index
		1	2	3	4	5	
1	The age, education, and farming experience impact MAP implementation.	192	21	30	19	8	0.6
2	Farmers' groups and various communication platforms promotes the use of MAP.	132	48	39	33	18	0.3
3	Understanding soil characteristics and climate is essential for implementing a MAP.	198	28	12	11	21	0.7
4	Organic farming and the use of MAP improve soil and plant health while reducing costs and pollution.	188	44	27	11	0	0.7
5	MAP enhances the performance and sales of the Grand Naine (G-9) variety in state and international markets.	152	58	34	19	7	0.6
6	Compare to suckers, tissue culture plantlets produce healthy, disease-free, uniform good export quality banana	164	48	33	14	11	0.6
7	Drip irrigation delivers water, fertilizers, and biofertilizers to plant roots to reduce waste, avoid overwatering and underwatering, keep plants healthy and hydrated.	238	23	9	0	0	0.9
8	Water-soluble fertilizers, biofertilizers, and agrochemicals applied through spray or root feeding can greatly enhance banana yields.	123	40	39	35	33	0.2
9	Drip irrigation can be done by monitoring soil moisture with tensiometers.	18	27	21	27	177	-0.7
10	Mulching with plant materials or plastic helps retain water by reducing evapotranspiration.	119	55	41	37	18	0.3
11	Crop rotation reduces the need for synthetic agrochemicals to control pests and weeds.	69	77	53	48	23	0.1
12	Using MAP can reduce the risk of fungal diseases like Fusarium TR4 and other related illnesses."	77	94	38	23	38	0.3
13	MAP allows banana cultivation year-round, with the flexibility to adjust planting space and density.	144	73	26	14	13	0.6
14	Workers can enhance their work quality, productivity, and benefits by improving technical skills through MAP.	188	49	21	9	3	0.8
15	MAP helps banana farmers in the area get ISO certification, which is important for selling and exporting their produce.	92	72	63	23	20	0.2
16	Intercropping improves benefits from growing bananas with other crops.	26	28	51	118	47	-0.6

17	MAP helps to protect banana crops and bunches from various environmental threats like sunlight, temperature, wind, weight, pests, and diseases.	194	32	22	14	8	0.7
18	Prolonged storage is not ideal for bananas. Cold storage facilities extend bananas' shelf life, promoting market competitiveness, export promotion, and increasing profitability.	68	88	39	46	29	0.2

Perspective decision of the respondent on a 5-point Likert scale as strongly agree (1), agree (2), partially agree (3), not agree (4), and unable to decide (5), n= No. of respondents=270 (First 5 column values in percentage) (Likert, 1932 in Google scholar) Source: field survey, 2024

4.7.1 Tissue Culture Plantlets

Tissue culture technology has become increasingly popular for the commercial production of bananas in recent years (www. shehrikisaan. in; 2023; Salunkhe, 2023). In accordance, 94.8% of farmers in the region prefer using banana tissue culture plantlets for cultivation, while only 5.2% choose suckers as a propagation method. Despite the availability and cost-effectiveness of suckers, farmers favour tissue culture plantlets due to their disease and pest-free nature, which ensures a reliable and high-quality harvest in a specific time frame, ultimately leading to better yields (Parekh et al., 2016; Joshi et al., 2020).

4.7.2 Variety

Selecting the right variety for cultivation is crucial due to environmental differences in India (kvk. icar.gov. in, 2023). Common banana cultivars in India include Dwarf Cavendish, Robusta, Monthan, Poovan, Nendran, Red banana, Nyali, and Grandnaine (G-9), among others (www. shehrikisaan. in; 2023). The preferred variety among farmers is Grand Naine (G-9)(Table 1) due to its resilience and high-quality production (www. shehrikisaan. in; 2023). Grand Naine has well-spaced hands, larger size, uniform yellow color, longer shelf life, and superior quality, leading to strong market demand. Overall, Grand Naine is the most preferred variety in the study area.

4.7.3 Season

Banana is traditionally planted in two seasons: June and July (Kharif/Mrig Baug) and also in October and November (rabbi/Kande Baug) (kvk. icar.gov. in, 2023; Salunkhe, 2023). However, farmers in the Indapur tehsil region have suggested that with the use of drip irrigation systems and tissue culture-raised plantlets, plantations can be carried out year-round. A survey revealed that 51.5% of farmers plant from June to September, 32.6% from October to January, and 15.9% from February to May (Table 1). This shows that banana cultivation takes place throughout the year in this region, allowing farmers to fetch good market prices and have fruit available consistently.

4.7.4 Plant Distance and Density

The distance between banana plants is important for maximum growth and yield (kvk. icar.gov. in, 2023). About,17.8% of farmers rely on their own experience for spacing, while 82.2% follow recommendations from plantlet production companies. Different spacing is recommended for different types of banana plants, with some farmers planting Grand Naine variety at specific distances for better results (Table 1). This spacing allows for 1452 plants per acre (3630 plants per hectare), and farmers believe it leads to good growth and yield due to competition for nutrients and sunlight.

4.7.5 Biofertilizer and Liquid Fertilizer Application

In the tehsil region, farmers use water-soluble chemical fertilizers and biofertilizers in

combination with drip irrigation (Table 1). Typically, micronutrient salts such as ZnSO4, FeSO4, CuSO4, and H3BO3 are utilized through drip irrigation or leaf spraying to combat deficiencies ((www. shehrikisaan. in; 2023).). Banana growers recognize that this fertigation method enhances nutrient delivery to the root zone, resulting in improved uniformity, efficiency, increased yield, and significant savings on fertilizers. These findings were consistent with experimental plots that used drip irrigation for nutrient application, resulting in a 25-30% increase in yields ((www. shehrikisaan. in; 2023).).

The majority of farmers who participated in the survey also used fertilizer solutions with micro and organic nutrients, along with adhesive agents such as teepol, on banana leaves, as well as feeding fertilizer granules through leaves to provide micronutrients (Table 1). This approach enhances nutrient absorption through leaves to promptly address deficiencies ((www. shehrikisaan. in; 2023).).

4.7.6 Bunch Feeding

The process of bunch feeding involves the direct application of nutrients and growth solutions to the banana bunch, resulting in improved fruit development, quality, and shelf life across different banana varieties like Champa (Sathish et al., 2021), Ney Poovan (Nayak et al., 2022), and Grand Naine (Shrestha et al., 2023; Reddy et al., 2024). Despite this, there is evidence to suggest that while some farmers believe in the benefits of this method for enhancing nutrient delivery and growth in bananas, many are unaware of the bunch feeding technique. Hence, it is important to educate banana farmers in the Indpur tehsil area about the benefits of bunch feeding.

4.7.7 Drip Irrigation

Efficient management of water is vital in Indapur tehsil due to its semi-arid climate. However, the majority of farmers have sufficient irrigation water, primarily sourced from wells or lift irrigation from rivers. Only a small percentage experience shortages during summer. Farmers attribute the widespread adoption of drip irrigation for banana farming to advancements in the durability and affordability of PVC pipes, tanks, valves, couplings, and drippers. Drip irrigation is now utilized by all farmers and has significantly improved irrigation systems, particularly for banana cultivation (Table 1). This method is especially effective in well-drained soils, helping conserve water and enhance crop yield. The use of drip irrigation has led to increased crop yields, reduced labour costs, and improved fertilizer efficiency (Parekh et al. 2016; Pratibha et al., 2023). While some farmers use electric pumps for irrigation, a small percentage opt for solar pumps (Table 1). Thus, there is need of awareness for use of solar pumps

4.7.8 Intercropping

Very small percentage (9.3%) of farmers intercrop with vegetables, pulses, and flowers during the first three months of banana growth. The majority (90.7%) of farmers believe intercropping competes for nutrients, water, and light, damaging the shallow root system of bananas and reducing production quality. Previous studies have shown that intercropping can lower both quality and yield of bananas (Parekh et al., 2016). The results of the present study, along with previous research, suggest that farmers who prioritize growing top-quality bananas avoid intercropping (Hamdani and Santoso, 2023).

4.7.9 Propping

The respondents recognize that banana plants have weak stems which can't support weight of fruit bunch and may fall due to strong winds. To address this issue, some farmers use bamboo or sticks for support while others tie plants together with string. (Table 1). Both methods have been shown to reduce the risk of damage from weight and wind, thereby minimizing potential losses (FAO, 2024).

4.7.10 Removal of Suckers and Ratoon crop

Banana plants produce suckers after 4-5 months, which can reduce productivity by competing for nutrients (Der et al., 2023). In order to address this issue, farmers in the area regularly remove the suckers every 5-6 weeks, with a preference for focusing on the main crop. A low number (4.8%) of farmers choose to keep just one strong sucker for a second crop, however, it is noted that the second harvest usually has lower quality.

4.7.11 Crop rotation

Crop rotation and keeping the land fallow for a specified period is an effective technique for improving soil quality and controlling diseases in banana plants, making it essential in banana farming. (Fan et al., 2020). A significant majority of farmers (91. 9%) engaged in crop rotation, succeeding the banana crop with maize, jawar, bajara, or different vegetables and seasonal fruits like watermelons and musk melons. A total of 8. 1% adhered to the fallow practice, anticipating a successful new banana crop.

4.7.12 Cold storage:

Bananas need cold storage at 12 to 14°C and 85-90% humidity to last longer, up to six weeks. Cold storage slows ripening, reduces spoilage, and preserves freshness. Cold storage is crucial for quality, market competitiveness, exports, and profits (Bhadke et al. 2024). Lack of cold storage in the tehsil market poses challenges for banana storage. Only 17.4% of respondents know about cold storage options, highlighting the need for more awareness and facilities in the Indapur tehsil region.

4.8 Impact of Geographic Challenges

The study addresses challenges like variable rainfall and possible drought risks, analysing how effectively farmers adjust their methods to manage these problems.

4.8.1 Drought and Bright Sunlight

Most farmers in the study area recognize the challenges of the tropical climate's year-round sunlight, especially bright sunlight in summer (Table 1). Farmers mentioned that the bunches and upper parts of the banana plants are at risk of sunburn and damage from intense sunlight during March, April, and May. To address this issue, 47.4% of farmers use dried banana leaves to cover these areas, while 32.6% use blue plastic sleeves for protection. These methods are similar to those used by banana farmers in Jalgaon, India (Salunkhe 2023).

Extensive research shows how climatic variations affect banana cultivation in different geographic regions (Abdoussalami et al., 2023). In the Indapur tehsil area, 93.7% of farmers reported facing drought and high temperatures in summer, causing stress on their banana crops. They observed issues like wilting and leaf drying, especially at the edges. Banana plants, with large leaves and weak stems, struggle in winds over 80 km/hr (Baral, 2019). Farmers mentioned that strong winds can damage leaves, bunches, or entire plants, leading to crop loss. To combat these problems, farmers watered their crops frequently, used mulching techniques, and planted bordering plants. These observations align with previous findings on the impacts of drought, water stress, light intensity, and temperature on bananas (Abdoussalami et al., 2023; Salunkhe 2023).

4.8.2 Pest, Disease and Weed Management

Banana cultivators in the region experienced minimal challenges related to diseases or pests concerning G-9 and indigenous varieties (Table 1). Nevertheless, 78.1% used chemical

pesticides during bad weather based on advice. A marginal percentage of farmers (21.9%) did not use synthetic chemicals. In contrast, banana producers in the Jalgaon district of India and exporters in Malaysia have faced recurrent diseases and pest infestations, which have significantly impacted their crops and economic viability (Salunkhe, 2023).

Concerning weed management, the respondent farmers noted that banana plants grow slowly in the first 1-4 months, allowing weeds to flourish and requiring special attention to weeding during this time. They use herbicides like Glyphosate and Duron along with hand weeding (Table 1). Most farmers take safety measures during spraying. A similar strategy has been documented for weed management in banana plantations due to labour scarcity and rising costs for mechanical weed removal (FAO 2023; Salunkhe 2023). The majority of participants dispose of agricultural waste by sending it to local waste collectors for recycling. Some farmers burn waste safely. About 34% of farmers have a separate storage area for fertilizers and supplies. According to FAO (2023) guidelines, 89.3% of respondents provide training on safe use of pesticides, fertilizers, and equipment in banana farming to ensure employee welfare. They also ensure fair working hours and rest periods for workers.

4.9 Perception of Farmers on Modern Agricultural Practices (MAP):

The study reveals farmers' perceptions of MAP adoption and its benefits (Table 2). The average perception index was determined by adding up the perception indices for all variables and dividing the sum by the total number of variables. The average perception index is 0.4, with high perceptions for drip irrigation and liquid fertilizer application. Factors like soil characteristics, organic cultivation, and crop protection were also considered. Age, educational qualifications, and farming experience also influenced MAP implementation. Strengthening farmers' organizations and diversifying information channels could improve MAP applications. However, the data depicted in table 2 suggested that, attention should be focused on foliar agrochemical applications, bunch feeding, tensiometers, mulching, crop rotation, diseases, intercropping, cold storage, and ISO certification.

4.10 Challenges in Technology Adoption:

The data presented in fig. 3 revealed that, financial constraints, lack of training, and limited outreach hinder the adoption of innovative agricultural practices in the region. Farmers struggle with skilled labour, high costs of modern technologies, adverse weather, and identifying banana varieties.

Fig. 3 . Challenges related to banana farming of the region. Source: field survey, 2024

Some face uneven plant growth due to mineral deficiencies and difficulty in removing post-harvest biomass (Fig. 3). After harvesting, the large biomass of leaves, pseudo-stem, and underground rhizome remains, making it difficult to remove. Most farmers recycle banana waste to produce organic manure, which aids in water conservation and soil quality. Access to clean water is limited, and transportation and storage methods contribute to losses. Market fluctuations and uncertainty surrounding export opportunities further impede the adoption of these practices.

4.11 Factors That Enhance Prospects in Banana Farming

Bananas are an excellent fruit crop for semiarid regions due to their adaptability, water needs,

resilience, durability, and year-round cultivation. Government subsidies for drip irrigation systems, favourable market prices, and job creation have strengthened banana cultivation. Bananas are ideal for transitioning from existence farming and encouraging crop diversification. Financial support from the Pune District Cooperative Bank and nationalized banks has enabled farmers to acquire necessary materials and labour. Banana crop consultants have introduced technological advancements to rural communities. Farmers in the study area are focusing on improving banana farming, including reducing costs, ensuring export-quality banana varieties, increasing crop insurance coverage, and establishing reliable cold storage facilities.

5. CONCLUSION, RECOMMENDATIONS AND PROSPECTS

The success of banana farming in the study area is due to favourable soil and weather conditions, access to irrigation water, and the use of drip irrigation and fertigation techniques. Additionally, the use of high-yielding G-9 tissue culture plantlets, cold-storage, and export facilities have also played a significant role. Vendors help with harvesting, labour, and transportation, ensuring better pricing and timely payments. Adoption of modern agricultural technologies, demographic factors, and minimal disease occurrence have facilitated the expansion of banana cultivation. Support from government and non-governmental organizations through training, subsidies, and marketing initiatives has been crucial in this success. The reliable infrastructure in Indapur tehsil has shifted cropping patterns from traditional cereals to high-value fruits like bananas. Some growers are experimenting with practices to improve production quality and yield. As a result, Indapur tehsil is becoming a prominent banana hub in Pune district, Maharashtra, India. However, banana growers in the region have different levels of success based on their socioeconomic status and application of modern agricultural practices.

Government agencies and researchers should focus on offering training in soil and farming methods, exploring new technologies to decrease reliance on bullocks, tackling issues like droughts, unpredictable weather, and pests with technological innovations, as well as creating and making available cost-effective automatic irrigation and fertilization systems. It is important to set up food processing industries that focus on using bananas as a raw material and making use of banana waste biomass. Reduce the challenging tasks involved in harvesting, lifting, and transporting heavy bunches of weight from the field to the transport area through the advancement of mechanized systems. It is essential to establish adequate cold storage facilities at a reasonable cost. Additionally, there is a need to enhance both domestic and export market infrastructures with certain assurances, as well as to create a system that ensures stable pricing while allowing for sufficient profit margins. Geographic awareness also shows significant gaps, particularly among less-educated farmers who may not fully understand how to optimize farming practices based on local environmental conditions. Therefore, there is a necessity for targeted initiatives to enhance education, market strategies, export chances, and maintain socioeconomic stability. Ground water recharge techniques should be implemented in order to enhance the levels of ground water.

The banana production in the region has the potential to enhance economic growth, improve fruit availability, and create job prospects. The Indapur tehsil area has favourable conditions for growing bananas and is making significant progress in banana production. Yet, there are challenges that need to be addressed in order to fully realize the tehsil's banana cultivation potential.

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DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

References:

Abdoussalami, A., Hu, Z., Islam, A.R.M.T. et al., (2023). Climate change and its impacts on banana production: a systematic analysis. Environ Dev Sustain. 25, 12217–12246.

Abedin, M., & Bose, S. K., (2023). Association between socio economic profile with knowledge of respondents towards improved banana cultivation practices in Vaishali district of Bihar. J. Exp. Agric. Int, 45(7), 99-104.

Anonymous. (2024). Feeding the future global population. Nature. Communication. 15, 222

Aryal, S., & Aryal, L.N., (2023). Pesticide residue and food safety: retrospection and prospects. In: Ghosh, S., et al., (eds) Emerging Solutions in Sustainable Food and Nutrition Security. Springer, Cham.

Baral, A., (2019). Bananas tackling drought and heat – with DREBs and more. Physiol. Plant. 165, 128–130.

Bhadke, T. G., Joshi, V. R., Garande, V. K., & Dhakare, B. B., (2024). Enhancing quality of banana by using different postharvest treatments. Int. J. Adv. Biochem. Res. 8(1), 253-267.

Bhore, J. B., Dangat, V.T., Jaybhaye R. G., & Gatkul, B. I., (2012). Fertility Status of Soil in the Green Belt of Indapur Tahsil, Dist - Pune (Maharashtra) India. Global J of Science Frontier Research Environment and Earth Sciences. 12(1), 25-28.

Bhore, J. B., Gatkul, B. I., & Shinde, A. S., (2021). Socioeconomic impact and environmental status in Ujjani dam affected area of Indapur tehsil, dist. -Pune (MH). Int. J. Science and Research.10 (9), 152-156.

CDAP., (2017). Comprehensive district agricultural plan report for Pune district in Maharashtra, India.

Der, M. L., Varu, J. D., Patil, S. J., & Gohil, M. M., (2023). Effect of different month of Ratooning with bunch spray of GA3 and BA on yield and yield attributes of banana (Musa paradisiaca L.) cv. Grand Nain. The Pharma Innovation Journal, 12(12), 1941-1943

Dhobale, G., (2020). Rainfall distribution and its variation in the Indapur tahsil district Pune, Maharashtra. IJIRMF, 6(5), 133-138.

Fan, P., Lai, C., Yang, J., Hong, S., Yang, Y., Wang, Q., …& Ruan, Y. (2020). Crop rotation suppresses soil-borne Fusarium wilt of banana and alters microbial communities. Archives of Agronomy and Soil Science, 68(4), 447–459.

FAO, (2023). Banana Market Review.

FAO, (2024). The state of food security and nutrition in the world– financing to end hunger, food insecurity and malnutrition in all its forms.

Gelaye, Y., & Negash, B., (2024). Residue of pesticides in fruits, vegetables, and their

management in Ethiopia. J. Chem. 24, 1-16

Hamdani., & Santoso, D., (2023). A strategic approach to agribusiness system development for accelerating Saba banana production. Univers. J. Agric. Res., 11(6), 1002 - 1012.

Joshi, A., Kalaunia, D., & Tiwarib, U., (2020). Application of good agricultural practices (gap) by the banana farmers of Chitwan, Nepal. BioRxiv, 6 (12),148551-25

Kumari, P., Singh, K.M., & Atre, S. K., (2018). Problems and constraints in banana cultivation: a case study in Bhagalpur district of Bihar, India. Int. J. Curr. Microbiol. App. Sci., 7(7), 1752-1759.

kvk.icar.gov.in (2023) ICAR-National Research Centre for Banana

Likert, R., (1932). A technique for the measurement of attitudes. Arch Psychology., 22(140):55. [Google Scholar]

Ogale, S. B., & Nagarale, V., (2014) Agricultural Productivity of the Baramati Tahsil, Pune District (Maharashtra). J. Agri. Vet. Sci.7(5), 25-30.

Ogale, S. B., (2022). The study of tourism development at Bhigwan bird sanctuary, Indapur tehsil, Pune District (Maharashtra), Review of research, 11(8),1-4.

Onyeaka, H., Ghosh, S., Obileke, K., Miri, T., Ode Yemi O. A., Nwaiwu, O., & Tamasiga, P., (2024). Preventing chemical contaminants in food: Challenges and prospects for safe and sustainable food production, Food Control,155, 110040

Parekh, B.V., Patel, N., Panchal, B. B., Patel, H. B., & Ramani, M. M., (2016). Recent advances in banana cultivation. Innovative Farming, 1(4), 143-146.

Pratibha, P., Suresh, K., Jagrati, B., Deshmanya, L. G. B., & Patil, K., (2023), Banana cultivation under drip and conventional irrigation methods in Karnataka: An economic analysis. Environment and Ecology 41 (4B), 2625—2632.

Reddy, C. G., Susila, T., & Rajeshwari, G., (2024). Bunch feeding technique in banana for higher fruit yield. Indian Farmer, 11(1),50-5.

Salunkhe, A., (2023). A study of problems faced by banana farmers in Jalgaon district. Int. J. Research in Engineering, IT and Social Sciences, 13(6), 15-17.

Santosh, D. T., Maitra, S., & Tiwari, K. N., (2024). Enhancing banana production through effective fertigation frequency management and plastic mulch: Impacts on crop growth and yield. Res. Crop. 25, 65-72.

Sathish, B. R., Yallesh K. H. S., Ganapathi, M., &Narayana, S. M., (2021). Effect of bunch feeding and bunch spraying on vegetative and yield parameters of tissue culture banana CV. Ney Poovan. Pharma Innovation,10(9), 1301-1306.

Shrestha, S., Bhattarai1, S., Tamang, P., & Ranabhat, A., (2023). Effect of bunch feeding on yield parameters of banana CV. Grand naine in Ratnanagar, Chitwan, Nepal. Int. J. Appl. Sci. Biotechnol. 11(1), 25-29.

UN, (2024). United nations, department of economic and social affairs, population division. world population prospects data sources.

Van Thanh, N., & Yapwattanaphun, C., (2015). Banana farmers' adoption of sustainable

agriculture practices in the Vietnam uplands: the case of Quang tri province. Agriculture and Agricultural Science Procedia 5, 67 – 74.

Varma, V., & Bebber, D. P., (2019). Climate change impacts on banana yields around the world. Nature Climate Change, 9(10), 752–757.

www.shehrikisaan.in;(2023) Banana cultivation in India: A comprehensive guide to successful banana farming and plantation practices including red banana cultivation.

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