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Assessment of Farm-Level Practices of Disease and Pest Management in the Banana Zone of Nawalparasi West district, Nepal

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Abstract

Banana (Musa paradisiaca) is a vital fruit crop in Nepal, especially in the Nawalparasi West district, where it can produce and generate income. However, banana farming faces many problems such as diseases and pests that reduce crop yield and quality. This research aimed to assess the state of pest control techniques and banana diseases, providing insights and recommendations for their improvement. A total of 125 banana farmers were selected and the data were analyzed using Microsoft Excel and the Statistical Package for the Social Sciences (SPSS). The findings revealed that the banana leaf and fruit scarring beetle emerged as a particularly troublesome pest (severity index: 0.93), closely followed by the banana aphid (0.67), banana stem weevil (0.51), mealy bug (0.46), and banana rhizome stem borer (0.34). Similarly, diseases such as sigatoka leaf spot exhibited the highest severity (0.76), followed by anthracnose (0.59), bunchy top virus (0.52), bacterial wilt (0.51), and panama wilt (0.43). All participants employed diverse pest management practices, including mechanical, cultural, biological, and chemical methods. Notably, 82.4% utilized fungicides and 100% employed cultural methods, with no adoption of biological approaches. In pest management, 31.2% employed mechanical/physical methods, 95% embraced cultural methods, and all the respondents used pesticides. Positive and significant relationships were identified between respondents' education level, training, farming experience, contact with extension agents, and adoption of disease and pest management practices in banana cultivation.

Introduction

Banana (*Musa paradisiaca*), globally renowned as one of the most popular fruits, has its origins in the tropical regions of Asia, specifically India, Indonesia, the Philippines, and Thailand. Often referred to as the "poor man's fruit crop," bananas thrive in tropical and subtropical zones, ranking fourth in monetary value among major food crops, following rice, wheat, and maize (Almadhoun & Abu-Naser, 2018). Bananas are rich in bioactive substances such as phytosterols, carotenoids, biogenic amines, and phenolics, and play a vital role in promoting human health and well-being, making them a sought-after dietary component (Singh et al., 2016).

In Nepal, banana production witnessed a significant upswing, reaching 308.39 thousand metric tons across 21.63 thousand ha in 2020/21. Subsequently, during 2021/22, production surged to 339.45 thousand metric tons, expanding cultivation to 26.64 thousand ha (MoALD, 2022). However, the prosperity of banana cultivation is threatened by an array of diseases and pests, leading to substantial economic losses for farmers (Tiwari et al., 2006). The unchecked movement of banana plants and products, coupled with lapses in sanitary and phytosanitary measures, has facilitated the global dissemination of diseases (Ramsey et al., 1990), including

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black sigatoka, fusarium wilt, and banana bunchy top viruses (Jain & Swennen, 2004). Fusarium wilt, commonly known as panama disease, is a devastating vascular affliction that jeopardizes banana production and is of high concern (Ploetz, 2015). The emergence of TR4, a highly virulent pathogen race, poses a grave threat to the Cavendish group, which dominates the global export market. The rapid spread of TR4 to Asian and Australian countries underscores the urgency of contingency plans to prevent its potential global impacts (Pocasangre et al., 2011). Other afflictions, such as yellow sigatoka caused by the fungus *Mycosphaerella musicola* and banana bunchy top virus (BBTV) compound the challenges, cause severe yield losses and threaten the livelihoods of millions of farmers (Hooks et al., 2008; Surridge et al., 2003).

In addition to diseases, insects and pests contribute significantly to reduced banana production, compromised quality, and diminished market value. A survey in Nepal highlighted poor management practices in banana orchards, particularly in neglected areas, resulting in considerable infestation by banana stem weevils and crop losses (Tiwari et al., 2006). The banana weevil (*Cosmopolites sordidus*) infests the rhizome, causing substantial yield loss (Akello et al., 2008). Another formidable pest, the banana leaf and fruit-scaring beetle, inflicts damage to leaves and fruits, particularly upon emergence from pupae, posing a significant threat to young leaves and fruits (Shankar, 2016). Aphids, through sap-sucking, virus transmission, and honeydew production, further exacerbate damage to leaves and fruits (Shankar, 2016).

Addressing these challenges requires an integrated approach involving resistant varieties, disease-free planting materials, proper irrigation and fertilization practices, timely removal of infected plants and debris, and vigilant monitoring of disease occurrence and weather conditions (Ghimire & Chhetri, 2023; Raut & Ranade, 2004). In western Nawalparasi, where banana serves as a crucial income source, despite favorable climate and soil conditions, productivity lags behind the national average of 15.85 tons per ha (MoALD, 2022). This study introduces novelty by undertaking a systematic assessment and addressing the intricate challenges confronting banana cultivation in the largely unexplored context of Nawalparasi West district, Nepal. Notably, this district has remained underrepresented in previous research, adding a unique dimension to our understanding of banana cultivation challenges in Nepal. This research endeavors to fill this significant gap, contributing valuable insights that have been largely absent in the local agricultural discourse. The inadequacy of traditional practices, such as chemical pesticides, owing to limited knowledge and access, underscores the need for alternative, eco-friendly methods to combat diseases. This study aimed to determine the prevalence of diseases and pests in banana orchards, recommend appropriate methods, and evaluate actual practices, thereby distinguishing between observed and recommended practices to ensure the health and quality of banana fruit. Through its empirical insights, this research contributes to the broader agricultural knowledge base, offering practical implications for enhancing banana cultivation practices in the Nawalparasi West district of Nepal.

Methods

Study site and sampling technique

The feasibility study was conducted in the Prime Minister Agriculture Modernization Project (PMAMP) Banana Zone, covering wards 6, 7, and 8 of Pratappur, as well as wards 4 and 5 of the Susta rural municipality in Nawalparasi West district, Nepal (Figure 1). The study period extended from February to July 2023, with the study site situated between 27.32˚ N latitude and 83.40˚ E longitude.

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The sampling population for this feasibility study comprised commercial banana growers in the Pratappur and Susta rural municipalities. The sampling frame consisted of a list of banana growers engaged in commercial cultivation rather than solely for home consumption. Using a simple random sampling technique, 125 farmers were selected to participate in this study (Table 1). The survey questionnaire was approved by the Agriculture and Forestry University Institutional Review Board (AFU-IRB) at the Agriculture and Forestry University, Nepal, with approval granted under the reference number IRB-2023-281. All participants provided informed consent after being briefed on the nature and purpose of the study, ensuring their voluntary participation.

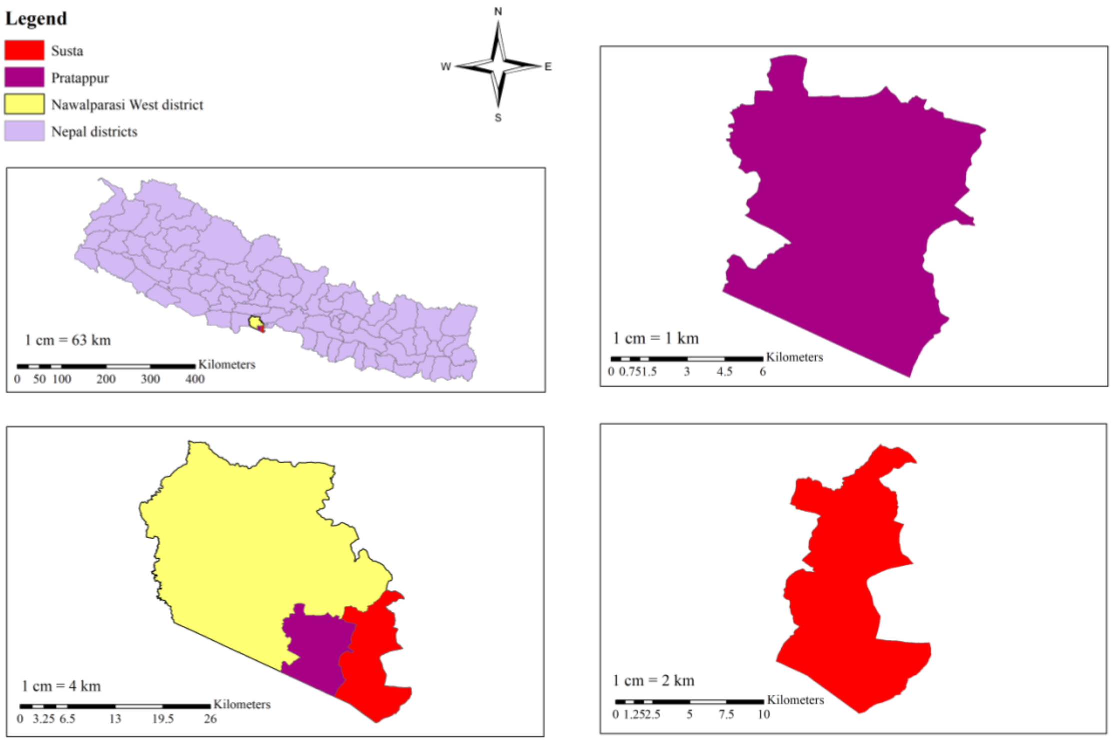

Figure 1. Map of Nepal showing study area

Table 1. Showing the sample size for sampling in the study area

Rural municipality	Ward number	No. of samples
Pratappur	6	25
Pratappur	7	25
Pratappur	8	25
Susta	4	25
Susta	5	25
Total		**125**

Survey design and data collection methods

Preliminary insights into the field conditions, socio-cultural settings, and demographic and topographic features of the study area were acquired through frequent field visits, as suggested by Ghimire and Chhetri (2023), Ghimire and Rauniyar (2023) and Thapa et al. (2024). These visits informed the preparation of interview schedules, design of the sampling framework, and application of sampling techniques, facilitating efficient data collection during the subsequent household survey.

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Both primary and secondary sources were used for data collection. Primary data collection involved the use of a validated questionnaire for a household survey, which included semi-structured interviews. Additional primary sources included focus group discussions (FGDs) and key informant interviews (KIIs). The household survey, conducted during April-May, utilized pre-tested interview schedules to gather information on demographic, educational, socio-cultural, behavioral, and economic aspects, specifically related to the assessment of major pests and diseases in Nawalparasi West. Face-to-face interviews were conducted with respondents at their homes scheduled for convenience. Five FGDs were conducted using an open-structured checklist involving leader farmers, progressive farmers, ward representatives, cooperative presidents, farmer group members, and zone management committee participants. The insights from these discussions were cross-referenced with the responses from the household survey. The KIIs involving 12 individuals identified as vital stakeholders in banana production and marketing were conducted. These key informants included leader farmers, members of the Samanya Samiti zone, managers of fruit wholesale businesses, local government representatives in Nawalparasi West, and cooperative representatives. An interview checklist was used to assess the interactions.

Climatological data crucial for evaluating the feasibility of banana cultivation, including temperature, rainfall, wind, and humidity, were obtained from a local weather station. To complement the primary data, various published and unpublished secondary sources, such as reports from non-governmental organizations (NGOs) and international non-governmental organizations (INGOs), agriculture knowledge centers, PMAMP profiles, Nepal Agriculture Research Council (NARC), and relevant reports, journals, and books, were consulted.

Methods and technique of data analysis

The extensive data collected from field research necessitate a systematic approach to make sense of information. The initial step involves condensing the voluminous text through the coding and classification of related concepts, ensuring systematic recording, and facilitating retrieval for future use. Information gathered from the field survey, key informant interviews, and focus group discussions underwent a coding process before being entered into a computer. The data entry process used the Statistical Package for Social Science (SPSS) (Version 26) and Microsoft Excel 2019. A descriptive analysis was employed to analyze the dataset. Various measures, such as frequency, percentage, mean, standard deviation, and range, were utilized to examine the socio-economic factors influencing the adoption of disease/pest management practices. These factors included age, sex, educational level, and active members within the family. Descriptive statistics were also applied to analyze the introductory aspects of the orchards, including orchard type, area, irrigation method, and source of seed samples.

The adoption level of farmers was quantified using the adoption quotient (AQ), as per the formula proposed by Naik et al. (2022) and illustrated in Equation 1. Statistical analysis was performed using Student’s t-tests, assuming equal variance, to ascertain the significance of adoption levels. This comprehensive analysis aims to uncover patterns, trends, and significant factors influencing disease and pest management adoption among banana farmers in the Nawalparasi West district. Based on the overall adoption quotient, the respondents were grouped into two categories, low and high, considering the mean and standard deviation as a measure of check.

$$\text{Adoption quotient} = \frac{\text{Adoption Score of the Respondents}}{\text{Maximum Possible adoption Score}} \quad (1)$$

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Logit regression analysis

The logit regression analysis model was employed to discern the influential factors affecting the adoption of disease and pest management practices in Nawalparasi West district. Ten independent variables, including age, sex, education level, family size, annual income, organizational affiliation, orchard size, training received, farming experience, and contact with extension agents, were attributed to binary dependent variables representing orchard sanitation (physical and chemical weeding), proper spacing, use of resistant varieties, use of biological methods, use of fungicides, use of pesticides, intercropping, post-harvest practices, and water management. The binary nature of the dependent variables indicates the adoption of a specific practice (coded as 1) or otherwise (coded as 0).

Throughout this process, marginal fixed effects were calculated to ascertain the probabilities of different factors influencing the adoption of disease and pest management practices. The logistic model facilitates the analysis of binary or dichotomous responses, providing insights into the impact of changes in independent variables on the probabilities of various outcomes (Tranmer et al., 2020). This robust statistical approach contributes to a comprehensive understanding of the determinants influencing the adoption of disease and pest management practices among banana farmers in Nawalparasi West district.

If $y_i = 1;\ P\ (y_i = 1) = p_i$

$y_i = 0; P\ (y_i = 0) = 1 - P$

Where: $p_i = E\ (Y = \frac{1}{X})$

Thus, the probability of adopting the technology then expressed as,

$$P\ (y_i = 1) = Pi = \frac{1}{1 + exp^{-z}}$$

Where: $Z = \alpha + \Sigma\beta iXi + \varepsilon$

The logit equation of the probability of adopting the recommended technology, P (Yi) (Gujarati, 2003), is shown below:

$$Li = \ln \frac{Pi}{1 - Pi} = Zi = \beta 0 + \beta 1x1 + \beta 2x2 + \beta 3x3 + \dots \dots \dots \dots \dots \dots + \beta ixi$$

Where; Yi = Adoption level (Dichotomous dependent variable with value 1 if adopter and 0 if non adopter), Li= Logit, Pi/1-Pi = odd ratios, ln = base of natural logarithm, $\beta 0$= intercept ε = Error and $\beta 1$, $\beta 2$, $\beta 3$, βi are the slope against the independent variables $x1$, $x2$, $x3$, … … …… xi, respectively.

Among the different socioeconomic variables to be studied the independent variables taken into the consideration on the basis of literature review to study their effect on the dependent variable of adoption are listed in Table 2.

Table 1. Description about independent variable

Independent variables	Type	Description
Age	Continuous	Years
Gender	Dummy	1= Male ,0= Female
Education of Respondent	Continuous	Years
Family Size	Continuous	Numbers

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Annual Income	Continuous	Rupees
Experience of farming	Continuous	Years
Orchard size	Continuous	Hectare
Affiliation to organization	Dummy	1=Yes, 0=No
Training received	Dummy	1=Yes, 0=No
Contact with extension agent	Dummy	1=Yes, 0= No

Relative yield loss (RYL)

Yield loss is frequently expressed as the fraction (percentage) of the attainable yield lost to disease/pest injuries. It is then called relative yield loss (RYL) and is computed as Equation 2 (Zadoks, 1985).

$$RYL = 100 * [(Ya\text{-}Y) / Ya] \qquad (2)$$

Where, Ya = attainable yield and Y = actual yield.

Problems ranking

A special ranking level for production problems, diseases, and pests was made by identification. Data scores were obtained to assess the level of knowledge of the farmers based on the results of the questionnaire. Indexing was computed using Equation 3 (Dawadi et al., 2023; Ghimire & Kandel, 2023; Ghimire & Rauniyar, 2023; Poudel Chhetri et al., 2023).

$$I\ imp = \sum (si \times fi/N) \qquad (3)$$

Where, I imp = index of importance, $\sum$ = summation, si = scale value and fi = frequency of importance given by the respondents.

Results and Discussion

Demographic and socio-economic information

The demographic profile of the surveyed banana-growing farmers provides valuable insights into the sociocultural context that influences disease and pest management practices. Gender dynamics, age distribution, cultural diversity, educational background, economic dependencies, training gaps, and the impact of agricultural subsidies collectively underscore the multidimensional nature of challenges and opportunities in enhancing agricultural sustainability in the region. The overwhelming majority of participants were male (95.2%), aligning with the broader gender dynamics in agricultural management (Table 3). This skew towards male participation may stem from traditional gender roles within the societal context, impacting decision-making in farming practices. Compared to males, women often have fewer rights, limited mobility, less access to timely information, and lack independent sources of income (Poudel Chhetri & Ghimire, 2023). Gender plays a significant role in labor division in agricultural practices, with men primarily involved in land preparation and plowing, whereas women manage nurseries, transplanting, and marketing (Joshi & Kalauni, 2019). Understanding these dynamics is essential for developing inclusive agricultural policies and practices that recognize the contributions of all individuals in agriculture. The age distribution revealed that a substantial proportion of respondents (86.4%) fell within the 20 to 59 age range, indicating the active involvement of the younger population in agriculture. This demographic trend suggests a potential succession of agricultural practices among the younger generation, underscoring the need for targeted interventions and technological adaptations catering to this age group. The ethnic diversity in the study region was notable, with Janajati constituting the dominant group (67.2%). This study recognized the significance of considering diverse cultural

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perspectives in designing interventions for disease and pest management practices. The prevalence of Hinduism as the primary religion (87.2 %) also provides a cultural context that may influence agricultural beliefs and practices. Education has emerged as a crucial factor influencing attitudes towards technology. The majority of respondents had completed elementary schooling (44.8%) or secondary schooling (36.8%), indicating a potential correlation between education levels and the adoption of modern agricultural practices. The adoption of modern agricultural methods is strongly influenced by formal agricultural education. Higher education can result in higher yields, more efficient technology, and early adoption of innovations and best management techniques, as formal education leads to lower risk aversion, stronger skills, and better decision-making abilities (O'Donoghue & Heanue, 2018). Agriculture remains the primary source of income for the majority of households (90.4%), reaffirming the centrality of farming in the economic landscape. Training has emerged as a critical gap in the surveyed population, with only 11.2% having access to PMAMP training. Farmers were unaware of the training programs or their availability, which was the primary cause of their lack of training. This deficiency in training, especially in postharvest management, may contribute to the suboptimal implementation of effective agricultural practices. This signals the need for targeted training programs to improve awareness and skill sets among farmers. The study also highlights the influential role of agricultural subsidies in the adoption of effective techniques. The correlation between access to subsidies and adoption of improved agricultural practices underscores the need for continued policy support to promote sustainable farming methods.

> *"Farmer Field Schools (FFS) has been implemented as a successful training initiative to address training gaps and promote sustainable farming practices. The FFS approach involves small groups of farmers meeting regularly over a farming season to learn and experiment together in their fields. Facilitated by agricultural extension officers or trained farmers, these sessions focused on practical, hands-on learning, covering topics such as integrated pest management, soil health improvement, and crop diversification. FSS participants demonstrated significant improvements in their knowledge and adoption of sustainable farming practices compared to non-participants. They can increase yields, reduce pest damage, and improve soil fertility, leading to enhanced farm profitability and resilience. The success of the FFS can be attributed to its participatory and experiential learning approach, which empowers farmers to make informed decisions based on their local context. Additionally, the supportive group dynamics fostered within the FFS encourage knowledge sharing and peer-to-peer learning, further enhancing the program's effectiveness. By incorporating elements of the FFS approach into training programs in the Banana Zone of Nawalparasi West district, Nepal, policymakers and agricultural extension agencies can capitalize on proven strategies to address training gaps and promote sustainable farming practices among local farmers. Regarding subsidies, it's vital to remember that the success of banana farming in Nepal has been greatly attributed to government support. Since the majority of Nepalese farmers work at subsistence levels, they would require government subsidies or financial facilities to engage in large-scale agricultural activities. These incentives have improved the farmers' standard of living in addition to increasing banana production".*

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Table 2. Summary statistics of socio-demographic variables of respondents

Variable	Frequency	Percent
Gender		
Male	119	95.2
Female	6	4.8
Age group		
Below 20 years	0	0
20 to 40 years	54	43.2
40 to 60 years	54	43.2
Above 60 years	17	13.6
Ethnic community		
Janajati	84	67.2
Dalit	23	18.4
Chettri	4	3.2
Religion		
Hindu	109	87.2
Buddhist	3	2.4
Muslim	13	10.4
Major source of income		
Agriculture	113	90.4
Service	6	4.8
Remittance	3	2.4
Business	3	2.4
Education status		
Illiterate	15	12.0
Primary	56	44.8
Secondary	46	36.8
Bachelor and above	8	6.4
Affiliation to organization		
Yes	58	46.4
No	67	53.6
Training		
Yes	14	11.2
No	101	88.8

General information on banana cultivation

Land use pattern in banana cultivation

The impact of the subsidies and expansion program implemented by PMAMP in Nawalparasi West is evident in the increasing trend of banana cultivation within the designated zone. The total land ownership across the study area encompasses an expansive 226.97 ha, reflecting the substantial agricultural footprint in the region. Table 4 provides a detailed breakdown of the land use pattern specific to banana cultivation, revealing that out of the total land area, 91.09 ha are dedicated to banana farming. The mean land ownership was 1.81 ha, while the mean land under banana cultivation was 0.76 ha. The data highlights the variability in land sizes, with the minimum land ownership being 0.17 ha and the minimum land under banana cultivation being 0.13 ha. On the other end of the spectrum, the maximum land ownership is 20.95 ha, with the corresponding maximum land under banana cultivation being 7.43 ha. These

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figures not only underscore the diverse scale of agricultural activities but also emphasize the considerable contribution of banana cultivation within the broader land-use pattern. The substantial land area dedicated to banana farming signifies its importance and growing significance within the agricultural dynamics of Nawalparasi West.

Table 4. Land use pattern in banana cultivation in the study area

	Land ownership	Land under banana cultivation
Mean	1.81	0.76
Minimum	0.17	0.13
Maximum	20.95	7.43
Sum	226.97	91.09

Experience of banana farming of respondents

An analysis of the experience levels of the surveyed banana farmers revealed noteworthy insights into the farming landscape of the study area. A substantial proportion of respondents (45.6 %) reported having accumulated 4-6 years of experience in banana farming. This suggests a significant presence of farmers who have gained moderate expertise in banana cultivation. Furthermore, there was a considerable proportion of new entrants to agriculture, with 24.8% of respondents indicating a farming experience of ≤ 3 years. This influx of new farmers underscores growing interest and engagement in agricultural activities within the community. On the other end of the spectrum, a relatively smaller percentage, specifically 10.4% of respondents, reported having an extensive farming experience of more than 10 years. This indicates the presence of seasoned farmers, who bring a wealth of knowledge and expertise to agricultural practices in the study area. The tabulated data in Table 5 further provides a breakdown of the frequency and percentage distribution across different experience categories. The mean experience level among respondents was calculated to be 5.77 years, providing an average measure that signifies the cumulative farming experience within the surveyed population.

Table 5. Experience of farming in the study area

Years of farming	Frequency	Percent
≤ 3 years	31	24.8
4-6 years	57	45.6
7-9 years	24	19.2
≥10 years	13	10.4
Mean	5.77	

Variety used for banana cultivation

An overwhelming trend was observed among the surveyed banana farmers, with almost 100% of respondents exclusively cultivating the G9 variety. The predominant adoption of the G9 variety underscores its widespread popularity in the farming community in the study area. The G9 variety is favored for its inherent resistance to diseases, coupled with the notable characteristic of producing long bunches in the short harvesting period, which gives higher yields than other varieties and increases the profitability of farmers. Additionally, consumer preference for the G9 variety has prompted its importation from India, further solidifying its status as the preferred choice among farmers. The uniform adoption of the G9 variety signifies a strategic and collective decision among banana farmers, emphasizing the variety's resilience to diseases, increased sustainability of production, and minimization of environmental impact.

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As resistant cultivars are less prone to disease, farmers may save money by using fewer chemicals, which also benefits the environment and improves soil health. Improved farm sustainability can result from using sustainable farming methods, both in terms of long-term profitability and environmental impact. This homogeneity in variety selection not only streamlines agricultural practices, but also contributes to the creation of a standardized and market-oriented banana cultivation landscape in the study area. The prominence of the G9 variety serves as a pivotal aspect of the local banana farming dynamics, reflecting a conscious choice made by farmers to maximize disease resistance and cater to consumer demands

Intercropping practices in banana cultivation

The survey sheds light on the intercropping practices employed by banana farmers in the study area, revealing a dynamic approach for optimizing agricultural benefits. During the initial year, farmers commonly intercrop small vegetables with bananas to derive additional advantages from this strategic cultivation technique. Subsequently, from the second year onward, intercropping activities were observed after the completion of the vegetative stage of the banana suckers. Table 6 provides a breakdown of the different crops intercropped with bananas, showing the diversity of agricultural practices within the study area. The data revealed that groundnut, radish, potato, and spanish are among the intercrops cultivated alongside bananas, each contributing to the agricultural diversity within the banana orchards. In our study, the ground was the most preferred intercrop (10.4%) due to its low demand for water, climate preference, and higher income returns, followed by Spanish (5.6%) and radish (3.2%), which are fast-growing plants that could be used for vegetable purposes. Notably, a significant proportion of the surveyed farmers (78.4%) reported practicing banana cultivation without intercropping. This information reflects the varied strategies employed by farmers to enhance the overall productivity of banana orchards, whether through diverse intercropping choices or focused cultivation of banana without additional crops. The observed intercropping practices underscore the adaptive and strategic approaches adopted by farmers in the study area to optimize the utilization of agricultural resources.

Table 6. Different intercrops grown under banana orchard in the study area.

Crop	Frequency	Percent
Groundnut	13	10.4
Radish	4	3.2
Potato	3	2.4
Spanish	7	5.6
No intercrop	98	78.4

Insect pest of banana

Status of banana pests

In the Banana zone of Nawalparasi West district, the cultivation of bananas faces a formidable challenge in the form of pest infestations. Although the exact magnitude of the damage remains unquantified, the Prime Minister Agriculture Modernization Project (PMAMP), in the Banana zone, has identified five prominent insects as major pests in the region. The severity of their impact has been systematically assessed, utilizing a ranking system categorizing damage levels from "Very High Severity" to "No Severity." The resultant severity index offers a quantitative measure of the overall effect of each pest on banana crops. The banana leaf and fruit-scaring beetles had a severity index of 0.93, securing the highest rank. It is closely followed by the banana aphid (Severity Index: 0.67) and the banana stem weevil (Severity Index: 0.51),

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securing the second and third ranks, respectively (Table 7). The mealy bug (Severity Index: 0.46) and banana rhizome stem borer (Severity Index: 0.34) complete the roster of major pests, each assigned a rank based on their severity. This comprehensive assessment not only identifies the key pests affecting banana cultivation, but also provides a nuanced understanding of their relative impact, which is crucial for devising targeted pest management strategies to safeguard the vitality and productivity of banana orchards in the study area.

Table 7. Major Pests in the study area

Pest	Scale vale and Frequency (fi)					Severity Index	Rank
	1	0.8	0.6	0.4	0.2		
Banana stem weevil	7	24	34	26	34	0.51	III
Banana rhizome stem borer	0	8	19	25	73	0.34	V
Banana leaf and fruit scaring beetle	89	34	1	0	1	0.93	I
Banana aphid	10	59	32	15	9	0.67	II
Mealy bug	2	16	39	31	37	0.46	IV

Note: 1 = very high severity, 2 = high severity, 3 = moderate severity, 4 = low severity and 5 = no severity.

Identification of banana pest

A noteworthy aspect of the study revealed that a substantial majority of respondents in the banana orchards of Nawalparasi West district exhibited a commendable ability to identify pests within their orchards. Among the surveyed farmers, 80.8% demonstrated the capacity to identify at least one pest in their orchards. Impressively, none of the respondents failed to recognize any of the pests, highlighting a keen awareness among banana growers regarding the pest population in their cultivation spaces. A mere 19.2% of respondents acknowledged the challenges in identifying all pests present in their orchards. This finding underscores the farmers' level of engagement and knowledge concerning prevalent pests, which is instrumental in effective pest management practices.

Management practices of pest of banana orchard

This study analyzed insect pest management practices in a banana grower's area, focusing on five categories: cultural, physical, biological, quarantine measures, and chemical. Farmers had limited knowledge of these practices, and only 1.6% knew about biological methods (Table 8). The chemical method was the predominant method, followed by mechanical methods such as hand-picking, egg destruction, and sticky traps. Cultural methods included field sanitation, summer plowing, use of well-decomposed farmyard manure (FYM), use of resistant varieties, and de-suckering.

Botanicals were the only biological methods used by farmers, with Jholmal being the only botanical used. Only one respondent adopted biopesticides, such as neem-based pesticides. Natural enemies and pathogens were not widely used for pest control. Chemical methods were adopted by all respondents, with their use being higher in summer than in winter.

Integrated Pest Management (IPM) is a holistic approach to pest control that involves multiple pest control techniques. IPM techniques used in banana farming include monitoring, biological control, chemical control, cultural control, physical control, and genetic control (Driesche et al., 2009). The second major pest, aphids, is a pest of many crops and ornamental plants. They cause damage by sucking sap, transmitting viruses, and producing honeydew, which attracts ants and fungi (Shankar, 2016). Moreover, aphids produce a sticky substance called 'honeydew,

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which attracts sooty mold fungi. Fungi can reduce fruit quality and interfere with photosynthesis by covering leaf surfaces. Ants are often associated with aphids and protect them from natural enemies, in exchange for honeydew (Hu et al., 1996). Spraying plants with insecticidal soap or neem oil, which can smother and kill aphids, is a solution. Another option is to introduce natural predators, such as ladybugs or lacewings, which feed on aphids and help control their populations (Shankar, 2016). However, farmers did not use natural enemies to control pests; spiders, earwigs, praying mantids, and ladybugs were present during field visits in the study area. Ladybugs and praying mantids are used to control aphids, mealy bugs, and their eggs. Some farmers have used pseudostem traps to control banana weevils. In addition, the assessment of rhizome damage is a destructive process that can only be performed on harvested plants, which imposes constraints on monitoring in some systems of banana cropping.

Table 8. Mechanical methods of pest management in the study area

SN	Method	Frequency	Percent
Mechanical methods			
1	Hand picking and egg destruction	38	30.4
2	Sticky traps	1	0.8
Cultural methods			
1	Use of well decomposed FYM	121	96.8
2	De-suckering	119	95.2
3	Field sanitation	109	87.2
4	Ploughing	53	42.4
Biological methods			
1	Botanicals	1	0.8
2	Biopesticides	1	0.8
3	Natural enemies and pathogens	0	0
Chemical methods			
1	Pesticides	125	100

Disease of banana

Status of banana disease and severity

In the study area, the cultivation of bananas was confronted with a substantial challenge in the form of diseases, which constituted another major hurdle for banana growers. Although the exact extent of the damage remains unquantified, the Prime Minister Agriculture Modernization Project (PMAMP), Banana zone, has identified five significant diseases affecting banana crops in the region. Employing a severity ranking system, ranging from "Very High Severity" to "No Severity," the severity index has been calculated to gauge the impact of each disease on banana cultivation.

Table 9 illustrates the major diseases that were prevalent in the study area. Sigatoka leaf spot emerged as the most severe disease with a severity index of 0.76, securing the highest rank. This was followed by banana anthracnose (Severity Index: 0.59), bunchy top virus (Severity Index: 0.52), bacterial wilt (Severity Index: 0.51), and panama wilt (Severity Index: 0.43), each assigned a rank based on their severity. This comprehensive assessment not only identifies the key diseases affecting banana cultivation but also provides a nuanced understanding of their relative impact. Such insights are crucial for formulating targeted disease management strategies and ensuring sustained health and productivity of banana orchards in the study area.

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Table 9. Major disease in the study area

Disease	Scale vale and frequency (fi)					Severity Index	Rank
	1	0.8	0.6	0.4	0.2		
Panama wilt	4	25	16	19	61	0.43	V
Sigatoka leaf spot	28	57	31	4	5	0.76	I
Bunchy top virus	4	14	61	23	23	0.52	III
Banana anthracnose	7	34	47	18	19	0.59	II
Bacterial wilt	3	24	39	30	29	0.51	IV

Note: 1 = very high severity, 2 = high severity, 3 = moderate severity, 4 = low severity and 5 = no severity.

Identification of banana disease

The ability to identify and recognize the diseases prevalent in orchards is a critical aspect of effective management. The study revealed that only a limited proportion of respondents demonstrated a comprehensive understanding of the diseases that affect their orchards. Specifically, 23 respondents (18.4%) were able to identify all the diseases present in their orchards. In contrast, a larger proportion of respondents, comprising 83 individuals (66.4%), could identify at least one disease in their orchards. However, 19 respondents (15.2%) faced challenges in recognizing any diseases present in their banana orchards. This disparity in the ability to identify diseases underscores the importance of educational initiatives to enhance farmers' knowledge and skills in disease recognition. Such interventions can play a pivotal role in empowering banana growers to adopt informed and targeted disease management practices, thereby contributing to the overall health and productivity of banana crops in the study area.

Management practices of banana disease

Effective management of banana diseases is integral to sustaining a healthy and productive orchard. Cultural methods emerged as the most widely adopted practices, with a significant proportion of respondents employing strategies such as orchard sanitation (65.6%), water management (89.6%), appropriate spacing (92%), de-suckering (95.2%), and cultivation of resistant varieties, particularly the G9 variety (100%). Interestingly, none of the respondents reported the use of biological methods, such as biocontrol agents, for disease management during the survey period (Table 10). Chemical methods, specifically the use of fungicides, constitute a substantial approach adopted by 82.4% of the respondents for disease management. This snapshot of disease management practices underscores the reliance on cultural and chemical approaches, signaling an opportunity to explore and promote the integration of biological methods. Emphasizing a holistic and integrated disease management strategy could enhance the resilience of banana orchards and ensure sustainable cultivation practices in the study area.

Table 10. Various method of banana disease management practices in study area.

Method	Frequency	Percent
A. Cultural method		
1. Orchard sanitation	82	65.6
2. Water management	112	89.6
3. Spacing	115	92
4. De-suckering	119	95.2
5. Resistant variety	125	100

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B. Biological method		
Biocontrol agents	0	0
C. Chemical method		
Fungicides	103	82.4

Relatively yield loss (RYL)

Understanding the relative impacts of diseases and pests on banana yield is essential for devising targeted management strategies. Table 11 presents a comparative analysis of the Relative Yield Loss (RYL) caused by diseases and pests in the study area. This study revealed that the estimated relative yield loss attributed to diseases ranged from 1% to 30%, with a mean of 9.64% and a standard deviation of 6.221. This suggests a discernible impact of disease on banana yield in the surveyed orchards. In contrast, the relative yield loss resulting from pests exhibited a broader spectrum, varying from 3% to 75%. The mean RYL due to pests was 20.99% with a standard deviation of 11.477. Notably, the impact of pests appeared to be more pronounced, indicating that banana crops are more susceptible to pest-related challenges. These findings underscore the significance of developing targeted pest management interventions to effectively mitigate yield losses. Addressing both the disease and pest dynamics is crucial for sustaining and enhancing banana production in the study area.

Table 11. Estimated loss by disease and pest in the study area

Variables	N	Minimum (%)	Maximum (%)	Mean (%)	Std. Deviation
RYL due to disease	125	1	30	9.64	6.221
RYL due to pest	125	3	75	20.99	11.477

Problems of disease and pest management

Effective disease and pest management are critical for sustaining banana cultivation. However, the study area presents several challenges that hinder these efforts, impacting the production systems and economic stability (Olivares et al., 2021). One of the most significant challenges identified was the high price of chemicals (fungicides and pesticides), ranking as the top concern with a severity index of 0.87 (Table 12). Farmers emphasized the financial strain imposed by the elevated costs of essential chemicals, hampering their ability to implement effective control measures against pests and diseases. The second major challenge, with a severity index of 0.80, was the lack of training. This underscores the importance of farmer education and training programs to enhance the understanding and implementation of effective disease and pest management practices. Training plays a significant role in the adoption of improved technology. Sapkota et al. (2017) found a positive relationship between training received and adoption of improved technology. Furthermore, the positive impact of training on technology adoption decisions was observed by farmers in the agricultural sector (Kattel, 2015). Adverse climate conditions emerged as the third-ranked challenge with a severity index of 0.65. Unfavorable weather patterns contribute significantly to the proliferation of diseases and pests, posing a substantial hurdle for their effective management. The fourth challenge, with a severity index of 0.53, was poor knowledge of management practices. This highlights the need for improved awareness and understanding of optimal disease and pest management strategies among farmers. Addressing the fifth-ranked challenge, labor issues, with a severity index of 0.31, is crucial for implementing effective control measures. Labor-related challenges, although not the most severe, still contribute to the overall complexities faced in disease and pest management.

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Table 12. Major problem in management practise in the study area

Problems	Scale vale and frequency (fi)					Scale index	Rank
	1	**0.8**	**0.6**	**0.4**	**0.2**		
High prices of chemicals	78	16	30	1	0	0.87	I
Lack of training	16	96	8	4	1	0.80	II
Poor knowledge on management	13	23	15	56	18	0.53	IV
Labour	1	0	22	18	84	0.31	V
Adverse climate	36	5	53	14	17	0.65	III

Note: 1 = very high, 2 = high, 3 = moderate, 4 = low and 5 = no.

Status of adoption

The study aimed to investigate the determinants influencing disease and pest management practices among banana farmers, with a focus on assessing the adoption status. The adoption quotient, served as a metric to gauge the extent of adoption among the study population. The average adoption quotient, determined to be 43.7%, served as a threshold to categorize the population. Farmers with an adoption quotient above this average were considered adopters, while those below were classified as non-adopters. It's crucial to note that non-adopters, in this context, do not signify a complete lack of adoption practices. Instead, it indicates that their adoption quotient falls below the calculated average.

Table 13 illustrates that 79 farmers, constituting 63.2% of the population, are categorized as adopters, indicating a higher level of adoption of various management practices. On the other hand, 46 farmers, contributing 36.8% of the total respondents, are classified as non-adopters, suggesting a more limited adoption, with adherence to only a few of the recommended practices. These findings provide insights into the varying degrees of adoption within the study population, emphasizing the need for targeted interventions to promote widespread and effective adoption of disease and pest management practices among banana farmers.

Table 13. Extent of adoption of management practices among banana farmers

Variables	Frequency	Percent	Mean
Adopters	79	63.2	43.7
Non-adopters	46	36.8	

Adoption level of different management practices

The evaluation of the adoption level was based on ten identified practices (Table 14). These findings shed light on the overall adoption quotient derived from these procedures, revealing nuanced patterns in the adoption of different practices. Practice-wise adoption analysis delineates the varying degrees of acceptance among farmers. Practices such as the use of resistant varieties (G9) and pesticides exhibited higher adoption rates, with 100% adoption observed. In contrast, practices such as intercropping and biological methods had lower adoption rates, indicating areas where targeted interventions or awareness programs could enhance adoption levels. The insights derived from this analysis can guide the formulation of strategies to promote the widespread adoption of effective disease and pest management practices within banana farming communities.

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Table 14. Practice-wise extent of adoption of disease and pest management practices among banana farmers.

Practices	Adopters	Non-adopters
Orchard sanitation	87.2	12.8
Spacing	92	8
Resistant variety	100	0
Intercropping	21.6	78.4
Water management	89.6	10.4
Biological methods	0.8	99.2
Mechanical methods	31.2	66.8
Use of fungicides	82.4	17.6
Use of pesticides	100	0
Post-harvest practices	6.4	93.6

Factors affecting the adoption of management practices

Several variables were used to determine the adoption of different management practices. The independent variables and dependent variable (adoption) were analyzed using a logit regression model, and a summary of the results is given in Table 15. Some variables, such as education, farming experience, training, and contact with extension agents, had a significant impact on the adoption of management practices. Gender, family size, annual income, orchard size, and affiliation with organizations were statistically insignificant.

Table 15. Logit regression analysis of adoption of management practices with independent variables

Adoption	dy/dx	Coefficient	S.E.	P>|z|
Age	-0.007	-0.0341	0.0053	0.186
Gender	0.088	0.402	0.291	0.76
Education of Respondent	**0.028*** **	**-0.1363**	**0.2758**	**0.003**
Family size	0.025	0.1245	0.0171	0.134
Total Income	0.0001	0.0008	0.0002	0.459
Affiliation to organization	0.028	-0.1353	0.1163	0.809
Orchard Size	0.001	0.0052	0.0044	0.776
Training	**0.236****	**1.0229**	**0.242**	**0.01**
Experience of farming	**0.053***	**0.2567**	**0.0293**	**0.062**
Contact with extension agent	**0.74*****	**3.8063**	**0.1008**	**0.001**
Constant			1.9	0.041
Number of observations		125		
LR Chi2(10)		73.34		
prob>chi2		0		
Pseudo R2		0.4459		

The log likelihood of the adoption of production technologies is -45.562923 and that of the likelihood ratio chi square is 73.34. The pseudo R2 value of 0.446 suggests that the variables in this model have been able to explain 44.6% probability of decision to adopt or not adopt management practices, which is quite high and the remaining percentage is due to other factors.

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The relationship between disease adoption and pest management practices with different significant variables is described below.

Level of education

Increased adoption might result from improved education; this is a potent element that could persuade farmers to adopt. As anticipated, education was shown to be positively significant ($p>0.01$), indicating that adoption increases with school year. According to the table, there is a 2.8% chance that the adoption rate will increase for every unit in which farmers' educational attainment increases. A higher education level of household heads gives them the ability to interpret and respond to new information much faster than their counterparts with lower education (Feder et al., 1985). This result is consistent with the findings of Dhital and Joshi (2016) and Kattel (2015).

Training

Table 15 showed that the awareness of banana growers was positively significant with the received training (Dhital & Joshi, 2016). The marginal effect was 23.6%. Hothongcum et al. (2014) reported that training helped farmers recognize important farm management practices, know about new advancements of technology, identify the problems on farms and find the scientific way of solving the problem. It helped farmers develop skills, critical thinking, and creative learning, and helped them learn to make better decisions. Hence, banana growers who received training had a higher level of knowledge than untrained farmers.

Experience of farming

The adoption of management practices of banana farmers was positively significant with years of farming and indicated the increase in adoption with the increase in farming years. The result explains that the probability of adoption of practices increased by 5.3% with 1 year rise in farming. Knowledge acquisition becomes sustainable when this hands-on learning is combined with current scientific understanding (Anderson, 2004). The primary source of information for farmers comes from their own experience and experiments; the longer they work on their farm, the more knowledgeable they become. The years of farming represented the experience of the farmer which was expected to have a positive influence on production, profitability and awareness (Joshi et al., 2019), in fruit farming (Dagne, 2018). Growing more farming years also gives banana growers greater expertise in managing pests and diseases, which makes them more competitive in the market and boosts their profitability.

Contact with extension agent

According to the findings, adoption is positively and statistically significant among farmers who have access to extension services, with the marginal rate of 74%, highest among the observed variables. It indicates that the likelihood of extension services access having an impact on management practice adoption is high. Access to extension services was determined by Ullah et al. (2018) to be a suitable element in promoting the use of technology. Our outcome is consistent with the conclusion made by Upadhyay et al. (2020).

Conclusion

The main diseases and pests affecting banana fruit were identified in a study carried out in the Nawalparasi rural municipalities of Pratappur and Susta, along with the prevalent pest and disease control techniques used by banana producers. The banana rhizome stem borer, mealy bug, banana leaf, fruit scarring beetle, and banana stem weevil were the main pests. Similarly, sigatoka leaf spot, banana bunchy top virus, banana wilt, and panama wilt were the main

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diseases identified. Over time, insect infestation has increased due to climate change, yet there are not enough effective control techniques. The majority of the farmers lacked technical expertise and contemporary pest and disease management techniques, as they had not received training. Of the respondents, 19.2% and 33.6% could not identify the disease and pests that were present in their orchards, respectively. Chemical and cultural techniques are the only effective PD management techniques that are widely used. Farmers faced a steady reduction in productivity due to the limitations of biological techniques and the extremely low adoption of organic management practices. The education level of the respondents, training received, experience of farming, and contact with extension agents had a positive and significant relationship with the adoption of disease and management practices of bananas. The report also highlights the main issues with disease and pest management practices. The potential for improving farming practices is great among farmers who have a high level of education, are a secondary source of income, and engage in large-scale commercial farming. To address banana farmers' issues, government planning and action are needed, including gender-sensitive policies, youth-friendly policies, ICT-encouraging policies, disease and pest prevention strategies, creating better ways to communicate eligibility for subsidies, and lowering barriers related to certain subsidy requirements and technology costs. Research on hybrid disease-resistant varieties and upgrading existing varieties to cater to consumer preferences is necessary. Policymakers, development workers, and extension agents should effectively use this potential to raise farming living standards through agricultural development.

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