ISSN: 2347-4688, Vol. 11, No.(2) 2023, pg. 484-498

Current Agriculture Research Journal

www.agriculturejournal.org

Evaluation of Postharvest Losses of Banana Growers in North East India: An Ordered Probit Analysis

TIKEN DAS and ABDULLAH AHMED

Department of Economics, Nowgong College (Autonomous), Old A. T. Road, Nagaon, Assam, India.

Abstract

This study aimed to examine postharvest losses encountered by banana cultivators in the northeastern Indian states of Assam and Meghalaya across three discrete temporal phases: prior to the onset of COVID-19, during the COVID-19 pandemic, and in the aftermath of COVID-19. A total of 100 households, distributed among the selected villages with 10 households per village, were chosen through a random selection process. Furthermore, the current study evaluates the impact of diverse socio-economic variables on these losses through the application of an ordered probit model. The findings of the study suggested that, during both pre- and post-COVID 19 periods, the postharvest losses of banana farmer ranges between 1 to 32%, whereas, it was between 34 to 70% during COVID 19 period. Moreover, the study argued that the postharvest losses of banana farmers were influenced by the locational indicator, education, farming experience, land pattern as well as some other production and cost related factors of farmers. Despite this, the factors that influenced postharvest losses exhibited a significant change in direction across the various time periods. The study suggests that in less developed regions such as North East India, decreasing postharvest losses could play a vital role in alleviating poverty and fostering rural advancement by creating more opportunities for agribusiness livelihoods.

Article History

Received: 09 April 2023

Accepted: 01 September 2023

Keywords

Banana Growers;
Covid 19;
Ordered Probit Model;
Postharvest Losses.

Introduction

Since bananas are a crucial commodity in horticulture, the worldwide production of bananas is projected to have increased significantly, rising from 69 million metric tons (Mt) during 2000-2002 to approximately 116 million Mt in the period of 2017-2019.[1] This growth in production corresponds to an estimated value of around USD 31 billion.[1] In India, during the fiscal year 2020, the banana was cultivated across 877 thousand hectares of land, with the production of 297 lakh million tonnes.[2] In 2019, India ranked one in annual banana production, accounting

CONTACT Tiken Das tikenhyd@gmail.com Department of Economics, Nowgong College (Autonomous), Old A. T. Road, Nagaon, Assam, India.

Doi: https://dx.doi.org/10.12944/CARJ.11.2.10

for 26.08% of the total global banana production, with cultivation extending over 866,000 hectares and a yield of 351,732 hg/ha.[1] It was reported that, 290 lakh million tonnes of banana (97%) were consumed domestically, whereas approximately 5 lakh million tonnes were lost because of its perishability.[2] Moreover, the COVID 19 pandemic had destroyed the value chains of banana in almost all countries, who were engaged in the production and export of banana.[3] A detailed study on estimating postharvest losses in banana was initiated in India through the 1989 Indo-USAID project. The study reported an average physical loss of 16.64% from farm to retail level and an average economic loss of 12.63% at the market level. The highest loss of 4.7% was recorded during the ripening stage due to inaccurate postharvest handling methods.[4] Further studie in bananas with losses of 1.33%, 1.14%, and 2.42% during harvesting, transportation, and storage, respectively.[5] In addition, another study conducted in Karnataka observed losses of 5.53%, 6.65%, and 16.66% at the field and assembly, wholesale, and retail levels, respectively, while studying the marketing losses and its effect on marketing margins of bananas.[6] It was found that postharvest losses of banana in two districts of Tamil Nadu were 2.19 to 2.52% during transportation, while the loss was 3.9% in the farm level sorting.[7] According to this study, the primary reason for higher postharvest losses during transportation was the long distance. In Assam, postharvest handling resulted in a 22% loss of bananas,[8] while in Karnataka, the loss was between 18 to 29%,[9] and approximately 19 to 21% in Tamil Nadu.[7] The study argued that the operational efficiency of banana marketing can be enhanced by reducing the postharvest losses from 29 to 18% through the lower marketing cost, strict procurement procedure and better transportation and handling.[10] Davara and Patel[11] assessed the postharvest losses of banana in Gujarat and found that losses from harvesting to ripening amounted to 15.43%, including losses at the field level (0.77%), during ripening (8.80%), and during transportation and handling (5.86%). In the Shimoga district of Karnataka, the study reported an overall postharvest loss of 24.12% in the local market, which comprised losses at the field level (7.64%), during transit (5.09%), during ripening (4.95%), and at the retail level (6.44%).[12] In the distant market, the overall postharvest loss was 27.18%, with higher losses during transit (8.31%) and ripening (6.11%) compared to the local market.[12]

Studies have unveiled that the marketing landscape for bananas in India is predominantly influenced by a substantial presence of intermediaries and traders. This prevalence not only escalates the marketing costs, consequently diminishing the portion that producers receive from prices, but also contributes to elevated levels of post-harvest losses.[13-15] The issue of excessive reliance on intermediaries in the marketing process is exacerbated by the insufficiency of appropriate and sufficient post-harvest infrastructure. The absence of facilities like cooling sheds, cold storage, and warehouses has emerged as a significant factor contributing to substantial physical losses in the post-harvest handling of produce. In India, challenges linked to transportation stand out prominently, primarily because cost-effective and efficient transportation methods are lacking, and there is a notable absence of refrigerated vans tailored for the transportation of bananas.[16,17] Highlighted by Ramesh *et al.*,[18] the principal factors contributing to post-harvest losses of bananas encompass harvesting injury, the presence of undersized and premature fruits, canker, fissures, bird infestations in the cultivation phase, and the emergence of decayed fruits, fungal growth, and the development of black layers during the transition to wholesale and retail levels. Illustrated by Nayak *et al.*,[19] the primary contributors to post-harvest losses in Chhattisgarh's bananas vary across stages: at the farm level, issues encompass small-sized fruits, cracks and cankers, sunburn, as well as injuries incurred during harvesting. At the wholesale market stage, the losses are attributed to losses due to over-ripening, physical damage, physiological dryness, and pressed and crushed fruits. Likewise, at the retailers' level, the main causal agents encompass fruits that have sustained physical damage and those that have undergone over-ripening.

Assam and Meghalaya, located in the North Eastern (NE) region of India, have a climate that is well-suited for banana cultivation due to their humid sub-tropical nature. These two states are the major contributors to banana production in the NE region of India, accounting for approximately 4.09% of India's total banana production. The Darrangiri

market, located in Goalpara district of Assam, is considered the largest market of banana in South Asia. In this locality, around 3,700 hectares of land are cultivated by nearly 800 farmers and produces 40,000 metric tonnes of bananas every year.[20] Nevertheless, due to the COVID 19 pandemic restrictions, this iconic market of bananas had also been affected severely in the wake of the breaking of the supply chain. It was argued that, in the Darrangiri market, during the second phase of the COVID 19 pandemic in 2020, the sale price for a bunch of bananas was ₹50 to ₹80, as compared to the normal price of ₹300 to ₹400.[20]

The literature discussed previously indicates that there are only a few studies focused on evaluating the postharvest losses of banana farmers in the NE states of India, particularly those that employ micro level data. In contrast, our area of research is distinct from most existing studies, which primarily examine the topic in other regions of India, such as the South and North Indian states. This study is an initial empirical investigation in Assam and Meghalaya to carefully evaluate the magnitude of postharvest losses and the factors influencing them among banana farmers. It is likely the first empirical research in India to quantify postharvest losses of banana farmers in the wake of the COVID 19 pandemic. Statistical data for current banana postharvest handling losses in Assam and Meghalaya is not available, which creates a crucial gap in the literature and has significant policy implications. In this context, the current research will endeavour to calculate the postharvest losses of banana farmers in the districts of Goalpara and East Garo Hills in Assam and Meghalaya during three time periods - pre-COVID 19, COVID 19, and post-COVID 19. It is important to note that Darranggiri serves as the primary trading centre for bananas from the entire region encompassing these two districts. Additional contributions of this study are that: a) to identify the socio-economic factors influencing perceived postharvest losses of banana farmers across pre-COVID 19, COVID 19 and post-COVID 19 periods, and b) to assess the vulnerability of small-scale banana farmers during the aftermath of COVID 19 pandemic. Thus, the main focus of the current study to answer the critical question- how the volume of postharvest losses of banana farmers varies across time periods (pre-COVID 19, COVID 19 and post-COVID 19 periods)? Moreover, an attempt is also made to answer the additional questions: (a) what are the determinants of postharvest losses for small and large banana farmers during the aftermath of COVID 19 pandemic? (b) do the heterogeneous determinants of postharvest losses of banana affect differently across different time periods? (c) is the nature of the impact of the determinants varies across the banana farmers of Assam and Meghalaya?

The paper is structured as follows: Section 2 explains the data and methodology used. Section 3 presents the results and discussions. In Section 4, we highlight limitations and potential future research. Finally, Section 5 concludes the paper and discusses policy implications.

Data and Methodology

Data Source and the Sample

To gather socio-economic information and assess postharvest losses, this study employed a household survey where banana farmers provided self-assessments. A cross-sectional approach was utilized to collect data from households growing bananas for income and food. This research took place in Assam and Meghalaya, the two major banana-producing states in the NE region of India. Figure 1 displays a map of Assam and Meghalaya, indicating the study districts and development blocks. The districts chosen for this study, Goalpara in Assam and East Garo Hills in Meghalaya, were selected purposefully because they are located close to each other and to the main areas where bananas are produced in both states. Darranggiri, which is the primary trading center for bananas from the region that includes these two districts, is also noteworthy. According to the National Horticulture Board, both Goalpara and East Garo Hills districts are among the most promising areas for banana production in India. Thus, this study focused on a cluster area that included four Community Development Blocks (CDBs), with two from each district. The reason for selecting the four Community Development Blocks (CDBs) as the study area is because they are among the main areas where bananas are produced in the districts, and most of the banana growers are concentrated in these localities. Therefore, a multi-stage random sampling technique was used to collect primary data. Firstly, Kushdhowa and Rangjuli

CDBs in Goalpara district of Assam, and Kharkhutta and Resubelpara CDBs in East Garo Hills district of Meghalaya were chosen in the first stage. Then, in the second stage, 10 villages were randomly selected from the chosen CDBs. The sample villages were chosen based on the population of the selected Community Development Blocks (CDBs). Two, three, two, and three villages were selected from Kushdhowa, Rangjuli, Kharkhutta, and Resubelpara CDBs, respectively. The households that were involved in banana cultivation were the units of observation for this study. Farmers in each of the selected villages were classified as small or large based on the size of their landholdings. In the third stage, a random selection of sample farmers was conducted. A sample of 100 households, with 10 households per village, was randomly selected from all the chosen villages. In the final stage, the selected sample of farmers was interviewed using a pre-tested questionnaire. The questionnaire was used to collect information on the socio-economic and demographic status of households, postharvest activities and practices, and the farmers' own assessment of quantitative postharvest losses over three time periods: pre-COVID 19 (January 2019 to December 2020), COVID 19 (March 2020 to May 2021), and post-COVID 19 (October 2021 to September 2022).

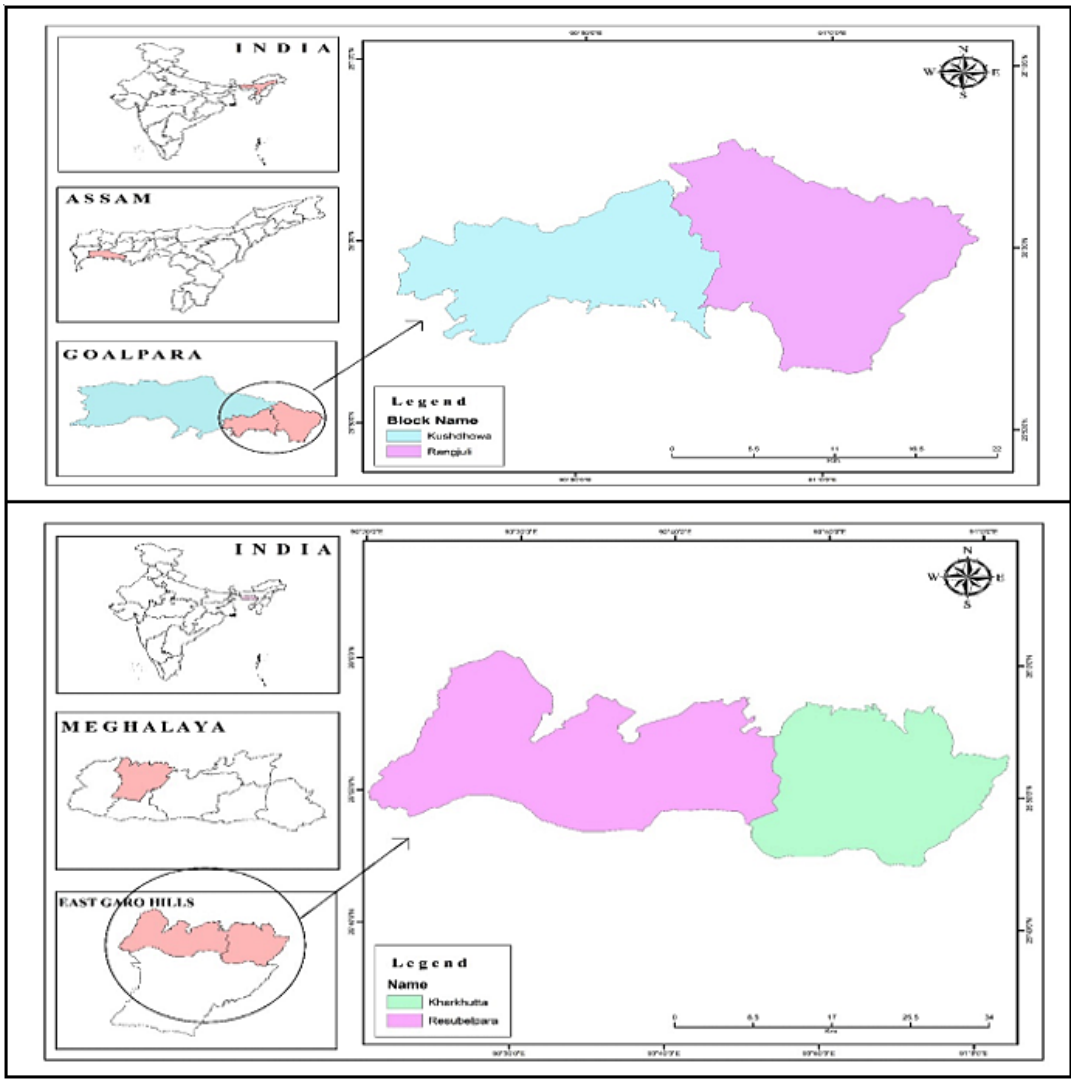

Fig. 1: Map of Sampled Districts and Development Blocks in Assam and Meghalaya

Data Analysis

In the present investigation, the assessment of perceived quantitative postharvest losses was derived through a participatory activity referred to as the 'bean exercise'. This involved engaging 100 farmers who were tasked with symbolizing their overall banana production in terms of bunches during three distinct temporal phases: pre-COVID-19, COVID-19, and post-COVID-19. Subsequently, farmers actively engaged in postharvest activities were requested to specify the number of banana bunches lost before dispatching them to the market for sale. This multifaceted approach enabled the current study to compute the percentage of postharvest losses sustained by farmers during the aforementioned time spans. This computation was conducted individually for each time period, incorporating both the banana production volume and the cumulative postharvest losses within each corresponding period. Further, the postharvest losses were presented into four categories, namely- % of farmers with minimal loss, % of farmers with low loss, % of farmers with moderate losses, and % of farmers with high loss. Although, the criteria for this categorization are similar in both pre- and post-COVID 19 periods, but the different criteria were used for COVID 19 period because of the extent of the volume of postharvest losses. Hence, the variable, postharvest loss estimates, was presented as a categorical variable, as estimates were reported in ordered range term (i.e., % of farmers across four categories of postharvest losses). Since the estimates of postharvest losses of banana are ordinal and categorical, therefore, the ordered probit and logit models can be the most suitable econometric tool to evaluate the determinants of postharvest losses of farmers. But the ordered probit model assumes a normal distribution for the latent variable underlying the observed ordinal categories. This can be a more flexible assumption compared to the proportional odds assumption of the ordered logit model, which assumes constant logit slopes across different levels of the outcome (Greene, 2012).[21] Hence, this study estimated an ordered probit model to pin down the factors of self-responded perceived postharvest losses of banana farmers. In line with Wooldridge (2010),[22] the dependent variable z, which is ordinal in nature, may take the values {0, 1, 2, ……, k} with the integer k. The dependent variable, z, can be arrived from a latent continuous variable z*, and this can be pointed as below:

$$z_i^* = m_i\alpha + u_i \quad ...(1)$$

Here, u_i follows a standard normal distribution with a mean of zero and a variance of one. The parameter α, an unidentified vector, requires estimation, and mi represents a matrix of explanatory factors encompassing the socio-economic attributes of farmers as well as their postharvest procedures related to bananas. In consistent with Wooldridge (2010),22 let us assume $\beta_1 < \beta_2 < \ldots < \beta_k$ to be unknown threshold points and these thresholds can be defined as below:

$$z = 0 \text{ if } z^* \leq \beta_1 \quad ...(2)$$
$$z = 1 \text{ if } \beta_1 < z^* \leq \beta_2 \quad ...(3)$$
$$z = k \text{ if } z^* > \beta_k \quad ...(4)$$

In this current investigation, z exhibits the potential to assume four distinct values: 1 (representing minimal loss), 2 (indicating low loss), 3 (characterizing moderate loss), and 4 (signifying high loss). Moreover, it's plausible for z to encompass three tentative threshold values (for instance, 1%, 3%, and 7%). Given the normally distributed nature of the error term, the ensuing response probabilities can be delineated as follows:

$$p(z=0 \mid m) = €(\beta_1 - m'\alpha) \quad ...(5)$$

$$p(z=1 \mid z) = €(\beta_2 - m'\alpha) - €(\beta_1 - m'\alpha) \quad ...(6)$$

$$p(z=k \mid m) = 1 - €(\beta_k - m'\alpha) \quad ...(7)$$

where €(.) is the standard normal cumulative distribution. This can be defined as the generalized form of binary probit model, in which, parameters β and α are calculated by maximizing the log-likelihood equation as outlined below:

$$L_i(\beta,\alpha) = [z_i=0]\log[€(\beta_1 - m'\alpha)] + [z_i=1]\log[€(\beta_2 - m'\alpha) - €(\beta_1 - m'\alpha)] + [z_i=k]\log[1 - €(\beta_k - m'\alpha)] \quad ...(8)$$

Thus, the marginal effect of a rise in m on the probability of choosing an alternative k can be outlined as follows:

$$(\partial p_{ij})/(\partial m_i) = [€(\beta_{k-1} - m'\alpha) - €(\beta_k - m'\alpha)]\alpha \quad ...(9)$$

where € (.) is the standard normal density function.

Description of Variables and Descriptive Statistics

A group of explanatory factors was determined by reviewing the literature and considering the theory related to banana postharvest losses. Table 1 provides details about the variables, including the hypothesized relationship and the rationale for selecting each one. Table 2 displays the summary statistics for the variables. As Table 2 outlines, in the study sample, the mean years of schooling of the banana farmer (EF_i) is 5.43 years (range: from 0 to 12). Likewise, the mean age of the farmer (AF_i) is 46.44 years, while the average farming experience of the farmers (FE_i) is 18.11 years with the range from 5 to 35 years. In the study area, the average agricultural land of the farmer (OL_i) is 11.41 bigha and the maximum and minimum are 30 and 3, respectively. It can be observed that the average production value of the banana during pre-COVID 19 period (VBBPrCj) is ₹394660.5, while during COVID 19 period, it is rather low (₹119834.1). However, during post-COVID 19 period, it surges to ₹493095.7. Table 2 also highlights that the average expenditure of the farmer on banana cultivation increases considerably during post-COVID 19 period, as against pre-COVID 19 and COVID 19 periods. Similarly, the mean of the number of bunches of banana increases during post-COVID 19 period in comparison with the other two time periods. It can also be noted that the 85% of the survey farmers are small farmers.

Table 1: Description of the determinants of postharvest losses of farmers across time periods

Explanatory variables	Notation	Definition	Hypothesized relation
District dummy	DD_j	Dummy: whether the surveyed district is Goalpara; D=1 if so and 0, otherwise	-
Education	EF_j	Education of the farmer (numbers of schooling year)	-
Age of the farmer	AF_j	It measures the working ability of the farmer and unit of measurement is number of years	-/+
Farming experience of the farmer	FE_j	It shows the experience of the farmer on banana farming. The unit of measurement is the number of years farmer engaged in banana cultivation.	-
Own land of the farmers	OL_j	Farming land owned by the farmer. The unit of measurement is 'bigha'. Here, 1 bigha= 0.133780 hectare	-
Whether small farmer	SF_j	Dummy: Whether the surveyed farmer is a small farmer; D=1 if so and 0, otherwise. Farmers with ≤ 2 hectare of agricultural land is denoted as a small farmer.	+
Production value of banana during pre-COVID 19 period	$VBBP_rC_j$	It measures the total market value (in ₹) of the banana produced by the farmer during January 2019 to December 2020.	-/+
Production value of banana during COVID 19 period	$VBBDC_j$	It measures the total market value (in ₹) of the banana produced by the farmer during March 2020 to May 2021.	-/+
Production value of banana during post-COVID 19 period	$VBBPoC_j$	It measures the total market value (in ₹) of the banana produced by the farmer during October 2021 to September 2022.	-/+

Expenditure on banana during pre-COVID 19 period	$EBPrC_j$	It measures the total expenditure (i.e., production cost) (in ₹) of the farmer on banana cultivation during January 2019 to December 2020.	+
Expenditure on banana during COVID 19 period	$EBDC_j$	It measures the total expenditure (i.e., production cost) (in ₹) of the farmer on banana cultivation during March 2020 to May 2021.	+
Expenditure on banana during post-COVID 19 period	$EBPoC_j$	It measures the total expenditure (i.e., production cost) (in ₹) of the farmer on banana cultivation during October 2021 to September 2022.	+
Bunches of bananas during pre-COVID 19 period	$BBPrC_j$	Total bunches of bananas produced by the farmer during January 2019 to December 2020.	-/+
Bunches of bananas during COVID 19 period	$BBDC_j$	Total bunches of bananas produced by the farmer during March 2020 to May 2021.	-/+
Bunches of bananas during post-COVID 19 period	$BBPrC_j$	Total bunches of bananas produced by the farmer during October 2021 to September 2022.	-/+

Table 2: Descriptive statistics of the determinants of postharvest losses of banana (Amount in ₹)

Variables	Mean	Standard Deviation	Minimum	Maximum
EF_j	5.43	3.69	0	12
AF_j	46.44	7.83	28	75
FE_j	18.11	6.56	5	35
OL_j	11.41	6.26	3	30
$VBBPrC_j$	394660.5	398715.1	5000	1900000
$VBBDC_j$	119834.1	221107.2	2500	1700000
$VBBPoC_j$	493095.7	568619.7	6500	4000000
$EBPrC_j$	64896.18	68769.86	0	300000
$EBDC_j$	65557.07	69781.47	0	290000
$EBPoC_j$	123597.1	222774	0	1700000
$BBPrC_j$	2256.94	1777.11	168	10400
$BBDC_j$	2284.89	1801.39	165	10400
$BBPrC_j$	2785.31	2262.14	190	15000
Proportion of small farmer (SFj): 85%				
Observations: 100				

Source: Authors' estimation based on field survey, 2022

Results and Discussion

Postharvest Losses of Banana Farmers Across Time Periods

Table 3 presents the percentage of respondents reporting four postharvest loss categories in pre- and post-COVID 19 period across study districts. It can be pointed from Table 3 that the postharvest losses of banana ranges from 1 to 32% during both time periods. It shows that, during pre-COVID 19 period, overall, 55% of the respondents reported losses to be on 'low loss' category, followed by 28% on 'minimal loss' category. Thus, the study highlights that, most of the farmers (78%) postharvest losses ranges between 1 to 16%. It can be shown that during the same time period, 64% and 46% farmers perceive to be on the low loss category in Goalpara and East Garo Hills districts, respectively. At the post-COVID 19 period, both survey districts as a whole, about 46% of respondents reported losses to be 'low loss' and another 37% respondents reported their losses to in the 'minimal loss' category. Thus, like pre-COVID 19 period, in post-COVID 19 period, the majority of the farmers (83%) placed on the 1 to 16% postharvest loss category. In the East Garo Hills district of Meghalaya, 54% respondents perceived their losses to be 'low loss' range, while in Goalpara district of Assam, 42% farmers placed on the 'minimal loss' category. Thus, the current study found relatively high postharvest losses of banana farmers during both pre- and post-COVID 19 period in comparison with the existing studies. It has been reported a farmer level loss of 6.81% when investigating postharvest losses of bananas in the Jalgaon district of Maharashtra, which differs from the findings of our study.[23] It has been showed that the average farm level postharvest loss of bananas in sample farms in Assam was found to be 0.309% of total production, with marginal farms experiencing losses of 0.315% and medium farms experiencing losses of 0.305%.[24] In the Tangail district of Bangladesh, the loss estimation at the farmer's level was noted 3.33% of total production.[25] One study conducted in the Boyo Division of the North West Region of Cameroon reported a farm level loss of 37.99% for smallholder farmers, which is similar to the findings of the current study.[26] According to previous studies, losses in banana production in Indian states ranged from 4.00% to 28.84%, with an average of 18.42% between 1994 and 2002.[5,27] It suggests that the reasons behind the high postharvest losses experienced by banana farmers in Assam and Meghalaya can include mechanical, physiological, pathological, and environmental factors.[28] Additionally, socio-economic factors, such as gender, farming experience, decision-making about harvest timing, level of education, marketing experience, and other factors, can significantly affect postharvest losses for banana farmers in the studied states. It can also be argued that the poor postharvest handling practices of the farmer also influence the banana loss of the farmer in the study area. In contrast to other states in India, the farmers in the studied districts do not have access to appropriate storage facilities. This means that they must store their produce in simple sheds, which can lead to high levels of spoilage. Furthermore, the assembling points in the study villages are open spaces without any structures. Moreover, because there are no processing units for adding value to raw bananas, postharvest residues in the study area may go to waste.

Table 3: Percent of banana farmers indicating postharvest losses across different loss categories

Banana loss category	During pre-COVID 19 period			During post-COVID 19 period		
	Goalpara	East Garo Hills	Overall	Goalpara	East Garo Hills	Overall
Minimal loss (1-8%)	36	20	28	42	32	37
Low loss (9-16%)	64	46	55	38	54	46
Moderate loss (17-24%)	0	18	9	16	8	12
High loss (25-32%)	0	16	8	4	6	5
Number of observations	**50**	**50**	**100**	**50**	**50**	**100**

Source: Authors' estimation based on field survey, 2022

Table 4 indicates that during COVID 19 period, the postharvest losses of banana farmers ranges between 34 to 70%. In can be shown that, overall, 50% of the respondents reported 'moderate losses, as against 24% farmers on the 'high loss' category. At disaggregate level, in Goalpara district, 56% farmers report on the 'moderate loss' category, whereas it is 44% in the East Garo Hills district. It is worth mentioning here that, in the East Garo Hills district, 30% farmers placed on the 'high loss' category, as against 18% in Goalpara district. Thus, this indicates the more vulnerable position of the farmers of the East Garo Hills district of Meghalaya during COVID 19 pandemic, in compare with the Goalpara district of Assam. Thus, this enormous postharvest losses of farmers during COVID 19 period indicates the reduction of household income in the study area, which further may reduce the purchasing power, and prevented them from investing in farming activities. Experts in the field have suggested that during the COVID 19 period, food waste may increase due to broken supply chains, lack of labor, and storage problems.[29] According to experts, the COVID-19 pandemic has caused significant postharvest losses as a result of restrictions on transportation and distribution, which have made it difficult for farmers to sell their produce in local and urban markets.[29] Subsequently, the disruption in demand and the price of bananas within the country may also cause considerable postharvest losses in the study states. Further, Kyeyune[30] classified the causes of postharvest losses of horticultural crops during COVID 19 period into four: disruption in processing activities, disruptions in steady supply of produce, disruptions in consumer demand and the subsequent disruption in prices of bananas across the country. According to the NABARD[31] study, during COVID 19 period, the extent of the postharvest losses of horticulture products was different across Indian states. Because the prices of horticulture sector products were impacted unevenly by COVID 19. While some states, such as Arunachal Pradesh, Kerala, and Mizoram, observed a rise in prices (15%, 13%, and 10.7% respectively), others like Karnataka, Tamil Nadu, Telangana, and Madhya Pradesh saw a drop in prices (23%, 15.8%, 15%, and 13.3% respectively). The study also revealed that overall, there was a 7.6% decrease in horticulture product prices at the national level in India.

Table 4: Percent of banana farmers indicating postharvest losses across different loss categories during COVID 19 period

Banana loss category	Goalpara	East Garo Hills	Overall
Minimal loss (34-42%)	2	10	6
Low loss (43-51%)	24	16	20
Moderate loss (52-60%)	56	44	50
High loss (61-70%)	18	30	24
Number of observations	**50**	**50**	**100**

Source: Authors' estimation based on field survey, 2022

Regression Results

Given the ordered and categorical nature of the dependent variable under examination, applying conventional ordinary least squares or multinomial logit/probit models might not be suitable. Consequently, in line with the methodology outlined, the study utilized the ordered probit model developed by McKelvey and Zavoina.[32] The findings of the factors affecting postharvest losses at each time period node are displayed in Table 5. Since postharvest losses could be influenced by environmental circumstances, a dummy variable for district was employed in the ordered probit estimation to account for this factor. The outcomes depicted in Table 5 reveal that the coefficients for the district dummy variable (DDj) are statistically significant. During the COVID-19 period, farmers from Goalpara district were less likely to report higher postharvest losses compared to those from East Garo Hills district. Nevertheless, no statistically significant outcomes were observed during the pre-COVID-19 and post-COVID-19

periods. This implies that unlike their counterparts in Assam, farmers situated in Meghalaya encountered escalated postharvest losses attributable to COVID-19 restrictions. This phenomenon could potentially be attributed to their geographically remote locations from major market centers, which hindered small-scale farmers in Meghalaya from accessing contemporary storage and distribution networks tailored for perishable commodities during the pandemic. The assessment of the EFj variable suggests that farmers with higher education levels exhibit a reduced likelihood of falling into the higher loss category during the pre-COVID-19 period. This observation could be construed as education enhancing individuals' awareness of diverse strategies for mitigating postharvest losses while also fostering aspirations for greater income generation through the expansion of marketable surplus. Notably, a positive correlation between the level of education and postharvest losses at the wholesale market level has been identified, aligning with the findings of several prior research studies.[33] Also, it was noted that the main reasons for postharvest losses were the lack of knowledge regarding quality and safety maintenance of perishables among producers, wholesalers, and retailers.[34] Nevertheless, the lack of significance in the outcome for the variable EFj concerning postharvest losses of bananas during both the COVID-19 period and the subsequent post-COVID-19 period underscores the limited relevance of farmers' education for the enhancement of economic activities. Conversely, the coefficient linked to the farmer's level of farming experience (FEj) displays a noteworthy positive significance (0.08 and 0.09 during the COVID-19 and post-COVID-19 periods, respectively). This suggests that farmers with greater experience in farming are more prone to falling into higher loss categories. This outcome diverges from the conclusions of certain other research endeavors, which illustrated that heightened experience among wholesalers was correlated with a decreased probability of incurring losses.[35,36] Farmers with significant farming experience and larger-scale operations can obtain capital to mitigate short-term impacts.[37] Conversely, smaller-scale farms had to rely on shared labor, diversification into subsistence crops, and asset sales. However, this variable (FEj) shows the insignificant result on the postharvest losses during pre-COVID 19 period.

Our findings show that unlike pre-COVID 19 and post-COVID 19 periods (in which it produces insignificant results), on the COVID 19 period, an increase of one unit of land of the farmer (OL_j) reduces the probability of attaining higher postharvest losses by 0.15%. This indicates the negative association between the quantity of own land of the farmers and the magnitude of postharvest losses of banana. The nature of this relationship suggests that the postharvest losses of the farmers decline with the expansion of households' assets such as land, which makes them richer to invest more on the postharvest handling practices. The outcomes of this study are in line with the research of some other studies, who stated that when farms grow larger, farmers tend to adopt agricultural machinery services that have been demonstrated to decrease harvest losses.[38]

The dummy variable, number of small farmers (SF_j), has a negative impact on the quantity of postharvest losses during both pre-COVID 19 and COVID 19 periods, whereas in post-COVID 19 period, it is statistically insignificant. Thus, it can be argued that, one unit increase of small farmer on the sample, leads to 1.27% and 2.33% decline in postharvest losses during pre-COVID 19 and COVID 19 periods, respectively. It seems that the small farmers of the study districts can manage the postharvest handling practices properly because of their small land size and volume of production.

Unlike the pre-COVID 19 period, the coefficient estimates of the production value of banana during post-COVID 19 period ($VBBPoC_j$) is significant and positive, suggesting that farmers with greater value of banana production are more likely to report they experience larger postharvest losses. The results reveal that the postharvest loss increases with the expansion of the volume of production of the farmer. Thus, the study can argue that larger farmer with greater production value incur higher postharvest losses because of inadequate facilities to handle postharvest activities. However, during pre-COVID 19 period, the probability of falling on the higher loss category declines by 2.70% for every unit increase on the production value of bananas. The insignificant result of the production value of banana during COVID 19 period (VBBDCj) indicates the occurrence of postharvest losses of banana irrespective of the value of production of the farmer.

Table 5: Determinants of postharvest losses of banana across time periods

Variables	Pre-COVID 19 Period	COVID 19 Period	Post-COVID 19 Period
DD_j	-0.12 (0.59)	-0.76** (0.38)	-0.03 (0.35)
EF_j	-0.22*** (0.05)	0.02 (0.04)	0.03 (0.05)
AF_j	0.006 (0.03)	-0.007 (0.03)	0.02 (0.03)
FE_j	-0.01 (0.03)	0.08*** (0.03)	0.09* (0.03)
OL_j	-0.04 (0.06)	-0.15*** (0.05)	0.009 (0.06)
SF_j	-1.27* (0.73)	-2.33*** (0.68)	-0.10 (0.60)
$VBBPrC_j$	-2.70** (1.27)	--	--
$VBBDC_j$	--	4.08 (7.81)	--
$VBBPoC_j$	--	--	1.53* (8.20)
$EBPrC_j$	9.14* (5.07)	--	--
$EBDC_j$	--	6.89* (3.73)	--
$EBPoC_j$	--	--	-5.11** (2.54)
$BBPrC_j$	0.07*** (0.05)	--	--
$BBDC_j$	--	-0.23*** (0.09)	--
$BBPrC_j$	--	--	-0.06* (0.03)
Intercept/cut1	-3.50 (1.48)	-4.95 (1.40)	1.63 (1.41)
Intercept/cut2	-1.23 (1.44)	-3.54 (1.34)	3.38 (1.44)
Intercept/cut3	-0.44 (1.44)	-1.95 (1.31)	4.25 (1.45)
Pseudo R^2	0.27	0.16	0.21
Log likelihood (LR)	-80.81	-99.22	-89.70
LR chi^2	25.09**	27.56***	19.03***
Observations	**100**	**100**	**100**

Notes: *, **, ***Significant at 10, 5 and 1 percent level, respectively; Standard errors in parentheses

During both pre-COVID 19 and COVID 19 periods, farmers with higher expenditure on banana cultivation ($EBPrC_j$ and $EBDC_j$, respectively) are more likely to make greater postharvest losses. Thus, the current study highlights that the postharvest losses augment with the investment on the banana cultivation. Nevertheless, the probability of declaring the highest postharvest losses of banana turns down by 5.11% for post-COVID 19 period (EBPoCj), with a unit expansion of the expenditure of banana cultivation of the farmer. This result reflects that the farmers may spend more on the postharvest handling activities during post-COVID 19 period to tackle from the postharvest losses incurred on COVID 19 period.

As expected, number of bunches of bananas (BBDCj and $BBPrC_j$), has a negative effect on the postharvest losses of banana of the farmers during both COVID 19 and post-COVID 19 periods, while it shows statistically significant positive result for pre-COVID 19 period. This result contradicts with the results of the variable, $VBBPoC_j$, which shows the positive relationship between the production value of banana and the postharvest losses during post-COVID 19 period. Thus, it seems that postharvest losses of banana shrink by 0.23% and 0.06% during COVID 19 and post-COVID 19 periods, respectively, while it expands by 0.07% in pre-COVID period with a unit addition on the bunches of bananas.

It is worth mentioning here that the variable, average age of the farmer (AF_j), has not shown any significant result in all three time periods. Thus, it can be argued that the age of the farmer has nothing to do with the postharvest losses of banana in the study districts of Assam and Meghalaya. However, it was pointed that, age is an important factor which may determine the experience in farming as well as leading to better control on the postharvest losses.[38]

Table 6: Marginal effects of factors responsible for postharvest losses of banana during pre-COVID 19 period

Variables	Minimal loss (34-42%)	Low loss (43-51%)	Moderate loss (52-60%)	High loss (61-70%)
DD_j	0.014 (0.012)	-0.002 (0.003)	-0.01 (0.05)	-0.002 (0.02)
EF_j	0.058*** (0.02)	-0.03** (0.02)	-0.02* (0.009)	-0.008* (0.004)
AF_j	-0.002 (0.008)	0.0008 (0.004)	0.0006 (0.003)	0.0006 (0.002)
FE_j	0.0045 (0.009)	-0.002 (0.004)	-0.002 (0.004)	-0.0005 (0.001)
OL_j	0.01 (0.02)	-0.005 (0.008)	-0.004 (0.006)	-0.001 (0.002)
SF_j	0.23*** (0.08)	0.08* (0.18)	-0.19** (0.12)	-0.12* (0.14)
$VBBPrC_j$	0.915** (0.15)	-0.325** (0.03)	-0.24** (0.05)	-0.35** (0.02)
$EBPrC_j$	-0.06* (0.07)	0.047* (0.004)	0.007* (0.005)	0.006** (0.004)
$BBPrC_j$	-0.07*** (0.06)	0.035* (0.02)	0.005** (0.02)	0.03* (0.02)
Observations	100	100	100	100

Notes: *, **, ***Significant at 10, 5 and 1 percent level, respectively; Standard errors in parentheses

The study also conducts computations for the marginal impacts of the ordered probit model as delineated in Equation 9. Given the consistent alignment of marginal effect estimations with their primary parameter evaluations across all three temporal spans, we focus solely on discussing the pre-COVID-19 period's marginal effect estimation as an illustrative example, as shown in Table 6. The Table presents four distinct sets of marginal impacts, revealing that farmers with higher educational attainment (EFj) exhibit a 5.8% increased inclination towards perceiving 'minimal losses,' a 3% diminished likelihood of perceiving 'low losses,' a 2% reduced likelihood of perceiving 'moderate losses,' and a 0.08% decreased likelihood of associating with 'high postharvest losses.' Also, the marginal effects attributable to the binary variable, representing the count of small-scale farmers (SFj), indicate that the likelihood of belonging to the 'minimal loss' and 'low loss' categories escalates by 23% and 8%, respectively, for each additional unit of small-scale farmers compared to their counterparts. Conversely, the probabilities of being classified under the 'moderate loss' and 'high loss' categories decline by 19% and 12%, respectively. Likewise, in the case of the variable $VBBPrC_j$, farmers with a higher banana production value are more likely to experience minimal losses by 91.5%, and less likely to experience low, moderate, and high losses by 32.5%, 24%, and 35%, respectively. The marginal impacts of expenditure on bananas during the pre-COVID-19 phase (EBPrCj) signify that a unitary increment in EBPrCj is linked to a 6% reduction in the probability of falling into the 'minimal loss' classification, a 4.7% elevation in the probability of belonging to the 'low loss' category, a 0.7% augmentation in the likelihood of being categorized under 'moderate loss,' and a 0.6% upswing in the probability of associating with 'high loss.' Additionally, it is observable that a one-unit elevation in banana bunch production relates with a 7% dip in the likelihood of being positioned in the 'minimal loss' category. Conversely, this increment results in a 3.5% rise in the likelihood of being placed in the 'low loss' category, a 0.05% rise in the probability of falling into the 'moderate loss' segment, and a 3% rise in the probability of aligning with the 'high loss' classification. As expected by the ordered probit model, these marginal effects coalesce to yield a cumulative sum of zero for each individual variable.

Limitations of the Study and Areas for Further Research

The current study did not assess the postharvest losses and the factors that determine them across various stages of the value chain, and this shortcoming is an area that requires further investigation. Moreover, it would be beneficial to validate and reproduce the outcomes using a larger sample size that encompasses farmers with diverse socioeconomic backgrounds. While these limitations exist, they do not invalidate the results of this study, and future research should focus on addressing them.

Conclusions and Policy Implication

The study aimed to assess the postharvest losses of banana in the Indian states of Assam and Meghalaya during three different time periods, namely pre-COVID 19, COVID 19, and post-COVID 19. To achieve this objective, an ordered probit model was utilized to determine how socio-economic factors influenced the postharvest losses of banana during the different time periods. Moreover, an attempt was also made to understand whether the impact of the socio-economic determinants varies across the banana farmers of Assam and Meghalaya. It was found that the postharvest losses of banana farmer ranges between 1 to 32% during both pre- and post-COVID 19 periods, whereas during COVID 19 period, it was between 34 to 70%. The findings of the current study indicated the more vulnerable position of the farmers of Meghalaya during COVID 19 pandemic, in compare with the farmers of Assam. Thus, the study argued that, the enormous postharvest losses of farmers during COVID 19 period shrink the household income in the study area, which further may reduce the purchasing power, and prevented them from investing in farming activities. We observed that, in general, postharvest losses of banana are influenced by the locational indicator (DD_j), education of the farmer (EF_j), farming experience of the farmer (FE_j), own land of the farmer (OL_j) as well as some other production and cost related factors. Nonetheless, the causal direction of the factors impacting postharvest losses exhibits a distinct shift throughout the three distinct temporal phases. The results of the present study suggest that, during both pre-COVID 19 and COVID 19 periods, the small farmers of the study districts can manage the postharvest handling practices properly because of their small land size and volume of production. Further, the study argued that the insignificant results of the variable, age of the farmer (AFj), highlighted the irrelevance of this factor on the postharvest losses of banana during the stated time periods.

Assessing the volume of postharvest losses of banana farmers and determining the factors is one of the initial steps towards planning suitable future loss prevention strategy. Expanding agribusiness livelihood opportunities in underdeveloped regions such as NE India can help reduce poverty and promote rural development. This can enhance the competitiveness and growth potential of the banana industry, ultimately contributing to broader economic growth in the NE region of India.

Acknowledgement

The authors extend their appreciation to the Indian Council of Social Science Research, New Delhi, for generously providing funding for this study.

Funding

The study received funding from the Indian Council of Social Science Research, New Delhi. Nonetheless, the funding source played no role in shaping the study's design, gathering or analysing data, interpreting findings, or composing the manuscript.

Conflict of Interests

The authors declare no conflicts of interest.

References

1. FAO. 2019 Food Outlook - Biannual Report on Global Food Markets –Rome Cultivation area of banana across India from financial year 2014 to 2019, with an estimate for 2020. (2020, October 21). Retrieved 10 August 2021 from, https://www.statista.com/statistics/874031/india-area-for-bananas-production/
2. Pandey, S. & Sadam, R. (2021). Andhra is going bananas — how India's largest producer of the fruit is breaking own record. The Print. Retrieved 10 April 2021 from, https://theprint.in/india/andhra-is-going-bananas-how-indias-largest-producer-of-the-fruit-is-breaking-own-record/622466/
3. Chase, R. & Roux, N. (2020). How COVID-19 is impacting banana-producing countries. Retrieved 10 August 2021 from, https://www.bioversityinternational.org/news/detail/how-covid-19-is-impacting-banana-producing-countries/
4. Anonymous. (1992). Final report of Indo-USAID subproject on postharvest technology of fruits and vegetables. *Indian Council of*

Agricultural Research, New Delhi

5. Nanda, S. K., Vishwakarma, R. K., Bathla, H.V.L., Rai, A., & Chandra, P. (2010). Harvest and Postharvest losses of major crops and livestock produce in India. *All India coordinated research project on postharvest technology (ICAR), Ludhiana*
6. Sreenivasa Murthy, D., Gajanana, T.M. and Sudha, M. 2007.Post-harvest losses and marketing efficiency: a case study of banana in Karnataka. *Bihar Journal of Agricultural Marketing,* 10:221-230
7. Gajanana, T.M., Sreenivasa Murthy, D., & Sudha, M. (2002). Marketing practices and post-harvest loss assessment of banana var. Poovan in Tamil Nadu. *Agricultural Economics Research Review,* 15(1): 56-65
8. Anonymous, 2005. Postharvest practices and loss assessment of some commercial horticultural crops of Assam. An article published by *Directorate of Research (Agriculture), Assam Agricultural University, Jorhat*
9. Sreenivasa Murthy, D., Gajanana, T.M., & Sudha, M. (2002). Marketing practices and post-harvest loss estimation in mango var. Baganapalli at different stages of marketing — A methodological perspective. *Agricultural Economics Research Review,* 15(2): 188-200.
10. Murthy, D.S., Gajanana, T.M., Sudha, M., &Dakshinamoorthy, V. (2007). Marketing Losses and Their Impact on Marketing Margins: A Case Study of Banana in Karnataka. *Agricultural Economics Research Review,* 20 (1), 47-60. DOI. 10.22004/ag.econ.47422
11. Davara, P.R., & Patel, N.C. (2009). Assessment of post-harvest losses in banana grown in Gujarat. *Journal of Horticultural Science.* 4 (2): 187-190
12. Ramesh, G.B., Gajanana, T.M., & Umesh, T.M. (2013). Marketing practices and post-harvest losses in banana (Var. Robusta) - A study in Shimoga district, Karnataka. *Indian Journal of Agricultural Marketing,* 27(3), 220-226.
13. Patel, A.K. (2017). An economic analysis of production and marketing of banana in Bemetara district of Chhattisgarh. M.Sc. (Agri.) Thesis, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India.
14. Halder, P., & Pati, S. (2011). A need for Paradigm Shift to Improve Sufpply Chain Management of Fruits & Vegetables in India. Asian Journal of Agriculture and Rural Development, 1(1), 1-20.
15. Veena, Babu, K. N., & Venkatesha, H. R. (2011). Supply Chain: A Differentiator in Marketing Fresh Produce. *The IUP Journal of Supply Chain Management,* 8(1), 23-36.
16. Singh, S. P., Sikka, B. K., & Singh, A. (2009). Supply Chain Management and Indian Fresh Produce Supply Chain: Opportunities and Challenges. *International Food & Agribusiness Management Association, 19th Annual World Symposium.*
17. Narula, S. A. (2011). Reinventing cold chain industry in India: need of the hour. Interview with Mr. Sanjay Aggarwal. *Journal of Agribusiness in Developing and Emerging Economies,* 1(2).
18. Ramesh, G.B., Gajanana, T.M., & Umesh, T.M. (2013). Marketing practices and post-harvest losses in banana (Var. Robusta) - A study in Shimoga district, Karnataka. *Indian Journal of Agricultural Marketing,* 27(3), 220-226.
19. Nayak, A.K., Nahar, S., & Dinesh, K. (2018). An economic study of post-harvest losses of banana in Durg district of Chhattisgarh. *International Research Journal of Agricultural Economics and Statistics,* 9(1), 82-89.
20. Darrangiri Banana Market, Asia's Largest, also Hit by COVID-19 Pandemic. (2020, April 23). Retrieved 31 August 2021 from, https://www.insidene.com/darrangiri-banana-market-asias-largest-also-hit-by-covid-19-pandemic/amp/
21. Greene, W. H. (2012). Econometric Analysis. Pearson.
22. Wooldridge, J. M. (2010). Econometric analysis of cross section and panel data. Cambridge, MA: MIT Press
23. Jadhav, R. J., Shaikh, N. B., Pawar, K. B., Mendhe, A. R., & Chaure, J. S. (2020). Assessment of post-harvest losses in banana under Jalgaon condition, in Maharashtra. I*nternational Journal of Chemical Studies,* 8(3), 889-892. https://doi.org/10.22271/

chemi.2020.v8.i3k.9315

24. Saikia, T, S., Bora, K. C., & Horindra, G. (2018). Economic analysis of postharvest loss of banana in Nagaon district of Assam. *International Research Journal of Agricultural Economics and Statistics*, 9(2), 341-345. DOI. 10.15740/has/irjaes/9.2/341-345
25. Saha, C. K., Ahamed, M. K., Hosen, M. S., Nandi, R., & Kabir, M. (2021). Post-harvest Losses of Banana in Fresh Produce Marketing Chain in Tangail District of Bangladesh. *Journal of the Bangladesh Agricultural University,* 19(3), 389-397. https://doi.org/10.5455/JBAU.74902
26. Nkwain, K. T., Odiaka, E. C., Ikwuba, A. A., & Nkwi, G. E. (2021). Analysis of post-harvest losses of banana and the economic wellbeing of farmers in Boyo Division, North West Region of Cameroon.*Dutse Journal of Pure and Applied Sciences*, 7(4b), 78-88. https://dx.doi.org/10.4314/dujopas.v7i4b.14
27. Anonymous. (2002). Group Workers Meeting of AICRP on PHT of horticultural crops.Trial Data of 2000-2001 presented in Workshop held at Konkan Krishi Vidyapeeth, Dapoli from 5th to 7th March 2002.
28. Sharma, B., Choudhury, M., Sarma, R., & Nath, R. K. (2020). Production constraints of banana cultivation in western district of Assam. *Journal of Pharmacognosy and Phytochemistry,* 9(4), 1829-1830.
29. Middendorf, B. J., Traoré, H., Middendorf, G., Jha, P. K., Yonli, D., Palé, S., & Prasad, P. V. (2022). Impacts of the COVID-19 pandemic on vegetable production systems and livelihoods: Smallholder farmer experiences in Burkina Faso. *Food and Energy Security,* 11(1), e337. DOI. 10.1002/fes3.337
30. Kyeyune, F. (2020). Status Report COVID-19. (September 2020), 0–24
31. NABARD. (2020). Impact Assessment of COVID-19 on Indian Agriculture & Rural Economy. Government of India, *Department of Economic Analysis & Research.* Retrieved 18 November 2022 from https://www.nabard.org/auth/writereaddata/tender/1211203145Impact%20Assessment%20of%20COVID.pdf
32. McKelvey, R. D., & Zavoina, W. A. (1975). Statistical model for the analysis of ordinal level dependent variables. *The Journal of Mathematical Sociology,* 4(1), 103–120.
33. Mebratie, M.A., Haji, J., Woldetsadik, K., Ayalew, A. and &Ambo, E., 2015. Determinants of postharvest banana loss in the marketing chain of central Ethiopia. *Food Science and Quality Management,* 37, pp.52-63.
34. Hailu, G., & Derbew, B. (2015). Extent, causes and reduction strategies of postharvest losses of fresh fruits and vegetables–A review. *Journal of Biology, Agriculture and Healthcare,* 5(5), 49-64.
35. Thogori, M., Gathungu, G. K., & Muigai, J. K. (2021). Socio-economic Factors affecting uptake of banana value addition among smallholders in Chuka Sub- County, Tharaka Nithi County, Kenya. *Asian Journal of Agricultural Extension, Economics & Sociology,* 39(1), 22-34. https://doi.org/10.9734/ajaees/2021/v39i130497
36. Tripathi, H. G., Smith, H. E., Sait, S. M., Sallu, S. M., Whitfield, S., Jankielsohn, A., &Nyhodo, B. (2021). Impacts of COVID-19 on diverse farm systems in Tanzania and South Africa. *Sustainability,* 13(17), 9863. https://doi.org/10.3390/su13179863
37. Luo, Y., Huang, D., Qu, X., & Wu, L. (2022). An Inverse Relationship between Farm Size and Rice Harvest Loss: Evidence from China. *Land,* 11(10), 1760. https://doi.org/10.3390/land11101760
38. Krishna, M. A., Charyulu, D., Suhasini, K., & Chary, D. S. (2022). Assessment of Post-harvest Losses of Major Vegetables in Rangareddy District of Telangana. *International Journal of Environment and Climate Change,* 12(11), 1610-1619. https://doi.org/10.9734/ijecc/2022/v12i1131144