Archives of Agriculture and Environmental Science 10(1): 75-80 (2025)
https://doi.org/10.26832/24566632.2025.1001011

e-ISSN: 2456-6632

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: journals.aesacademy.org/index.php/aaes

ORIGINAL RESEARCH ARTICLE

Effect of different concentrations of Ethephon on ripening and postharvest quality of banana (cv. Malbhog) in Chitwan district, Nepal

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ARTICLE HISTORY

Received: 22 December 2024
Revised received: 10 February 2025
Accepted: 19 February 2025

Keywords

Banana
Postharvest
Quality
Ripening
Ethephon

ABSTRACT

The present investigation on the effect of different concentrations of Ethephon on ripening and postharvest quality of banana (cv. Malbhog) in Chitwan district, Nepal, was conducted to find out the best concentration of Ethephon on ripening and quality parameters after harvest under ambient room temperature (28±5°C) and 64% RH. The experiment was laid out in Completely Randomized Design (CRD), which comprised five treatments: Control, Ethephon @200 ppm, Ethephon @400 ppm, Ethephon @600 ppm, and Ethephon @800 ppm replicated four times. Different postharvest parameters were recorded on alternate days for 9 days. The use of Ethephon @600 ppm and Ethephon @800 ppm was found more effective regarding banana ripening. On the 9th day after storage, firmness decreased significantly with ripening, with the lower firmness recorded in bananas treated with Ethephon @800 ppm (1.23 kg/cm²) and Ethephon @600 ppm (1.35 kg/cm²). Similarly, the highest pulp-to-peel ratio (3.71) was recorded with Ethephon @800 ppm. The maximum TSS (23.75 ˚Brix) was recorded in bananas treated with Ethephon @800 ppm, which was at par with the effect of other concentrations of Ethephon. TA also peaked in bananas treated with Ethephon @800 ppm (0.67%). Moreover, Ethephon significantly accelerated ripening, with bananas treated with Ethephon @800 ppm requiring only 5.50 days and Ethephon @600 ppm requiring 6.00 days. Thus, in this study, the respondent gave higher scores for bananas treated with Ethephon @600 ppm and @800 ppm, with better sweetness and flavour compared to the control.

Citation of this article: Mahato, B., & Shah, B. (2025). Effect of different concentrations of Ethephon on ripening and postharvest quality of banana (cv. Malbhog) in Chitwan district, Nepal. *Archives of Agriculture and Environmental Science*, *10*(1), 75-80, https://dx.doi.org/10.26832/24566632.2025.1001011

INTRODUCTION

Banana is a tropical crop grown in warm areas of tropical and subtropical regions. It is a monocotyledonous plant in the Musaceae (Zingiberales) family (Heslop-Harrison & Schwarzacher, 2007). Bananas are native to Southeast Asia and are cultivated in over 130 countries throughout the tropical and subtropical regions of the world (Mohandas & Ravishankar, 2016). Bananas are exported in larger volume and to a larger value than any other fruit (Gittleson, 2018). Bananas are the fourth most commonly grown fruit crop in Nepal, following citrus, mango, and apple. In Nepal, banana has a potential productive area of 27261 ha, produces 404,670 tons, and yields 16.66 mt/ha. It is a prioritized, high-value agricultural product that contributes 1.04% to Nepal's national AGDP (MOALD, 2022). Nepal only shares 0.24% of the production of bananas in the world (Ghimire *et al.*, 2023). The major banana-growing districts are Morang, Jhapa, Chitwan, and Saptari (Joshi *et al.*, 2020). Chitwan has been the leading district for the commercialization of banana farming for a few years. The district's production has increased at a whopping rate, i.e., 566% over the past decade (Ghimire *et al.*, 2016). The total area of banana production in Chitwan district is 2,205 ha, with a productive area of 2,139 ha with a production of 54,243 mt & yield of 25.36 mt/ha has been reported (MOALD, 2022). Bananas are highly perishable climacteric fruits that are typically harvested at their mature green stage and artificially ripened in a ripening room (Maduwanthi & Marapana, 2019). As the fruit is harvested at its green mature stage, artificial ripening is a very important aspect at commercial levels (Payasi *et al.*, 2009). Under natural ripening conditions, ripening fruits produce ethylene gas on their own. However, the fruits ripen slowly and unevenly (Desale & Pawar, 2021). Thus, unripe bananas must be exposed to an exogenous source of ethylene gas to ensure firm pulp texture, good flavour, and bright peel colour (Subbaiah *et al.*, 2013).

Banana ripening in Nepal focuses on the challenges that banana farmers face after harvest. Despite the potential for banana production, Nepal's current productivity is low due to inadequate postharvest management (Ghimire *et al.*, 2023). Postharvest losses of bananas can range from 20% to 80%. It happens in two stages: wholesale and retail. Retail losses were caused by weight loss and quality degradation during the banana display. Poor packaging, ripening methods, and transportation-related damage were the causes of wholesale losses (FAO, 2018). Every year, approximately 50,651,745 kg of bananas are imported to fill the production gap caused by low national production (Bhatta *et al.*, 2023). A significant amount of bananas is imported because a large number of indigenous bananas suffered post-harvest losses, and most of them are not appropriately valued due to their unattractive appearances, which made them less preferred by consumers. It is mainly due to poor traditional methods of ripening, such as smoke treatment, storage in banana leaves, gunny bags, straw, and so on (Mebratie *et al.*, 2016). Farmers frequently engage in traditional production practices that are expensive, inefficient, and unprofitable. Banana traders are having problems with chemical ripening methods. They are unaware of the safe and appropriate doses of Ethephon (Timilsina & Shrestha, 2022). It is critical to conduct research on chemical ripening methods in order to address these issues and gain scientific insights into the effectiveness of these methods in maintaining fruit quality. As a result, the purpose of this study is to investigate chemical ripening techniques in terms of quality parameters such as physiological loss in weight, pulp-to-peel ratio, firmness, TSS, TA, pH, and ripening days. The purpose of this study is to improve banana ripening techniques that address both safety and fruit quality during the ripening process.

MATERIALS AND METHODS

Location of research site

The experiment was carried out in the Horticulture laboratory of the Faculty of Agriculture, Agriculture and Forestry University, Rampur, Chitwan, Nepal. Geographically, Rampur is located in the Terai belt at 27° 40' N latitude and 84° 19' E longitude at an altitude of 228 masl. This place has a humid subtropical climate where summers are hot and winters are cold, with total annual rainfall reported as 1582.6 mm.

Design of the experiment

The Malbhog cultivar was selected for the research, which is one of the most popular and commonly cultivated cultivars in Chitwan District, Nepal. The experiment was laid out in Completely Randomized Design (CRD) with five treatments, and each treatment was replicated four times. There were the 4 different concentrations of Ethephon, i.e., 200 ppm, 400 ppm, 600 ppm, 800 ppm, and one control. Kripon (Ethephon 39% SL) was chosen to meet the required Ethephon concentration. To obtain 200 ppm, 400 ppm, 600 ppm, and 800 ppm, 0.51 ml, 1.02 ml, 1.54 ml, and 2.05 ml of Kripon (Ethephon) 39% SL per liter of distilled water was used.

The different concentrations of Ethephon were made using the following formula:

$$C1V1 = C2V2$$

Details of the operation

Research was carried out from the second week of April to the fourth week of April, 2024, and each treatment was labelled. On the interval of one day, data was recorded for 9 days. Fifteen fingers were dehanded and classified as five non-destructive and ten destructive in each replication. Five non-destructive samples were used for the observation, such as PLW% and ripening days. Ten destructive samples were used for the observation, such as pulp-to-peel ratio, firmness, pH, TSS, and TA.

Physiological loss in weight (PLW%): It was calculated in % by the following formula (Paudel & Regmi, 2024):

$$PLW\% = \frac{\text{Initial weight} - \text{Next measurement weight} * 100}{\text{Initial weight}}$$

Pulp firmness: A penetrometer was used to assess the firmness of the banana. The instrument was pressed on the top, middle, and bottom of the fruit, and the average of the three readings were taken to determine the fruit's firmness. The results were expressed in kg/cm².

Pulp-to-peel ratio: It was measured by dividing pulp weight to peel weight.

$$\text{Pulp} - \text{to} - \text{peel ratio} = \frac{\text{Pulp weight}}{\text{Peel weight}}$$

Total Soluble Solids (TSS): A hand-held refractometer was used to determine the value in °Brix. One to two drops of homogenized juice were placed on the prism of the refractometer to obtain a reading. Before recording the observation, calibration was performed.

Titratable acidity (TA%): To measure the titratable acidity of banana juice, 0.1N NaOH, phenolphthalein, a pipette, a beaker, a burette, and a burette stand were used. Two grams of NaOH were dissolved in 0.5 liters of distilled water to prepare the solution of 0.1 N NaOH.

It was calculated by using a formula (Paudel & Regmi, 2024):

$$\text{Titratable acidity (\%)} = \frac{\text{ml of NaOH used} * 0.1\text{N NaOH} * \text{equivalent wt} * \text{dilution factor} * 100}{\text{ml of juice taken} \times 1000}$$

Table 1. Scale assigned for different parameters.

Scale	Sweetness	Flavour	Astringency	Overall Acceptability
1	Excellent	Excellent	Very much astringent	Excellent
0.8	Good	Good	Astringent	Fair
0.6	Fair	Fair	Medium	Good
0.4	Poor	Poor	Less	Poorly acceptable
0.2	Very poor	Very poor	No astringent	Unacceptable

pH of banana: Digital pH meter was used to measure pH of banana juice.

Ripening days: It was measured by observing how long bananas took to mature from green to fully ripe and ready for consumption.

Organoleptic test: The organoleptic test in bananas was evaluated by groups of four people for the flavour, astringency, sweetness, and overall acceptability of bananas on the 9th day after storage. Rating and scoring were performed using a five-point rating scale technique (Ghimire *et al.*, 2021). Four people were given different treatments and replications of bananas and asked to evaluate their sensory quality attributes (Table 1).

Data analysis techniques

Duncan's multiple range test (DMRT) was used to compare treatment means and to identify significant differences between means.

RESULTS AND DISCUSSION

Effect of Ethephon on physiological loss in weight (PLW%) and pulp-to-peel ratio

The physiological loss in weight (PLW%) and pulp-to-peel ratio increased across all treatments as the storage period lengthened, as shown in Table 2. On Day 3, no significant differences in PLW% were found between treatments. However, from Day 5, higher concentrations of Ethephon resulted in higher PLW% values, with significant differences emerging. On the ninth DAS (days after storage), bananas treated with Ethephon @800 ppm (8.37%) and Ethephon @600 ppm (8.19%) had the highest PLW%, followed by Ethephon @400 ppm (7.71%) and Ethephon @200 ppm (7.01%). The lowest PLW% was observed in untreated bananas (6.60%). The statistical analysis supports the conclusion that greater concentrations accelerate weight loss over time. These results are in harmony with the results of Timilsina *et al.* (2021), who reported an increase in the physiological loss in weight of bananas with an increase in the concentration of Ethephon. Similarly, Ethephon treatment increased the weight of the fruit pulp while decreasing the weight of the peel during ripening. The pulp-to-peel ratio showed a significant difference from the third day after storage. The highest pulp-to-peel ratio (3.71) was observed in bananas treated with Ethephon @800 ppm, and the lowest (2.29) was with control on the 9th day after storage. This result aligns with the findings of (Jangman *et al.*, 2023), who reported the pulp-to-peel ratio of banana fruits during ripening increased with the increase in the Ethephon concentration.

Effect of Ethephon on firmness and pH

The data related to the firmness and pH of bananas treated with different concentrations of Ethephon are presented in Table 3. Fingers become less firm as the ripening process advances in all treatments. The highest firmness (3.68 kg/cm²) was observed on untreated (control) bananas, while the lowest firmness (1.23 kg/cm²) was obtained with Ethephon @800 ppm on the 9th day of storage, which was at par with the effect of Ethephon @600 ppm and Ethephon @400 ppm. This report is consistent with the findings of Timilsina & Shrestha (2022), who reported that Ethephon application resulted in decreased firmness during ripening. Likewise, the current experiment revealed a decrease in pH during the storage period. On the 7th day after storage, the lowest pH was found in bananas treated with Ethephon @800 ppm (4.16), which was at par with the effect of other concentrations of Ethephon.

Table 2. Physiological loss in weight (PLW%) and pulp-to-peel ratio of banana fruit under treatment with different concentrations of Ethephon.

Treatments	Physiological loss in weight (PLW%)				Pulp-to-peel ratio			
	Day 3	Day 5	Day 7	Day 9	Day 3	Day 5	Day 7	Day 9
Control	4.18^{a}	4.19^{b}	5.26^{c}	6.60^{c}	2.29^{a}	2.25^{a}	2.29^{b}	2.29^{c}
200 ppm	4.44^{a}	4.57^{b}	6.15^{b}	7.01^{c}	2.38^{a}	1.92^{b}	1.99^{b}	3.26^{ab}
400 ppm	4.45^{a}	4.66^{b}	6.49^{ab}	7.71^{b}	2.33^{a}	1.65^{c}	2.31^{b}	2.92^{b}
600 ppm	4.49^{a}	5.37^{a}	7.09^{a}	8.19^{a}	2.33^{a}	1.87^{bc}	2.35^{ab}	2.89^{bc}
800 ppm	4.89^{a}	5.42^{a}	7.33^{a}	8.37^{a}	2.37^{a}	2.36^{a}	2.74^{a}	3.71^{a}
LSD(0.05)	0.85	0.68	0.88	0.45	0.19	0.27	0.41	0.62
SEm(±)	0.32	0.10	0.13	0.07	0.03	0.04	0.06	0.09
F-probability	NS	<0.01	<0.01	<0.001	NS	<0.001	<0.05	<0.01
CV%	12.51	2.13	9.04	3.94	5.26	8.82	11.68	13.56
Grand mean	4.49	4.84	6.46	7.58	2.34	2.01	2.34	3.01

Here CV = Coefficient of Variation, SEm(±) = Standard error of the mean, LSD = Least Significant Difference, NS= Non-Significant

In contrast, the highest pH was recorded in the untreated bananas (5.28). Similarly, on the 9th day after storage, the result was non-significant. This result is in accordance with Ghimire *et al.* (2021) in bananas, where the lowest pH was observed in Ethephon-treated fruits and the highest pH was observed in control bananas.

Effect of Ethephon on Total Soluble Solids (TSS) and Titratable acidity (TA%)

The statistical analysis of data revealed that all of the treatments under investigation resulted in a significant variation in the banana's TSS and TA% as depicted in Table 4. The Ethephon significantly affects TSS, with maximum ˚Brix values of 23.75 under bananas treated with Ethephon @800 ppm on the 9th day after storage, which was at par with the effects of other concentrations of Ethephon. In contrast, control bananas had the lowest TSS, i.e., 16.88 ˚Brix on the 9th day after storage. This result aligns with the findings of Timilsina *et al.* (2021), who reported all artificially ripened fruits had a higher level of TSS than the control fruits. Correspondingly, on the 9th day after storage, bananas treated with Ethephon @800 ppm had the highest titratable acidity (0.67%), followed by Ethephon @600 ppm (0.6%). There was no significant difference in the titratable acidity of banana fruits treated with Ethephon @200 ppm (0.44%) and Ethephon @400 ppm (0.44%). Untreated fruits exhibited the lowest titratable acidity (0.40%). The titratable acidity (TA) of bananas rises during specific stages of ripening. However, for Malbhog, peak acidity is typically reached at stage 4, after which it begins to decline as the fruit matures. This result is in harmony with the findings of Mathias *et al.* (2021).

Effect of Ethephon on organoleptic test

The parameters used for the organoleptic test on the 9th day after storage (DAS), such as sweetness, flavour, astringency, and overall acceptability, were influenced by various Ethephon treatment combinations measured using a hedonic scale, as illustrated in Table 5. The treatments differed significantly in terms of sweetness. The respondent scored the bananas treated with Ethephon @600 ppm and Ethephon @800 ppm higher than the control bananas. Ethephon-treated bananas were found to be more acceptable in terms of sweetness and flavour than untreated bananas. The index values for overall acceptability (0.85), sweetness (0.9), and flavour (0.75) were the highest in bananas treated with Ethephon @800 ppm. However, this finding contradicts the findings of Timilsina & Shrestha (2022), who found that panellists gave higher scores to bananas that had been ripened naturally without the use of any ripening agents than to those that had been treated with Ethephon.

Table 3. Firmness and pH of banana fruit under treatment with different concentrations of Ethephon.

Treatments	Firmness (kg/cm^2)				pH			
	Day 3	Day 5	Day 7	Day 9	Day 3	Day 5	Day 7	Day 9
Control	8.25^a	8.64^a	6.65^a	3.68^a	6.04^a	6.01^a	5.28^a	4.42^a
200 ppm	8.17^{ab}	5.83^b	4.48^b	2.55^b	5.44^{bc}	4.97^{bc}	4.22^b	4.37^a
400 ppm	8.00^{ab}	5.53^b	3.68^{bc}	1.65^c	5.47^b	5.16^b	4.24^b	4.15^a
600 ppm	7.60^b	4.08^c	3.25^c	1.35^c	5.48^b	4.83^c	4.20^b	4.14^a
800 ppm	6.60^c	3.50^c	2.90^c	1.23^c	5.38^c	4.90^c	4.16^b	4.10^a
LSD(0.05)	0.63	0.90	1.17	0.59	0.09	0.19	0.40	0.31
SEm(±)	0.09	0.13	0.17	0.09	0.01	0.03	0.06	0.05
F-probability	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	NS
CV%	5.43	10.84	18.61	18.59	1.12	2.51	6.03	4.81
Grand mean	7.73	5.51	4.19	2.09	5.56	5.19	4.42	4.24

Here CV = Coefficient of Variation, SEm(±) = Standard error of the mean, LSD = Least Significant Difference, NS= Non-Significant.

Table 4. Total soluble solids (TSS) and titratable acidity (TA%) of banana fruit under treatment with different concentrations of Ethephon.

Treatments	Total Soluble Solids (TSS)				Titratable acidity (TA%)			
	Day 3	Day 5	Day 7	Day 9	Day 3	Day 5	Day 7	Day 9
Control	4.38^b	4.38^c	6.88^b	16.88^b	0.34^a	0.47^{bc}	0.60^c	0.40^b
200 ppm	5.63^a	12.81^b	19.06^a	22.50^a	0.34^a	0.44^c	0.67^{bc}	0.44^b
400 ppm	6.25^a	13.75^{ab}	20.00^a	22.81^a	0.37^a	0.54^b	0.67^{bc}	0.44^b
600 ppm	5.94^a	15.00^{ab}	20.94^a	23.12^a	0.40^a	0.64^a	0.77^b	0.60^a
800 ppm	6.25^a	17.19^a	21.56^a	23.75^a	0.40^a	0.70^a	0.97^a	0.67^a
LSD(0.05)	0.81	3.78	4.75	1.26	0.09	0.09	0.13	0.08
SEm(±)	0.12	0.56	0.70	0.19	0.61	0.06	0.09	0.06
F-probability	<0.001	<0.001	<0.001	<0.001	NS	<0.001	<0.001	<0.001
CV%	9.41	19.88	17.81	3.84	15.57	11.22	11.97	10.74
Grand mean	5.69	12.63	17.69	21.81	0.37	0.56	0.74	0.51

Here CV = Coefficient of Variation, SEm(±) = Standard error of the mean, LSD = Least Significant Difference, NS= Non-Significant.

Table 5. Acceptability of banana fruit for different organoleptic parameters as influenced by different treatments.

Organoleptic test on 9th DAS						
Parameters	**Ratings**	**T1**	**T2**	**T3**	**T4**	**T5**
Sweetness	Index value	0.4^{b}	0.4^{b}	0.6^{ab}	0.8^{ab}	0.9^{a}
	Rank	IV	IV	III	II	I
Flavor	Index value	0.45^{a}	0.70^{a}	0.40^{a}	0.70^{a}	0.75^{a}
	Rank	III	II	IV	II	I
Astrigency	Index value	0.75^{a}	0.60^{a}	0.60^{a}	0.55^{a}	0.50^{a}
	Rank	I	II	II	III	IV
Overall acceptability	Index value	0.45^{a}	0.50^{a}	0.50^{a}	0.70^{a}	0.85^{a}
	Rank	IV	III	III	II	I

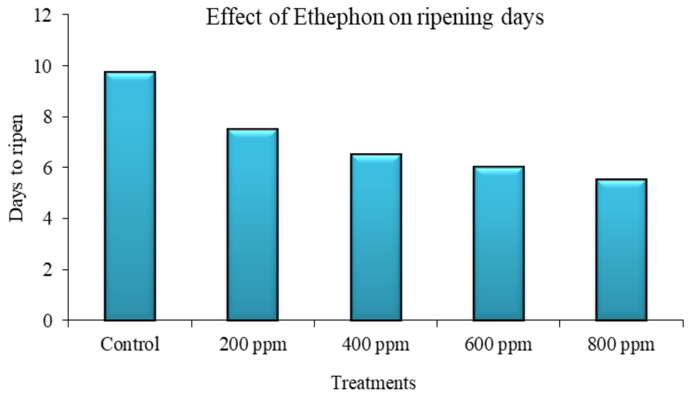

Figure 1. *Effect of different concentrations of Ethephon on ripening days.*

Effect of Ethephon on ripening days

The data concerning the influence of different concentrations of Ethephon on ripening days of bananas is presented in Figure 1. Higher concentrations of Ethephon, i.e., 800 ppm, accelerated the ripening process significantly more than other low concentrations of Ethephon. Bananas treated with Ethephon @800 ppm took 5.50 days to ripen, which was at par with the effect of Ethephon @600 ppm (6.00 days), Ethephon @400 ppm (6.50 days), followed by Ethephon @200 ppm (7.50 days). However, the untreated bananas took the longest days to ripen, i.e., 9.75 days. The results are in harmony with the findings of Ruwali *et al.* (2022), who reported that Ethephon-treated bananas ripened earlier than the control bananas.

Conclusion

This study demonstrates the effectiveness of Ethephon in accelerating the ripening process and improving the quality of banana fruits under ambient storage conditions. Higher concentrations of Ethephon resulted in increased physiological loss in weight (PLW%) and pulp-to-peel ratio, while also causing a significant reduction in firmness and pH. Bananas treated with Ethephon @800 ppm exhibited the highest TSS and titratable acidity, indicating faster ripening. Organoleptic evaluation showed that Ethephon-treated bananas were rated better in terms of sweetness and flavour compared to untreated fruit. Additionally, Ethephon significantly reduced the days required for ripening, with the highest concentration (800 ppm), achieving full ripeness much faster than the control bananas. These results suggest that Ethephon can be used as an effective ripening agent to enhance fruit quality, reduce ripening time, and meet consumer demands for fast turnover markets. However, further research is warranted to optimize Ethephon concentration to balance ripening acceleration with fruit quality. This study provides valuable insights for postharvest management and commercial ripening of bananas, emphasizing the need for controlled application to achieve desirable ripening characteristics while minimizing potential quality deterioration.

ACKNOWLEDGEMENT

We would like to express our deepest gratitude to our advisory committee, family, friends and all the concerned people for their unwavering support, guidance and untiring cooperation throughout the research work.

DECLARATIONS

Author contribution statement

Conceptualization: B.M. and B.S.; Methodology: B.M.; Software and validation: B.M. and B.S.; Formal analysis and investigation: B.M.; Resources: B.M.; Data curation: B.M.; Writing—original draft preparation: B.M.; Writing—review and editing: B.M. and B.S.; Visualization: B.M.; Supervision: B.M.; Project administration: B.M.; Funding acquisition: B.M. All authors have read and agreed to the published version of the manuscript.

Conflicts of interest: The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Ethics approval: This study did not involve any animal or human participant and thus ethical approval was not applicable.

Consent for publication: All co-authors gave their consent to publish this paper in AAES.

Data availability: The data that support the findings of this study are available on request from the corresponding author.

Supplementary data: No supplementary data is available for the paper.

Funding statement: There was no specific funding for this research from the public, commercial, or non-profit sectors. We are aware of no conflicts of interest related to this publication, and there has been no significant financial assistance for this work that could have influenced the results.

Additional information: No additional information is available for this paper.

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