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Impact of post-shooting sprays and protective covers on fruit quality attributes banana (*Musa paradisiaca* L.) cv. grand naine

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Abstract
This research delves into the influence of post-shooting spray and bunch covering material on the fruit quality characteristics of Banana (*Musa paradisiaca* L.) cv. Grand Naine. Over a comprehensive investigation spanning two years, various post-shooting sprays and bunch covering materials were scrutinized for their effects on key fruit quality parameters. The findings reveal crucial insights into optimizing fruit quality, with notable outcomes such as the efficacy of CPPU at 4 mg/l in reducing physiological loss in weight and non-woven material bag covering positively influencing the pulp: peel ratio. The application of SOP at 2% in post-shooting sprays demonstrated significant enhancements in total soluble solids and total sugar content, emphasizing the pivotal role of potassium in these processes. Moreover, the study shed light on the positive impact of SOP at 2% in increasing reducing sugar levels. Notably, acidity levels remained unaffected by the experimental treatments. The absence of significant interaction effects underscores the distinct and predominant influence of individual factors. This research contributes valuable insights for improving banana fruit quality and informs practical strategies for enhanced crop management practices in banana cultivation.

Keywords: Fruit quality, post-shooting spray, bunch covering material, grand naine cultivar

Introduction

Banana (*Musa paradisiaca* L.) stands as a cornerstone in global agriculture, providing essential nutrients and contributing significantly to food security (FAO, 2019) [4]. The cultivar Grand Naine, celebrated for its high yield and superior fruit quality, holds a prominent position in the international banana market (FAO, 2020) [5]. However, challenges in cultivation persist, prompting a growing interest in optimizing practices to enhance yield and fruit quality. Post-shooting sprays and covering materials have emerged as promising interventions in banana cultivation, capable of modifying the microenvironment around developing bunches and influencing fruit quality parameters (Robinson, 2018) [21]. These interventions have been recognized for their potential to mitigate environmental stressors, reduce pest infestations, and enhance overall crop health (Gomez *et al*., 2022) [8]. Despite the importance of these factors, knowledge gaps exist, particularly in understanding their specific effects on the Grand Naine cultivar.

This research aims to fill this void by systematically investigating the impact of post-shooting sprays and covering materials on the bunch for fruit quality characteristics of Grand Naine bananas. The study endeavors to unravel the intricate interactions between these interventions and the physiological processes governing fruit development. Such insights are critical for informed decision-making and sustainable agricultural practices (Smith *et al*., 2021) [25]. Through a comprehensive analysis, this research will contribute to the body of knowledge surrounding banana cultivation practices, offering practical recommendations for growers and researchers alike.

Materials and Methods

The experiment was conducted at the Horticultural Research Farm, Department of Horticulture, B. A. College of Agriculture, Anand Agricultural University, Anand, over the growing seasons of 2017-18 and 2018-19. The study utilized a Completely Randomized Design (Factorial) with three replications. Prior to planting, the experimental plot underwent thorough preparation, including deep ploughing, harrowing, and leveling.

Pits of dimensions 30 x 30 x 30 cm were excavated at a spacing of 1.8 x 1.8 m², and each pit received well-decomposed, fine-textured Farm Yard Manure (FYM) at a rate of 10 kg.

Planting involved the use of well-hardened, healthy, and uniformly sized tissue-cultured plants of the Grand Naine banana variety, each possessing 5-6 leaves. The experiment consisted of six levels of post-shooting sprays, namely: control, humic acid 2%, 2,4-D 30 mg/l, gibberellic acid (GA3) 100 mg/l, CPPU 4 mg/l, and sulphate of potash (SOP) 2%, combined with two levels of bunch covering materials- non-woven material bag covering and blue-colored polyethylene sleeve (6% perforated) bag covering.

Post-shooting sprays were administered twice, with the first spray occurring after complete opening of the inflorescence and the second spray after 30 days of the first spray. Subsequently, the bunches were immediately covered after the second spray. Daily observations were made for various quality characters, including Pulp: Peel ratio, Total Soluble Solids (TSS, measured in ⁰Brix), Acidity (%), Reducing Sugars (%), Total Sugars (%), and Physiological Loss in Weight (%).

To calculate the Pulp: Peel ratio, the respective weights of pulp and peel were measured using fruits designated for weight loss observations during ripening. TSS values were determined using a hand refractometer with a range of 0-32 ⁰Brix. Acidity (%) was calculated based on the method outlined for the estimation of titrable acidity. The recorded data underwent statistical analysis following the procedures outlined by Gomez and Gomez (1984) [7].

Results and Discussion

Physiological Loss in Weight (%)

Effect of Post-Shooting Spray:

The results indicate a significant influence of various post-shooting sprays on the physiological loss in weight of bananas during the years 2017-18, 2018-19, and on a pooled basis. Specifically, the post-shooting spray with CPPU at 4 mg/l (S5) recorded a significantly lower physiological loss in weight, i.e., 13.28%, which was comparable to the control (S1) at 16.92% in the year 2018-19. In 2017-18 and in the pooled analysis, CPPU at 4 mg/l (S5) also showed significantly minimum physiological loss, i.e., 12.47% and 12.87%, respectively, comparable to SOP at 2% (S6) at 12.80% and 13.30%, and GA3 at 100 mg/l (S4) at 12.88% and 13.35%, respectively, as compared to the control. Conversely, the control (S1) exhibited significantly higher physiological loss in weight at 17.19%, 17.63%, and 17.41% during the years 2017-18, 2018-19, and in the pooled analysis, respectively.

This phenomenon could be attributed to the role of CPPU in enhancing physiological activities, suppressing fruit softening, and delaying peaks of respiration, in association with inhibiting the peaks of ethylene production rate in bananas (Huang *et al*., 2014; Rajan, 2017) [9, 19].

Effect of Bunch Covering Material

Observations on bunch covering materials revealed a significant impact on physiological loss in weight. Non-woven material bag covering (B1) recorded significantly lower physiological loss in weight, i.e., 13.05%, 13.88%, and 13.46%, compared to blue-colored polyethylene sleeve (B2) at 15.03%, 15.54%, and 15.29% during 2017-18, 2018-19, and in the pooled analysis, respectively.

This observation could be attributed to the decrease in fruit weight during the storage period, influenced by physiological processes such as higher rates of respiration and transpiration from the fruit surface, degradation of reserve carbohydrates with the release of water, and transpiration through the fruit skin. Additionally, a decrease in peel thickness during the ripening period could contribute to accelerated weight loss in the fruit (Patil and Shanmugasundaram, 2015; Santosh *et al*., 2017) [17, 22]. The decline in fruit weight was more rapid in the control compared to non-woven bags, consistent with findings by Pathak *et al*. (2017) [16] in bananas.

Table 1: Effect of post shooting sprays and bunch covering materials on physiological loss in weight and pulp: peel ratio

Treatments	Physiological loss in weight (%)			Pulp: peel ratio		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
Post shooting spray (S)						
S_1: Control	16.87	16.92	16.89	2.58	2.56	2.57
S_2:Humic acid @ 2%	13.95	14.48	14.22	2.83	2.76	2.79
S_3: 2,4-D @ 30 mg/l	13.85	14.23	14.04	2.86	2.72	2.79
S_4: GA3 @ 100 mg/l	12.88	13.81	13.35	3.03	2.97	3.00
S_5: CPPU @ 4 mg/l	12.47	13.28	12.87	3.09	2.99	3.04
S_6: SOP @ 2%	12.80	13.80	13.30	3.05	2.95	3.00
S.Em ±	0.34	0.42	0.27	0.09	0.08	0.06
CD at 5%	0.98	1.22	0.76	0.25	0.22	0.16
Bunch Covering Material (B)						
B_1: Non- woven material bag covering	12.84	13.61	13.23	3.09	2.99	3.04
B_2: Blue colour polyethylene sleeve	14.76	15.23	15.00	2.72	2.66	2.69
S.Em ±	0.19	0.24	0.15	0.05	0.04	0.03
CD at 5%	0.57	0.70	0.76	0.15	0.13	0.16
Interaction effect (S X B)						
S.Em ±	0.47	0.59	0.39	0.12	0.11	0.12
CD at 5%	NS	NS	NS	NS	NS	NS
Pooled Interaction						
Source	Y x S	Y x B	YxSxB	Y x S	Y x B	YxSxB
S.Em ±	0.38	0.22	0.54	0.08	0.05	0.12
CD at 5%	NS	NS	NS	NS	NS	NS
CV %	5.95	7.11	6.58	7.35	6.58	6.99

Pulp: Peel Ratio

Effect of post-shooting spray: The data regarding various post-shooting sprays exhibited a significant effect on the pulp: peel ratio. The post-shooting spray with CPPU at 4mg/l (S5) recorded the significantly highest pulp: peel ratio, i.e., 3.09 and 2.99, comparable to SOP at 2% (S6) with 3.05 and 2.95, GA3 at 100mg/l (S4) with 3.09 and 3.00, and 2,4-D at 30mg/l (S3) with 2.86 and 2.72 during the experimental period of both years 2017-18 and 2018-19, respectively. In the pooled analysis, CPPU at 4mg/l (S5) recorded the significantly highest pulp: peel ratio at 3.04, comparable to SOP at 2% (S6) with 3.00, and GA3 at 100mg/l (S4) with 3.00, as compared to other treatments. Conversely, the control (S1) exhibited the significantly lowest pulp: peel ratio at 2.58, 2.56, and 2.57 in the years 2017-18, 2018-19, and in the pooled analysis, respectively. This observation is likely attributed to the role of CPPU in enhancing physiological activities, suppressing fruit softening, and delaying peaks of respiration, in association with inhibiting the peaks of ethylene production rate in bananas (Huang *et al*., 2014; Rajan, 2017) [9, 19]. Similar results were obtained by Curry and Greene (1993) in apples and Marzouk and Kassem (2011) in grapes.

Effect of bunch covering material

Observations on bunch covering materials indicated a significant effect on the pulp: peel ratio. Non-woven material bag covering (B1) exhibited significantly better pulp: peel ratio, i.e., 3.09, 2.99, and 3.04 compared to blue-colored polyethylene sleeve (B2) at 2.72, 2.66, and 2.69 during 2017-18, 2018-19, and in the pooled analysis, respectively.

The increase in pulp: peel ratio of banana fruit during ripening is attributed to the gradual reduction in moisture content of the peel and an increase in the pulp with ripening. The pulp portion continues to grow even in later stages of maturation, and bunch protection materials contribute to enhancing fruit quality (Burdon *et al*., 1994; Nakasone and Paul, 1998) [2, 15] in bananas. Similar results were noted by Amarante *et al*. (2002) [1], Sarkar (2014) [263], and Santosh *et al*. (2017) [22].

Total Soluble Solids (ºBrix)

Effect of Post-Shooting Spray

The results indicate a significant influence of various post-shooting sprays on the total soluble solids of banana fruit. The post-shooting spray with SOP at 2% (S6) recorded significantly higher total soluble solids, i.e., 22.78, 22.32, and 22.55 ºBrix, which was comparable to CPPU at 4mg/l (S5) with 22.33, 21.60, and 21.97 ºBrix, and GA3 at 100 mg/l (S4) with 22.47, 21.62, and 22.04 ºBrix, as compared to the rest of the treatments. In contrast, the lowest total soluble solids were observed under the control (S4) with 19.66, 19.22, and 19.44 ºBrix in the years 2017-18, 2018-19, and in the pooled analysis, respectively.

The maximum total soluble solids were noted in the bunch spray with SOP at 2% treatment. This observation could be attributed to the post-shooting application of potassium, favoring the conservation of starch into simple sugars during ripening by activating sucrose synthesis enzymes, resulting in higher total soluble solid content in fruits. Similar results were also noted by Venkatarayappa *et al*. (1979) [27], Kumar *et al*. (2008) [12], Kumar and Kumar (2010) [11], Gamit *et al*. (2017) [6], and Kachhadia *et al*. (2017) [10] in bananas.

Effect of bunch covering material: Observations on bunch covering materials revealed a significant effect on total soluble solids. Non-woven material bag covering (B1) exhibited significantly higher total soluble solids, i.e., 22.67, 21.78, and 22.23 ºBrix compared to blue-colored polyethylene sleeve (B2) at 20.52, 20.17, and 22.23 ºBrix during 2017-18, 2018-19, and in the pooled analysis, respectively.

This observation might be attributed to the fact that during the climacteric stage, the accumulated polysaccharide is rapidly degraded, and most of it is converted into soluble sugars, forming a large proportion of total soluble solids in bananas (Seymour *et al*., 1993) [24]. The present result of non-woven bag coincides with the findings of Sarkar (2014) [23] and Santosh *et al*. (2017) [22] in bananas.

Table 2: Effect of post shooting sprays and bunch covering materials on total soluble solids and acidity

Treatments	Total soluble solids (ºBrix)			Acidity (%)		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
Post shooting spray (S)						
S_1: Control	19.66	19.22	19.44	0.308	0.319	0.314
S_2:Humic acid @ 2%	20.94	20.47	20.71	0.306	0.315	0.311
S_3: 2,4-D @ 30 mg/l	21.40	20.63	21.02	0.302	0.311	0.307
S_4: GA3 @ 100 mg/l	22.47	21.62	22.04	0.300	0.308	0.304
S_5: CPPU @ 4 mg/l	22.33	21.60	21.97	0.302	0.311	0.306
S_6: SOP @ 2%	22.78	22.32	22.55	0.306	0.316	0.311
S.Em ±	0.44	0.39	0.30	0.006	0.014	0.008
CD at 5%	1.30	1.15	0.85	NS	NS	NS
Bunch Covering Material (B)						
B_1: Non- woven material bag covering	22.67	21.78	22.23	0.302	0.311	0.306
B_2: Blue colour polyethylene sleeve	20.52	20.17	20.34	0.306	0.316	0.311
S.Em ±	0.26	0.23	0.17	0.003	0.008	0.004
CD at 5%	0.75	0.66	0.85	NS	NS	NS
Interaction effect (S X B)						
S.Em ±	0.63	0.56	0.59	0.008	0.020	0.004
CD at 5%	NS	NS	NS	NS	NS	NS
Pooled Interaction						
Source	Y x S	Y x B	YxSxB	Y x S	Y x B	YxSxB
S.Em ±	0.42	0.24	0.59	0.011	0.006	0.015
CD at 5%	NS	NS	NS	NS	NS	NS
CV %	5.04	4.61	4.84	4.73	10.87	8.47

Acidity (%)

Effect of Post-Shooting Spray

All the treatments of post-shooting sprays, bunch covering material, and their interactions were found to be non-significant concerning acidity during the years 2017-18, 2018-19, and in the pooled analysis.

Reducing Sugar (%)

Effect of Post-Shooting Spray

The results indicate that various post-shooting sprays had a significant effect on the reducing sugar content of banana fruits. The significantly maximum reducing sugar was recorded with SOP at 2% (S6), i.e., 13.31%, 12.96%, and 13.13%, which was on par with CPPU at 4mg/l (S5), i.e., 13.20%, 12.70%, and 12.95%, and S4 (GA3 at 100 mg/l), i.e., 12.91%, 12.48%, and 12.70%, as compared to the rest of the treatments. Conversely, the minimum non-reducing sugar was recorded in S1 (control), i.e., 11.37%, 11.02%, and 11.19% in the years 2017-18, 2018-19, and in the pooled analysis, respectively.

This phenomenon might be attributed to potassium's vital role in carbohydrate synthesis, breakdown, translocation, protein synthesis, and neutralization of physiologically important organic acids (Tisdale and Nelson, 1966) [26]. Potassium is also involved in phloem loading and unloading of sucrose and amino acids, as well as starch storage in developing fruits, by activating enzymes such as starch synthase (Mengel and Kirkby, 1987) [14]. In plants well-supplied with potassium, the osmotic potential of the phloem sap and the volume flow rate are higher, resulting in increased sucrose concentration in the phloem sap. Similar results were reported by Venkatarayappa *et al*. (1979) [27], Kumar *et al*. (2008) [12], Kumar and Kumar (2010) [11], Kachhadia *et al*. (2017) [10], and Pebbudi *et al*. (2017) [18] in bananas.

Effect of bunch covering material

The results reveal that the reducing sugar content of banana fruits was significantly influenced by different bunch covering materials. Higher reducing sugar was recorded with non-woven material bag covering (B1), i.e., 13.06%, 12.64%, and 12.85%, compared to blue-colored polyethylene sleeve (B2), i.e., 11.87%, 11.55%, and 11.71% during the years 2017-18, 2018-19, and in the pooled analysis, respectively.

This observation might be due to a significantly positive association with temperature. Covered bunches had more reducing sugar, possibly because the higher temperature inside the covered bunch is favorable for the conversion of starch into sugar. A similar result was reported by Sarkar (2014) [23] in bananas.

Table 3: Effect of post shooting sprays and bunch covering materials on reducing sugar and total sugar (%)

Treatments	Reducing sugar (%)			Total sugar (%)		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
Post shooting spray (S)						
S_1: Control	11.37	11.02	11.19	19.40	18.58	18.99
S_2:Humic acid @ 2%	12.01	11.72	11.87	20.50	19.77	20.13
S_3: 2,4-D @ 30 mg/l	11.98	11.68	11.83	20.45	19.69	20.07
S_4: GA3 @ 100 mg/l	12.91	12.48	12.70	22.03	21.07	21.55
S_5: CPPU @ 4 mg/l	13.20	12.70	12.95	22.53	21.42	21.98
S_6: SOP @ 2%	13.31	12.96	13.13	22.72	21.85	22.28
S.Em ±	0.29	0.26	0.19	0.52	0.48	0.35
CD at 5%	0.85	0.75	0.55	1.53	1.40	1.01
Bunch Covering Material (B)						
B_1: Non- woven material bag covering	13.06	12.64	12.85	22.28	21.32	21.80
B_2: Blue colour polyethylene sleeve	11.87	11.55	11.71	20.26	19.47	19.87
S.Em ±	0.17	0.15	0.11	0.30	0.28	0.20
CD at 5%	0.49	0.43	0.55	0.88	0.81	1.01
Interaction effect (S X B)						
S.Em ±	0.41	0.36	0.38	0.74	0.68	0.65
CD at 5%	NS	NS	NS	NS	NS	NS
Pooled Interaction						
Source	Y x S	Y x B	YxSxB	Y x S	Y x B	YxSxB
S.Em ±	0.27	0.16	0.39	0.50	0.29	0.71
CD at 5%	NS	NS	NS	NS	NS	NS
CV %	5.71	5.21	5.47	6.03	5.74	5.90

Total Sugar (%)

Effect of Post-Shooting Spray

The results indicate a significant impact of various post-shooting sprays on the total sugar content of banana fruit. The post-shooting spray with SOP at 2% (S6) recorded higher total sugar, i.e., 22.72%, 21.85%, and 22.28%, which was on par with CPPU at 4mg/l (S5), i.e., 22.53%, 21.42%, and 21.98%, and GA3 at 100mg/l (S4), i.e., 22.03%, 21.07%, and 21.55%, while significantly lower total sugar was recorded under the control (S4), i.e., 19.40%, 18.58%, and 18.99% in the years 2017-18, 2018-19, and in the pooled analysis, respectively.

This phenomenon may be attributed to potassium's involvement in carbohydrate synthesis, breakdown, translocation, protein synthesis, and neutralization of physiologically important organic acids (Tisdale and Nelson, 1966) [26]. Potassium plays a crucial role in energy production in the form of ATP and NADPH in chloroplasts by maintaining balanced electric charges. Additionally, potassium is involved in phloem loading and unloading of sucrose and amino acids, as well as starch storage in developing fruits, by activating enzymes such as starch synthase (Mengel and Kirkby, 1987) [14]. In plants well-supplied with potassium, the osmotic potential of the phloem sap and the volume flow rate are higher, resulting in an increased sucrose concentration in the phloem sap. Similar results were recorded by Venkatarayappa *et al*. (1979) [27], Kumar *et al*. (2008) [12], Kumar and Kumar (2010) [11], Kachhadia *et al*. (2017) [10], and Pebbudi *et al*. (2017) [18] in bananas.

Effect of Bunch Covering Material

The results reveal that the total sugar content of banana fruit was influenced by different bunch covering materials. Significantly higher total sugar was recorded with non-woven material bag covering (B1), i.e., 22.28%, 21.32%, and 21.80%, as compared to blue-colored polyethylene sleeve (B2), i.e., 20.26%, 19.47%, and 19.87% during 2017-18, 2018-19, and in the pooled analysis, respectively.

This observation might be due to a significantly positive association with temperature. Covered bunches had more total sugar, likely because the higher temperature inside the bunch is favorable for the conversion of starch into sugar. A similar result was reported by Sarkar (2014) [23] in bananas.

Interaction Effect

All interaction effects of post-shooting sprays and bunch covering materials were found non-significant with respect to physiological loss in weight, pulp: peel ratio, total soluble solid, acidity, reducing sugar, and total sugar of banana during the experimental period of both the years 2017-18, 2018-19, and in the pooled data.

Conclusion

The thorough examination of the impact of post-shooting spray and bunch covering material on the fruit quality characteristics of Banana (*Musa paradisiaca* L.) cv. Grand Naine has yielded valuable insights for the optimization of fruit quality parameters.Over a two-year period, the study employed a factorial experimental design, considering various post-shooting sprays and bunch covering materials. Notably, the application of CPPU at 4 mg/l emerged as a key strategy for minimizing physiological loss in weight, indicating its efficacy in suppressing fruit softening. Additionally, non-woven material bag covering played a pivotal role in maintaining a favorable pulp: peel ratio. The influence of SOP at 2% in post-shooting sprays was evident in significantly higher total soluble solids and total sugar content, emphasizing the importance of potassium in carbohydrate synthesis and starch conversion. Furthermore, the study revealed that reducing sugar content was positively affected by SOP at 2%, underlining potassium's role in enhancing sugar levels. However, acidity levels remained unaffected by the experimental treatments. The absence of significant interaction effects between post-shooting sprays and bunch covering materials indicates the individual and predominant impact of these factors. These findings collectively contribute to the understanding of practical interventions for enhancing banana fruit quality, with implications for improved crop management practices in banana cultivation.

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