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Post-shooting sprays of nutrients for improving fruit quality, antioxidant properties and shelf-life in banana (*Musa* sp.)

MUDE RAMYA SREE[1]*, PATIL S N[2], ANIL I SABARAD[1], AMULYA S[2] and SANJAY K SINGH[3]

Kittur Rani Channamma College of Horticulture (University of Horticultural Sciences, Bagalkot, Karnataka), Arabhavi, Karnataka 591 306, India

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ABSTRACT

An experiment was conducted during 2018–21 at the research farms of Kittur Rani Channamma College of Horticulture (University of Horticultural Sciences, Bagalkot, Karnataka), Arabhavi, Karnataka to study the effect of post-shooting sprays of nutrients for improving fruit quality, antioxidant properties and shelf-life in banana (*Musa* sp.). Effects of potassium sulphate (SOP) @20 g/L and micro-nutrients, viz. customised micronutrient mix Arka Banana Special^{TM} @5 g/L, zinc sulphate @1 g/L, boric acid @ 2 g/L, ferrous sulphate- EDTA @3 g/L and copper sulphate @2 g/L sprays in different combinations imposed at post-shooting stage were evaluated in terms of fruit quality and shelf-life after ripening in banana cv. Grand Naine. Treatment comprising of SOP @20 g/L and Arka Banana Special^{TM} @5 g/L improved pulp TSS (22.30^0B), TSS: TA ratio (71.26), fruit firmness (5.16 lb), MSI (18.12%) and peroxidase (POD) activity ($15.98\Delta A_{470}$/min/g). While polyphenol oxidase (PPO) activity (120.42 U/ mg protein), peel browning index (1.42), fruit weight loss (12.73%) and titratable acidity (0.31%) were declined. An increase in green life (8.22 days) and yellow life (3.93 days) of fruits by potassium application, enhancing the storage and shelf-life of the fruits. Pulp TSS was positively correlated with total sugars (0.938^{**}), TSS: acid ratio (0.981^{**}), shelf-life (0.955^{**}), fruit firmness (0.931^{**}) and MSI (0.921^{**}), and negatively correlated with TA (-0.980^{**}) and PPO activity (-0.967^{**}).

Keywords: Arka banana special^{TM}, Banana, Fruit quality, Micro-nutrients, Potassium sulphate, Shelf-life

Banana (*Musa* sp.) is an evergreen perennial monocotyledonous and monocarpic herb that belongs to the family Musaceae. India produces 30.46 mt of bananas from an area of 866 mha with a productivity of 35.17 MT/ha (Anonymous 2019). A serious technical challenge affecting commercial banana production in South Asian countries is the productivity and exportable fruit quality. Hence, the timely application of fertilizers at the critical fruit growth stage is most crucial (Torres *et al*. 2019). To ensure the production of high-quality fruits, it is important to maintain a high level of soil nutrient status. Banana is an intense feeder of nutrients and requires large quantities of mineral nutrition for proper growth and development. An estimated, about 30–40% of the cost of production of banana is on manures and fertilizers alone (Meghwal *et al.* 2021).

Being a high nutrient feeder, single stage application of nutrients leads to heavy nutrient leaching, contaminating the groundwater thus creating an imbalance between vegetative and reproductive growth (Kim *et al.* 2016). Nowadays, the practice of application of nutrients during the post-shooting stage has been suggested to improve the fruit development, early maturity, yield, enhancement in quality and shelf-life of banana fruits. Pottasium sulphate (SOP) is used instead of muriate of potash commercially as it helps to improve bunch yield and quality, besides enhancing the shelf-life. Moreover, potassium increases fruit weight and induces biotic, and abiotic stress tolerance. Similarly, micronutrients play a key role in a balanced plant defense system besides increasing banana yield and quality. It has been found that banana responds favourably to micronutrient (zinc, iron, copper, and boron) spray and it also affects the leaf growth, pseudostem and overall production (Robinson and Galan 2012). In the present study, an effort was made to investigate the effect of post-shooting sprays of potassium sulphate and micro-nutrients in different combinations on fruit quality, antioxidant properties and shelf-life for fruits in tissue cultured raised banana.

MATERIALS AND METHODS

The experiments were conducted at the research farms of Kittur Rani Channamma College of Horticulture

[1]Kittur Rani Channamma College of Horticulture (University of Horticultural Sciences, Bagalkot, Karnataka), Arabhavi, Karnataka; [2]University of Horticultural Sciences, Udyanagiri, Bagalkot, Karnataka; [3]ICAR-Indian Agricultural Research Institute, New Delhi. *Corresponding author email: muderamyasree@gmail.com

(University of Horticultural Sciences, Bagalkot, Karnataka), Arabhavi (16.22' N and 74.83' E), Karnataka during 2018–21 on banana cv. Grand Naine. The healthy plants (15 cm height) raised through tissue culture were planted at a spacing of 1.8 m × 1.8 m. Thereafter, the recommended dose of fertilizers, manures and plant protection chemicals was applied to raise a healthy crop during the two seasons. At 260 days after planting, i.e. at the shooting stage different nutrient treatments were applied as spray, which included, T_1, control (double-distilled water spray); T_2, spray with SOP (20 g/L); T_3, spray of micronutrients [Zn (1 g/L) + B (2 g/L) + Fe (3 g/L) + Cu (2 g/L)]; T_4, spray of Arka Banana Special^{TM} (5 g/L) supplied by ICAR-IIHR, Bengaluru; T_5, spray with SOP (20 g/L) + micronutrient [Zn (1 g/L) + B (2 g/L) + Fe (3 g/L) + Cu (2 g/L)]; and $T_{6,}$ spray with SOP (20 g/L) + Arka Banana Special^{TM} @ 5 g/L). Two sprays of the treatments were done at the last hand opening stage and 30 days after the first spray using knapsack sprayers. The experiment was laid out in the Randomized Block Design comprising 6 treatments in 4 replications with 32 plants per treatment, taken to improve precision and reduce variability.

Mature green banana fruit bunches were procured from the experimental plots (Fig 1). Four hands per replicates were analysed for each parameter. For uniform ripening the hands were washed air-dried and staked in single layer in plastic crates, which were shifted to the ethylene ripening chamber. These crates were exposed to ethylene gas (1000 ppm) for 12 h at a temperature of 16–18°C and 90–95% RH. The fruits from the third-hand ripened hand distal end of the bunch were sampled in each treatment. The total soluble solids of pulp were recorded using a hand-held refractometer (ERMA). Titratable acidity, vitamin C, total sugars in fruit pulp, peel browning and per cent PLW were estimated and calculated by the standard methods.

The harvested fruits at the physiological maturity stage were examined to record the green-life, yellow-life was expressed in days and shelf-life (days) was noticed based on the appearance and marketability. Fruit pulp firmness was measured using a digital basic force gauge. Leakage of ions from peel was measured in the peel discs (2 cm) and expressed as membrane stability index percentage (MSI). The colorimetric coordinates of fresh banana peel for each treatment were measured (L^*, a^* and b^*) using a colour meter (Minolta Chroma Meter CR 400). The total fruit weight loss was calculated on an initial weight basis and expressed in percentage. The weight loss (%) was calculated at 3, 6, 9 and the senescence stage of five middle fingers from bunches in each treatment.

Total phenols concentration in the pulp and peel tissues was measured according to Hoff and Singleton (1977) and expressed as g/kg FW gallic acid equivalent (GAE). Total flavonoids were determined using a modified colorimetric method (Zhishen *et al.* 1999). Antioxidant enzyme activities for POD (EC 1.11.1.7) and PPO (EC 1.14.18.1) were assayed (Castillo *et al.* 1984, Matto and Diamond 1963, respectively).

The data on post-shooting sprays of potassium and micronutrients on fruit quality, antioxidant properties and shelf-life were undertaken for analysis. The descriptive statistics of selected phytochemical parameters were calculated using MS Excel 2007. ANOVA was determined for each parameter using SAS package (9.3 SAS Institute, Inc., USA). A simple correlation of coefficient among the different parameters was calculated using Pearson's correlation coefficient programme.

RESULTS AND DISCUSSION

Effect on fruit quality parameters: The data related to fruit quality parameters as influenced by post-shooting sprays were found significant (Table 1). The highest pulp TSS (22.30^{0}Brix) was noticed in spray T_6 followed by T_2 (21.85^{0}Brix) and T_4 (21.15^{0}Brix), while it was lowest in T_1 (18.60°Brix). An increase in TSS due to the exogenous application of potassium is known due to increase in flow of assimilates from the source to the active sink, i.e. developing fruits (Bons *et al.* 2015). The lowest acidity (0.31%) was observed in the spray with treatment $T_{6,}$ while it was highest in T_1 (0.41%). The enhanced potassium (K) level due to exogenous application led to a decline in acid content of fruit pulp, contrasting to control which had lower K content, the phosphoenol pyruvate (PEP) was shifted into alternate pathways resulting in the shortage of acetyl Co-A (Singh *et al.* 2020). The organic acids are neutralized in tissues and rapidly metabolically transformed into sugars in presence of high potassium level, thus resulting in reduction in acidity. Application of Arka Banana Special^{TM}- a micronutrient mix resulted in the reduction of acidity, also due to a higher accumulation of sugars in fruit owing to synergistic effect with K (Krishnamoorthy and Hanif 2017).

The maximum total sugars (16.61%) were recorded in treatment T_6 compared to the lowest in T_1 (16.28%). Higher total sugars content may be due to the direct role of sulphate (SO_4) ion, leading to enhanced appearance of fruits where chloride uptake is restricted, the activity of anabolic

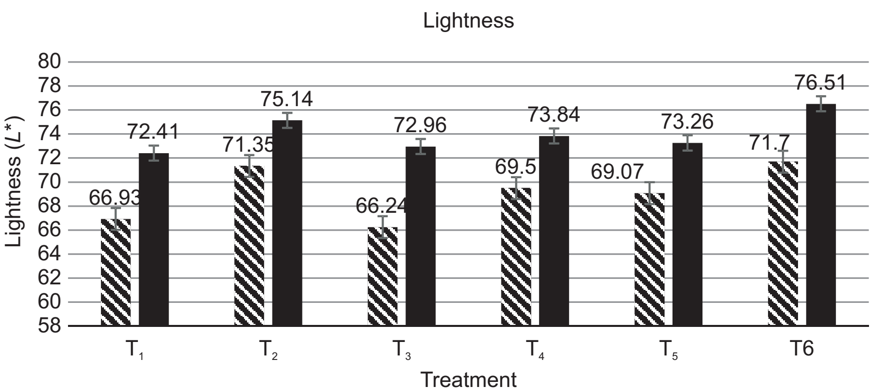

Fig 1 Effect of potassium and micronutrients on fruit peel colour indices of banana cv. Grand Naine at maturity and ripened stages.

Table 1 Effect of potassium and micronutrients sprays on fruit quality parameters of banana cv. Grand Naine

Treatment	TSS (˚Brix)	Titratable acidity (%)	Total sugars (%)	TSS: acid ratio	Vitamin C (mg/100 g pulp)	Pulp *p*H	Total phenols (g/kg)		Total flavonoids (g/kg)		POD (ΔA_{470}/ min/g)	PPO (U/mg protein)
							Peel	Pulp	Peel	Pulp		
T_1	18.60^{e}	0.41^{a}	16.28^{d}	44.43^{f}	0.075^{a}	5.01^{d}	0.61^{e}	0.47^{d}	0.35^{a}	0.12^{d}	7.15^{f}	145.69^{a}
T_2	21.85^{b}	0.33^{e}	16.52^{b}	65.81^{b}	0.069^{bc}	6.12^{ab}	0.69^{c}	0.55^{b}	0.29^{c}	0.19^{b}	14.50^{b}	125.54^{e}
T_3	20.35^{d}	0.38^{b}	16.33^{c}	52.23^{e}	0.065^{c}	5.13^{cd}	0.95^{a}	0.45^{e}	0.35^{a}	0.15^{c}	8.49^{e}	132.47^{c}
T_4	21.15^{c}	0.34^{d}	16.50^{bc}	61.61^{c}	0.067^{c}	5.86^{b}	0.63^{d}	0.52^{c}	0.30^{bc}	0.19^{ab}	12.81^{c}	127.58^{d}
T_5	20.50^{d}	0.36^{c}	16.38^{c}	55.27^{d}	0.065^{c}	5.42^{c}	0.83^{b}	0.46^{e}	0.31^{b}	0.13^{d}	10.22^{d}	137.77^{b}
T_6	22.30^{a}	0.31^{f}	16.61^{a}	71.26^{a}	0.072^{ab}	6.38^{a}	0.52^{f}	0.60^{a}	0.24^{d}	0.21^{a}	15.98^{a}	120.42^{f}
SEm±	0.76	0.002	0.08	0.20	0.02	0.09	0.01	0.01	0.01	0.01	0.02	0.01
LSD (P<0.05)	0.23	0.006	0.24	0.60	0.006	0.28	0.03	0.03	0.02	0.02	0.07	0.03

*Common letters are non-significant according to Duncan's multiple range test where P<0.05.

enzymes led to higher accumulation of highly polymerized carbohydrates, i.e. starch, which subsequently disintegrated into sugars upon ripening (Sreekanth *et al.* 2017). The maximum pulp Brix: acid ratio (71.26) was recorded in T_6, while it was minimum (44.43) was in T_1. It is well known that sulphate ions are favoured by plants over chloride, thus enhancing the activity of anabolic enzymes resulting in the accumulation of highly polymerized carbohydrates, i.e. starch which subsequently disintegrates into sugars on ripening (Johnson *et al.* 1998). The vitamin C content was recorded maximum (0.075 mg/100 g pulp) in T_1, while it was minimum (0.065 mg/100 g pulp) in T_3, T_4 and T_5. The highest pulp *p*H was observed in T_6 (6.38), while it was lowest in T_1 (5.01).

Effect on post-harvest parameters: As evident in the post-shooting sprays, significant results were observed with respect to post-harvest parameters (Table 2). The highest green life (8.22 days) of the hands was noticed in T_6, while it was lowest in T_1 (6.44 days). Almost similar trends were observed with respect to the yellow-life and shelf-life alterations. An increase in the number of days from green turning to yellow may be due to reduced respiration rate and ethylene production due to potassium application, which maintains the endogenous cytokinin levels thus delaying the senescence (Premalatha and Suresh 2019).

The fruit firmness was reduced in all treatment combinations with a progressive ripening process. The highest fruit firmness (5.16 lb) was observed in T_6 compared to the minimum in the treatment T_1 (4.19 lb). Similarly, the peel MSI was observed maximum (18.12%) in T_6, while it was recorded minimum in the treatment T_1 (15.35%). Reduced weight loss could be due to better stabilization and consolidation of both cell wall integrity and permeability in the tissues. The nutrient spray application preserved the epicuticular waxes, which minimized moisture loss (Abraham *et al.* 2008).

Effect on physical parameters: Physical parameters differed as the change in the fruit surface colour indices (at harvest) at different ripening stages with and without post-shooting spray treatments considerably (Fig 1 and 2). Colour index like lightness (L^*) increased, whereas, the chroma $(a^{*2} + b^{*2})^{½}$ decreased in the treated fruits as

Table 2 Effect of potassium and micronutrients sprays on post-harvest parameters and attributes related to fruit physical characters of banana cv. Grand Naine

Treatment	Green-life (days)	Yellow-life (days)	Shelf-life (days)	Fruit firmness (lb)	MSI (%)	Peel browning index	Weight loss (%)			
							After 3 days	After 6 days	After 9 days	At senescence stage
T_1	6.44^{b}	3.00^{d}	9.44^{e}	4.19^{c}	15.35^{c}	2.06^{a}	1.29^{a}	7.12^{a}	9.87^{a}	19.13^{a}
T_2	7.89^{a}	3.80^{ab}	11.69^{b}	5.03^{a}	17.54^{ab}	1.75^{abc}	1.11^{b}	2.88^{e}	5.10^{e}	14.68^{c}
T_3	6.78^{b}	3.37^{c}	10.15$_{d}$	4.31^{bc}	15.65^{c}	1.99^{ab}	1.28^{a}	4.56^{b}	6.56^{c}	16.67^{b}
T_4	7.22^{ab}	3.54^{bc}	10.77^{c}	4.80^{ab}	16.89^{b}	1.64^{bc}	1.15^{b}	3.66^{d}	6.05^{d}	14.37^{c}
T_5	7.44^{-ab}	3.49^{c}	10.93^{c}	4.43^{bc}	15.87^{c}	1.81^{ab}	1.19^{ab}	3.92^{c}	7.61^{b}	18.40^{a}
T_6	8.22^{a}	3.93^{a}	12.16^{a}	5.16^{a}	18.12^{a}	1.42^{c}	1.09^{b}	2.63^{f}	5.85^{d}	12.73^{d}
SEm±	0.36	0.11	0.09	0.18	0.217	0.126	0.03	0.03	0.09	0.28
LSD (P<0.05)	1.08	0.30	0.27	0.54	0.655	0.381	0.11	0.10	0.30	0.85

*Common letters are non-significant according to Duncan's multiple range test where P<0.05.

Table 3 Correlation analysis between fruit quality and post-harvest parameter, biochemical traits and antioxidants of banana cv. Grand Niane

Trait	TSS	TA	TS	T:A	GL	YL	SL	F	MSI	WL (3)	WL (6)	WL (9)	WL (S)	PB	TP	TF	POD	PPO
TSS	1.000																	
TA	-0.980**	1.000																
TS	0.938**	-0.978**	1.000															
T:A	0.981**	-0.994**	0.986**	1.000														
GL	0.927**	-0.949**	0.914*	0.947**	1.000													
YL	0.990**	-0.979**	0.936**	0.981**	0.968**	1.000												
SL	0.955**	-0.967**	0.929**	0.966**	0.996**	0.986**	1.000											
F	0.931**	-0.960**	0.987**	0.978**	0.915*	0.934**	0.929**	1.000										
MSI	0.921**	-0.949**	0.986**	0.974**	0.911*	0.927**	0.924**	0.996**	1.000									
WL(3)	-0.915*	0.968**	-0.965**	-0.959**	-0.947**	-0.930**	-0.949**	-0.965**	-0.948**	1.000								
WL(6)	-0.979**	0.952**	-0.871*	-0.934**	-0.905*	-0.968**	-0.933**	-0.856*	-0.834*	0.880*	1.000							
WL(9)	-0.928**	0.855*	-0.794NS	-0.859*	-0.745NS	-0.881*	-0.795NS	-0.807NS	-0.782NS	0.759NS	0.926**	1.000						
WL(S)	-0.903*	0.898*	-0.936**	-0.926**	-0.765NS	-0.864*	-0.805NS	-0.923**	-0.930**	0.824*	0.813*	0.847*	1.000					
PB	-0.873*	0.942**	-0.957**	-0.932**	-0.876*	-0.876*	-0.884*	-0.902*	-0.907*	0.916*	0.823*	0.669NS	0.869*	1.000				
TP	0.800NS	-0.855*	0.937**	0.894*	0.834*	0.819*	0.837*	0.949**	0.968**	-0.880*	-0.676NS	-0.615NS	-0.880*	-0.872*	1.000			
TF	0.908*	-0.910*	0.950**	0.937**	0.781NS	0.872*	0.819*	0.947**	0.949**	-0.857*	-0.818*	-0.854*	-0.995**	-0.867*	0.898*	1.000		
POD	0.949**	-0.981**	0.993**	0.990**	0.941**	0.954**	0.953**	0.995**	0.989**	-0.981**	-0.889*	-0.812*	-0.910*	-0.929**	0.929**	0.932**	1.000	
PPO	-0.967**	0.935**	-0.927**	-0.954**	-0.831*	-0.935**	-0.872*	-0.917*	-0.917**	0.841*	0.911*	0.928**	0.973**	0.852*	-0.821*	-0.967**	-0.918**	1.000

*Correlation is significant at the 0.05 level and **Correlation is significant at the 0.01 level

TSS, Total soluble solids (˚Brix); TA, Titratable acidity (%); TS, Total sugars (%); T:A, TSS: acid ratio; GL, Green-life (days); YL, Yellow-life (days); SL, Shelf-life (days); F, Firmness; MSI, Membrane stability index (%); WL(3), Weight loss in per cent after 3 days; WL(6), Weight loss in per cent after 6 days; WL(9),Weight loss in , per cent after 9 days; WL(S) ,Weight loss in per cent at senescence stage; PB, Peel browning index; TP, Total phenols in pulp (g/Kg); TF, Total flavonoids (g/Kg); POD, Peroxidase activity in pulp (ΔA_{470}/min/g); PPO, Polyphenol oxidase activity in pulp (U/mg protein).

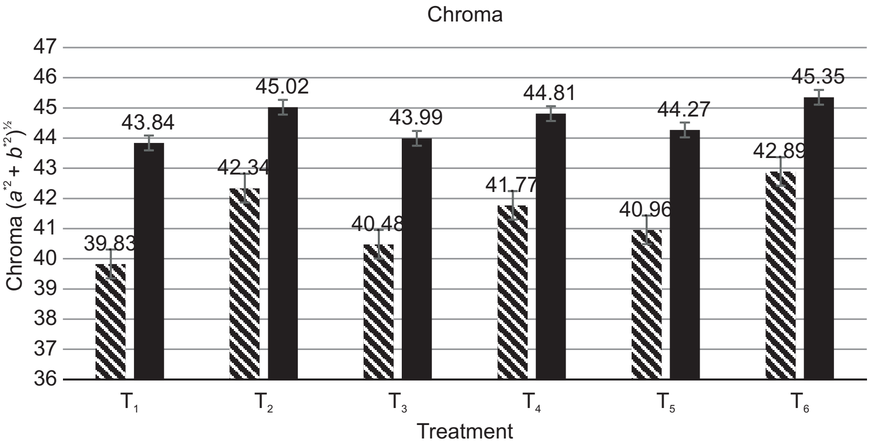

Fig 2 Effect of potassium and micronutrients on fruit peel colour indices like chroma $(a^{*2} + b^{*2})^{½}$ of banana cv. Grand Naine at maturity and ripened stages.

compared to control. The least weight loss (%) and peel browning index were observed in treated fruits than the control fruits (Table 2). Among all the treatments, the minimum weight loss was observed in the treatment T_6 (1.09, 2.63, 5.85 and 12.73 g at 3, 6, 9 days and at the senescence stage, respectively), while it was maximum in the treatment T_1 (1.29, 7.12, 9.87 and 19.13 g). It has been observed that K is most essential for facilitating translocation of the photosynthates into sink organs, besides maintaining the turgidity and activation of enzymes, which helped in improving the fruit physical appearance (Tadayon 2021). Peel browning index was observed to be highest in the controlled fruits than in the treated fruits, i.e. lowest (1.42) in T_6, with highest in T_1 (2.06).

Effect on biochemical parameters and antioxidant enzyme activity: The total phenolic and flavonoid contents in pulp significantly changed during ripening, i.e. initially increase but at a later stage decreased a bit when the fruits became overripe (Table 1). In control (naturally ripened banana), the phenolic contents gradually increased in the fruit peel but decreased thereafter in the later stages. The total phenols content in pulp was maximum in T_6 (0.60 g/kg) compared to the lowest (0.47 g/kg) in T_1. The total flavonoid content in pulp was maximum in the treatment T_6 (0.21 g/kg) compared to lowest in T_1 (0.12 g/kg). The reduction in fruit peel phenolics and PPO activity at the overripe stage, is mainly by a reduction in primary metabolism, resulting in a lack of substrates necessary for phenol biosynthesis (Xu *et al.* 2014). The POD activity increased in the treated fruits compared to the control. The peel of overripe fruits lost antioxidant capacity and other functional components (total phenols and flavonoids) considerably. The antioxidant properties like POD in banana pulp showed the highest activity (15.98 ΔA_{470}/min/g) in treated fruits in T_6 with the minimum in T_1 (7.15ΔA_{470}/min/g). The PPO activity was also reduced in the treated fruits than in the control. The application of potassium is also known to enhance the non-structural carbohydrates, photosynthetic pigments, antioxidative activity and minimizing lipid peroxidation that resulted increment in fruit yield (Lu *et al.* 2016).

Correlation studies: The correlation analysis amongst the various traits related to the fruit quality, post-harvest parameter, biochemical traits and antioxidants of banana showed 74 positive and 77 negative correlations (Table 3). TSS (˚Brix) were positively correlated with total sugars (0.938**), TSS: acid ratio (0.981**), green-life (0.927**), yellow-life (0.990**), shelf-life (0.955**), fruit firmness (0.931**), MSI (0.921**), total flavonoids (0.908*) and POD activity (0.949*), while it was negatively correlated with titratable acidity (-0.980**), PPO activity (-0.967**) and peel browning index (-0.873*). Titratable acidity was positively correlated with peel browning index (0.942*) and PLW. All the post-harvest parameters were positively correlated with total phenols, total flavonoids, POD activity and other quality traits. The PLW (%) at all stages was positively correlated with PPO. The negative correlations were observed between the quality and physical characteristics of the fruits like PLW.

Post-shooting sprays of potassium (SOP-20 g/L) and Arka Banana Special™ (5 g/L) can be suggested as an effective method to improve the fruit quality, antioxidant properties and shelf-life in Grand Naine banana. The fruit quality parameters including TSS, total sugars, TSS: acid ratio and *p*H were found to improve considerably. An increase in the fruits' green-life and yellow-life was noted with enhanced storage and the shelf-life. On the other hand, the antioxidant capacity of the peel tissue was also enhanced as the fruit ripened but declined thereafter towards the overripe stage, indicating phenolics rather than chlorophylls and carotenoids to be associated with the antioxidant activities.

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