Bio-efficacy studies of Unique in relation to growth, yield and shelf life of Nanasaheb Purple Seedless grape variety under multilocation

Abstract

Grape production, particularly seedless varieties like Nanasaheb Purple Seedless, is highly valued for both domestic and export markets. However, environmental stressors such as drought and salinity often affect the quality and yield of grapes leading to fluctuations in output. This study explored the effectiveness of biostimulant (Unique) in enhancing grape yield, quality and shelf life across two locations: ICAR-NRC for Grapes, Pune and Walwa, Sangli District. While, biostimulants have shown potential in promoting plant growth and stress resilience, there is limited research on the optimal dosage and application timing for specific varieties like Nanasaheb Purple Seedless. The primary objective of this study was to identify the most effective dose and application schedule of Unique to maximize yield, berry quality and shelf life. A randomized block design (RBD) was employed with three treatment levels (20, 25 and 30 ml/L) of Unique applied via foliar spray at five key growth stages. Growth, yield and quality parameters were measured and compared to a control across five replicates. Results revealed that Unique application at 30 ml dose at five critical growth stages significantly enhanced bunch weight, berry size and yield. Additionally, biochemical markers such as phenol, protein and reducing sugar levels increased. Physiological parameters like leaf area and chlorophyll content also improved, facilitating better nutrient absorption and photosynthesis. Shelf life was extended with reduced weight loss during storage. The foliar application of 30 ml of Unique at specific growth stages is recommended to optimize the quality, yield and shelf life of Nanasaheb Purple Seedless grapes. However, bio stimulant application for grapevine management offering a sustainable solution to enhance grape production under tropical condition.

Keywords: Bio stimulant, Unique, Yield, Quality, Shelf life, Nanasaheb Purple Seedless

Introduction

Grape(*Vitis vinifera* L). is a highly profitable fruit crop widely cultivated in India. The primary grape-producing regions include Maharashtra, Karnataka, Andhra Pradesh, Madhya Pradesh and Mizoram, benefiting from the adaptability of grape genotypes to diverse agroecological zones. In 2024, grape production reached 3,896 thousand metric tons from an area of 176.91 thousand hectares (Anonymous, 2024). During the fiscal year 2023-24, the country exported 343,982.34 metric tons, valued at 417.07 million USD (APEDA, 2024). A significant portion of the grape harvest is consumed as table grapes, both domestically and in export markets. Consumer preferences for table grapes are driven by qualitative traits such as bunch size, berry shape, skin colour, skin thickness, flesh firmness, flavour, aroma and sugar-to-acid ratio (Deshmukh et al., 2023). Notably, Nanasaheb Purple Seedless is promising black seedless grape variety developed by clonal selection from black seedless Sharad Seedless. It has high demand in domestic market due to its quality and attractive colour. At present, it is being grown in four states viz. Maharashtra, Andhra Pradesh, Madhya Pradesh and Karnataka and due to its high berry quality, is well-accepted in both domestic and international market. Key consumer preferences include berry size and shelf life (Deshmukh et al., 2023). However, seasonal fluctuations in environmental conditions, coupled with biotic and abiotic stresses have a detrimental impact on the yield and quality of grapes (Sharma et al., 2023). Unseasonal rains, increasing salinity, drought and inadequate irrigation water are significant challenges in producing grapes of optimal quality and size. Drought stress is one of the leading agricultural problems limiting the growth and production of plants in most arid and semiarid regions of the world (Irani et al., 2021). Numerous morphological, physiological and biochemical functions of plants are affected by drought stress in fruit trees. While several studies have explored the use of traditional plant growth regulators (PGRs) to modulate growth and berry size, their synthetic nature poses challenges to achieve sustainable agricultural practices (Basile et al., 2021). In recent years, grape growers have increasingly shifted their focus towards sustainable practices, emphasizing the use of biostimulants to enhance both yield and berry quality. Biostimulants are known to stimulate metabolic activity and regulate growth during the vegetative and reproductive stages of grapevines. They can be effective even at low concentrations (Bulgari et al., 2019), promoting physiological development and providing defensive responses against extreme temperatures, drought, salinity and metal stress (Bulgari et al., 2019; Monteiro et al., 2022). Their mechanism of action includes triggering enzymatic activities and gene expression which in turn improves plant performance (Liu et al., 2016). Biostimulants have also been shown to enhance yield by promoting cell division and enlargement, improving nutrient uptake and efficiency and increasing CO2 assimilation (Asghari and Reazei-Rad, 2018). Irani et al. (2021) demonstrated that the application of bio stimulants, particularly seaweed extract (SE) significantly improved berry weight, yield and total soluble solids (TSS) content, while reducing acidity under drought stress conditions. Additionally, the bio stimulant treatment led to a notable increase in chlorophyll content, abscisic acid (ABA), proline, total phenols and the activity of antioxidant enzymes. Furthermore, elevated levels of essential nutrients, including nitrogen (N), phosphorus (P), potassium (K), as well as trace elements like iron (Fe) and zinc (Zn) were observed under drought stress attributed to the bio stimulant application. In light of these benefits, an experiment was conducted to determine the optimal dosage and frequency of bio stimulant applications to regulate the yield and quality of Nanasaheb Purple Seedless grapes.

Materials and Methods

Experimental ~~conditions~~ Conditions

The experimental trials were conducted at two different locations (ICAR-National Research Centre for Grapes, Pune (18°32′N and 73°51′E) and Walwa (19°42′N and 74°28′E) in Sangli district of Maharashtra during the year 2023-24. The experiment was laid out in RBD with four treatments and five replications with five vine per replication. In both the locations, the vines are pruned twice in a year; first pruning was done during mid-last week of April, 2023 (foundation pruning) while the second pruning during mid-last week of October, 2023 (fruit pruning). Four treatments were imposed through foliar spray during the experiment i.e., T1- control (water spray), T2- foliar spray of Unique@ 20 ml/~~L~~l, T3- foliar spray of Unique@ 25 ml/~~L~~ land T4 -foliar spray of Unique (give technical name)@ 30 ml/~~L~~ l at five different stages, 1st - ~~After~~ after 12 to 13 days of fruit pruning, 2nd ~~After~~ after 23 to 25 days of fruit pruning, 3rd on 75 to 100% flowering stage, 4th on 100% setting of fruits stage (2 mm b~~B~~erry s~~S~~ize) and 5th after 8 to 10 days (100% setting of fruits stage).Water volume used based on the canopy size (250 to 400 ~~L~~l/acre).

Growth ~~parameters~~Parameters

Shoot length was measured from the 1st ~~st~~ node at 90 days after fruit-pruning and expressed in cm. Shoot diameter between the fifth and sixth nodes was measured with a Vernier calliper and averaged for five canes per vine and expressed in mm. Leaf area was calculated using the formula: Leaf area (A) = L x B x K (0.810) (write full form of L, B K and reference) and expressed in cm².

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Bunch and Yield parameters

The mean number of bunches per vine were calculated from five selected vines after berry set. Similarly, the average number of berries per bunch was determined from five bunches per treatment. The mean bunch weight was recorded by averaging 10 bunches from five randomly selected vines at harvest. Berry weight was calculated from 50 randomly selected berries. Grapes were harvested at proper maturity and yield was recorded.

Berry Quality Parameters

Ten randomly selected berries per replication were measured for length and diameter using a Vernier calliper (mm). Juice was extracted from selected berries to determine total soluble solids (°Brix) using a hand refractometer. Titratable acidity (%) was measured by titrating the juice with 0.1 N NaOH. Chlorophyll content in leaves was estimated using the DMSO method give references of allmethods given by.

Biochemical Parameter

The Folin-Ciocalteu method (Singleton and Rossi, 1965) was used to estimate phenols and expressed in mg/g. Soluble protein content in grape berries was measured using Lowry's method (1951) and expressed in mg/g. Reducing sugars in grapes were determined using DNSA method (Miller, 1972) and expressed in percentage. Calcium (ppm) was measured using the neutral normal ammonium acetate method, while phosphorus content in petiole samples was determined using the Venadomolybdo phosphoric acid method (Jackson, 1973), with absorbance at 470 nm on a spectrophotometer.

Physical properties of treated grapes

Pedicel thickness was measured with a vernier calliper and expressed in mm. The skin thickness of ten randomly selected grape berries was measured using a portable digital calliper. To assess physical changes during storage, physiological loss in weight (PLW) was calculated as the percentage of ~~mass~~ mass or weightlost over time. Each treatment's weight was recorded daily for 5 days to determine PLW (%) at each interval was calculated as:

$$\text{Physiological loss in weight (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

Statistical analysis

The data recorded was statistically analysed by using Randomized Block Design (RBD).

Result and discussion

At 90 days after fruit pruning, the treatment T1 showed highest shoot length (87.10 cm) and shoot diameter (7.20 mm) while treatment T4 showed minimum shoot length (82.50 cm) and shoot diameter (7.00 mm) while the leaf area varied significantly among the different concentrations of Unique over the untreated control (Table 1). It was higher in T4 (160.20 cm^2) which was at par with T3 (157.00 cm^2) over the control treatment T1 (153.70 cm^2) at ICAR-NRCG.A similar trend was recorded in Walwa. Among the different treatments of Unique, there was not much difference in shoot growth. An increase in shoot length and diameter directly affects grape productivity by influencing photosynthesis and nutrient allocation. As shoot length increases, more photosynthetic products are used for shoot growth, reducing the resources available for cane development and fruit growth (Somkuwar et al., 2024). Optimal shoot growth enhances berry composition and size leading to better overall grape quality (Somkuwar et al., 2024d). However, excessive vegetative growth can negatively impact yield and quality by diverting resources away from reproductive parts. Maintaining an optimal leaf area is crucial for improving grapevine yield and quality as it boosts carbohydrate production (Somkuwar et al., 2024a; 2024b; 2024c).

Table 1: Effect of Unique on growth parameters of Nanasaheb Purple Seedless grapes

Treatments	Pune location			Sangli location		
	Shoot length (cm)	Shoot diameter (mm)	Leaf area (cm2)	Shoot length (cm)	Shoot diameter (mm)	Leaf area (cm2)
T_1- Control	87.10	7.20	153.70	90.00	7.50	162.00
T_2- Unique @ 20 ml (write per litre or other concentration for all treatments)	85.60	7.00	155.40	95.20	7.70	163.00
T_3- Unique @ 25 ml	85.00	7.00	157.80	96.80	7.65	166.00
T_4- Unique @ 30 ml	82.50	7.10	160.20	97.70	7.80	168.50
CD at 5%	**2.02**	**0.16**	**3.71**	**2.32**	**0.18**	**3.90**
Sig	** **(explain meaning of * and ** in Note)**	**	*	**	*	*

Bunch and yield parameters

The data recorded on number of bunches/vines, number of berries/bunch, average bunch weight (g), 50-berry weight and yield/vine are presented in Table 2. The application of Unique, did not affect number of bunches/vine and number of berries/bunch. This was mainly because the fruit bud differentiation was already been completed during the period of 40 to 70 days after the foundation pruning. In addition, considering the quality yield for export purpose, bunch thinning is also done after berry set. In the present study, treatment T4 significantly showed highest average bunch weight (580.40 g), 50 berry weight (423.01 g) and yield/vine (16.12 kg) followed by T3 (550.30 and 386.50 g and 15.89 kg) over the control treatment T1 (510.70 g, 364.84 g, 13.97 kg respectively) at ICAR-NRCG. A more or less similar trends with different values was recorded at Walwa. The application of Unique led to notable physiological improvements in grapevines particularly increasing average bunch weight, 50-berry weight and overall yield. Additionally, biostimulants such as seaweed extracts and humic acids have been demonstrated to enhance nutrient uptake by grapevines, either directly or indirectly (Nardi et al., 2016). These enhancements in nutrient availability combined with improved physiological responses contributed to higher yields (Shahrajabian et al., 2021; Irani et al., 2021). The yield increase was primarily due to the larger size and weight of the bunches and berries which likely improved carbon assimilation efficiency through enhanced photosynthesis and protein synthesis a result of biostimulant application (Deshmukh et al., 2023). The observed improvements in bunch weight and overall yield with unique treatments could be attributed to the biostimulants' ability to modify molecular processes that improve water and nutrient use efficiency, promote plant development and mitigate abiotic stress (Van Oosten et al., 2017) by stimulating both primary and secondary metabolism (Rao et al., 2016). Secco et al. (2016) also reported the highest increases in berry and bunch weight. Significant yield improvements from biostimulant use in grape varieties such as Thompson Seedless and Sharad Seedless were similarly reported by Sharma et al. (2023) and Deshmukh et al. (2023).

Table 2: Effect of Unique on bunch and yield parameters of Nanasaheb Purple Seedless grapes

Treatments	No of bunches/ vine	No of berries/bunch	Average bunch weight (g)	50 berry weight (g)	Yield/vine kg)
Pune location					
T_1- Control	27.30	70.00	510.70	364.84	13.97
T_2- Unique @ 20 ml	28.40	69.01	520.50	377.20	14.81
T_3- Unique @ 25 ml	28.81	71.21	550.30	386.50	15.89
T_4- Unique @ 30 ml	27.80	68.90	580.40	423.01	16.12
CD at 5%	**2.10**	**4.16**	**12.86**	**21.98**	**1.32**
~~Sig~~ write full in all tables	**NS**	**NS**	**	**	*
Sangli location					
T_1- Control	29.60	73.00	630.00	431.55	18.68
T_2- Unique @ 20 ml	30.50	74.50	632.00	424.20	19.32
T_3- Unique @ 25 ml	32.00	75.00	635.00	423.41	20.41
T_4- Unique @ 30 ml	33.00	74.50	650.00	436.28	21.47
CD at 5%	**3.64**	**1.79**	**14.77**	**0.16**	**0.96**
Sig	**NS**	**NS**	*	**	**

Berry quality parameters

Statistically significant variations were recorded for berry length and diameter with different concentrations of Unique (Table 3). The treatment T4 recorded highest berry length and berry diameter (24.00 mm and 22.40 mm) followed by T2 (23.60 mm and 21.50 mm, respectively) over untreated control T1 (22.10 and 20.00 mm, respectively). The application of Unique did not affect TSS in grape berries, however, the TSS ranged from 16.90°Brix (T3) to 18.60°Brix (T2). The acidity ranged from 0.40 % in T1 to 0.48 % in T4 treatment at ICAR-NRCG. Though the overall trend was similar, the recorded values at Walwa were different. The TSS and acidity in grape berries were within the acceptable limit of grape export in all the treatments studied. Bio stimulants, such as protein hydrolysates and humic substances have been shown to significantly increase berry size. Research indicated that berries treated with these biostimulants exhibit greater length and diameter compared to untreated controls (Nardi et al., 2016; Shahrajabian et al., 2021). This increase in berry size is likely due to the stimulation of cell division and elongation triggered by the application of bio stimulants (Warusavitharana et al., 2008; Deshmukh et al., 2023). Since berry length and diameter are key factors determining berry shape, these findings align with the results of Sharma et al. (2023) who also reported that biostimulants significantly enhance berry size. However, at harvest no significant effects on total soluble solids were observed as noted by Frioni et al. (2019) and Sharma et al. (2023). Similarly, Deshmukh et al. (2023) reported a non-significant effect of biostimulants on TSS, although they reported significant impact on titratable acidity.

Table 3: Effect ofUnique on berry quality parameters of Nanasaheb Purple Seedless grapes

Treatments	Berry length (mm)	Berry diameter (mm)	TSS (°Brix)	Acidity (%) (In materials and methods Titratable acidity is written)
Pune location				
T_1- Control	22.10	20.00	18.20	0.40
T_2- Unique @ 20 ml	23.60	21.50	18.60	0.43
T_3- Unique @ 25 ml	23.20	21.00	16.90	0.45
T_4- Unique @ 30 ml	24.00	22.40	17.60	0.48
CD at 5%	**0.55**	**0.49**	**3.08**	**0.005**
Sig.	**	**	**NS**	**
Sangli location				
T_1- Control	24.00	21.50	17.70	0.50
T_2- Unique @ 20 ml	24.40	21.60	17.90	0.52

T_3- Unique @ 25 ml	24.20	21.80	18.00	0.52
T_4- Unique @ 30 ml	25.10	22.40	18.20	0.53
CD at 5%	**0.56**	**0.51**	**0.42**	**0.012**
Sig.	**	**	NS	**

Chlorophyll content in leaf

At 45 days after fruit pruning, application of Unique had significantly higher chlorophyll a content in leaf in T4 (10.98 ug/ml) followed by T2 (10.08 ug/ml) as compared to control T1 (8.85 ug/ml). The same trend was also reported for chlorophyll b content. Total chlorophyll content in leaves also varied significantly with higher concentration in T4 (14.16 ug/ml) followed by T2 (13.14 ug/ml) as compared to control T1 (11.63 ug/ml). Increase in chlorophyll a and b in T4 treatment also resulted into higher concentration of total chlorophyll. After 90 days of fruit pruning, chlorophyll b content in grape leaf were higher in T4 (3.94 ug/ml) followed by T3 (3.47 ug/ml) as compared to T1 (2.70 ug/ml). The differences for chlorophyll a and total chlorophyll content were non-significant at ICAR-NRCG. A roughly comparable trend (though the values different) was recorded for chlorophyll content at 45 days. Although, 90 days after the fruit pruning, the treatment T4 recorded significantly higher concentration of chlorophyll a, b and total chlorophyll in grape leaves (14.84 ug/ml, 4.21 ug/ml and 19.05 ug/ml) followed by T3 (13.98 ug/ml, 3.86 ug/ml and 17.84 ug/ml respectively) as compared to the control T1 (12.41 ug/ml, 2.91 ug/ml and 15.32 ug/ml respectively) at Walwa. The increase in chlorophyll content in Unique-treated plants can be attributed to improved nutrient absorption and enhanced physiological conditions. These improvements lead to healthier leaves and increased photosynthetic efficiency, facilitating the transfer of sugars and starches while also activating key enzymes involved in chlorophyll synthesis. As a result, treated plants exhibit higher overall chlorophyll levels (Battacharyya et al., 2015; Sharma et al., 2023). Additionally, the rise in chlorophyll content is linked to a reduction in its degradation and an improvement in chloroplast biogenesis. Previous studies have shown that one of the key effects of biostimulant treatment is the increased chlorophyll content in treated plants as noted by Battacharyya et al. (2015) and Sharma et al. (2023).

Table 4. Effect of Unique on chlorophyll content in leaf of Nanasaheb Purple Seedless grapes

Treatments	90 Days Foundation Pruning			90 Days Fruit Pruning		
	Chlorophyll a (ug/ml)	Chlorophyl l b (ug/ml)	Total Chlorophyll (ug/ml)	Chlorophy ll a (ug/ml)	Chlorophyll b (ug/ml)	Total Chlorophyll (ug/ml)
Pune location						
T_1- Control	8.85	2.78	11.63	12.90	2.70	15.60

T_2- Unique @ 20 ml	10.08	3.06	13.14	13.63	2.88	16.51
T_3- Unique @ 25 ml	9.65	2.52	12.17	11.98	3.47	15.45
T_4- Unique @ 30 ml	10.98	3.18	14.16	12.33	3.94	16.27
CD @ 5%	0.74	0.49	0.89	2.24	0.26	2.15
Sig	**	*	**	**NS**	**	**NS**
Sangli location						
T_1- Control	9.45	2.94	12.39	12.41	2.91	15.32
T_2- Unique @ 20 ml	9.65	2.98	12.63	13.20	3.15	16.35
T_3- Unique @ 25 ml	10.25	3.26	13.51	13.98	3.86	17.84
T_4- Unique @ 30 ml	11.38	3.65	15.03	14.84	4.21	19.05
CD @ 5%	**0.37**	**0.98**	**0.98**	**0.29**	**0.06**	**0.26**
Sig	**	**NS**	**	**	**	**

Biochemical parameters in grape berries

Phenol content in grape berries was relatively higher in T3 (0.54 mg/g) while it was lowest in T2 (0.44 mg/g) treatment (Table 5). The maximum protein content was recorded in T4 (14.50 mg/g) followed by T3 (14.28 mg/g) while minimum in T1 (12.70 mg/g). Reducing sugar varied significantly among the different treatments. The treatment T4 recorded higher concentration (293.47 mg/g) followed by T3 (287.92 mg/g) whereas T2 recorded lowest reducing sugar (263.63 mg/g). The maximum calcium content in grape berries was recorded in treatment T4 (48.01 ppm) followed by T3 (44.86 ppm) while minimum calcium content was recorded in T1 control (36.91 ppm). At full bloom and veraison stage of berry development, the phosphorus content was non-significant at ICAR-NRCG.Similar trend was reported in Walwa. Except, significant difference recorded for phosphorus content while, treatment T1 showed lowest phosphorus at full bloom and veraison (0.521 and 0.299 % respectively). There was positive correlation between phosphorus (%) and fruitful canes (1.000). Phenolic compounds are a crucial class of plant metabolites involved in a wide range of physiological processes making them essential for plant health and development (Martínez-Lorente et al., 2024). Research indicated that the use of biostimulants can significantly increase the accumulation of phenolic compounds in various plant tissues, including fruits, leaves and roots, across numerous crops (Martínez-Lorente et al., 2024). This enhancement in phenolic content plays a key role in supporting fruit maturation, maintaining sugar levels and boosting the concentrations of beneficial compounds such as anthocyanins and polyphenols (Salvi et al., 2015). Among the various biostimulants, seaweed extracts have shown effectiveness in enhancing phenolic content in grapevines which is essential for improving fruit quality and antioxidant properties (Irani et al., 2021). These extracts stimulate key enzymes involved in phenolic metabolism, resulting in a marked increase in phenolic concentrations in grape berries (Nardi et al., 2016). Additionally, biostimulants contribute to optimizing nitrogen metabolism, a fundamental process in protein synthesis. Enhanced nitrogen availability, especially during the bloom phase has been associated with higher protein levels in plant tissues (Shahrajabian et al., 2021). Protein hydrolysates a type of bio stimulant is particularly effective at supplying amino acids, directly supporting protein synthesis in grapevines (Nardi et al., 2016). Bio stimulants also play a significant role in promoting sugar accumulation in grapevines, particularly under stress conditions. For example, seaweed extracts have been shown to increase total soluble solids (TSS) including reducing sugars in grapevines subjected to drought stress (Irani et al., 2021). The interplay between nitrogen availability and light exposure during the veraison phase is critical for sugar accumulation with biostimulants helping to regulate these factors leading to improved sugar levels during this vital stage of development (Sharma et al., 2023). In terms of mineral uptake, biostimulants contribute to better grape quality by increasing berry weight and reducing acidity (Irani et al., 2021). Seaweed extracts and humic substances in particular, promote root hair development, improving the absorption of essential nutrients such as calcium and phosphorus (Nardi et al., 2016; Irani et al., 2021). Phosphorus is a key nutrient for plants, facilitating energy transfer through the formation of ATP and other nucleotide triphosphates. It is essential for the synthesis of critical molecules such as sucrose, phospholipids, cellulose and nucleic acids (DNA and RNA), which are crucial for maintaining the structural integrity and functionality of the protoplasm, nucleus and cell walls. Phosphorus mobility within the plant allows for its efficient translocation, ensuring that it reaches all parts of the plant to sustain essential cellular activities (El-Boray et al., 2007). Proper nutrient absorption, especially of phosphorus and calcium is vital for healthy plant growth as these nutrients are required for the production of essential metabolites and enzymes and serve as cofactors in various physiological processes. Numerous studies have shown that biostimulants can significantly enhance the uptake of phosphorus (P) and calcium (Ca) in fruit crops promoting better growth and higher yields (Martínez-Lorente et al., 2024).

Table 5: Effect of Unique on biochemical parameters of Nanasaheb Purple Seedless grapes

Treatments	Phenol mg/g	Protein mg/g	Reducing sugar mg/g	Calcium (ppm)	Phosphorus (%) full bloom	Phosphorus (%) at veraison
Pune location						

T_1- Control	0.46	12.70	281.66	36.91	0.795	0.273
T_2- Unique @ 20 ml	0.44	13.70	263.63	37.24	0.507	0.286
T_3- Unique @ 25 ml	0.54	14.28	287.92	44.86	0.523	0.309
T_4- Unique @ 30 ml	0.51	14.50	293.47	48.01	0.501	0.298
CD at 5%	**0.03**	**0.35**	**9.68**	**1.80**	**0.022**	**0.03**
Sig	**	**	**	**	**NS**	**NS**
Sangli location						
T_1- Control	0.49	13.80	285.00	38.20	0.521	0.299
T_2- Unique @ 20 ml	0.46	14.50	267.25	39.65	0.527	0.308
T_3- Unique @ 25 ml	0.57	16.40	290.35	46.28	0.539	0.312
T_4- Unique @ 30 ml	0.54	16.82	295.18	50.02	0.565	0.319
CD at 5%	**0.014**	**0.40**	**6.95**	**1.42**	**0.014**	**0.008**
Sig	**	**	**	**	**	**

Shelf life **(explained PLW but heading is shelf life clarify it, if it is shelf life define the criteria used for shelf life)**

The data on shelf life of grapes in terms of PLW (%) during storage at room temperature is presented in Fig. 1. In all the treatments, the PLW (%) increased with the advancement in storage duration. The minimum PLW was recorded in T4 from 1st day (1.53 %), 2nd day (2.28 %), 3rd day (3.35 %), 4th day (3.87 %) and 5th day (5.52 %). The PLW in grape berries of control treatment increased rapidly from 1st day (1.78 %), 2nd day (2.50 %), 3rd day (3.81 %), 4th day (4.45 %) and 5th day (5.91 %) at ICAR-NRCG.A broadly similar trend yet with difference in values was found at Walwa. The data recorded on pedicel thickness and skin thickness of fresh grape berries is presented in Fig. 2. Pedicel thickness was relatively higher in T4 (0.540 mm) while it was lowest in T1 (0.500 mm) treatment. The treatment T4 also recorded maximum skin thickness (0.190 mm) while it was minimum in T2 (0.175 mm) at ICAR-NRCG.A more or less similar trends with different values was recorded at Walwa. The results of the present study indicated the importance of use of Unique in improving berry quality of grapes. In their study, Deshmukh et al. (2023) further noted that the maximum skin thickness was observed in biostimulant-treated vines, which significantly extended the storage life of grapes compared to untreated ones. Biostimulants appear to activate various lipid peroxidation processes and defense-related enzymes, which are key to preserving berry firmness. As a result, fruit drop is reduced, physiological weight loss is minimized and berry decay is prevented during the storage period (Liu et al., 2016; Zaharah et al., 2012; Deshmukh et al., 2023; Sharma et al., 2023).

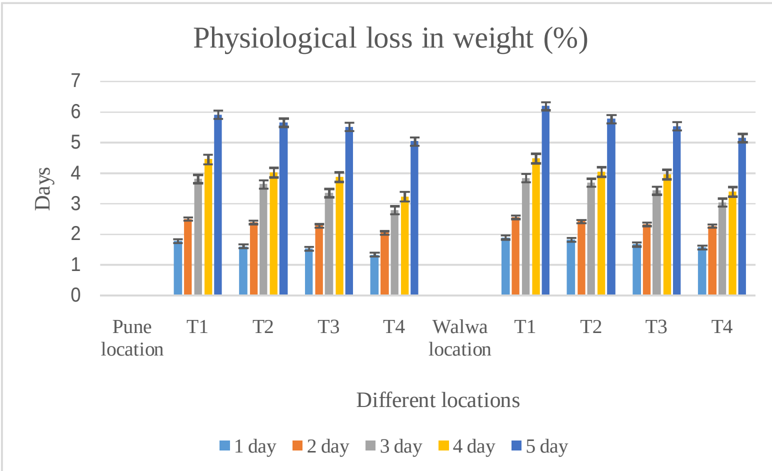

Fig. 1. **Effect of Unique on physiological loss in weight (%) of Nanasaheb Purple Seedless grapes**

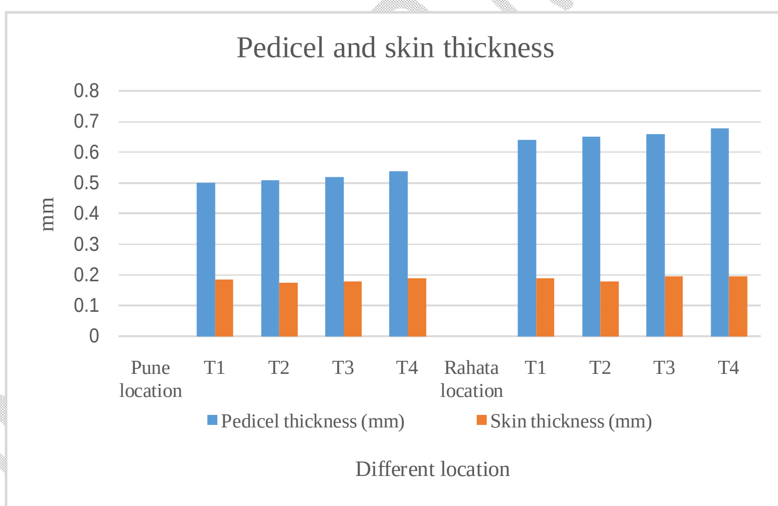

Fig. 2. **Effect of Unique on pedicel thickness (mm) and skin thickness (mm) of Nanasaheb Purple grapes**

Conclusion

The present study demonstrated the effectiveness of the Unique (biostimulant) in improving the growth, yield and shelf life of Nanasaheb Purple Seedless grapes through a multilocation trial. The research showed that applying Unique at different growth stages significantly boosts berry quality, bunch weight and overall yield. The best results were achieved with a 30 ml dose applied at five different stages, 1st - after 12 to 13 days of fruit pruning, 2nd after 23 to 25 days of fruit pruning, 3rd on 75 to 100% flowering stage, 4th on 100% setting of fruits stage (2 mm Berry Size) and 5th after 8 to 10 days (100% setting of fruits stage). However, unique was found an effective tool for improving grape quality and productivity, offering a sustainable solution for grape growers.

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