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Effect of Novel Plant Growth Regulators and Fruit Bagging on Yield and Shelf Life of Guava (*Psidium guajava* L.)

Gourav Gupta [a++*], Gurjar P.K.S [a#], Naruka I.S [a†], Ausari P.K. [a++], Nagar B.L [a++], Yadav R.K [a++] and Ramprakash Chandravanshi [a++]

[a] *Department of Horticulture, RVSKVV, Gwalior, Madhya Pradesh, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present investigation was carried out to identify the effect of novel Plant Growth Regulators and fruit bagging techniques on the yield and shelf life of guava cv Gwalior-27. Yield and shelf life parameters such as yield tree^{-1}, yield hectare^{-1}, yield hectare^{-1}, physiological loss in weight, and

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[++] *Ph.D. Research Scholar;*
[#] *Scientist;*
[†] *Professor and Head;*
**Corresponding author: E-mail: gauravkawardha@gmail.com;*

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rotting were analyzed. Brassinosteroids (BRs) have emerged as pleiotropic phytohormone owing to their wide function in crop growth and metabolism. Homo brassinolide (HBR) being an analogue of BRs is known to improve the growth, yield and quality parameters in many crop plants. Salicylic acid is accepted as safe and natural chemical compound for pre and post-harvest application on fruits to delay ripening, softening and reduction in lipid peroxidation and chilling injury in fruits. The experiment was laid in Factorial Randomized Block Design with 20 treatment combinations. It was observed that treatment combination P_3B_3 (Brassinosteroid (1.5 ppm) + White polyethylene bag) produced the maximum yield, while the maximum shelf life of guava fruits was attained in treatment combination P_5B_3 (Salicylic acid 600ppm + White polyethylene bag).

Keywords: Fruit bagging; guava; novel PGRs; shelf life; yield.

1. INTRODUCTION

Guava (*Psidium guajava* L.) is very popular fruit. Its available throughout the year except during the summer season. Guava commonly referred to as the "apple of the tropics" or "poor man's apple," is one of the most widely grown fruits in tropical and subtropical climates. India produced 5.59 million metric tons of guava across 359,000 hectares of land in 2023. It is indigenous to Tropical America, which stretches from Mexico to Peru, and is a member of the Myrtaceae family with chromosome number 2n= 22 (Radha and Mathew, 2007). It is a perishable and has a short postharvest shelf life at environment temperature due to climacteric ripening with changes in physicochemical properties. Early in the 17th century, the Portuguese brought the plant to the Indian subcontinent. However, at the moment, the main nations that produce guavas are Mexico, Indonesia, Brazil, Bangladesh, China, Thailand, India, and Pakistan. But given its accessibility, abundance of nutrients, and affordability for the average person, the fruit appears to be indigenous to India (Dinesh and Vasugi, 2010). India is the major producer of guava fruit in the world and it shares about 45 % of total production of guava. A selection of Guava variety Gwalior 27 comes from the Allahabadi Safeda Seedlings. The fruits are medium to medium-sized, with thick flesh, few seeds, cream white color, acid sweetness, and good quality.

In guava plants, the induction of flowers is significantly facilitated by plant growth regulators. The ovary enlarges and fruit development is initiated by the process of pollination and fertilization, which also causes the ovary to produce growth regulators. Brassinosteroids (BRs) have emerged as pleiotropic phytohormone owing to their wide function in crop growth and metabolism. Homo brassinolide (HBR) being an analogue of BRs is known to improve the growth, yield and quality parameters in many crop plants. Brassinosteroids are a new group of polyhydroxy steroids that have been recognized as a class of phytohormones. Brassinosteroids play prominent roles in many developmental processes including the increase of cell elongation, pollen tube growth, flowering, fruit set senescence, abscission and maturation (Swamy and Rao, 2008). Brassinosteroids (BRs) are a group of polyhydroxylated steroidal phytohormones that are required for the development, growth, and productivity of plants.

Moreover, Pre-harvest bagging significantly protects the fruit from biotic and abiotic stresses such as incidence of pests, birds damage, risk of microbial pathogens and disease incidence in fruit, physical and mechanical damage (Teixeira et al., 2011) (Jia et al., 2005; Sharma et al*.,* 2013) (Hofman et al., 1997). On tree fruit bagging influences quality of guava harvested at different maturity stages during summer. Fruit fly infestation adversely affects guava crop especially during summer and resulted in significant economic losses. Therefore, the current experiment focuses on the improvement of yield and shelf life of guava fruits by application of novel PGRs and fruit bagging techniques.

2. MATERIALS AND METHODS

2.1 Experimental Site

The current research was performed in the field of Horticulture Research Orchard, Department of Horticulture, College of Agriculture, RVSKVV, Gwalior (M.P.). The research was conducted during 2022-23 and 2023-24. Gwalior lies at 26^0 13' N latitude and 78^0 14' E longitudes at an altitude of 211.5 m above mean sea level in Gird region. It experiences subtropical climate with summer temperature exceeding 45 ^{0}C in May-June, while the winters are too cold with chilling temperature as low as 2^0C in December and January. The annual rainfall ranges between 650 to 751 mm, most of which received from end of June to end of September. Drought is the common feature due to the scanty and uneven distribution of rainfall. The soil of experimental area was sandy loam having good drainage.

2.2 Experimental Layout

The experiment was laid in Factorial Randomized Block Design with 20 treatment combinations of novel Plant Growth Regulators and fruit bagging techniques with control. The treatment combination is presented in Table 1.

2.3 Experimental Procedure

2.3.1 Number of fruits plant^{-1}

The total number of fruits harvested from each plant was counted and average fruits per plant were also computed.

2.3.2 Yield tree^{-1} (kg)

The fruit of each plant were weighed separately by digital weighing balance and recorded at each picking.

2.3.3 Yield hectare^{-1} (q)

The yield per hectare were calculated in quintal per hectare by calculating total number of plants per hectare and multiplied with average yield per plant.

2.3.4 Physiological loss in weight (%)

Fruits from each treatment were taken to record the physiological loss in weight. The weight of the fruits was recorded using electronic weighing balance (model: Essae, DS-852, Teraoaka Ltd.) before storage. Thereafter, the weights were recorded at two days interval during storage and the cumulative PLW was calculated with the following formula.

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

2.3.5 Rotting (%)

The number of days the mature guava fruits were in edible condition was taken as the shelf life or keeping quality of fruits.

Table 1. Treatment combination

S. No.	Notation	Treatment combination
1	P_1B_1	Control
2	P_1B_2	News paper
3	P_1B_3	White polyethene bag
4	P_1B_4	Brown paper bag
5	P_2B_1	Brassinosteroid (0.75 ppm)
6	P_2B_2	Brassinosteroid (0.75 ppm) + News paper
7	P_2B_3	Brassinosteroid (0.75 ppm) + White polyethylene bag
8	P_2B_4	Brassinosteroid (0.75 ppm) + Brown paper bag
9	P_3B_1	Brassinosteroid (1.5 ppm)
10	P_3B_2	Brassinosteroid (1.5 ppm) + News paper
11	P_3B_3	Brassinosteroid (1.5 ppm) + White polyethylene bag
12	P_3B_4	Brassinosteroid (1.5 ppm) + Brown paper bag
13	P_4B_1	Salicylic acid (400 ppm)
14	P_4B_2	Salicylic acid (400 ppm) + News paper
15	P_4B_3	Salicylic acid (400 ppm) + White polyethylene bag
16	P_4B_4	Salicylic acid (400 ppm) + Brown paper bag
17	P_5B_1	Salicylic acid (600 ppm)
18	P_5B_2	Salicylic acid (600 ppm) + News paper
19	P_5B_3	Salicylic acid (600 ppm) + White polyethylene bag
20	P_5B_4	Salicylic acid (600 ppm) + Brown paper bag

3. RESULTS AND DISCUSSION

3.1 Number of Fruits Plant^{-1}

Through the analysis of the data presented in Table 2 and Fig. 1 it was found that the interaction effect of the two factors i.e. novel PGRs and fruit bagging exerted statistically significant effect on the number of fruits per plant. Maximum number of fruits per plant in the first second and pooled data was recorded in treatment P_3B_3 (Brassinosteroid (1.5 ppm) + White polyethylene bag) with 152.07, 157.30 and 154.68, whereas minimum number of fruits per plant in the first, second and pooled data was observed in P_1B_1 (control) with 75.11, 80.80 and 77.95 respectively. The findings are in accordance with Cao et al*.* (2005) who reported that at the organism level, brassinosteroids promote overall growth, reproductive development, shorten the period of vegetative growth, increase crop yield and improve the quality of fruits in Arabidopsis. The results are also in agreement with Sharma et al*.* (2020) observed the effects of five different types of bags on the rainy-season crop of 'Allahabad Safeda' guava. All bags significantly advanced fruit maturity and improved fruit weight, texture, visual appeal, quality, and functional attributes over unbagged (control) fruits.

3.2 Yield Tree^{-1} (kg)

Through the evaluation of the data presented in Table 3 and Fig. 2 it was found that the highest yield per tree in the first, second and pooled data was obtained in treatment P_3B_3 (Brassinosteroid (1.5 ppm) + White polyethylene bag) with 43.79, 40.45 and 42.12 (kg), whereas minimum yield per tree in the first, second and pooled data was recorded in P_1B_1 (control) with 22.05, 21.27 and 21.66 respectively. The findings are in accordance with Rajan et al*.* (2017) who found that post-shooting spray of banana bunches with brassinosteroid at the rate of 2.0 mg L-1 resulted in a yield of 114.46 t ha^{-1} in cultivar Grand Naine as against 84.24 t ha^{-1} in control. The improvement in yield was attributed to the effect of brassinosteroids on cell elongation by increasing the cell permeability to water and osmotic solutes of the cells.

Table 2. Interaction effect of novel PGR's and fruit bagging on Number of fruits per plant of guava during 1st year, 2nd year and polled data

	Number of fruits per plant Novel PGR's 1st year				
Fruit bagging	**P_1**	**P_2**	**P_3**	**P_4**	**P_5**
B_1	75.11	142.90	138.71	132.45	136.59
B_2	119.29	143.62	147.12	131.85	138.81
B_3	131.52	146.21	152.07	136.91	141.17
B_4	123.20	142.66	149.41	134.53	139.57
	2nd year				
B_1	80.80	145.46	138.57	133.21	139.24
B_2	123.13	146.35	149.29	134.14	140.28
B_3	134.50	146.04	157.30	139.50	143.82
B_4	127.10	143.83	152.10	136.26	142.11
	Pooled data				
B_1	77.95	144.18	138.64	132.83	137.92
B_2	121.21	144.99	148.20	133.00	139.55
B_3	133.01	146.12	154.68	138.21	142.50
B_4	125.15	143.24	150.76	135.39	140.84
	1st year		**2nd year**		**Pooled**
SE(M)	5.86		6.43		6.14
CD (5%)	16.78		18.41		17.58

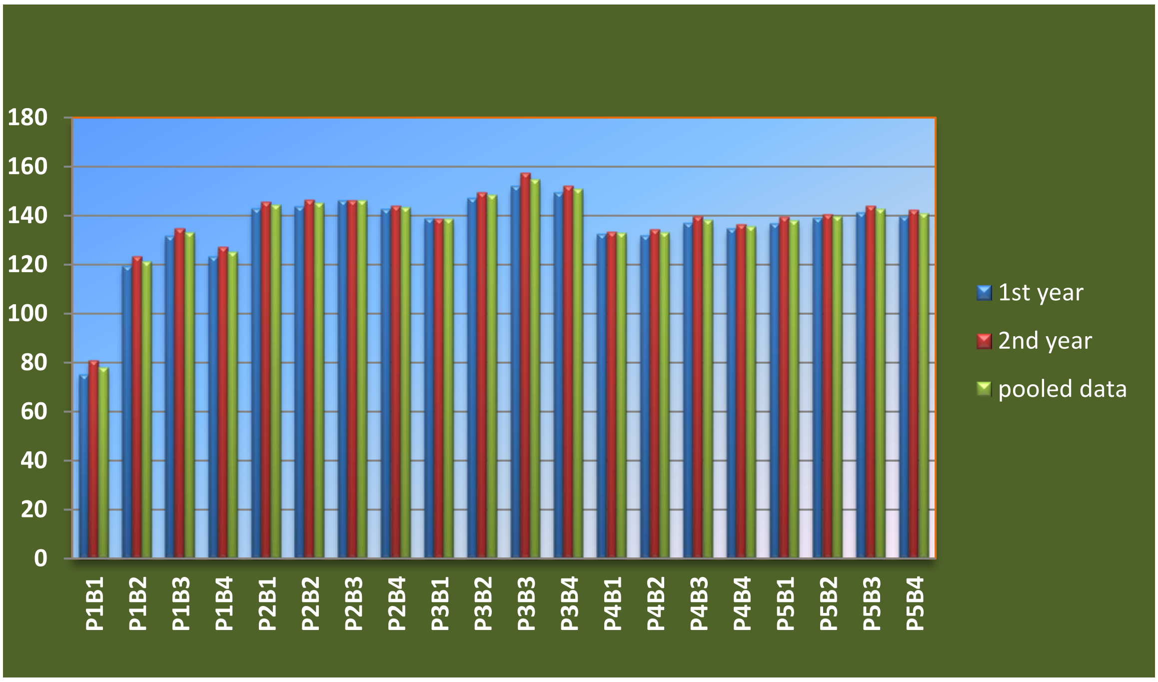

Fig. 1. Interaction effect of novel PGR's and fruit bagging on number of fruit per plant of guava

Table 3. Interaction effect of novel PGR's and fruit bagging on Yield per tree of guava during 1st year, 2nd year and polled data

	Yield per trees Novel PGR's 1st year				
Fruit bagging	**P_1**	**P_2**	**P_3**	**P_4**	**P_5**
B_1	22.05	31.85	32.22	29.63	29.68
B_2	25.36	33.75	34.97	31.62	31.52
B_3	28.96	34.59	43.79	30.51	32.33
B_4	26.80	34.54	37.13	31.39	32.05
	2nd year				
B_1	21.27	33.98	33.96	30.73	30.32
B_2	26.91	33.83	34.95	31.30	31.50
B_3	30.15	35.08	40.45	32.83	33.73
B_4	27.52	33.73	37.31	31.51	31.88
	Pooled data				
B_1	21.66	32.92	33.09	30.18	30.00
B_2	26.13	33.79	34.96	31.46	31.51
B_3	29.06	34.84	42.12	31.67	33.03
B_4	27.66	34.14	37.22	31.45	31.97
	1st year		**2nd year**		**Pooled**
SE(M)	**1.349**		**1.609**		**1.351**
CD (5%)	**3.862**		**4.606**		**3.867**

3.3 Yield Hectare^{-1} (q)

The examination of the data presented in Table 4 and Fig. 3 revealed that the maximum yield per hectare in the first, second and pooled data was found in treatment P_3B_3 (Brassinosteroid (1.5 ppm) + White polyethylene bag) with 184.17, 171.04 and 176.60 (q), while the minimum yield per hectare in the first, second and pooled data was recorded in P_1B_1 (control) with 92.23, 89.99

and 99.32 (q) respectively. The findings are in agreement with Gomes et al*.* 2006 who reported that the application of brassinosteroid analog (BR-3) during a period of reproductive development has increased the yield by 65% in passion fruit over control. It stimulated better accumulation of photosynthates resulting into increased fruit number. Similarly, the increased yield was also observed in Navel orange and sweet cherry due to BRs application by Sugiyama and Kuraishi 1989; Roghabadi and Pakkish 2014. Asrey et al*.* (2011) concluded that under subtropical climatic condition, there is frequent fluctuation in atmospheric humidity and steep variation in day night temperature. This phenomenon makes the pomegranate suture (rind) more prone to cracking. Bagging films act as physical barriers and regulate water loss as well as temperature fluctuation and thus prevents fruit cracking.

3.4 Physiological Loss in Weight (%)

The interaction effect of the two factors i.e. novel PGRs and fruit bagging on the physiological loss in weight of guava fruits presented in Table 5 and Fig. 4 demonstrates that minimum physiological loss in weight of guava fruits was recorded in the combination P_5B_3 (Salicylic acid 600ppm + White polyethylene bag) i.e. (2.98, 4.52 and 5.86) (3.07, 4.59 and 5.85) (3.08, 4.56 and 5.86) respectively throughout 3rd day, 6th day and 9th day of storage in ambient condition in both the year as well as in pooled data. While the maximum physiological loss in weight of guava fruits was recorded in the combination P_1B_1 (control) i.e. (4.23, 6.11 and 7.62) (4.70, 6.13 and 8.12) (4.46, 6.12 and 7.87) respectively throughout 3rd day, 6th day and 9th day of storage in ambient condition in 1st year, 2nd year and in pooled data. The results are in accordance with Arafat (2019) who reported that salicylic acid (SA) different concentrations assessed on mycelial linear growth inhibition (MLGI %) of (*P. capitalensis*) in vitro. Exogenous postharvest treatment of guava fruit with SA tested at five concentrations, three times of immersion and kept for three period time of shelf life. DS per cent evaluated after three period times. Total soluble solids (TSS) and weight loss (WL) evaluated after three period times. The findings are in agreement with Son and Kim, (2010) who examined the effects of bagging periods on berry cracking during development in grape cv. Kyoho and concluded that the berry weight was highest in late period of bagging treated at 7 to 9 weeks after full bloom as compared to the lowest in unbagged fruits. Bagging also critically reduced the fruit cracking rate as compared with the unbagged treatments.

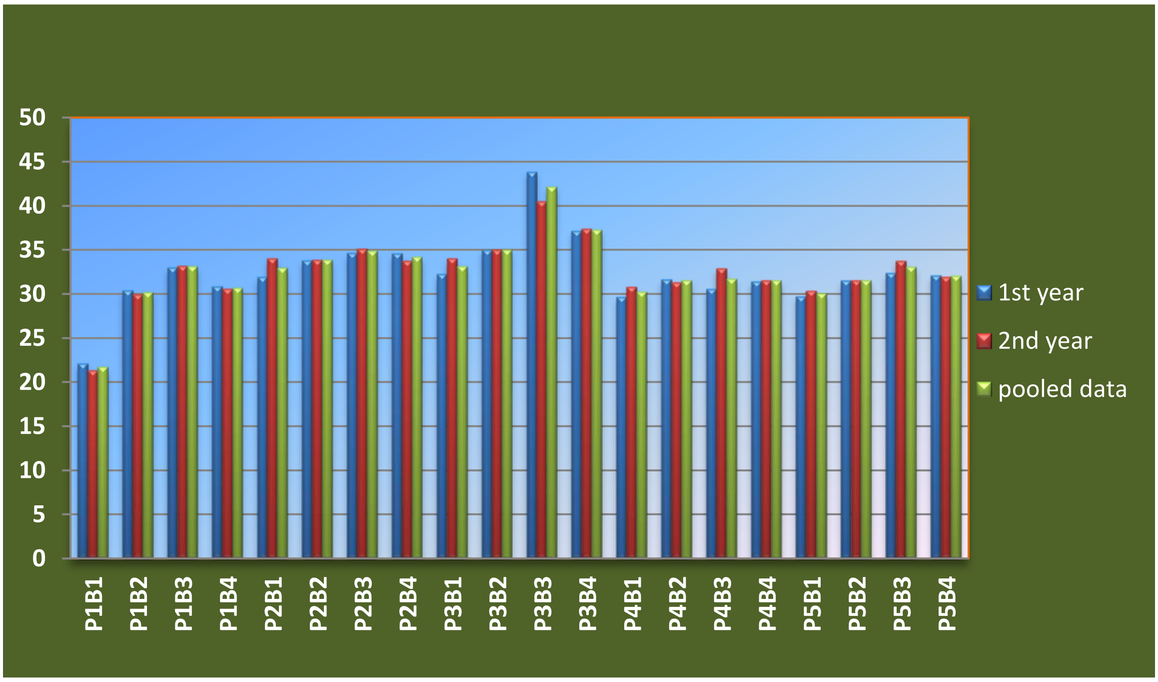

Fig. 2. Interaction effect of novel PGR's and fruit bagging on yield per tree of guava

Table 4. Interaction effect of novel PGR's and fruit bagging on Yield per hectare of guava during 1st year, 2nd year and polled data

	Yield per hectare				
	Novel PGR's				
	1st year				
Fruit bagging	P_1	P_2	P_3	P_4	P_5
B_1	92.23	136.44	137.57	127.56	127.72
B_2	130.45	144.00	148.57	134.15	135.37
B_3	134.98	151.74	184.17	135.07	138.35
B_4	132.22	147.20	157.55	134.58	136.03
	2nd year				
B_1	89.99	144.92	144.84	131.93	130.24
B_2	132.65	144.30	148.37	134.21	135.03
B_3	136.96	149.35	171.04	140.34	143.93
B_4	131.15	144.77	159.18	135.07	136.53
	Pooled data				
B_1	99.32	147.67	148.20	138.73	147.28
B_2	134.55	147.15	151.52	137.19	138.07
B_3	135.55	151.36	176.60	138.70	142.14
B_4	134.67	148.57	161.35	137.83	139.31
	1st year		2nd year		Pooled
SE(M)	5.257		6.269		5.211
CD (5%)	15.049		17.947		14.918

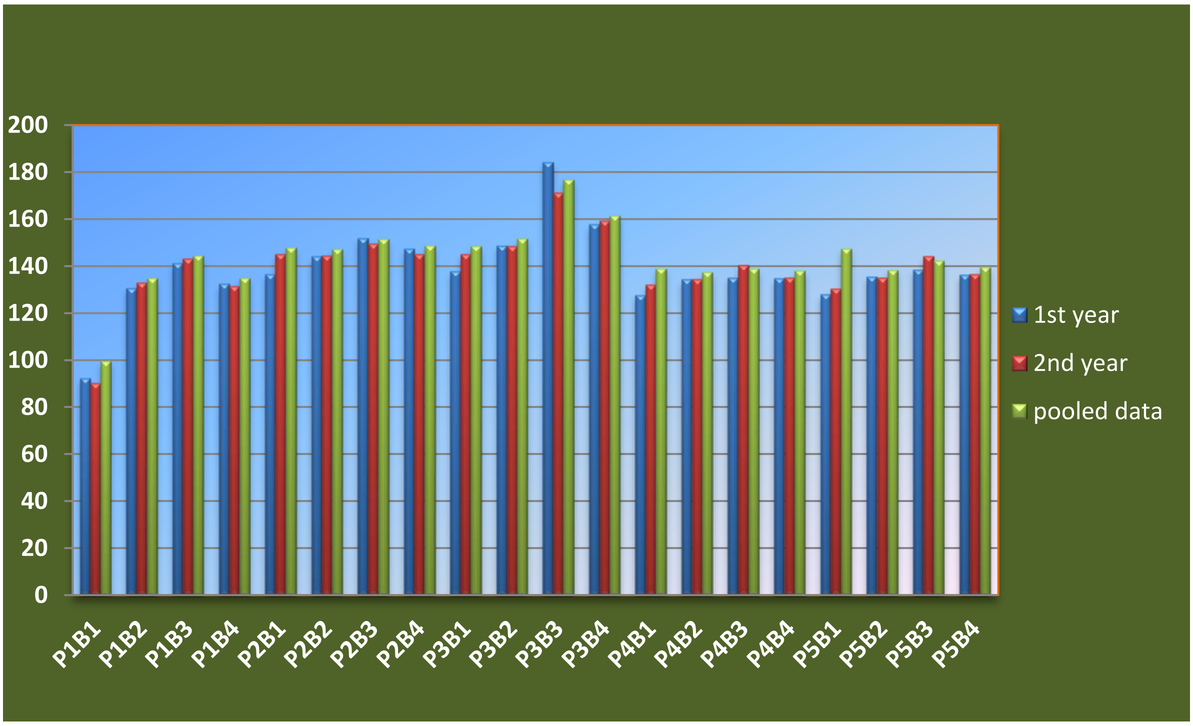

Fig. 3. Interaction effect of novel PGR's and fruit bagging on yield per hectare (q) of guava

Table 5. Interaction effect of novel PGR's and fruit bagging on physiological loss in weight of guava during 1st year, 2nd year and polled data

Fruit bagging	Physiological loss in weight (%)														
	3rd day					6th day					9th day				
	Novel PGR's														
	P_1	P_2	P_3	P_4	P_5	P_1	P_2	P_3	P_4	P_5	P_1	P_2	P_3	P_4	P_5
B_1	4.23	4.08	3.73	3.45	3.27	6.11	5.63	5.31	4.92	4.80	7.62	6.97	6.64	6.26	6.15
B_2	4.32	3.93	3.65	3.41	3.12	5.86	5.47	5.19	4.96	4.68	7.21	6.82	6.53	6.30	6.03
B_3	4.18	3.81	3.53	3.34	2.98	5.73	5.39	5.08	4.85	4.52	7.07	6.72	6.42	6.20	5.86
B_4	4.26	3.88	3.58	3.38	3.06	5.81	5.42	5.13	4.86	4.60	7.15	6.77	6.47	6.22	5.95
	2nd year														
B_1	4.70	4.22	3.89	3.59	3.41	6.13	5.83	5.51	5.12	5.01	8.12	7.47	7.10	6.82	6.67
B_2	4.44	4.05	3.76	3.53	3.26	5.89	5.67	5.38	5.16	4.88	7.40	7.00	6.85	6.67	6.39
B_3	4.38	4.00	3.70	3.49	3.07	5.75	5.58	5.28	5.06	4.59	7.06	7.12	6.59	6.45	5.85
B_4	4.31	3.96	3.66	3.44	3.19	5.81	5.62	5.32	5.07	4.80	7.24	6.88	6.71	6.49	6.20
	Pooled data														
B_1	4.46	4.15	3.81	3.52	3.34	6.12	5.73	5.41	5.02	4.91	7.87	7.22	6.87	6.54	6.41
B_2	4.38	3.99	3.70	3.42	3.19	5.88	5.57	5.29	5.06	4.78	7.31	6.91	6.69	6.49	6.21
B_3	4.28	3.91	3.61	3.47	3.08	5.74	5.48	5.18	4.95	4.56	7.07	6.92	6.51	6.33	5.86
B_4	4.29	3.92	3.62	3.41	3.10	5.81	5.52	5.22	4.97	4.70	7.20	6.83	6.59	6.36	6.08
	1st year		**2nd year**		**Pooled**	**1st year**		**2nd year**		**Pooled**	**1st year**		**2nd year**		**Pooled**
SE(M) ±	0.033		0.031		0.056	0.030		0.035		0.063	0.028		0.058		0.110
CD (5%)	0.094		0.087		0.161	0.086		0.101		0.181	0.080		0.165		0.315

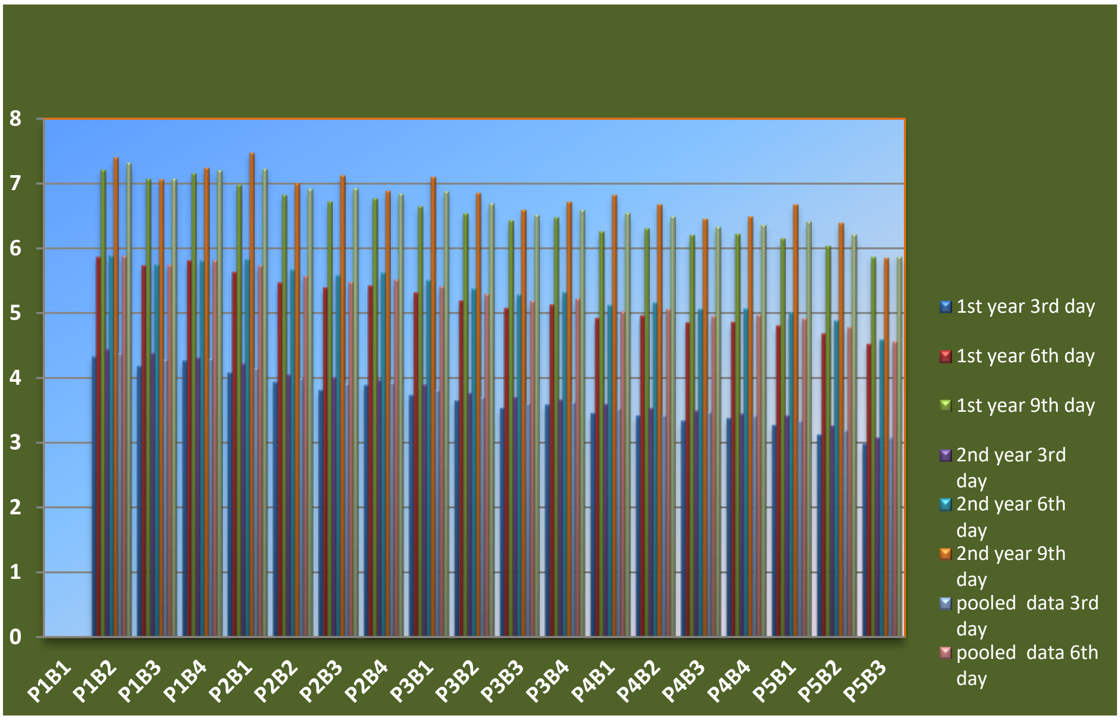

Fig. 4. Interaction effect of novel PGR's and fruit bagging on physiological loss in weight (%)

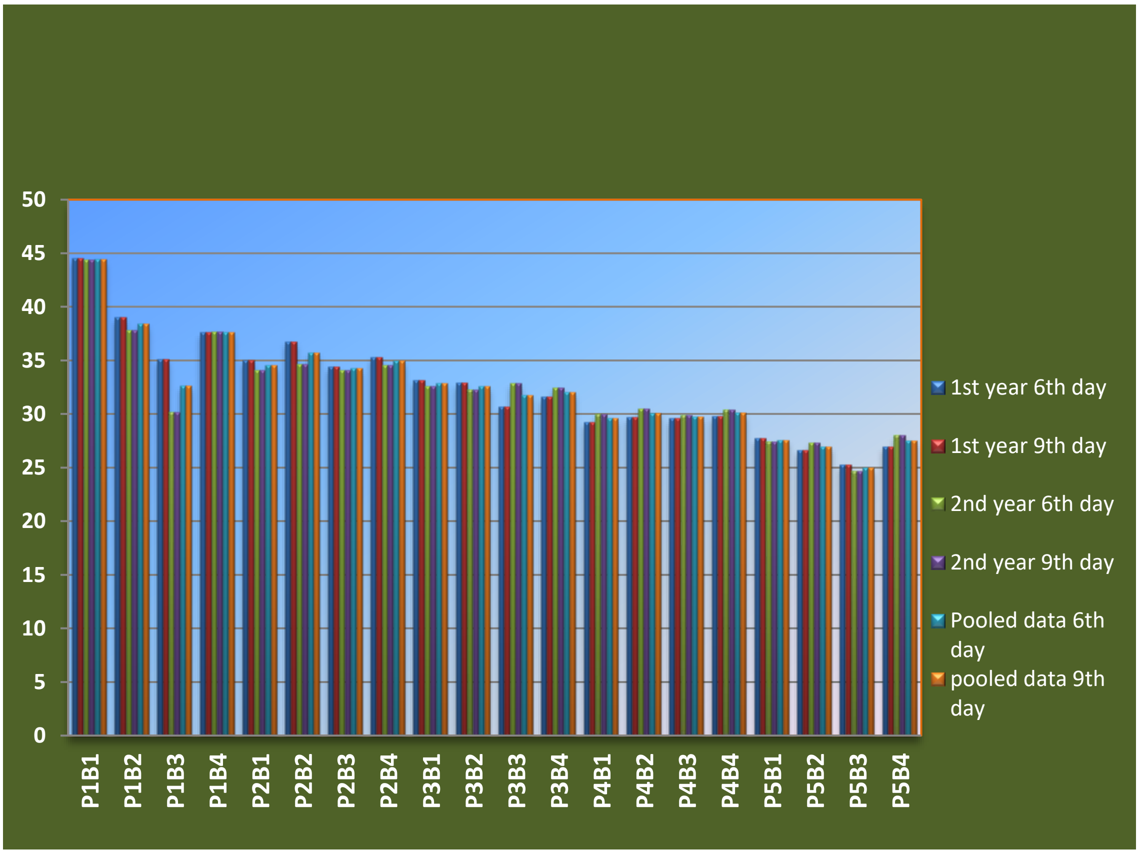

Fig. 5. Interaction effect of novel PGR's and fruit bagging on rotting (%) of guava

Table 6. Interaction effect of novel PGR's and fruit bagging on rotting percentage of guava during 1st year, 2nd year and polled data

Fruit bagging	Rotting %														
	3rd day					6th day					9th day				
	Novel PGR's														
	P_1	P_2	P_3	P_4	P_5	P_1	P_2	P_3	P_4	P_5	P_1	P_2	P_3	P_4	P_5
B_1	-	-	-	-	-	32.42	23.76	22.11	18.71	17.70	44.52	35.00	33.11	29.22	27.70
B_2	-	-	-	-	-	25.04	23.97	20.55	19.17	16.60	38.97	36.73	32.89	29.67	26.60
B_3	-	-	-	-	-	23.11	23.32	19.64	19.28	15.27	35.11	34.40	30.64	29.58	25.23
B_4	-	-	-	-	-	26.32	23.79	21.46	12.35	17.80	37.58	35.29	31.58	29.77	26.93
	2nd year														
B_1	-	-	-	-	-	32.48	22.57	21.57	19.43	17.40	44.347	34.067	32.567	29.933	27.400
B_2	-	-	-	-	-	26.31	23.13	21.23	19.93	17.27	37.800	34.633	32.233	30.433	27.267
B_3	-	-	-	-	-	18.10	23.80	21.63	19.37	14.77	30.133	34.067	32.833	29.867	24.667
B_4	-	-	-	-	-	26.00	23.03	21.67	19.90	18.00	37.667	34.533	32.427	30.400	28.000
	Pooled data														
B_1	-	-	-	-	-	32.45	23.17	21.84	19.07	17.55	44.43	34.54	32.84	29.58	27.55
B_2	-	-	-	-	-	25.67	23.55	20.89	19.55	14.98	38.39	35.68	32.56	30.05	26.93
B_3	-	-	-	-	-	25.20	23.56	20.89	19.32	15.02	32.62	34.23	31.74	29.72	24.95
B_4	-	-	-	-	-	26.16	23.41	21.56	19.44	17.90	37.62	34.91	32.00	30.09	27.47
	1st year		**2nd year**		**Pooled**	**1st year**		**2nd year**		**Pooled**	**1st year**		**2nd year**		**Pooled**
SE(M) ±						1.576		1.274		2.029	0.990		1.590		0.876
CD (5%)						4.513		3.648		5.808	0.279		4.552		2.509

3.5 Rotting (%)

The interaction effect of the two factors i.e. novel PGRs and fruit bagging on the total sugar shown in Table 6 and Fig. 5 reveals that the minimum rotting was found in the combination P_5B_3 (Salicylic acid 600ppm + White polyethylene bag) i.e. (0, 15.27 and 25.23) (0, 30.13 and 24.66%) (0, 15.02 and 24.95%) in the first, second and pooled data respectively. While the maximum total rotting was found in the combination P_1B_1 (control) i.e. (0, 32.42 and 44.52%) (0, 32.48 and 44.34%) (0, 32.45 and 44.43%) in the first year, second year and pooled data respectively. The findings are in accordance with Baliga et al*.* (2011) who reported that the loss in moisture causes a rapid rise in the concentration of sugars, leading to the maturation of the fruit. Salicylic acid can improve physical properties of fruits such as size in Thompson seedless grapevine. Pre-harvest spray of salicylic acid on Thompson Seedless grape increased cluster weight, length, and berry shape index compared to the control. Abbasi et al*.* (2018) noticed that bagging techniques can protect fruits from pests and eliminates the use of pesticides, thus improves the quality of fruit, by different materials viz. newspaper bags, perforated polyethylene bags, muslin cloth bags and netted cloth bags used for on-tree bagging of guava fruit to improve fruit quality.

4. CONCLUSION

The evaluation of the effect of novel Plant Growth Regulators and fruit bagging on the yield and shelf life parameters of guava revealed that treatment combination P_3B_3 (Brassinosteroid (1.5 ppm) + White polyethylene bag) exerted most significant effect on the yield of guava, whereas treatment combination P_5B_3 (Salicylic acid 600ppm + White polyethylene bag) was found most significant in the enhancement of shelf life of guava fruits. Therefore, it can be concluded that Brassinosteroids can applied to enhance the yield of guava along with suitable fruit bagging technique. Salicylic acid combined with fruit bagging plays an important role in reducing the physiological loss in weight and rotting of fruits. Further studies should be performed to analyze the impact of different novel PGRs and fruit bagging materials on yield and shelf life of different fruits.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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