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B Lakshmi Devi
Department of Fruit Science, Dr. Y.S.R.H.U-College of Horticulture, Dr. YSR Horticultural University Anatharajupeta, Annamayya, Andhra Pradesh, India

KT Venkata Ramana
Principle scientist and Head, Department of Horticulture Horticulture Research Station Anatharajupeta, Annamayya, Andhra Pradesh, India

VNP Sivarama Krishna
Professor, Department of Fruit Science, College of Horticulture, Pulivendhula, YSR Kadapa, Andhra Pradesh, India

D Sreedhar
Senior Scientist, Department of Horticulture Horticulture Research Station Anatharajupeta, Annamayya, Andhra Pradesh, India

G Sarada
Assistant professor, Department of Entomology Dr. Y.S.R.H.U-college of Horticulture, Dr. YSR Horticultural University Anatharajupeta, Annamayya, Andhra Pradesh, India

Y Sharath Kumar Reddy
Scientist, Department of Plant Physiology, Horticulture Research Station, Anatharajupeta, Annamayya, Andhra Pradesh, India

Corresponding Author:
B Lakshmi Devi
Department of Fruit Science, Dr. Y.S.R.H.U-College of Horticulture, Dr. YSR Horticultural University Anatharajupeta, Annamayya, Andhra Pradesh, India

Effect of different bagging materials on fruit physical parameters in mango cv. Banganpalli

B Lakshmi Devi, KT Venkata Ramana, VNP Sivarama Krishna, D Sreedhar, G Sarada and Y Sharath Kumar Reddy

Abstract
A field investigation was conducted to improve the quality of mango cv. Banganpalli fruits through bagging at Dr. YSRHU-College of Horticulture, Anantharajupeta, Dr. YSR Horticultural University, Andhra Pradesh during April 2022 and April 2023 of two successive years. Various Bagging material *i.e*, Nylon, Organza, News-paper, Two-layered yellow, brown and reddish brown colour, Butter paper, Polythene, Zip lock, Polythene coated brown paper bags were used for the study and uncovered fruits were kept as control. The results revealed that fruit bagging in general, improved the growth and physiological development of mango fruits as compared to Unbagging control. Maximum fruit size was found in Two layered reddish brown colour bag followed by Two layered brown colour and yellow colour bags. Maximum fruit quality parameters *i.e.*, fruit length (12.74 cm), fruit width (9.24 cm), average fruit weight (577.50 g), fruit volume (363.75 ml) and fruit firmness (1.2 kg/cm^2) was recorded under Reddish brown colour bag. Among the various fruit covering materials used, reddish brown coloured bag was found to be the best for overall improvement of quality of mango cv. Banganpalli under tropical climate of Andhra Pradesh.

Keywords: Mango, Banganpalli, bagging material, fruit quality parameters

Introduction
Mango (*Mangifera indica* L.), often hailed as the "King of Fruits," holds a special place in the hearts of most Indians. Belonging to the Anacardiaceae family, it is native to the Indo-Burma region and possesses a chromosome number of 2n=40. Mango cultivation extends to approximately 87 countries worldwide, with India proudly leading the globe in production, contributing a remarkable 40.1% of the total mango yield. In India, mango cultivation spans an area of 2,339 thousand hectares, resulting in a total production of 20,336 thousand tonnes (NHB, 2021-2022) [9].

The primary mango-growing districts in Andhra Pradesh encompass Chittoor, Krishna, Vizianagaram, and Kadapa. Of these, Chittoor takes the lead both in terms of cultivation area and production. In South India, noteworthy varieties include Totapuri, Neelum and Banganpalli (Ravikumar *et al.*, 2013) [10].

In the state of Andhra Pradesh, the predominant commercial mango cultivar is 'Banganpalli,' encompassing approximately 70% of the total mango cultivation area.

Fruit bagging stands as one of the most effective pre-harvest techniques for safeguarding fruit, particularly against threats like fruit fly infestation and fungal diseases. This method ensures the production of high-quality fruits on the tree (Sharma *et al.*, 2014) [14]. Recently, fruit bagging has emerged as an essential component of fruit cultivation for both domestic consumption and export markets in nations like Japan, China, Korea, Australia, and the USA. It is valued for being a secure and environmentally friendly approach to shield fruits from various stressors while preserving or enhancing their overall quality. In the early days, fruits in Korea were initially wrapped in newspaper bags to safeguard them against pest and disease damage. Nowadays, a variety of bagging materials are accessible, promoting the cultivation of high-value organic fruits. In fact, the practice of fruit bagging enhances attributes such as colour, weight, sugar levels, and organic acid content, all of which contribute to the organoleptic quality of the fruit. This process renders the final product more visually appealing compared to the "natural" unbagged fruits. Sarker *et al.* (2009) [12] conducted a study that revealed mango fruits bagged with brown paper exhibited the highest total soluble solids (T.S.S) content and superior physical quality.

Fruit fly infestation is a major problem since it makes fruits contaminated and unfit for sale when they are harvested. In order to tackle this issue and fulfil the export-quality requirements for mangoes, this experiment was designed to examine the efficiency of the bagging method, including the materials and timing employed for the process. In light of the current situation, the study is to evaluate different bagging materials to ascertain their potential to improve fruit quality and protect against infestations by pests and diseases.

Materials and Methods

The details of the material and the methods adopted during the course of investigation are briefly discussed in this chapter. The experiments was carried out at College of Horticulture, Anantharajupeta which falls under tropical zone and geographically situated at a $13^0.98^1$N latitude and $79^0.40^1$E longitude with an altitude of 162 meters (531 feet) above mean sea level (MSL). The experiment was carried out during 2021-2022 and 2022-2023 in Factorial Randomized Block Design (FRBD) comprising of 11 treatments, replicated thrice with three plants per replication @ twenty bags per replication. The treatments are given below.

The Experimental material taken Uniformly grown and physiologically fully developed Banganpalli fruits at two months after fruit set and three months after fruit set were selected for bagging. Different materials of bags are used for fruit bagging purpose. Bagging material used:- Treatment details: T_1 Organza bag, T_2 Nylon bag, T_3 Paper bag, T_4 Two layer yellow colour bag, T_5 Two layer brown colour bag, T_6 Reddish brown colour bag, T_7 Butter paper bag, T_8 Polythene bag, T_9 Zip lock bag, T_{10} Polythene coated brown paper bag, T_{11} control. Six fruits from each treatment were randomly selected immediately after harvesting length and width were measured using digital vernier callipers, their average was computed and expressed in centimetres. The average fruit weight was measured with the help of digital weighing balance and the average fruit weight was calculated and expressed in grams. Other parameters like firmness of fruit was tested with the help of a pocket penetrometer (FR-5120 Digital Fruit Firmness Tester) and fruit volume was recorded by the water displacement method and statistically calculated.

Results and Discussions

Fruit length (cm)

The data pertaining to fruit length of mango as significantly influenced by different bagging material and time of bagging are presented in Table-1

The fruit length differed significantly among different bagging materials during first year, second year as well as pooled analysis. Fruit length was recorded maximum in the treatment (T_6) Reddish brown colour bag (12.40, 13.07 and 12.74 cm) which was comparable with (T_5) Two-layer brown colour bag (12.26, 12.29 and 12.27) and (T_4) Two-layer yellow colour bag (12.23, 12.25 and 12.24 cm) whereas, minimum fruit length (11.15, 11.27 and 11.21 cm respectively) was recorded in T_{11} (control).

Fruit bagging at three months after fruit set (P_2) showed significantly maximum fruit length (12.02, 12.23 and 12.12 cm respectively) during first year, second years as well as in pooled analysis.

The interaction effects of different bagging material and time of bagging were found non-significant effect during both the years and as well as pooled analysis.

The results are in line with findings of Kireeti *et al.* (2018) [7] who reported increased fruit length of mango cv. Kesar significantly by bagging with newspaper bag and brown paper bag over control.

Fruit width (cm)

Data pertaining to fruit width (Tables -2) revealed significant influence by different bagging material and time of bagging during first year, second year as well as in pooled analysis.

Among the different bagging materials and time of bagging showed significant difference during first year and pooled analysis. Whereas, different bagging materials showed non-significant difference in second year. Interaction effect of different bagging materials and time of bagging showed significant difference during first year only.

Maximum fruit width had shown in the treatment (T_6) Reddish brown colour bag (9.34, 9.14 and 9.24 cm) which was on par with (T_5) Two-layer brown colour bag (9.29, 8.99 and 9.24 cm) and (T_4) Two-layer yellow colour bag (9.10, 8.94 and 9.02 cm).

Bagging at three months after fruit set (P_2) showed significantly maximum fruit width (9.20, 8.99 and 9.10 cm respectively) during both the seasons and pooled data.

Among the treatment combinations, maximum fruit width (9.83 cm) was recorded in (T_6P_2) reddish brown colour bag used three months after fruit set, which was statistically at a par with (T_5P_2) two-layer brown colour bag used three months after fruit set (9.48 cm) and (T_7P_2) Butter paper bag used at three months after fruit set (9.39 cm).

Fruit weight (g)

Fruit weight was differed (Table -3 and Fig-1) significantly due to different bagging materials and time of bagging during first year, second year and pooled analysis.

The interaction effect of bagging material and time of bagging showed significant difference during first year and pooled analysis. Whereas, non-significant difference was recorded in second year. Different bagging treatments and time of bagging showed significant difference during first year, second year and as well as in pooled data.

With regard to interactions, highest fruit weight was recorded in the treatment combination of (T_6P_2) reddish brown colour bag used three months after fruit set (638.33, 566.00 and 602.17 g) whereas, lowest fruit weight was recorded in the treatment combination of ($T_{11}P_1$) two months after fruit set in control (393.00, 419.67 and 406.33 g) during first year, second year and pooled data.

Maximum fruit weight had shown in the treatment (T_6) Reddish brown colour bag (6233. 67, 531.33 and 577.50 g) which was on par with the (T_5) Two-layer brown colour bag (599.50, 517.17 and 558.33 g) and (T_4) Two-layer yellow colour bag (59.17, 510.50 and 550.33 g) and lowest fruit weight (468.17, 421.08 and 444.63 g respectively) was recorded in (T_{11}) control during first year, second year and pooled data.

Bagging at three months after fruit set (P_2) was recorded maximum fruit weight (574.67, 494.23 and 534.45 g respectively) during first year, second year and pooled analysis.

In the present study the fruit weight was increased due to the micro-environment of the bagged fruits, which can prevent the impact of adverse environmental factors such as sun burning, rain, germ, insect pests and mechanical damage on the development of fruits. In addition, bagging can provide a relatively moderate high temperature environment for the

fruit, resulting in accelerating the breathing rate of the fruit and a strong cell division occurred and improves the single fruit weight (Huang, 2010) [3].

Fruit weight increase may be due to differences in the light reflectance, absorbance and for transmission patterns in the visible, far-red, and/or infra-red regions of the spectrum as mentioned by Watanawan *et al.* (2008) [16]. Research findings reveals that the increasing of temperature by 0.5°C for exercising bagging in fruit crops increased the rate of fruit development which results in production of fruit having approximately 10-16% greater size and weight. The increased fruit size can be attributed to the microenvironment created by bagging material which might have a congenial effect on fruit growth. Similar observations have been reported by Islam *et al.* (2017) [4], Islam *et al.* (2019) [5], Yang *et al.* (2009) [17], Harhash and AlObeed, (2010) [2] and Zhou *et al.* (2012) [18].

Fruit volume (ml)

The treatment T_6 (Reddish brown colour bag) showed highest fruit volume (446.67 and 363.75, ml) which was on par with (T_5) Two-layer brown colour bag (410.00 and 338.75 ml) and lowest fruit volume was observed in (T_{11}) control (275.00 and 214.17 ml respectively) during second year and pooled data.

As per pooled mean, bagging at three months after fruit set (P_2) showed significantly highest fruit volume (300.00 ml).

Interaction effect of different bagging materials and time of bagging showed non-significant difference during first year of study. Whereas, statistically significant difference was observed during second year and as well as in pooled data. Highest fruit volume was recorded in (T_6P_2) Reddish brown colour bag + three months after fruit set (483.33 and 378.33 ml) which was on par with (T_5P_2) Two-layer brown colour bag + three months after fruit set (468.33 and 365.83 ml) whereas, lowest fruit volume was recorded in ($T_{11}P_1$) control at two months after fruit set (331.36 and 277.20 ml respectively) during second year and pooled data.

Present study findings are in accordance with the findings of Daniells *et al.* (2005) [1] who reported that the higher fruit volume in banana fruits might be due to higher humidity and appropriate microclimate inside the bags, which results in proper growth and development of fruits. Similar observations had been reported by Johnson *et al.* (1994) [6] that bagging on Keitt mango fruit at 91-112 days before harvest increased dry matter accumulation by 2% relative to unbagged. Paper bagging is found influence the weight of fruit by providing the favorable microclimate and pathogen free environment, also acting as thermo resistor which control the temperature and help in cell division and cell expansion which may develop the fruit weight as reported by Muchui *et al.* (2010) [8]. Further, Robinson (1996) [11] attributed the reason for increase in fruit growth due to increase in temperature (0.5 °C) inside the bag.

Fruit firmness (kg/cm^2)

The data pertaining to fruit firmness as influenced by different bagging material and time of bagging and their interaction are presented in Tables of 5 and Fig -2.

During first year and pooled analysis, different bagging material showed significant difference on fruit firmness. Highest fruit firmness was recorded in the treatment T_6 Reddish brown colour bag (3.04 and 2.1 kg/ cm^2) which was on par with T_5 Two-layer brown colour bag (2.51 and 2.5 kg/ cm^2) and lowest fruit firmness was found in T_8 Polythene bag (1.97 and 1.80 kg/ cm^2 respectively). whereas fruit firmness was non-significant when fruit bagging done at different months. Whereas, in interactions highest fruit firmness was found in (T_6P_1) bagging at two months after fruit set with reddish brown colour bag (3.44 and 3.11 kg/cm^2 respectively) and lowest fruit firmness (1.70 and 1.70 kg/cm^2) was observed in the treatment combination of bagging at three months after fruit set with polythene bag (T_8P_2).

The enhanced fruit firmness has positively correlated with extending the shelf life of fruit. Usually, the fruit firmness gradually decreases during ripening process by breakdown of insoluble protopectin into soluble pectin. Preharvest fruit bagging maintains microclimate and also act as a physical barrier by interfering the transpiration rate of the fruit compared to unbagged fruit. Bagging also influences the calcium ion accumulation on the fruit reported by Sharma *et al.* (2013b) [15].

The results are also in conformation with findings of Sharma *et al.* (2013) [13] who reported that pre-harvest fruit bagging with light yellow-coloured bags used in apple also enhanced the synthesis of anthocyanins and the amount of lycopene in apples, leading to an improvement in the fruit's colour and firmness.

Table 1: Fruit length as influenced by different bagging materials and time of bagging during 2021-22, 2022-23 and pooled data.

Fruit length (cm)									
	2021-22			2022-23			Pooled mean		
Treatment/P	P_1	P_2	Mean	P_1	P_2	Mean	P_1	P_2	Mean
T_1	11.42	12.03	11.72	11.77	11.77	11.77	11.60	11.90	11.75
T_2	11.77	11.77	11.77	11.70	12.17	11.94	11.74	11.97	11.85
T_3	11.90	12.10	12.00	11.83	12.64	12.24	11.87	12.37	12.12
T_4	11.97	12.49	12.23	11.80	12.69	12.25	11.88	12.59	12.24
T_5	12.01	12.51	12.26	12.07	12.51	12.29	12.04	12.51	12.27
T_6	12.18	12.63	12.40	12.66	13.48	13.07	12.42	13.05	12.74
T_7	11.70	12.17	11.94	11.92	12.38	12.15	11.81	12.27	12.04
T_8	11.08	11.90	11.49	11.48	11.52	11.50	11.28	11.71	11.50
T_9	11.48	11.52	11.50	11.32	11.88	11.60	11.40	11.70	11.55
T_{10}	11.32	11.88	11.60	11.42	12.03	11.72	11.37	11.95	11.66
T_{11}	11.11	11.18	11.15	11.11	11.42	11.27	11.11	11.30	11.21
Mean	11.63	12.02		11.74	12.23		11.68	12.12	
Source	T	P	T X P	T	P	T X P	T	P	T X P
S.Em±	0.25	0.11	0.36	0.23	0.10	0.32	0.17	0.07	0.25
CD at 5%	0.72	0.31	NS	0.65	0.28	NS	0.50	0.21	NS

*NS – non-significant, P_1- Two months after bagging P_2- Three months after bagging

Table 2: Fruit width as influenced by different bagging materials and time of bagging during 2021-22, 2022-23 and pooled data

Fruit width (cm)									
	2021-22			2022-23			Pooled mean		
Treatment/P	P_1	P_2	Mean	P_1	P_2	Mean	P_1	P_2	Mean
T_1	8.23	9.04	8.64	8.28	9.04	8.66	8.25	9.04	8.65
T_2	8.06	9.36	8.71	8.63	8.88	8.75	8.34	9.12	8.73
T_3	8.31	9.34	8.82	8.96	8.90	8.93	8.64	9.12	8.88
T_4	8.96	9.23	9.10	8.54	9.33	8.94	8.75	9.28	9.02
T_5	9.09	9.48	9.29	8.85	9.12	8.99	8.97	9.30	9.14
T_6	8.85	9.83	9.34	8.93	9.34	9.14	8.89	9.59	9.24
T_7	8.16	9.39	8.77	8.74	8.81	8.78	8.45	9.10	8.77
T_8	8.16	8.67	8.41	8.06	8.74	8.40	8.11	8.70	8.41
T_9	8.03	9.24	8.63	8.17	8.85	8.51	8.10	9.04	8.57
T_{10}	8.03	9.24	8.63	8.03	9.24	8.63	8.03	9.24	8.63
T_{11}	8.37	8.38	8.37	8.16	8.63	8.40	8.27	8.51	8.39
Mean	8.39	9.20		8.49	8.99		8.44	9.10	
Source	T	P	T X P	T	P	T X P	T	P	T X P
S.Em±	0.13	0.06	0.19	0.22	0.09	0.31	0.14	0.06	0.20
CD at 5%	0.37	0.16	0.53	NS	0.26	NS	0.40	0.17	NS

*NS – non-significant, P_1- Two months after bagging P_2- Three months after bagging

Table 3: Fruit weight as influenced by different bagging materials and time of bagging during 2021-22, 2022-23 and pooled data

Fruit weight (g)									
	2021-22			2022-23			Pooled mean		
Treatment/P	**P_1**	**P_2**	**Mean**	**P_1**	**P_2**	**Mean**	**P_1**	**P_2**	**Mean**
T_1	472.33	572.00	522.17	429.00	462.00	445.50	450.67	517.00	483.83
T_2	515.00	548.00	531.50	496.67	505.00	500.83	505.83	526.50	516.17
T_3	576.67	598.00	587.33	484.50	536.33	510.42	530.58	567.17	548.88
T_4	579.67	600.67	590.17	509.67	511.33	510.50	544.67	556.00	550.33
T_5	565.33	633.67	599.50	490.67	543.67	517.17	528.00	588.67	558.33
T_6	609.00	638.33	623.67	496.67	566.00	531.33	552.83	602.17	577.50
T_7	485.00	638.33	561.67	468.00	537.67	502.83	476.50	588.00	532.25
T_8	451.00	494.00	472.50	419.33	461.83	440.58	435.17	477.92	456.54
T_9	432.67	543.33	488.00	420.00	464.67	442.33	426.33	504.00	465.17
T_{10}	505.33	511.67	508.50	464.67	425.48	445.07	485.00	468.57	476.79
T_{11}	393.00	543.33	468.17	419.67	422.50	421.08	406.33	482.92	444.63
Mean	507.73	574.67		463.53	494.23		485.63	534.45	
Source	T	P	T X P	T	P	T X P	T	P	T X P
S.Em±	17.35	7.40	24.54	16.86	7.19	23.84	11.31	4.82	16.00
CD at 5%	49.52	21.11	70.03	48.11	20.51	NS	32.28	13.76	45.65

*NS – non-significant, P_1- Two months after bagging P_2- Three months after bagging

Table 4: Fruit volume as influenced by different bagging materials and time of bagging during 2021-22, 2022-23 and pooled data.

Fruit volume (ml)									
	2021-22			2022-23			Pooled mean		
Treatment/P	**P_1**	**P_2**	**Mean**	**P_1**	**P_2**	**Mean**	**P_1**	**P_2**	**Mean**
T_1	190.00	273.33	231.67	326.67	318.33	322.50	258.33	295.83	277.08
T_2	303.33	173.33	238.33	310.00	320.00	315.00	306.67	246.67	276.67
T_3	205.00	283.33	244.17	346.67	368.33	357.50	275.83	325.83	300.83
T_4	238.33	266.67	252.50	376.67	355.00	365.83	307.50	310.83	309.17
T_5	271.67	263.33	267.50	351.67	468.33	410.00	311.67	365.83	338.75
T_6	288.33	273.33	280.83	410.00	483.33	446.67	349.17	378.33	363.75
T_7	205.00	276.67	240.83	255.00	435.00	345.00	230.00	355.83	292.92
T_8	255.00	200.00	227.50	326.67	318.33	322.50	290.83	259.17	275.00
T_9	120.00	273.33	196.67	310.00	286.67	298.33	215.00	280.00	247.50
T_{10}	190.00	273.33	231.67	351.67	300.00	325.83	270.83	286.67	278.75
T_{11}	186.67	192.66	189.67	280.00	270.00	275.00	233.33	231.34	232.34
Mean	223.03	249.94		331.36	356.67		277.20	300.00	
Source	T	P	T X P	T	P	T X P	T	P	T X P
S.Em±	29.05	12.39	41.08	22.27	9.50	31.50	16.66	7.10	23.56
CD at 5%	NS	NS	NS	63.56	NS	89.89	47.54	20.27	67.24

*NS – non-significant, P_1- Two months after bagging P_2- Three months after bagging

Table 5: Fruit firmness as influenced by different bagging materials and time of bagging during 2021-22, 2022-23 and pooled data.

Fruit firmness (kg/cm^2)									
	2021-22			2022-23			Pooled mean		
Treatment/P	**P_1**	**P_2**	**Mean**	**P_1**	**P_2**	**Mean**	**P_1**	**P_2**	**Mean**
T_1	2.39	2.13	2.26	2.39	2.17	2.28	2.39	2.08	2.24
T_2	2.35	2.13	2.24	2.35	1.83	2.09	2.35	1.73	2.04
T_3	2.48	2.01	2.25	2.25	2.33	2.29	2.36	2.17	2.26
T_4	2.09	2.61	2.35	2.37	2.61	2.49	2.22	2.61	2.42
T_5	2.28	2.75	2.51	2.59	2.72	2.65	2.43	2.72	2.58
T_6	3.44	2.64	3.04	3.19	2.83	3.01	3.11	2.50	2.81
T_7	2.30	2.33	2.32	2.46	2.29	2.38	2.36	2.31	2.33
T_8	2.24	1.70	1.97	1.70	1.70	1.70	1.91	1.70	1.80
T_9	2.13	2.17	2.15	1.49	2.17	1.83	1.80	2.17	1.98
T_{10}	2.16	2.11	2.14	1.83	2.14	1.99	2.00	2.14	2.07
T_{11}	2.22	1.99	2.11	1.77	1.73	1.75	1.99	1.68	1.84
Mean	2.37	2.23		2.22	2.23		2.27	2.16	
Source	T	P	T X P	T	P	T X P	T	P	T X P
S.Em±	0.14	0.06	0.19	0.14	0.06	0.19	0.12	0.05	0.17
CD at 5%	0.39	NS	0.55	0.39	NS	NS	0.35	NS	0.50

*NS – non-significant, P_1- Two months after bagging P_2- Three months after bagging

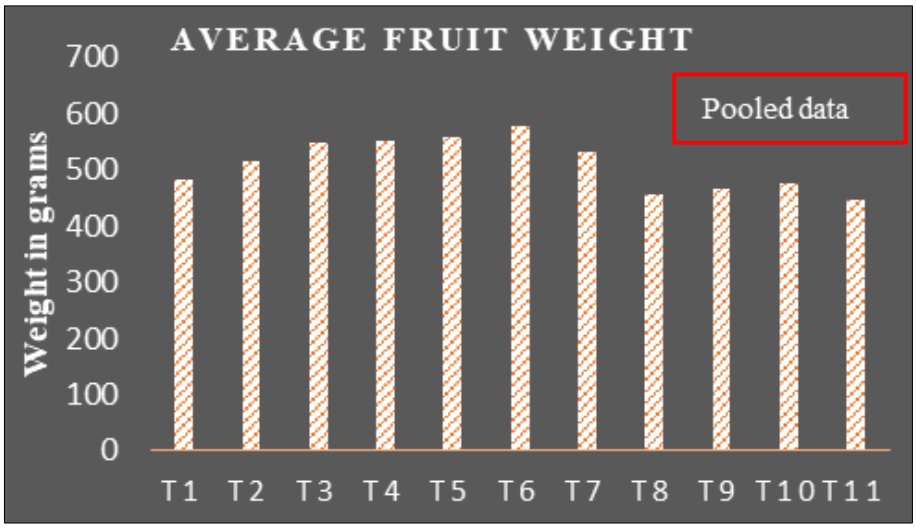

Fig 1: Fruit weight as influenced by different bagging materials and time of bagging during 2021-22 2022-23 and pooled data.

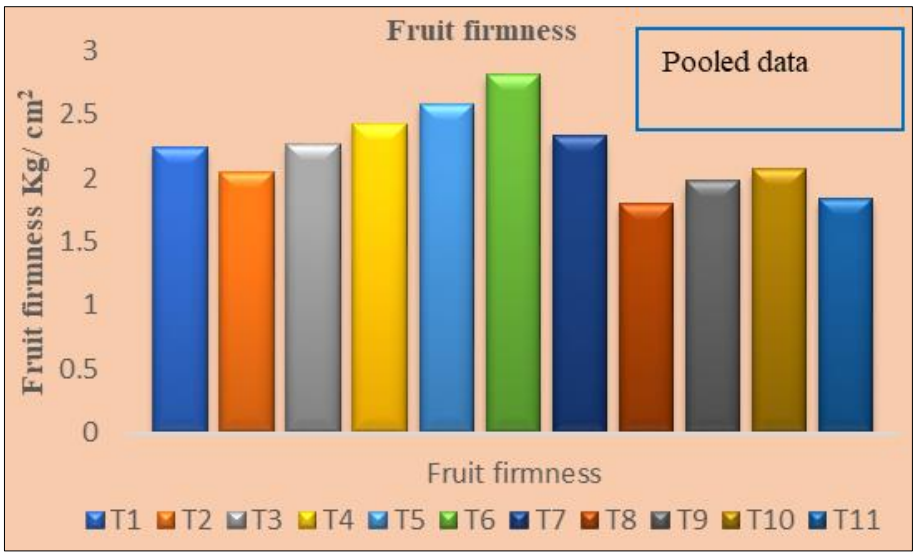

Fig 2: Fruit weight as influenced by different bagging materials and time of bagging during 2021-22, 2022-23 and pooled data

Conclusion

Mango fruits were bagged with ten different types of bagging material along with un bagged control were evaluated and results were recorded for different parameters. The results revealed significantly highest values for fruit length, fruit width, average fruit weight, fruit volume, fruit firmness, juice content and number of days taken for fruit ripening was recorded in fruits bagged with Reddish brown colour bag and the results were on par with two-layered brown colour bag.

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