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Effect of fruit bagging on yield and quality of tomato (*Solanum lycopersicum* L.)

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Abstract
Tomato crop requires some of the basic practices during cultivation to obtained high yield and quality attributes without affected from adverse biotic and abiotic factors. These attributes can be maintained though several ways, which will have beneficial for the farmers to fetching better economy from the quality produce into the domestic market or by, export. Among the various practices, fruit bagging has emerged as an effective method. Bagging is a physical protection method which not only improves the visual quality of fruit by promoting skin coloration and reducing blemishes but can also change the micro-environment for fruit development, which can have several beneficial effects on internal fruit quality. Seven different type of bagging (Fruit covering materials) were applied in five randomized selected plants from each plot. These seven bagging are News Paper bagging, Butter Paper bagging, Transparent Polythene Bagging, Black polythene bagging, Muslin net (cloth) bagging, jute bagging and No bagging (control). Different treatments have been shown various effects *viz:* significantly highest fruit yield (3.136 kg/plant) has been recorded under butter paper bagging. Lowest fruit yield was recorded under control (2.250 kg/plant) closely followed by jute bag bagging (2.752 kg/plant). Significantly highest ascorbic acid (27.33 mg100^{-1}g) was recorded in butter paper bag while lowest ascorbic acid content (19.36 mg100^{-1}g) was recorded in control fruits.

Keywords: Tomato, bagging, lycopene, quality attributes, microenvironment, yield

Introduction

Tomato (*Solanum lycopersicum* L.,) is a perennial crop but some of its cultivars are grown as an annual crop in various parts of the world and it belongs to the diverse family Solanaceae, which includes more than 3000 species, occupying a wide variety of habitats [1]. The tomato is considered as "Poor man's Orange" in India while "Love of Apple" in England. A native of Peru-Ecuador-Bolivia area of the Andes (South America) with basic chromosome number 2n=24, is one of the most popular protective foods because of its high nutritive value, and widely grown vegetables in the world next to potato.Tomato is a warm season vegetable crop requires a long season optimum temperature is 21 to 24^0 C. Temperature has been significant influence on growth and development of tomato fruits [2]. Temperature and light intensity affected the fruit set, pigmentation and nutritive value. It is a rich source of vitamin A and C, and also contains minerals like iron, phosphorus [40]. Furthermore, tomato is the richest source of nutrients, dietary fibers antioxidant like lycopene and β-carotene, the compounds that protect cells from cancer [40]. Several epidemiological studies have underlined the beneficial effect of tomato consumption in the prevention of chronic diseases such as cancer and cardiovascular disease [3]. This effect has been attributed mainly to the antioxidant activity of tomato phyto-chemicals, in particular lycopene, a very efficient radical quencher capable to neutralize reactive oxygen and thus avoid cell injury; however several other mechanisms of the healthy action of carotenoids have been suggested [3]. Tomato plant is highly affected by serious insects (fruit borer) and diseases (late blight) which causes deteriorate fruit quality and reduced yield. The affected fruits gain poor price in the market and such fruits are also rejected for processing. It causes serious economic loss to mango growers [35]. The abiotic factors *viz.* temperature and humidity play critical role in fruit growth and development. Temperature is the most important environmental factor that affects quality, very low or very high temperature may injure sensitive crops. High temperature (35 ^{0}C) specially inhibits accumulation of lycopene due to stimulation of conversion of lycopene into β-carotene [5]. Tomato is a very good source of income to small and marginal farmers, and provides nutrients to the consumers.

Quality of the produce is the final manifestation of inter-relation between the commodity and its environment. Fresh tomato quality is determined by appearance, flavor, colour, firmness; the latter two qualities attributes being major factors in consumer preference of tomatoes [6]. Fruit color is the basic point of attraction for the consumers. Attractive colour improves the physical appearance of the fruit, which helps to get better price in the domestic or export market [7, 41]. Pre-harvest fruit bagging has emerged as a novel technology in practice, which is simple, grower friendly, safe and beneficial for production of quality fruits [8]. Bagging is a physical protection method which not only improves the visual quality of fruit by promoting skin colouration and reducing blemishes, but can also change the micro-environment for fruit development, which can have several beneficial effects on internal fruit quality [35, 42]. Pre-harvest bagging of fruit is practiced in Japan, Australia, and China during peach, apple, pear, grape, and loquat cultivation in order to optimize fruit quality by reducing physiological and pathological disorders and to improve fruit colouration to increase market value leading to an improved appearance [13, 19]. Some countries such as Mexico, Chile, Argentina do not import apples unless they are bagged [35]. There have been contradictory reports on the effects of pre-harvest fruit bagging on fruit size, maturity, skin colour, flesh mineral content, and fruit quality, all of which may be due to differences in the type of bag used, the stage of fruit development when bagged, the duration of exposure to natural light following bag removal and/or fruit- and cultivar-specific responses [12, 35, 42]. Pre-harvest bagging with different types of bag has given significant result on the physical quality of fruits. In a field experiment was conducted by at Ratnagiri, Maharashtra on influence of bagging of fruits at marble Stage on quality of mango cv. Alphonso [8]. Bagging of tomato fruit clusters with TNT or organza fabric may be an excellent option to reduce damage by insect borers and diseases for a significant economic gain [10]. Bagging can prevent damage by insects and reduce pesticide use, without interfering with fruit formation and color development [10]. Thus, these all yield and qualitative attributes was observed by pre-harvest fruit bagging on tomato at marble stage of fruits in experimental field.

Materials and Methods

The present investigation was conducted on during winter season of 2016-17 at the Horticultural Farm of Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan. The Farm is situated at 23˚40' N latitude and 87˚40'3" longitude, and at an altitude of 40 meter above the mean sea level under sub-humid, sub-tropical and lateritic belt of West-Bengal. The experiment was carried out in a Randomized Block Design with 4 replications to assess the performance of different bagging materials. Seven different type of bagging (Fruit covering materials) were applied in five randomized selected plants from each plot. These seven bagging are News Paper bagging(T_1), Butter Paper bagging(T_2), Transparent Polythene Bagging(T_3), Black polythene bagging(T_4), Muslin net (cloth) bagging(T_5), jute bagging(T_6) and No bagging or control (T_7). The crop was raised in check basin system. The seeds of tomato were sown in nursery beds in row to row and line to line on 7th November, 2016. Seedlings of tomato were transplanted on 1st December, 2016 at a spacing 60 cm (plant to plant) and 45 cm (row to row). Five randomly selected plants of each plots and replications were tagged for data collection. Fruit bagging were done with different bagging materials at marble stage during 1st week of February, 2017. Fruits have been harvested after maturity and subjected to physio-chemical observations as well as storage study. The physical and chemical composition was estimated by the following procedures:

Yield per plant (kg): The weight of every fruits from each of the five randomized selected plants was recorded with the help of an electrical balance and got the average value after calculated.

Yield per hectare (q): The yield per hectare was estimated from yield per plant.

Fruit weight (g): The weight of an every fruits was recorded with the help of an electrical balance.

Fruit polar diameter (mm): The polar diameter of the fruit was measured at the both top and bottom central end portion of fruits by the slide caliper.

Fruit equatorial diameter (mm): The equatorial diameter of the fruit was measured at the both side of middle portion of fruits with help of the slide caliper.

Fruit volume (ml): Volume of fruit was measured by beaker into filled water, with the dipping of every fruit and calculated.

Post harvest storage (days): It was measured by storing days of fresh fruit in the glass trays in room temperature at 26˚c and calculated the spoilage days of the fruits.

Total soluble solid (˚Brix): Total soluble solid contain of the fruit juice was measured with the help of an ERMA hand refractometer (o - 32˚Brix) corrected at 20˚C. The refractometer was adjusted at 0% level with the help of distilled water and clean with cotton and dried. The data thus obtained were adjusted for temperature correction from standard correction table.

Reducing sugar and total sugar (%): Total and reducing sugar contents of the fruit extracted juice was determinate by titrating against Fehling solution A and B reagents using methyl blue as an indicator [21]. The reducing sugar content was calculated by the following formula:

Reducing sugar (%) in the juice (i.e. g of glucose/100g of juice) =20/x

Where, x= burette reading.

Ascorbic acid (%): Ascorbic acid was analysis with 3% metaphosphoric acid by titrating against the dye solution i.e.V_2 [21]. The ascorbic acid calculated by the following formula:

Amount of ascorbic acid mg/100g sample.

$$= \frac{0.5\ \text{mg}}{V_1\text{ml}} \times \frac{V_2}{5\ \text{ml}} \times \frac{100\text{ml}}{\text{weight of sample.}} \times 100$$

Lycopene content (%): Lycopene content was estimated by spectrophotometric method as per Davies (1976) and expressed as mg/100g of fruit pulp. The osmotic density of the solution recorded by spectrophotometer at 503 nm visual wave length taking petroleum ether: acetone in 97:3 as reference. The lycopene content had calculated by the following formula:

$$\text{Lycopene (mg/100g)} = \frac{3.1206 \times \text{OD value} \times \text{Final value} \times \text{Dilution} \times 100}{\text{Weight of the sample.}}$$

Where, Absorbance (1 unit) = 3.1206 µg of lycopene /ml.

Dry weight (%): The dry weight of fruit was calculated with the following formula:

$$\%\ \text{dry weight of fruit pulp} = \frac{DW}{FW} \times 100$$

Where, FW= Fresh weight of fruit pulp and DW = Dried weight of fruit pulp.

Per cent total weight loss of fruit: Per cent weight loss was calculated by using following formula:

$$\text{Percent weight loss (\% WL)} = \frac{IW - FW}{IW} \times 100$$

Where, % WL: Per cent weight loss, IW: Initial fruit weight with crown and FW: Final fruit weight.

Results and Discussion

The present experiment was carried out to study the "Effect of fruit bagging on yield and quality of tomato (*Solanum lycopersicum* L.) under sub-humid tropics of West Bengal, at Horticulture Farm, Department of Horticulture and Post Harvest Technology, Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan West Bengal during 2016-17.

Visual appearance of the fruit

In the present experiment the visual appearance on the basis of shape, size, freshness etc. it was noted that unblemished bright red peel and pulp colour fruit was found in butter paper bag whereas un-bagged fruits colour was not more satisfied. Although, both bagged and unbagged fruits have attained maturity more or less same time.

In an experiment also found that the cosmetic quality and appearance of litchi fruits can be improved by bagging fruits [30]. It has now been established that fruit bagging is an effective way to promote anthocyanin synthesis and improve fruit coloration in apples [34]. So the findings of the present experiment have conformity with the findings of Purbey and Kumar (2015) [7, 34].

Fruit weight (g.)

The result of the present experiment shows that the fruits weight of tomato signifantly effected by fruit bagging (table 1 and figure 1). Significantly maximum fruit weight was obtained in case of butter paper bag (59.93g) followed by control (57.57g) and lowest fruit weight was observed in transparent polythene bagging (49.46g).

Increase in fruit size may be due to the development of specific microclimate favourable for fruit development as a result of using bagging materials. Bagging increased fruit weight, size over unbagged control fruits reported by Chonhenchob *et al*., 2011 and Purbey and Kumar, 2015. Thus the result of the present experiment corroborates the findings of Chonhenchob *et al*. (2011) and Purbey and Kumar (2015) [7, 23].

Fruit polar diameter (mm) and equatorial diameter (mm)

Observations on polar diameter of tomato fruits revealed that bagging of fruits has significant effect on polar diameter which was ranged from 40.30 to 48.79mm (table 1 and figure 1). Maximum fruit polar diameter has been obtained in butter paper bag (48.79 mm) followed by news paper bag (47.47 mm) and lowest in control (40.30 mm).

Significantly highest fruit equatorial diameter was noticed in news paper bagging (58.07mm) whereas lowest was observed under control (45.65 mm). Smilar trend has been found in the experiment done by Chonhenchob *et al*. (2011) where bagging increased fruit weight, size over unbagged (control) fruits [23]. It is because of temperature has been significant influence on growth and development of tomato fruits [11].

Days to first harvest from bagging (day)

It is clear from the data presented n the table 1 and figure 2 that, the significantly earliest harvesting is done under polythene bagging (within 21.24 days), whereas the late harvesting was noted in un-bagged or control at 27.08 days.

It is because of inside the bag higher accumulation of CO_2 and light through transparency of bagging materials, consequently might increasing transpiration rate and ethylene synthesis and transformation of chloroplasts into chromoplasts and from the degradation of chlorophyll in tomato thereby achieved early maturity of fruit resulting possible to early harvesting by reducing the delay of maturity. Similar result also found by different scientists these are (Fallahi, Colt, Baird, & Chun, 2001 Debnath & Mitra, 2007; Leite *et al.*, 2014) [9, 10, 43, 44].

Fruit volume (ml)

Statistical analysis of observations on fruit volume reveals that fruit bagging with different materials has increased fruit volume (table 1 and figure 1). In the present study fruit volume was found higher under butter paper bag (71.76 ml) which was statistically *at par* with news paper bagging (71.12 ml) and the lowest fruit volume was noticed in control (51.34 ml).

This higher fruit volume may be attributed to higher respiration rate, biochemical changes and low humidity surrounding the fruit. Similar result of also found by Harach and Wanichkul, 2006 [43, 45].

Average number of fruits

Different types of bagging influenced the fruit production of tomato plants which is evident from the data of average number of fruits presented in the table number 1 and figure 2. Significantly maximum numbers of fruits were found under transparent polythene bagging (62.75). Lowest number of fruits has been observed under control (29.50)

Increase in number of fruits may be due to the influence of bagging of existing fruits on flowering and fruit set of the plants.

Yield (kg) per plant

The result of the present experiment shows the significant variation of yield of tomato plants as effected by fruit bagging (table 1 and figure 2). Significantly highest fruit yield (3.136 kg/plant) has been recorded under butter paper bagging. Lowest fruit yield was recorded under control (2.250 kg/plant) closely followed by jute bag bagging (2.752 kg/plant).

This increase in yield was due to the higher number of fruits along with higher fruit weigh which collectively increased fruit yield/plant. Because of bagging decrease light intensity inside the bagging material thus increase humidity and temperature and on the fruit. It also reduces fruit transpiration water loss during growth [12, 13, 18, 23].

Total Soluble Solids (TSS in ºBrix): Statistical analyses of observation on total soluble solids (table 2 and figure 3) denote that bagging of tomato fruits by different materials has significant effect on total soluble solids of fruits. In the present experiment maximum TSS was found under news paper bagging (6.18 ºBrix) which was *at par* with jute bagging fruits (5.92 ºBrix); closely followed by butter paper bagging (5.89 ºBrix). However, significantly minimum TSS has been observed in black polythene bag (4.01).
Increase in TSS is due to increased accumulation of reducing sugars and partial breakdown of pectin and celluloses during ripening. Similar finding of TSS increment by fruit bagging on other fruits was reported by Worrell *et al*. (1998) [14].

Total sugar (%): Effect of bagging of different materials on tomato fruits was significant (table 2 and figure 3). The observation on total sugar reveals that the treatments varied from 4.01 to 6.18% with respect to total sugar. Significantly highest total sugar (6.18%) was recorded in news paper bag. On contrary lowest total sugar has been recorded under black polythene bag (4.01%) which was statistically at par with control (4.12%).
The variation in total sugar under different bagging treatment may be attributed to the variation of microclimate developed inside various bagging materials. Worrell *et al*. (1998) reported the increase n sugar content of fruits when covered with different materials [14].

Reducing sugar (%): The result of the present experiment shows significant variation in reducing sugar of tomato fruits covered with various bagging materials (table 2 and figure 3). The range of reducing sugar varied from 1.08 to 1.90%. Significantly highest reducing sugar was recorded in fruits covered with butter paper bags (1.90%) which was lowest in control fruits (1.08%). In news paper bagging 1.81% reducing sugar was recorded which was second highest.
More conversion of large molecule of sugars into simpler form under protected condition i.e. under bagging perhaps the cause of higher reducing sugar in bagged fruits than n control. Purbey and Kumar (2015) also reported higher reducing sugar in litchi fruits covered by different bagging materials [30].

Acidity (%)
It is clear from the data presented in table .2 that the bagging of fruits with various bagging materials has no significant effect on titrable acidity of tomato fruits. However t was ranged from 0.45 to 0.50%. Minimum titrable acidity was observed in fruits covered with news paper bags and maximum titrable acidity has been observed under control. This higher acidity in the uncovered fruits may be due to open condition which offers higher temperature and real time fluctuation of environmental components.

Ascorbic acid content ($mg100g^{-1}$): The significant result has been observed in the present experiment with respect to the effect of various bagging materials on tomato fruits in its ascorbic acid content (table 2). Significantly highest ascorbic acid (27.33 $mg100^{-1}g$) was recorded in butter paper bag. However, higher ascorbic acid content (26.17 $mg100^{-1}g$) was also recorded under news paper bagging. On the other hand significantly lowest ascorbic acid content (19.36 $mg100^{-1}g$) was recorded in control fruits.
The variation in total ascorbic acid under different bagging treatment may be attributed to the variation of microclimate developed inside various bagging materials. Worrell *et al*. (1998) reported the increase in ascorbic acid content of fruits when covered with different materials [14].

Lycopene content ($mg\ 100g^{-1}$): The statistical analysis of the data recorded under lycopene content of tomato fruits reveals that different bagging condition significantly effected the fruit lycopene content (table 2). Lycopene content of tomato fruits varied from 152.33 to 310.26 $mg100^{-1}g$). Significantly highest amount of lycopene was found in the fruits covered with butter paper bag (310.26 $mg100^{-1}g$) followed by news paper bag (293.73 $mg100^{-1}g$). However, significantly minimum lycopene content (152.33 $mg100^{-1}g$) was noticed under control treatment.
Higher lycopene content in the covered fruits may be due to the higher conversion of carotenoides lke lycopene by lower light penetration in the covered fruits. However the fruits receved more light under control treatment and transparent polythene bagging has produced less lycopene. The fndngs of Chonhenchob *et al*. (2011) and Purbey and Kumar (2015) also supports the better colour development of bagged fruits [23, 30].

Fruit dry weight (g)
Perusal of the data on the result of dry weight of fruits has made significant differences under different treatments of fruit bagging noted that, higher dry weight gave from black polythene bag (5.43 g) and lowest weight in muslin cloth bag (3.70g).
Perhaps bagging decrease light intensity inside the bagging material thus increase humidity and temperature and on the fruit. It also reduces fruit transpiration water loss during growth. Chonhenchob et al. (2011), Amarante *et al*. (2002a), Joyce *et al*., (1997) and Hofman (1997) reported the similar findings [12, 13, 18, 23].

Table 1: Effect of fruit bagging on fruit physical parameters and yield of tomato cv. Lakshmi

Treatments	Treatment details	Fruit wt (g)	Polar Diameter (mm)	Equatorial Diameter (mm)	Volume (ml)	Average No. of fruits /plant	Yield(kg) per plant	Day to 1st harvest from bagging
T1	News Paper Bag	54.09	47.47	58.07	71.12	49.00	2.813	23.15
T2	Butter Paper Bag	59.93	48.79	56.42	71.76	54.75	3.136	23.42
T3	Transparent Polythene Bag	49.46	42.86	48.90	58.41	62.75	2.381	21.24
T4	Black Polythene Bag	50.74	42.92	47.31	57.09	55.00	2.457	27.08
T5	Muslin Cloth Bag	53.68	43.01	47.72	54.61	41.50	2.705	25.51
T6	Jute Bag	55.18	45.24	51.86	64.47	36.50	2.752	25.17
T7	Control	57.57	40.30	45.65	51.34	29.50	2.250	24.29
SE(m)		1.63	0.74	1.03	1.80	3.21	0.038	0.48

$CD_{0.05}$		4.26	2.01	3.32	4.68	8.90	0.110	1.32
CV		17.63	10.94	12.63	14.15	27.72	9.54	11.57

Table 2: Effect of fruit bagging on fruit physical parameters and yield of tomato cv. Lakshmi

Treatments	Treatment details	TSS (^{0}Brix)	Total sugar (%)	Reducing sugar (%)	Titrable acidity (%)	Ascorbic acid ($mg100^{-1}g$)	Lycopene ($mg100^{-1}g$)	Dry wt. (%)
T1	News Paper Bag	6.18	1.90	1.81	0.47	26.17	293.73 a	5.25
T2	Butter Paper Bag	5.89	1.50	1.90	0.45	27.33	310.26	5.43
T3	Transparent Polythene Bag	4.94	1.20	1.34	0.48	21.09	258.54	4.58
T4	Black Polythene Bag	4.01	1.42	1.27	0.49	20.84	152.33	4.40
T5	Muslin Cloth Bag	5.37	1.27	1.55	0.48	22.88	265.90	4.21
T6	Jute Bag	5.92	1.00	1.60	0.47	23.51	276.22 b	4.55
T7	Control	4.12	1.46	1.08	0.50	19.36	231.64	4.70
SE(m)		0.29	0.07	0.07	0.01	0.37	4.80	0.09
$CD_{0.05}$		0.76	0.21	0.21	NS	1.02	14.34	0.27
CV		15.29	10.23	10.23	13.56	14.52	16.29	12.13

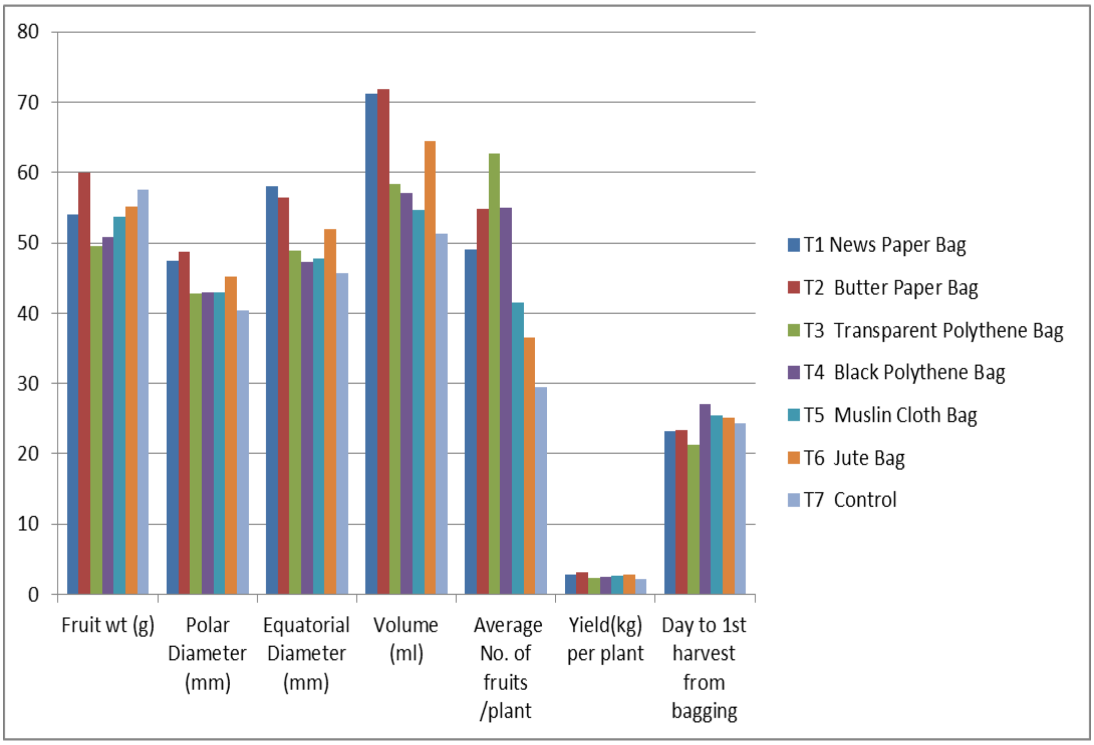

Fig 1: Effect of fruit bagging on different fruit physical parameters of tomato.

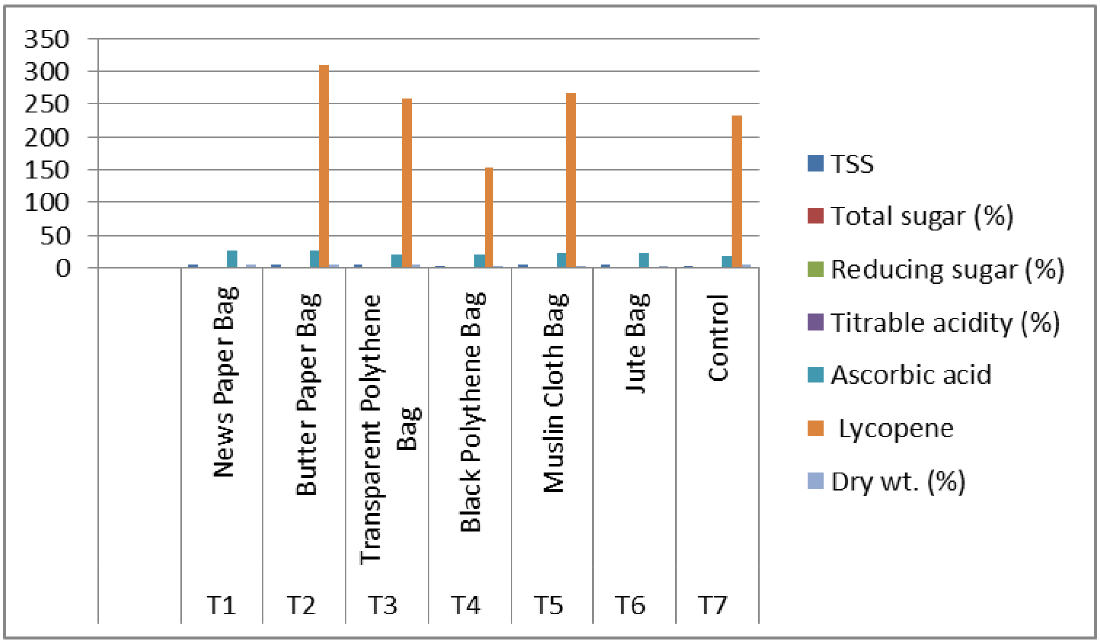

Fig 2: Effect of fruit bagging on average number of fruits, yield per plant and days to first harvest

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