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Shelf Life and Visual Fruit Quality of Bell Pepper Fruits Exposed To Arbuscular Mycorrhizal Fungi in Owerri

Anah, Chinweizu .O[1]., Eze, Emeka .U.,[1]

[1](Department of Agricultural Technology, Federal Polytechnic Nekede Owerri, Nigeria).

Corresponding Author Email: cobinna@fpno.edu.ng Phone No: +234(0)8068234564

Abstract:

Background: Bellpeppers (Capsicum annum L.) are widely cultivated and consumed in Nigeria. It is an essential ingredient in many delicacies. They are however very susceptible to biochemical and physiological deterioration as a result of high temperature and humidity. Howevr, pre-harvest nutrition has an effect on postharvest physiology of fruits. Inoculation with Arbuscular mycorrhizal fungi has shown beneficial effects on post-harvest quality of fruits and vegetables.

Materials and Methods: Freshly harvested mature green, without blemish and uniformly sized bell peppers from 12 treatment combinations of Arbuscular mycorrhiza inoculation and non-inoculation were used for the visual fruit quality scores and shelflife experiment. Five pieces of the bell pepper fruits harvested from the treatments were stored in four different storage materials at ambient temperature and replicated 3 times. The experiment was factorial arranged in complete randomized design.

Results: The results obtained from the storage materials show that jute sack was statistically similar with raffia basket ($p>0.05$) in the number of days to spoilage (12.5days) but was significantly different from paper fibre cartons and plastic container (10.5days). The fruits from Arbuscular mycorrhiza inoculated plants (T4-T12) were significantly different in the number of days to spoilage (11-13 days) compared with the non-inoculated (9 days).

Conclusion: Hence to increase shelflife in bellpepper fruits, inoculation of Arbuscular mycorrhiza during its cultivation is important and at ambient temperature, thefruits should be kept in jute sacks or raffia baskets.

Keywords: Shelflife; Visual fruit quality; Arbuscular mycorrhiza; Bellpepper.

Introduction:

Bell pepper (*Capsicum annum* L.), also known as Sweet pepper, is an important vegetable crop in many countries of the tropical and subtropical ecology where it is an important component of the diet (Adetula and Olakojo, 2006). It is an essential ingredient in most stews and sauce enjoyed in Nigeria. It is an important source of vitamins and minerals especially iron and phosphorus (Renzende *et al*., 2003). Arbuscular mycorrhizal fungi are members of the kingdom fungus and they are the most important component of natural resource and agriculture (Smith and Read, 2008; Tahat *et al*., 2010). The peculiar association between root trees and ectomycorrhizal fungi was given the name "MYCORRHIZA" by Frank in 1885 (Koide and Dickie, 2002).

The application of mycorrhizal inocula has emerged as a reliable technique to enhance the agricultural productivity and nutritional value of edible vegetables whereas reducing environmental costs (Berruti *et al*., 2016; Goicoechea and *Bettoni et al*. 2017). This is the case of strawberry fruits, whose levels of phenolic compounds and minerals increased when plants were inoculated with the arbuscular mycorrhizal fungus *Glomus intraradices*. Some color parameters of strawberry fruits were also affected by AMF (Castellanos-Morales *et al*., 2010). Similarly, Hart *et al*. (2015) found that mycorrhizal inoculation enhanced the concentrations of several minerals (N, P, Cu), carotenoids, and some flavor compounds, as well as the antioxidant capacity in tomato fruits. This beneficial effect of AMF on the quality of tomatoes was corroborated by Bona *et al*., (2017) in a field study performed in a real industrial tomato farm. In another study carried out under nature conditions, Zeng *et al*. (2014) found that *Glomus versiforme* improved the quality of citrus fruits by increasing the ratio of sugar to acid, and the amounts of vitamin C, flavonoids and minerals. Mycorrhizal fungi also improved the antioxidant potential of leaves from sweet basil, an aromatic plant widely used for medicinal and cooking purposes (Hristozkova *et al*., 2017).

Fresh bell peppers are highly perishable due to high water content and thereby susceptible to rapid deterioration but are preferentially consumed while fresh; in consequence, the fruit quality and shelf life are important factors in its commercial value. Temperature management is the most effective tool for extending the shelf life of fresh horticultural commodities. Cooling peppers as soon as possible after harvest will extend their shelf life. Once the

fruit is cooled, peppers can be stored for two to three weeks under the proper conditions (Coolong, 2010). However, there are no or limited cold storage facilities and electric power available to the local farmers and fresh produce seller in Nigeria.

Due to increase in demand for fresh fruits and vegetables there is need to develop improved method for enhancing produce quality and shelf life. Hence this research is aimed at examining the effect of bell pepper pre-harvest inoculation on its shelf life and visual fruit quality.

Material and Methods

Description of study area: The study was carried out in 2020 at the Teaching and Research farm screen house of Agricultural Technology Department, Federal Polytechnic Nekede Owerri Imo State, Southeastern Nigeria. The area lies between Latitude 5^0 21' N and 50 25' N and Longitude 70 03' E and 70 15' E. the area has an average annual rainfall range of 2000mm- 2250 and annual temperature range of 27^0 C- 30^0 C.

Sample preparation

Freshly harvested, mature and uniformly sized green and unblemished 'california wonder' sweet pepper fruits gotten from a field experiment were wiped with soft cloth moistened with distilled water to remove dirt and then surface-sterilized by soaking in 200 mg·L-1 sodium hypochlorite for 2 min.

Shelf life

Five fruits harvested from twelve plants inoculated with different levels of Arbuscular mycorrhiza fungi and water regime were stored in four different storage materials in ambient temperature and the number of days before deterioration sets in were recorded. The experiment was 3x4 factorial in completely randomized design replicated 3 times to give a total 48 experimental units. The treatments were:

Storage materials;

1. Jute sack (Control)
2. Raffia basket
3. Paper Fibre cartons
4. Plastic container

Amf inoculation;

1. W1+ 0g AMF
2. W2+ 0g AMF
3. W3 + 0g AMF
4. W1 + 10g AMF
5. W2 + 10g AMF
6. W3 +10g AMF
7. W1 +15g AMF
8. W2 + 15g AMF
9. W3+ 15g AMF
10. W1 + 20g AMF
11. W2 + 20g AMF
12. W3 + 20g AMF

Where W1 = water every day; W2 = water every 3 days; W3 = water every 5 days.

0g, 10g, 15g and 20g AMF are 0, 10, 15 and 20 grams inoculation with *Arbuscular mycorrhizal* fungi.

Visual fruit quality

The treatments from the shelf life experiment were also observed for their visual fruit quality at 3 days' interval for 15 days. The visual fruit quality was based on the following subjective values: 9 = excellent, 7 = good, 5 = regular, 3 = fair and 1 = unusable, where an average of 6 is fruit in the limit of shelf life (Kader and Cantwell, 2010)

Statistical analysis

Data collected were subjected to analysis of variance (ANOVA) and treatment means were separated by Fishers Least Significance Difference (F-LSD) at 5% level of probability using R desktop version 1.4.1717 (R Core Team, 2021).

Results

Shelf life

The storage materials had a significant effect on the number of days to spoilage of the bell peppers. The fruits stored in jute sack and raffia basket stored longer by 2 days compared to those in paper fibre cartons and plastic container (table 1). The AMF inoculation also showed a significant variation. Fruits from plants that did not receive AMF inoculation (T1-T3) had the least number of days to spoilage while those that received 15-20-gram inoculation of AMF stored the longest (T7-T12).

Table 1. Number of days to spoilage of Bell pepper fruits as affected by *Arbuscula mycorrhiza* inoculation and storage materials

Treatment sources	Number of days to spoilage
A. Storage materials	
Jute sack (JS) (Control)	12.5a
Raffia basket (RB)	12.5a
Paper Fiber cartons (CT)	10.5b
Plastic container (PC)	10.5b
B. AMF inoculated	
T1 (W1+ A0)	9.0c
T2 (W2+ A0)	9.0c
T3 (W3 +A0)	9.0c
T4 (W1 + A10)	11.0b
T5 (W2 + A10)	11.0b
T6 (W3 +A10)	11.0b
T7 (W1+A15)	13.0a
T8 (W2 + A15)	13.0a
T9 (W3+ A15)	13.0a
T10 (W1 + A20)	13.0a
T11 (W2 + A20)	13.0a
T12 (W3 + A20)	13.0a

According to Fishers LSD, means in the same column with the same letters are not significantly different ($p>0.05$).

The interaction of storage materials and AMF inoculated bell pepper fruits was significant. Storing bell pepper fruits that received 20g inoculation of AMF in Jute sack and Raffia basket in ambient temperature significantly ($p<0.05$) had a longer shelf life than the fruits from the non-inoculated plants and those that received less than 20g AMF inoculation and was kept in paper carton or plastic container (table 2).

Table 2. Interaction of storage materials and AMF inoculated bell pepper fruits.

Treatment sources	Number of days to spoilage
JS X T1 (W1+ A0)	10.0c
JS X T2 (W2+ A0)	10.0c
JS X T3 (W3 +A0)	10.0c
JS X T4 (W1 + A10)	12.0b
JS X T5 (W2 + A10)	12.0b
JS X T6 (W3 +A10)	12.0b

JS X T7 (W1+A15)	14.0a
JS X T8 (W2 + A15)	14.0a
JS X T9 (W3+ A15)	14.0a
JS X T10 (W1 + A20)	14.0a
JS X T11 (W2 + A20)	14.0a
JS X T12 (W3 + A20)	14.0a
RB X T1 (W1+ A0)	10.0c
RB X T2 (W2+ A0)	10.0c
RB X T3 (W3 +A0)	10.0c
RB X T4 (W1 + A10)	12.0b
RB X T5 (W2 + A10)	12.0b
RB X T6 (W3 +A10)	12.0b
RB X T7 (W1+A15)	14.0a
RB X T8 (W2 + A15)	14.0a
RB X T9 (W3+ A15)	14.0a
RB X T10 (W1 + A20)	14.0a
RB X T11 (W2 + A20)	14.0a
RB X T12 (W3 + A20)	14.0a
CT X T1 (W1+ A0)	8.0d
CT X T2 (W2+ A0)	8.0d
CT X T3 (W3 +A0)	8.0d
CT X T4 (W1 + A10)	10.0c
CT X T5 (W2 + A10)	10.0c
CT X T6 (W3 +A10)	10.0c
CT X T7 (W1+A15)	12.0b
CT X T8 (W2 + A15)	12.0b
CT X T9 (W3+ A15)	12.0b
CT X T10 (W1 + A20)	12.0b
CT X T11 (W2 + A20)	12.0b
CT X T12 (W3 + A20)	12.0b
PC X T1 (W1+ A0)/jc	8.0d
PC X T2 (W2+ A0)	8.0d
PC X T3 (W3 +A0)	8.0d
PC X T4 (W1 + A10)	10.0c
PC X T5 (W2 + A10)	10.0c
PC X T6 (W3 +A10)	10.0c
PC X T7 (W1+A15)	12.0b
PC X T8 (W2 + A15)	12.0b
PC X T9 (W3+ A15)	12.0b
PC X T10 (W1 + A20)	12.0b
PC X T11 (W2 + A20)	12.0b
PC X T12 (W3 + A20)	12.0b

According to Fishers LSD, means in the same column with the same letters are not significantly different ($p>0.05$).

The visual fruit quality was based on the subjective values: 9 = excellent, 7 = good, 5 = regular, 3 = fair and 1 = unusable, where an average of 6 is fruit in the limit of shelf life. At 3 days in storage, the jute sack and raffia basket contents were almost in excellent condition (8.5), still looking fresh as when harvested with no sign of moisture loss and significantly different from paper cartons and plastic container which looked good (7.0) but not as fresh as the other group. The fruits from the non -inoculated bell pepper plants (T1-T3) had a visual fruit quality of 7 (good) and was significantly different from fruits from the inoculated plants (T4-12) which had a score of 8 (table 3).

At 6 days in storage, the fruits in the Jute sack and raffia basket had a score of 6.5 and was significantly different from paper cartons and plastic container which had a score of 5. The AMF non- inoculated T1-T3 had the lowest score of 4 at 6 days of storage, was significantly different from T4-T6 with a score of 6.0 and T7-T12 with a score of 6.5. At 9 days in storage, the visual fruit quality dropped below the regular score of 5. Jute sack and raffia basket contents score (4.5) were significantly different ($p< 0.05$) from paper carton and plastic container contents score

(2.8). The T1-T3 treatments as expected had the lowest visual fruit score of 2 in which the fruits were almost becoming unusable, were significantly different from T4-T6 (3.5) and T7-T12 (4.5).

At 12 days in storage the quality of bell pepper fruits had dropped drastically. The jute sack contents and raffia basket contents were 2.9 (a bit fair and still usable) and significantly different from paper carton and plastic container with a score of 2.0 (almost becoming unusable). Bell pepper fruits from T1-T3 (non- inoculated plants) were already unusable with a score of 1 while T7-T12 had score of 3-3.5 being fair. At 15 days in storage, all the treatments were not significantly different and had a score of 1 being unusable.

Table 3. Visual fruit quality as affected by AMF inoculation

Treatment sources	Visual fruit quality scores				
	3days	6days	9days	12days	15days
A. Storage materials					
Jute sack (JS) (Control)	8.5a	6.5a	4.5a	2.9a	1.0a
Raffia basket (RB)	8.5a	6.5a	4.5a	2.9a	1.0a
Paper Fiber cartons (CT)	7.0b	5.0b	2.8b	2.0b	1.0a
Plastic container (PC)	7.0b	5.0b	2.8b	2.0b	1.0a
B. AMF inoculated					
T1 (W1+ A0)	7.0b	4.0c	2.0c	1.0d	1.0a
T2 (W2+ A0)	7.0b	4.0c	2.0c	1.0d	1.0a
T3 (W3 +A0)	7.0b	4.0c	2.0c	1.0d	1.0a
T4 (W1 + A10)	8.0a	6.0b	3.5b	2.0c	1.0a
T5 (W2 + A10)	8.0a	6.0b	3.5b	2.0c	1.0a
T6 (W3 +A10)	8.0a	6.0b	3.5b	2.0c	1.0a
T7 (W1+A15)	8.0a	6.5a	4.5a	3.0b	1.0a
T8 (W2 + A15)	8.0a	6.5a	4.5a	3.5a	1.0a
T9 (W3+ A15)	8.0a	6.5a	4.5a	3.5a	1.0a
T10 (W1 + A20)	8.0a	6.5a	4.5a	3.5a	1.0a
T11 (W2 + A20)	8.0a	6.5a	4.5a	3.5a	1.0a
T12 (W3 + A20)	8.0a	6.5a	4.5a	3.5a	1.0a

According to Fishers LSD, means in the same column with the same letters are not significantly different ($p>0.05$). Subjective scale values of bell pepper fruits: 9 = excellent, 7 = good, 5 = regular, 3 = fair and 1 = unusable

The visual fruit quality as affected by AMF inoculation and storage materials interaction at 3 days in storage had a significant effect ($p<0.05$). The interaction effect of JS X T4-T12 and RB X T4-T12 were significantly the same ($p>0.05$), the fruits were in excellent condition (9.0) but significantly different from all the other interactions which were in good conditions (7). The same trend was followed at 6, 9 and 12 days in storage with JS X T4-T12 and RB X T4-T12 having better visual fruit quality score and being significantly different from the other interactions. However, with the progression of days the visual fruit quality declines. At 15 days in storage all the fruits had already deteriorated and no longer fit for usage (table 4).

Table 4. Visual fruit quality as affected by AMF inoculation and storage materials interaction.

Treatment sources	Visual fruit quality scores				
	3 days	6 days	9 days	12 days	15 days
JS X T1 (W1+ A0)	7.0b	5.0c	3.0c	1.0c	1.0a
JS X T2 (W2+ A0)	7.0b	5.0c	3.0c	1.0c	1.0a
JS X T3 (W3 +A0)	7.0b	5.0c	3.0c	1.0c	1.0a
JS X T4 (W1 + A10)	9.0a	7.0a	5.0a	3.0b	1.0a
JS X T5 (W2 + A10)	9.0a	7.0a	5.0a	3.0b	1.0a
JS X T6 (W3 +A10)	9.0a	7.0a	5.0a	3.0b	1.0a
JS X T7 (W1+A15)	9.0a	7.0a	5.0a	3.0b	1.0a
JS X T8 (W2 + A15)	9.0a	7.0a	5.0a	4.0a	1.0a
JS X T9 (W3+ A15)	9.0a	7.0a	5.0a	4.0a	1.0a
JS X T10 (W1 + A20)	9.0a	7.0a	5.0a	4.0a	1.0a
JS X T11 (W2 + A20)	9.0a	7.0a	5.0a	4.0a	1.0a

JS X T12 (W3 + A20)	9.0a	7.0a	5.0a	4.0a	1.0a
RB X T1 (W1+ A0)	7.0b	5.0c	3.0c	1.0c	1.0a
RB X T2 (W2+ A0)	7.0b	5.0c	3.0c	1.0c	1.0a
RB X T3 (W3 +A0)	7.0b	5.0c	3.0c	1.0c	1.0a
RB X T4 (W1 + A10)	9.0a	7.0a	5.0a	3.0b	1.0a
RB X T5 (W2 + A10)	9.0a	7.0a	5.0a	3.0b	1.0a
RB X T6 (W3 +A10)	9.0a	7.0a	5.0a	3.0b	1.0a
RB X T7 (W1+A15)	9.0a	7.0a	5.0a	3.0b	1.0a
RB X T8 (W2 + A15)	9.0a	7.0a	5.0a	4.0a	1.0a
RB X T9 (W3+ A15)	9.0a	7.0a	5.0a	4.0a	1.0a
RB X T10 (W1 + A20)	9.0a	7.0a	5.0a	4.0a	1.0a
RB X T11 (W2 + A20)	9.0a	7.0a	5.0a	4.0a	1.0a
RB X T12 (W3 + A20)	9.0a	7.0a	5.0a	4.0a	1.0a
CT X T1 (W1+ A0)	7.0b	3.0d	1.0e	1.0c	1.0a
CT X T2 (W2+ A0)	7.0b	3.0d	1.0e	1.0c	1.0a
CT X T3 (W3 +A0)	7.0b	3.0d	1.0e	1.0c	1.0a
CT X T4 (W1 + A10)	7.0b	5.0c	2.0d	1.0c	1.0a
CT X T5 (W2 + A10)	7.0b	5.0c	2.0d	1.0c	1.0a
CT X T6 (W3 +A10)	7.0b	5.0c	2.0d	1.0c	1.0a
CT X T7 (W1+A15)	7.0b	6.0b	4.0b	3.0b	1.0a
CT X T8 (W2 + A15)	7.0b	6.0b	4.0b	3.0b	1.0a
CT X T9 (W3+ A15)	7.0b	6.0b	4.0b	3.0b	1.0a
CT X T10 (W1 + A20)	7.0b	6.0b	4.0b	3.0b	1.0a
CT X T11 (W2 + A20)	7.0b	6.0b	4.0b	3.0b	1.0a
CT X T12 (W3 + A20)	7.0b	6.0b	4.0b	3.0b	1.0a
PC X T1 (W1+ A0)	7.0b	3.0d	1.0e	1.0c	1.0a
PC X T2 (W2+ A0)	7.0b	3.0d	1.0e	1.0c	1.0a
PC X T3 (W3 +A0)	7.0b	3.0d	1.0e	1.0c	1.0a
PC X T4 (W1 + A10)	7.0b	5.0c	2.0d	1.0c	1.0a
PC X T5 (W2 + A10)	7.0b	5.0c	2.0d	1.0c	1.0a
PC X T6 (W3 +A10)	7.0b	5.0c	2.0d	1.0c	1.0a
PC X T7 (W1+A15)	7.0b	6.0b	4.0b	3.0b	1.0a
PC X T8 (W2 + A15)	7.0b	6.0b	4.0b	3.0b	1.0a
PC X T9 (W3+ A15)	7.0b	6.0b	4.0b	3.0b	1.0a
PC X T10 (W1 + A20)	7.0b	6.0b	4.0b	3.0b	1.0a
PC X T11 (W2 + A20)	7.0b	6.0b	4.0b	3.0b	1.0a
PC X T12 (W3 + A20)	7.0b	6.0b	4.0b	3.0b	1.0a

According to Fishers LSD, means in the same column with the same letters are not significantly different ($p>0.05$). Subjective scale values of bell pepper fruits: 9 = excellent, 7 = good, 5 = regular, 3 = fair and 1 = unusable

Discussion

Temperature has been established to be the most significant factor in maintaining product quality of fresh horticultural crops such as sweet pepper longer (Leon *et al.* 2013). Sweet peppers stored under ambient conditions could have an excessive amount of water loss leading to quality deterioration because of its very low relative humidity. The shelf life of fruits stored in jute sack and raffia basket were longer than those in paper cartons and plastic. The better shelf life could be attributed to the ventilating and absorbent properties of the storage materials.

Fruits form plants were inoculated with Arbuscula mycorrhiza had longer shelf life than the fruits from the non-inoculated plants. This could be because Arbuscula mycorrhiza enhanced the biological active substances in the fruits (Nurzy´nska-Wierdak *et al*. 2021) leading to longer time before spoilage in storage.

The visual fruit quality scores of fruits stored in jute sack and raffia basket were significantly better than that of the fruits stored in paper cartons and plastic container. This is expected because if they have shelf life longer in jute sack and raffia basket, it is obvious that their visual fruit quality score should be better. This could be the reason why in the open market in Nigeria the majority of bell pepper fruit sellers store them in raffia baskets. The result obtain here is however in contrast to Leon et al., (2013) who observed a lower fruit quality and shelf life at ambient temperature for green peppers. This variation could be as a result of differences in storage materials and pre-harvest treatment.

Conclusion

The findings reveal that bell pepper post- harvest fruit quality is affected by pre-harvest nutrition and that Arbuscular mycorrhiza inoculation of bell peppers during cultivation could enhance the fruit quality. Also, to meet up with the demand for fresh bell pepper fruits in developing countries where cold storage is limited, it would be recommended that bell pepper plants be inoculated with Arbuscula mycorrhiza fungi and at ambient temperature should be stored in jute sacks and raffia baskets.

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