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Effects of Harvesting Stages, Packaging Materials and Storage Duration on Seed Quality of Tomato (Lycopersicon lycopersicon Mill) Varieties

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Abstract

Three laboratory experiments on two varieties of tomato (Gianfranco Fuscello and Rio-grande) were conducted in 2017 and repeated in 2018.The experiments were aimed to study the effects of harvesting stages, packaging materials and storage duration on seed quality of tomato varieties. Two varieties of tomato, three harvesting stages, three packaging materials and three storage durations were used as treatments in a 2x3 and 2x3x3 factorial in Completely Randomized Design with four replications. Observations were recorded on germination counts (6 and 12 days after planting), post-emergence mortality, germination percentage, germination rate, germination index, seedling height, seedling fresh weight and seedling dry weight. Tomato fruits were harvested at three different stages as green matured, partially ripened matured and ripened matured at 40, 60, and 80 days after anthesis. Results were as follows; eighty days after anthesis recorded higher germination counts (6 and 12 days after planting), germination percentage, germination index, as compared to other harvesting stages; Aluminum foil bag was significantly higher in all the parameters observed; while the highest germination percentage was found after 3 months of storage. The study therefore recommends 80 days after anthesis as the best harvesting stage of tomato for optimum seed germination, growth and yield; also, aluminum foil is recommended as packaging material for farmers for adoption; Duration three and six months of storage are also recommended to farmers for better seed quality of tomato.

(Keywords: Harvest stages, packaging materials, storage duration)

Introduction

Tomato (Lycopersicon lycopersicon Mill) is a popular grown horticultural commodity in the world and by weight ranks third in global production of all horticultural produce only behind potatoes and sweet potatoes (Tan et al., 2010). In Africa, the total tomato production is 17.938 million tons, with Egypt leading the continent with 8.62 tons, followed by Nigeria, 1.56 tons.

Tomato is eaten fresh in a multiple of processed forms. The three major processed products are (a) tomato preserves (whole peeled tomato, tomato juice, tomato pulp, tomato puree, tomato paste and pickled tomatoes);
(b) dried tomato (tomato powder, tomato flakes and dried tomato fruits), and
(c) tomato-based foods (tomato soup, tomato sauces and ketchup) (Costal and Heuvelink, 2005).

Rao *et al.(*1998) found that tomatoes and tomato products have numerous heath benefits and also contribute to a well balanced diet. Tomato products are key sources of essential materials including vitamins A,C and E (Beaeher, 1998), providing approximately 20 mg of vitamin C per 100 grams of edible products (Wilcox et al., 2003). One medium ripe tomato (145 grams) can provide up to 40% of the recommended daily allowance of vitamin C and 20% of vitamin A (Kelly and Boyham, 2010). Tomatoes also contain lycopen, a red pigment serving as a natural anti-oxidant (Shi and Manguer, 2000; Sies et al., 1992), calcium, water and niacin which are essential for metabolism (Olaniyi et al., 2010).

Tomato has the tendency of improving the lives of small scale farmers in most developing countries of the world. Besides the health benefits derived from tomato-based foods, the crop can serve as source of income for farmers as a result of its numerous uses. The tomato industry can increase the foreign exports earning of many African countries thereby contributing to GDP growth. In Ghana for instance, the tomato industry has been identified as an area that has the ability for poverty reduction because of its potentials for growth and development creation (Anang et al., 2013).

In modern age, packaging has become very important because of protection of seeds from contamination by micro and macro-organisms and their filth, prevention from loss or gain of moisture, shielding the seeds from oxygen and to facilitate handling (Butt, 2004).This places a high demand on selecting materials that provide the needed properties to maintain the quality of seeds, as faulty packaging can lead to quick deterioration of seeds (Okaka and Okaka, 2004). Packaging type is known to affect the organoleptic properties of seeds. For example, a material such as low density polyethylene is a good water barrier but will scalp certain compounds from seeds (Cooksey, 2004).

Apart from the physical and mechanical damage on tomato quality, serious losses occur on the seed quality of tomatoes. Improper harvesting time (maturity), ripening conditions and lack of suitable packaging materials usually cause a glut during the time

of raising the seeds on the nursery beds (Akamine, 1970). Therefore, reduction of these seed looses will be so important to recover part of the grower's cost. Suitable harvesting stages of fruit (maturity), optimum packaging materials to have the best tomato seed quality and their long duration of storage have not been completely recognized by tomato growers. The aim of this study is therefore to find the optimum stage of harvesting and the right packaging material that will ensure better quality of tomato seeds for a long storage and marketing.

The specific objectives of this research are :
To determine the actual stage of harvesting that will give best tomato seed quality.
To determine the right packaging material that will maintain high seed quality.
To establish the best storage duration for high tomato seed quality.

Materials and Methods

Experimental Site

The experiments were conducted at the Teaching and Research Farm and Plant Breeding and Seed Science Laboratory of the University of Agriculture, Makurdi (Latitude 7.41°N, Longitude 8.35°E, 97m above sea level) in Benue State, Nigeria. The location falls within the Southern Guinea Savannah Agro-ecological zone of Nigeria (Kowal and Kassan, 1998; and Agboola, 1979).

Experimental Materials

The Gianfranco Fuscello tomato was obtained from the King's Garden Kano, while Rio Grande tomato was obtained from Mufty Agro-allied Nigeria Ltd. The two varieties were said to be high yielding. The following materials were also used during the experiment: Wheelbarrow, poultry manure, dry grasses, Petri-dishes, fertilizer, pegs, tape, water, syringe and jotter.

Methods

Establishment of Tomato Seedlings

Nursery beds were constructed 1m x 1.5m and the beds were raised to a height of 0.3 – 0.4m. The soil was then mixed with 25kg of poultry manure and one wheelbarrow of sand for each bed. Seeds were thoroughly mixed with sand and broadcasted on the beds and were lightly covered with soil. Dry grasses were spread on the beds to provide greater moisture retention and cover for the seedlings. The beds were watered morning and evening until the seedlings were ready for transplanting. The nursery was provided with shades 1m above the beds immediately after germination, thinning was done and seedlings were kept free from weeds at interval of two weeks.

The seedlings were then allowed to grow in the nursery for a period of five weeks before they were transplanted to the main field.

Field Establishment and Management

The field was cleared, cultivated, and then marked out using tapes and pegs and ridges were constructed. After five weeks of emergence, old seedlings that appeared uniform and healthy and similar were transplanted to the field at the spacing of 50cm x 75cm between plants and 75cm between rows. Weeding was manually done at 21 days after planting (DAP) to allow tomato plants to grow without competition. Compound fertilizer NPK 15:15:15 fertilizer was applied at the rate of 500kg split in two doses. The first dose was three weeks after planting and the second dose was at fruiting. Flowers were carefully tagged on daily basis until when they were 50% flowering. The fruits from each block were harvested separately at 40, 60 and 80 days after anthesis (DAA) from proximal (premature green, partially ripened and ripened stages).

Experimental Design

Factorial arrangement in a Randomized Complete Block Design (RCBD) was used to generate seeds for the laboratory experiments. The laboratory experiments were set up in a 2x3 and 2x3x3 factorial in a Completely Randomized Design (CRD) with four replications for the first and second experiments.

Experiment One

Effects of Harvesting Stages on Seed Quality of Tomato

Tomato fruits were harvested at three different stages as green mature partially ripened matured and ripened matured at 40, 60 and 80 days after anthesis. Seeds were extracted manually from the fruits using a steel knife. The extracted fruits were then washed with running tap water and spread to dry in perforated baskets for four days under room temperature.

Two hundred seeds from each stage of harvest and each genotype were then laid in a petri dish and observed for germination in the laboratory. The effects of harvesting stages on seed quality were determined. The stage of harvest with the highest germination percentage was then selected and packed in aluminum foil bag, paper bag and polythene bag and stored under room temperature for 3, 6 and 9 months to be used for the second experiment.

Experiment Two

Effects of Packaging Materials And Storage Duration on Seed Quality Of Tomato

Two hundred seeds each from the stored packaging materials were

removed and used separately for laboratory germination at 3, 6 and 9 months of storage. Fresh filter papers were spread on petri-dishes and moistened. The selected seeds were then placed in the petri-dishes and covered, the petri-dishes were monitored and watered on daily basis with 3mls of water using syringe until the last day of germination count.

Data Collection

The following data were collected in all the laboratory experiments conducted:
Germination count (6 DAP)
Germination count (12DAP)
Pre- emergence mortality
Post- emergence mortality

$$\text{Germination Rate(GR)} = \frac{\text{Germination index}}{\text{Total germination percentage (decimal)}}$$

$$\text{Germination percentage(GP)} = \frac{\text{No.of seedlings germinated}}{\text{Total No.of seeds planted}} \times 100$$

$$\text{Germination index (GI)} = \sum \frac{\text{No. of plants emerged in a day}}{\text{Total No. of plants emerged by the last day}}$$

Seedling length: Root and shoot length of five normal seedlings selected at random in each treatment were added together to get seedling length.
Seedling fresh weight (g)
Seedling dry weight (g)

Data Analysis

All the data collected were analyzed statistically using the Genstat statistical package (Discovery Edition 10.3 DE).Treatments were compared by the Least Significant difference (LSD) Procedure (Little and Hill, 1978; Singh and Chaudhary, 1979; Steel and Torrie, 1980).

Results

Effects of Harvesting Stages on Seed Quality Of Tomato

The mean squares of two tomato varieties subjected to three harvesting stages in Makurdi are presented in Table 1. Highly significant difference in harvesting stages was observed in first germination count (6 DAP); second germination count (12 DAP); pre-emergence mortality;

germination percentage; germination rate and germination index. Year, variety and interactions of year x variety, year x Harvesting Stages, Variety x Harvesting Stages, Year x variety x Harvesting Stages were not significant in all the parameters observed.

Results on effects of harvesting stages on seed quality of tomato in Table 2 showed that harvesting stages differed significantly in other parameters except in seedling height, seedling fresh weight and seedling dry weight. Eighty (80) days after anthesis (DAA) recorded higher germination counts, germination percentage and germination index as compared to other harvesting stages observed.

Effects of Packaging Materials On Seed Quality Of Tomato

Table 3 revealed that the three packaging materials exhibited significant difference in

germination counts (6 and 12 DAP), pre-emergence mortality, germination percentage, germination rate and germination index .Among the three packaging materials used, Aluminum Foil Bag (AFB) proved to be significantly higher in germination counts (6 and 12 DAP), germination percentage and germination index; while paper bag ranked significantly higher in pre-emergence mortality and germination rate.

Effects of Variety and Packaging Materials Interaction on Seed Quality of Tomato.

Table 4 is a summary of results on variety X packaging materials interaction on seed quality of tomato varieties. Gianfranco Fuscello X Aluminum Foil Bag interaction differed significantly ($P \leq 0.05$) in germination counts (6 and 12 DAP), germination percentage and seedling height. But Rio- Grande X Aluminum Bag interaction was significantly higher in pre – emergence mortality and seedling dry weight. Rio-Grande X Polyethylene Bag was lower in germination counts (64.20 and 95.0), while Gianfranco X Polyethylene Bag interaction recorded lower pre-emergence mortality (24.20) and germination percentage (16.67).

Table 1: Mean Square Estimates from Analysis of Variance for Effects of Harvesting Stages on Seed Quality of Tomato Varieties in Makurdi.

SOV	DF	1ST Ger. Count (6 DAP)	2nd Ger. Count (12DAP)	PEM	Ger.%	Ger. Rate	Ger. Index	Seedling Ht (cm)	SFW (g)	SDW (g)
Variety	1	133.30 NS	8.30NS	8.30NS	0.00NS	0.04 NS	0.11 NS	0.03 NS	0.00 NS	0.01 NS
H.S	2	41008.30**	102633.30**	102633.30**	25777.08**	5.33 **	0.15 **	0.12 NS	0.00 NS	0.01 NS

KEY:
HS = Harvest Stages **SFW** = Seedling Fresh Weight **Y** = Year
SDW = Seedling Dry Weight. **V** = Varieties **NS** = Non-significant
PEM = Pre-Emergence mortality * = Significant
DAP = Days after Planting ** = Highly Significant

Table 2: Effects of Harvest Stages on Seed Quality of Tomato Varieties in Makurdi

Harvest Stages	1ST Ger. Count (6 DAP)	2nd Ger. Count (12DAP)	PEM	Ger.%	Ger. Rate	Ger. Index	Seedling Height cm)	SFW (g)	SDW (g)
40 DAA	16.20	36.20	163.20	18.10	1.32	19.12	6.43	0.40	0.03
60 DAA	46.20	78.80	121.20	38.80	0.51	19.02	6.46	0.45	0.05
80 DAA	115.00	191.20	8.80	95.60	0.20	40.20	6.62	0.47	0.05
LSD(0.05)	**10.00**	**10.35**	**10.35**	**5.28**	**0.36**	**2.21**	**NS**	**NS**	**NS**

KEY:
DAA = Days after Anthesis **NS** = Non-Significant **PEM** = Post Emergence Mortality
SFW = Seedling Fresh Weight **DAP** = Days after Planting **SDW** = Seedling Dry Weight

Table 3: Effects of Packaging Materials on Seed Quality of Tomato Varieties in Makurdi

Packaging Materials	1ST Ger. Count (6 DAP)	2nd Ger. Count (12DAP)	PEM	Ger.%	Ger. Rate	Ger. Index	Seedling Height (cm)	SFW (g)	SDW (g)
PB	82.90	109.20	88.80	54.58	0.44	21.44	5.99	0.42	0.02
PEB	94.20	138.70	61.30	69.37	0.32	20.53	5.95	0.42	0.02
AFB	120.80	159.60	40.00	80.21	0.33	25.87	6.02	0.42	0.02
LSD(0.05)	**10.73**		**12.04**		**12.58**	**5.98**	**0.13**		**2.22**
NS	**NS**	**NS**							

KEY:
PB = Paper Bag **SFW** = Seedling Fresh Weight **PEM** = Post Emergence Mortality
NS= Non-Significant **PEB**= Polyethylene Bag **SDW** = Seedling Dry Weight **AFB** = Aluminum Foil Bag.

Table 4: Interaction Effects of Variety X Packaging Materials on Seed Quality of Tomato Varieties in Makurdi**.**

Variety	Packaging Materials	1ST Ger. Count (6 DAP)	2nd Ger. Count (12DAP)	PEM	Ger.%	Ger. Rate	Ger. Index	Seedling Height (cm)	SFW (g)	SDW (g)
Gianfranco Fuscello	PB	102.70	123.30	24.20	16.67	0.39	21.84	6.00	0.41	0.22
	PEB	115.80	164.20	35.80	82.08	0.36	20.89	5.92	0.43	0.27
	AFB	145.00	175.00	76.70	87.92	0.34	22.75	6.06	0.42	0.28
Rio Grande	PB	64.20	95.00	55.80	47.50	0.48	22.65	5.98	0.42	0.02
	PEB	72.50	113.30	86.70	56.67	0.38	22.66	5.99	0.41	0.03
	AFB	95.80	144.20	100.80	72.50	0.35	23.68	5.98	0.41	0.35
	LSD(0.05)	**6.20**	**8.59**	**21.79**	**8.46**	**NS**	**NS**	**0.09**	**NS**	**0.01**

KEY:
PEB = Paper Bag **NS** = Non-Significant **AFB** = Aluminum Foil Bag
SFW = Seedling Fresh Weight **DAP** = Days After Planting **SDW** = Seedling Dry Weight
PEM = Pre- Emergence Mortality **PB** = Polyethylene Bag

Effects of Storage Duration on Seed Quality of Tomato

Results on effects of storage duration on seed quality of tomato varieties were summarized in Table 5. The results showed that there was significant difference in all the parameters observed. Three months duration was significantly higher in almost all the parameters observed except in pre-emergence mortality and germination rate. Nine months storage duration was significantly higher in pre-emergence mortality (72.10) and in germination rate (0.44) as compared to other storage durations.

Table 6 is a summary of results on interaction effects of variety X Storage duration on seed quality of tomato varieties. Significant difference was observed in first and second germination counts, pre-emergence mortality, germination percentage, seedling height and seedling dry weight. The Gianfranco X 3 months interaction yielded significantly higher in first and second germination counts (6 and 12 DAP), germination percentage and seedling height (Table 7).The results of year X storage duration interaction are presented on Table 7.The results indicated that year X storage duration interaction exerted significant effects on germination counts (6 and 12 DAP), pre-emergence mortality, germination percentage, seedling height and seedling fresh weight. But, year one X 3 months storage duration interaction produced significantly higher first and second germination counts (124.20 and 150.00), germination percentage (75.42) and seedling height (6.55 cm); while year one X 9 months produced significantly higher pre-emergence mortality (82.50). Other year X storage duration interactions were not significant.

Effects of Packaging Materials X Storage Duration Interaction on Seed Quality of Tomato Varieties

The results of packaging materials X Storage duration interaction on seed quality of tomato are summarized in Table 8. Results showed that packaging materials X Storage duration interaction exerted significant effects on germination counts (6 and 12 DAP), pre-emergence mortality and germination percentage. 3 months X Aluminum Foil interaction was significantly higher in first and second germination counts (149.50 and 168.70 respectively) and in germination percentage (85.00).

Interaction Effects Of Year X Packaging Materials X Storage Duration On Seed Quality Of Tomato Varieties

Table 9 showed year x packaging materials x storage duration interaction on seed quality of tomato varieties. The results revealed that year one x Aluminum Foil Bag X Three months interactions showed significantly

higher first and second germination counts (150.00 and 175.60) and germination percentage (88.75) compared to other interactions. Of all the packaging materials used, aluminum foil bag gave better results in all the years followed by polyethylene bag.

Interaction Effects Of Year X Variety X Packaging Materials X Storage Duration On Seed Quality Of Tomato Varieties

Results in Table 10 indicated that Gianfranco Fuscello stored better in Aluminum Foil Bag in all the years. Three months of storage gave higher significant difference in all the parameters used; this reduced at every stage of storage.

Table 5: Effects of Storage Duration on Seed Quality of Tomato Varieties in Makurdi

Storage Durations	1ST Ger. Count (6 DAP)	2nd Ger. Count (12DAP)	PEM	Ger.%	Ger. Rate	Ger. Index	Seedling Height (cm)	SFW (g)	SDW (g)
3 MAH	118.80	144.20	55.80	72.29	0.33	22.80	6.43	0.45	0.03
6 MAH	104.60	135.80	62.10	67.92	0.32	21.72	5.72	0.43	0.02
9 MAH	74.20	127.50	72.10	63.96	0.44	19.32	5.80	0.41	0.01
LSD(0.05)	**7.59**	**8.51**	**12.58**	**5.10**	**0.11**	**2.22**	**0.16**	**0.02**	**0.01**

KEY: **MAH** = Months After Harvest **DAP** = Days After Planting
PEM= Pre- Emergence Mortality **NS**= Non-Significant.

Table 6: Interaction Effects of Variety X Storage Duration on Seed Quality of Tomato Varieties in Makurdi

Variety	Storage Duration	1ST Ger. Count (6 DAP)	2nd Ger. Count (12DAP)	PEM	Ger. %	Ger. Rate	Ger. Index	Seedling Height (cm)	SFW (g)	SDW (g)
Gianfranco Fuscello	3 MAH	147.20	167.50	32.50	83.75	0.38	23.55	6.55	0.42	0.03
	6 MAH	130.00	157.50	42.50	78.75	0.28	21.96	6.15	0.43	0.03
	9 MAH	84.00	135.50	61.70	69.17	0.32	19.98	6.11	0.41	0.02
Rio Grande	3 MAH	89.20	120.80	79.20	60.83	0.42	22.06	6.32	0.43	0.03
	6 MAH	79.20	114.20	81.70	57.08	0.42	21.49	5.30	0.42	0.02
	9 MAH	78.30	117.50	82.50	58.78	0.34	18.66	5.49	0.40	0.02
	LSD(0.05)	**15.18**	**17.02**	**17.79**	**8.46**	**NS**	**NS**	**0.09**	**NS**	**0.01**

KEY: MAH = Months After Harvest **SFW** = Seedling Fresh Weight **DAP** = Days After Planting **NS** = Non-Significant **SDW** = Seedling Dry Weight **PEM** = Pre-Emergence Mortality **STD** = Storage Duration

Table 7: Interaction Effects of Packaging Materials X Storage Duration on Seed Quality of Tomato Varieties

Packaging Materials	Storage Duration	1ST Ger Count (6 DAP)	2nd Ger. Count (12DAP)	PEM	Ger.%	Ger. Rate	Ger. Index	Seedling Height (cm)	SFW (g)	SDW (g)
	3 MAH	124.20	150.00	50.00	75.42	0.31	21.29	6.55	0.42	0.03
1	6 MAH	105.80	137.50	58.30	68.75	0.34	21.25	6.15	0.39	0.02
	9 MAH	70.00	116.70	82.50	58.75	0.35	19.54	6.00	0.36	0.02
	3 MAH	113.30	138.30	61.70	69.17	0.49	23.68	6.31	0.47	0.03
2	6 MAH	10.30	138.30	65.80	69.17	0.37	22.20	5.30	0.45	0.02
	9 MAH	78.30	134.30	61.70	61.70	0.31	19.10	5.10	0.44	0.02
LSD(0.05)	**13.15**	**14.43**	**15.41**	**7.33**	**NS**	**NS**	**0.20**	**0.03**	**NS**	**NS**

KEY: MAH= Months After Harvest **DAP**= Days After Planting **NS** = Non-Significant
SFW = Seedling Fresh Weight **SDW** = Seedling Dry Weight

Table 8: Interaction Effects of Packaging Materials X Storage Duration on Seed Quality of Tomato Varieties

Packaging Materials	Storage Duration	1ST Ger. Count (6 DAP)	2nd Ger. Count (12DAP)	PEM	Ger.%	Ger. Rate	Ger. Index	Seedling Height (cm)	SFW (g)	SDW (g)
	3 MAH	100.00	122.50	77.50	61.25	0.42	23.13	6.45	0.45	0.03
PB	6 MAH	87.50	115.00	78.80	57.50	0.42	20.98	5.67	0.45	0.02
	9 MAH	61.20	90.00	110.00	45.00	0.46	20.21	5.85	0.45	0.01
	3 MAH	108.80	141.20	58.80	70.50	0.34	21.52	6.40	0.43	0.03
PEB	6 MAH	98.70	138.70	63.80	69.37	0.33	21.05	5.67	0.43	0.03
	9 MAH	75.00	136.20	61.30	68.12	0.28	19.03	5.78	0.41	0.03
	3 MAH	147.50	168.70	31.30	85.00	0.43	23.75	6.44	0.41	0.03
AFB	6 MAH	127.50	156.20	43.80	78.12	0.13	23.14	5.83	0.42	0.02
	9 MAH	86.20	153.70	45.00	77.50	0.25	18.73	5.77	0.42	0.02
LSD(0.05)		**10.73**	**12.04**	**12.58**	**5.10**	**NS**	**NS**	**NS**	**NS**	**NS**

KEY:
MAH= Months After Harvest **NS** = Non-Significant **DAP**= Days After Planting
PEM = Pre-Emergence Mortality **SDW** = Seedling Dry Weight **SFW** = Seedling Fresh Weight **AFB** = Aluminum **PEB** = Polyethylene Bag **PB** = Paper Bag

Table 9: Interaction Effects of Year X Packaging Materials X Storage Duration on Seed Quality of Tomato Varieties

Packaging Materials	Storage Duration	1ST Ger. Count (6 DAP)	2nd Ger. Count (12DAP)	PEM	Ger.%	Ger. Rate	Ger. Index	Seedling Height (cm)	SFW (g)	SDW (g)
	3 MAH	107.50	125.00	25.00	65.50	0.25	22.22	6.58	0.39	0.03
PB	6 MAH	95.50	115.00	40.00	57.50	0.27	21.39	6.28	0.39	0.02
	9 MAH	57.50	90.00	60.00	45.00	0.28	19.30	6.19	0.37	0.01
	3 MAH	115.00	150.00	50.00	75.00	0.31	21.35	6.51	0.42	0.04
PEB	6 MAH	100.00	137.50	62.50	68.75	0.34	21.21	6.13	0.39	0.02
	9 MAH	67.50	122.50	77.50	61.25	0.33	19.60	6.15	0.37	0.01
	3 MAH	150.00	175.60	100.00	88.75	0.37	22.21	6.58	0.44	0.03
AFB	6 MAH	125.00	160.00	75.00	80.00	0.60	21.14	6.13	0.38	0.02
	9 MAH	85.00	137.50	72.50	70.00	0.45	1973	6.15	0.35	0.01
	3 MAH	92.50	120.00	37.50	60.00	0.41	25.29	6.30	0.35	0.01
PB	6 MAH	82.50	115.00	47.50	57.50	0.34	24.90	5.39	0.43	0.04
	9 MAH	65.00	90.00	30.00	45.00	0.22	18.14	5.34	0.47	0.03
	3 MAH	102.50	132.50	67.50	66.25	0.38	21.69	6.30	0.44	0.03
PEB	6 MAH	97.50	135.00	65.00	67.50	0.31	20.89	5.30	0.49	0.03
	9 MAH	82.50	155.00	45.00	77.50	0.25	18.46	5.57	0.46	0.02
	3 MAH	145.00	162.50	80.00	85.00	0.49	24.05	6.33	0.45	0.04
AFB	6 MAH	130.00	152.00	88.00	81.26	0.44	20.32	5.21	0.46	0.03
	9 MAH	87.50	170.00	110.00	76.50	0.47	20.70	5.54	0.42	0.02
LSD(0.05)		**10.73**	**12.04**	**12.58**	**5.10**	**NS**	**NS**	**NS**	**NS**	**NS**

KEY:
MAH= Months After Harvest **NS** = Non-Significant **AFB** = Aluminum
DAP= Days After Planting **SFW** = Seedling Fresh Weight **PB** = Paper Bag
PEM = Pre-Emergence Mortality **SDW** = Seedling Dry Weight **PEB** = Polyethylene Bag

Table 10: Interaction Effects of Year X Variety X Packaging Materials X Storage Duration on Seed Quality of Tomato Varieties**.**

Year	Variety	PM	Storage Duration	1ST Ger. Count (6 DAP)	2nd Ger. Count (12DAP)	PEM	Ger.%	Ger. Rate	Ger. Index	Seedling Height (cm)	SFW (g)	SDW (g)
			3 MAH	130.00	145.00	55.00	75.50	0.31	22.72	6.71	0.44	0.03
		PB	6 MAH	110.00	135.00	65.00	65.00	0.33	21.88	6.14	0.38	0.02
			9 MAH	70.00	90.00	11.00	45.00	0.49	21.45	6.10	0.35	0.02
			3 MAH	140.00	180.00	20.00	90.00	0.24	21.42	6.45	0.41	0.04
	Gianfranco	PEB	6 MAH	120.00	170.00	30.00	85.00	0.24	20.42	6.01	0.40	0.02
	Fuscello		9 MAH	85.00	135.00	65.00	67.50	0.32	21.72	6.89	0.38	0.02
			3 MAH	185.00	190.00	10.00	95.00	0.25	23.70	6.67	0.41	0.03

		AFB	6 MAH	155.00	175.00	25.00	87.50	0.26	22.67	6.62	0.39	0.03
			9 MAH	100.00	150.00	45.00	77.00	0.26	19.72	6.28	0.38	0.02
1			3 MAH	85.00	105.00	95.00	52.50	0.42	21.70	6.44	0.45	0.03
		PB	6 MAH	75.00	95.00	80.00	47.00	0.48	20.40	6.20	0.39	0.01
			9 MAH	45.00	90.00	110.00	45.00	0.41	18.00	6.11	0.35	0.01
			3 MAH	90.00	120.00	80.00	60.00	0.38	21.26	6.56	0.42	0.04
	Rio-Grande	PEB	6 MAH	80.00	105.00	95.00	52.50	0.34	22.00	6.08	0.39	0.02
			9 MAH	50.00	110.00	90.00	55.00	0.33	17.45	6.10	0.36	0.01
			3 MAH	115.00	160.00	40.00	82.50	0.25	20.74	6.51	0.39	0.03
		AFB	6 MAH	95.00	145.00	55.00	72.50	0.28	20.12	6.35	0.38	0.01
			9 MAH	70.00	125.00	75.00	62.50	0.31	18.90	6.11	0.38	0.01
			3 MAH	120.00	140.00	60.00	70.00	0.42	22.75	6.34	0.48	0.03
		PB	6 MAH	110.00	135.00	65.00	67.50	0.83	21.85	5.68	0.43	0.03
			9 MAH	70.00	95.00	105.00	47.50	0.44	20.85	5.06	0.42	0.01
			3 MAH	135.00	165.00	35.00	87.50	0.27	22.10	6.16	0.49	0.04
	Gianfranco	PEB	6 MAH	130.00	160.00	40.00	82.00	0.27	21.96	5.60	0.49	0.04
	Fuscello		9 MAH	85.00	175.00	25.00	80.00	0.20	17.83	5.40	0.43	0.92
			3 MAH	180.00	185.00	15.00	95.00	0.28	23.67	6.35	0.47	0.04
		AFB	6 MAH	155.00	180.00	20.00	90.00	0.27	22.96	5.55	0.47	0.03
			9 MAH	95.00	175.00	25.00	85.00	0.20	18.34	5.31	0.43	0.03
2			3 MAH	65.00	100.00	100.00	50.00	0.55	20.55	6.33	0.47	0.04
		PB	6 MAH	55.00	95.00	105.00	47.50	0.56	20.36	5.35	0.45	0.03
			9 MAH	60.00	85.00	115.00	42.50	0.49	19.78	5.41	0.43	0.03
			3 MAH	70.00	100.00	100.00	67.50	0.50	21.28	6.44	0.48	0.03
	Rio-Grande	PEB	6 MAH	65.00	110.00	90.00	55.00	0.35	19.82	5.53	0.43	0.02
			9 MAH	80.00	135.00	65.00	50.00	0.29	19.09	5.20	0.44	0.02

	3 MAH	110.00	140.00	60.00	80.00	0.40	22.91	6.28	0.47	0.03
AFB	6 MAH	105.00	135.00	65.00	70.00	0.42	22.83	5.38	0.45	0.03
	9 MAH	80.00	160.00	40.00	67.50	0.23	17.95	5.23	0.43	0.02
LSD (0.05)		**18.59**	**2085**	**0.23**	**10.36**	**NS**	**NS**	**0.01**	**NS**	**NS**

KEY
PM = Packaging Materials **PEB** = Polyethylene Bag **SFW** = Seedling Fresh Weight
SD = Storage Duration **AFB** = Aluminum Foil Bag **SDW** = Seedling Dry Weight
MAH = Months After Harvest **DAP** = Days After Planting **PB** = Paper Bag
NS = Non Significant

Discussion

Effects of Harvesting Stages on Seed Quality of Tomato Varieties

There were different harvesting stages of tomato that were observed, notably, 40, 60 and 80 days after anthesis. The results revealed that harvesting seeds earlier than the mature period resulted in poor seed quality owing to physiological disorder. The more mature the seeds became, the higher its effects on seed quality attributes. Higher values in germination parameters were observed from seeds harvested at 80 days after anthesis, which was closely followed by seeds harvested at 60 days after anthesis. The tomato seeds harvested at the early date (40 DAA) produsedseeds that were lower in value in all the parameters observed . This result agrees with the report of Bhingande and Dumbre (1993) who studied some engineering properties of greengram and observed that seeds which were harvested 355 days after anthesis proved higher in all the parameters observed. In a similar manner, Shete *et al*. (1992) in their study on seed germination and vigour as influenced by seed position and stage of harvest in sunflower, also reported increase in all the germination parameters with advancement of harvesting dates.

These effects include lower respiration rate, lower metabolic activities and higher seed vigor through the storage periods. They identified higher seed vigor with the Aluminum foil bag which is similar to the findings of this research.

Seeds packed in Aluminum foil bag (PM3) recorded higher first (6 DAP) and second (12 DAP) germination count, followed by seeds packed in polyethylene bag. Packaging materials such as aluminum foil and polyethylene bags played significant roles as moisture barriers in maintaining lower moisture content in the seeds. Lower moisture content resulted in lower respiration rate, lower metabolic activities and high vigor.

Effects of Storage Duration on Seed Quality of Tomato

Results on Table 7 revealed that tomato seed germination varied significantly due to storage duration. Tomato germination percentage decreased with increase in storage duration. Higher tomato germination percentage (72.29) was found after 3 months of storage, while the lowest tomato germination percentage (63.96) was observed at 9 months of storage. A similar research was conducted on rice using similar parameters and the result agreed with the findings of this research work. According to Christenson and Lopez (1995), the moisture level invasion of rice by storage germination percentage is proportional to the increase in moisture content and length of storage.

All the parameters observed after 3, 6 and 9 months of storage were significantly lower in values compared to values before storage. The seedling height (growth) parameter decreased with an increase in storage duration which might be the cause of attaining dormancy of seeds due to increase in storage duration.
The observed significant interaction between variety and storage duration on tomato seed germination was attributed to varietal differences.

Conclusion

Seed is the most valuable, basic and vital living input for increasing crop production. It has been significantly proved that quality seed alone can contribute to increase in yield. Therefore, quality seed harvested at appropriate time and seed maturity are necessary for a successful crop production. However, the present investigation revealed that the highest germination percentage (95.60%) was obtained from the third harvest (80 DAA), nevertheless, seeds harvested at 60 days after anthesis were also observed and found to be of use for seed quality and yield.

It can be concluded that harvesting of tomato seeds at 60-80 days after anthesis would give physiologically matured seeds that would lead to the highest seed quality. The study also reviewed that packaging materials significantly influenced the germination of tomato seeds under a conducive room temperature storage condition. Among the three packaging materials used, aluminum foil bag was observed to be the best for storing tomato seeds. Again, the study concluded that increasing storage periods from 3 to 6 and 9 months resulted to decline in germination percentage with respective values of 72.29, 67.92 and 63.96. Moreover, tomato varieties can retain viability of 60% and above up to 9 months in storage under short term storage conditions using a normal room temperature.

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