AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

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Batch 37

1. SUBJECT CLASSIFICATION

A. PRIMARY
Agriculture — AN10-0000-0000

B. SECONDARY
Agricultural engineering and structures

2. TITLE AND SUBTITLE
Transoceanic shipment and subsequent storage of nine kinds of seed packaged in different containers at various moisture levels

3. AUTHOR(S)
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4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1963	29p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS
Miss.State

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*

9. ABSTRACT

10. CONTROL NUMBER
PN-AAC-229

11. PRICE OF DOCUMENT

12. DESCRIPTORS
Marine transportation
Materials handling
Moisture content
Packaging
Seeds
Storage

13. PROJECT NUMBER

14. CONTRACT NUMBER
AID/W-607 GTS

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

AID/W-607 GTS
PN-AAC-229

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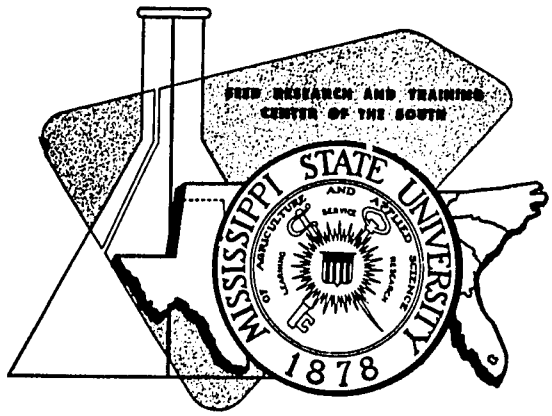
TRANSOCEANIC SHIPMENT AND SUBSEQUENT STORAGE OF NINE KINDS OF SEED PACKAGED IN DIFFERENT CONTAINERS AT VARIOUS MOISTURE LEVELS



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STATE COLLEGE, MISSISSIPPI

A PORTION OF THE SERVICES RENDERED
UNDER THE AGREEMENT BETWEEN THE
AGENCY FOR INTERNATIONAL DEVELOPMENT
AND
MISSISSIPPI STATE UNIVERSITY
AID-W-607

OCTOBER 1963

Transoceanic Shipment and Subsequent Storage of Nine Kinds of Seed Packaged in Different Containers at Various Moisture Levels

James D. Helmer, William P. Caldwell, and H. Dean Bunch [1]

The maintenance of seed viability during transoceanic shipment and subsequent storage has for many years concerned those who deal in international seed trade. With international seed sales increasing, the problem is of paramount importance. It is imperative that seed intended for planting purposes arrive at their destination with high germination capacity and with the ability to maintain this capacity in storage for a reasonable period of time. Conditions of shipment and storage that do not meet these prerequisites not only result in a large monetary loss, but, in many instances, the loss of an entire crop.

Three seed shipment and storage studies were conducted from 1960-62 by the Mississippi Seed Technology Laboratory in cooperation with the National Taiwan University Seed Laboratory in Taipei, Taiwan, the Republic of China; the Thailand Ministry of Agriculture in Bangkok, Thailand; and the Bureau of Plant Industries of the Republic of the Philippines in Manila. These investigations were a part of the services performed by Mississippi State University under a contractural agreement with the Agency of International Development providing for training, research, service, and backstopping in the field of seed technology. The US AID offices in each cooperating country provided valuable assistance in a laison capacity with local cooperators during the initiation and early stages of the experiment.

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[1] Assistant Agronomist; former Assistant Agronomist, now with Northrup King and Company; and Agronomist, respectively, Mississippi Agriculture Experiment Station.

The main objective of these studies was to collect information regarding the most suitable packaging container and seed moisture content for overseas shipment and storage of different kinds of seed.

In each experiment, three kinds of seed were adjusted to three moisture levels and packaged in four types of containers. After packaging, the containers were placed in wooden crates and shipped via regular land and ocean routes to their respective destinations. Upon arrival, the containers were stored in a room with no temperature or humidity control.

Thirteen samples of each moisture level of each seed kind were prepared for each type of container to provide for sampling upon arrival and at 12 monthly intervals.

At each sampling date, seed moisture content, germination percentage, and a seed vigor index were determined by seed technicians in the respective countries. Seed moisture was calculated on a wet weight seed basis and standard germination tests were conducted on each type of seed according to procedures described in the "Rules for Testing Seeds". [2/] Vigor indices were calculated by multiplying the number of seedlings removed from 100 seeds planted by the reciprocal of the days since planting for each day that seedlings were removed. Seedlings were counted and removed from the germinating medium when the seedling had a normal root system, and the length of the radicle was equal to or exceeded 15 mm. in cabbage, onion, and cauliflower, and 25 mm. in soybeans, peanut, castorbeans, and tomato. Wheat seedlings

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[2/] Anon. Rules for Testing Seeds. 1960. Proc. Assoc. Off. Seed Anal. 49.

having a normal root system and a plumule 10 mm. or longer were removed, while the criterion of measurement for the plumule of corn was 38 mm. In the tables throughout this report, initial seed moisture levels are designated as Lots 1, 2, and 3, with Lot 1 indicating the lowest initial storage moisture level.

TAIWAN STORAGE STUDY

Seeds of cabbage, wheat and soybean were used in this experiment. Cabbage seed were adjusted to 6.01%, 7.83%, and 9.88% moisture content; wheat to 10.51%, 12.44%, and 13.88%; and soybean to 6.96%, 7.75%, and 12.83%. The desired moisture levels were accomplished by drying the seeds in a forced air dryer to the lower moisture levels, and by moisture absorption in a closed high humidity chamber for the higher moisture levels.

The four different packaging containers used were as follows: cloth bags 7" x 9 1/2", #3 size tin can, .010 gauge polyethylene bags size 8 3/4" x 5 1/4", and multiwall kraft bags, 8" x 12" with a polyethylene-aluminum foil kraft paper laminated insert. One pound samples of each of the three kinds of seed adjusted to the above moisture levels were placed in the various packaging containers. The containers were sealed in the following ways: the cloth bags by sewing; the tin cans by a pressure sealer; the polyethylene bags by heat-sealing. The polyethylene-aluminum foil kraft paper inserts were heat sealed then placed inside a four ply kraft paper bag, and the end sewed.

Results:

Kraft paper multiwall bags with laminated paper aluminum foil-polyethylene inserts were as effective as tin cans in maintaining a moisture barrier, while the 10 mil polyethylene bags were slightly less effective than the cans. Especially was this true in the storage of cabbage seed, Table 1, and to a lesser degree in the storage of wheat and soybeans, Tables 2 and 3, respectively.

Table 1. Storage data for cabbage from the Taiwan Experiment.

Storage Period		Storage Container											
		Cloth Bag			Plastic Bag			Multiwall Bag			Tin Can		
		Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3
0 Months (At Time of Shipment)	Moisture %	6.01	7.83	9.88	6.01	7.83	9.88	6.01	7.83	9.88	6.01	7.83	9.88
	Viability %	93.50	93.50	93.50	93.50	93.50	93.50	93.50	93.50	93.50	93.50	93.50	93.50
	Vigor Index	31.56	31.56	31.56	31.56	31.56	31.56	31.56	31.56	31.56	31.56	31.56	31.56
2 Months (Upon Arrival)	Moisture %	8.10	8.06	8.09	6.17	7.90	8.96	5.48	8.36	9.13	5.42	8.43	9.36
	Viability %	96.50	92.25	97.00	94.50	96.25	97.00	94.75	94.50	91.75	97.75	95.00	94.25
	Vigor Index	29.67	30.00	29.85	28.89	30.44	27.85	29.32	28.86	26.92	29.50	27.97	27.11
6 Months	Moisture %	10.77	10.87	10.83	8.40	9.34	9.82	6.01	8.40	9.31	5.97	8.59	9.51
	Viability %	44.00	45.30	46.25	91.00	80.00	57.75	95.75	86.75	65.75	95.25	84.00	63.25
	Vigor Index	7.18	7.44	7.40	26.91	18.46	11.09	30.07	22.34	13.63	30.19	22.26	12.88
10 Months	Moisture %	12.17	11.73	11.73	8.75	9.42	9.81	7.63	8.66	9.64	6.16	8.19	9.66
	Viability %	30.50	29.75	25.25	88.75	72.75	53.50	92.50	77.50	43.25	95.00	75.50	48.50
	Vigor Index	4.57	4.09	3.38	24.19	14.32	8.60	26.78	16.04	7.10	26.86	15.93	8.26
14 Months	Moisture %	10.00	9.51	9.41	9.92	10.43	10.61	5.92	8.98	9.81	6.00	8.83	9.68
	Viability %	0.25	0.25	0.25	77.50	35.25	18.75	92.75	72.75	29.75	95.75	77.00	36.75
	Vigor Index	0.03	0.03	0.03	18.11	5.77	2.62	30.27	16.06	4.46	30.24	16.77	5.23

Table 2. Storage data for wheat from the Taiwan Experiment.

Storage Period		Storage Container											
		Cloth Bag			Plastic Bag			Multiwall Bag			Tin Can		
		Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3
0 Months (At Time of Shipment)	Moisture %	10.51	12.44	13.88	10.51	12.44	13.88	10.51	12.44	13.88	10.51	12.44	13.88
	Viability %	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00
	Vigor Index	26.54	26.54	26.54	26.54	26.54	26.54	26.54	26.54	26.54	26.54	26.54	26.54
2 Months (Upon Arrival)	Moisture %	12.13	12.09	12.34	10.07	11.73	13.11	9.99	11.85	13.00	9.91	11.73	13.06
	Viability %	95.25	92.00	95.75	96.50	98.00	95.25	96.50	95.75	96.75	95.50	95.75	93.00
	Vigor Index	24.68	22.80	23.46	24.65	23.54	23.24	23.59	23.41	23.37	23.92	23.17	23.21
6 Months	Moisture %	14.33	14.33	14.29	10.63	12.32	13.24	10.10	12.08	13.24	10.15	12.13	13.18
	Viability %	0.00	0.00	0.00	94.25	93.75	60.50	94.00	93.75	68.25	93.50	94.50	70.50
	Vigor Index	0.00	0.00	0.00	27.61	26.30	15.24	23.54	26.50	17.32	27.99	25.68	15.98
10 Months	Moisture %				10.61	12.21	13.73	10.12	12.49	13.56	10.12	12.21	13.25
	Viability %				95.50	92.50	49.25	92.75	93.25	53.00	96.00	93.75	55.25
	Vigor Index				19.28	16.83	8.34	18.27	17.96	9.13	18.92	18.19	8.84
14 Months	Moisture %				11.01	12.76	13.42	9.95	12.05	13.31	10.11	12.05	13.20
	Viability %				95.25	87.00	40.50	94.00	87.00	49.00	94.25	91.00	48.25
	Vigor Index				22.56	20.22	7.71	27.21	20.86	10.42	23.43	21.72	9.91

Table 3. Storage data for soybeans from the Taiwan Experiment.

Storage Period		Storage Container											
		Cloth Bag			Plastic Bag			Multiwall Bag			Tin Can		
		Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3
0 Months (At Time of Shipment)	Moisture %	6.96	7.75	12.83	6.96	7.75	12.83	6.96	7.75	12.83	6.96	7.75	12.83
	Viability %	86.00	86.00	86.00	86.00	86.00	86.00	86.00	86.00	86.00	86.00	86.00	86.00
	Vigor Index	28.23	28.23	28.23	28.23	28.23	28.23	28.23	28.23	28.23	28.23	28.23	28.23
2 Months (Upon Arrival)	Moisture %	10.82	10.97	9.57	7.29	7.90	12.13	7.32	7.90	12.23	7.32	7.93	12.35
	Viability %	85.25	91.75	85.25	84.00	89.75	67.25	83.50	91.50	69.75	87.00	88.00	69.00
	Vigor Index	24.81	25.62	21.99	24.48	24.74	15.92	24.75	26.62	16.83	24.94	25.18	16.04
6 Months	Moisture %	13.43	13.80	13.25	7.67	8.44	12.26	7.33	8.13	12.21	7.38	8.18	12.31
	Viability %	0.00	0.00	0.00	84.75	92.25	0.25	86.25	92.50	0.00	86.00	87.00	0.00
	Vigor Index	0.00	0.00	0.00	25.01	28.17	0.06	25.22	27.70	0.00	24.14	25.39	0.00
10 Months	Moisture %				8.57	8.89	13.46	8.33	8.83		7.93	9.14	
	Viability %				89.75	90.00	0.00	82.50	91.25		80.75	83.00	
	Vigor Index				19.63	20.90	0.00	18.04	20.76		20.22	22.39	
14 Months	Moisture %				8.13	8.59		7.35	7.98		7.18	7.78	
	Viability %				90.00	90.50		85.50	91.75		85.50	89.00	
	Vigor Index				23.27	24.52		21.14	24.88		21.35	24.81	

Throughout this study vigor declined at a more rapid rate than did viability, which bears out the observation of Delouche and Caldwell.[3/] The relationship between viability and vigor decline within each kind of seed is shown in Figures 1, 2, and 3.

Figure 4 illustrates the effect of moisture content upon viability of soybean seed. Surprisingly, the viability loss was greater in seed at 6.96% moisture than at 7.75%. Although it has been reported that seeds will deteriorate at low moisture levels, these levels have been in the range of 1 to 4%. It is possible that soybean is sensitive to excessively dry conditions. Seed stored in tin cans at a moisture level of 12.5% deteriorated more rapidly than those in cloth bags which had free moisture exchange with the atmosphere.

The effect of moisture content upon wheat viability is shown in Figure 5. Very little difference in viability deterioration occurred between seed stored at 10.5% moisture and 12.4%. A decided drop was noted, however, in seeds stored at 13.5%.

Figure 6 shows the effect of moisture on viability of cabbage seed. This data shows the typical trend with the least deterioration occurring at the lowest moisture level and the greatest at the highest level.

[3/] Delouche, J. C., and W. P. Caldwell. 1960. Seed vigor and vigor tests. Proc. Assoc. Off. Seed Anal. 50: 124-129.

Figure 1. Viability and Vigor Loss of Wheat Stored in Tin Cans at 13.88% Moisture.

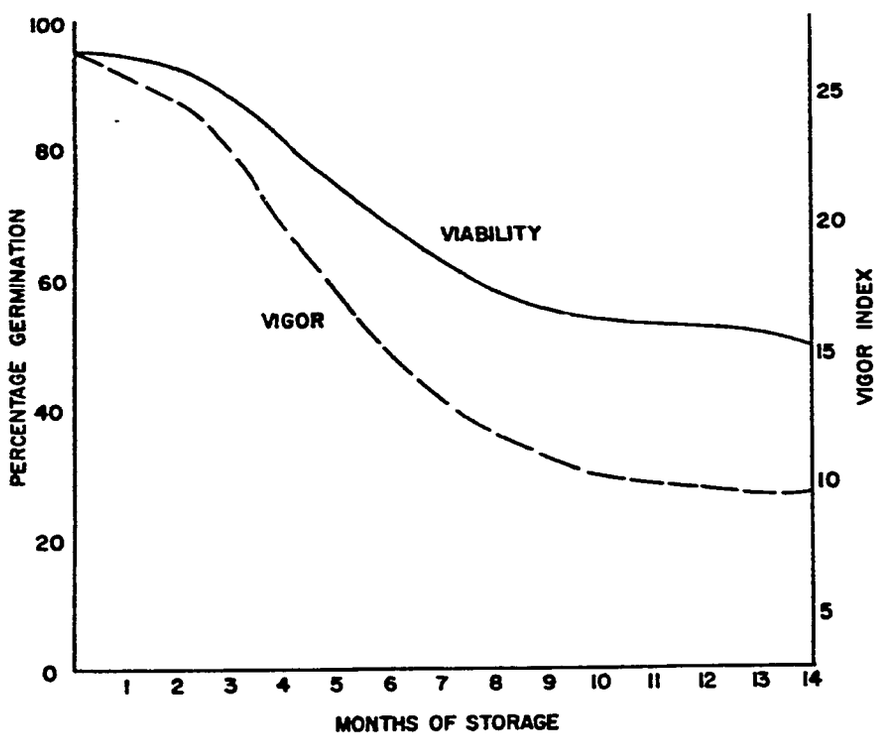


Figure 2. Viability and Vigor Loss of Soybeans Stored in Tin Cans at 12.83% Moisture.

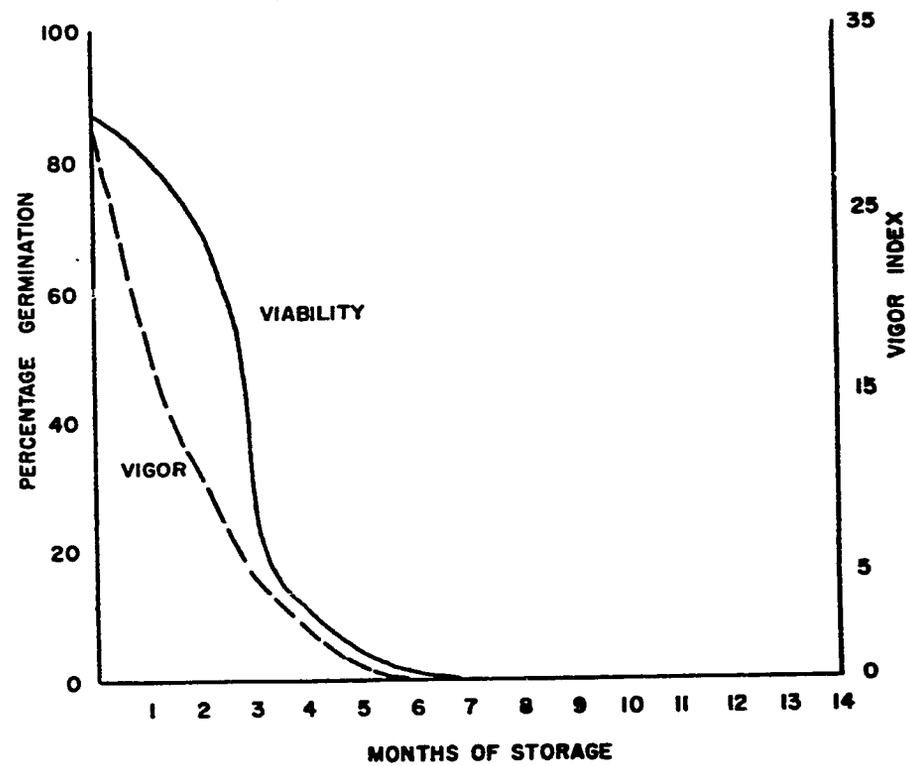


Figure 3. Viability and Vigor Loss of Cabbage Stored in Tin Cans at 9.88% Moisture.

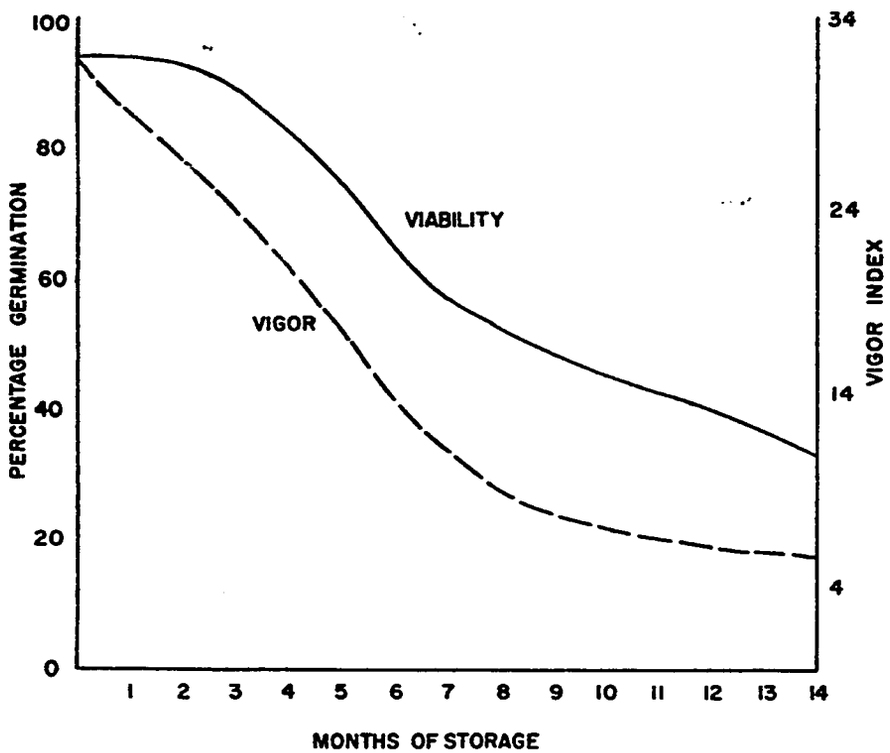


Figure 4. Viability Loss of Soybeans Stored at Various Moisture Levels.

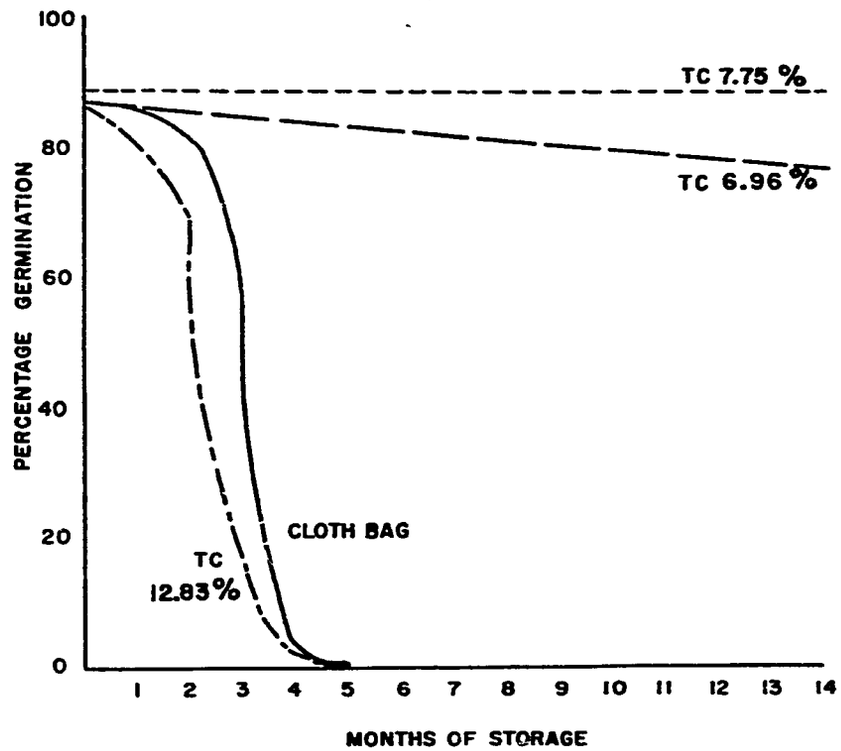


Figure 5. Viability Loss of Wheat Stored at Various Moisture Levels.

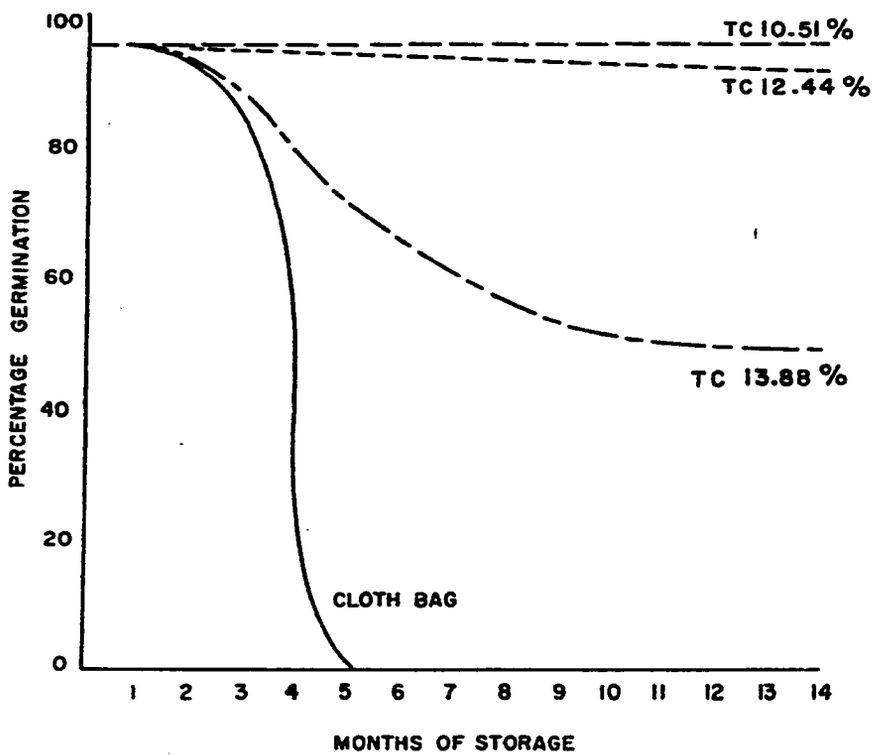
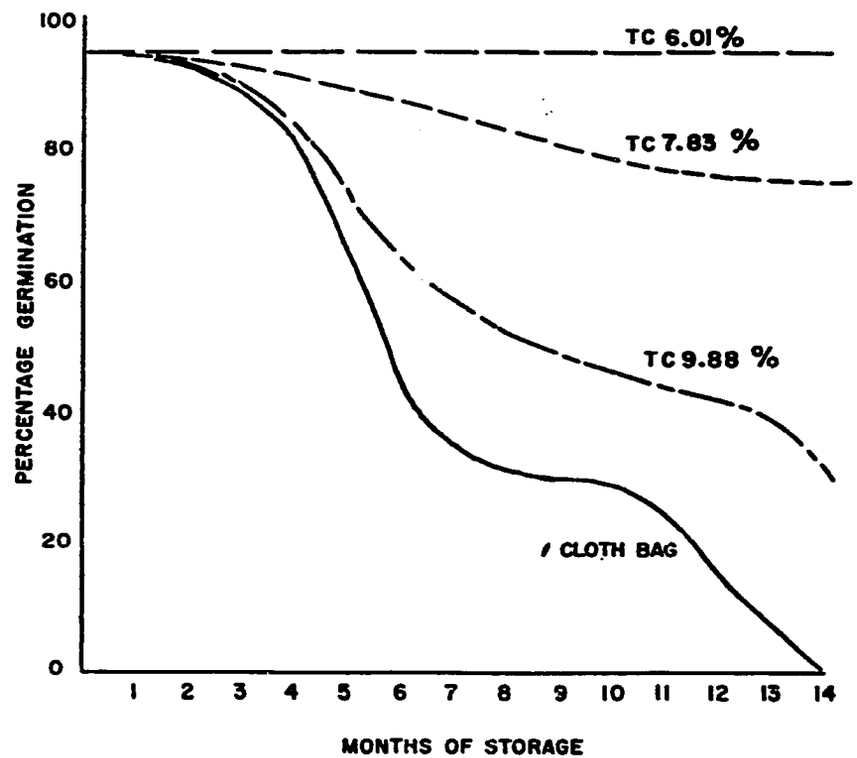


Figure 6. Viability Loss of Cabbage Stored at Various Moisture Level



THAILAND STORAGE STUDY

In this study, the three kinds of seed used were corn, peanut, and castorbean. Seeds of corn were adjusted to 7.68%, 10.70%, and 13.53%, moisture content; those of peanut to 6.99%, 8.79%, and 12.63%; and those of castorbean to 7.26%, 8.57%, and 11.33%.

Types of seed packaging containers were the same as used in the Taiwan storage experiment.

Seed moisture content, standard germination percentages, and vigor indices were conducted by laboratory personnel in Thailand in the manner previously described.

Results:

Seeds of peanut and castorbean declined very rapidly in germination and vigor under all storage conditions. A great loss in germination and vigor of castorbeans occurred during the 4-month shipment period in all packaging containers at the various moisture levels (Table 4). Castorbean seed packaged in plastic bags, multiwall bags with laminated inserts and tin cans at initial seed moisture content of 8.57% and 11.33% were non-viable upon arrival in Thailand.

The viability and vigor loss during shipment of peanut seed packaged at 6.99% moisture was considerably less in seed stored in tin cans, plastic bags, and multiwall bags with laminated inserts than in seed stored in cloth bags at the same moisture level (Table 5). However, 6 months after the study was initiated, all seed, regardless of initial moisture level or packaging container, were unfit for planting purposes. Peanut seed packaged in cloth bags

Table 4. Storage data for castorbean from the Thailand experiment.

Storage Period		Storage Container											
		Cloth Bag			Plastic Bag			Multiwall Bag			Tin Can		
		Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3
0 Months (At Time of Shipment)	Moisture %	7.26	8.57	11.33	7.26	8.57	11.33	7.26	8.57	11.33	7.26	8.57	11.33
	Viability %	74.50	71.50	54.00	74.50	71.50	54.00	74.50	71.50	54.00	74.50	71.50	54.00
	Vigor Index	10.50	11.76	7.84	10.50	11.76	7.84	10.50	11.76	7.84	10.50	11.76	7.84
4 Months (Upon Arrival	Moisture %	7.00	7.80	7.00	6.00	8.00	10.00	7.00	9.50	12.00	7.00	8.00	10.50
	Viability %	21.25	34.50	44.25	32.50	2.00	0.00	35.75	0.00	0.00	37.75	1.00	0.00
	Vigor Index	1.79	3.36	4.17	3.08	0.15	0.00	3.37	0.00	0.00	3.47	0.12	0.00
6 Months	Moisture %	6.06	8.08	6.80	7.00	10.00		7.50			6.20	7.60	
	Viability %	23.25	14.00	34.25	19.50	0.00		24.50			16.25	0.00	
	Vigor Index	2.00	1.22	3.00	1.68	0.00		2.05			1.32	0.00	

Table 5. Storage data for peanut from the Thailand experiment.

Storage Period		Storage Container											
		Cloth Bag			Plastic Bag			Multiwall Bag			Tin Can		
		Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3
0 Months (At Time of Shipment)	Moisture %	6.99	8.79	12.63	6.99	8.79	12.63	6.99	8.79	12.63	6.99	8.79	12.63
	Viability %	86.00	65.50	39.00	86.00	65.50	39.00	86.00	65.50	39.00	86.00	65.50	39.00
	Vigor Index	17.88	13.32	8.37	17.88	13.32	8.37	17.88	13.32	8.37	17.88	13.32	8.37
4 Months (Upon Arrival)	Moisture %	8.60	8.50	7.00	6.50	7.00	12.00	8.00	7.50	12.00	7.00	7.50	12.50
	Viability %	33.25	36.50	54.50	81.25	21.25	0.00	81.00	27.25	0.00	73.50	3.00	0.00
	Vigor Index	3.96	3.66	4.70	8.32	1.78	0.00	7.94	2.39	0.00	7.57	0.29	0.00
6 Months	Moisture %	7.20	7.57	8.00	6.36	8.08		6.40	7.83		6.26	8.00	
	Viability %	3.00	13.00	0.00	2.25	0.00		3.00	0.00		12.50	0.00	
	Vigor Index	0.23	1.01	0.00	0.19	0.00		0.24	0.00		1.09	0.00	

at the higher moisture level, 12.63%, showed an increase in germination upon arrival in Thailand. A seed dormancy condition not detected before shipment probably was responsible.

Corn seed shipped and stored very well in three of the four packaging containers at the lower moisture level. After 12 months storage, those seed packaged at 7.68% moisture in cloth bags were dead while those seed at the same initial moisture level stored in tin cans, plastic bags and multiwall bags were very high in total germination percentage although a loss in vigor was indicated (Table 6). These results illustrate the effectiveness of the plastic bag, multiwall bag with laminated insert, and tin can in preventing free moisture exchange with the atmosphere; the cloth bag was ineffective in controlling movement of moisture. At the higher initial moisture storage levels, 10.70% and 13.53%, seed deterioration was slower in the cloth bags than in the other 3 packaging containers. Figure 7 illustrates the effectiveness of tin can packaging containers over cloth bags in maintaining viability of corn seed at the lower moisture level. The effect of seed moisture content of corn viability packaged in tin can containers is graphically illustrated in Figure 8.

Table 6. Storage data for corn from the Thailand experiment.

Storage Period		Storage Container											
		Cloth Bag			Plastic Bag			Multiwall Bag			Tin Can		
		Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3
0 Months (At Time of Shipment)	Moisture %	7.68	10.70	13.53	7.68	10.70	13.53	7.68	10.70	13.53	7.68	10.70	13.53
	Viability %	98.00	97.50	97.50	98.00	97.50	97.50	98.00	97.50	97.50	98.00	97.50	97.50
	Vigor Index	21.14	21.09	19.43	21.14	21.09	19.43	21.14	21.09	19.43	21.14	21.09	19.43
4 Months (Upon Arrival((a)	Moisture %	12.00	12.50	13.00	10.00	12.00	15.00	9.00	11.00	15.00	9.00	11.82	14.50
	Viability %	98.00	95.25	94.00	99.00	97.25	19.00	96.75	96.00	15.25	94.50	90.50	19.75
	Vigor Index	15.79	14.78	15.02	16.27	14.96	2.56	15.73	15.42	2.03	16.76	14.11	2.19
8 Months	Moisture %	10.80	11.16	11.50	9.40	11.00	14.00	8.24	11.20	14.24	9.00	11.90	14.00
	Viability %	82.00	76.75	73.00	94.00	80.75	0.00	97.50	78.25	0.00	95.50	61.00	0.00
	Vigor Index	7.27	6.87	6.42	8.54	11.00	0.00	8.85	6.89	0.00	8.68	5.36	0.00
12 Months (b)	Moisture %	14.00	12.00	12.50	6.50	7.00		10.00	12.50		9.50	13.00	
	Viability %	0.00	0.00	0.00	97.00	7.25		93.25	21.50		94.75	11.75	
	Vigor Index	0.00	0.00	0.00	11.43	0.60		11.81	1.25		12.52	1.08	

(a) - 5 months for Lot 2 - Tin Can
(b) - 11 months for all Lots - Plastic Bag

Figure 7. Viability Loss of Corn Stored in Cloth Bag and Tin Can.

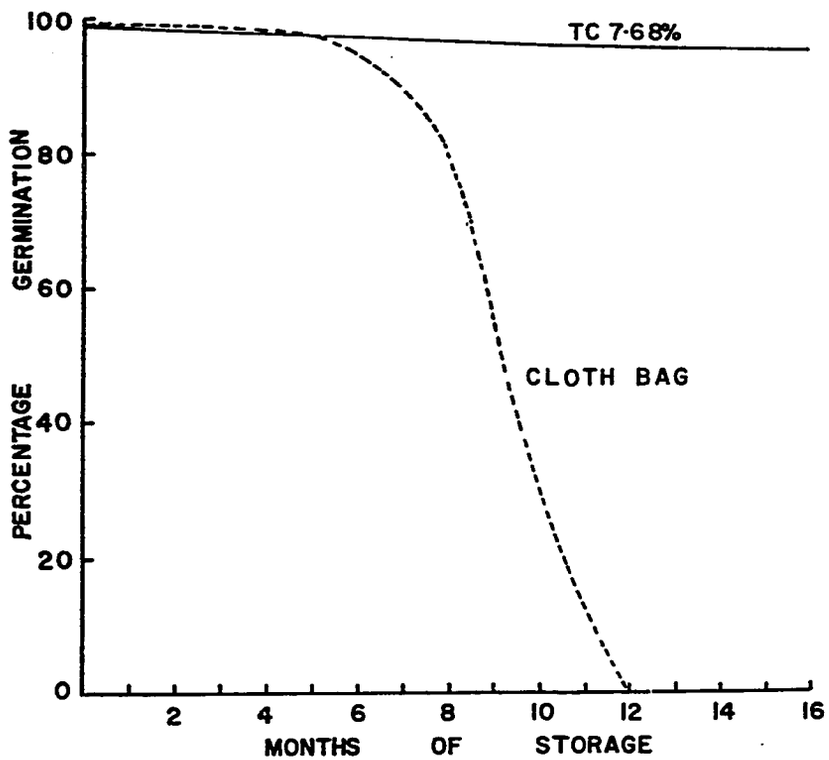
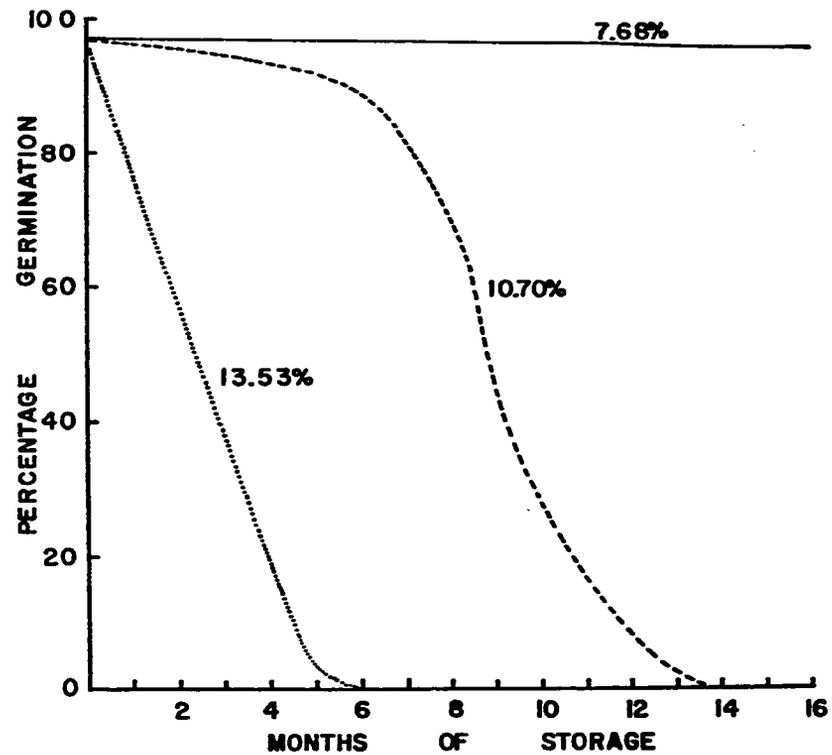


Figure 8. Viability Loss of Corn Stored in Tin Cans at Various Moisture Levels.



PHILIPPINE STORAGE STUDY

In this experiment, seeds of cauliflower, tomato, and onion were used. Seed moisture adjustments were as follows: cauliflower 6.08%, 7.78%, and 12.00%; tomato 6.56%, 8.82%, and 12.25%; and onion 6.66%, 9.63%, and 12.52%.

Seed packaging containers were the same for this experiment as for the Taiwan and Thailand study except that kraft multiwall bags with a paper liner were used in lieu of .010 gauge polyethylene bags.

Seed testing and moisture content determinations were conducted by the seed research personnel in Manila in a similar manner as the other storage studies previously described.

Results:

Onion seed containing 6.66% and 9.63% initial moisture which were packaged in tin cans and multiwall bags with laminated inserts deteriorated at a much slower rate than similar seed stored in cloth bags, and multiwall bags with a paper liner (Table 7). Especially was this true with onion seed packaged at 6.66% moisture. After 12 months storage in tin cans and multiwall bags with laminated inserts at this moisture content, onion seed viability was reduced only approximately 10% while the same seed lot stored in cloth bags and multiwall bags with paper liners at 6.66% was dead.

Seed moisture data measured after the various storage intervals and presented in Table 7 indicate the ineffectiveness of the multiwall bag with paper liner and the cloth bag to provide a barrier to moisture exchange between the seed and the atmosphere outside the bag. Figure 9 illustrates graphically

Table 7. Storage data for onion from the Philippine experiment.

Storage Period		Storage Container: Cloth Bag			Multiwall Bag Paper Liner			Tin Can			Multiwall Bag Laminated Liner		
		Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3
0 Months (At Time of Shipment)	Moisture %	6.66	9.63	12.52	6.66	9.63	12.52	6.66	9.63	12.52	6.66	9.63	12.52
	Viability %	94.20	94.00	90.70	94.20	94.00	90.70	94.20	94.00	90.70	94.20	94.00	90.70
	Vigor Index	14.74	14.57	13.62	14.74	14.57	13.62	14.74	14.57	13.62	14.74	14.57	13.62
4 Months (Upon Arrival)	Moisture %	13.30	13.25	13.08	12.80	13.05	12.83	7.68	9.62	12.62	7.36	9.34	12.68
	Viability %	46.00	48.80	49.50	27.00	39.80	45.30	91.50	82.00	27.80	89.50	88.30	22.00
	Vigor Index	6.34	7.06	7.54	5.54	5.32	7.04	16.55	15.44	4.09	16.55	15.47	3.25
8 Months	Moisture %	11.33	11.94	11.90	11.39	11.70	12.09	7.01	9.38	12.15	7.10	9.50	12.32
	Viability %	3.25	6.50	3.50	6.00	6.25	4.50	81.75	79.25	0.00	88.75	77.25	0.00
	Vigor Index	1.06	0.78	0.73	1.33	1.22	1.21	18.29	15.50	0.00	18.45	14.80	0.00
12 Months	Moisture %	12.85	13.27	13.18	12.94	13.28	13.26	7.71	10.04		8.26	10.34	
	Viability %	0.00	0.00	0.00	0.00	0.00	0.00	86.25	54.00		85.25	47.75	
	Vigor Index	0.00	0.00	0.00	0.00	0.00	0.00	18.73	8.86		17.36	7.98	
16 Months	Moisture %							7.73	10.12		8.98	10.80	
	Viability %							81.25	21.00		84.00	8.00	
	Vigor Index							17.26	3.70		16.57	.62	

Figure 9. Viability Loss of Onion Stored at 6.66% Moisture in Multiwall Bags with Laminated and Paper Liner.

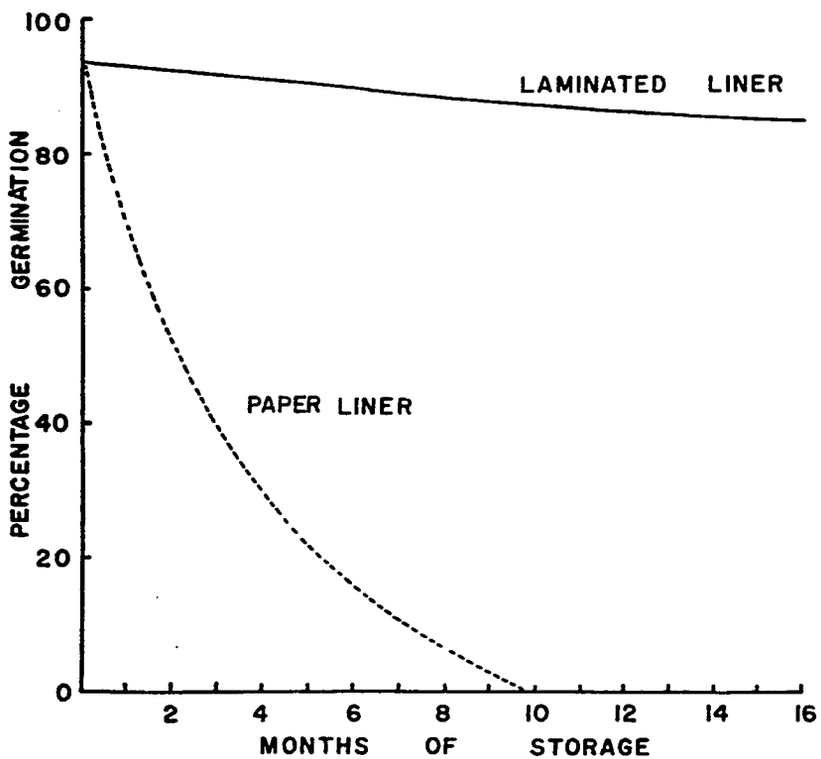
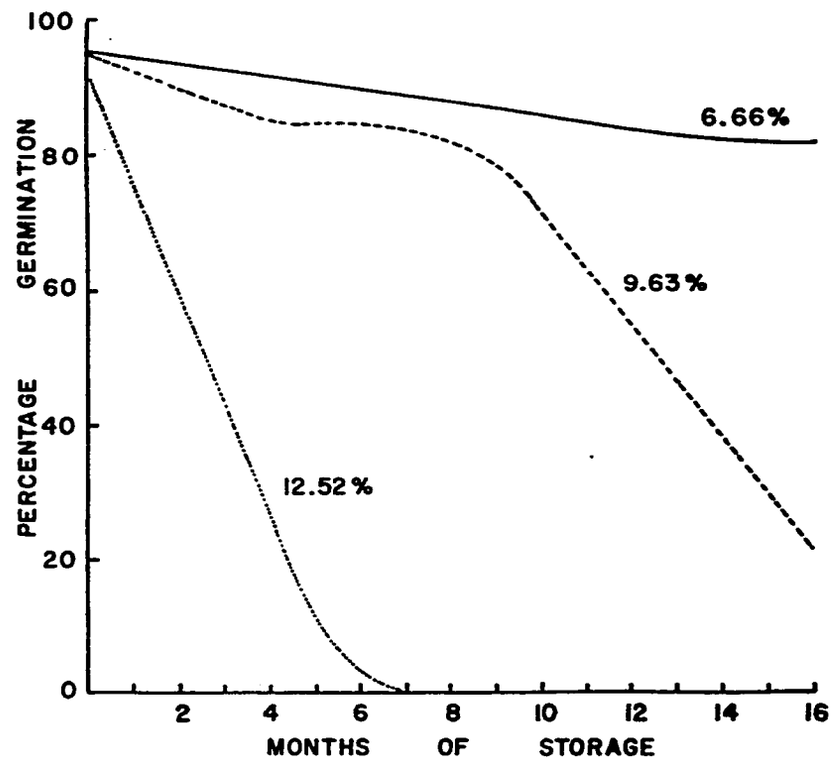


Figure 10. Viability Loss of Onion Stored in Tin Cans at Various Moisture Levels.



the difference between a kraft multiwall bag with a laminated liner and a paper liner in maintaining the germinating capacity of onion seed initially packaged at 6.66% moisture. The effect of seed moisture content on storage of onion seed in tin cans is presented in Figure 10.

Cauliflower seed packaged in tin cans and multiwall bags showed very little loss in viability when the initial moisture content of the seed was 6.08%; a loss of 40% in germination at seed moisture of 7.78%; and complete loss at the end of 8 months of 12% moisture seed (Table 8).

Cauliflower seed stored in cloth bags and multiwall bags with paper liners decreased progressively in germination at all initial moisture levels, and after 12 months were unfit for planting purposes.

Figure 11 compares graphically the two types of multiwall bags in the maintenance of cauliflower seed packaged at 6.99% moisture. The influence of initial seed moisture content on cauliflower germination packaged in tin cans appears in Figure 12.

Tomato seed with an initial storage moisture content of 6.65% exhibited no loss in either germination or vigor after 12 months of combined shipment and storage in tin cans and multiwall bags with a laminated insert (Table 9). However, tomato seed packaged at an initial moisture content of 12.52% were dead after 12 months storage in these same containers. After storage for 12 months in cloth bags and multiwall bags with a paper liner, germination of tomato seed initially packaged at 6.65% moisture was reduced approximately 40%. Apparently sampling variation was responsible for tomato seed of the highest

Table 8. Storage data for cauliflower from Philippine experiment.

Storage Period		Storage Container: Cloth Bag			Multiwall Bag Paper Liner			Tin Can			Multiwall Bag Laminated Liner		
		Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3
0 Months (At Time of Shipment)	Moisture %	6.08	7.78	12.00	6.08	7.78	12.00	6.08	7.78	12.00	6.08	7.78	12.00
	Viability %	99.00	98.20	97.20	99.00	98.20	97.20	99.00	98.20	97.20	99.00	98.20	97.20
	Vigor Index	23.63	23.04	22.91	23.63	23.04	22.91	23.63	23.04	22.91	23.63	23.04	22.91
4 Months (Upon Arrival)	Moisture %	7.78	8.80	8.23	9.71	9.28	10.29	6.16	8.05	12.20	5.99	7.74	12.76
	Viability %	64.50	68.75	62.25	70.25	71.25	63.25	91.00	87.50	11.50	88.25	88.00	26.50
	Vigor Index	16.99	14.49	15.23	11.03	9.39	9.95	18.59	18.29	.07	12.81	16.40	0.81
8 Months	Moisture %	8.37	8.39	8.54	8.78	8.86	8.96	5.89	8.20	12.73	5.97	8.37	11.76
	Viability %	59.50	58.00	65.75	58.00	64.00	56.75	88.50	79.25	0.00	89.75	83.50	0.00
	Vigor Index	6.21	4.34	5.03	7.01	7.48	7.83	8.47	5.08	0.00	12.84	10.63	0.00
12 Months	Moisture %	13.04	13.06	13.33	13.24	13.38	13.34	5.76	8.30		6.45	8.50	
	Viability %	1.75	2.25	1.75	6.00	4.50	3.75	91.75	61.00		93.00	66.50	
	Vigor Index	.09	--	--	--	--	--	8.53	4.56		19.58	8.84	
16 Months	Moisture %	8.76	8.75	8.86	8.59	8.44	8.39	5.75	7.93		6.69	8.70	
	Viability %	0.00	0.00	0.00	0.00	0.00	0.00	89.50	38.00		90.00	24.00	
	Vigor Index	0.00	0.00	0.00	0.00	0.00	0.00	4.84	2.21		5.94	2.60	

Figure 11. Viability Loss of Cauliflower Stored at 6.08% Moisture in Multiwall Bags with Laminated and Paper Liner.

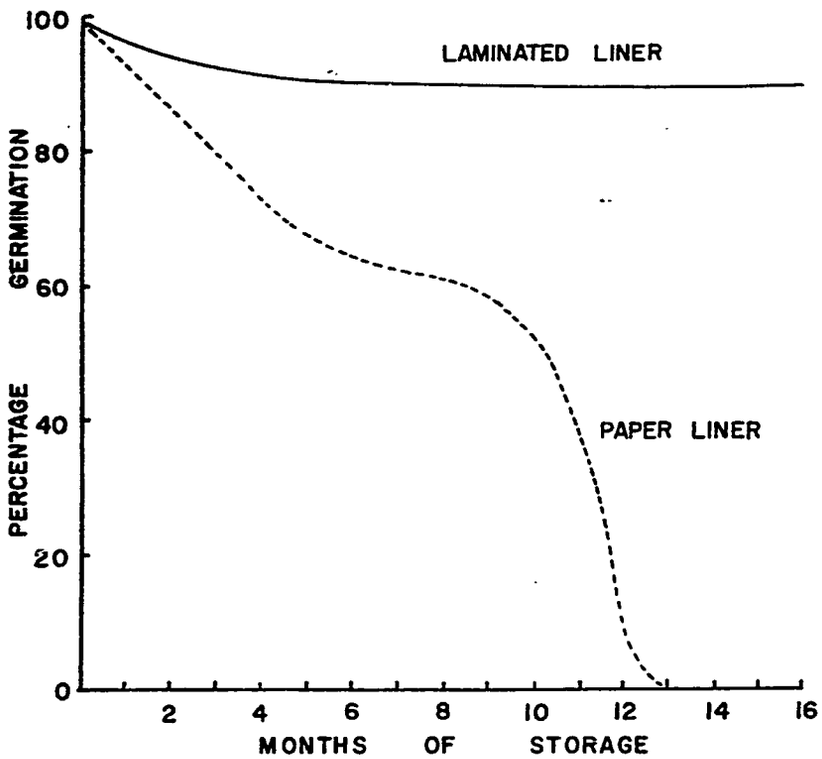


Figure 12. Viability Loss of Cauliflower Stored in Tin Cans at Various Moisture Levels.

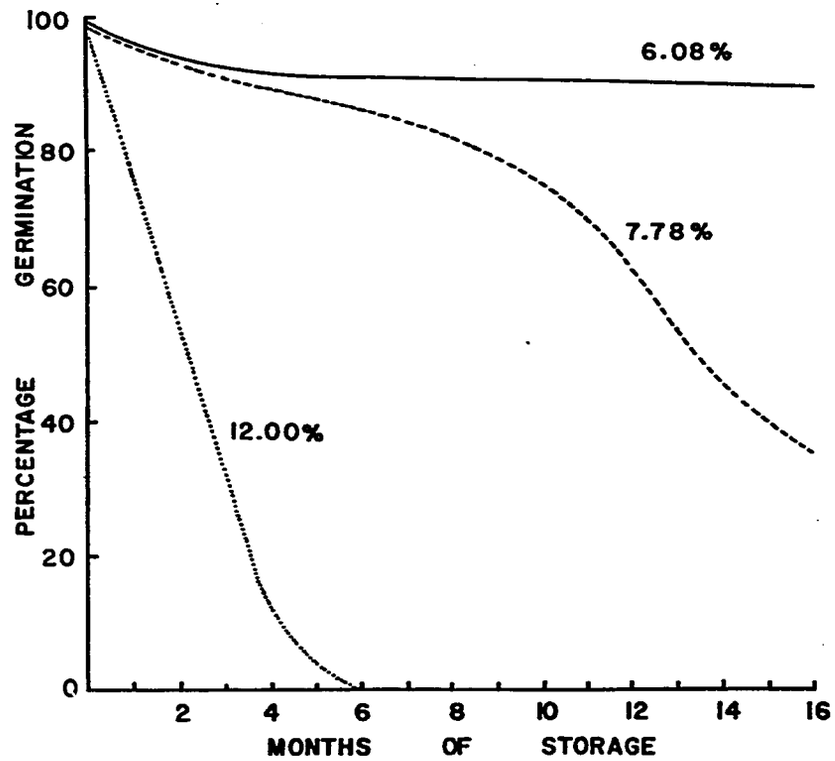


Table 9. Storage data for tomato from the Philippines experiment.

Storage Period		Storage Container: Cloth Bag Lot 1	Cloth Bag Lot 2	Cloth Bag Lot 3	Multiwall Bag Paper Liner Lot 1	Multiwall Bag Paper Liner Lot 2	Multiwall Bag Paper Liner Lot 3	Tin Can Lot 1	Tin Can Lot 2	Tin Can Lot 3	Multiwall Bag Laminated Liner Lot 1	Multiwall Bag Laminated Liner Lot 2	Multiwall Bag Laminated Liner Lot 3
O Months (At Time of Shipment)	Moisture %	6.65	8.82	12.25	6.65	8.82	12.25	6.65	8.82	12.25	6.65	8.82	12.25
	Viability %	75.75	81.00	79.50	75.75	81.00	79.50	75.75	81.00	79.50	75.75	81.00	79.50
	Vigor Index	11.63	12.17	12.41	11.63	12.17	12.41	11.63	12.17	12.41	11.63	12.17	12.41
4 Months (Upon Arrival)	Moisture %	7.02	9.14	9.68	8.18	9.24	10.11	6.50	8.66	10.22	6.28	8.04	10.28
	Viability %	72.50	61.50	58.25	74.25	74.00	73.75	78.25	69.00	48.25	78.75	76.75	60.76
	Vigor Index	7.80	7.89	8.42	7.50	8.80	9.31	10.82	8.96	5.46	10.63	8.65	5.87
8 Months	Moisture %	7.69	7.89	8.08	7.70	7.63	7.64	5.41	7.88	11.17	5.77	7.54	10.09
	Viability %	68.50	70.25	79.25	69.00	71.00	74.00	81.50	66.25	4.75	80.00	71.50	17.50
	Vigor Index	8.97	7.86	9.88	7.86	7.86	8.39	11.50	7.51	0.16	11.73	10.11	1.17
12 Months	Moisture %	11.26	11.24	11.36	11.26	11.15	11.03	5.98	8.22	10.86	6.08	7.91	9.97
	Viability %	46.50	45.25	63.25	44.25	50.50	61.25	81.50	54.00	0.00	83.00	58.00	0.00
	Vigor Index	6.45	4.95	7.13	4.54	4.06	5.94	14.30	6.41	0.00	12.61	6.49	0.00
16 Months (a)	Moisture %	8.58	8.77	8.82	8.92	8.76	8.71	5.96	8.33		6.90	8.35	
	Viability %	17.50	22.25	15.75	13.25	13.00	11.50	83.75	52.25		78.75	48.25	
	Vigor Index	.82	.87	1.45	.23	.57	.82	10.99	2.44		8.73	7.74	

(a) - 14 Months for storage in Tin Cans

moisture level showing higher germination readings than the lower levels after 12 months storage. The effectiveness of a laminated liner over a paper liner for the maintenance of tomato seed viability packaged at 6.65% moisture is illustrated in Figure 13. Figure 14 shows the effect of initial seed moisture content on the storage of tomato seed in tin cans.

Figure 13. Viability Loss of Tomato Stored at 6.65% Moisture in Multiwall Bags with Laminated and Paper Liner.

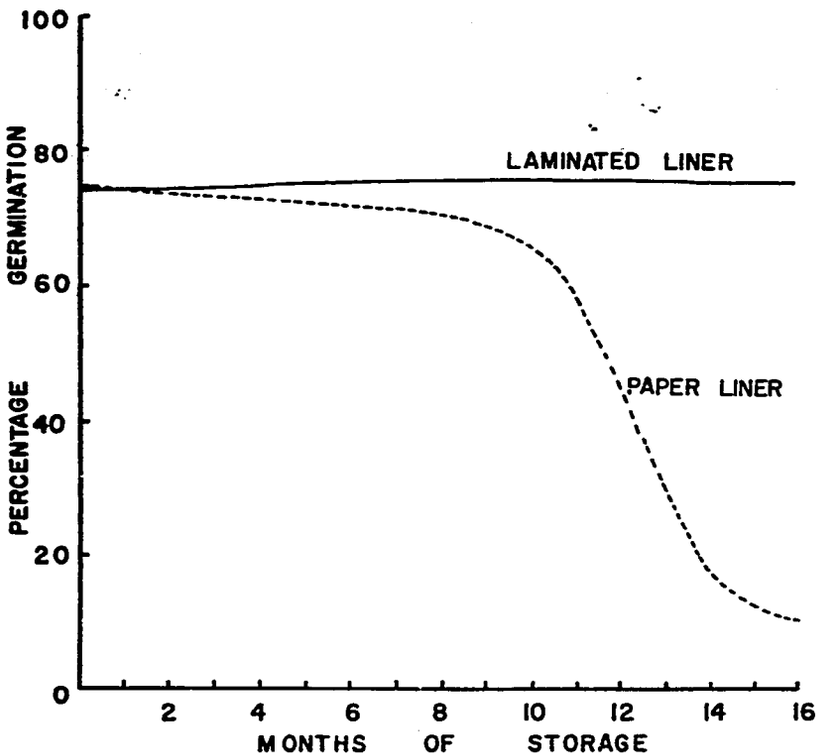
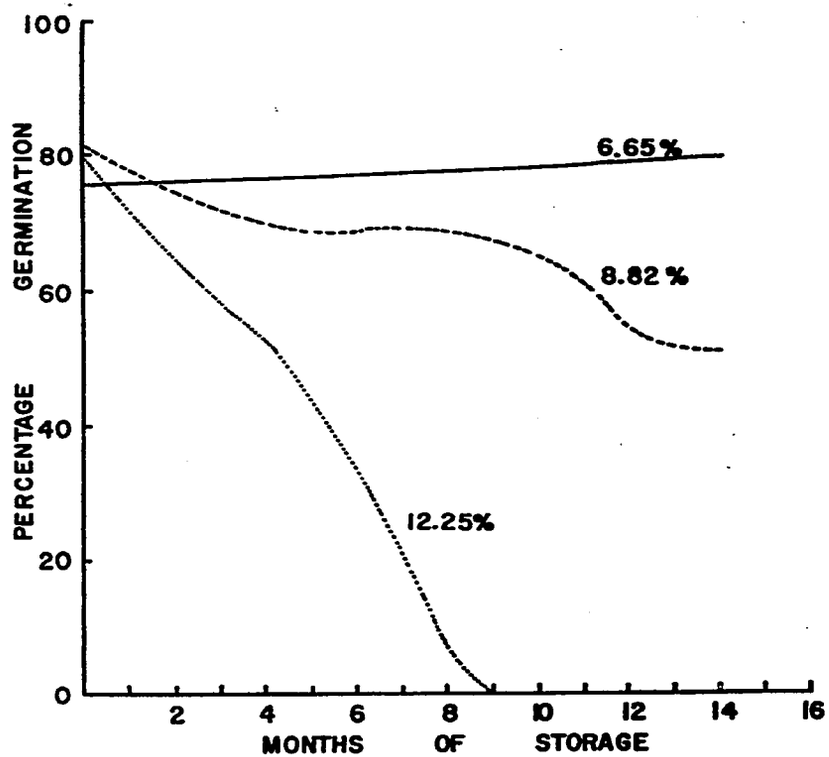


Figure 14. Viability Loss of Tomato Stored in Tin Cans at Various Moisture Levels.



DISCUSSION

In all seed experiments, final results are largely dependent upon the initial condition of the seed when placed in storage. Certain lots of seed will store for a much longer period of time under given conditions than other lots of the same kind. In other words, the initial so-called "vigor" of the seed influences its longevity. The varied results of seed storage research reported in the literature can likely be attributed to this initial vigor difference in the seed lots used. For example, in these investigations wheat seed shipped and stored very satisfactorily for a period of 14 months in sealed storage at an initial moisture content of 10.5 percent. Because of initial vigor differences, every lot of wheat seed containing 10.5 percent moisture should not be expected to perform equally. The same applies to the eight other varieties of seeds used in the tests. The results, however, do serve as guides. But until research discovers reliable methods of measuring vigor and standardizing vigor tests, the initial differences in seed lots placed in storage will continue to cause variation in the end results.

The data presented in tabular form in this report do not include all results obtained from each testing period. In an effort to show trends without obscurring salient points with an enormous number of figures, only data from specific testing intervals were selected for presentation.

Finally, even the lowest initial seed storage moisture level at which peanut and castorbean seed were shipped proved to be too high for satisfactory retention of viability during shipment and storage of such seed. Therefore, some initial seed moisture level lower than the lowest level used here could be assumed to give satisfactory storage.

SUMMARY AND CONCLUSIONS

1. Tin cans and multiwall bags with laminated inserts were very effective in maintaining a moisture barrier and in retaining viability of seed initially stored at a low moisture level.
2. In the Taiwan storage experiment, .010 polyethylene bags were comparable to tin cans and multiwall bags with laminated inserts in maintaining wheat and soybean viability, but less effective in maintaining cabbage seed viability. The polyethylene bags were less effective as a moisture barrier.
3. Multiwall bags with a paper liner were no more satisfactory than cloth bags as a storage container, both ineffective for transoceanic shipment and storage of seed to the Philippines.
4. These investigations showed the following approximate initial seed moisture levels to be best in maintaining seed vigor and viability at a high level during transoceanic shipment and storage.

Wheat	10.5%	Peanut	<7.0%
Soybeans	7.75%	Tomato	6.5%
Cabbage	6.0%	Cauliflower	6.0%
Corn	7.75%	Onion	6.5%
Castorbeans	< 7.25%		

<The lowest moisture level tested, but still too high.