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Effect of different storage conditions and seed treatments on seed viability in soybean [Glycine max (L.) Merr.]

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Abstract: The present investigation was carried out in laboratory of the Department of Seed Science and Technology, College of Agriculture, Junagadh Agricultural University, Junagadh from the April 2013 to April 2015, wherein two kg of freshly harvested quality seed of soybean cv. Gujarat Junagadh Soybean 3 having high germination percentage and low moisture content (below 8%) was taken for each repetition and for each combination of treatments. The treatment consisted of two storage conditions (C) viz., C_1 (Ambient temperature) and C_2 (Cold storage at $7^0C \pm 2^0C$), and five seed treatments (S) viz., S_1 = Control, S_2 = Carbendazim @ 2g/kg seed, S_3 = Mancozeb @ 2g/kg seed, S_4 = Neem leaf powder @ 10g/kg seed, and S_5 = Neem Oil @ 5 ml/kg seed. The experiment was carried out using Completely Randomized Design (Factorial) repeated three times. After proper mixing or smearing the seeds as per the treatments, seeds were packed in cloth bag and kept in laboratory under two different storage conditions. Observations were recorded at 90 days interval on germination (%), root length (cm), shoot length (cm), seedling dry weight (g), seed vigour index I, seed vigour index II and seed moisture content (%). The results revealed that storage condition (C) and seed treatments (S) exhibited significant differences almost for the all the traits for germination and seedling parameters after 2 years of storage. The results of soybean seed stored in two different storage conditions showed that on an average, the seed stored under cold storage ($7^0C \pm 2^0C$) noted higher values for all the traits studied except seed moisture content after 2 years of storage. Among the seed treatments, on an average, after 2 years of seed storage, significantly ($P<0.05$) higher values were recorded by all the seed treatments over the control. However, seed treated with Mancozeb @ 2g/kg of seed recorded the significantly highest germination percentage (71.50 %) and it was at par with Neem leaf powder @ 10 g / kg seed (70.67%) and Carbendazim @ 2g /kg seed (69.67%) after 2 years of storage. The germination percentage noted in control treatment was 33.17 per cent after 2 years of storage. An ISTA standard for germination in soybean is 70 per cent. Most of the interactions effects were found significant ($P<0.05$) for all the traits studied.

Keywords: Seed treatment, Soybean, Storage condition, Viability

INTRODUCTION

Soybean (*Glycine max* (L.) Merr) is an important oilseed crop, is listed as poor storer. It loses viability rapidly under warm and humid storage conditions. One of the major constraints in soybean cultivation is the non-availability of high vigour seeds at the time of sowing. Now-a-days, the area and production of this crop is increasing gradually, but productivity remains almost constant (Mahesh Babu and Hunje, 2008). Poor seed germination is a major constraint for increasing the productivity of soybean.

High quality seed that provides adequate plant stand is the basis for profitable production and expansion of soybean crop. In order to increase the production of soybean, a source of high quality, disease free seed must be established and maintained. Loss of viability and vigour under high temperature and relative humidity conditions is a common phenomenon in many crop seeds but it is well marked in soybean. Under adverse conditions such as the temperature above 30°C and relative air humidity from 80 to 90 per cent, the variation in seed germination rate can be high. It seems that temperature, moisture and storage duration are the most important individual factors which affected the stored product quality and quantity (Sisman, 2005). Fabrizius *et al.* (1999) confirmed the possibility of predicting the actual germination rate of soybean seed during natural aging by applying the accelerated aging test, the main factors being the time of natural aging duration and degree of seed deterioration.

Many of synthetic chemicals look effective, but they are not readily degradable physically or biologically which yield more toxic residues. Hence, the feasible approach is the treatment of seeds with botanicals which are safe, economical, eco-friendly, cheap, easily locally available and non-harmful to seeds, animals and human beings. It will be of immense use to the farming community. Therefore, the present investigation was carried out to know how the soybean seed can be stored by treating them with fungicides or botanicals under specific storage conditions for longer period

with minimum qualitative and quantitative changes.

MATERIALS AND METHODS

The present investigation was carried out in laboratory of the Department of Seed Science and Technology, College of Agriculture, Junagadh Agricultural University, Junagadh from the April 2013 to April 2015, wherein two kg of freshly harvested quality seed of soybean cv. GJS 3 having high germination percentage and low moisture content (below 8%) was taken for each repetition and for each combination of treatments. The treatment consisted of two storage conditions (C) *viz*., C_1 (Ambient temperature) and C_2 (Cold storage at $7^oC \pm 2^oC$), and five seed treatments (S) *viz*., S_1 = Control, S_2 = Carbendazim @ 2g/kg seed, S_3 = Mancozeb @ 2g/kg seed, S_4 = Neem leaf powder @ 10g/kg seed, and S_5 = Neem Oil @ 5 ml/kg seed. The experiment was carried out using Completely Randomized Design (Factorial) repeated three times. After proper mixing or smearing the seeds as per the treatments, seeds were packed in muslin cloth bag and kept in laboratory under two different storage conditions. Observations were recorded at 90 days interval on germination (%), root length (cm), shoot length (cm), seedling dry weight (g), seed vigour index I, seed vigour index II and seed moisture content (%).Germination test was carried out using paper towel technique as per the procedure given by ISTA (1999). Germinated seeds were counted on 8th day and 10 germinated seedlings were selected from each replication of the treatment for calculating the seedling vigour index. The seedling vigour index (length and dry weight) was calculated as per the formula suggested by Abdul-Baki and Anderson, 1973). The shoot and root length of each of the 10 seedlings were measured in centimeters. Seedling dry weight was measured of all the germinated seedlings after oven drying. Seed moisture content was determined by oven dry method. The data were statistically analyzed as per the method of Cochran and Cox (1957) for Completely Randomized Design (Factorial).

RESULTS AND DISCUSSION

The results presented in Table 1 revealed that storage condition (C) and seed treatments (S) exhibited significant differences for germination per cent under laboratory in soybean for almost all the dates of recording observations and after 2 years of storage. The data of soybean seed stored under two storage conditions revealed that seed stored under cold storage ($7^oC \pm 2^oC$) noted significantly higher germination (76.13%) after the period of 2 years of storage. Among the seed treatments, seed treated with Mancozeb @ 2g/kg of seed recorded the significantly highest germination percentage (71.50%) and it was at par with Neem leaf powder @ 10g/kg seed (70.67%) and Carbendazim @ 2g/kg seed (69.67%) after 2 years of storage. The germination percentage noted in control treatment was 33.17 per cent after 2 years of storage stored under ambient condition. An ISTA standard for germination is 70 per cent for soybean. Over all the treatment

Table 1. Effects of storage condition and various seed treatments on germination in soybean.

Factor/Period	3 Month	6 Month	9 Month	12 Month	15 Month	18 Month	21 Month	24 Month
C_1	96.20	94.20	94.33	89.93	82.33	75.67	63.66	48.20
C_2	95.47	88.20	95.33	90.40	89.53	90.07	85.53	76.13
Mean	95.83	91.20	94.83	90.17	85.93	82.87	74.60	62.16
S. Em $\pm$	0.30	0.57	0.15	0.64	0.46	0.55	0.42	0.54
C.D. at 5%	NS	1.70	0.44	NS	1.37	1.63	1.25	1.61
S_1	95.00	89.83	94.83	91.00	78.17	72.00	61.50	33.17
S_2	96.67	89.50	95.00	88.83	87.17	85.33	77.17	69.67
S_3	96.00	92.83	95.00	90.17	88.83	86.83	79.17	71.50
S_4	94.67	91.33	93.17	89.17	88.00	84.33	79.17	70.67
S_5	96.83	92.50	96.17	91.67	87.50	85.83	76.00	63.83
Mean	95.83	91.20	94.83	90.17	85.93	82.87	74.60	62.16
S. Em $\pm$	0.48	0.91	0.24	1.01	0.73	0.87	0.66	0.86
C.D. at 5%	1.42	NS	0.70	NS	5.16	2.58	1.97	2.55
C_1 X S_1	95.67	93.33	95.00	93.33	76.00	68.33	57.33	33.00
C_1 X S_2	98.00	93.33	94.67	88.00	84.33	78.00	65.00	54.00
C_1 X S_3	95.67	95.33	96.67	89.00	85.67	78.33	65.00	55.00
C_1 X S_4	94.67	94.33	90.00	88.67	82.67	76.00	64.33	55.00
C_1 X S_5	97.00	94.67	95.33	90.67	83.00	77.67	66.67	44.00
C_2 X S_1	94.33	86.33	94.67	88.67	80.33	75.67	65.67	37.33
C_2 X S_2	95.33	85.67	95.33	89.67	90.00	92.67	89.33	85.33
C_2 X S_3	96.33	90.33	93.33	91.33	92.00	95.33	93.33	88.00
C_2 X S_4	94.67	88.33	96.33	89.67	93.33	92.67	94.00	86.33
C_2 X S_5	96.67	90.33	97.00	92.67	92.00	94.00	85.33	83.67
Mean	95.83	91.20	94.83	90.17	85.93	82.87	74.60	62.16
S. Em $\pm$	0.68	1.28	0.33	1.43	1.03	1.23	0.94	1.21
C.D. at 5%	NS	NS	0.99	NS	3.05	3.65	2.78	3.61
CV %	1.22	2.44	0.61	2.75	2.07	2.57	2.18	3.39

Table 2. Effects of storage condition and various seed treatments on seedling root length in soybean.

Factor/Period	3 Month	6 Month	9 Month	12 Month	15 Month	18 Month	21 Month	24 Month
C_1	8.74	6.69	9.00	8.90	8.59	9.36	5.49	5.49
C_2	9.36	6.39	8.07	8.13	7.77	10.90	5.48	5.40
Mean	9.05	6.54	8.53	8.51	8.18	10.13	5.49	5.45
S. Em ±	0.36	0.15	0.10	0.10	0.19	0.20	0.13	0.12
C.D. at 5%	NS	NS	0.31	0.29	0.56	0.60	NS	NS
S_1	10.25	6.47	9.48	9.33	7.54	9.96	5.81	6.00
S_2	9.52	6.61	9.10	8.89	8.46	9.70	5.24	5.16
S_3	9.61	6.39	8.32	8.48	7.34	10.51	5.89	5.71
S_4	8.56	6.53	7.54	7.69	8.53	9.72	5.26	5.22
S_5	7.33	6.70	8.23	8.17	9.04	10.77	5.23	5.14
Mean	9.05	6.54	8.53	8.51	8.18	10.13	5.49	5.45
S. Em ±	0.56	0.23	0.16	0.16	0.30	0.32	0.21	0.19
C.D. at 5%	1.67	NS	0.48	0.46	0.89	NS	NS	0.56
C_1 X S_1	11.31	6.45	9.30	9.05	7.88	8.81	5.73	6.14
C_1 X S_2	9.54	6.68	9.21	8.87	8.76	9.13	5.22	5.19
C_1 X S_3	9.40	6.96	9.03	9.30	8.59	10.13	5.86	5.64
C_1 X S_4	8.33	6.54	8.65	8.51	8.84	8.85	5.29	5.21
C_1 X S_5	5.20	6.84	8.85	8.77	8.89	9.86	5.36	5.29
C_2 X S_1	9.18	6.48	9.66	9.60	7.19	11.10	5.89	5.85
C_2 X S_2	9.50	6.55	8.98	8.91	8.16	10.26	5.25	5.16
C_2 X S_3	9.88	5.88	7.61	7.67	6.09	10.89	5.92	5.77
C_2 X S_4	8.78	6.53	6.44	6.88	8.22	10.59	5.23	5.23
C_2 X S_5	9.47	6.57	7.60	7.57	9.19	11.68	5.10	5.00
Mean	9.05	6.54	8.53	8.51	8.18	10.13	5.49	5.45
S. Em ±	0.80	0.33	0.23	0.22	0.42	0.45	0.30	0.27
C.D. at 5%	2.36	NS	0.68	0.65	1.26	NS	NS	NS
CV %	15.21	8.72	4.65	4.45	8.99	7.69	9.41	8.45

Table 3. Effects of storage condition and various seed treatments on seedling shoot length in soybean.

Factor/Period	3 Month	6 Month	9 Month	12 Month	15 Month	18 Month	21 Month	24 Month
C_1	5.16	3.36	4.13	4.70	4.30	5.78	4.60	4.49
C_2	5.39	3.55	3.40	4.41	3.70	6.45	5.29	5.37
Mean	5.27	3.45	3.76	4.56	4.00	6.11	4.95	4.93
S. Em ±	0.19	0.23	0.05	0.14	0.12	0.15	0.14	0.10
C.D. at 5%	NS	NS	0.15	NS	0.37	0.43	0.40	0.29
S_1	5.85	3.18	3.99	4.88	3.76	6.64	4.59	4.59
S_2	5.76	3.28	3.93	4.78	3.87	5.93	4.82	5.02
S_3	5.28	3.95	3.68	4.37	4.24	5.88	4.69	4.65
S_4	5.35	3.21	3.63	4.34	4.03	5.89	5.14	5.23
S_5	4.12	3.63	3.58	4.41	4.07	6.23	5.49	5.16
Mean	5.27	3.45	3.76	4.56	4.00	6.11	4.95	4.93
S. Em ±	0.29	0.36	0.08	0.21	0.20	0.23	0.21	0.16
C.D. at 5%	0.87	NS	0.24	NS	NS	NS	0.64	0.46
C_1 X S_1	5.92	3.02	4.14	4.86	4.05	6.20	4.30	4.26
C_1 X S_2	6.16	3.28	4.09	4.76	3.94	5.34	4.50	4.62
C_1 X S_3	5.55	3.53	4.03	4.54	5.01	5.45	4.59	4.30
C_1 X S_4	5.29	3.36	4.08	4.57	4.24	5.78	5.19	5.07
C_1 X S_5	2.86	3.82	4.11	4.77	4.24	6.12	4.43	4.23
C_2 X S_1	5.79	3.34	3.84	4.90	3.47	7.08	4.88	4.91
C_2 X S_2	5.26	3.28	3.77	4.81	3.81	6.52	5.13	5.41
C_2 X S_3	5.01	4.37	3.23	4.20	3.47	6.30	4.79	5.00
C_2 X S_4	5.41	3.30	2.99	4.11	3.82	5.99	5.08	5.40
C_2 X S_5	5.36	3.44	3.05	4.04	3.91	6.34	6.56	6.10
Mean	5.27	3.45	3.76	4.56	4.00	6.11	4.95	4.93
S. Em ±	0.12	0.50	0.12	0.30	0.28	0.33	0.30	0.22
C.D. at 5%	0.41	NS	0.34	NS	NS	NS	0.90	0.66
CV %	13.61	15.14	5.35	11.53	11.93	9.25	10.62	7.77

Table 4. Effects of storage condition and various seed treatments on seedling dry weight in soybean.

Factor/Period	3 Month	6 Month	9 Month	12 Month	15 Month	18 Month	21 Month	24 Month
C_1	8.81	9.65	9.79	8.48	8.84	9.42	4.53	4.48
C_2	8.74	10.05	10.19	8.57	9.49	8.89	4.47	4.37
Mean	8.77	9.85	9.99	8.52	9.16	9.16	4.50	4.42
S. Em ±	0.10	0.11	0.11	0.12	0.11	0.11	0.04	0.05
C.D. at 5%	NS	0.33	0.34	NS	0.34	0.34	NS	NS
S_1	8.97	9.31	9.73	9.00	8.81	9.14	4.73	4.60
S_2	8.73	9.74	10.10	9.00	8.95	8.94	4.60	4.62
S_3	8.98	10.23	10.43	8.53	9.33	9.57	4.39	4.28
S_4	8.31	9.87	9.63	8.12	9.48	9.00	4.38	4.25
S_5	8.88	10.10	10.04	7.97	9.24	9.13	4.42	4.37
Mean	8.77	9.85	9.99	8.52	9.16	9.16	4.50	4.42
S. Em ±	0.17	0.18	0.18	0.19	0.18	0.18	0.06	0.08
C.D. at 5%	NS	0.53	0.53	0.56	NS	NS	0.16	0.23
C_1 X S_1	9.08	9.13	10.03	8.78	8.57	9.85	4.73	4.63
C_1 X S_2	9.23	9.15	9.73	9.09	8.61	9.14	4.61	4.69
C_1 X S_3	8.55	10.60	10.46	8.52	8.97	10.01	4.39	4.21
C_1 X S_4	8.29	9.52	9.01	8.22	8.74	9.27	4.28	4.22
C_1 X S_5	8.87	9.89	9.76	7.77	9.30	8.84	4.63	4.64
C_2 X S_1	8.86	9.52	9.46	9.22	9.04	8.42	4.72	4.57
C_2 X S_2	8.22	10.38	10.53	8.92	9.28	8.75	4.59	4.55
C_2 X S_3	9.41	9.95	10.42	8.54	9.69	9.13	4.38	4.35
C_2 X S_4	8.33	10.31	10.28	8.02	10.23	8.74	4.47	4.29
C_2 X S_5	8.89	10.35	10.36	8.16	9.18	9.42	4.20	4.10
Mean	8.77	9.87	10.04	8.52	9.16	9.16	4.50	4.42
S. Em ±	0.23	0.25	0.25	0.26	0.25	0.26	0.08	0.11
C.D. at 5%	0.69	0.75	0.75	NS	NS	0.76	0.23	0.32
CV %	4.61	4.40	4.38	5.37	4.80	4.80	2.98	4.25

Table 5. Effects of storage condition and various seed treatments on seed vigour index-I in soybean.

Factor/Period	3 Month	6 Month	9 Month	12 Month	15 Month	18 Month	21 Month	24 Month
C_1	1336.68	947.18	1236.04	1223.24	1044.97	1187.04	801.41	480.57
C_2	1407.99	876.08	1092.46	1126.83	975.59	1453.25	854.09	819.40
Mean	1372.33	911.63	1164.25	1175.03	1010.28	1320.14	827.75	649.98
S. Em ±	46.79	17.33	11.98	17.94	20.70	22.65	21.09	11.42
C.D. at 5%	NS	51.48	35.59	53.29	61.50	67.27	NS	33.93
S_1	1530.30	866.44	1280.54	1292.00	587.91	720.99	357.84	372.26
S_2	1480.56	885.40	1237.37	1200.74	1097.48	1406.61	898.60	715.61
S_3	1426.58	960.33	1141.59	1158.12	1032.49	1556.63	1018.41	747.02
S_4	1318.78	889.53	1026.68	1072.06	1120.54	1446.77	929.67	741.94
S_5	1105.45	956.43	1135.06	1151.85	1212.98	1469.72	934.21	673.08
Mean	1372.33	911.63	1164.25	1175.03	1010.28	1320.14	827.75	649.98
S. Em ±	73.99	27.40	18.94	28.36	32.73	35.80	33.53	18.06
C.D. at 5%	219.81	NS	56.27	84.27	97.23	106.37	99.09	53.65
C_1 X S_1	1648.37	877.87	1276.17	1297.59	598.92	602.71	328.60	342.96
C_1 X S_2	1544.94	930.75	1259.30	1199.64	1117.95	1258.87	877.82	529.80
C_1 X S_3	1418.90	999.75	1262.69	1232.44	1182.54	1474.45	1037.10	546.47
C_1 X S_4	1294.05	911.37	1144.96	1158.31	1117.38	1356.72	889.90	565.48
C_1 X S_5	777.14	1009.49	1237.08	1228.21	1208.04	1242.42	873.61	418.13
C_2 X S_1	1412.22	848.35	1284.91	1286.41	576.92	839.27	387.08	404.56
C_2 X S_2	1416.17	840.05	1215.44	1201.85	1077.01	1554.35	919.38	901.43
C_2 X S_3	1434.25	920.92	1020.49	1084.58	882.43	1638.81	999.72	947.57
C_2 X S_4	1343.52	867.69	908.40	985.81	1123.69	1536.82	969.45	918.40
C_2 X S_5	1433.77	903.37	1033.05	1075.49	1217.92	1697.01	994.81	928.03
Mean	1372.33	911.63	1164.25	1175.03	1010.28	1320.14	827.75	649.98
S. Em ±	104.64	38.75	26.79	40.11	46.29	50.64	47.17	25.54
C.D. at 5%	310.86	NS	78.58	NS	137.51	NS	NS	75.87
CV %	13.20	7.36	3.98	5.91	7.93	6.64	9.87	6.81

Table 6. Effects of storage condition and various seed treatments on seed vigour index-II in soybean.

Factor/Period	3 Month	6 Month	9 Month	12 Month	15 Month	18 Month	21 Month	24 Month
C_1	847.45	910.43	925.44	762.09	758.23	797.33	377.65	214.73
C_2	834.92	894.33	973.40	773.43	850.71	802.84	382.19	331.09
Mean	841.18	902.38	949.42	767.76	804.47	800.08	379.92	272.91
S. Em ±	11.60	13.58	11.12	15.46	16.43	10.03	4.39	3.25
C.D. at 5%	NS	NS	33.05	NS	34.54	NS	NS	9.64
S_1	852.24	837.89	924.17	818.80	688.76	654.52	290.68	161.96
S_2	846.00	878.58	962.59	790.92	797.21	802.68	413.26	320.90
S_3	860.79	954.45	992.12	769.02	836.05	916.32	404.85	307.11
S_4	788.33	905.00	900.43	729.34	850.28	840.37	404.42	301.07
S_5	858.56	935.96	967.78	730.74	850.05	786.51	386.37	273.52
Mean	841.18	902.38	949.42	767.76	804.47	800.08	379.92	272.91
S. Em ±	18.35	21.48	17.59	24.45	18.37	15.85	6.94	5.13
C.D. at 5%	NS	63.83	52.26	NS	54.58	47.10	20.62	15.25
$C_1 \times S_1$	835.97	852.06	952.85	819.50	650.88	672.69	271.21	152.55
$C_1 \times S_2$	783.93	853.63	921.42	798.61	758.71	794.84	416.77	253.51
$C_1 \times S_3$	906.35	1010.79	1011.17	758.55	780.41	961.30	397.88	231.71
$C_1 \times S_4$	788.68	899.51	810.80	729.25	745.90	871.24	388.35	231.90
$C_1 \times S_5$	859.66	936.18	930.99	704.53	855.24	686.57	414.03	204.00
$C_2 \times S_1$	868.50	823.71	895.48	818.09	726.64	636.36	310.15	171.36
$C_2 \times S_2$	908.07	903.53	1003.76	783.22	835.70	810.52	409.75	388.30
$C_2 \times S_3$	815.22	898.15	973.10	779.48	891.69	871.33	411.81	382.52
$C_2 \times S_4$	787.98	910.50	990.07	729.43	954.67	809.51	420.49	370.26
$C_2 \times S_5$	857.47	935.76	1004.60	756.94	844.87	886.46	358.72	343.03
Mean	841.18	902.38	949.42	767.76	804.47	800.08	379.92	272.91
S. Em ±	25.95	30.38	52.26	34.57	25.98	22.42	9.81	7.26
C.D. at 5%	77.10	NS	73.91	NS	77.18	66.61	29.16	21.56
CV %	5.34	5.83	4.53	7.79	5.59	4.85	4.47	4.61

Table 7. Effects of storage condition and various seed treatments on seed moisture in soybean.

Factor/Period	3 Month	6 Month	9 Month	12 Month	15 Month	18 Month	21 Month	24 Month
C_1	3.37	4.87	5.97	5.61	5.31	6.07	7.02	7.19
C_2	3.44	4.31	4.72	4.76	4.93	5.31	5.29	5.49
Mean	3.40	4.59	5.35	5.19	5.12	5.69	6.15	6.34
S. Em ±	0.02	0.04	0.02	0.04	0.09	0.04	0.03	0.07
C.D. at 5%	NS	0.13	0.06	0.11	0.27	0.11	0.08	0.21
S_1	3.48	4.48	5.41	5.34	4.90	5.65	6.17	6.29
S_2	3.45	4.71	5.53	5.15	4.91	5.57	6.37	6.55
S_3	3.50	4.75	5.32	5.34	5.16	5.89	6.07	6.20
S_4	3.58	4.73	5.43	5.31	5.64	5.55	6.10	6.35
S_5	3.01	4.30	5.04	4.79	4.99	5.80	6.06	6.30
Mean	3.40	4.59	5.35	5.19	5.12	5.69	6.15	6.34
S. Em ±	0.04	0.07	0.03	0.06	0.15	0.06	0.04	0.11
C.D. at 5%	0.11	0.20	0.10	0.18	0.43	0.17	0.13	NS
$C_1 \times S_1$	3.51	4.67	5.95	5.69	5.35	5.95	6.88	7.07
$C_1 \times S_2$	3.38	5.04	6.03	5.81	4.45	6.09	7.40	7.56
$C_1 \times S_3$	3.44	4.84	5.86	5.50	5.60	6.40	6.94	7.10
$C_1 \times S_4$	3.43	5.30	6.13	5.73	5.83	5.81	6.90	7.20
$C_1 \times S_5$	3.08	4.51	5.70	5.31	5.30	6.10	6.97	7.07
$C_2 \times S_1$	3.45	4.28	4.88	4.99	4.44	5.34	5.45	5.53
$C_2 \times S_2$	3.52	4.37	4.83	4.49	5.37	5.04	5.34	5.53
$C_2 \times S_3$	3.55	4.67	4.78	5.18	4.72	5.38	5.21	5.33
$C_2 \times S_4$	3.73	4.16	4.73	4.90	5.45	3.30	5.31	5.51
$C_2 \times S_5$	2.94	4.09	4.38	4.25	4.68	5.49	5.15	5.53
Mean	3.40	4.59	5.35	5.19	5.12	5.69	6.15	6.34
S. Em ±	0.05	0.10	0.05	0.08	0.21	0.08	0.06	0.16
C.D. at 5%	0.16	0.29	0.14	0.25	0.61	0.25	0.18	NS
CV %	2.65	3.61	1.54	2.80	6.93	2.53	1.74	4.39

Table 8. Germination percentage recorded in soybean seed after bringing out the sample stored under cold storage condition ($7^0C \pm 2^0C$) packed with cloth bag.

Days after sample bringing out from cold storage condition	DATE of sampling	Date of re-cording germination	Mencozeb @ 2g/kg seed	Carbendazim @ 2g/kg seed	Neam Leaf powder @ 10g/ kg seed	Neem Oil @ 5ml/kg seed
0	12-10-2015	20-10-2015	83	87	84	83
2	14-10-2015	22-10-2015	83	85	84	81
3	15-10-2015	23-10- 2015	71	82	73	80
5	17-10-2015	26- 10- 2015	76	86	80	85
7	19-10-2015	27-10-2015	75	83	84	84
9	21-10-2015	29-10-2015	84	79	79	80
11	23-10-2015	01-11-2015	82	77	79	83
14	26-10-2015	03-11-2015	81	80	79	80
16	28-10-2015	05-11-2015	80	80	79	79
18	30-10-2015	07-11-2015	69	78	79	77
20	02-11-2015	09-11-2015	68	71	66	70
22	04-11-2015	12-11-2015	83	66	67	81
24	06-11-2015	14-11-2015	73	77	80	71
25	07-11-2015	16-11-2015	72	74	72	73
38	20-11-2015	28-11-2015	72	68	77	72
45	27-11-2015	05- 12-2015	69	70	73	68
53	05-12-2015	14-12-2015	66	68	70	67
64	16-12-2015	24-12-2015	73	66	73	63

combinations, more than 80 per cent germination was recorded by the combination of seed treated with fungicide and stored in cold storage after two years of storage. These results are in accordance with the results of Gupta *et al.* (1976), who reported that soybean seeds are short lived as compared to maize, rice, wheat, etc. The soybean seeds having only high initial germination (> 80-90%) could be recommended for one season storage. Storing soybean seeds beyond first planting season at room temperature may not be successful even in moisture resistant containers. Upto second planting season soybean could be safely stored in cold storage (4-5°C temperature and 50-60% relative humidity). Mbofung *et al*. (2013) reported that treated soybean seeds could be carried over for two seasons, if the storage temperature is maintained at 10° C and the relative humidity is below 40 per cent.

The results presented in Table 2 revealed that storage condition (C) and seed treatments (S) exhibited significant differences for seedling root length in soybean for most of the dates. Over all the treatment combinations showed non-significant difference with respect to root length after 2 years of storage. The results presented in Table 3 revealed that storage condition (C) and seed treatments (S) exhibited significant differences for seedling shoot length in soybean after 2 years of storage. The data of soybean seed stored under two storage conditions revealed that seed stored under cold storage ($7^oC \pm 2^oC$) noted significantly higher seedling shoot length (5.37 cm) after the period of 2 years of storage. Among the seed treatments, seed treated with Neem leaf powder @ 10g/kg seed recorded the significantly highest seedling shoot length (5.23 cm) after 2 years of storage. Over all the treatment combinations, $C_2 X S_5$ recorded the highest value for shoot length (6.10cm).

The results presented in Table 4 revealed that seed treatments (S) exhibited significant differences for seedling dry weight in soybean after 2 years of storage, while storage condition (C) exhibited non-significant for this trait after 2 years of storage. Among the seed treatments, seed treated with Carbendazim @ 2g/kg seed recorded the significantly highest seedling dry weight (4.62g) after 2 years of storage. Over all the treatment combinations, $C_1 X S_2$ recorded the highest value for seedling dry weight (4.69g).

The results presented in Table 5 revealed that storage condition (C) and seed treatments (S) exhibited significant differences for seed vigour index I in soybean after 2 years of storage. The data of soybean seed stored under two storage conditions revealed that seed stored under cold storage ($7^oC \pm 2^oC$) noted significantly higher seed vigour index I (819.40) after the period of 2 years of storage. Among the seed treatments, seed treated with Mancozeb @ 2g/kg of seed recorded the significantly highest seed vigour index I (747.02) and it was at par with Neem leaf powder @ 10g/kg seed (741.94) and Carbendazim @ 2g/kg seed (715.61) after 2 years of storage. Seed vigour index I noted in control treatment was 372.26 after 2 years of storage. Over all the treatment combinations, more than 900 seed vigour index was recorded by the combination of seed treated with fungicide and stored in cold storage after two years of storage. The results presented in Table 6 revealed that storage condition (C) and seed treatments (S) exhibited significant differences for seed vigour index II in soybean after 2 years of storage. The data of soybean seed stored under two storage conditions revealed that seed stored under cold storage ($7^oC \pm 2^oC$) noted significantly higher seed vigour index II (331.09) after

the period of 2 years of storage. Among the seed treatments, seed treated with Carbendazim @ 2g/kg of seed recorded the significantly highest seed vigour index II (320.11) and it was at par with mancozeb @ 2g/kg seed (307.11) after 2 years of storage. Seed vigour index II noted in control treatment was 161.96 after 2 years of storage. Over all the treatment combinations, more than 200 seed vigour index was recorded by the combination of seed treated with fungicide and stored in cold storage after two years of storage.

The results presented in Table 7 revealed that storage condition (C) and exhibited significant differences for seed moisture content after 2 years of storage, however, seed treatments (S) and treatment combinations ($C_X S$) were non-significant after two years of storage. The results of soybean seed stored in two storage conditions showed that on an average, the seed stored in ambient storage condition manifested significantly higher seed moisture content.

The decline in germination percentage may be attributed to ageing effect leading to depletion of food reserves and decline in synthetic activity of embryo apart from death of seed because of fungal invasion, insect damage, fluctuating temperature, relative humidity. Similar results were reported by Vidhyasekaran *et al*. (1980) in sorghum and millet, Ashokan *et al.* (1981) in finger millet, Hooda and Singh (1993) in wheat and Anitha *et al*. (2013) in soybean.

The variation in germination percentage of soybean seed decreased with increase storage period which might be due to the deleterious effects of moisture which resulted from the storage materials and perhaps environmental conditions. This agrees with Tame (2011) who reported that germination percentage of soybean seed decreased with increase in storage period. Arif *et al.* (2006) recorded that highest germination percentages in soybean were in seed stored at 4ºC than room temperature. Kandil *et al.* (2013) observed maximum seed germination parameters in soybean, when the seeds of Giza 111 cultivar stored under refrigerator conditions (10 ± 1ºC) in cloth bags for 3 months.

In recent years however, attempts have been made to replace synthetic (inorganic) seed treatment chemicals with organic materials of plant origin which are cheaper, safer and eco-friendly. Among the various methods followed, use of botanicals has been a traditional method and is being given much attention. Arati (2000) reported that Bengalgram seeds treated with neem leaf powder recorded higher germination (65.91%) and vigour index (1282) compared to control at the end of 10 months of storage period. Maraddi (2002) observed cowpea seeds treated with neem leaf powder (5g/kg) recorded higher germination (39.5%) and vigour index (1072) compared to control (34.2% and 864, respectively) at the end of 10 months of storage period. Oyekole *et al.* (2012) reported that seed treatment with neem leaf powder is specifically recommended for pre-treatment storage of sesame seeds, as it maintained seed viability and seedling vigour optimally among all other treatments.

Conclusion

It can be concluded that soybean seed may be stored under cold storage ($7^oC \pm 2^oC$) condition in muslin cloth bag with seed treatment of Mancozeb @ 2g/kg seed or Carbendazim @ 2g /kg seed or Neem leaf powder @ 10 g / kg seed for a period of 2 years without deterioration in germination and seedling vigour.

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