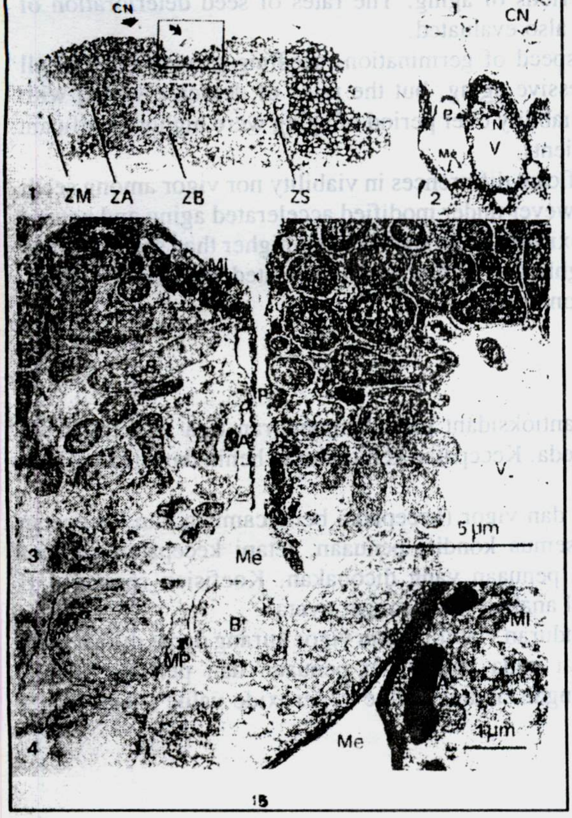
Gambar 6 : Gambar detail irisan memanjang bintil akar pada zone bakteroid penyemat N2 dan jaringan korteks, 24 jam setelah dipangkas tangkai daun dan stolonnya, pembesaran 560X (BT).

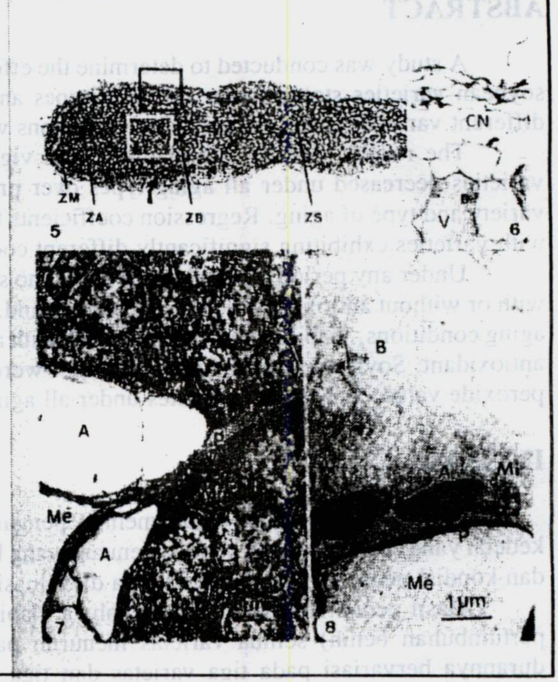
Gambar 7 : Gambar detail zone bakteroid penyemat N2, 24 jam setelah dipangkas tangkai daun dan stolonnya.

Gambar 8 : Butiran amylum dekat dengan ruang interselluler pada zone bakteroid penyemat N2, 24 jam setelah dipangkas tangkai daun dan stolonnya (metode Thiery).

Lampiran 1



Lampiran 2



Il. Pert. 6(1) : 8 - 16 . 1997

INHIBITION OF SOYBEAN (*Glycine max* (L.) Merr.) SEED DETERIORATION USING ANTIOXIDANTS UNDER DIFFERENT ACCELERATED AND NATURAL AGING

Suyadi Mitrowihardjo[1)]

ABSTRACT

A study was conducted to determine the effect of various antioxidants on seed deterioration of three soybean varieties stored under different types and periods of aging. The rates of seed deterioration of different varieties under varied aging conditions were also evaluated.

The results showed that viability, and vigor (speed of germination, seedling growth rate) of all varieties decreased under all aging types over progressive aging, but the rates of decrease varied with variety and type of aging. Regression coefficients for viability over period of aging were highly significant with varieties exhibiting significantly different coefficients.

Under any period of accelerated aging, no significant differences in viability nor vigor among seeds with or without antioxidant treatments were found. However under modified accelerated aging and natural aging conditions, viability and vigor of seeds with antioxidants were significantly higher than seeds without antioxidant. Soybean seed viability and vigor were highly and significantly correlated with iodine vallue, peroxide value, and solute leachates under all aging conditions.

INTISARI

Penelitian dilakukan untuk melihat pengaruh antioksidant pada kemunduran tiga varietas benih kedelai yang disimpan pada kondisi penuaan yang berbeda. Kecepatan kemunduran benih dari tiga varietas dan kondisi penuaan yang berbeda juga dievaluasi.

Hasil penelitian menunjukkan bahwa viabilitas dan vigor (kecepatan berkecambah dan kecepatan pertumbuhan benih) semua varietas menurun pada semua kondisi penuaan, tetapi kecepatan kemundurannya bervariasi pada tiga varietas dan tiga cara penuaan yang dicobakan. Koefisien regresi dari viabilitas terhadap periode penuaan menunjukkan hasil analisis yang sangat nyata.

Pengaruh antioxidant dalam menghambat kemunduran viabilitas dan vigor kurang dapat dilihat pada penuaan yang dipacu/dipercepat, tetapi nyata terlihat pada modifikasi penuaan dan penuaan alami. Viabilitas dan vigor benih sangat nyata berkorelasi dengan 'iodine vallue', 'peroxide value', dan 'solute leachates' pada semua kondisi penuaan.

Key words : antioxidant, soybean, accelerated aging

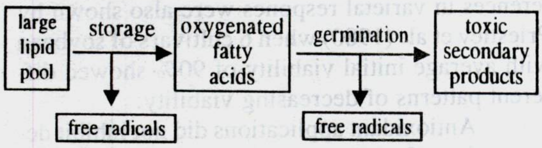
INTRODUCTION

One of the major constraints in tropical soybean production is the fast rate of seed deterioration in storage resulting in a lack of adequate supply of high quality seeds for planting. Rapid loss of viability and vigor during storage resulting in poor stand, poor establishment, poor growth and low production. The rate of seed deterioration is affected by microorganisms (pathological factors), mechanical (physical damage), and varietal or genetic factors (Copeland, 1976). However, important factors which cause seed deterioration in storage include the relative humidity of the air which controls seed moisture content, and temperature which affects the rates of biochemical processes in seeds (Kozlowski, 1972). It has been reported that deterioration of membranes and damage to phospholipid are the major reasons in

[1)] Dept. of Agronomy, Fac. of Agriculture, Gadjah Mada University

declining viability of seeds (Petruzzelli and Taranto, 1984; Priestley et al., 1980). One of the widely promoted hypothesis to explain deterioration is aging of seeds resulting in lipid peroxidation. Lipid peroxidation is responsible for membrane perturbation which is due to alteration of unsaturated fatty acids (Priestley et al., 1980; Steward and Bewley, 1980; Harman and Mattick, 1976; Gorecki and Harman, 1987).

Hypothetical model of the damage mechanism of lipid peroxidation on dry seeds proposed by Wilson and Mc Donald (1986) suggest that membrane lipids are more sensitive under dry conditions where subject to direct autocatalytic attack by atmospheric oxygen. It produces oxygenated fatty acids, hydroperoxides, and free radicals. The free radicals are unstable and may react with and damage nearby molecules. Total amount of oxygenated fatty acid would be proportional to the age of the seed and the rate of formation. When the seed imbibes water early in germination, the reaction of lipids with oxygen decreases as the membranes hydrate and organize. Hydroperoxide lyase becomes active and breaks down oxygenated fatty acids. This reaction may damage the seed further by producing an inrease in free radicals and by forming toxic secondary products which inhibit respiration, protein and DNA synthesis, and denature proteins. These events are summarized by the diagram below (Wilson and Mc Donald, 1986).



Lipid autoxidation in seeds proposed by Harrington (1973) is shown by the following sequence of events:

1. Unsaturated fats —(metal ions)→ free radicals
2. Free radicals + O2 —(light and other irradiation)→ hydroperoxides
3. Hydroperoxides ——→ carbonyls
4. Carbonyl + proteins ——→ inactivation of enzymes, membrane injury, histone denaturation
5. Carbonyls + nucleic acids ——→ chromosomal mutation

An antioxidant is one of the promising substance in reducing the rate of lipid peroxidation resulting to the inhibition of seed deterioration. Kaloyereas et al. (1961) showed the beneficial effect of antioxidants in reducing the rate of okra and onion seed deterioration. The same results were also found by Gorecki and Harman (1987) using tocopherol and butylated hydroxytoluene (BHT) in pea (*Pisum sativum*) seeds. In both references however, the relation of deterioration to unsaturated fatty acid peroxidation was not widely discussed.

Some recent studies on seed storability or longevity employed "accelerated aging techniques" which was developed by Delouche and Baskin (1973). Accelerated aging may cause loss of vigor in a manner quite different from natural aging, especially in terms of lipid peroxidation (Priestley and Leopold, 1983). However, Steward and Bewley (1980) and Harman and Mattick (1976) demonstrated the similarity of accelerated aging and natural aging, in terms of decreasing levels of unsaturated fatty acids. The levels of linolenic and linoleic acids did not decrease under accelerated aging of soybean seed (Priestley and Leopold, 1983). However, malondialdehyde (a product of triunsaturated lipid peroxidation) was observed to increase in soybean with accelerated aging (Steward and Bewley, 1980). Declining levels of unsaturated fatty acids under accelerated aging and natural aging were also found in pea seed by Harman and Mattick (1976).

A parallel study between accelerated aging and natural aging may be useful in uncovering the mechanism of aging and the similarity in mechanism between the two. It will also help explain differences in results in the two aging methods as obtained in various reports. The knowledge of the effect of antioxidants will also be useful in defining means of preventing deterioration of soybean or other legumanious or of any seed containing high proportion of lipids.

The objectives of the study were :

1. To compare the effect of various antioxidants on seed viability, vigor, and lipid peroxidation of three soybean varieties subjected to different aging periods and conditions;

2. To compare the rate of seed deterioration of three soybean varieties under different aging conditions;

3. To determine the association among seed deterioration parameters.

MATERIALS AND METHODS

The study was divided into three experiments, representing three aging types. These were : accelerated aging (42-43 ^{0}C and 90-100% RH), modified accelerated aging (34-36 ^{0}C and 80-90% RH), natural aging (25-30 ^{0}C and 70-80% RH).

Each experiment was conducted using a 3x3x5 factorial arrangement of cultivar, type of antioxidant, and period of aging in a completely randomized design with three replications. The soybean cultivars used were BPI-Sy4, GS-20B, and EGSy-19. Antioxidant treatments were alpha-tocopherol, BHT, and control (no antioxidant). Periods of aging were representated by 0, 3, 6, 9, and 12 days of subjecting seeds in accelerated aging, or 0, 15, 30, 45, and 60 days in modified-accelerated aging, or 0, 30, 60, 90, and 120 days under natural aging.Seeds were applied with antioxidants before exposure various aging conditions. Antioxidants alpha-tocopherol (1% w/v) and BHT (0% w/v) were prepared by using acetone as a solvent (Gorecki and Harman, 1987). Accelerated aging and modified-accelerated aging were made based on the methos developed by Delouche and Baskin (1973).

Observations were done on seeds viability, seeds vigor (speed of germination and seedling growth rate), iodine value, peroxide value, and solute leachates.

Seeds viability, and seeds vigor were assessed using the standard methods of ISTA(ISTA, 1981; 1985). Iodine value, which reflects the number or proportion of unsaturated fatty acids in a tissue, was determined using the Hanus method (Pearson, 1976; Meyer, 1971). Peroxide value, which reflects the amount of peroxides produced during lipid peroxidation (Meyer, 1971), was evaluated using the method developed by Pearson (1976). The amount of solute leachates reflects the degree of membrane integrity of cells (Simon, 1974), and to some extent the degree of solute leachates were determined using the method of Gorecki and Harman (1987).

RESULTS AND DISCUSSION

A. Soybean Seed Viability and Vigor

The effect of antioxidant treatments on seed viability and vigor (speed of germinations and seedling growth rates) over 5 periods and types of aging were assessed using 3 soybean varieties. The relative performance between varieties and antioxidants in terms of viability and vigor was consistent throghout the different aging periods as shown by the non-significant 3-way interaction of antioxidant, variety, and period of aging. The relative effect of antioxidants, however, varied over aging periods under modified-accelerated aging, antioxidants performed consistently over perioed of aging. Varieties were not consistent in performances over period of aging. This was true for any of the traits mentioned and under any aging type, indicating that varieties followed different rates of deterioration.

The response of varieties to antioxidants in all three traits were consistent under accelerated aging. However, viability and speed of germination of seeds under modified-accelerated and natural aging were not consistent. Generally, varieties significantly differed from each other in terms of viability and vigor averaged over periods of aging. Variety BPI-Sy4 consistently ranked highest in viability and vigor under all aging conditions (Tables 1, 2, and 3). Variety EGSy-19 ranked consistently second in all traits and under all aging conditions except for seedling growth rate where it ranked third. Initial viability determinations showed that BPI-Sy4, EGSy-19, and AGS-208 had 98, 95, and 88% germination, respectively, consistent with the rankings after treatments. Differences in varietal respones were also shown by Priestley et al. (1980) when 6 cultivars of soybean with average initial viability of 90% showed different patterns of decreasing viability.

Antioxidant applications did not inhibit deterioration of seeds under accelerated aging (Tables 1, 2, and 3). Under natural aging, however, the antioxidants gave significantly higher results than control. The two antioxidants were generally similar in effectivity. However, their advantage over the control was generally less than 5%. The protection advantage were more apparent for viability than for vigor traits, and only seem to be more effective for AGS-208 and EGSy-19 than for BPI-Sy4.

Despite the insignificant differences between BHT and alpha-tocopherol, BHT was still more effective than alpha-tocopherol and AGS-208 (Tables 1 and 2). Specificity of alpha-tocopherol and BHT were also shown among species when BHT treatment were found better in onion and pepper and alpha-tocopherol better in parsley seed (Woddstock et al., 1983).

B. Lipid Peroxidation and Solute Leaching

The effectivity of antioxidants in inhibiting lipid peroxidation and membrane damage were evaluated through the iodine value, peroxide value, and electrical conductivity of solute leachates. These traits were determined before and after seed exposure to 12, 60, and 120 days of accelerated, modified-accelerated, and natural aging, respectively.

It was observed that antioxidants did not affect the seeds under accelerated aging. Highly significant differences were observed with varieties performing consistently over the different antioxidant treatments for any of the aging condition. Effect of antioxidant was higly significant under natural aging and only moderately significant between the control and antioxidant under modified-accelerated aging and only for iodine and peroxide value. The difference between control and antioxidant treatments however, may be considered low for practical purposes. Alpha-tocopherol and BHT were not significantly different in their effects regardless of trait and type of aging.

Considering iodine value, PBI-Sy4 gave the highest results under all aging condtions, followed by EGSy-19 then AGS-208 (Table 4). Ranking was reverse for peroxide value (Table 5) and for electrical conductivity of solute leachates (Table 6). Differences among varieties were greater under modified-accelerated and natural aging than under accelerated aging. AGS-208 showed the highest peroxide value and conductivity under all types of aging.

Peroxide value indicates the amount of peroxide produced during lipid peroxidation and therefore is expected to increase with increased deterioration due to lipid peroxidation. Iodine value, on the other hand, indicates the number or proportion of unsaturated fatty acids in a tissue. The number of fatty acids decreases as unsaturated fatty acid is converted to free radicals, hydroperoxides, and carbonyls (Copeland, 1976). Greater solute leachates, measured by electircal conductivity test, indicates weaker or more disoraganized membrane which may be a consequence of aging (Bewley, 1986; Simon, 1974).

Results with iodine value, peroxide value, and electrical conductivity of solute leachates were consistent with viability and vigor results for the different varieties (Tables 1, 2 and 3). BPI-Sy4, the most resistant variety against deterioration also showed least reduction in unsaturated fatty acids (i.e., it had highest iodine values), or lowest peroxidation and conductivity. AGS-208, the least resistant variety against deterioration, showed the highest peroxidation and leachate conductivity values.

C. Regressions and Correlations

Storage and deterioration studies often employ the accelerated aging technique as quick approximation of natural aging conditions although the similarity in mechanism between the two aging conditions remains unresolved (Wilson and Mc Donald, 1986), the techniques still finds potential use in approximating relative storability of seedlots (Delouche and Baskin, 1973).

Viability, speed of germination, and seedling growth rate declined sharply in all varieties subjected to accelerated aging. Conversely, seeds exposed to natural aging showed the slowest rate of decline. Regression equations of viability against period of aging (in days) for each variety under accelerated, modified-accelerated, and natural aging conditions are shown in Table 7. Curves could be approximated by either linear or quadratic response with very high coefficient of determination. These regression equations are potentially useful in providing some means to predict soybean seed storability.

Correlations among seed traits reflecting degree of deterioration were high (Table 8), with r absolute values over 0.9 (except with seedling growth rate). The relatively low correlation between seedling growth rate and the other traits of seed deterioration must be considered. Most notable are the correlations between viability and speed of germination, iodine value, and peroxide value. Speed of germination was also highly correlated with iodine value and peroxide value. These results are consistent with reports that seed deterioration is manifested by decreasing viability and vigor and reduced number of unsaturated fatty acids (Steward and Bewley, 1980). The high degree of correlation among iodine value, peroxide value, and electrical conductivity of leachates supports the idea that membrane integrity and degree of lipid peroxidation are correlated (Pearson, 1976; Meyer, 1971).

CONCLUSIONS

Varieties showed different patterns in decreasing of viability, vigor through speed of germination, and seedling growth rate regardless of aging condition. BPI-Sy4 showed the slowest decline in these traits inspite of its high initial viability. AGS-208, which had the lowest intial viability, rapidly deteriorated with aging. Another inherent varietal characteristic which differed among varieties may also contribute to such differences.

Beneficial effects of antioxidants were not observed under accelerated aging. Significant results were observed mostly under natural aging. The role of lipid peroxidation has been claimed less important under accelerated aging, where moisture contents were relatively high. However, moisture contents under modified-accelerated and natural aging were also greater than 10%, levels where lipid peroxidation is claimed less important. The use of antioxidants could provide means of elucidating the nature of seed deteriorations in storage. Results of this study indicate that the advantage of using antioxidant is apparent only after 30 days under modified-accelerated aging and 60 days under natural aging. There is a need to improve application techniques in preventing seed deterioration.

The highly significant associations between traits reflecting seed deterioration support the claim that lipid peroxidation traits can be use as indicators of seed deterioration. It also suggest that lipid peroxidation may be an important factor in soybean seed deterioration even for accelerated aging. However, it could not be concluded here that lipid peroxidation is a cause of aging. Other studies should be conducted to correlate these parameters across various aging treatments to verify the similarity in mechanism of deterioration of different types of aging.

Verification studies must, however, be done in other varieties, viability levels, and storage conditions. Other sources of variability such as seed size, initial viability, and pre-storage history must be taken into account.

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Table 1. Speed viability (averaged over period of aging) of soybean varieties subjected to varied antioxidant treatments and aging conditions

	VIABILITY (%)			
	BPI-SY4	AGS-208	EGSY-19	MEAN[1]
Accelerated Aging				
No Antioxidant	59.27	38.20	43.80	47.09 p
Tocopherol	57.93	37.67	43.47	46.36 p
BHT	5740	37.60	43.33	46.78 p
Mean [1]	58.87 a	37.82 c	43.53 b	(VxA) ns
Modified Accelerated Aging				
No Antioxidant	80.40 f[2]	55.07 i	63.93 h	66.47
Tocopherol	80.07 f	57.87 i	66.87 gh	68.27
BHT	80.13 f	57.53 i	71.00 g	69.89
Mean	80.53	56.82	67.27	(VxA) *
Natural Aging				
No Antioxidant	80.47	55.93	64.80	67.07 q
Tocopherol	82.47	59.73	65.93	69.38 p
BHT	82.46	58.67	69.27	70.13 p
Mean [1]	81.80 a	58.11 c	66.67 b	(VxA) ns

1. Mean or group comparison using orthogonal contrast at 5% prob. level
2. Means were compared using DMRT at 5% probability level

Table 2. Speed of germination of seeds (averaged over period of aging) of soybean varieties subjected to varied antioxidant treatments and aging conditions

	SPEED OF GERMINATION (NO OF SEEDLINGS/DAY)			
	BPI-SY4	AGS-208	EGSY-19	MEAN[1]
Accelerated Aging				
No Antioxidant	11.73	7.49	8.65	9.29 p
Tocopherol	11.59	7.37	8.59	9.18 p
BHT	11.85	7.53	8.60	9.33 p
Mean [1]	11.72 a	7.46 c	8.61 b	(VxA) ns
Modified Accelerated Aging				
No Antioxidant	16.06 f[2]	55.07 i	63.93 h	66.47
Tocopherol	15.99 f	57.87 i	66.87 gh	68.27
BHT	16.03 f	57.53 i	71.00 g	69.89
Mean	16.03	56.82	67.27	(VxA) *
Natural Aging				
No Antioxidant	15.98 f	11.08 i	12.83 gh	13.30
Tocopherol	16.36 f	11.84 h	13.05 g	13.75
BHT	16.32 f	11.65 i	13.76 g	13.91
Mean [1]	16.22	11.52	13.21	(VxA) ns

1. Mean or group comparison using orthogonal contrast at 5% prob. level
2. Means were compared using DMRT at 5% probability level

Table 3. Seedling growth rate of seeds (averaged over period of aging) of soybean varieties subjected to varied antioxidant treatments and aging conditions

	SEEDLING GROWTH RATE (G)			
	BPI-SY4	AGS-208	EGSY-19	MEAN[1]
Accelerated Aging				
No Antioxidant	0.322	0.286	0.244	0.284 p
Tocopherol	0.323	0.289	0.246	0.286 p
BHT	0.325	0.290	0.246	0.287 p
Mean [1]	0.323 a	0.288 b	0.245 c	(VxA)[2] ns
Modified Accelerated Aging				
No Antioxidant	0.428	0.367	0.291	0.362 p
Tocopherol	0.429	0.379	0.293	0.367 p
BHT	0.430	0.377	0.297	0.368 p
Mean	0.429 a	0.374 b	0.294 c	(VxA) ns
Natural Aging				
No Antioxidant	0.425	0.383	0.295	0.368 q
Tocopherol	0.436	0.397	0.301	0.378 p
BHT	0.436	0.395	0.305	0.379 p
Mean [1]	0.432 a	0.392 b	0.300 c	(VxA) ns

1. Mean or group comparison using orthogonal contrast at 5% prob. level
2. Means were compared using DMRT at 5% probability level

Table 4. Iodine value of seeds of soybean varieties with various antioxidant treatments and subjected to different aging conditions

	IODINE VALUE[1] (ME/KG)			
	BPI-SY4	AGS-208	EGSY-19	MEAN[1]
Accelerated Aging (12 days)				
No Antioxidant	21.97	20.19	21.02	21.06 p
Tocopherol	22.24	20.20	21.27	21.24 p
BHT	22.14	20.18	20.93	21.08 p
Mean [2]	22.12 a	20.19 c	21.07 b	(VxA) ns
Modified Accelerated Aging 60 (days)				
No Antioxidant	24.98	21.13	23.06	23.06 q
Tocopherol	25.09	22.18	23.47	23.58 p
BHT	24.93	21.53	24.06	23.51 p
Mean [2]	25.00 a	21.61 c	23.53 b	(VxA) ns
Natural Aging (120 days)				
No Antioxidant	24.67	21.37	22.94	22.99 q
Tocopherol	25.09	22.07	23.64	23.60 p
BHT	24.87	21.77	23.94	23.53 p
Mean [2]	24.88 a	21.74 c	23.51 b	(VxA) ns

1. Mean or group comparison using orthogonal contrast at 5% prob. level
2. Means were compared using DMRT at 5% probability level

Table 5. Peroxide value of seeds of soybean varieties with various antioxidant treatments and subjected to different aging conditions

	PEROXIDE VALUE[1] (ME/KG)			
	BPI-SY4	AGS-208	EGSY-19	MEAN[1]
Before Aging	1.24	1.38	1.32	1.31
Accelerated Aging (12 days)				
No Antioxidant	4.15	6.09	5.25	5.16 p
Tocopherol	4.11	5.93	5.18	5.07 p
BHT	4.17	5.94	5.15	5.09 p
Mean [2]	4.14 c	5.99 a	5.19 b	(VxA)[2] ns
Modified Accelerated Aging (60 days)				
No Antioxidant	2.64	5.33	3.81	3.93 p
Tocopherol	2.53	5.07	3.73	3.78 q
BHT	2.58	5.18	3.52	3.76 q
Mean [2]	2.58 c	5.19 a	3.69 b	(VxA) ns
Natural Aging (120 days)				
No Antioxidant	2.77	5.37	3.96	4.03 p
Tocopherol	2.47	4.82	3.55	3.61 q
BHT	2.43	4.86	3.58	3.62 q
Mean [2]	2.56 c	5.02 a	3.70 b	(VxA) ns

1. Average of three replacations
2. Mean or group comparison using orthogonal contrast at 5% prob. level

Table 6. Peroxide value of seeds of soybean varieties with various antioxidant treatments and subjected to different aging conditions

	PEROXIDE VALUE[1] (ME/KG)			
	BPI-SY4	AGS-208	EGSY-19	MEAN[1]
Before Aging	0.37	0.77	0.37	0.50
Accelerated Aging (12 days)				
No Antioxidant	1.89	2.74	1.68	2.10 p
Tocopherol	1.88	2.73	1.68	2.10 p
BHT	1.88	2.74	1.67	2.09 p
Mean [2]	4.14 c	5.99 a	5.19 b	(VxA)[2] ns
Modified Accelerated Aging (60 days)				
No Antioxidant	1.07	2.37	1.42	1.62 p
Tocopherol	1.05	2.33	1.42	1.60 p
BHT	1.03	2.35	1.42	1.60 p
Mean	2.58 c	5.19 a	3.69 b	(VxA) ns
Natural Aging (120 days)				
No Antioxidant	1.20	2.35	1.45	1.67 p
Tocopherol	0.95	2.19	1.23	1.46 q
BHT	0.94	2.16	1.28	1.46 q
Mean	1.03 c	2.23 a	1.32 b	(VxA) ns

1. Average of three replacations
2. Mean or group comparison using orthogonal contrast at 5% prob. level

Table 7. Regression equations of viability (Y) against period of aging (X) for seeds of soybean varieties under different types of aging

ACCELERATED AGING (X=0-12 DAYS)	MODIFIED-ACCELERATED AGING (X=0-60 DAYS)	NATURAL AGING (X=0-12 DAYS)
BPI-Sy4 variety :		
Y=99.98. 98-6.79x (r^2=0.97**)	Y=99.90-0.68X (r^2=0.99**)	Y=97.83-0.05X-0.0015X^2) (r^2=0.99**)
AGS-208 variety :		
Y=92.22-13.82X+0.53X^2 (r^2=0.94**)	Y=90.58-1.18X (r^2=0.99**)	Y=90.10-0.37X (r^2=0.99**)
EGSy-19 vriety :		
Y=98.45-12.43x+0.37X^2 (r^2=0.99**)	Y=98.65-1.48X+0.0071X^2 (r^2=0.98**)	Y=95.18-0.31X (r^2=0.99**)

*,** significant at 5 and 1% probability level, respectively

Table 8. Correlation matrix (pooled for three varieties) for traits of soybean seeds (without antioxidant) after exposure to different periods and types of aging

	SPEED OF GERMINATION	SEEDLING GROWTH RATE	IODINE VALUE	PEROXIDE VALUE	ELECTRICIAL CONDUCTIVITY
viability					
Acc. Aging[1]	0.99**	0.93**	0.97**	-0.98**	-0.89**
Mod. Acc. Aging[2]	0.99**	0.81 *	0.96**	-0.97**	-0.93**
Natural Aging[3]	0.99**	0.82 *	0.97**	-0.97**	0.92**
speed of germination					
Ac. Aging		0.93**	0.98**	-0.98**	-0.89**
Mod. Acc. Aging		0.81 *	0.96**	-0.97**	-0.92**
Natural Aging		0.82 *	0.97**	-0.97**	-0.91**
seedling growth rate					
Acc. Aging			0.82 *	-0.81 *	-0.70 *
Mod. Acc. Aging			0.76 *	-0.78 *	-0.64 *
Natural Aging			0.79 *	-0.80 *	-0.64 *
iodine value					
Acc. Aging				-0.97**	-0.92**
Mod. Acc. Aging				-0.96**	-0.95**
Natural Aging				-0.98**	-0.95**
peroxide value					
Acc. Aging					0.93**
Mod. Acc. Aging					0.95**
Natural Aging					0.94**

*, ** significant at 5 and 1% probability level, respectively