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EFFECT OF PRIMING AND CONTAINERS ON SEED QUALITY OF MAIZE (*ZEA MAIZE* L.) HYBRIDS DURING STORAGE

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SUMMARY

The study was conducted to assess the effect of priming on seed quality and storability of five maize hybrids *viz*., PMH-1, IIMRNH 2015-3, IIMRNH 2015-4, P3396 and Dekalb 9144 during 2018-19. The seeds were primed in tap water, KH_2PO_4 (2.0%), KNO_3 (1.0%) and GA_3 (50 ppm) for 17 hours at room temperature and then dried to original moisture content for 24 hours at 40°C temperature. The primed seed packed in two containers-polythene bags (700 gauge) and cloth bags were stored under ambient conditions and primed seeds were evaluated for various seed quality parameters *viz.*, germination (%), seedling length, seedling dry weight and vigour indices at 3 months intervals. The results revealed that all the seed priming treatments (17 h priming by complete soaking) showed negative effect on seed quality parameters and unprimed seeds showed superiority by registering maximum germination (92.5%), Seedling length (30.9cm), Seedling dry weight (59.6g), vigour index-I (2866) and vigour index-II (5557) in polythene bags after nine months of storage. However, among the priming treatments, maximum germination (77.6%), vigour index-I (2237) and vigour index-II (4011) was recorded in seeds primed with KNO_3 @1.0 % while maximum seedling length (28.3cm) and seedling dry weight (51.0g) was observed in seeds primed with KH_2PO_4 @2.0%. Among the hybrids, maximum germination (88.9%), seedling length (30.3cm), seedlings dry weight (53.4g), vigour index–I (2693), vigour index-II (4764) were recorded in hybrid IIMRNH-2015-4 after nine month of storage which was at par with hybrid IIMRNH 2015-3 in almost all the seed quality parameters. In polythene bags, the germination was reduced from 97.6% to 92.5% while reduction in germination in cloth bags was 97.6 to 84.5% at the end of storage period (nine months). It is concluded from the study that priming of seeds is affected by temperature, priming duration, priming method, volume of priming agents etc, so it must be standardized, otherwise it may adversely affect the seed quality. Hybrid, IIMRNH-2015-4 was found more vigorous which can be used in further breeding programmes. For maintenance of seed quality in maize, the seed should be stored at optimum moisture level in vapour proof containers *i.e.* Polythene bags (>700 gauge).

Key words : *Zea mays*, priming, seed quality, hybrids, germination and storage

Maize (*Zea mays* L.) is one of the most diverse crops adaptable over wider agro-climatic conditions. Globally, maize is known as queen of cereals because it has the highest genetic yield potential among the cereals and occupies the largest area under cultivation among other cereals (Kumar *et al.,* 2021). The crop ranks third after rice and wheat in India as well as in the world. United States of America ranks first in maize production which contributes 40 per cent of the world while India contributes merely about 2.5 per cent in world maize production. A total of 20.22 million tonnes was produced during *kharif* 2018 and 7.58 million tonnes during *rab*i 2018-19 (Anonymous, 2019). Karnataka, Rajasthan, Andhra Pradesh, Maharashtra, and Uttar Pradesh are the major maize producing states; together contribute 60 per cent of area and 70 per cent of maize production in India. Production of the crop depends on the supply and availability of quality seeds (Arya *et al.,* 2016).

Seed priming is the post harvest practice applied to ameliorate physiological quality of the seed. It is the process of controlled hydration of seeds to a level that permits pre germination metabolic activity to proceed, but prevents actual emergence of the radicle (Heydecker, 1973). Possible mechanisms encountered during priming include initiation of epigenic changes, repair of membranes due to accumulation of protein signals and activation of antioxidant enzyme activities under environmental stress (Fahim *et al*. 2019). Priming is used as pre-sowing or mid-storage treatment for seed lots that have lost vigour due to improper storage conditions (Singh *et al*., 2001). Various studies have been carried

out on seed priming and have shown positive results over non-primed seeds, though the methods are not widely used (Rasool *et al.* 2014; Hafeez *et al.* 2015).The effectiveness of priming is mainly affected by aeration, duration of priming process, temperature, osmotic potential, seed quality, dehydration after priming, priming method, priming agent and addition of promotive substances (Vanangamudi *et al.* 2010).

Deterioration of seeds during storage is an irreversible process which leads to various changes at different levels *viz.*, impairment or shift in metabolic activity, compositional changes, decline or change in enzyme activities, phenotypic, cytological changes apart from quantitative losses. Proper packaging materials is of paramount important for storing seeds after harvest till the next planting season without impairing the quality which is of prime important for successful seed production. Container properties greatly affect the interaction of the seed with the surrounding environment. The rate at which moisture content enters and leaves the container determines the seed longevity (Walters, 2007). The better barrier properties of packaging materials the higher germination of seed (Fu, 2018). Containers with good storage barriers can be used to control A. *flavus* and aflatoxin accumulated in moist maize seed due to reduced oxygen concentration (Wiliams *et al.* 2014). As the seed is hygroscopic in nature, when stored in humid environments tend absorb moisture until new moisture equilibrium is attained. High moisture content and temperature increase the rate of seed deterioration (Roberts, 1972). To combat these factors, it's essential to store the seeds in moisture vapour proof containers such as polythene bags, gunny bags lined with polythene with or without desiccating agent to maintain the quality of seed for longer period (Vijayalakshm and Malabasari, 2018). Generally storage of primed seed under ambient condition leads to short shelf life of the seed as compared to unprimed seed (Tarquis and Bradford, 1992). Increased lipid peroxidation and reduced antioxidant enzymes activities have been associated with poorer storage of primed seeds when compared to unprimed seeds. This evidence was reported in sweet corn (Chang and Sung, 1998). Wattanakulpakin *et al.* (2012) observed that lipid peroxidation occurred during priming treatment, particularly during the imbibition step, and caused the deterioration of primed seeds of maize. Limited information is available on storability of primed seed of this crop. Therefore, the present study was planned to assess the effect of containers on primed seed during storage under ambient condition.

MATERIALS AND METHODS

The study was conducted on freshly harvested seeds of following five maize hybrids from public and private sector at laboratories of Department of Seed Science & Technology, CCS, Haryana Agricultural University, Hisar during 2018-19 :

Hybrid	Source
Dekalb/DKC 9144	Bayer Crop Science (DEKALB Hybrids)
P3396	Pioneer HI Pvt. Ltd, Hyderabad, India
PMH-1	Panjab Agricultural University, Ludhian
IIMRNH 2015-4	Indian Institute of Maize Research (IIMR), Ludhiana
IIMRNH 2015-3	Indian Institute of Maize Research (IIMR), Ludhiana

The seeds were primed with KH_2PO_4 (2.0%), KNO_3 (1.0 %), GA_3 (50 ppm) and hydration with water followed by dressing with vitavax power @ 2.5g/kg seed for 17 hours at room temperature and then dried to original moisture content for 24 hours at temperature of 34.5°C (Day temp. 40°C and night temp. 29°C). Unprimed seeds were used as control. After drying at optimum moisture level (8%), the primed seeds were stored in cloth bags and polythene bags (>700gauge) under ambient conditions and seeds were evaluated for various seed quality parameters after 3 months interval: Hundred seeds from each treatment with three replications were placed in between saturated moistened rolled blotter papers (BP) and kept at 25°C in seed germinator. The count was taken on 7th day and only normal seedlings were considered for percent germination as given to the rules of International Seed Testing Association (ISTA, 2019). Ten normal seedlings were randomly selected from each replication at the time of final count of germination and average seedling length was calculated which was expressed in centimeters. These ten seedlings were then dried in a hot air oven for 24 hrs at 80±1°C and average seedling dry weight was calculated in mg. Seedling vigour indices were calculated according to the method as per Baki and Anderson (1973) :

Vigour index-I= Standard Germination (%) x Average seedling length (cm)

Vigour index-II=Standard Germination (%) x Average seedling dry weight (g)

TABLE 1
Effect of priming and storage containers on germination (%) of maize hybrids during storage

Treatments	Initial	Storage period (Months)					
		3		6		9	
		Polythene bag	Cloth bag	Polythene bag	Cloth bag	Polythene bag	Cloth bag
Priming treatments (T)							
T_0	97.6	96.3	95.3	94.0	92.8	92.5	84.5
T_1	95.2	81.9	76.7	69.3	67.5	60.0	45.9
T_2	93.9	89.6	86.7	83.3	78.3	73.9	63.2
T_3	94.4	90.1	87.0	81.3	76.7	77.6	62.4
T_4	94.4	87.7	87.0	71.9	64.3	63.1	53.6
T_5	92.5	84.5	82.0	74.3	66.0	64.3	49.3
Hybrids (H)							
H_1	99.8	96.2	95.1	90.6	86.7	83.8	75.3
H_2	93.3	77.1	76.0	55.7	46.4	48.2	27.8
H_3	85.6	79.8	78.9	65.6	62.1	59.0	47.6
H_4	97.1	94.9	95.3	93.3	91.8	88.9	76.7
H_5	97.6	93.8	92.9	90.0	84.2	79.6	71.8
CD at 5 %	T=1.547, H=1.412, H X T=3.459	T=1.219, C= 0.704, H=1.113, C X H= NS, C X T =NS, H X T =2.727, C X H X T = NS				T= 1.703, H =1.554, C= 0.983, C X H = 2.198, C X T = 2.408, H X T =3.807, C X H X T =5.384	
		T=3.562, C=2.056, H=3.252, CX H= 4.598, C X T =NS, H X T=7.965, C X H X T = 11.264					

TABLE 2
Effect of priming and storage containers on seedling length (cm) of maize hybrids during storage

Treatments	Initial	Storage period (Months)					
		3		6		9	
		Polythene bag	Cloth bag	Polythene bag	Cloth bag	Polythene bag	Cloth bag
Priming treatments (T)							
T_0	35.2	32.2	30.9	29.3	29.0	30.9	26.0
T_1	33.5	29.3	28.9	24.1	22.6	27.4	21.9
T_2	32.9	30.6	27.5	28.1	24.8	28.3	24.7
T_3	33.3	29.7	28.5	27.7	25.7	27.9	23.8
T_4	32.3	29.3	28.2	27.2	24.3	27.7	23.1
T_5	31.0	28.6	27.9	24.5	23.6	25.4	22.2
Hybrids (H)							
H_1	39.8	36.5	34.0	32.9	30.2	35.7	30.8
H_2	27.6	23.3	21.9	17.4	15.9	20.3	14.5
H_3	31.3	28.7	28.6	26.9	25.6	27.8	23.3
H_4	34.2	31.2	30.3	28.0	26.8	30.3	24.9
H_5	32.3	30.1	28.6	28.3	26.5	28.9	24.5
CD at 5 %	T=1.277, H=1.166,6 H X T =2.85	T=1.256, C=0.725, H=1.147, C X H= NS, C X T =N.S, H X T =2.809, C X H X T = NS				T=0.943, C=0.544, H=0.861, C X H= N/A, C X T =1.334, H X T =2.109, C X H X T= 2.982	
		T=2.551, C=1.473, H=2.329, C X H= NS, C X T = NS, H X T =5.705, C X H X T = NS					

The experiment was conducted in completely randomized design (CRD). The data obtained from experiment were analyzed as per standard method suggested by Panse and Sukhatme (1985) and using the online statistical tool by Sheoran, 2010.

RESULTS AND DISCUSSION

The results of study revealed all the seed priming treatments (17 h priming by complete soaking) showed negative effect on seed quality parameters

and unprimed seeds showed superiority by registering maximum germination (92.5%), Seedling length (30.9cm), Seedling dry weight (59.6g), vigour index-I (2866) and vigour index-II (5557) in polythene after nine months of storage. However, among the priming treatments, maximum germination (77.6%), vigour index-I (2237) and vigour index-II (4011) was recorded in T_3 (Hydration with KNO_3@1.0 %) while maximum seedling length (28.3cm) and seedling dry weight (51.0g) was observed in T_2 (Hydration with KH_2PO_4@2.0%). Delayed and poor germination in seeds subjected to hydro-priming for 60 h is probably due over priming, as was reported by Lee and Kim (1999, 2000) for rice. Canak *et al.*, 2016 reported that seeds primed in dishes using water (hydropriming) and two different concentrations of KNO_3 solution (0.1% and 0.5%) at 25° C for 17 h showed positive effect on some seed germination parameters at low and mixed temperature. Priming practices are applied to enhance seed performance in many crop species, but reduces the storability of the seeds (Vanangamudi *et al*. 2006). Decreased in vigour of primed maize seed has been associated with decrease of oligosaccharides during storage (Wattanakulpakin *et al*. 2010). Wattanakulpakin *et al*. (2012) conducted the study on loss of maize vigour as affected by biochemical changes during hydro priming. Hydro priming of TSK 11 and PS 54 maize lines for 6 to 12 hours improved germination for both lines but enhanced vigour of TSK 11 primed for 12 h and PS 54 primed for 6 hours after storage. Hydro priming for 12 h to 18 h decreased the vigour and germination of both lines during storage.

Among the hybrids, maximum germination (88.9%), seedling length (30.3cm), seedlings dry weight (53.4g), vigour index-I (2693), vigour index-II (4764) was recorded in hybrid H_4 (IIMRNH-2015-4) after nine month of storage which was at par with H_5 (IIMRNH-2015-3) in almost all the seed quality parameters. Hence, both these hybrids can be used in further breeding programmes. Between storage containers, polythene bags maintained the seed quality for longer time. In polythene bags, the germination was reduced from 97.6% to 92.5% while reduction in germination in cloth bags was 97.6 to 84.5% at the end of storage period (nine months). Reduction in germination was more in cloth bags which might be due to more fluctuations in moisture content of seeds during storage period. Maintenance of optimum moisture content of seed in polythene (700 m) bags, due to its impervious nature might have resulted in slow rate of lipid peroxidation, thereby release of minimum free radicals, leads to maintenance of membrane integrity. This results in slow leakage of intracellular substances (electrolytes and other solutes), which is responsible for maintenance of seed germination during storage. The reduction in seed quality parameters was more during storage period

TABLE 3
Effect of priming and storage containers on Seedling dry weight (mg) of maize hybrids during storage

Treatments	Initial	Storage period (Months)					
		3		6		9	
		Polythene bag	Cloth bag	Polythene bag	Cloth bag	Polythene bag	Cloth bag
Priming treatments (T)							
T_0	84.2	77.1	74.3	66.3	66.5	59.6	55.7
T_1	70.1	65.9	61.3	53.8	52.6	48.6	42.8
T_2	64.7	61.0	59.9	54.0	53.5	51.0	47.9
T_3	67.3	63.7	61.7	52.6	51.5	50.0	44.8
T_4	67.8	59.5	57.4	49.3	47.9	45.2	38.5
T_5	69.7	64.0	62.1	54.7	51.5	50.6	45.5
Hybrids (H)							
H_1	80.2	76.1	71.0	71.4	67.0	67.3	61.1
H_2	48.7	44.2	43.9	36.4	32.6	32.4	23.9
H_3	67.6	65.4	64.3	51.0	52.2	47.9	43.6
H_4	76.4	66.2	64.6	59.2	59.0	53.4	51.9
H_5	80.3	74.1	70.0	57.6	58.8	53.1	48.8
CD at 5 %	T=1.952, H=1.782, H X T =4.366	T=2.28, C=1.32, H=2.08, C X H= NS, C X T =N.S, H X T =5.1, C X H X T = NS		T=2.4, C=NS, H=2.19, C X H= 3.1, C X T =NS, H X T =5.37, C X H X T = NS			
		T=3.126, C=1.805, H=2.853, C X H= N.S, C X T =NS, H X T =6.989, C X H X T = NS					

TABLE 4
Effect of priming and storage containers on Vigour index-I of maize hybrids during storage

Treatments	Initial	Storage period (Months)					
		3		6		9	
		Polythene bag	Cloth bag	Polythene bag	Cloth bag	Polythene bag	Cloth bag
Priming treatments (T)							
T_0	3,440	3,110	2,972	2,696	2,693	2,866	2,218
T_1	3,198	2,475	2,396	1,844	1,684	1,803	1,127
T_2	3,100	2,769	2,472	2,384	1,984	2,218	1,642
T_3	3,157	2,698	2,556	2,297	2,046	2,237	1,601
T_4	3,069	2,597	2,519	2,033	1,661	1,892	1,348
T_5	2,872	2,447	2,348	1,931	1,673	1,875	1,224
Hybrids (H)							
H_1	3,976	3,507	3,233	2,982	2,628	2,994	2,312
H_2	2,575	1,828	1,683	1,066	865	1,119	529
H_3	2,678	2,286	2,263	1,781	1,600	1,633	1,117
H_4	3,315	2,963	2,888	2,614	2,453	2,693	1,913
H_5	3,153	2,827	2,651	2,545	2,239	2,304	1,762
CD at 5 %	T=136.6, H=124.4, H X T =304.8	T=111.3, C=64.24, H=101.6, C X H= N.S, C X T =NS, H X T =248.8, C X H XT =NS			T= 74.52, C= 43.02, H=68.03, C X H= 96.21, C X T =105.4, H X T =166.6, C X H X T = 235.7		
		T= 210.3, C= 121.4, H=192, C X H= NS, C X T =N/A, H X T =470.2, C X H X T =NS					

TABLE 5
Effect of priming and storage containers on Vigour index-II of maize hybrids during storage

Treatments	Initial	Storage period (Months)					
		3		6		9	
		Polythene bag	Cloth bag	Polythene bag	Cloth bag	Polythene bag	Cloth bag
Priming treatments (T)							
T_0	8,229	7,435	7,139	6,272	6,187	5,557	4,808
T_1	6,678	5,640	5,122	4,060	3,966	3,206	2,210
T_2	6,126	5,553	5,412	4,649	4,339	3,900	3,260
T_3	6,376	5,807	5,556	4,469	4,116	4,011	3,175
T_4	6,439	5,281	5,108	3,755	3,369	2,988	2,398
T_5	6,490	5,495	5,259	4,282	3,629	3,532	2,526
Hybrids (H)							
H_1	8,001	7,324	6,758	6,489	5,835	5,675	4,681
H_2	4,584	3,560	3,478	2,332	1,858	1,837	1,093
H_3	5,793	5,225	5,082	3,370	3,270	2,816	2,051
H_4	7,406	6,282	6,160	5,527	5,412	4,764	3,986
H_5	7,831	6,952	6,518	5,187	4,964	4,236	3,505
CD at 5 %	T= 937.707, H=856.005, H X T = NS	T= 211.71, C= 122.231, H= 193.264, C X H= 273.316, C X T =NS, H X T = 473.397, C X H X T = NS			T= 218.678, C= 126.254, H= 199.625, C X H= 282.312, C X T =NS, H X T = 488.979, C X H X T = NS		
		T= 265.459, C= 153.263, H=242.33, C X H= NS, C X T =NS,H X T = 593.584, C X H X T = 839.454					

T_0- Control, T_1-Hydration in tap water, T_2-Hydration with KH_2PO_4 (2.0%), T_3-Hydration with KNO_3 (1.0 %), T_4-Hydration with GA_3 (50 ppm), T_5-Hydration and treatment with vitavax (2.5 g/kg seed). H_1-DKC 9144, H_2-P3396, H_3-PMH-1, H_4-IIMRNH-2015-4, H_5-IIMRNH-2015-3.

indicating that priming is beneficial for pre-sowing and not suitable for storage of seeds.

CONCLUSION

It is concluded from the study that priming of seeds is affected by temperature, priming duration, priming method, volume of priming agents etc, so it must be standardized, otherwise it may adversely affect the seed quality. Hybrid, IIMRNH-2015-4 was found more vigorous which can be used in further breeding programmes. For maintenance of seed quality in maize, the seed should be stored at optimum moisture level in vapour proof containers *i.e.* Polythene bags (>700 gauge).

REFERENCES

Abdul-Baki, A.A. and J.D. Anderson, 1973 : Vigour determination in soyabean by multiple criteria. *Crop Science,* **13**: 630-633.

Anonymous, 2019: Department of Agriculture & Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India.

Arya, R. K., M. C. Kamboj and Suresh Kumar 2016 : Evaluation of late maturing maize hybrids under semi-arid and humid conditions of Haryana. *Haryana J. Agron*., **32**: (in press).

AOSA, 1983 : Seed vigour testing Hand book. Association of Official Seed Analysts. Contribution No.32:88.

Canak, P., M. Mirosavljevic, B. Ciric, J. Vujoševic, D. Kešelj, Stanisavljevic and B. Mitrovic, 2016 : Seed priming as a method for improving maize seed germination parameters at low temperatures. *Ratarstvo i povrtarstvo*, **53**(3): 106-110.

Chang, S.M. and J.M. Sung, 1998 : Deteriorative changes in primed sweet corn seeds during storage. *Seed Sci. Technol.*, **26**:613-626.

Fahim, N., M. Naeem, A. Akram, M.Y. Ashraf, K.S. Ahmad and B. Zulfiqar, 2019 : Seed priming with KNO_3 mediates biochemical processes to inhibit lead (Pb) toxicity in maize (*Zea mays* L.*). Journal of Science of Food and Agriculture,* **97**(14): 4780-4789.

Fu, X., S. Xing, H. Xiong, H. Min, X. Zhu, J. He and H. Mu, 2018 : Effects of packaging materials on storage quality of peanut kernels. *Plos one,* **13**(3): 1-10.

Hafeez, U.R., I. Hasan, S.M.A. Basra and I. Afzal, 2015 : Seed priming improves early seedling vigor, growth and productivity of spring maize. *Journal of Integrative Agriculture,* **14**(9): 1745-1754.

Heydecker, W., 1973 : Glossary of terms. In "Seed Ecology". Ed W. Heydecker. Proceedings 19th Easter School in Agricultural Science, University of Nottingham. Butterworths, London. 578 pp.

ISTA, 2019 : Informational rules for seed testing. *International Seed Testing Association*. Zurich. Switzerland.

Kumar, S. R. K. Arya, N. Singh and Satpal, 2021 : Response of zero-till rainfed maize to super absorbent polymer and mulching in maize-wheat cropping system under semi-arid conditions of Haryana. *Forage Res.,* **47** : 125-129.

Maguire, J.D., 1962 : Speed of germination-Aid in selection and evolution for seedling emergence and vigour. *Crop Science & Technology,* **28**:155-162.

Moore, R.P., 1985 : Handbook of tetrazolium testing. *International Seed Testing Association*, Zurich, Switzerland.

Panse, V.G. and P.V. Sukhatme, 1985 : Statistical methods for agricultural workers, 4th Ed., ICAR, New Delhi.

Rasool, H.M., S. Basu, M. Dadlani, S. Nagarajan and P. Aggrawal, 2014 : Bio-physical and physiological changes associated with seed enhancement treatments in specialty maize (*Zea mays*). *Indian Journal of Agricultural Sciences,* **84** (7): 867-72.

Roberts, E.H., 1972 : Cytological, genetic and metabolic changes associated with loss of viability Pp. 253-306. In: E.H Roberts (ed.) Viability of seeds. Chapman and Hall limited, London.

Sheoran, O.P., 2010 : Online statistical analysis (OPSTAT) software developed by Chaudhary Charan Singh Haryana Agricultural University, Hisar, India. http://www.hau.ernet.in/opstat.html.

Singh, G., S.S. Gill, and K.K. Sandhu, 2001 : Storage of primed seeds of muskmelon (*Cucumis melo* L.). *Seed Research,* **29**(2): 235-237.

Tarquis, A.M. and K.J. Bradford, 1992 : Prehydration and priming treatments that advance germination also increase the rate of deterioration of lettuce seeds. *J. Exp. Bot*, **43**: 307-317.

Vanangamudi, K., S. Kalaivani, M. Vanangamudi, Djanaguiraman, K. Raja and T. Saravanan, 2006 : Seed Physiology. Pp 201-213, Associated Publishing Company, New Delhi.

Vijayalakshm, N. and T.A. Malabasari, 2018 : Effect of Packaging Materials and Form Son Storability of Summer Groundnut (*Arachis hypogaea* L.) *Cv.* G2-52. *International Journal of Current Microbiology and Applied Sciences,* **7**(11): 760-766.

Walters, C., 2007 : Materials used for seed storage containers: response to Gómez-Campo. *Seed Science Research,* **17**(4):233-242.

Wattanakulpakin, P., K. L. Kyu, K. Ratanakhanokchai, and S. Photchanachai, 2010 : The effect of hydropriming on sugar metabolism and vigour of maize (*Zea mays* L.) seeds. *In: International Conference on Agricultural Extension* 2010, Putrajaya, Malaysia. 26-28 Oct. 2010. p. 722-740.

Wattanakulpakin, P., S. Photchanachai, S. Miyagawa and K. Ratanakhanokchai, 2012 : Loss of Maize Seed Vigor as Affected by Biochemical Changes during Hydropriming. *Crop Science*, **52**(6): 2783-2793.

Williams, S.B., D. Baributsa, and C. Woloshuk, 2014 : Assessing Purdue Improved Crop Storage (PICS) bags to mitigate fungal growth and aflatoxin contamination. *Journal of Stored Products Research,* **59**: 190-196.