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Standardisation of polymer coating in maize for maintenance of seed quality during storage

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Abstract
An experiment was laid out in Completely Randomised Design with three replications and twelve treatments. The polymer coated maize seeds and one untreated lot were stored in cloth bags, while another untreated lot was stored in polythene bag (700 gauge). All the treatments were stored under ambient conditions for six months from November 2016 to April 2017. Monthly observations on seed quality parameters were recorded. After 6 months of storage, seeds treated with Little's Polykote Red™ @ 3 ml/kg recorded lowest seed moisture content (10.62 %) with maximum germination (93.00%), shoot length (19.31 cm), root length (16.17 cm), seedling dry weight (0.61 g), seed vigor index-I (3299.64), seed vigor index-II (56.73), field emergence (92.00%), total dehydrogenase activity (0.67), total soluble protein content (9.56%) and lowest infection (1.00%) of seed borne pathogen. From the present investigation, it can be concluded that maize seeds coated with Little's Polykote Red™ @ 3 ml/kg seed can be used to maintain significantly high germination and other seed quality parameters during storage in cloth bags, in comparison with the untreated seed stored either in cloth bag or polythene bags.

Keywords: Maize seed, polymer coating, quality during storage, standardisation

1. Introduction

Maize (*Zea mays* L.) is the third most important cereal crop having worldwide significance as human food, animal feed and as good source of starch, protein, fat, oil and sucrose in addition to some of the important vitamins and minerals. Maize grains are rich in vitamins A, C and E, carbohydrates and essential minerals and contain 9-10% protein. One of the major causes of low productivity in maize, is the use of relatively poor quality seeds by the farmers. Most quality seeds available in the market are hybrids supplied by the private companies. Maize seeds suffer from rapid loss of germinability and vigor, mainly under coastal agro-climatic conditions, where high temperature and high humidity conditions prevail for several months during the year. Many private seed companies employ techniques of seed polymer coating, in which a polymer along with other desired materials are coated over the seeds with negligible increase in the thickness or weight of the seeds.

The polymer coat which are ideally be thin, easy to apply, hydrophobic with regards to water vapour, but readily diffusing in soil upon contact with water to allow the seed to germinate, and most importantly be non-toxic to the seed or seedlings during germination, provides protection from the stress conditions. It should also be eco-friendly so as to maintain soil health in the rhizosphere. The polymer film may also act as physical barrier reducing the leaching of inhibitors from the seed coat and may restrict oxygen diffusion to the embryo which enriches the endogenous level of newly bioactive substances (Vanangamudi *et al.* 2003) [1]. Polymer coating can also make room for including all the required ingredients like inoculants, protectants, nutrients, herbicides, oxygen suppliers, etc. Coating with polymers also provides resistance against mechanical damage in the seed drill, thus, improving the appearance and quality of polymer coated seeds. The application of polymers to seed serves as an extra exterior shell in order to give the desired seed characteristics *viz.*, quick or delayed water uptake and enhanced germination that would be beneficial for better emergence and establishment in the given condition (Taylor *et al.*, 1998) [2].

Seed coating technique developed rapidly during past 20 years and provides an economical and better approach to seed enhancement. Benefit of seed coating is that the seed enhancement material (fungicide and insecticide) is placed directly on the surface of the seed without changing the seed shape. It has been reported that by polymer coating the improvement in seed weight ranges from 1-10% only since it is of an extremely thin coating and allows multiple layers on the seed.

The storability of polycoated seeds has to be investigated in order to determine the viability of seeds for long term. Polycoated seeds can be stored for long term, if adequate storage conditions are provided (Giang and Gowda, 2007; Vijay Kumar *et al*., 2007) [3, 4].

Keeping in view the above discussion, the present investigation was proposed to screen out and standardise the dosage and seed coating technique of suitable polymers in maize seed in order to improve its storability under ambient conditions in coastal region of Odisha. The storability of uncoated maize seeds in polythene bags with that of polymer coated seeds in cloth bags were compared and the pattern of biochemical changes occurring in polymer coated seeds during storage under ambient conditions were studied.

Materials and Methods

Source of seed

Freshly harvested seeds of maize hybrid CAH-1511 were procured from the Department of Plant Breeding and Genetics, College of Agriculture, OUAT, Bhubaneswar.

Methodology

Prior to coating of the seeds, assessment of their germinability and vigor was done. The seeds were coated with various polymers, viz. Methyl Cellulose, Polyvinyl Pyrrolidone, Ethyl Cellulose, Little's Polykote Red^{TM} and Hydroxy Propyl Cellulose, each at two doses, 3 ml/kg seed and 4 ml/kg seed, along with insecticide Imidachloprid. After coating, the seeds were dried to original moisture content and stored under ambient conditions in cloth bags (moisture pervious container). The storage experiment was set up in the Seed Physiology Laboratory of the Department of Seed Science and Technology, College of Agriculture, OUAT, Bhubaneswar. Regular observations on various seed physiological quality parameters were recorded at monthly intervals.

Experimental details

Crop: Maize
Variety: CAH -1511
Storage Time Period: November 2016- April 2017
Experimental design: Completely Randomised Design
No. of replications: 3

Treatments

T_1: Uncoated seeds stored in cloth bag (Control)
T_2: Uncoated seeds stored in 700 gauge polythene bag
T_3: Polymer coating with Methyl Cellulose @ 3 ml/kg seed, stored in cloth bag
T_4: Polymer coating with Methyl Cellulose @ 4 ml/kg seed, stored in cloth bag
T_5: Polymer coating with Polyvinyl Pyrrolidone @ 3 ml/kg seed, stored in cloth bag
T_6: Polymer coating with Polyvinyl Pyrrolidone @ 4 ml/kg seed, stored in cloth bag
T_7: Polymer coating with Ethyl Cellulose @ 3 ml/kg seed, stored in cloth bag
T_8: Polymer coating with Ethyl Cellulose @ 4 ml/kg seed, stored in cloth bag
T_9: Polymer coating with Little's Polykote Red^{TM} @ 3 ml/kg seed, stored in cloth bag
T_{10}: Polymer coating with Little's Polykote Red^{TM} @ 4 ml/kg seed, stored in cloth bag
T_1: Polymer coating with Hydroxy Propyl Cellulose @ 3 ml/kg seed, stored in cloth bag
T_{12}: Polymer coating with Hydroxy Propyl Cellulose @ 4 ml/kg seed, stored in cloth bag

Seed coating with synthetic polymers

Three kilogram seed for each treatment were weighed and kept separately in plastic jars. Desired quantity of the polymer material, along with the insecticide Imidacloprid were slowly poured on to the seed and mixed by slow stirring of the jars to obtain uniform coating. The coated seeds were then spread in thin layers on a polythene sheet and allowed to dry in shade for one day, followed by sun drying for three days to bring the moisture back to the original level. The coated and uncoated seeds were then stored in the respective containers. The coated seeds of various treatments were packed in cloth bags in three replications and stored under ambient conditions in the laboratory. Monthly observations on the moisture content, seed physiological quality and biochemical parameters were recorded for a period of six months.

Method of storage

The coated seeds of various treatments were packed in cloth bags in three replications and stored under ambient conditions in the laboratory. One uncoated lot was stored in polythene bag (700 gauge), in order to simulate the common practice of seed companies, while another uncoated control was stored in cloth bag. Seed quality evaluations were made initially and subsequently at monthly intervals for six months.

Observations recorded

Monthly observations on the moisture content, seed physiological quality and biochemical parameters were recorded for a period of six months.

Seed moisture content

The seed material was grinded in a seed grinder into a fine powder. About 5 g of finely ground seed material was taken separately from each treatment in a pre-weighed (M_1) moisture box and the weight was recorded (M_2). The moisture boxes were then placed in a hot air oven maintained at 130±1°C for 4 hours. After that the moisture boxes were taken out and allowed to cool to room temperature in a desiccator. The final weight (M_3) was recorded. The moisture content was calculated using the following formula and expressed as percentage on wet weight basis (ISTA, 1999) [5].

$$M = \frac{\text{Loss in weight}}{\text{Initial weight of seed}} \times 100 = \frac{M_2 - M_3}{M_2 - M_1} \times 100$$

Germination and Speed of germination

Germination test was conducted in three replications of 100 seeds each by adopting between paper method as recommended by (ISTA, 1999) [5]. Seeds were incubated at vertical position in a germinator. The temperature of 25±1ºC and RH of 95 percent were maintained during the germination test. First count was taken after four days and final count after seven days. Germination percentage was calculated as:

$$\text{Germination (\%)} = \frac{\text{Number of normal seedlings produced}}{\text{Total number of seeds put for germination}} \times 100$$

Speed of germination

For this test daily counts of germinated seeds were taken during the entire duration of standard germination test.

$$\text{Speed of germination} = \sum \frac{n}{d}$$

Where, n = no. of seeds germinated (radicle has emerged)
d = days from sowing

Root length
Ten normal seedlings were selected randomly for every treatment from all the replications after taking the ultimate germination count test. The root length was measured from the tip of the primary root to base of hypocotyl with the assistance of a scale and mean root length was expressed in centimetre.

Shoot length
Those ten normal seedlings which were used for root length measurement, were also used for the measurement of shoot length. The shoot length was measured form the tip of the first leaf to the bottom of the hypocotyl and mean shoot length was expressed in centimetre.

Seedling dry weight
The ten normal seedlings used for root and shoot length measurements were for measurement of seedling dry weight. After removing the remnant portion of the seed, only the plumule and radicle were put in butter paper packet and kept in hot air oven at 70± 1°C for 24 hours. The dry weight of the 10 seedlings was recorded and their mean value expressed in gram.

Seedling Vigor index
The seeding Vigor index was calculated by adopting the method suggested by Abdul-Baki and Anderson (1973) [6] and expressed in number by using below formula.
Seedling Vigor Index-I = Germination (%) x Mean seedling length (cm)
Seedling Vigor Index-II = Germination (%) x Mean seedling dry weight (g)

Electrical conductivity of seed leachate
Three replications of 5 g seeds from each treatment were drawn and pre-washed well with distilled water to remove any adhering chemicals and then soaked in 25 ml distilled water for 12 hours at room temperature. After soaking, the seed steep water was decanted to obtain the seed leachate. The electrical conductivity of the seed leachate was measured in a digital conductivity meter with a cell constant of one and expressed as dSm^{-1} (Presley, 1958) [7].

Total Dehydrogenase Activity (TDH)
The total dehydrogenase activity was determined by the method described by Perl *et al.* (1978)[8] with slight modifications. Ten seeds were selected randomly and pre-conditioned by imbibing the seeds for 10 hours. After that the seeds were soaked in 0.5 percent Tetrazolium solution at 30+1°C for a period of 8 hours. Then they were washed thoroughly with distilled water. The red colour (Formazan) was eluted from the stained embryos by soaking in 5ml of 2-methoxy ethanol for 10 hours. The extract was decanted and the colour intensity was measured at 480 nm using Spectro UV-VIS Double Beam PC Scanning Spectrophotometer (UVD-2950). The total dehydrogenase activity was expressed in terms of absorbance at 480 nm.

Field emergence
One hundred maize seeds selected randomly from each treatment in three replications were used for the field emergence studies. The seeds were sown in well prepared soil at 4 to 5 cm deep and covered with soil. Field emergence count was taken on the 7th day after sowing and the emergence percentage was calculated taking into account the number of seedlings emerged three centimetre above the soil surface.

$$\text{Field emergence (\%)} = \frac{\text{Number of seedlings emerged on 7}^{\text{th}}\text{ day}}{\text{Total Number of seeds sown}} \times 100$$

Statistical analysis
The observations recorded for each parameter were statistically analyzed using analysis of variance appropriate for completely randomized design. The treatment effects were compared using LSD test at 0.05 level of probability, when the F-values were significant (Steel and Torrie, 1984) [9].

Result and Discussion
Seed ageing and deterioration of seed are irreversible, inexorable process, but the rate of seed deterioration could be slowed down either by storing the seeds under controlled condition or by imposing seed with polymer coating along with seed treatment chemicals (Duan and Burris, 1997) [10]. The rapid deterioration of stored seed is a serious problem, particularly, in India where high temperature and relative humidity prevail and associate to accelerate is the phenomenon seed ageing. As the controlled seed storage condition involves huge cost, the seed coating and treatment remain a good alternative approach to maintain the seed quality during storage. Polymer coating is a new concept in which the plasticizer polymer forms flexible film that adheres and protects fungicide and insecticide preventing wastage of the chemical, the film is readily soluble as it is hydrophilic and do not impede germination.

Seed Moisture Content
In the present study lowest moisture content (10.01%) was recorded during first month in the treatment T_9: Polymer coating with Little's Polykote Red™ @ 3 ml/kg seed, stored in cloth bag and highest (11.28%) was noticed in control (T_1) and lowest in T_9 (Polymer coating with Little's Polykote Red™ @ 3 ml/kg seed) i.e 10.62% at the end of six month of storage. The seeds coated with synthetic polymer will cover the pores in the seed coat and prevents the entry of both water and fungal mycelia and provide protection from physical damage which can occur during handling and storage (West *et al*., 1985) [11]. The results are in accordance with the findings of Meena *et al.* (1998) [12], Shivayogi Ryavalad *et al.* (2009) [13] and Badiger (2011) [14] in cotton.

Seed germination
Seed germination (%) was declined progressively over a period of storage due to seed coating polymers. Among packaging materials, seeds stored in polythene bag of 700 gauge thickness recorded highest germination (86.67%) and to lowest (84.00%) in cloth bag at the end of sixth month of storage as against the initial seed germination of 98.00 per cent. With respect to the treatments, Little's Polykote red @ 3 ml/kg (T_9) recorded significantly highest germination (93.00%) and lowest (84.00%) was in control (T_1) at the end of six month of storage. The decrease in germination percentage may be due to ageing effect caters to reduction of food reserves and reduction in synthetic activity of embryo apart from death of seed because of fungal invasion, fluctuating temperature, relative humidity and storage

container in which seeds are stored. Increased accumulation of total peroxide, malondialdehyde content, and leakage of electrolytes due to ageing of seeds. Germination (%) was higher in polythene bag, which may attribute to low rate of respiration compared to cloth bag. These findings are in agreement with the results obtained by Shekhar Gouda *et al.* (1998) [15] in sunflower, Hunje *et al.* (1990) [16] in cowpea and Badiger (2011) [14] in cotton.

Shoot and root length

Shoot length, root length (cm) decreased gradually with advancement in storage period however, at the end of six months of storage the packaging materials, seeds stored in polythene bag recorded highest (18.12cm,14.39cm) compared to cloth bag (18.08cm,14.37cm) of shoot length and root length respectively. Among the treatments, Little's Polykote Red^{TM} @ 3 ml/kg of seeds recorded significantly the highest shoot length and root length (19.31cm and 16.17cm) and lowest (18.08cm, 14.37cm) was in control (T_1), respectively as against the initial data at the end of six months of storage. These findings are in agreement with results obtained Iqbal *et al*. (2002) [17] and Vijaykumar *et al.* (2007) [4] in cotton.

Seedling dry weight

Seedling dry weight declined with advancement of storage period and at the end of storage period of six months, the highest seedling dry weight (0.56g) was recorded in polythene bag compared to cloth bag (0.52g). The treatment Little's Polykote Red^{TM} @ 3 ml/kg of seeds (T_9) recorded the highest seedling dry weight (0.61g) and lowest (0.52g) was in control (T_1). Dry weight of seedling decreased with increase in storage period. This may be due to ageing, which resulted in deterioration of seed, decrease in the germination percentage and seedling dry weight. These results are in agreement with the findings of Mahendrapal and Grewal (1985) [18] in pigeon pea, Paul *et al*. (1996) [19] in mungbean, Shivayogi Ryavalad *et al.* (2009) [13] and Badiger (2011) [14] in cotton.

Seed vigor index

Assessment of seedling vigor index is also more relevant as the germination alone may not reveal the real potential of seed lots. The seedling vigor index based on seedling length is well correlated with seedling vigor index based on mean seedling dry weight, at the end of six month storage period, the seed stored in polythene bag recorded the highest seedling vigor index-I (2817.6417) compared to cloth bag (2725.8), while the highest seedling vigor index-I (3299.64) in the treatment Little's Polykote Red^{TM} @ 3 ml/kg of seeds (T_9) and lowest (2725.8) was in Control (T_1) as against the initial seedling vigor index-I. Similarly the seed stored in polythene bag recorded the highest seedling vigor index-II (48.53) compared to cloth bag (43.68), while the highest seedling vigor index-II (56.73) in the treatment Little's Polykote Red^{TM} @ 3 ml/kg (T_9) and lowest (43.68) was in Control (T_1) at the end of six month of storage. The decline in seedling vigor indices may be attributed to decrease in germination per cent, seedling length and dry matter accumulation in seedling. These findings are in agreement with the results obtained by Meena *et al.* (1998) [12], Vijaykumar *et al.* (2007) [4], Shivayogi Ryavalad *et al.* (2009) [13], Badiger (2011) [14] in cotton.

Electrical conductivity

Electrical conductivity of seed leachate (dSm^{-1}) is one of the bio-chemical characters assessed for seed deterioration, at the end of six months of storage period, among the packaging materials, seeds stored in polythene bag (700 gauge) recorded the lowest electrical conductivity (175.777 dSm-1) compared to cloth bag (259.888 dSm^{-1}). Whereas, the treatment Little's Polykote Red^{TM} @ 3 ml/kg (T_9) registered the lowest electrical conductivity (172 dSm^{-1}) and the highest (259.888 dSm^{-1}) was in control (T_1). Progressive increase in electrical conductivity of seed leachate (dSm^{-1}) was observed as advancement of storage period. Increase in electrical conductivity may be attributed to permeability of the seed membrane as seed ages, many substances such as sugars, free amino acids, organic acids will leach out in the presence of water, disruption of membrane integrity and increase in free fatty acid level and free radical productivity by lipid peroxidation leads to leakage of electrolytes due to ageing of seed. These results are in agreement with the findings obtained by Basra *et al.* (2003) [20], Vijaykumar *et al.* (2007) [4], Shivayogi Ryavalad *et al.* (2009) [13], Badiger (2011) [14] in cotton.

Field emergence

Field emergence decreased progressively with advancement of storage period. At the end of six months storage, the seeds stored in polythene bag recorded the highest field emergence (84.33%) compared to cloth bag (84.00%). The treatment Little's Polykote Red^{TM} @ 3ml/kg (T_9) recorded the highest field emergence (92.00%) and the lowest (84.00%) was in control (T_1), further field emergence was declined in all the treatments as compared to initial field emergence of 98.5 per cent. This decrease infield emergence may be due to age induced deteriorative changes in cell and cell organelles and germination capacity of seed under natural soil conditions. As field emergence and germination are positively correlated, the decline in field emergence may be attributed to decrease in germination per cent, seedling vigor, seed ageing and seed deterioration and loss of seed viability over a period of storage. Coating of polymer and chemicals avoid rapid water uptake and imbibitions damage resulting in rapid emergence from the soil. The higher field emergence was recorded in chemical treated seeds which may be due to protection of seeds from microorganisms and in turns help in establishment of seedling in the field condition. These results are similar to the findings of Badiger (2011) [14] in cotton.

Total dehydrogenase activity (TDH)

The total dehydrogenase activity (TDH) was decreased with increase in storage period. This enzyme is essential for protein synthesis and energy production during germination. The TDH activity at the initial month of storage was (1.00) and at the end of six months of storage, the seed stored polythene bag recorded the highest total dehydrogenase activity (0.59) compared to cloth bag (0.58) .Among the treatments, Little's Polykote Red^{TM} @ 3 ml/kg (T_9) recorded the highest dehydrogenase activity (0.67) compared to the lowest in control (T_1) (0.58). This shows that viability of the seeds decreased with increase in storage period. These results are similar to the findings obtained by Saxena and Maheswari (1980) [21] in soybean.

Total soluble protein content

Total soluble protein content (%) of the seed decreased over storage period and the total soluble protein content at the initial month of storage was (11.15%) and at the end of six months of storage, the seed stored polythene bag recorded the highest total soluble protein content (9.29%) compared to cloth bag (8.68%). Among the treatments, Little's Polykote

Red™ @ 3 ml/kg of seeds (T_9) recorded the highest total soluble protein content (9.56%) and the lowest (8.68%) was in control (T_1). Decrease in total soluble protein may be attributed to seed deterioration and rise in free amino acid level due to ageing. These results are similar to the findings of Roberts (1979) [22] in groundnut.

Seed infection

The seed infection (%) was increased with increase in storage period in control and seed coating with polymers. At the end of six months of storage, the seed stored polythene bag recorded the lowest seed borne pathogen (3.00%) compared to cloth bag (3.67%). Among the treatments, Little's Polykote Red™ @ 3 ml/kg of seed (T_9) recorded lowest percentage of infected seed i.e 1.00% after six months of storage while, the maximum seed borne infection was (3.67%) in control (T_1). Storage fungi have been reported to invade and destroy seeds of several species. Under favourable conditions they can invade any kind of seeds. This invasion leads to loss of viability, development of musty odour and discolouration of seeds. The infection rate differed with synthetic polymer coating, seed treatment with chemicals, packaging materials and storage period. This might be due to fluctuations in the moisture pervious in cloth bag. The occurrence of storage fungi coupled with higher moisture content in control seed leads to loss of seed quality parameters during storage. This results are similar to the findings obtained by Mukewar (1994) [23], Chhabra and Shersinghverma (1997) [24] and Badiger (2011) [14] in cotton.

Table 1: Changes in moisture content of maize seeds over 6 month of storage under ambient condition as influenced by seed polymer coating

Treatment	Moisture content (%)						
	Nov 2016	Dec 2016	Jan 2017	Feb 2017	Mar 2017	Apr 2017	Mean
T_1	10.29	10.39	10.59	10.82	11.01	11.28	10.73
T_2	10.28	10.36	10.56	10.74	10.96	11.22	10.70
T_3	10.11	10.21	10.32	10.45	10.61	10.80	10.42
T_4	10.04	10.14	10.26	10.43	10.57	10.75	10.36
T_5	10.21	10.30	10.42	10.57	10.71	10.97	10.53
T_6	10.19	10.30	10.40	10.56	10.70	10.97	10.52
T_7	10.05	10.17	10.29	10.43	10.57	10.88	10.40
T_8	10.05	10.17	10.31	10.44	10.57	10.88	10.40
T_9	10.01	10.05	10.13	10.27	10.42	10.62	10.25
T_{10}	10.02	10.09	10.24	10.36	10.53	10.80	10.34
T_{11}	10.15	10.25	10.38	10.51	10.66	10.94	10.48
T_{12}	10.16	10.23	10.39	10.52	10.67	10.94	10.49
SEM(±)	0.014	0.014	0.016	0.017	0.019	0.021	
CD(0.05)	0.043	0.042	0.048	0.050	0.058	0.062	
CV	0.26	0.25	0.28	0.29	0.32	0.34	

Table 2: Changes in germination (%) of maize seeds over 6 month of storage under ambient condition as influenced by seed polymer coating

Treatment	Seed germination (%)						
	Nov 2016	Dec 2016	Jan 2017	Feb 2017	Mar 2017	Apr 2017	Mean
T_1	91 (9.53)*	91 (9.53)*	87.67 (9.36)*	86.33 (9.29)*	85.33 (9.24)*	84.00 (9.17)*	87.56
T_2	93.33 (9.66)*	93 (9.64)*	87.67 (9.36)*	86.67 (9.31)*	86.67 (9.30)*	86.67 (9.31)*	89.00
T_3	93.00 (9.64)*	90.33 (9.50)*	89.00 (9.43)*	88.67 (9.42)*	86.00 (9.27)*	85.67 (9.26)*	88.78
T_4	91.33 (9.56)*	91.33 (9.56)*	90.00 (9.49)*	88.33 (9.40)*	86.33 (9.29)*	86.33 (9.29)*	88.94
T_5	92.00 (9.59)*	90.67 (9.52)*	89.33 (9.45)*	88.67 (9.42)*	88.00 (9.38)*	85.67 (9.26)*	89.06
T_6	91.67 (9.57)*	90.33 (9.50)*	90.33 (9.50)*	88.67 (9.42)*	87.00 (9.33)*	85.67 (9.26)*	88.94
T_7	92.00 (9.59)*	91.33 (9.56)*	89.00 (9.43)*	88.33 (9.4)*	87.67 (9.36)*	86.67 (9.31)*	89.17
T_8	91.67 (9.57)*	90.67 (9.52)*	90.00 (9.49)*	88.00 (9.38)*	87.33 (9.35)*	87.00 (9.33)*	89.11
T_9	97.00 (9.85)*	96.33 (9.81)*	95.33 (9.76)*	94.33 (9.71)*	94.00 (9.70)*	93.00 (9.64)*	95.00
T_{10}	97.00 (9.85)*	96.33 (9.81)*	94.67 (9.73)*	94.00 (9.70)*	93.00 (9.64)*	91.67 (9.57)*	94.44
T_{11}	90.67 (9.52)*	90.33 (9.50)*	89.00 (9.43)*	88.00 (9.38)*	86.67 (9.31)*	86.00 (9.27)*	88.50
T_{12}	92.67 (9.63)*	91.00 (9.54)*	88.67 (9.42)*	88.67 (9.42)*	86.33 (9.29)*	86.33 (9.29)*	88.94
SEM(±)	0.333	0.471	0.673	0.552	0.535	0.593	
CD(0.05)	0.972	1.375	1.965	1.613	1.563	1.731	
CV	0.62	0.89	1.30	1.08	1.06	1.18	

* Figures in the parentheses are square root transformed values [$y=\sqrt{x}$]

Table 3: Changes in shoot length of maize seeds over 6 month of storage under ambient condition as influenced by seed polymer coating

Treatment	Shoot length						
	Nov 2016	Dec 2016	Jan 2017	Feb 2017	Mar 2017	Apr 2017	Mean
T_1	20.14	19.35	18.84	18.60	18.33	18.08	18.89
T_2	21.03	19.40	18.86	18.65	18.41	18.12	18.94
T_3	21.88	20.54	20.26	19.84	18.83	18.07	19.91
T_4	21.76	20.58	20.25	20.05	18.96	18.23	19.97
T_5	20.18	19.91	19.60	19.34	18.90	18.15	19.35
T_6	20.79	20.28	20.03	19.69	19.09	18.35	19.71
T_7	21.07	20.87	20.65	20.24	19.24	18.79	20.14
T_8	21.24	20.93	20.91	20.52	19.75	19.01	20.40
T_9	22.48	22.01	21.79	21.28	20.41	19.31	21.21

T_{10}	22.45	21.84	21.34	21.02	20.13	18.96	20.96
T_{11}	20.59	20.13	19.81	19.36	19.07	18.08	19.51
T_{12}	20.69	20.19	19.82	19.42	18.82	17.98	19.49
SEM(±)	0.135	0.149	0.136	0.136	0.108	0.113	
CD(0.05)	0.396	0.437	0.399	0.399	0.315	0.331	
CV	1.11	1.27	1.17	1.20	0.98	1.07	

Table 4: Changes in Root length of maize seeds over 6 month of storage under ambient condition as influenced by seed polymer coating

Treatment	Root length						
	Nov 2016	**Dec 2016**	**Jan 2017**	**Feb 2017**	**Mar 2017**	**Apr 2017**	**Mean**
T_1	16.20	16.02	15.85	15.64	14.60	14.37	15.45
T_2	17.07	16.09	15.86	15.66	14.63	14.39	15.62
T_3	16.33	16.24	15.91	15.70	14.63	14.40	15.54
T_4	16.61	16.22	16.07	15.75	15.05	14.38	15.68
T_5	16.45	16.20	16.13	15.96	14.72	14.61	15.68
T_6	16.50	16.25	16.12	16.03	14.74	14.63	15.71
T_7	17.10	16.83	16.40	16.13	15.68	15.44	16.26
T_8	16.67	16.46	16.33	15.75	15.02	14.52	15.79
T_9	18.11	18.11	17.66	17.20	16.41	16.17	17.28
T_{10}	17.98	17.73	17.57	17.17	16.39	16.16	17.17
T_{11}	17.22	16.67	16.46	16.43	15.44	15.39	16.27
T_{12}	16.88	16.66	16.52	16.09	15.39	15.05	16.10
SEM(±)	0.224	0.144	0.186	0.177	0.200	0.210	
CD(0.05)	0.656	0.421	0.543	0.519	0.584	0.615	
CV	2.31	1.51	1.97	1.91	2.27	2.44	

Table 5: Changes in Seedling dry weight of maize seeds over 6 month of storage under ambient condition as influenced by seed polymer coating

Treatment	Seedling Dry weight						
	Nov 2016	**Dec 2016**	**Jan 2017**	**Feb 2017**	**Mar 2017**	**Apr 2017**	**Mean**
T_1	0.64	0.62	0.60	0.58	0.55	0.52	0.59
T_2	0.69	0.68	0.63	0.61	0.58	0.56	0.62
T_3	0.70	0.63	0.62	0.59	0.56	0.54	0.61
T_4	0.71	0.65	0.63	0.61	0.58	0.56	0.63
T_5	0.67	0.65	0.62	0.61	0.58	0.55	0.61
T_6	0.66	0.64	0.62	0.61	0.57	0.54	0.61
T_7	0.70	0.67	0.64	0.62	0.60	0.59	0.64
T_8	0.71	0.67	0.64	0.61	0.60	0.57	0.64
T_9	0.74	0.72	0.66	0.64	0.63	0.61	0.67
T_{10}	0.73	0.71	0.66	0.63	0.62	0.60	0.66
T_{11}	0.69	0.67	0.63	0.61	0.58	0.57	0.63
T_{12}	0.70	0.65	0.62	0.59	0.56	0.55	0.61
SEM(±)	0.004	0.009	0.005	0.005	0.007	0.007	
CD(0.05)	0.013	0.028	0.017	0.015	0.020	0.021	
CV	1.11	2.51	1.60	1.50	2.11	2.26	

Table 6: Changes in SVI-I of maize seeds over 6 month of storage under ambient condition as influenced by seed polymer coating

Treatment	Seed vigor index I						
	Nov 2016	**Dec 2016**	**Jan 2017**	**Feb 2017**	**Mar 2017**	**Apr 2017**	**Mean**
T_1	3306.94	3218.67	3041.2723	2955.9392	2809.9169	2725.8	3009.7564
T_2	3555.873	3300.57	3043.9024	2973.6477	2863.5768	2817.6417	3092.5352
T_3	3553.53	3322.3374	3219.13	3151.3318	2877.56	2781.7049	3150.9323
T_4	3504.3321	3360.944	3268.8	3162.214	2936.0833	2815.2213	3174.5991
T_5	3369.96	3274.0937	3191.7609	3130.051	2958.56	2806.5492	3121.8291
T_6	3418.3743	3299.7549	3265.4295	3167.2924	2943.21	2825.3966	3153.2429
T_7	3511.64	3443.141	3297.45	3212.5621	3061.4364	2966.7141	3248.8239
T_8	3475.2097	3390.1513	3351.6	3191.76	3036.4641	2917.11	3227.0491
T_9	3937.23	3864.7596	3760.7685	3629.8184	3461.08	3299.64	3658.8827
T_{10}	3921.71	3811.7781	3683.6097	3589.86	3396.36	3219.4504	3603.7947
T_{11}	3428.2327	3324.144	3228.03	3149.52	2990.9817	2878.42	3166.5547
T_{12}	3481.6119	3353.35	3222.2678	3148.6717	2953.3493	2851.4799	3168.4551
SEM(±)	38.639	29.785	23.306	23.044	54.392	25.761	
CD(0.05)	112.764	86.923	68.016	67.251	158.736	75.182	
CV	1.89	1.51	1.23	1.25	3.11	1.54	

Table 7: Changes in SVI-II of maize seeds over 6 month of storage under ambient condition as influenced by seed polymer coating

Treatment	Seed Vigor index II						
	Nov 2016	Dec 2016	Jan 2017	Feb 2017	Mar 2017	Apr 2017	Mean
T_1	58.24	56.42	52.602	50.0714	46.9315	43.68	51.3241
T_2	64.3977	63.24	55.2321	52.8687	50.2686	48.5352	55.7570
T_3	65.1	56.9079	55.18	52.3153	48.16	46.2618	53.9875
T_4	64.8443	59.3645	56.7	53.8813	50.0714	48.3448	55.5343
T_5	61.64	58.9355	55.3846	54.0887	51.04	47.1185	54.7012
T_6	60.5022	57.8112	56.0046	54.0887	49.59	46.2618	54.0430
T_7	64.4	61.1911	56.96	54.7646	52.602	51.1353	56.8421
T_8	65.0857	60.7489	57.6	53.68	52.398	49.59	56.5171
T_9	71.78	69.3576	62.9178	60.3712	59.22	56.73	63.3961
T_{10}	70.81	68.3943	62.4822	59.22	57.66	55.002	62.2614
T_{11}	62.5623	60.5211	56.07	53.68	50.2686	49.02	55.3536
T_{12}	64.869	59.15	54.9754	52.3153	48.3448	47.4815	54.5226
SEM(±)	0.506	0.853	0.413	0.468	0.625	0.612	
CD(0.05)	1.478	2.490	1.207	1.367	1.825	1.786	
CV	1.30	2.42	1.26	1.49	2.09	2.14	

Table 8: Changes in Electrical conductivity of maize seeds over 6 month of storage under ambient condition as influenced by seed polymer coating

Treatment	Electrical conductivity						
	Nov 2016	Dec 2016	Jan 2017	Feb 2017	Mar 2017	Apr 2017	Mean
T_1	211.00	240.67	250.33	273.33	291.67	292.33	259.888
T_2	130.33	145	165	185	202.33	227	175.777
T_3	178.33	198.33	218.33	232	194.67	270.666	215.388
T_4	198.33	218.33	234.66	246	270.00	289	242.777
T_5	147	165.66	182.33	200.66	207.67	229.333	188.777
T_6	140.66	159	173	191	213.67	234.666	185.333
T_7	205.33	231	238.33	263	282.33	287	251.166
T_8	134.66	149.33	165.66	185.66	205.67	211.666	175.444
T_9	126.33	143.33	163.33	175.00	199.00	225.00	172
T_{10}	142	154	175	181.33	209.67	223.333	180.888
T_{11}	134.33	147.33	170	179.66	203.67	215	175
T_{12}	133	145.66	173.33	177	203.67	224	176.111
SEM(±)	2.430	3.638	3.510	6.385	5.860	7.972	
CD(0.05)	7.039	10.619	10.245	18.633	17.102	23.265	
CV	2.69	3.60	3.16	5.33	4.54	5.66	

Table 9: Changes in Field emergence (%) of maize seeds over 6 month of storage under ambient condition as influenced by seed polymer coating

Treatment	Field emergence (%)						
	Nov 2016	Dec 2016	Jan 2017	Feb 2017	Mar 2017	Apr 2017	Mean
T_1	91.00 (9.54)*	90.67 (9.52)*	88.66 (9.42)*	87.67 (9.36)*	85.67 (9.26)*	84.00 (9.17)*	87.94
T_2	91.33 (9.56)*	91 (9.54)*	88.67 (9.42)*	88.00 (9.38)*	85.67 (9.26)*	84.33 (9.18)*	88.17
T_3	93.67 (9.68)*	93.00 (9.64)*	92.67 (9.63)*	90.67 (9.52)*	91.00 (9.54)*	89.67 (9.47)*	91.78
T_4	93.33 (9.66)*	92.67 (9.63)*	91.33 (9.56)*	88.67 (9.42)*	89.67 (9.47)*	86.33 (9.29)*	90.33
T_5	92.00 (9.59)*	91.67 (9.57)*	91.67 (9.57)*	90.33 (9.50)*	89.33 (9.45)*	86.00 (9.27)*	90.17
T_6	91.00 (9.54)*	90.67 (9.52)*	90.33 (9.50)*	89.33 (9.45)*	88.00 (9.38)*	85.67 (9.26)*	89.17
T_7	93.67 (9.68)*	92.67 (9.63)*	91.67 (9.57)*	91.00 (9.54)*	88.33 (9.40)*	86.33 (9.29)*	90.61
T_8	94.33 (9.71)*	93.67 (9.68)*	91.67 (9.57)*	90.33 (9.50)*	89.33 (9.45)*	86.33 (9.29)*	90.94
T_9	98.00 (9.90)*	97.67 (9.88)*	96.33 (9.81)*	94.67 (9.73)*	94.33 (9.71)*	92.00 (9.59)*	95.50
T_{10}	98.33 (9.92)*	96.67 (9.83)*	95.00 (9.75)*	94.33 (9.71)*	93.67 (9.68)*	92.00 (9.59)*	95.00
T_{11}	94.67 (9.73)*	94.67 (9.73)*	91.67 (9.57)*	90.33 (9.50)*	87.33 (9.35)*	86.00 (9.27)*	90.78
T_{12}	93.67 (9.68)*	92.67 (9.63)*	91.67 (9.57)*	90.00 (9.49)*	88 (9.38)*	87.67 (9.36)*	90.61
SEM(±)	0.461	0.419	0.396	0.408	0.440	0.585	
CD(0.05)	1.346	1.224	1.157	1.191	1.286	1.708	
CV	0.85	0.78	0.75	0.78	0.86	1.16	

* Figures in the parentheses are square root transformed values [$y=\sqrt{x}$]

Table 10: Changes in Total dehydrogenase activity of maize seeds over 6 month of storage under ambient condition as influenced by seed polymer coating

Treatment	Total dehydrogenase activity						
	Nov 2016	Dec 2016	Jan 2017	Feb 2017	Mar 2017	Apr 2017	Mean
T_1	0.91	0.81	0.72	0.68	0.65	0.58	0.72
T_2	0.92	0.82	0.73	0.69	0.67	0.59	0.74
T_3	0.96	0.87	0.77	0.74	0.70	0.64	0.78

T_4	0.94	0.86	0.76	0.73	0.69	0.64	0.77
T_5	0.94	0.84	0.73	0.70	0.66	0.62	0.75
T_6	0.91	0.83	0.73	0.69	0.66	0.62	0.74
T_7	0.95	0.83	0.73	0.70	0.66	0.61	0.75
T_8	0.92	0.89	0.73	0.70	0.66	0.61	0.74
T_9	0.97	0.89	0.80	0.77	0.73	0.67	0.81
T_{10}	0.96	0.89	0.79	0.76	0.72	0.67	0.80
T_{11}	0.93	0.84	0.74	0.71	0.67	0.62	0.75
T_{12}	0.93	0.84	0.74	0.70	0.67	0.62	0.75
SEM(±)	0.003	0.002	0.003	0.003	0.003	0.004	
CD(0.05)	0.011	0.007	0.009	0.010	0.008	0.012	
CV	0.73	0.53	0.73	0.85	0.79	1.21	

Table 11: Changes in Seed protein content of maize seeds over 6 month of storage under ambient condition as influenced by seed polymer coating

Treatment	Seed protein content						
	Nov 2016	**Dec 2016**	**Jan 2017**	**Feb 2017**	**Mar 2017**	**Apr 2017**	**Mean**
T_1	10.54	10.31	9.74	9.50	9.06	8.68	9.64
T_2	11.00	10.70	10.31	10.02	9.63	9.29	10.16
T_3	10.68	10.55	10.07	9.80	9.34	9.08	9.92
T_4	10.67	10.34	9.94	9.61	9.26	9.01	9.80
T_5	10.81	10.39	10.01	9.75	9.27	9.08	9.88
T_6	10.78	10.38	10.01	9.74	9.18	9.04	9.85
T_7	10.62	10.31	9.91	9.65	9.15	9.03	9.78
T_8	10.64	10.36	9.82	9.58	9.18	8.99	9.76
T_9	11.01	10.73	10.32	10.03	9.68	9.56	10.22
T_{10}	10.79	10.40	10.15	9.62	9.32	9.09	9.90
T_{11}	10.81	10.61	10.21	9.82	9.21	8.93	9.93
T_{12}	10.74	10.53	10.14	9.72	9.17	8.84	9.86
SEM(±)	0.051	0.073	0.048	0.051	0.050	0.073	
CD(0.05)	0.151	0.215	0.142	0.150	0.147	0.213	
CV	0.84	1.22	0.84	0.92	0.94	1.40	

Table 12: Changes in percent infected seed (%) of maize seeds over 6 month of storage under ambient condition as influenced by seed polymer coating

Treatment	Percent infected seed (%)						
	Nov 2016	**Dec 2016**	**Jan 2017**	**Feb 2017**	**Mar 2017**	**Apr 2017**	**Mean**
T_1	1.00 (1.22)*	1.00 (1.22)*	2.33 (1.68)*	1.67 (1.46)*	2.00 (1.58)*	3.67 (2.04)*	1.94
T_2	0.67 (1.05)*	1.00 (1.22)*	2.00 (1.58)*	2.00 (1.58)*	1.67 (1.46)*	3.00 (1.87)*	1.72
T_3	2.00 (1.58)*	2.00 (1.58)*	2.00 (1.58)*	2.00 (1.58)*	2.00 (1.58)*	2.67 (1.74)*	2.11
T_4	1.00 (1.22)*	0.67 (1.05)*	1.67 (1.46)*	1.67 (1.46)*	2.33 (1.68)*	2.33 (1.68)*	1.61
T_5	1.67 (1.46)*	1.67 (1.46)*	1.67 (1.46)*	2.00 (1.58)*	2.00 (1.58)*	3.33 (1.82)*	2.06
T_6	2.67 (1.77)*	1.33 (1.29)*	1.33 (1.29)*	2.00 (1.58)*	2.33 (1.68)*	3.33 (1.82)*	2.17
T_7	1.00 (1.22)*	1.33 (1.29)*	2.00 (1.58)*	1.67 (1.46)*	2.33 (1.68)*	2.67 (1.77)*	1.83
T_8	1.33 (1.29)*	1.67 (1.46)*	1.67 (1.46)*	2.33 (1.68)*	2.00 (1.58)*	2.00 (1.58)*	1.83
T_9	0.67 (1.05)*	0.67 (1.05)*	1.00 (1.22)*	1.33 (1.29)*	1.33 (1.29)*	1.00 (1.22)*	1.00
T_{10}	0.00 (0.70)*	0.33 (0.88)*	1.00 (1.22)*	1.33 (1.29)*	1.67 (1.46)*	2.33 (1.68)*	1.11
T_{11}	1.33 (1.29)*	2.00 (1.58)*	1.33 (1.29)*	1.67 (1.46)*	2.33 (1.68)*	2.00 (1.58)*	1.78
T_{12}	1.33 (1.29)*	1.33 (1.29)*	2.00 (1.58)*	1.67 (1.46)*	1.67 (1.46)*	1.67 (1.46)*	1.61
SEM(±)	0.254	0.272	0.333	0.321	0.430	0.430	
CD(0.05)	0.742	0.794	NS	NS	NS	1.255	
CV	36.08	37.71	34.64	31.09	37.79	29.81	

* Figures in the parentheses are square root transformed values [$y = \sqrt{(x+0.5)}$]

Conclusion

From the present investigation, it can be concluded that maize seeds coated with Little's Polykote Red™ @ 3 ml/kg seed can be used to maintain significantly high germination and other seed quality parameters during storage in cloth bags, in comparison with the untreated seed stored either in cloth bag or polythene bags. After 6 months of storage, seeds treated with Little's Polykote Red™ @ 3 ml/kg of seeds recorded the lowest seed moisture content (10.62%) with maximum germination (93.00%), shoot length (19.31 cm), root length (16.17 cm), seedling dry weight (0.61 g), seed Vigor index-I (3299.64), seed Vigor index-II (56.73), field emergence (92.00%), total dehydrogenase activity (0.67), total soluble protein content (9.56%) and lowest infection (1.00%) of seed borne pathogen.

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