

Effects of polymers as a main component of coating formulations on quality and effects of stability of cucumber seeds

Tidarat Kaewkham¹, Padungkwan Chitropas², Anan Wongcharoen¹, Russell K. Hynes³,
Jakkrapong Kangsopa¹ and Boonmee Siri^{1*}

ABSTRACT: Seed coating is used for delivery pesticide and bio-fungicide on the seed for protects seed from pest infestation. The objectives of this study were to determine the effects of formulations on germination percentage and germination index under laboratory and greenhouse conditions of hybrid cucumber seed var. CU023 for immediately coated seed and stored seed under controlled and ambient conditions. Treatments included hydroxypropyl methyl cellulose (5%)+additives, polyvinyl alcohol (5%)+additives, polyvinylpyrrolidone-K30 (10%)+additives, polyvinylpyrrolidone-K90 (5%)+additives and commercial seed coating substance (80%)+20% water as a control treatment. Data were recorded for viscosity, pH, film dissolving percentage, germination percentage and germination index. The experiments were laid in a completely randomized design with four replications. All tested formulations were less viscous than an un-identified commercial control and the viscosity and pH of all tested formulations were stable. The tested formulations were similar to commercial control and untreated control for germination percentage and germination index. The most suitable polymer will depend entirely on the needs of a particular slurry mix.

Keywords: Germination index, polymers, seed coating formulation, seed stability, viscosity

Introduction

Seed is always important for crop production and seed industry tries to increase seed quality and reduce seed production cost to gain higher profit. Seed coating is used to increase seed quality as other active ingredients can be added to coating materials and the active ingredients provide protection against insect pests and pathogens in storage (Taylor and Harman, 1990).

The method in coating seed is also important as some specific materials such as fungicides, pesticides and micro-nutrients to the surface of seed could provide seed protection from pathogenic contamination and insect pest damages, and enhance a better plant stand

establishment and others (Brooker et al., 2007; Jamieson, 2008). Several materials are used for coating seed without changing the size and shape of the seed and without any disadvantages on growth of the seedlings (Taylor and Harman, 1990). Mixing various polymers and co-polymers with insecticides as seed coating stuffs on maize seed aimed to protect seeds from soil-born insect pests (Kevin et al., 1998). The coating on broccoli's seed with an aqueous suspension of hydroxy-ethyl-cellulose improved homogeneity and uniformity of the coated seed bring none of harmful effect on seed quality (Almeida et al., 2005). Seed coating substances can be liquids containing dissolved or suspended solids to form a layer covering the surface of seed (Scott, 1989).

¹ Department of Plant Science and Agricultural Resources, Faculty of Agriculture, Khon Kaen University, Khon Kaen 40002, Thailand

² Faculty of Pharmaceutical Sciences, Khon Kaen University, Khon Kaen, 40002, Thailand

³ Agriculture and Agri-Food Canada, 107 Science Place, Saskatoon, SK., Canada.

* Corresponding author: boonmee@kku.ac.th

Polymer, plasticizer and colorants can be used as seed coating substances (Taylor et al., 1998). Starch and cellulose, poly-vinyl alcohol and poly-vinylpyrrolidone can be used as adhesive substances for seed coating purposes (Ehsanfar and Modarres-sanavy, 2005). The producers can select these coating materials for specific situations such as low price and mixing with specific active ingredients.

Thailand has exported cucumber seeds to other countries and the commercial seed is coated with unidentified coating materials. The company claimed that cost of seed coating was high and new seed coating materials with similar or better performance with lower cost is worth exploring. The objectives of this study were to investigate physical and chemical properties of coating formations after mixing and after storage, to determine the effects of formulations on germination percentage and germination index under laboratory and greenhouse conditions of hybrid cucumber seed var.CU023 for immediately coated seed and stored seed under different conditions. The materials may be used in other similar seeds of different species with some verification. The information obtained from this study is useful for seed industry.

Material and methods

Polymer solutions and seed coating formulations

Five treatments were consisting of hydroxypropylmethyl cellulose (5%)+additives, polyvinyl alcohol (5%)+additives, polyvinylpyrrolidone-K30 (10%)+additives, polyvinylpyrrolidone-K90 (5%)+additives and commercial seed coating substance (80 %)+20 % water were arranged in

a completely randomized design with four replications. Commercial substance was also used as a control treatment for comparison of coating formulation properties.

The chemical name and the compositions of the commercial substance could not be identified as the substance is under the patent of the company. Five additives consisted of PEG6000, colorant, titanium dioxide (TiO_2), iriodin and food colouring. All polymers were tested from 5% up to 10% solutions (w/v). polyvinylpyrrolidone-K90 (5%) and Hydroxypropylmethyl cellulose (5%) were completely dissolved at a concentration of 5%, whereas polyvinylpyrrolidone-K30 (10%) was completely dissolved at 10%. Five additives of the PEG6000, colorant, titanium dioxide (TiO_2) iriodin and food colouring were added into the polymer solutions at room temperature in accordance with its specific proportions.

The viscosity was measured with a Ford cup viscosity (Model ASTM D1200-10) at room temperature. The pH was determined with the Checker[®] pH meter (Model HI 98103). A 20 ml of each coating formulation was loaded on glass petri dishes and dried at 50 °C for 4 hours to develop film of the coating formulation. The film was removed from the petri dishes and cut into 4×4 cm sections. The cut film was dissolved in water at room temperature for 5 min and oven-dried at 50 °C for 4 hours. The percentage of the film that was dissolved in water was calculated as the study of Korkasetwit (2008). After mixing the formulation treatments, the treatments were sealed in plastic bottles and stored at ambient temperature (25-30 °C) for six months. The evaluation of the stability of the treatments was carried out at monthly intervals for

six months at Khon Kaen University, Khon Kaen, Thailand, and the data were recorded for viscosity and pH.

Cucumber seed and its coating processes

Mature seeds of hybrid cucumber seeds var. CU023 were coated with five coating formulations at a rate of 150 ml kg⁻¹ seed with the use of the Centri Coater, Model CC10, Cimbria Heid GmbH, Stockerau, Austria. After the coating process was completed, the coated seed was dried in a forced air seed dryer at 35 °C for 3 hours.

Immediate germination test and after storage test

Four replications of 100 seeds from each treatment were carried out to test seed germination under laboratory and greenhouse conditions. In laboratory germination test, the seeds were placed between two wetted paper towel sheets then incubated at 20-30 °C, whereas, germination test under the greenhouse condition, the seeds were germinated in peat-moss medium. Germination percentage was recorded at 4 and 8 days after sowing (DAS) by the seed germination counting which all counts followed the seed testing protocol described by the International Seed Testing Association (ISTA, 2008). In addition, daily germination was recorded for each test and the germination index. The seeds of the same treatments were also stored at ambient and controlled conditions for ten months, and carried out at two-month intervals for germination testing under laboratory and greenhouse conditions.

Statistical analysis

The data were analyzed according to a completely randomized design with four

replications using the Proc Mixed Procedure in SAS. Means were separated by the Duncan's new multiple range test (DMRT).

Results

Viscosity, pH and film dissolving percentage at mixing

Viscosity values ranging from 11.9 to 58.4 m/sec were observed among the treatments (Table 1). Significant differences among the treatments were observed and none of the treatments was as viscous as the control (58.4 m/sec). The tested formulations had viscosity values ranging from 11.9 to 36.1 m/sec, which were much lower than commercial formulation control. The treatments were significantly different for pH values ranging from 3.5 to 8.4, and none of the tested treatments had high pH as the control (8.4) (Table 1). Treatments were also significantly different for film dissolving percentage ranging from 8.8% for commercial control to 56.4% for polyvinylpyrrolidone-K90 (5%). Basically, all the tested treatments dissolved faster than the commercial product (8.8%).

Viscosity and pH under storage

Significant differences among the treatments were observed for viscosity at 1, 2, 3, 4, 5 and 6 months after storage (Table 2). The viscosity did not show consistent patterns as polyvinyl alcohol (5%) and hydroxypropylmethyl cellulose (5%) were rather stable whereas polyvinylpyrrolidone-K30 (10%), polyvinylpyrrolidone-K90 (5%) and commercial control had a small increase in viscosity.

Table 1 Means for viscosity, pH and film dissolving (%) of five seed coating polymers (treatments) used as seed coating materials for hybrid cucumber.

Formulation	Viscosity (m/sec)	pH	Film dissolving (%)
polyvinyl alcohol (5%)	21.6 ^c	6.5 ^b	25.3 ^c
polyvinylpyrrolidone-K30 (10%)	13.3 ^d	3.5 ^c	35.2 ^b
polyvinylpyrrolidone-K90 (5%)	11.9 ^d	3.5 ^c	56.4 ^a
hydroxypropylmethyl cellulose (5%)	36.1 ^b	6.3 ^b	25.0 ^c
Commercial control	58.4 ^a	8.4 ^a	8.8 ^d
C.V. (%)	3.8	1.9	8.8

Means in the same column followed by the same letter are not significantly different by least significant differences (LSD) at 0.05 probability level, C.V. (%) = variation coefficient percentages

Similar to viscosity at immediate evaluation (Table 1), commercial control had the highest viscosity (87.7 to 102.8 m/sec), whereas other treatments had viscosity values between 11.8 and 23.5 m/sec. For the pH values of all treatments seemed to increase after storage, but the increase

was rather small and not consistent. Similar to pH values at immediate evaluation in Table 1, commercial control had the highest pH values ranging from 7.3 to 8.3, whereas other treatments had pH values ranging from 3.1 to 6.9.

Table 2 Means for viscosity and pH of five seed coating polymers (treatments) used as seed coating materials for hybrid cucumber seed stored under ambient condition and evaluated at one-month for six months

Formulation ¹	Storage periods (months)											
	Viscosity (m/sec)						pH					
	1	2	3	4	5	6	1	2	3	4	5	6
T1	18.3 ^c	18.4 ^c	18.3 ^d	19.0 ^d	18.6 ^d	18.3 ^c	6.0 ^b	6.4 ^b	6.9 ^b	6.7 ^c	6.8 ^c	6.7 ^b
T2	11.8 ^d	11.8 ^d	13.0 ^e	13.4 ^e	13.3 ^e	13.2 ^d	3.1 ^d	3.3 ^d	3.7 ^c	4.0 ^d	3.4 ^c	3.4 ^c
T3	19.5 ^c	19.8 ^c	20.7 ^c	21.5 ^c	22.4 ^c	23.5 ^b	3.5 ^c	3.7 ^c	3.7 ^c	3.8 ^e	3.4 ^c	3.3 ^c
T4	25.4 ^b	24.8 ^b	23.5 ^b	23.8 ^b	24.6 ^b	21.5 ^{bc}	6.0 ^b	6.2 ^b	6.8 ^b	6.8 ^b	6.8 ^b	6.7 ^b
T5	87.7 ^a	91.4 ^a	87.7 ^a	93.0 ^a	102.3 ^a	102.8 ^a	7.5 ^a	7.3 ^a	7.5 ^a	7.7 ^a	8.3 ^a	7.8 ^a
C.V. (%)	4.16	5.78	3.42	4.38	2.39	7.83	3.49	3.80	1.51	1.59	1.88	3.2

¹T1= Coated seed with polyvinyl alcohol (5%); T2= Coated seed with polyvinylpyrrolidone-K30 (10%); T3= Coated seed with polyvinylpyrrolidone-K90 (5%); T4= Coated seed with hydroxypropylmethyl cellulose (5%); T5= Commercial control; T6= Untreated seed

Means in the same column followed by the same letter are not significantly different by least significant differences (LSD) at 0.05 probability level, C.V. (%) = variation coefficient percentages

Germination percentage and germination index

Germination percentage values ranging from 97 to 100% were observed among treatments and the treatments were not significantly different for germination percentage at immediate evaluation under laboratory conditions (Table 3). Significant differences among treatments were observed for germination percentage at immediate evaluation under greenhouse conditions, whereas other treatments ranging from 98 to 99% were similar to commercial and untreated controls (100%).

Differences among treatments were also significant for germination index. All tested treatments ranging from 22.8 to 24.3 were significantly higher than untreated control (21.1),

whereas three tested treatments (polyvinyl alcohol (5%), K30 (10%) and hydroxypropyl methyl cellulose (5%)) ranging from 23.8 to 24.3 were significantly higher than commercial control.

Germination percentage under laboratory condition

Germination percentages ranging from 94 to 100% were observed among treatments stored under controlled conditions, whereas germination percentages ranging between 95 and 100% were observed among treatments stored under ambient conditions (Table 4). The treatments were not significantly different at most evaluation times for seeds stored under controlled and ambient conditions.

Table 3 Germination percentages and germination index of hybrid cucumber seeds coated with different formulation evaluated immediately after coating under laboratory and greenhouse conditions

Formulation	Germination (%)		Germination index
	Laboratory	Greenhouse	
polyvinyl alcohol (5%)	99	98 ^{ab}	24.1 ^a
polyvinylpyrrolidone-K30 (10%)	99	99 ^a	24.3 ^a
polyvinylpyrrolidone-K90 (5%)	99	99 ^a	22.8 ^{ab}
hydroxypropylmethyl cellulose (5%)	100	97 ^b	23.8 ^a
Commercial control	99	100 ^a	22.0 ^{bc}
Untreated control	97	100 ^a	21.1 ^c
CV. (%)	1.74	1.4	4.6

Means in the same column followed by the same letter are not significantly different by least significant differences (LSD) at 0.05 probability level, C.V. (%) = variation coefficient percentages

Under controlled conditions, significant differences among the treatments were observed at 6 months after storage. Under ambient conditions, differences among the treatments were significant at 10 months after storage. Polyvinylpyrrolidone-K90 (5%) with germination percentage of 95% was significantly lower than commercial control (99%) and untreated control (99%).

Germination percentage under greenhouse condition

Under controlled conditions, germination percentages ranging from 78 to 100% were observed among the treatments evaluated at two-month intervals for 10 months (Table 5). The treatments were not significantly different for most evaluation times except at six months after storage. Polyvinylpyrrolidone-K30 (10%) and

polyvinylpyrrolidone-K90 (5%) with germination percentages of 94 and 96%, respectively, were significantly lower than commercial control (100%) and untreated control (100%).

Table 4 Means for germination percentage of hybrid cucumber treated seeds with coating formulations, stored under ambient and controlled conditions and evaluated under laboratory condition at two-month intervals for 10 months

Formulation ¹	Storage intervals (months)									
	Controlled condition					Ambient condition				
	2	4	6	8	10	2	4	6	8	10
T1	98	98	99 ^{ab}	98	100	97	98	98	99	100 ^a
T2	100	97	94 ^c	98	98	99	98	97	94	99 ^a
T3	100	99	96 ^{bc}	99	100	98	98	95	97	95 ^b
T4	100	100	99 ^{ab}	98	99	99	100	97	96	100 ^a
T5	97	97	100 ^a	97	99	97	97	98	98	99 ^a
T6	99	99	100 ^{ab}	98	99	99	98	99	98	99 ^a
C.V. (%)	1.6	1.96	2.5	1.89	1.38	2.03	1.9	3.3	3.3	1.84

¹T1= Coated seed with polyvinyl alcohol (5%); T2= Coated seed with polyvinylpyrrolidone-K30 (10%); T3= Coated seed with polyvinylpyrrolidone-K90 (5%); T4= Coated seed with hydroxypropylmethyl cellulose (5%); T5= Commercial control; T6= Untreated seed

Means in the same column followed by the same letter are not significantly different by least significant differences (LSD) at 0.05 probability level, C.V. (%) = variation coefficient percentages

Table 5 Means for germination percentage of hybrid cucumber treated seed with coating formulations, stored under controlled and ambient conditions and evaluated under greenhouse condition at two-month intervals for 10 months

Formulation ¹	Storage periods (months)									
	Controlled condition					Ambient condition				
	2	4	6	8	10	2	4	6	8	10
T1	100	97	98	95 ^{ab}	82	100 ^a	98	99	75 ^b	79
T2	100	98	98	93 ^{abc}	86	94 ^b	97	98	92 ^a	86
T3	100	100	98	96 ^a	84	99 ^a	98	97	92 ^a	76
T4	100	99	98	90 ^{bc}	84	100 ^a	98	97	99 ^a	67
T5	100	97	97	88 ^c	78	98 ^a	95	98	96 ^a	77
T6	100	97	97	90 ^{bc}	83	99 ^a	98	98	93 ^a	81
C.V. (%)	0.6	2.2	2.0	3.71	7.7	2.4	3.7	3.3	6.9	10.5

¹T1= Coated seed with polyvinyl alcohol (5%); T2= Coated seed with polyvinylpyrrolidone-K30 (10%); T3= Coated seed with polyvinylpyrrolidone-K90 (5%); T4= Coated seed with hydroxypropylmethyl cellulose (5%); T5= Commercial control; T6= Untreated seed

Means in the same column followed by the same letter are not significantly different by least significant differences (LSD) at 0.05 probability level, C.V. (%) = variation coefficient percentages

Under ambient conditions, germination percentages were ranging from 75 to 100%. Significant differences among the treatments were observed at 2 and 8 months after storage, whereas the treatments were not significantly different at other evaluation times. At eight months after storage, polyvinyl alcohol (5%) with germination percentage of 75% was significantly lower than commercial control (96%) and untreated control (93%), whereas other treatments were not significantly different from commercial control and untreated control.

Germination index

Under controlled conditions, germinations index were ranging from 19.2 to 25.0 (Table 6). Polyvinylpyrrolidone-K90 (5%) with germination index of 23.8 was significantly higher than commercial control (21.8) and untreated control (22.1), whereas other treatments were similar to commercial control and untreated control. Under ambient conditions, germination index ranged between 14.8 and 24.9.

Table 6 Means for germination index of hybrid cucumber treated seed with coating formulations, stored under controlled and ambient conditions and evaluated under greenhouse condition at two-month intervals for 10 months

Formulation ¹	Storage periods (months)									
	Controlled condition					Ambient condition				
	2	4	6	8	10	2	4	6	8	10
T1	25.0	23.3	24.2	23.5 ^{ab}	20.1	24.7 ^a	22.4 ^{ab}	24.4	18.0 ^c	19.6 ^{ab}
T2	24.9	23.8	24.2	22.9 ^{abc}	21.3	23.0 ^b	23.9 ^a	24.1	22.1 ^b	21.1 ^a
T3	24.8	24.1	24.2	23.8 ^a	20.8	24.5 ^a	23.6 ^a	23.9	22.6 ^{ab}	16.8 ^{bc}
T4	25.0	24.1	24.2	22.3 ^{bc}	20.6	24.9 ^a	23.8 ^a	24.1	24.2 ^a	14.8 ^c
T5	24.7	23.0	23.6	21.8 ^c	19.2	24.2 ^a	21.0 ^b	24.1	23.2 ^{ab}	18.1 ^{abc}
T6	25.0	23.8	24.0	22.1 ^{bc}	20.6	24.6 ^a	23.7 ^a	24.3	22.9 ^{ab}	20.1 ^{ab}
C.V. (%)	0.7	3.1	2.05	0.9	8.0	2.7	4.3	3.7	5.8	12.8

¹T1= Coated seed with polyvinyl alcohol (5%); T2= Coated seed with polyvinylpyrrolidone-K30 (10%); T3= Coated seed with polyvinylpyrrolidone-K90 (5%); T4= Coated seed with hydroxypropylmethyl cellulose (5%); T5= Commercial control; T6= Untreated seed

Means in the same column followed by the same letter are not significantly different by least significant differences (LSD) at 0.05 probability level, C.V. (%) = variation coefficient percentages

Significant differences among the treatments were observed at 2, 4, 8 and 10 months after storage. At 2 months after storage, polyvinylpyrrolidone-K30 (10%) with germination index of 23.0 was significantly lower than commercial control (24.2) and untreated control

(24.6). At 10 months after storage, hydroxypropyl methyl cellulose (5%) with germination index of 14.8 was significantly lower than commercial control (18.1) and untreated control (20.1), and other treatments were similar to commercial control and untreated control.

Discussion

Viscosity, film dissolving and pH of coating formulations

All tested formulations were similar in viscosity, pH and film dissolving. The tested formulations had lower viscosity and pH than did the commercial product, and they also dissolved much faster than the commercial product. The pH values in this study were in the ranges reported previously (Harwood and Johnson, 1994; Abu Baker, 2012). Coating polymers should possess optimal pH values within a range from 6 to 8 (Kittipongpattana, 2005). Polyvinylpyrrolidone-K30 (10%) and polyvinylpyrrolidone-K90 (5%) were not suitable for seed coating as they had the pH values lower than this range although viscosity was acceptable.

The chemical and physical properties of the coating formulations were considered as the properties of mixed formations, and they were not the properties of individual components. It is difficult to judge the appropriate formulations based on viscosity alone as high viscosity does not indicate high quality. Seed industry can select the range of viscosity that is appropriate for seed coating when the formations are mixed with other materials such as additive and active ingredients. Appropriate formulations should be related with the coating machines. In general, higher viscosity can cause thicker layer of the polymers adhered to the seeds.

The tested formulations were dissolved faster than the commercial product. The rapid film dissolving ability of the tested formulations may not be of advantage due to a rapid loss of important coating elements such as insecticide, fungicide and others. The losses may be taken

place more rapidly by the processes of seepage and percolation in soil.

Hydroxypropyl methyl cellulose (5%) (HPMC) mixed as a formulation had higher viscosity than other tested polymers but it still had much lower viscosity than the commercial product. The high viscosity value of HPMC was reported previously in other studies (Korkasetwit et al., 2008; Chitropas et al., 2008). In this study, pH values of HPMC as a formulation not an individual component ranging between 6.0-6.8, and the pH values were in the range reported in other investigation (Korkasetwit et al., 2008). The polyvinylpyrrolidone-K30 (10%) and polyvinylpyrrolidone-K90 (5%) had low viscosity values ranging from 11.8 to 13.4 m/sec and 19.5 to 23.5, respectively, and low viscosity values could result in thin layer of seed coating which is considered unfavorable. Different types of coating polymers possessed different values of viscosity and pH when used as coating formulations (Chitropas et al., 2008). In this current study, it was found that the viscosity values of most formulations were not changed after 6 months of the storage except the commercial product which was slightly increased about 15%. Stability of the super-hydrophobic coating polymers was relatively high and able to last for several days, particularly with the mildly basic and strong acidic solutions but deteriorated faster under strong basic conditions (Zimmermann et al., 2007). In terms of stability, the tested formulations were more stable than commercial product and they could be used as alternative formulations as stability of the formulation is a favorable property.

Germination percentage and germination index

Seed coating is used for adding active ingredients for protecting seeds from storage

pests and diseases, soil born diseases and insects. The active ingredients may eliminate pathogenic contamination, and able to protect seeds from other biological damages. When they are sown into the soil for crop production it may largely induce the growth of the seedlings with time (Brooker et al., 2007; Jamieson, 2008). Germination test was carried out immediately after seed coating under both laboratory and greenhouse. The results revealed that the germination percentages were rather similar among the treatments. However, clearer differences among the treatments were observed for germination index, and all tested formulations had higher germination index than did commercial control and untreated control. The results indicated that germination index might be a better parameter than germination percentage and could better discriminate the small differences among the treatments.

The ranges of germination percentages in laboratory were high under both controlled and ambient conditions although the seeds were stored for 10 months. In general, there was no real effect of formulation on germination percentage as significant differences among the treatments were found only one sampling date under controlled (6 months after storage) and ambient (10 months after storage) conditions. The low variation among the treatments for germination percentage would be possibly due to high germination percentage and low effect of treatment. The results indicated that this seed lot was very stable although it was stored for 10 months and the polymers used in this study did not affect germination percentage. Seed coating formulations should not possess any undesirable effects to seeds such as deformation, abnormality during germination processes (Kumar et al.,

2007). Some polymers could be toxic to the seeds and the toxicity was dependent on polymer and crop species (Bardin and Huang, 2003).

Similar to germination in laboratory, germination in greenhouse did not show real effect of treatment although significant differences among the treatments were found for controlled conditions at 8 months after storage and for ambient conditions at 2 and 8 months after storage. The difference between germination in laboratory and greenhouse was the low germination percentage in greenhouse at late sampling dates indicating that the quality of the seed lot was reduced when the seed was stored for long period and germinated in greenhouse.

Germination index provided the results similar to germination percentage especially for germination in laboratory in which under controlled conditions. However, significant differences among the treatments was found at 8 months after storage only. Although storage under ambient conditions provided high variation for germination index, the differences among the treatments were still not clear because of the interactions between treatment and sampling date. In this study, the tested formulations of seed coating were similar to commercial control and untreated control either immediately after application or over time during storage.

Conclusion

The tested formulations were similar to commercial product and untreated control for germination percentage and germination index. The results indicated that the tested formulations did not have deleterious effects on germination percentage and germination index. The results in this study supported general findings that coating

materials do not have significant effects on seed germination and germination index. None of the tested formulations posed a risk to seed quality. All tested formulations were less viscous than an un-identified commercial coating and the viscosity of all tested formulations was stable. The most suitable polymer will depend entirely on the needs of a particular slurry mix.

Acknowledgements

We would like to thank The Royal Golden Jubilee Ph.D Program (RGJ) scholarship (IUG/006/2550), for the financial support for this research. We would also like to thank AG Universal Seed Company, Khon Kaen University, Thailand for donating cucumber seed for this project. Mr. Thawan Kesmala provided careful review of the paper.

References

- Abubaker, O. 2012. Polyvinyl alcohol. In: Handbook of pharmaceutical excipients. 7th Edition. pp: 639-641. R.C. Rowe, P.J. Sheskey, W.G. Cook and M.E. Fenton (eds.). The Pharmaceutical Press, London, UK.
- Almeida, C.D., S.C.S. Rocha, and L.F. Razera. 2005. Polymer coating, germination and vigour of broccoli seeds. *Sci. Agric.* 62(3): 221-226.
- Bardin, S.D., and H.C. Huang. 2003. Efficacy of stickers for seed treatment with organic matter or microbial agents for the control of damping-off of sugar beet. *Plant pathology bulletin.* 12: 19-26.
- Brooker, N.L., C.D. Lagalle, A. Zlatanic, I. Javni, and Z. Petrovic. 2007. Soy polyol formulations as novel seed treatments for the management of soil-borne diseases of soybean. *Comm. Appl. Biol. Sci.* 72(2): 35-43.
- Chitropas, P., C. Pathumthanasup, and B. Siri. 2008. Development of coating formulation for corn seed using hydrophilic polymer as a film former. *Agricultural Sci.* 39(3): 370-372.
- Ehsanfar, S., and S.A.M. Modarres-sanavy. 2005. Crop protection by seed coating. *Comm. Appl. Biol. Sci.* 70(3): 225-230.
- Harwood, R.J., and J.L. Johnson. 1994. Hydroxypropyl methylcellulose. In: Handbook of pharmaceutical excipients. 2nd Edition. pp:229-232. Wade A. and Weller P.J. (eds.). The pharmaceutical Press, London.
- ISTA. 2008. International Rule for Seed Testing, Seed Science and Technology. 27 Supplement.
- Jamieson, G. 2008. New perspectives on seed enhancement. *Acta Hort.* 782: 143-150.
- Kevin, M.T., F. Sioux, S. Dak, A.C. Yugu, Lakeville, and Minn. 1998. Insecticidal seed coating. United States patent, USA.
- Kittipongpattana, O.S. 2005. Coating substance: bachelor degree handouts in preparing tablets course. Division of Pharmaceutical Science, Faculty of Pharmacy, Chiang Mai University, Chiang Mai, Thailand.
- Korkasetwit, S. 2008. Effects of coating substances on quality and longevity of sweet corn seed. M.Sc. Thesis in Agronomy, Graduate School, Khon Kaen University, Khon Kaen, Thailand.
- Korkasetwit, S., P. Chitropas, and B. Siri. 2008. Effect of coating substance on coating characterization and quality of super sweet corn seed. *Agricultural Sci.* 39(3): 218-221.
- Kumar, J., K. Nisar., A.M.B. Kumar, S. Walia, N.A. Shakil, R. Prasad, and B. Parmar. 2007. Development of polymeric seed coats for seed quality enhancement of soybean (*Glycine max*). *Indian J. Agr. Sci.* 77(11): 738-43.
- Scott, J.M., 1989. Seed coatings and treatments and their effects on plant establishment *Adv. Agron.* 42: 43-83.
- Taylor, A.G., and G.E. Harman. 1990. Concepts and technologies of selected seed treatments. *Annu. Rev. Phytopathol.* 28: 321-339.
- Taylor, A.G., P.S. Allen, M.A. Bennett, K.J. Bradford, J.S. Burris, and M.K. Misra. 1998. Seed enhancements. *Seed sci. res.* 8: 245-256.
- Zimmermann, J., G.R.J. Artus, and S. Seeger. 2007. Long term studies on the chemical stability of superhydrophobic silicone nanofilament coating. *Appl. Surf. Sci.* 253(14): 5972-5979.