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Effect of polymer seed coating and seed dressing with pesticides on seed quality and storability of hybrid cucumber

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Abstract

The purpose of this study was to compare hybrid cucumber seed germination and germination index of polymer (hydroxypropyl methycellulose) coated seed to seed dressing with pesticides, metalaxyl and imidacloprid. Cucumber seed was treated with polymer alone, polymer + metalaxyl 1X and 2X product label rate, polymer + imidacloprid 1X and 2X product label rate, polymer + metalaxyl 1X and imidacloprid 1X product label rate. Seed dressing treatments mirrored those above with the exception of the dual pesticide treatment which was omitted. Seed germination tests were conducted under laboratory (25 °C) and greenhouse conditions (35 °C) immediately, following accelerated seed aging (42 °C, about 100% RH) and seed storage under controlled (15 °C, 40% RH) and ambient (25°C,75% RH) conditions. Seed germination values immediately following treatment were not significantly different ($P \leq 0.05$) and varied from 85 to 95% in the laboratory and greenhouse. Seed germination values from accelerated ageing tests revealed some significant differences among treatments; however, there was no clear differentiation among polymer seed coating and seed dressing with pesticides. Seed germination of polymer coated seed, seed dressed and untreated seed stored for 8 months under controlled conditions were not significantly different. In contrast, seed germination of polymer coated seed stored under ambient conditions for 8 months decreased 58 and 46%, as compared to 13 and 11% for seed dressed treatments tested in the laboratory and greenhouse, respectively. This study indicated that polymer seed coating of hybrid cucumber was not compatible with seed viability following storage at 25 °C, 75% RH.

Keywords: Polymer seed coating, seed dressing, pesticide, imidacloprid, metalaxyl.
Abbreviations: HPMC_hydroxypropyl methylcellulose, RH_relative humidity), G.I_germination index.

Introduction

Seed and seedling diseases contribute significantly to reduced seed germination and stand establishment resulting in an uneven crop density, increased weed density and reduced crop yield. Delivery of seed applied pesticides to provide crop protection from seed and soil-borne diseases relies on several seed treatment techniques including, seed-dressing, polymer film coating, pelleting and encrustment (Brooker et al., 2007; Jamieson, 2008). Maximum germination and seedling establishment of seed treated with pesticides, growth regulators, biologicals or micro-nutrients relies on firm attachment of these products to the seed coat during packaging, handling, and planting (Williams and Hopper, 1998; Junges et al., 2013). Loss of these materials from the seed coat is called dust-off and results in reduced crop performance and environmental contamination. Seed treatment techniques that contribute to pesticide dust-off are detrimental to non-target organisms including humans, wildlife and beneficial insects and neighboring crops (Ehsanfar and Modarres-Sanavy, 2005; Nuyttens et al., 2013). For example, a strong correlation of neonicotinoid-treated seed and colony die off of pollinators, honey bees and bumble bees, has been established in some regions and is attributed to exposure of bees to contaminated flowering plants (Stevens and Jenkins, 2013; Walters, 2013). Current seeding practices that use pneumatic seeding drills for precision seeding exacerbate environmental contamination of pesticides from seed dust-off. Seed dressing with pesticides relies on the pesticide dust or residue from an aqueous or powder application to adhere to the seed coat. This application technique has drawbacks as it may contribute significantly to pesticide dust-off during handling and seeding. In addition, uniform dressing among seed lots or within a seed lot maybe difficult to obtain, therefore, excessive amounts of pesticides are usually applied in order to obtain the desired seed quality i.e. germination and vigour following seeding. New seed coating techniques have contributed to reduced pesticide contents per seed and reduced cost because of improved seed adherence (Gevrek et al., 2012). Polymer seed coating or film coating depends on coating agents, ex. chemically modified celluloses and proprietary polymers, to deliver and release pesticides following seeding (Brooker et al., 2007). These seed coatings provide uniform coverage from seed to seed and are highly effective at minimizing pesticide dust-off. However, critical to the advancement of new seed coating polymers is assurance that there is compatibility between the polymer and seed germination, plant growth and timely delivery of the pesticides. Cucumber (*Cucumis sativus*, Cucurbitaceae) and its closely related species that includes squash and muskmelon is a widely cultivated vegetable crop in Asia and worldwide. In commercial production, cucumber frequently encounters destructive insect and fungal pests. To mitigate these and other pests, growers sow seed dressed with conventional pesticides, insecticides, and fungicides. Alternately, biocontrol based insecticide chitosan coating of cucumber and soybean improved seed germination, stand establishment and yield as compared with untreated controls (Defang et al., 2011, 2012). A polymer (hydroxylpropyl methylcellulose) seed coating has been developed for cucumber, however the effect of coating with pesticides, metalaxyl and imidacloprid, on seed germination and germination index following short and long term storage is not known. The objectives of this study were to evaluate polymer seed coat treatment with these pesticides and compare seed germination and germination index in the laboratory and greenhouse to the current practice of seed dress application.

Results

Effect of polymer coating and seed dressing of pesticides on cucumber germination immediately following seed treatment

Seed germination and germination index immediately following polymer coating and seed dressing with pesticides were not significantly ($P \leq 0.05$) different in the laboratory and greenhouse as compared to the polymer alone and non-treated seed treatments. Seed germination in the greenhouse assay was slightly higher than in the laboratory. Cucumber germination varied from 84.0 to 95% under laboratory conditions, whereas germination in the greenhouse varied from 92 to 97% (Table 1). The mean percent germination from laboratory and greenhouse tests were 89 and 93%, respectively, and germination index was 13, ranging from 13 to 14 (Table 1).

Effect of polymer coating and seed dressing of pesticides on cucumber germination following accelerated aging

Seed germination following accelerated aging of treated and non-treated seed, under laboratory conditions, varied from 66 to 82%. Significant ($P \leq 0.05$) differences in seed germination were observed in laboratory tests after accelerated aging (Table 2). Seed germination of all seed dress treatments and polymer treatments, metalaxyl 1X, imidacloprid 2X and the metalaxyl 1X + imidacloprid 1X was significantly, ($P \leq 0.05$), increased over the non-treated seed treatment (Table 2). Seed germination following accelerated aging under greenhouse conditions varied from 65 to 76% (Table 2). No significant differences in seed germination with polymer seed coating treatments, with and without metalaxyl (1 and 2X) and imidacloprid (1 and 2X) and combined, and the non-treated seed treatment were observed (Table 2). Significant ($P \leq 0.05$) differences in seed germination were observed with seed dressed treatments, metalaxyl (2X) and imidacloprid (1 and 2X) and the non-treated seed but not with the polymer seed coated treatments (Table 2). Germination index ranged from 9 (non-treated seed treatment) to 11 (seed dress metalaxyl 2X). There were no significant ($P \leq 0.05$) differences between the non-treated seed treatment and polymer seed coated treatments. Only seed dress treatments with metalaxyl 2X and imidaclprid 2X were significantly ($P \leq 0.05$) different from the non-treated seed treatment (Table 2). Accelerated aging reduced seed germination and germination index by 19% and 3.4%, respectively, when considering all treatments and laboratory and greenhouse germination conditions (Tables 1 and 2).

Effect of polymer seed coating and seed dressing of pesticides on cucumber seed germination in the laboratory and greenhouse following storage under controlled and ambient conditions

The effect of polymer seed coating and seed dressing of pesticides on seed germination following storage at ambient (25 °C, 75% RH) and controlled conditions (15 °C, 40 %RH) was determined in the laboratory following 2, 4, 6 and 8 months storage (Table 3). Under controlled conditions seed germination decreased 20% over 8 months (averaged over all treatments). There were significant ($P \leq 0.05$) differences in seed germination among some treatments at particular sampling times, however, no clear trend was evident to suggest that polymer seed coating or seed dressing methods or pesticide type was influencing seed germination (Table 3). Germination of the non-treated seed treatment declined 24%, showing the greatest change after 4 months (Table 3). Seed germination under ambient conditions decreased 40 % (average of all treatments). Germination of the non-treated seed treatment decreased 41%, showing the greatest decline after 6 months (Table 3). Seed germination decreased the greatest, 58%, over 8 months with the polymer seed coated treatments (Table 3). Seed germination of polymer seed coating, plus and minus pesticides treatments decreased approximately 20% at each sampling interval resulting in only 21% germination after 8 months. Seed germination of seed dressed treatments decreased about 3% at each sampling interval or 13% after 8 months storage (Table 3). Seed germination of seed dressed treatments stored under ambient conditions were similar to results collected from the same treatments stored under controlled conditions (Table 3). Seed germination of polymer coated seed, seed dressed and non-treated seed treatments was determined in the greenhouse following 2, 4, 6 and 8 months storage intervals under controlled (15 °C, 40 %RH) and ambient (25 °C, 75% RH) conditions (Table 4). Under controlled conditions seed germination decreased 6% over 8 months (averaged of all treatments). There were significant ($P \leq 0.05$),differences in seed germination among some of the treatments at the 8 month sampling time, however, no clear trend was evident to suggest that polymer seed coating or seed dressing method or pesticide type was influencing percent seed germination (Table 4). Germination of the non-treated seed treatment decreased 4% over 8 months (Table 4). Seed germination under ambient storage conditions in the greenhouse decreased 31% (average of all treatments), however polymer seed coating of seed clearly demonstrated the greatest and significant, ($P \leq 0.05$), decrease, 46%, over 8 months (Table 4). Germination of seed dressed treatments decreased 11% over 8 month's storage (Table 4). Germination of the non-treated seed treatment decreased 20%, showing the greatest loss after 4 months (Table 4). In polymer seed coated treatments, with and without pesticides, germination decreased approximately 20% at sampling times 4 and 6 months and 10% at 8 months resulting in only 30% germination after 8 months, while seed germination of seed dressed treatments with pesticides decreased about 11% at each sampling time resulting in 74% germination after 8 months (Table 4). After 8 months storage under ambient conditions seed germination of seed dressed treatments was > untreated > polymer seed coated and each treatment group was significantly different from the other (Table 4). Seed

Table 1. Percent germination and germination index of hybrid cucumber seed in laboratory and greenhouse tests immediately following treatment.

Treatment	Germination (%)		Germination index[2]
	Laboratory[1]	Greenhouse	
Untreated control	92[a]	97[a]	14[a]
Polymer alone	84[a]	94[a]	14[a]
Polymer + metalaxyl, 1X[3]	88[a]	92[a]	13[a]
Polymer + metalaxyl, 2X	88[a]	94[a]	14[a]
Polymer + imidacloprid, 1X	86[a]	92[a]	13[a]
Polymer + imidacloprid, 2X	94[a]	93[a]	13[a]
Polymer + metalaxyl + imidacloprid 1X	87[a]	94[a]	14[a]
Metalaxyl, 1X	87[a]	93[a]	13[a]
Metalaxyl, 2X	95[a]	92[a]	13[a]
Imidacloprid, 1X	86[a]	92[a]	13[a]
Imidacloprid, 2X	90[a]	92[a]	13[a]
Mean	89	93	13

Means in the same column with the same letter (s) are not significantly different ($P \leq 0.05$). [1] See Material and Methods for description of the laboratory and Greenhouse assays used.[2] Number of seedlings emerging daily determined from day of planting until germination is complete. Germination index (G.I.) is computed by using the following formula: G.I. =N/d, N= number of seedlings; d=day of planting (Gupta, 2014).
[3] Product label instructions for application to cucumber seed.

Table 2. Percent germination in laboratory and greenhouse tests and germination index of hybrid cucumber seeds following accelerated aging[1].

Treatment	Germination (%)		Germination index
	Laboratory	Greenhouse	
Untreated control	66[e]	65[c]	9[c]
Polymer alone	70[de]	67[bc]	10[abc]
Polymer + metalaxyl, 1X	75[bcd]	67[bc]	10[abc]
Polymer + metalaxyl, 2X	66[e]	69[abc]	10[abc]
Polymer + imidacloprid, 1X	66[e]	66[c]	9[c]
Polymer + imidacloprid, 2X	72[cd]	70[abc]	10[abc]
polymer + metalaxyl + imidacloprid 1X	76[bc]	72[abc]	10[abc]
Metalaxyl, 1X	78[ab]	74[abc]	10[abc]
Metalaxyl, 2X	75[bcd]	76[a]	11[a]
Imidacloprid, 1X	74[bcd]	71[ab]	10[abc]
Imidacloprid, 2X	82[a]	75[a]	11[a]
Mean	73	70	10

Means in the same column with the same letter (s) are not significantly different ($P \leq 0.05$). [1] 42 °C and 100% RH for 72 hours.

germination values of seed dressed treatments stored under controlled and ambient conditions were similar (Table 4).

Determination of seed germination index stored under controlled and ambient conditions

Germination index of polymer coated seed, seed dressed and non-treated seed treatments was determined at 2, 4, 6 and 8 months storage times under controlled and ambient conditions (Table 5). Germination index of all treatments under controlled conditions decreased 0.9% (average) (Table 5). There were significant ($P \leq 0.05$) differences among some of the treatments at the 6 and 8 month sampling times, however, no clear trend was evident to suggest that polymer coating or seed dressing method or pesticide type was influencing percent seed germination (Table 5). Non-treated seed GI did not change over 8 months of storage under controlled conditions (Table 5). In conclusion there were no significant differences in GI among seed treatments after 8 months storage (Table 5). Germination index of seed treatments stored under ambient conditions decreased 4%, untreated, 2%, seed dressed and polymer seed coated, 6%. Germination indices of all polymer seed coated treatments stored under ambient conditions were significantly, ($P \leq 0.05$), reduced to GI's of all other treatments after 2 months storage and GI of polymer coated seed continued to decline with each sampling time (Table 5).

Discussion

Reducing the hazards of pesticide dust-off and exposure to farm operators and the environment while improving pesticide efficacy can be achieved by strengthening the physical integrity of the carrier to the seed coat. Seed applied polymer coatings or films are reported to reduce pesticide dust-off and environmental contamination because of improved adherence to the seed coat and timely release of the pesticides (Williams and Hopper, 1998). However, for new polymer seed coatings to be commercially adopted there must be compatibility between the polymer coating agents, pesticides and seed germination and seedling establishment. In addition, polymer seed coatings must not inhibit movement of gases, moisture, soil nutrients through the seed coat and release of seed borne germination inhibitors from the seed (Duan and Burris, 1997). The objective of this study was to compare cucumber seed germination and germination index following pesticide application using polymer seed coating and seed dressing carriers. Metalaxyl is a systemic fungicide used to control plant diseases caused by the Oomycetes; is effective in controlling many fungal diseases such as downy mildew (Chandrasekhara Rao et al., 1988) and seedling damping-off (Palakshappa et al., 2010). Imidacloprid is a systemic insecticide, belongs to a class of chemicals called the neonicotinoids which act on the central nervous system of insects, effective in controlling sucking insects, termites and some soil insects at seedling

Table 3. Percent germination of hybrid cucumber seeds in laboratory tests following storage under controlled[1] and ambient conditions[2].

Treatment	Controlled conditions[1]				Ambient conditions[2]			
	2 months	4 months	6 months	8 months	2 months	4 months	6 months	8 months
Untreated control	94^{abcd}	92^{a}	77^{a}	70^{bc}	91^{a}	79^{ab}	77^{ab}	50^{bc}
Polymer alone	97^{a}	94^{a}	71^{a}	75^{abc}	79^{d}	70^{cdef}	45^{de}	20^{d}
Polymer + metalaxyl , 1X	92^{abcd}	90^{a}	76^{a}	70^{bc}	82^{bcd}	63^{f}	55^{cd}	23^{d}
Polymer + metalaxyl, 2X	93^{abcd}	901^{a}	76^{a}	69^{bc}	80^{cd}	66^{ef}	28^{fg}	18^{d}
Polymer + imidacloprid, 1X	90^{cde}	90^{a}	80^{a}	76^{ab}	81^{cd}	70^{cdef}	24^{g}	27^{d}
Polymer + imidacloprid, 2X	96^{ab}	88^{a}	75^{a}	69^{bc}	78^{d}	67^{def}	35^{efg}	21^{d}
Polymer + metalaxyl + imidacloprid 1X	86^{e}	90^{a}	73^{a}	74^{bc}	78^{d}	67^{def}	41^{def}	19^{d}
Metalaxyl, 1X	90^{cde}	89^{a}	53^{a}	62^{c}	78^{d}	68^{def}	65^{abc}	57^{b}
Metalaxyl, 2X	89^{de}	88^{a}	73^{a}	66^{bc}	86^{abc}	77^{ab}	80^{a}	71^{a}
Imidacloprid, 1X	94^{abc}	90^{a}	71^{a}	73^{bc}	80^{ab}	72^{bcd}	72^{ab}	73^{a}
Imidacloprid, 2X	91^{bcde}	89^{a}	72^{a}	86^{a}	87^{ab}	81^{a}	80^{a}	77^{a}
Mean	92	90	73	72	82	70	55	41

Means in the same column with the same letter (s) are not significantly different ($P \leq 0.05$). [1] 15 °C, 40% RH [2] 25°C 75% RH

Table 4. Percent germination of hybrid cucumber seeds in greenhouse tests following storage under controlled[1] and ambient conditions[2].

Treatment	Controlled conditions[1]				Ambient conditions[2]			
	2 months	4 months	6 months	8 months	2 months	4 months	6 months	8 months
Untreated control	87^{a}	88^{a}	84^{a}	82^{ab}	81^{abc}	81^{abc}	67^{a}	61^{b}
Polymer alone	89^{a}	86^{a}	83^{a}	78^{bc}	77^{bcd}	64^{d}	50^{bcd}	28^{d}
Polymer + metalaxyl, 1X	90^{a}	85^{a}	79^{a}	84_{ab}	77^{bcd}	74^{c}	56^{b}	33^{c}
Polymer + metalaxyl, 2X	87^{a}	86^{a}	84^{a}	85^{ab}	76^{bcd}	65^{d}	41^{d}	20^{d}
Polymer + imidacloprid, 1X	85^{a}	78^{a}	70^{a}	77^{bc}	73^{d}	64^{d}	43^{d}	34^{c}
Polymer + imidacloprid, 1X	88^{a}	81^{a}	85^{a}	79^{bc}	75^{cd}	66^{d}	44^{cd}	33^{c}
Polymer + metalaxyl + imidacloprid,1X	87^{a}	82^{a}	88^{a}	81^{ab}	78^{bcd}	66^{d}	45^{cd}	32^{c}
Metalaxyl, 1X	87^{a}	84^{a}	85^{a}	83^{ab}	87^{a}	86^{a}	73^{a}	74^{a}
Metalaxyl, 2X	83^{a}	84^{a}	86^{a}	90^{a}	88^{a}	83^{ab}	75^{a}	77^{a}
Imidacloprid, 1X	84^{a}	87^{a}	84^{a}	70^{c}	85^{a}	84^{ab}	72^{a}	73^{a}
Imidacloprid, 2X	86^{a}	85^{a}	83^{a}	79^{bc}	85^{a}	86^{a}	76^{a}	71^{a}
Mean	86	84	83	81	80	74	59	49

Means in the same column with the same letter (s) are not significantly different ($P \leq 0.05$). [1] 15 °C, 40% RH[2] 25°C 75% RH

Table 5. Germination index of hybrid cucumber seeds following storage under controlled[1] and ambient[2] conditions.

Treatment	Controlled conditions[1]				Ambient conditions[2]			
	2 months	4 months	6 months	8 months	2 months	4 months	6 months	8 months
Untreated control	12^{a}	13^{a}	12^{a}	12^{ab}	12^{abc}	12^{abc}	9^{a}	8^{b}
Polymer alone	13^{a}	12^{a}	11^{a}	11^{ab}	11^{bcd}	9^{d}	7^{bcd}	4^{cd}
Polymer + metalaxyl, 1X	13^{a}	12^{a}	11^{a}	12^{ab}	11^{bcd}	11^{c}	8^{b}	5^{c}
Polymer + metalaxyl, 2X	12^{a}	12^{a}	12^{a}	12^{ab}	11^{bcd}	9^{d}	6^{d}	3^{c}
Polymer + imidacloprid, 1X	12^{a}	11^{a}	10^{b}	11^{cb}	10^{d}	9^{d}	6^{d}	5^{c}
Polymer + imidacloprid, 2X	12^{a}	11^{a}	12^{a}	11^{cb}	11^{cd}	9^{d}	6^{d}	5^{c}
Polymer + metalaxyl + imidacloprid, 1X	12^{a}	12^{a}	12^{a}	12^{ab}	11^{bcd}	9^{d}	6^{d}	5^{c}
Metalaxyl, 1X	12^{a}	12^{a}	12^{a}	12^{ab}	12^{a}	12^{a}	10^{a}	11^{a}
Metalaxyl, 2X	12^{a}	12^{a}	12^{a}	13^{a}	13^{a}	12^{ab}	11^{a}	11^{a}
Imidacloprid, 1X	12^{a}	12^{a}	12^{a}	10^{c}	12^{a}	12^{ab}	10^{a}	10^{a}
Imidacloprid, 2X	12^{a}	12^{a}	12^{a}	11^{cb}	12^{a}	12^{a}	11^{a}	10^{a}
Mean	12	12	12	11	11	10	8	7

Means in the same column with the same letter (s) are not significantly different ($P \leq 0.05$). [1] 15 °C, 40% RH [2] 25°C 75% RH

stage (Zeng and Wang, 2010). The comparative effects of seed dressing and polymer seed coating on cucumber seed germination and germination index of cucumber have not been investigated. Experiments conducted in the greenhouse and laboratory compared polymer seed coating and seed dressing on seed germination and germination index immediately following treatment, accelerated aging (42 °C, for 72 hr.) and following storage (controlled (15 °C, 40% RH) and ambient (25 °C, 75% RH) conditions) for 8 months. Understanding seed germination characteristics following polymer seed coating in relation to seed dressing, the industry standard technique of applying pesticides to cucumber, and non-treated seed would provide critical information to allow informed choices on decisions to adopt new methods of delivering pesticides to cucumber seed. Seed germination and germination index provide valuable information on seed performance following the introduction of new coatings or pesticide combinations and contribute to determining possible incompatibilities. Results of cucumber seed germination and germination index following application of pesticides, metalayxl and/or imidacloprid using polymer seed coating or seed dressing techniques were not significantly ($P \leq 0.05$) different in greenhouse and laboratory tests immediately following treatment and with accelerated aging. These results suggest that under these conditions the polymer seed coating could replace seed dressing as a means of delivering these pesticides. Similarly, cucumber seed germination and germination index following application of pesticides, metalayxl and/or imidacloprid using polymer seed coating or seed dressing techniques performed similarly in greenhouse and laboratory tests following storage under controlled conditions over 8 months. However, when polymer coated seed, in the presence and absence of pesticides, was stored under ambient conditions seed germination and germination index was observed to decline significantly ($P \leq 0.05$) as compared to the non-treated and seed dressed treatments at each sampling period over the 8 month study. Elevated relative humidity is known to be detrimental to seed viability (Crocker and Barton, 1957) and a direct relationship between seed moisture content and relative humidity, including cucumber, is documented (Fang et al., 1998). Non-treated seed viability and vigour decreased under conditions of elevated relative humidity (Crocker and Barton, 1957; Mbofung et al., 2013; Suma et al., 2013). Alternately, Duan and Burris (1997) reported that polymer film coating (2% w/w) of sugar beet seed resulted in significantly reduced germination. Further research suggested that the film coating had restricted oxygen supply to the enclosed embryo and retention of water soluble germination inhibitors (Duan and Burris, 1997). It is possible in our study that gaseous exchange, O_2 and CO_2, by polymer coated cucumber seed stored under ambient conditions was inadequate resulting in significantly reduced seed viability. However, it is very likely that the ambient relative humidity contributed significantly to the decline in germination of the polymer coated cucumber seed. The results highlight the importance of proper storage conditions for maintaining adequate germination and the limits of seed coating technique of cucumber seed. It was beyond the scope of this study to extend the investigation into the result of poor germination following cucumber stored under ambient conditions. Polymer seed coating have improved the performance of other important crops. For example, winter canola (*Brassica napus*), coated with polymers CelGard, Spectrum 511 or DiscoClear, alone improved stand establishment (Kaur and Bishnoi, 2011). Addition of insecticide, Helix, to the polymer seed coatings further improved stand establishment (Kaur and Bishnoi, 2011). Germination of broccoli, *Brassica oleracea*, seeds coated with hydroxyethyl cellulose were not significantly different from non-coated seed after accelerated aging (Almeida et al., 2005).

Materials and Methods

The study was conducted at the Seed Processing Plant, Faculty of Agriculture, Department of Plant Science and Agricultural Resources, Khon Kaen University, Thailand. Hybrid seeds of cucumber were obtained from A.G. Universal Seed Company. Seed germination was 95%.

Seed preparation for seed treatment experiments

Hydroxypropyl methycellulose polymer (Taian Ruitai Cellulose Co., Ltd., China), 0.5% aqueous, plus and minus pesticides (metalaxyl and imidacloprid), coated seed was prepared using a Centricoater model SKK08, and seed dressed treatments were prepared manually by mixed the seed with pesticides in a closed container. Following seed treatment seeds were dried under airflow at 30 °C for 3 hours to facilitate handling. For all experiments the moisture content of seed was equilibrated to 6.6% under controlled conditions. Experimental seed treatments included (1) untreated control, (2) polymer seed coating, no added pesticide, (3) polymer seed coating plus metalaxyl, 7 g/kg seed (1X), (4) polymer seed coating plus metalaxyl, 14 g/kg seed (2X), (5) polymer seed coating plus imidacloprid 5g/kg seed (1X), (6) polymer seed coating plus imidacloprid, 10 g/kg seed (2X), (7) polymer seed coating plus metalaxyl (1X) and imidacloprid, (1X), (8) seed dressing plus metalaxyl 7 g/kg seed (1X), (9) seed dressing plus of metalaxyl 14 g/kg seed (2X), (10) seed dressing plus imidacloprid, 5g/kg seed (1X),(11) seed dressing plus imidacloprid 10 g/kg seed (2X). Application of metalaxyl and imidacloprid followed product label instructions for 1 and 2 times rate (1 and 2X).

Effect of polymer seed coating and seed dressing of pesticides on cucumber germination immediately following seed treatment

Seed germination tests were conducted under laboratory (25 °C) and greenhouse conditions (35 °C). In the laboratory, germination tests were conducted with three replications of 100 seeds per replication per treatment. Seed was placed between two wetted paper towel sheets and incubated at 25 °C. In greenhouse tests seed was sown into peat moss 2 cm deep. Seed germination was recorded after 4 (first count) and 8 days (final count). Germination index, the status of seed germination, speed of germination was determined daily between 4 and 8 days (Gupta, 1993; ISTA, 1996).

Effects of polymer seed coating and seed dressing of pesticides on cucumber germination following accelerated aging

All seed treatments were exposed to accelerated aging in a humidity chamber, (42 °C and 100% relative humidity (RH)), for 72 hours. Germination testing of the seed treatments was conducted in the laboratory and greenhouse as described above. Germination indices of the seed treatments were determined as described above.

Effect of polymer seed coating and seed dressing of pesticides on cucumber seed germination in the laboratory and greenhouse following controlled and ambient storage conditions

Twenty grams of each of the polymer coated seed, seed dressed and untreated seed treatments were stored under controlled, (15 °C and 40% RH), and ambient, (25 °C and 75% RH), conditions for 8 months. At 2 month intervals 100 seeds per replication per treatment under both storage conditions were collected and seed germination was tested in the laboratory and greenhouse as described above. Germination indices were determined as described above.

Data analysis

Analysis of variance was performed for each parameter and evaluated separately according to a complete randomized design using MSTAT-C package (Freed et al., 1989). When the main effect was significant, Duncan's multiple range test (DMRT) was used to compare means. The level of significance tested was P≤ 0.05.

Conclusions

Cucumber seed germination, either coated with polymer carrying pesticides metalayxl and imidacloprid or seed dressed with pesticides, was not significantly different as compared to the non-treated seed treatment when seed was sown immediately, subjected to accelerated aging (42 °C, for 72 hr) and sown or stored (15 °C, 40% RH) for 8 months and sown in the greenhouse and in a laboratory assay. However, germination of cucumber seed treated with polymer seed coating with and without pesticides and stored under ambient (25 °C, 75% RH) conditions was significantly (P≤0.05) reduced as compared to seed treatments dressed with pesticides and the non-treated seed stored under ambient conditions. The results suggest that polymer seed coating of cucumber is an appropriate means of delivering pesticides metalayxl and imidacloprid providing the seed is stored appropriately.

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References

Almeida CD, Rocha SCS, Razerera LF (2005) Polymer coating, germination and vigor of broccoli seeds. Sci Agr. 62: 221-226 .

Brooker NL, Lagalle CD, Zlatanic A, Javni I, Petrovic Z (2007) Soy polyol formulations as novel seed treatments for management of soil-borne diseases of soybean. Comm Agr Appl Biol Sci. 72: 25-43.

Chandrasekhara Rao K, Balasubramanian K, Singh SD (1988) Effect of storage of metalaxyl treated seed on downy mildew of pearl millet. Indian J Plant Prot. 16: 1-7.

Crocker W, Barton LV (1957) Physiology of Seeds: An introduction to the experimental study of seed and germination problems. Chronica Botanica, Waltham, Mass, U.S.A.

Defang Z, Renjie T, Shan W (2011) Preparation and application of a novel environmentally friendly cucumber seed coating agent. J Yeast Fungal Res. 2: 7-12.

Defang Z, Luo X, Tu R (2012) Application of bioactive coatings based on chitosan for soybean seed protection. Int J Carb Chem. Article ID 104565:1-5.

Duan X, Burris JS (1997) Seed physiology, production & technology. Crop Sci. 37:515-520.

Ehsanfar S, Modarres-Sanavy SA (2005) Crop protection by seed coating. Comm Agr Appl Biol Sci. 70: 225-229.

Freed RD, Everson EH, Weber M, Paul E, Isleib D (1989) A microcomputer program for the design, management, and analysis of agronomic research experiments. In: MSTAT Development Team (eds) MSTAT-C users guide, Michigan State University, East Lansing, MI., U.S.A.

Gevrek MN, Atasoy GD, Yigit A (2012) Growth and yield response of rice (*Oryza sativa*) to different seed coating agents. Int J Agr Biol. 14: 826-830.

Fang J, Moore F, Roos E, Walters C (1998) Three-dimensional models represent seed moisture content as a function of relative humidity and temperature. HortScience. 33: 1207-1209.

Gupta PC (1993) Seed Vigour Testing. In: Agrawal PK Handbook of seed testing, Ministry of Agriculture, Government of India, New Delhi http://seednet.gov.in/Material/Handbook_of_seed_testing/Chapter%2015.pdf

ISTA – International Seed Testing Association (1996) International Rules for Seed Testing ISTA News Bulletin 118, Seed Science and Technology. Zurich, Switzerland.

Jamieson G (2008) New perspectives on seed enhancement. Acta Hortic. 782: 143-150.

Junges E, Toebe M, Santos RF, Finger G, Muniz MFB (2013) Effect of priming and seed-coating when associated with *Bacillus subtilis* in maize seeds. Rev Ciênc Agron. 44: 520-526.

Kaur G, Bishnoi UR (2011) Effect of polymer and pesticide seed coatings on winter canola seed germination at various osmotic potentials. Wolrld J Agric Sci. 7: 591-598.

Mbofung GCY, Goggi AS, Leandro LFS, Mullen RE (2013) Effects of storage temperature and relative humidity on viability and vigor of treated soybean seeds. Crop Sci. 53: 1086-1095.

Nuyttens D, Devarrewaere W, Verboven P, Foqué D (2013) Pesticide-laden dust emission and drift from treated seeds during seed drilling: A review. Pest Manag Sci. 69: 564-575.

Palakshappa M, Lokesh MS, Parameshwarappa KG (2010) Efficacy of ridomil gold (Metalaxyl M + Mancozeb (4+64 WP) against chilli damping off caused by *Pythium aphanidermatum*. Karnataka J Agric Sci. 23: 445-446.

Stevens SM, Jenkins PT (2013) Pesticide impacts on bumblebee decline: a missing piece. Conversation Letters. 6: 213-214.

Suma A, Sreenivasan K, Singh AK, Radhamani J (2013) Role of relative humidity in processing and storage of seeds and assessment of variability in storage behavior in *Brassica* spp. and *Eruca sativa*. Sci World J. Article ID 504141 9 pages.

Walters K (2013) Data, data everywhere but we don't know what to think? Neonicotinoid insecticides and pollinators. Outlooks on Pest Management. 24: 151-155.

Williams KD, Hopper NW (1998) Effect of polymer film coatings of cotton seed on dusting-off, imbibition, and germination. Paper presented at the Proceedings Beltwide Cotton Conferences, San Diego, California, USA. 5-9 January 1998.

Zeng CX, Wang JJ (2010) Influence of exposure to imidacloprid on survivorship, reproduction and vitellin content of the carmine spider mite, *Tetranychus cinnabarinus*. J Insect Sci. 10: 1-9.