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Review :
Seed Treatments Using Matriconditioning to Improve Vegetable Seed Quality

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INTRODUCTION

Sowing seed of high quality is necessary for commercial crop production. Poor quality seeds will result in low field emergence and in seedlings that are less tolerant to abiotic stress, more sensitive to plant diseases, and will reduce the quality and yield of crops produced. With the use of good seeds, one gets better results with less effort and expense.

High seed quality is characterized by high analytical purity. The seeds must be free of seeds of other species and varieties, weed seeds and inert matters. High vigor and germination capacity are the other characteristics of high seed quality. Another important attribute is free from seedborne disease.

Vegetable farmers experience losses due to pathogen problem during plant production affected by use of infected seeds. Seed pathogens are often the primary agents responsible for low seed quality and poor stand establishment. Seed is an effective means of disease dissemination. One infected seed can infect many plants in a seedbed before they are transplanted to the field. A few infected plants in the field can provide the source of inoculum to spread the disease to other plants (AVRDC, 1990).

The presence of seedborne pathogens in the seeds will either prevent the germination, or may result in disease epidemics due to transmission of the disease-causing pathogen from seed to the plant. This will have a negative impact on the quality and yield of crops produced.

Therefore, it is important to use healthy seeds from the beginning. An effort to develop various seed treatments to overcome seedborne pathogens may provide an opportunity to optimize seed quality, and improve plant stand eventually. This article is written based on the author's research with her students studied on seed science and technology as their thesis or dissertation, particularly with emphasis on vegetable seed quality improvement.

VARIOUS SEED TREATMENTS TO IMPROVE SEED QUALITY AND HEALTH, PLANT STAND AND YIELD

Seeds that are harvested under humid conditions favor the growth and development of fungal spores that may attack and damage the seeds. In addition, seeds suffering physical or mechanical injuries during harvesting and postharvest handling are also prone to fungal attack and are required to be protected by seed treatment.

Seed treatments are commonly applied to combat seedborne diseases, and diseases and pests that may be present in soil or be airborne when seedlings emerge. Specialized seed treatments such as priming (osmoconditioning or matriconditioning), coating, pelleting are often used to improve germination or protect seeds against pathogens.

In addition to the common seed treatments using hot water and chemicals to control numerous seedborne and soilborne diseases, seeds are also treated for specific purposes. Seed osmoconditioning and matriconditioning are presowing hydration treatments developed to facilitate seedling establishment. Khan et al. (1990) defined the term 'matriconditioning' for controlled seed hydration by moistened carriers with high water adsorptive matrix forces. Preplant seed conditioning with moist solid carriers has been proved to improve germination, field emergence, plant growth and yield of various crops.

Various attempts have been done at Seed Science and Technology Laboratory IPB to improve seed quality. Experiments on various seeds show that matriconditioning, a preplant physiological seed conditioning treatment, using moistened solid carrier with or without gibberellic acid improve seed quality, stand establishment and/or yield. This matrix property based seed conditioning proved better than osmoconditioning, an osmotic based one (Ilyas, 1994; Shalahuddin and Ilyas, 1994; Yunitasari and Ilyas, 1994; Ilyas and Suartini, 1998).

Table 1 shows that matriconditioning using sawdust applied on two seed lots of different age of

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yard-long bean improve viability and vigor. The ratio of seeds to carrier to water used was 1: 0.4: 0.5 (by weight in grams), and the sawdust passed through a 0.5 mm screen. The seeds are conditioned for 18 h at room temperature, and air-dried afterwards for 5 h. The treatment significantly increases pod yield 1.5 times as much as the untreated (Ilyas and Suartini, 1998).

Table 1. Effect of matriconditioning applied on two seed lots of different age on seed quality and field emergence of yard-long bean seeds

Seed lot	Matriconditioning	Germination (%)	T_{50} (d)	Field emergence (%)
Lot 1 (26-month old, 70% germination)	Untreated	75^c	4.25^a	64^d
	Rice hull ash	99^a	1.48^{cd}	92^{bc}
	Rice hull ash + GA_3	99^a	1.50^{cd}	89^{bc}
	Sawdust	100^a	1.43^d	99^a
	Sawdust + GA_3	99^a	1.53^{cd}	93^{bc}
Lot 2 (2-month old, 85% germination)	Untreated	87^b	2.15^b	89^c
	Rice hull ash	100^a	1.45^d	94^{ab}
	Rice hull ash + GA_3	98^a	1.58^c	92^{bc}
	Sawdust	97^a	1.43^d	91^{bc}
	Sawdust + GA_3	97^a	1.48^{cd}	91^{bc}

Note: Means suffixed with different letters are different at 5% of significance according to DMRT.
Source: Ilyas and Suartini (1997).

In other experiments (Hasan, 1998), yard-long bean seeds were aged artificially in an incubator of 43^{0}C and 100% relative humidity for up to 3 days. High, medium, and low vigor seeds were obtained from the seeds artificially aged for 0, 1, and 2 days, respectively, and utilized as initial seed vigor levels for further experiments.

Matriconditioning using either moist sawdust or vermiculite (210 μm) at 15^{0}C for 2 days in the light showed improvement in uniformity and speed of germination as compared to the untreated (Table 2). The

Table 2. Seed viability and vigor as affected by matriconditioning applied on different initial vigor levels of yard-long bean

Matri-conditioning	Initial vigor	Germination (%)	Uniformity (%)	Speed of germination (%/day)	Electrical conductivity (μMhos/g)
Untreated	High	82	51	19	135.88
	Medium	76	48	18	156.49
	Low	67	27	15	162.33
	Mean	75.0	42.0b	17.3b	151.57
Sawdust	High	89	72	22	124.72
	Medium	78	59	20	144.57
	Low	70	54	18	127.54
	Mean	79.0	61.7a	20.0a	132.28
Vermiculite	High	83	63	21	124.95
	Medium	82	69	21	114.19
	Low	71	49	17	156.90
	Mean	78.7	60.3a	19.7a	132.01

Note: Means suffixed with different letters are different at 5% levels of significance according to DMRT.
Source: Hasan (1998).

ratio of seed to carrier to water used was 1: 0.3: 0.5 (by weight in gram) for sawdust, and 1: 0.7: 0.5 for vermiculite. However, there was no significant difference between the sawdust and vermiculite treatments. Uniformity increased from 42% in the untreated to 61.7% in the sawdust- and 60.3% in the vermiculite-matriconditioned seeds. Speed of germination increased from 17.3% to 20.0% (sawdust) or 19.7% (vermiculite). Even though there were no significant differences in germination and electrical conductivity between matriconditioned seeds and the untreated ones, matriconditioning treatments increased percent of germination and reduced seed leakage as shown by reduction in the electrical conductivity values of the soaked water, thus improvement in membrane integrity has occurred.

Table 3 showed after six-months storage at air-conditioned room (22-27^{0}C, 50-62% RH) or at condition of 25-29^{0}C and 44-50% RH, matriconditioned yard-long bean seeds still have index vigor of 61% or 60% which are significantly differed from the untreated ones (23 or 37%, respectively) while the difference in percent germination does not exist (Rosliany, 1998).

Table 3. Effect of matriconditioning on yard-long bean seed quality after six month storage at different conditions

Storage condition	Germination (%)		Vigor index (%)	
	Untreated	Matriconditioning	Untreated	Matriconditioning
22-27^{0}C, 50-62% RH	72	70	23b	61a
22-26^{0}C, 43-47% RH	75	74	12b	51a
28-29^{0}C, 59-67% RH	70	56	21b	29b
25-29^{0}C, 44-50% RH	74	78	37a	60a

Note: Matriconditioning was done using moist sawdust. Means in the same rows suffixed with different letters are different at 5% levels of significance according to DMRT.
Source: Rosliany (1998).

Tomato seeds of low and high vigor were matriconditioned using rice hull ash (210 µ) for 48 h at room temperature, and the ratio of seeds to carrier to water was of 1: 3.5: 5.5. The results (Table 4) showed that matriconditioning improve seed quality of low vigor but does not affect the high vigor one. However, matriconditioned seeds had higher level of leakages than the untreated ones; this was probably due to the physical effect of rice hull ash used as the carrier injured the seed coat (Candranegara, 1998). Matriconditioning also improved seed vigor and plant growth of eggplant (Khusniyati, 1999).

Table 4. Effect of matriconditioning applied on two vigor levels on quality of tomato seeds

Vigor level	Treatment	T_{50} (d)	Uniformity (%)	Electrical conductivity (µMhos/cm)
High	Untreated	3.6^{c}	91^{a}	56.7^{c}
	Matriconditioning	3.5^{c}	90^{a}	110.8^{a}
Low (artificially deteriorated seeds)	Untreated	7.8^{a}	40^{c}	90.1^{b}
	Matriconditioning	5.2^{b}	58^{b}	107.9^{a}

Note: Means suffixed with different letters are different at 5% of significance according to DMRT. Low vigor seeds were obtained by exposing the seeds to 42^{0}C and 100% RH for 4 days, the germination was decrease from 99% before ageing to 65% afterwards.
Source: Candranegara (1998).

Study with hot pepper seed indicated that improvement in seed quality by sawdust-matriconditioning plus GA_3 treatment was related with increase in total protein content of the seed (Table 5). The seeds were conditioned for 6 days at 15^{0}C, and the ratio of seeds to carrier to water was 1: 2: 5 (Ilyas et al., 2002).

Similarly, total protein content of yard-long bean seeds matriconditioned with sawdust increased in comparison with the untreated ones (Hasan, 1998). Matriconditioning using moist sawdust increased total protein content in dry (1.7%) and imbibed seeds (7%) as compared to the untreated (Table 6).

Table 5. Effects of seed matriconditioning with sawdust plus GA_3 on seedling growth rate and total protein content of medium and high vigor hot pepper seeds

Seed treatment	Initial vigor	Seedling growth rate	Protein content	
			Total	Relative
		mg/normal seedling	mg/g seed	%
Untreated	Medium	7.8	97.0	100
	High	9.8	105.6	100
	Mean	8.8b*	101.3b*	100**
Matriconditioned	Medium	8.8	111.4	115
	High	10.0	124.6	117
	Mean	9.4a*	118.0a*	116**

*Means suffixed with different letters are different at 5% levels of significance according to DMRT.
**Calculated using (observed mean/untreated mean) x 100%
Source: Ilyas et al. (2002).

Table 6. Effect of matriconditioning with moist sawdust on total protein content of low and high vigor yard-long bean seeds before and after imbibition

Seed treatment	Initial vigor	Protein content			
		Before		After	
		Total (mg/g)	Relative (%)	Total (mg/g)	Relative (%)
Untreated	High	125.04	100	102.00	100
	Low	119.09	100	91.42	100
	Mean	122.07	100**	96.71b*	100**
Matriconditioned	High	127.71	102.14	111.18	109
	Low	120.59	102.26	95.70	105
	Mean	124.15	101.70**	103.44a*	106.96**

*Means suffixed with different letters are different at 5% levels of significance according to DMRT.
**Calculated using (observed mean/untreated mean) x 100%
Source: Hasan (1998).

An increase of total protein content in the matriconditioned seed supported Bray's study (1995). His study showed that priming (osmoconditioning) of leek seed increased protein biosynthesis. After the priming was completed, an increase of protein in high vigor seed was higher than low vigor one. When the primed seed was reimbibed, the increase of total protein even greater, but there was no difference between the high vigor seed and the low vigor one. These meant that protein biosynthesis might not occur in great amounts during priming, it was suggested that RNA synthesis occurred during priming. This was confirmed by Suzuki and Manikawa (1985), Vigna unguiculata seed imbibed for 2 h increased RNA activity by two times.

Bioprotectants and/or chemical pesticides can be used in combination with matriconditioning. Combining matriconditioning using sawdust with fungicide 'Benlate' 0.5% in hot pepper seeds cv. 'Jatilaba', which is sensitive to anthracnose, improves germination, vigor index, speed of germination and fruit weight per plant as compared to the untreated, fungicide alone or matriconditioning alone (Handayani, 1999). Recent study (Suryani, 2003) showed that application of matriconditioning using burned rice hull plus fungicide 'Dithane' 0.2% on hot pepper seed lots infected by Colletotrichum capsici reduced the contamination down to 3.2% as compared to 100% in untreated. The treatment also improved seed viability and vigor. Matriconditioning plus fungicide was better than matriconditioning alone or fungicide alone in improving seed viability and vigor while reducing the contamination (Table 7).

Table 7. Level of contamination, percent of germination, relative speed of germination, and index of vigor as influenced by matriconditioning plus fungicide seed treatments applied on hot pepper seed lots infected by Colletotrichum capsici

Seed treatments	Contamination (%)	Germination (%)	Relative speed of germination (%)	Index of vigor (%)
Untreated	100a	73bc	51c	2b
Fungicide	1.6b	69c	46bc	1b
Matriconditioning	98a	76b	93a	59a
Matric+fungicide	3.2b	81a	83b	60a

Note: Means in the same rows suffixed with different letters are different at 5% levels of significance according to DMRT.
Source: Suryani (2003).

However, it is important to reduce chemical uses and develop an environmentally-safe seed treatment as an alternative. Recent study by Anwar (2004) showed that clove oil 0.5% can be used as seed treatment to eliminate bacterial canker Clavibacter michiganensis subsp. michiganensis from tomato infected seed lots without reducing the seed viability and vigor (Table 8).

Table 8. Effect of seed treatments on population of Clavibacter michiganensis subsp. michiganensis, viability and vigor of the infected tomato seeds

Seed treatments	Population of Cmm (x 10^2 cfu/ml))	Germination (%)	Relative speed of germination (%)
Untreated	437.83d	88.33b	98.22b
Sterile water, 20 min	195.50c	83.55b	94.35b
Warm water 52^0C, 20 min	0.33ab	85.78b	88.73b
HCl 5%, 15 min	0.00a	9.00a	6.14a
Clove oil 0.5%, 20 min	3.83b	79.99b	86.22b

Note: Means in the same rows suffixed with different letters are different at 5% levels of significance according to DMRT.
Source: Anwar (2005).

Studies by Untari (2003) indicated matriconditioning using burned rice plus clove oil 0.06% or 0.1% were the effective seed treatments to improve index of vigor and relative speed of germination while reducing the levels of contamination in hot pepper seed lots infected by C. capsici. However, percent of germination was not significantly influenced by the treatment (Table 9).

Table 9. Level of contamination, percent of germination, relative speed of germination, and index of vigor as influenced by matriconditioning plus clove oil seed treatments applied on hot pepper seed lots infected by Colletotrichum capsici

Seed treatments	Contamination (%)	Germination (%)	Relative speed of germination (%)	Index of vigor (%)
Untreated	50a	69	57b	5c
Clove oil 0.06%	6b	80	69a	31b
Clove oil 0.1%	4b	66	50b	8c
Matric+clove oil 0.06%	4b	76	71a	47a
Matric+clove oil 0.1%	3b	80	74a	49a

Note: Means in the same rows suffixed with different letters are different at 5% levels of significance according to DMRT.
Source: Untary (2003).

Recent study on C. capsici infected hot pepper seeds indicated that matriconditioning plus clove oil was better than matriconditioning plus fungicide ‘Dithane’ in reducing the infection level, and maintained the seed viability and vigor for 12 month storage in ambient room (Asie, 2004).

Other useful treatments are biological seed treatments that use fungi or bacteria to control soil and seed pathogens instead of synthetic chemical seed treatments. These are gaining popularity because of safety concerns for human and the environment as well as phytotoxicity problems associated with excess use of pesticides. In addition, biological seed treatments offer the potential for protecting the plant throughout its entire life cycle rather than just during the seed/seedling stage (Copeland and McDonald, 1995). Biocontrol with beneficial microbes manipulates the environment around a crop plant to favor organisms that contribute to plant health and vigor, rather than simply applying pesticides to destroy a range of microorganisms including the target pathogen. Thus, biocontrol is less disruptive to ecosystems than are chemical pesticides. Bioprotectants can grow on and colonize plant parts such as root system, which can protect the entire root system from soilborne pathogens (Harman et al., 1989).

Some biological seed treatments are able to colonize plant roots and contribute to long-term pest control effectively. In field trials, stands of peas were not significantly enhanced by seed treatment with Trichoderma strains in the absence of solid matrix priming but were improved by Trichoderma plus priming (Harman et al., 1989). These treatments markedly enhance plant performance. Fungi such as T. harzianum control damping off and other diseases (Smith and Wehner, 1987). Bacteria such as Bacillus subtilis are being examined for their incorporation into seeds using seed enhancement technologies (Copeland and McDonald, 1995).

Experiments using biocontrol agents with or without matriconditioning have been done at IPB to improve hot pepper seeds infected by C. capsici. Biomatriconditioning, defined as seed treatment in which biocontrol agent is incorporated in matriconditioning, are more effective in reducing the contamination level than biopriming, an integration of biocontrol agent in priming. Research done by Kumalasari (2005) shows that the most effective seed treatment in reducing the contamination is biomatriconditioning with T. harzianum (83.7% reduction) followed by biomatriconditioning with T. pseudokoningii (82.3%), Bacillus sp. (79.8%), Gliocladium sp. (79.7%) and P. fluorescence (78.3 %). However, biopriming improved seed viability and vigor higher than biomatriconditioning (Table 11). Percent of germination increased from 71% in untreated seeds to 79% in Bacillus sp bioprimed seeds, which was not significantly different with T. harzianum (78%) and T. pseudokoningii (78%) bioprimed ones, but significantly different with P. fluorescence (72%) and Gliocladium sp. (67 %) bioprimed ones.

Table 10. Reduction in percent contamination of Colletotrichum capsici as affected by seed treatments plus biocontrol agents on hot pepper seeds

Biocontrol agents	Priming			Matriconditioning		
	pre	post	reduction	pre	post	reduction
	--- %---					
Untreated	85	36	49.0	85	28	57.0
Bacillus sp.	85	6.3	78.7	85	5.2	79.8
P. fluorescence	85	20	65.0	85	6.7	78.3
T. harzianum	85	9.3	75.7	85	1.3	83.7
T. pseudokoningii	85	13.3	71.7	85	2.7	82.3
Gliocladium sp.	85	13.3	71.7	85	5.3	79.7

Source: Kumalasari (2005).

There was marked improvement in vigor index of hot pepper seeds after biopriming with T. harzianum, 56% and 81% before and after the treatment, respectively (Table 11). The treatment was not significantly different as compared to biopriming with T. pseudokoningii (75%), followed by biopriming with Bacillus sp. (72%), biopriming with Gliocladium sp. (70%), and biopriming with P. fluorescence (67 %).

Table 11. Percent of germination and index of vigor as affected by priming or matriconditioning plus biological agents as seed treatments applied on hot pepper seed lots infected by Colletotrichum capsici

Biological agents	Germination (%)		Index of vigor (%)	
	Priming	Matriconditioning	Priming	Matricondition-ing
Untreated	71 bA	65 aB	56 dA	54 abB
Bacillus sp.	79 aA	60 abB	72 bcA	58 aB
P. fluorescence	72 bA	57 bB	67 cA	49 bcB
T. harzianum	78 aA	60 abB	81 aA	56 aB
T. pseudokoningii	78 aA	61 abB	75 abA	54 abB
Gliocladium sp.	67 bA	51 cB	70 bcA	43 cB

Note: Means in the same rows suffixed with different uppercase letters or in the same column with different lowercase letters are different at 5% levels of significance according to DMRT.
Source: Kumalasari (2005).

Further studies was done by Sutariati (2006) on the application of biocontrol agents as seed treatments in controlling C. capsici, the caused of antracnose disease in hot pepper seeds resulted in improvements of fruit yield and quality of harvested seeds (Table 12). Seed treatment with B. polymixa BG25 or P. fluorescence PG01 were effective to increase the number of fruits per plant, however, the most effective treatment was the combination of both agents. The incidence of anthracnose disease was suppressed by this biocontrol seed treatment, from 81% in untreated infected seeds down to 9%. This treatment is much more effective compared to the synthetic fungicide seed treatment in reducing the infection level (60%). The treatment also increased the germination and vigor index of the harvested seeds (78% and 37%, respectively) compared to untreated infected seeds, 56% and 18%, respectively (Table 12).

Table 12. Number of consumption fruit, disease incidence, percent of germination, and index of vigor as influenced by biological seed treatments applied on hot pepper seed lots infected by Colletotrichum capsici

Seed treatments	Number of consumption fruit	Disease incidence (%)	Germination (%)	Index of vigor (%)
BG25	23 b	12 c	75 a	33 a
PG01	24 b	12 c	75 a	32 a
BG25+PG01	27 a	9 d	78 a	37 a
Dithane	15 c	60 b	65 b	22 b
Infected seed	10 d	81 a	56 c	18 b
Non infected seed	15 c	62 b	62 b	21 b

Note: BG25 (Bacillus polymixa BG25), PG01 (Pseudomonas fluorescens PG01). Means in the same rows suffixed with different letters are different at 5% levels of significance according to DMRT.
Source: Sutariati (2006).

CONCLUSIONS

Various seed enhancement treatments have been proved to improve seed quality, growth and yield to some extent. When the quality of seeds is high, the plants will be able to withstand from various stresses encountered in the field. Seeds must be treated in order to protect them from pathogens. There are various seed treatments suitable for these purposes, starting from the use of agrochemicals (fungicides) to protect seeds against fungi to green chemicals (biopesticides) and beneficial microbes that have antagonist effects to pathogens. Seed enhancement treatment such as matriconditioning is adaptable to be integrated with hormones to improve germination, or with pesticides, biopesticides and beneficial microbes to combat seed and seedling diseases during stand establishment or to protect the whole life cycle, and to improve growth and yield of vegetable crops as well as to increase the quality of the harvested seeds.

REFERENCES

Anwar, A. 2004. Detection, identification, and eradication of seed-transmitted bacterial, Clavibacter michiganensis subsp. michiganensis-causal agent of bacterial canker on tomato. Dissertation, Graduate School, Bogor Agricultural University. 163p. (Indonesian)

Asie, K.V. 2004. Matriconditioning plus botanical fungicides as seed treatment for Colletotrichum capsici infected hot pepper seeds: Evaluation of seed quality during storage. Thesis, Graduate School, Bogor Agricultural University. 163p. (Indonesian)

AVRDC. 1990. Vegetable Production Training Manual. Asian Vegetable Research and Development Center. Tainan, Taiwan. 447p.

Bray, C.M. 1995. Biochemical processes during the osmopriming of seed, p. 767-789. In J. Kigel and G. Galili (eds.) Seed Development and Germination. Marcel Dekker, Inc. New York, Basel, Hongkong.

Candranegara, E. 1998. Effect of matriconditioning and vigor levels of seeds on viability and yield of tomato (Lycopersicum esculentum Mill). Thesis, Department of Agronomy, Bogor Agricultural University. 42p. (Indonesian)

Copeland, L.O., M.B. McDonald. 1995. Principles of Seed Science and Technology. Third edition. Chapman and Hall, New York. 409 p.

Handayani, D. 1999. Effect of matriconditioning plus fungicide on two vigor levels of hot pepper (Capsicum annuum L.) seeds on viability, vigor, growth and yield. Thesis, Department of Agronomy, Bogor Agricultural University. 45p. (Indonesian)

Harman, G.E., A.G. Taylor, T.E. Stasz. 1989. Combining effective strains of Trichoderma harzianum and solid matrix priming to improve biological seed treatments. Plant Disease Reporter 73: 631-637.

Hasan, A. 1998. Effect of invigoration treatment applied on different levels of seed vigor on physiological and biochemical changes in yard-long bean (Vigna unguiculata (L.) Walp.) seeds. Thesis, Graduate School, Bogor Agricultural University. 74p. (Indonesian)

Ilyas, S. 1994. Matriconditioning of pepper (Capsicum annuum L.) seeds to improve seed performance. Keluarga Benih 5 (1): 59-67. (Indonesian)

Ilyas, S., G.A. Sutariati, F.C. Suwarno, Sudarsono. 2002. Matriconditioning improved quality and protein level of medium vigor hot pepper seed. Seed Technology 24 (1): 67-77.

Ilyas, S., W. Suartini. 1998. Improving seed quality, seedling growth, and yield of yard-long bean (Vigna unguiculata (L.) Walp.) by seed conditioning and gibberellic acid treatment. p. 292-301. In: A.G. Taylor and Xue-Lin Huang (eds.) Progress in Seed Research: Proceeding of The Second International Conference on Seed Science and Technology, Guangzhou, China, 1997.

Khan, A.A., H. Miura, J. Prusinski, S. Ilyas. 1990. Matriconditioning of seeds to improve emergence. Proceedings of the Symposium on Stand Establishment of Horticultural Crops. 4-6 April, 1990. Minneapolis, USA.

Khusniyati, H. 1999. Effects of invigoration treatments on seed viability and vigor and plant growth of eggplant (Solanum melongena L.). Thesis, Department of Agronomy, Bogor Agricultural University. 34p. (Indonesian)

Kumalasari, V. 2005. Effects of biocontrol agents on in vitro growth of Colletotrichum capsici (Syd.) Butl. Et Bisby and quality of hot pepper seeds. Thesis, Department of Agronomy, Bogor Agricultural University. 57p. (Indonesian)

Rosliany, R.Y. 1998. Effect of matriconditioning on longevity of yard-long bean seeds (Vigna unguiculata (L.) Walp.). Thesis, Department of Agronomy, Bogor Agricultural University. 44p. (Indonesian)

Shalahuddin, A., S. Ilyas. 1994. Study of seed conditioning in yard-long bean (Vigna unguiculata (L.) Walp.). Keluarga Benih 5 (2): 1-8. (Indonesian)

Smith, E.M., F.C. Wehner. 1987. Biological and chemical measures integrated with deep soil cultivation against crator disease of wheat. Phytopathology 19: 87-90.

Suryani, N. 2003. Effect of matriconditioning plus fungicides on hot pepper seeds with various contamination levels of Colletotrichum capsici towards the seed viability and vigor. Thesis, Department of Agronomy, Bogor Agricultural University. 48p. (Indonesian)

Sutariati, G.A.K. 2006. Biological seed treatment in controlling anthracnose disease and improving yield and seed quality of hot pepper (Capsicum annuum L.). Dissertation, Graduate School, Bogor Agricultural University. 163p. (Indonesian)

Suzuki, Y., T. Manikawa. 1985. On the role of stored mRNA in protein synthesis in embryonic axes of germinating Vigna unguiculata seeds. Plant Physiol. 79: 327-331.

Untari, M. 2003. Effect of clove oil on contamination level of seedborne fungi Colletotrichum capsici (Syd.) Butl. Et Bisby and viability of hot pepper seeds (Capsicum annuum L.). Thesis, Department of Agronomy, Bogor Agricultural University. 64p. (Indonesian)

Yunitasari, M., S. Ilyas. 1994. Possible use of several solid carriers for matriconditioning of pepper (Capsicum annuum L.). Keluarga Benih 5 (2): 29-34. (Indonesian)