MATRICONDITIONING INTEGRATED WITH GIBBERELLIC ACID TO HASTEN SEED GERMINATION AND IMPROVE STAND ESTABLISHMENT OF PEPPER AND TOMATO[1]

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ABSTRACT - Emergence and stand establishment of tomato (*Lycopersicon lycopersicum* (L.) (Karsten ex Farw) and pepper (*Capsicum annus* L.) seeds are often slow and erratic, particularly under stress conditions. Field emergence trials sometimes have not responded to priming in pepper. This study examined the combined effects of matriconditioning and gibberellin application on the germination and stand establishment of pepper and tomato seeds. Pepper and tomato seeds were conditioned with a solid carrier, Micro Cel E, in the presence of gibberellic acid (GA) for 1, 2 , 3 and 4 days at 15 and 25ºC. The results showed that, in all cases, even under stress conditions, the combination of matriconditioning with GA was effective in improving germination and emergence of pepper and tomato. The germination time was, in average, reduced by 2 to 3 days by primed seeds. Thus, matriconditioning, during which germination is suspended, provides an unique means to rapidly and efficiently digest the endosperm by GA-induced enzymes and reduce the mechanical restraints of endosperm thus providing energy to start and sustain embryo growth.

Index terms: priming, growth regulator, endosperm.

MATRICONDICIONAMENTO INTEGRADO COM ÁCIDO GIBERÉLICO PARA ACELERAR A GERMINAÇÃO E MELHORAR O ESTANDE EM SEMENTES DE PIMENTÃO E TOMATE

RESUMO - A emergência e o estabelecimento do estande em sementes de pimentão (*Capsicum annus* L.) e de tomate (*Lycopersicon lycopersicum* (L.) (Karsten ex Farw) são freqüentemente lentos e desuniformes, principalmente sob condições de estresse. Experimentos de campo às vezes não têm fornecido resposta ao condicionamento em sementes de pimentão. Este trabalho estudou os efeitos combinados de matricondicionamento e aplicação de giberelina na germinação e estande de sementes de pimentão e tomate. Sementes de pimentão e de tomate foram condicionadas com um sólido matricial, Micro Cel E, na presença e ausência do ácido gilberélico, por um, dois, três e quatro dias, a 15 e 25ºC. Os resultados demonstram que, em todos os casos, os tratamentos combinados com a aplicação de ácido giberélico foram eficientes em melhorar a germinação e a emergência de sementes de pimentão e de tomate. O tempo para germinação sofreu redução, em média, de dois a três dias, nas sementes matricondicionadas. Assim, o matricondicionamento, durante o qual é suspenso o início do processo de germinação, proporcionou o único meio para que as enzimas induzidas pela aplicação de ácido gilberélico digerissem eficientemente as células do endosperma e reduzissem as barreiras mecânicas, fornecendo, assim, ao embrião, energia para seu desenvolvimento.

Termos para indexação: condicionamento de sementes, regulador de crescimento, endosperma.

INTRODUCTION

The emergence and stand establishment of tomato and pepper seeds are often slow and extremely erratic, particularly under cool stress conditions. Tomato and pepper seeds have a well defined non-starchy endosperm. It has become clear in recent years that the endospermic tissue enclosing the radicle tip of the embryo offers a mechanical barrier to the growing

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embryo, thus affecting germination (Watkins et al., 1985; Groot & Karssen, 1987; Andreoli & Khan, 1993).

Seed conditioning (priming) has consistently improved the rates of germination and emergence of pepper and tomato seeds under optimal conditions (Aljaro & Martinez, 1987; Alvarado & Bradford, 1988; Sundstorm & Edwards, 1989; Frett & Pill, 1991). However, field emergence sometimes gave little response to seed conditioning (Ghate & Phatak, 1982; Bradford et al., 1990). If these differences in response to stress condition are due to mechanical restraints of endosperm is a subject still unknown.

Very few studies have examined the role of the endosperm in germination. In lettuce seeds, the hydrolysis of mannan by mannanase during gibberellin application caused weakening of the endosperm cell wall. It does not appear to be a prerequisite for germination since the event is subsequent to radicle protrusion (Halmer et al., 1976). Gibberelins have also been shown to degrade endosperm both celery seeds and isolated endosperm (Jacobsen & Pressman, 1979). In studies with pepper seeds, Watkins & Cantlife (1983) and Watkins et al. (1985) found that the mechanical constraint by endosperm in the tip region of the radicle contributed to slow germination rate and that the weakening of the endosperm by externally applied (GA) occurred prior to germination. A weakening of the endosperm in response to red light, which mimics GA effect, has been shown in seeds of *Datura* spp. prior to radicle protrusion (Sanchez et al., 1990). Recently, Andreoli & Khan (1993) showed a substantial increase in emergence of papaya seeds when matriconditioning was combined with GA. It was observed that the pericarp split along a suture after conditioning and that the loosening and dissolving of the cell wall were induced by exogenous applied GA and matriconditioning. Evidence has been presented for the weakening of the endosperm enclosing the radicle tip during matriconditioning of carrot seeds and for the completion of initial related to the radicle protrusion (Dawidowizc-Grzegorewska & Maguire, 1993).

That the endogenously produced GA may be involved in the digestion of the endosperm prior to germination was indicated from recent studies with mutant tomato seeds. Unlike wild type, the GA-deficient mutant tomato seeds did not produce endo-β-mannanase needed for the digestion of the endosperm, thus implicating that the enzyme was induced by GA for endosperm degradation and germination (Groot & Karssen, 1987). That the endogenous GA may control germination of pepper and tomato seeds as well as of papaya (Khan & Andreoli, 1993) was further indicated by the fact that tetcyclasis, an inhibitor of GA synthesis, inhibited the germination and the process was reversed by adding GA.

Few studies have attempted to combine the unique advantage of rapidly removing the endosperm restraint with added GA during suspension of germination with the benefits of preplant conditioning in order to improve germination and stand establishment.

This paper explored the possibility of combining GA and matriconditioning as a means of reducing mechanical restraints of the endosperm cells in order to hasten pepper germination and improve emergence of pepper and tomato seeds.

MATERIAL AND METHODS

Seed lots of tomato cv. Super Marmande and pepper cv. El Paso were kindly supplied from Ferry Morse Seed Co., Modesto, CA and used in this study. The experiments were carried out at the Laboratory of Seed Science, Department of Horticultural Sciences, New York State Experimental Station, Cornell University, Geneva, NY, USA, in 1992.

Seeds of tomato and pepper were preconditioned in batches of 5 to 10 g with the moist solid carrier, Micro Cel E (a synthetic calcium silicate produced by hydrothermal reaction of diatomaceous silica, hydrated lime and water, Manville Products Corp., Denver, CO.). The ratio of seed: carrier: water or Gibberellic acid (GA_{4+7}) solution by weight in the conditioning mixture was 10:3:10. Water or aqueous solution of GA contained thiram 75W (tetramethylthiauram disulfide) at the rate of 3.4 kg^{-1} seeds. Seeds were firstly imbibed in water or GA solution containing the fungicide for 30 min at 25°C and then, the required amount of Micro Cel E was added. After thoroughly mixing the contents in 0.43 L jars, the jars were loosely capped and transferred to a 15 and 25°C room for 0, 1, 2, 3, 4 days. After matriconditioning, the mixture was washed with running water for 1 min to remove the carrier from the seed. Seeds were spread and wiped out on dry blotters on the laboratory bench, then were left to dry back to original moisture content at 25°C and 42% RH room for 4 hours. The nonconditioned seeds were treated with the same amount of fungicide in a slurry of 1.5% methylcellulose and dried overnight.

Laboratory germination tests were done on three replicates of 50 pepper seeds each in 9 cm Petri dishes lined with filter paper moistened with 5 mL water. The plates were incubated at 15 and 30°C with continuous fluorescent light. The seedlings were counted every day until no further germination was observed.

For seedling emergence trials, four replicates of 50 tomato seeds each were sown 2.0 cm deep in a plastic box containing moist Cornell peat-line mix in a growth chamber at 25 and 30°C set at 12 hours light/12 hours dark regime. Water was added to the mix as needed. Seeds of pepper cv. Yolo Wonder and El Paso were sown in a growth chamber at 32º C. Emergence of pepper and tomato were determined by daily counting with unfolded cotyledon leaves.

Field emergence trials were conducted at the Fruit & Vegetable Research Farm; New York State Agricultural Experiment Station, Cornell University, Geneva. One hundred tomato seeds replicated five times each were sown at a depth of 2.5 cm in rows 5 m long and 75 cm apart with a John Deer cone planter. The planting date was June 18, 1992. Counts of emerged seedlings (cotyledons unfolded) were recorded on alternate days until emergence was complete. Final emergence was calculated as a percentage of the number of seed planted.

RESULTS AND DISCUSSION

The period taken for conditioning pepper seed at 15°C combining with 200 µM GA did not affect the final counts and the rate of germination (Fig. 1). Control and conditioned seeds at 15°C from 1 to 4 days germinated more than 90%. Matriconditioning at 25°C for 2 days resulted in more rapid germination than untreated seeds (advanced the T_{50} for 2 days) and the final germination was nearly 100% after 4 days soaking. However, pepper seeds conditioned at 25°C for 4 days, reduced the germination, indicating that longer period of conditioning could be harmful to seeds, i.e. deterioration process has been initiated.

The effects of combined conditioning plus GA (0 to 400 µM) treatments of pepper seeds at 25°C on subsequent germination at 15 and 25°C are shown in Fig. 2. More than 80% of seeds germinated in 24 hours in the combined treatment containing 100 to 400 µM GA at 25°C, while untreated seed reached that level only after 6 days. Combined treatments

FIG. 1. The effect of matriconditioning for 0, 1, 2, 3, and 4 days plus 200 µM GA at 25ºC (A) and 15ºC (B) on germination of pepper seeds at 30ºC. Denotation: UNT: untreated seeds; GA 1, GA 2, GA 3 and GA 4: matriconditioning in the presence of 200 µM GA for 1, 2, 3, and 4 days.

FIG. 2. The effect of matriconditioning plus GA (0 to 400 µM) for 2 days at 25ºC on subsequent germination of pepper seeds at 25ºC (A) and 15º C (B). Denotation: UNT: untreated seeds; GA 50, GA 100, GA 200, and GA 400: matriconditioning in the presence of that respective dose of GA.

performed as well at 15°C, with no significant difference between treatments. Untreated (control) seeds or seeds conditioned in the presence of GA did not begin germination until the 3rd day of soaking.

The combined treatments (matriconditioning plus GA) consistently improved the final emergence and resulted in the most rapid seedling emergence of tomato (Fig. 3). At 25°C, matriconditioning alone improved emergence; however, matriconditioning in the presence of 20 µM of GA resulted nearly twice as many seedlings in 24 hours. At 30°C, the emergence start time was shortened by more than 2 days in seeds treated with matriconditioning + GA compared to the nonconditioned (untreated) seeds and more than one day compared to seeds conditioned in the absence of GA.

The effects of combined conditioning with 200 µM GA treatment of two pepper cultivars at 25°C and 15°C on subsequent seedling emergence at 32°C is shown in Fig. 4. The combined conditioning treatment at 25°C was more effective in reducing the emergence time and in ameliorating seedling stand over nonconditioned (UNT) seeds for both cultivars. Conditioning pepper seeds at 25°C in the presence of GA advanced the germination process by 4 to 6 days.

In the field with tomato seeds, the combined conditioning plus GA treatment improved emergence percentage by 20% of the control value and reduced the time for seedling emergence by 4 days (Fig. 5). Although the combined matriconditioning gave 90% field stand in 6 days after planting, only 80% of emergence was observed for matriconditioned and untreated seeds after 10 days. The effect of the treatments was more pronounced at the beginning of the emergence and there was no difference in the final counts.

The data of this experiment have demonstrated that matriconditioning in the presence of GA for 2 to 3 days, preferably at 25°C, followed by drying, greatly stimulates germination and seedling emergence of pepper and tomato seeds. The digestion of endosperm cells is an important phase of germination for many seeds. In monocots, this process has long been studied as the major pathway of mobilizing food reserves for the seedling. In many dicots, the endosperm cells are thick and consist largely of mannan. Several researches have speculated if enzyme activity (mannanase) occurred prior to radicle emergence and if the lack of that enzyme correlated with germination. A similar system has been reported in celery by Jacobsen & Pressman (1979). Also Watkins et al. (1985) and Groot &

FIG. 3. The effect of matriconditioning plus 200 µM GA for 2 days at 25ºC on seedling emergence of tomato seeds at 25ºC (A) and 30ºC (B). Denotation: UNT: untreated seeds; MC: matriconditioning with water; MC + GA: matriconditioning in the presence of GA.

FIG. 4. The effect of matriconditioning plus 200 µ GA of two cultivars of pepper on seedling emergence at 32ºC. Denotation: UNT: untreated seeds; —⊡— MC plus GA at 15ºC; —Δ— MC plus GA at 25ºC.

FIG. 5. The effects of matriconditioning in the presence of 200 µM GA on field establishment of tomato seeds. Denotation: UNT: untreated seeds; MC: matriconditioned seeds; MC + GA: matriconditioning plus GA.

Karssen (1987) found that GA-mediated enzyme activity may participate in the weakening of the endosperm of pepper and tomato prior to germination. The seed germination and stand improvement performance by matriconditioning has been suggested for several crops (Khan et al., 1990, 1992; Khan, 1992). Furthermore, Andreoli & Khan (1993) have found the additive effect of matriconditioning and GA for papaya seed. In this study, in all cases, even under stress conditions, the combined matriconditioning plus GA treatment was effective in improving germination and field stand of pepper and tomato seeds. Thus, matriconditioning during which germination is suspended, provided a unique means to rapidly and efficiently degrade the endosperm by GA, reducing not only the mechanical restraints but also providing the energy for embryo growth.

CONCLUSIONS

1. The integration of matriconditioning with 200 µM GA was effective in improving germination and stand establishment of pepper and tomato seeds.
2. The matriconditioning seed treatment provides a means to efficiently digest the endosperm cell by GA-induced enzymes and reduce the mechanical restraints of tomato and pepper.

REFERENCES

ALJARO, A.; MARTINEZ, M. Agronomic evaluation of the osmotic conditioning of sweet pepper seeds (*Capsicium annum* L.). I. Effects on the germinative process, under different temperatures. **Agricultura Técnica,** Santiago, v.47, p.248-253, 1987.

ALVARADO, D.A.; BRADFORD, K.J. Priming and storage of tomato (*Lycopersicum esculentum)* seeds. I. Effects of storage temperature on germination rate and viability. **Seed Science & Technology**, v.16, p.601-612, 1988.

ANDREOLI, C.; KHAN, A.A. Improving seedling emergence of papaya, *Carica papaya* L., by combining matriconditioning and gibberellin treatment. **HortScience**, v.28, n.7, p.708-709, 1993.

BRADFORD, K.F.; STEINER, J.J.; TRAWATHA, S.E. Seed priming influence on germination and emergence of pepper seed lots. **Crop Science**, v.30, p.718-721, 1990.

DAWIDOWIZC-GRZEGOREWSKA, A.; MAGUIRE, J.D. The effects of SMP on the ultrastructure of carrot seeds. In: INTERNATIONAL WORKSHOP ON SEEDS, 4., 1992, Angers. **Basic and applied aspects of seed biology**. Paris: Université Pierre et Marie Curie, 1993. v.2, p.1039-1044.

FRETT, J.J.; PILL, W.C. A comparison of priming agents for tomato and asparagus seeds. **HortScience**, v.26, n.9, p.1158-1159, 1991.

GHATE, S.R.; PHATAK, S.C. Performance of tomato and pepper seeds germinated before planting. **Journal of the American Society for Horticultural Science,** v.107, p.908-911, 1982.

GROOT, S.P.C.; KARSSEN, C.M. Gibberellins regulate seed germination in tomato by endosperm weakening: a study with gibberellin-deficient mutants. **Planta**, v.171, p.525-531, 1987.

HALMER, P.; BEWLEY, J.D.; THORPE, J.D. An enzyme to degrade lettuce endosperm cell walls. Appearance of a mannanase following phytochrome/and gibberellin-induced germination. **Planta,** v.30, p.189-196, 1976.

JACOBSEN, J.V.; PRESSMAN, E. A structural study of germination in celery (*Apium graveolens* L.) seed with emphasis in endosperm breakdown. **Planta**, v.144, p.241-248, 1979.

KHAN, A.A; Preplant physiological seed conditioning. **Horticultural Rewiew**, v.13, p.131-179, 1992.

KHAN, A.A; ANDREOLI, C. Hormonal control of seed dormancy and germination under stressful and non-stressful conditions. In: INTERNATIONAL WORKSHOP ON SEEDS, 4., 1992, Angers. **Basic and applied aspects of seed biology.** Paris: Université Pierre et Marie Curie, 1993. v.2, p.625-632.

KHAN, A.A; MAGUIRE, J.D.; ABAWI, G.S.; ILYAS, S. Matricondiotining of vegetable seeds to improve stand establishment in early field plantings. **Journal of the American Society for Horticultural Sciences,** v.17, p.41-47, 1992.

KHAN, A.A; MIURA, H.; PRUSINSKI, J.; ILYAS, S. Matricondiotining of seeds to improve emergence. In: SYMPOSIUM ON STAND ESTABLISHMENT OF HORTICULTURAL CROPS, 1990, Minneapolis, MN. **Proceedings**. Geneva: Cornell University, 1990. p.19-40.

SANCHEZ, R.A.; SUNNEL, L.A.; LABAVITCH, J.M.; BONNER, B.A. Changes in the endosperm cell wants of two *Datura* species before radicle protrusion. **Plant Physiology**, v.93, p.89-97, 1990.

SUNDSTORM, F.J.; EDWARDS, R.L. Pepper seed respiration, germination, and seedling development following priming. **HortScience**, v.24, p.343-345, 1989.

WATKINS, J.T.; CANTLIFE, J.D. Hormonal control of pepper seed germination. **HortScience**, v.18, n.3, p.342-343, 1983.

WATKINS, J.T.; CANTLIFE, J.D.; HUBER, D.J.; NELL, T.A. Gibberellic acid stimulated degradation of endosperm in pepper. **Journal of the American Society for Horticultural Science,** v.110, p.61-65, 1985.