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Solid Matrix Priming of Cabbage Seed Lots: Repair of Ageing and Increasing Seed Quality

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ABSTRACT

This study was conducted to determine the effect of solid matrix priming treatment on 25 cabbage seed lots of various ages in terms of enhanced germination, emergence, mean germination and emergence time, and electrical conductivity. Solid matrix priming at a seed: vermiculite: water rate of 1:2:2.5 (w:w:w) was applied at 25 °C for 16 hours in the dark. Matrix priming was found to increase germination and emergence, reduced mean germination, emergence times and solute leakage. The advantages of solid matrix priming were observed more in aged than fresh seeds. The results indicated that SMP may enhance aged cabbage seed quality.

Keywords: Seed pretreatment; Electrical conductivity; Mean germination time; Germination; Emergence

Lahana Tohum Partilerinde Katı Madde ile Priming: Yaşlılığın Tamiri ve Tohum Kalitesine Olan Etkisi

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ÖZET

Bu çalışmada, katı matriks priming uygulamalarının yaşlandırılmış 25 lahana tohum partisinde çimlenme, çıkış, ortalama çimlenme ve çıkış hızı ile birlikte elektiriksel iletkenlik testine olan etkisi incelenmiştir. Katı matriks priming koşullarında 1:2:2.5 tohum, vermikülit ve su karışımı ortamında olmak üzere tohumlar 16 saat karanlık ve 25 °C'de uygulanmıştır. Matriks priming uygulamasının çimlenme ve çıkışı artırdığı, ortalama çimlenme, çıkış hızı ile akıntıyı azalttığı tespit edilmiştir. Matriks priming'in etkisinin yaşlanmamış tohumlara oranla yaşlı tohumlarda daha avantajlı olduğu belirlenmiştir. SMP'nin yaşlı lahana tohumlarında tohum kalitesini artırdığı sonucuna varılmıştır.

Anahtar Kelimeler: Tohum ön uygulamaları; Elektriksel iletkenlik; Ortalama çimlenme süresi; Çimlenme; Çıkış

1. Introduction

Seed priming in solutions of low water potential e.g. polyethylene glycol salts, has been used extensively to increase germination and emergence percentages, and to reduce germination and emergence times (Heydecker & Coolbear 1977). Solid carriers, such as vermiculite, expanded calcined clay, agro-lig and synthetic calcium silicates have also been used for preplant seed conditioning, which is also referred to as solid matrix priming (Khan 1992; Parera & Cantliffe 1992; Hacısalihoglu 2007). Both the holding capacity and density of solid carriers and the amount of carrier relative to seed and water used for optimum conditioning have differed greatly (Khan et al 1992). Solid matrix priming has been proven to increase seed emergence percentages and seedling growth in various vegetables (Kubik et al 1988; Khan et al 1992; Carlos et al 1993; Jett et al 1996; Wang et al 2003; Pandita et al 2010), including, tomato, pepper, broccoli, okra and snap bean. Solid matrix priming increased germination at sub-optimal temperatures and increased anti-oxidative enzyme activity and levels of antioxidants in treated seeds (Wang et al 2003; Kepczynska et al 2007).

Cabbage seeds are intolerant to seed ageing in suboptimal storage conditions and the vigor of seed lots may be lost in a short time (Matthews et al 2009). Seed quality may be lost in a year or so in the event of seed storage conditions not being ideal, which is common in the less-developed regions of Turkey. Seed deterioration is major cause of poor emergence in modules and erratic emergence (Powell et al 2000), resulted in the low quality transplant production (Matthews et al 2012). Priming treatments are used to rejuvenate deteriorated seed after natural or artificial aging in different seeds (Taylor et al 1988; Powell et al 2000; Sung & Chiu 2001). However, solid matrix priming has been insufficiently tested for the reversal of seed deterioration in vegetable seeds. Solid matrix priming (SMP) can be a good means of repairing deterioration and enhancing seedling emergence potential, which is of great concern to transplant producers who often use left-over seed lots (one or two-year-old seeds). SMP offers some advantages, including the ease at which priming can be combined with such growth regulators as GA_3 (Pill & Kilian 2000), beneficial bacteria, fungicides (Parera & Cantliffe 1992) and better aeration (Khan et al 1992).

This study was conducted to test the effect of SMP on cabbage seeds of various ages in terms of enhanced germination, emergence percentages and the rate of germination and emergence, along with electrical conductivity, as an indicator of solute leakage amounts.

2. Material and Methods

Samples of 25 cabbage (*Brassica oleracea* var. capitata) seed lots belong to the Yalova-1 cultivar were obtained from different seed companies over the last three years. The production years of the cabbage lots as follows: 1 and 10 in 2014, 11 and 18 in 2013, 19 and 25 in 2012. The seeds were stored in laminated aluminum foil papers at 5 °C until use. The germination percentage of the seed lots ranged between 68 and 98%. Experiments were conducted on 50 seed samples on total, 25 of which were SMP treated and 25 were untreated.

The solid matrix priming (SMP) treatment carried out by mixing seed, vermiculite (No: 5) and water at the rate of 1:2:2.5 for 16 hours at 25 °C in 100 mL plastic cups (tightly closed), stored in the dark. After the treatment, the seeds were separated from the vermiculite and then dried at 25 °C down to initial seed moisture. Germination, emergence and electrical conductivity tests were conducted within three days of the treatment, during which the seeds were kept at 5 °C.

The treated and untreated seeds were germinated at 20 °C between wet paper towels (20 x 20 cm, Filtrak, Germany) for 14 days (ISTA 2008) in the dark. In each germination test, three replications of 50 seeds were used. Paper towels were rolled and placed into plastic bags in order to prevent water loss. The germinated seeds (2 mm radicle protrusion) were counted daily, and normal and abnormal seedlings were determined after 14 days.

The seedling emergence percentages of both the SMP treated and untreated samples were conducted in a peat moss:perlite mixture of 2:1. Then, three replications of 50 seeds were sown in seedling trays (25 cm x 34 cm x 6 cm) at a 1 cm depth. The seedling trays were watered everyday and emerge tests were carried out at 20±1 °C for 20 days at controlled climatic room. Light intensity was 72 µmol m^2 s^{-1} in a cycle of 16 h of light and 8 h of dark. The emerged seedlings were controlled daily (cotyledons parallel to surface) for 20 days. The mean germination and mean emergence times were calculated on the basis of daily counts using the Equation 1 and 2 (Mavi et al 2010).

$$MGT/MET = \Sigma\ (nd)/\Sigma n \qquad (1)$$

Where; n, number of seeds newly emerged at time d; d, days from sowing, beginning of tests.

$$\Sigma n = \text{final germination/emergence (\%)} \qquad (2)$$

For the electrical conductivity test, two replicates of 50 seeds in SMP treated and untreated seed samples were weighed and soaked in 40 mL of distilled water for 8 hours at 20 °C in the dark. The electrical conductivity of the seed soak water was measured using a conductivity meter (Schott-Gerate, GmbH Hofheim) and expressed as per gram of seeds (µS cm^{-1} g^{-1}). There is no accredited procedure in ISTA rules for Brassica seeds. Therefore procedure was conducted according to Mathews et al (2009).

A statistical analysis was performed using SPSS to carry out (for Windows 15.0) to test to compare mean of treated and untreated cabbage lots. The regression values (R^2) between the various germination and emergence criteria were calculated and the percentages were angle transformed prior to analysis.

3. Results

SMP was found to increase the germination and emergence percentages except lot 1, 2, 8, 10 in germination test and lot 1 in emergence test (Figures 1 and 2). The difference between the treated and untreated seed lots was greater in those lots that had lower germination and were untreated. The difference between the SMP-treated seed germination and untreated lots was found to be significant in 13 lots ($P<0.05$) in the germination test, and in 22 lots in the emergence test (Figures 1 and 2). A greater effect of SMP was seen in the older seeds lots that recorded seed germination at lower percentages. SMP treatment increased germination rates, indicated by a reduced time to germination and emergence (Figures 3 and 4). MGT values ranged from 39 h to 138 h in 25 seed lots. In the treated seed lots, MGT values were reduced to 31 h and 69 h in the fastest and the lowest germinating lots. Then the advantage of the treatment on MGT was changed between 8 and 69 hours. Similar effects were seen also in the mean emergence time values, which were lower in the treated seed lots than in the untreated ones, in all lots except lot 22.

The electrical conductivity (EC) of solute leakage after treatment was reduced, and a higher germination was accompanied with lower EC values in not only the treated, but also the untreated lots (Figure 5). In all seed lots, SMP treatment reduced the amount of solute leakage from the seeds. EC affected the germination percentages in both the untreated and treated lots, and the relationship was highly significant ($P<0.001$, $R^2= 0.60$ in untreated lots, $R^2= 0.49$ in treated lots).

The MGT and MET values were highly related to the EC levels in the cabbage seeds (Figures 6 and 7). The fast germinating or emerging of seed lots showed less solute leakage, indicating that good-quality seeds have the potential to emerge faster, which is related to the EC level in cabbage lots.

4. Discussion

The results of present study showed that solid matrix priming increased germination and seedling emergence percentages (Figures 1 and 2), reduced mean germination and emergence times in a large number of cabbage seed lots (Figures 3 and 4). The seed lots used in this study were obtained from different companies and different production years. Solid matrix priming was found to enhance the germination and emergence percentages in various crop seeds, either in modules in greenhouse or under field conditions (Parera & Cantliffe 1991; Khan et al 1992; Jett et al 1996; Pill & Kilian 2000;

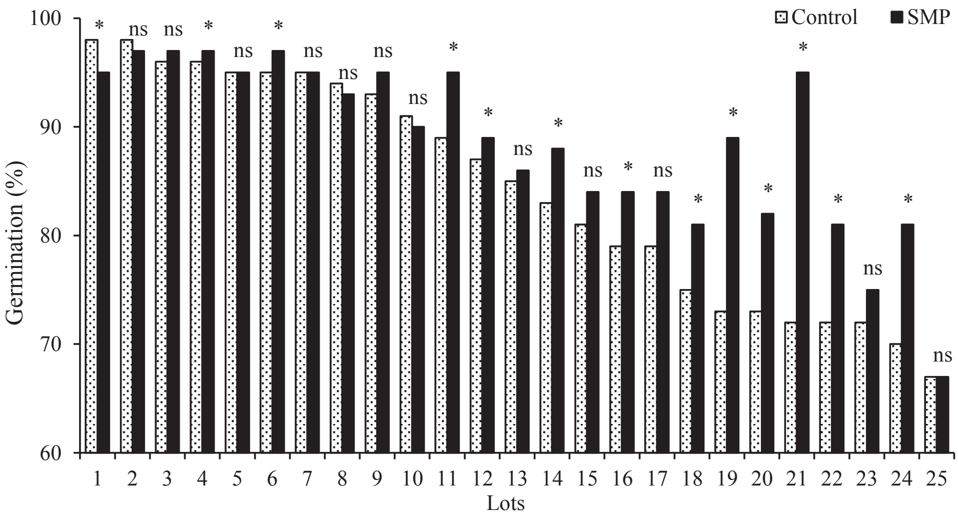

Figure 1- The effect of solid matrix primed (SMP) treatments on germination percentages of 25 different cabbage seed lots. An asterisks next to a lot indicates that the difference between the SMP and control samples was significant (P<0.05)

Şekil 1- Katı madde priming'in (KMP) 25 farklı lahana tohum partisinde çimlenme oranına etkisi. Her tohum partisinin üzerindeki yıldız işaretleri KMP ile kontrol örnekleri arasındaki farkın istatistiksel olarak (P<0.05) anlamlı olduğunu göstermektedir

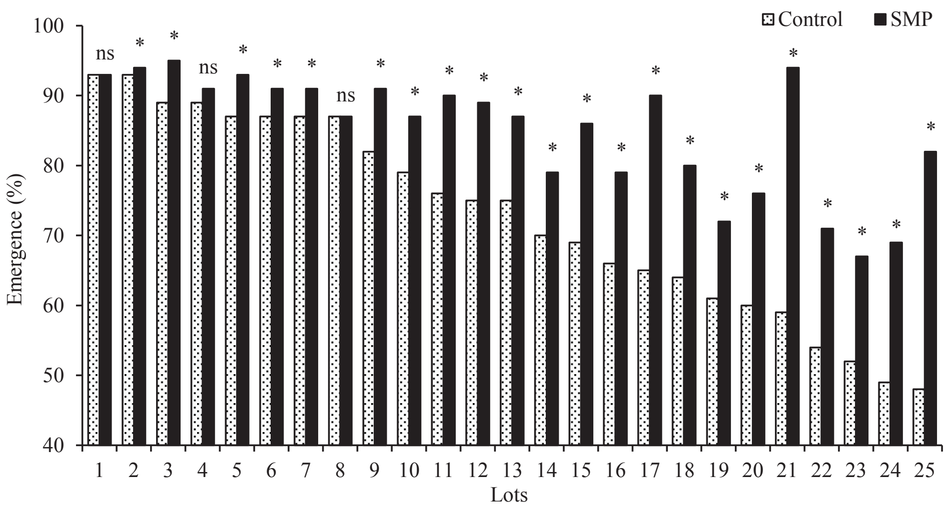

Figure 2- The effect of SMP on the emergence percentages of 25 cabbage seed lots. An asterisks next to a lot indicates that the difference between the SMP and control samples was significant (P<0.05)

Şekil 2- Katı madde priming'in (KMP) 25 farklı lahana tohum partisinde çıkış oranına etkisi. Her tohum partisinin üzerindeki yıldız işaretleri KMP ile kontrol örnekleri arasındaki farkın istatistiksel olarak (P<0.05) anlamlı olduğunu göstermektedir

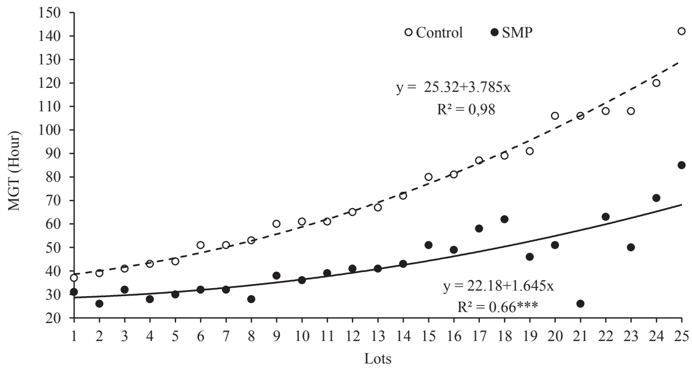

Figure 3- Changes in mean germination times (MGT) of SMP (●) and control (○) cabbage seed lots

Şekil 3- Lahana tohum partilerinde KMP (●) ile kontrol (○) arasında ortalama çimlenme hızı arasındaki değişim

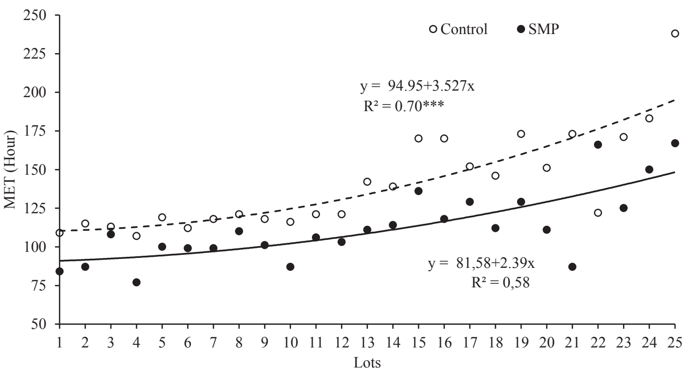

Figure 4- Changes in the mean emergence time (MET) of SMP (●) and control (○) cabbage seed lots

Şekil 4- Lahana tohum partilerinde KMP (●) ile kontrol (○) arasında ortalama çıkış hızı arasındaki değişim

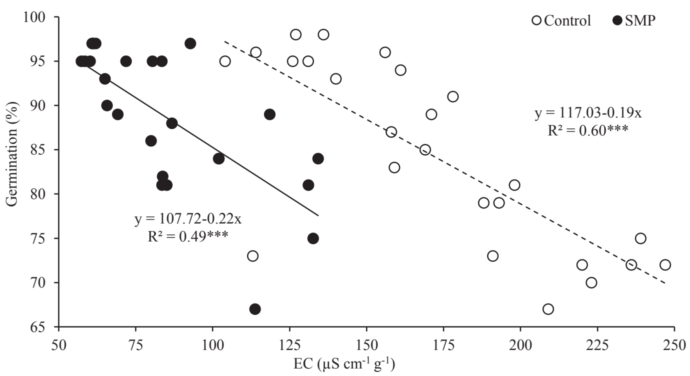

Figure 5- The relationship between EC and SMP (●) and control (○) cabbage seed lots

Şekil 5- Lahana tohum partilerinde KMP (●) ile kontrol (○) arasında elektriksel iletkenlik bakımından ilişki

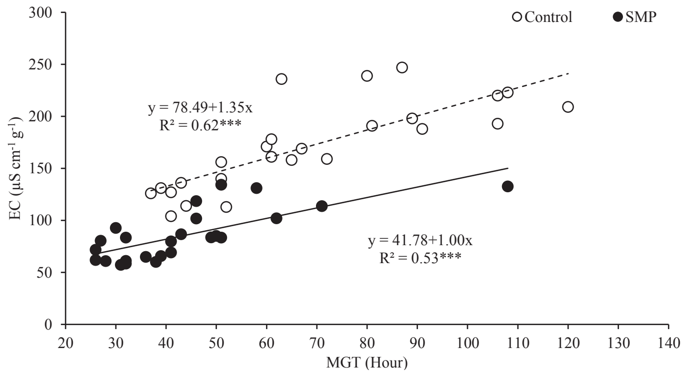

Figure 6- The relationship between mean germination time (MGT) and EC of SMP (●) and control (○) cabbage seed lots

Şekil 6- Lahana tohum partilerinde ortalama çimlenme zamanı (OÇZ) ile elektriksel iletkenlik bakımından KMP (●) ile kontrol (○) grubu arasındaki ilişki

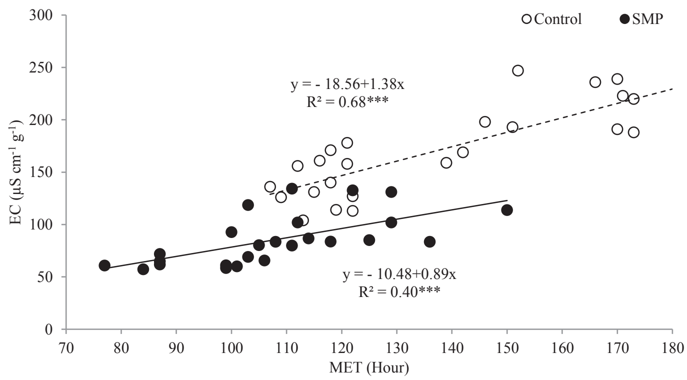

Figure 7- The relationship between mean emergence time (MET) and EC of SMP (●) and control (○) cabbage seed lots

Şekil 7- Lahana tohum partilerinde ortalama çıkış zamanı (OÇEZ) ile elektriksel iletkenlik bakımından KMP (●) ile kontrol (○) grubu arasındaki ilişki

Pandita et al 2010). Our results support the findings of previous studies of different crops regarding the earlier emergence of SMP treated lots. Our work reveals two important findings: 1) solid matrix priming can be used to repair ageing in left over and 2) can also be used for fast and well-developed transplant productions in cabbage seed lots.

In most seed companies, the seeds used in the production year may not necessarily be produced that same year. In some cases, seeds are left over from earlier production years, and may be earmarked for transplanting production season. In such cases, seed ageing may occur at different rates, depending on storage conditions (McDonald 1999), and seed quality may decline. This seed ageing process can be more severe in certain seeds, like cabbage. However, if this ageing level goes down to below 70%, it appears that matrix priming treatment may not be effective. This can be seen in control seeds in Figure 1.

This study revealed that seed quality, indicated by germination percentage, and emergence percentage and rates can be enhanced by SMP. SMP can be also used to repair ageing and make left-over seed lots usable. No hybrid seeds were included in the study, although improvements in seed quality or the repair of ageing can be more valuable in hybrid seeds due to their high cost. One of the basic problems of solid matrix priming is separating seeds from matrix material after the treatment. Normally researchers do this through sieving the material (Taylor et al 1988). In our work we separated seeds by hand. However, large amount of seeds can be primed in plastic perforated bags which let the seeds to take water but not get out. So seeds after the treatment can be easily taken out from the medium.

Fast germination and emergence following SMP will lead to larger seedlings and well-developed transplants in the modules (Mavi et al 2010). A large number of studies have indicated that earlier emergence results in larger transplants in either greenhouse or field conditions (Mavi et al 2010; Matthews et al 2012). One reason for fast emergence can be the completion of the first two imbibitions phases in the seed germination stages.

The repair mechanism of SMP or other priming treatments may involve various biochemical mechanisms, such as enzymes (Powell et al 2000; Sung & Chiu 2001), hormonal activity (Kepczynska et al 2007) or cell wall rejuvenation (McDonald 1999). In the present study, it was found that SMP reduced EC levels in treated seeds when compared to the control, which indicates that the treatment helped to rejuvenate cell structure and reduce leakage from the cell. Solid leakage is an indicator of a compact cell structure and is used as a seed vigor test (Matthews et al 2012).

High leakage (EC) is negatively correlated with seedling emergence and germination percentages. Moreover, a shorter time to germination (MGT and MET) is well correlated with high germination and emergence percentages. This indicates that treated seeds germinate faster and produce larger seedlings and such treatments repair cell wall structures that have deteriorated as a result of ageing, resulting in better performances in terms of germination and emergence.

SMP was found to be effective regarding the use of O_2, cheap and easy to apply in vegetable seeds (Khan 1992). The method is also considered as optimum for both larger seed species, such as beans (Parera & Cantliffe 1991), and smaller ones (Jett et al 1996). SMP has been used extensively to enhance emergence, however the present work makes a new approach, using SMP for the activation of the repair mechanism which can be used for the recovery of cabbage seed that has suffered rapid seed quality deterioration due to adverse conditions. Moreover, it can be considered a valuable approach for transplanting production companies, allowing them to save left over seeds. The effect of SMP is based on reducing seed leakage from the cell walls, among other physiological changes (Kepczynska et al 2007).

In conclusion, SMP treatments can be used enhance stored and relatively low-quality cabbage seed lots in terms of germination and emergence percentages, and can be considered a valuable method in ensuring strong, fast and high-quality cabbage transplants. Enhancing seed quality in aged seeds can also be used for saving left-over seeds in the production system which can be economically advantageous for companies.

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