e-GRO Edible Alert

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Pericarp Cracking and Moisture Management to Improve Spinach Germination

This eGRO Alert reports helpful information to improve spinach germination by seed technology (pericarp cracking) and precision rootzone management.

Spinach (*Spinacia oleracea*) (Fig. 1) is a leafy green commonly grown under controlled environment. However, one of the challenges to grow spinach hydroponically is their poor and inconsistent germination, which is largely affected by temperature and moisture content of the substrate used for germination. Spinach true seeds are enclosed inside a dry hard-shell structure called pericarp. Previous studies indicated that pericarp prevents germination both physically and chemically (e.g., endogenous inhibitors). A recent study in the Netherlands showed that pericarp likely limited critical oxygen availability for true seeds especially at high temperature and high moisture content (Magnee et al., 2020). Historically, physical removal of pericarp as well as pretreatment such as soaking seeds in water or water containing substances to promote germination were shown to be an effective method to improve germination rate. We know that spinach seeds without pericarp (also referred to as “naked seeds”) are widely available in Japan where usage of such seeds is essential in hydroponics. Removing pericarp without damaging true seeds requires special techniques. For example, some seed suppliers in Japan would use surface freezing method using liquid nitrogen (T. Maruo, Chiba University; personal communication). However, this is a rather expensive approach especially for treating

Figure 1. An example of high-density uniform spinach seedlings (Photo credit: Robert Conrad).

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small quantity of seeds. Seed priming and seed treatment suitable for spinach have been investigated by global seed companies, but the technological availability to do so seems to be limited in North America.

Therefore, we examined a scarification method to crack-open the dry pericarp (Fig. 2), a commonly used seed treatment of other species difficult to germinate. The purpose of scarification is to remove the physical barrier against germination and/or increase the oxygen availability for true seeds. Given the potential impact of such seed technology to a wider range of production systems and scales including greenhouse and vertical farms, Ball Horticultural Company developed a methodology of crack-opening spinach pericarps as a seed germination enhancement treatment and demonstrated its efficacy using several cultivars available in the US, in collaboration with the Ohio State University. The trials conducted at both sites showed a consistently high rate of seedling emergence (>80% at 20°C) when seeded on rockwool plug sheets, a substrate known to be problematic for germinating spinach seeds. In this article, we will show the significant improvement of spinach seed germination and the importance of rootzone management together with the seed treatment.

Concerns in substrate selection for spinach

Hydroponic/soilless cultivation employs substrates at least for germination stage. Rockwool is an inert substrate widely used by hydroponic growers and researchers due to its availability, consistency, and convenience. However, when it comes to the application of spinach germination, rockwool is a challenging substrate to achieve high germination, likely due to its high moisture holding capacity (WHC), which limits oxygen availability. While the high WHC is considered as advantageous for other crop production, this substrate tends to create too high moisture condition for spinach seeds, lowering germination rates.

Figure 2. Untreated (left) and crack-opened 'Corvair' spinach seeds (right) (photo credit: Samuel Offenbecher)

Previous experiences at the Ohio State University showed that seedling emergence rate with untreated spinach seeds can be 60% at best (Fig. 4). Previous research showed that chemical treatment such as hydrogen peroxide (H_2O_2) can enhance spinach germination (Katzman et al., 2001). This H_2O_2 treatment can improve germination); however, it tends to damage spinach radicles due to the chemically inert nature of rockwool, limiting the final seedling emergence in rockwool. Removal or lowering concentrations of H_2O_2 in the seed treatment protocol caused inconsistent results of germination rates (Offenbecher, unpublished data). Hydrogen peroxide treatment for seeds may work better in substrates containing more organic matter (such as peat-based mix), avoiding causing damage to radicles.

Sorting seeds by size

Seed size is known to affect germination rate. Selecting seeds of relatively similar sizes can actually improve the rate of seedling emergence. This is due to the improved uniformity of seedlings

Table 1. Spinach germination protocols (examples) using seeds with crack-open pericarp

Rockwool	Peat/perlite mix
1. Run the rockwool (200 plug count sheet; 10-12 mm well depth) under water until it is saturated. 2. Fill 1/3 (or so) of the hole with a coarse sand (works better than fine sand), then place a seed(s) on the first layer of sand. Then cover seeds and fill the hole with sand to the top surface of rockwool. 3. Keep the seeded tray under a tray cover (to maintain high humidity) for 4 days at 20°C (no light). 4. Then move the tray to greenhouse bench for additional 10 days with overhead watering on a bench and you get the full stand.	1. Fill the tray (288 counts) with selected substrate. 2. Adjust the tray weight and added moisture weight precisely. One example is 1250 gram total weight (substrate plus tray), then target a 1400 gram total weight after covering seeds with a thick vermiculite layer (6 mm) and water misting. 3. Keep the seeded tray under ~100% RH at 20°C (18 h/day lighting) for 2 days, followed by reducing RH at the same temperature/light for 5 days. Maintain the same total tray weight throughout the 7 days.

grown in the same tray at a relatively high density. Spinach seeds in North American market often contains seeds of a relatively wide range of sizes. Our preliminary study using 'Whales' spinach seeds showed that the final seeding emergence was improved to 75-82% when sorted seeds (in either range of 2.7-3.4 mm or 3.4-4.4 mm using industrial sieves) were used, while the original seeds with mixed sizes (2.7-3.9 mm) exhibited only 43% seedling emergence after 10 days of germination (Offenbecher, unpublished data). However, when the experiment was repeated, we could not show the consistently high emergence by sorting seeds alone.

Cracking seeds and rootzone management

Pericarp of spinach seeds is typically less than 0.5 mm thick, immediately below which is the seed coat of spinach. In some cases, there is a small air space between pericarp and seed coat. Crack-opening pericarps therefore must be done effectively without damaging true seeds inside. A proprietary method employed in our trial uniformly made ~2-mm long crack on the surfaces of pericarp (Fig. 2). 'Corvair' spinach seeds with crack-opened pericarps can start germinating as early as 1 day at 20°C after placing on rockwool sheet (Grodan AO Plug, The Netherlands) soaked with water. However, we found that additional modification was necessary mainly to allow roots to penetrate in rockwool substrate without coiling on the surface. A protocol developed to create a more ideal moisture profile and physical weight over seeds to force roots into the substrate was the use of a layer of coarse sand as interface between rockwool and creating downward force to root into the substrate. Step-by-step procedures that we recommend are summarized in Table 1. This table also shows an example protocol to achieve high germination rate in a peat-based substrate mix. Note that moisture content is controlled precisely in this approach. The optimum moisture content needs to be found by growers, as it is depending on substrate type and other germination conditions. When the optimum moisture content is achieved together with the use of crack-opened seeds, this procedure can consistently reach greater than 90% germination after 7 days of seeding (Conrad, unpublished data).

Side-by-side comparisons of germinating spinach seeds of selected cultivars.

Figure 3 shows a uniform 'Corvair' spinach seedling stand germinated in rockwool using our protocols (a photograph was taken at 18 days after seeding). In side-by-side comparisons conducted at Ball Horticultural Company, all five cultivars tested ('Space', 'Red Tabby', 'Lizard', 'Corvair', and 'Auroch') exhibited high seedling emergence rates (> 80%) while untreated seeds had lower emergence rates (except 'Red Tabby'). In these trials, we seeded only one seed per well to quantify germination rate accurately. However, most growers place more than one seed per plug cell, which can achieve even higher germination and more uniform stand when combined with this approach (e.g., Fig. 1).

Given that hydroponic growers in North America are producing baby spinach, achieving high germination rate and uniformity is critical because germination uniformity is translated as final stand uniformity and a few days of delay in germination is significant for a short cycle of baby leaf production. As seed performance will be varied for different cultivars, seed lots, environmental conditions, and other factors, growers will have to further refine the protocol to develop their own standard operation practices. However, this seed cracking approach is expected to mitigate some of the challenges known for spinach in North America and perhaps other countries where there is increasing demand of expanding hydroponic crops beyond traditional ones (e.g., lettuce, tomato, and cucumber).

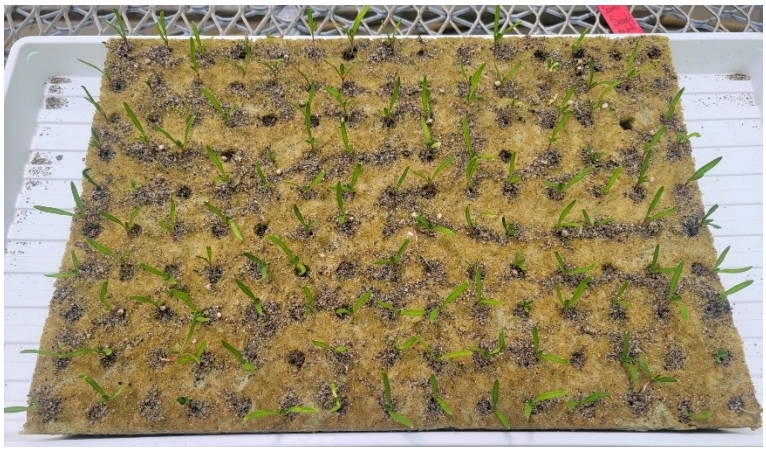

Figure 3. A uniform 'Corvair' spinach seedling stand (84% emergence) after 18 days of germination using the crack-opened seeds in rockwool (Photo credit: Samuel Offenbecher).

Figure 4. An example of poor germination/emergence (53%) of seedlings after 21 days of germination using untreated seeds in rockwool covered with vermiculite (Photo credit: Samuel Offenbecher).

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