Recent Developments in Seed Technology

H. J. Hill

INTRODUCTION

Seed enhancement technologies have expanded over the last 10 years due to the vegetable industry’s demands for strong and uniform stand establishment. Precision seeding reduces seed costs per acre and seed enhancement increases production flexibility and harvest pack-out. Since many of the leafy vegetables and cole crops mature in 60-90 days and flower-plug production requires even less time, plant uniformity in stand establishment has become a critical production consideration. The purpose of this paper is to describe selected seed technology advances that have assisted, or will in the near future, the development of better and more uniform vegetable stands.

SEED PELLETING AND PELLET IMPROVEMENTS

A working definition for seed pelleting is as follows: inert materials are added to change seed size and shape for improved plantability. Small and irregularly-shaped seed can now be treated as larger, round-shaped seed. Singulation of seed in the field is therefore easier. For crops like onion, precise seed placement is of great advantage as uniform bulb development is assured with equal distance planting.

There are two components to a seed pellet: bulking (or coating) material and binder. The bulking material can be a mixture of several different minerals and/or organic substances or a single component. The coating material is the “work-horse” of the duet. The coating material changes the size, shape and weight of the seed. Desirable characteristics of a good coating material include: uniformity of particle-size distribution, availability of material, and lack of phytotoxicity. The second component; the binder, holds the coating material together. Binder concentration is critical because too much binder will delay germination. Too little binder will cause chipping and cracking of

H. J. Hill is Seed Physiologist, Seed Dynamics, Inc., Salinas, CA 93901, USA.

© 1999 by The Haworth Press, Inc. All rights reserved.
pellets in the planter box, which can cause skips and/or wide gaps in the plant rows. Many different compounds have been used as binders, including various starches, sugars, gum arabic, clay, cellulose, vinyl polymers (Halmer, 1987), and even water (Burgesser, 1949).

Seeds of various sizes are commercially pelleted, from relatively large seeds like onion and tomato to very small seeds like Begonia sp. For onion, the seed can increase in weight 6-fold due to pelleting; there are approximately 230 raw seed per gram and after pelleting the diameter may be 13.5/64 inch (0.54 cm). The volume for 1000 propagules is 3.7 cm$^3$ for raw seed compared to 18.0 cm$^3$ after pelleting. The smallest seed that Seed Dynamics pellets is Begonia. Median seed weight for raw begonia is 88,000 seeds g$^{-1}$. After pelleting the seed count can average 857 seeds g$^{-1}$, an increased mass of over a 100-fold.

In the coastal and desert valleys of California and Southwest Arizona (as in other areas of the world), the most popular planter for field singulating pelleted vegetable seeds is the ‘Stanhay’. The Stanhay meters seeds with a continuous belt with pre-drilled holes. The diameter of the hole accepts only one pellet at a time, while the space between holes determines the within row seed spacing. This planter was first introduced in the US in the early 1970’s. Stanhay’s popularity is due to the ability to plant one or more rows per planter box, the flexibility to plant different sized pellets at different spacings, and the versatility of planting either pelleted or non-pelleted seeds. Several other planters can be used for pelleted seed such as the Milton and the Gramor. Even the Gaspardo vacuum planter (designed for raw seed) does an excellent job in planting pellets.

Historically, the increased usage of pelleted seed occurred with the outlawing of the short-handled hoe in California in the early 1970’s. This legislative change caused an increased demand for pellets, because only with pelleting could lettuce seed be adequately field singulated for thinning with a long-handled hoe. Several other methods of precision planting lettuce seeds have been commercially available over the years. Products like the seed tape (Gurley, 1970) and seed tablets (Robinson and Johnson, 1970; Sharples and Gentry, 1980) have been commercially available and tested on a large scale. However, the vegetable industry has retained seed pelleting as its preferred precision planting method.

As the demand for pelleted seeds increased so did the number of companies that produced pelleted seeds. Increased competition in the pelleted seed market has fostered the development of more effective pellets with greater capabilities and wider planting characteristics.

Pellet improvements over the last ten years include:

1. Increased oxygen penetration/availability
2. Wider pellet density range
3. Pellet loading
4. Better field visibility

These improvements and their significance will be discussed, except for better field visibility.

**Increased Oxygen Penetration.** Historically, the primary obstacle for pellet use has been slow and erratic emergence primarily associated with insufficient oxygen supply to the seed. Clay coatings, for example, have been shown to be a barrier to oxygen for the seed (Sachs et al., 1981). Even sand and diatomaceous earth coatings have been shown to limit oxygen supply (Sooter and Miller, 1978).

Sooter and Miller (1978) found that common pelleting materials like silica can extract dissolved oxygen from water as the liquid moves through the pellet. Increased oxygen supply for pelleted seed, especially in over-saturated soil conditions, has been achieved through the use of oxygen-donating chemicals (Sladdin and Lynch, 1983) and the development of splitting-pellet technology. The development of a splitting-pellet like the SDI High-Density® or the SDI Medium-Density® lettuce pellets have been especially beneficial to growers that plant lettuce under saturated soil-water conditions. Saturated soil conditions are caused by irrigation after sowing. A pellet that can split open upon hydration allows oxygenated water to move directly to the seed.

**Weight Delineation.** The development of different pellet weights and densities have been spurred over the years by growers’ needs to “fine-tune” plantability and ease-of-handling. For example, the greenhouse industry sows pepper seeds for transplanting in plug-trays using a vacuum-drum. Greenhouse managers prefer a light, smooth pellet that permits rapid adherence with a tight seal to the vacuum planting drum. Pellets such as the SDI Pro-Vac® have a 50% lower weight per pellet than conventional pellets like those used for field seeded onion. This lighter, smoother pellet is exclusively utilized in the greenhouse industry. Pellet weight is not important because there is little or no pellet “drop” during planting. Drop refers to the distance from the sowing metering device to the soil or greenhouse media.

The best example of pellet weight delineation to suit particular planting requirements is found with lettuce. Tractor speeds during planting in the Yuma and Imperial Valleys can be twice as fast as speeds used in the Coastal Valleys of California (due to larger fields and tighter planting schedules). Growers using the higher tractor speeds prefer a heavier-weighted pellet. The higher the pellet weight the better the pellet “drop.” Straighter drops during planting produce less bouncing in the seed furrow, thus field singulation and uniform plant spacing are maintained.

Lighter pellets weigh less per box or pail (boxes and pails are packed by seed number), so shipping costs are lower and handling is easier. Grower preferences in different regions of the US have initiated the development of
different pellet weights (Table 1). All pellets have the same volume; only the weight, and thus the density, of the pellet is different.

Pellet Loading. Because of the large increase in volume obtained when seeds are pelleted, pellets have been shown to be effective carriers of plant protectants (pesticides). The same plant protectants that are often deleterious if applied directly to the seed can be “carried” in the seed pellet. The act of applying a plant protectant in a band within the pellet is known as “pellet loading.” The pellet either acts to “dilute” the negative impact of a plant protectant as it moves through the pellet to the seed, or acts as a barrier to prevent direct seed contact. Active products can thus be “loaded” onto the seed while minimizing adverse seed germination effects. The total amount of “toxicants” applied per acre is less than with in-furrow or other soil applications.

For example, in Europe, Gaucho® is added to sugar beet pellets at concentrations that would be near phytotoxic (90 g a.i. per 100,000 seeds) if applied directly to the seed. By applying the plant protectant to the pellet the plant will be protected against insects such as thrips and leaf-hoppers. There is no need for conventional foliar applications and the amount of over-all pesticide usage per acre is lower than the conventional application methods (requiring 4.5-6.8 kg of pesticides for the equivalent 100,000 seeds). Other commercial examples of pellet loading include Pro-Gro® and Trigard® applied to onion pellets. These chemicals have been known to slow down or even inhibit onion seed germination. When applied in the pellet minimal adverse effects are noted and the seedlings are protected against smut and maggots, respectively.

In summary, chemical loading of the pellet provides a means to treat the seed directly. When possible, application of active ingredients to the seed is considered better than other applications such as in-furrow, foliar, or broadcast because of the following reasons:

1. Precise placement on the target
2. Minimum toxicant used
3. Minimum environmental impact
4. Minimum wildlife and beneficial organism exposure

FILM COATING

Film coating has gained popularity as a seed-coating method over the last several years because of worker safety considerations. Film coating is often used on seed species that do not require pelleting (e.g., Brassica sp.) for precision planting but the seed requires some encapsulation due to plant protectant application.

Encapsulation of plant protectants by film-coating insures a uniformity of application superior to slurry application, the older methodology. Once sealed to the seed, plant protectants dispersal to the environment prior to
TABLE 1. Lettuce pellet products with same volume formulated for different densities.

<table>
<thead>
<tr>
<th>Product name</th>
<th>Pellet to seed weight ratio*</th>
<th>Weight (g) per 100 pellets</th>
<th>Pellets (x 10^3) per kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Density®</td>
<td>1 to 17</td>
<td>1.9</td>
<td>53</td>
</tr>
<tr>
<td>Medium Density®</td>
<td>1 to 25</td>
<td>2.5</td>
<td>40</td>
</tr>
<tr>
<td>High Density®</td>
<td>1 to 35</td>
<td>3.8</td>
<td>26</td>
</tr>
</tbody>
</table>

*The average pellet weight divided by the average seed weight

planting is minimized. All the dosage originally applied to the seed will be available against the pests in the target environment and worker exposure to harmful dusts are minimized. Other advantages of film-coating include: increased flowability in the planter caused by better “slippage” between individual seeds; increased visibility of seed in the soil; and seed treatment identification by using different colorants.

Some disadvantages of film-coating include: plant protectants that inhibit germination may not be used because of inadequate separation between the seed and the active chemical. Seed size and shape and weight are not altered sufficiently to make a dramatic difference in plantability. Lastly, polymers and plasticizers in the film-coating may be toxic or inhibitory to the seed species. Seeds of different species can have different sensitivities to the same film-coating chemical.

**SEED PRIMING**

Priming could be defined as controlling the hydration level within seeds so that the metabolic activity necessary for germination can occur but radicle emergence is prevented. Different physiological activities within the seed occur at different moisture levels (Leopold and Vertucci, 1989; Taylor, 1997), the last physiological activity in the germination process is radicle emergence. The initiation of radicle emergence requires a high seed water content. By limiting seed water content all the metabolic steps necessary for germination can occur without the irreversible act of radicle emergence. Prior to radicle emergence, the seed is considered desiccation tolerant, thus the primed seed moisture content can be decreased by drying. After drying, primed seeds can be stored till time of sowing.

Several different priming methods have been reported to be used commercially. Among them, liquid or osmotic priming and solid matrix priming appear to have the greatest following (Khan et al., 1991). However, the actual techniques and procedures commercially used in seed priming are proprietary.
The benefits of seed priming have been well documented in previous review articles (Bradford, 1986; Khan, 1992; Taylor et al., 1998). For practical purposes seeds are primed for the following reasons:

1. To overcome or alleviate phytochrome-induced dormancy in lettuce and celery.
2. To decrease the time necessary for germination and subsequent emergence to occur.
3. To improve the stand uniformity in order to facilitate production management and enhance uniformity at harvest.

One of the primary benefits of priming has been the extension of the temperature range at which a seed can germinate (Valdes and Bradford, 1987; Ellis and Butcher, 1988). The mechanisms associated with priming have not yet been fully delineated. Several review articles have done an excellent job in describing the current state of knowledge (Taylor and Harman, 1990; Khan, 1992). From a practical standpoint priming enables seeds of several species to germinate and emerge at supra-optimal temperatures. Priming has also alleviated secondary dormancy mechanisms that can be imposed if exposure to supra-optimal temperatures lasts too long (Valdes et al., 1985) or in photo-sensitive lettuce varieties.

The other benefit of priming has been to increase the rate of germination at any particular temperature. On a practical level, primed seeds emerge from the soil faster and often more uniform (because of limited adverse environmental exposure) than non-primed seeds. Priming accomplishes this important development by shortening the lag or metabolic phase (or phase II in the triphasic water uptake pattern, Bewley and Black, 1978) in the germination process. The metabolic phase occurs just after seeds are fully imbibed and just prior to radicle emergence. Since seeds have already gone through this phase during priming, germination times in the field can be reduced by approximately 50% upon subsequent rehydration. The increase in emergence speed and field uniformity demonstrated with primed seeds have many practical benefits: emergence occurs before soil crusting becomes fully detrimental; crops can compete more effectively with weeds, and increased control can be exercised over water usage and scheduling. Lastly, priming has been commercially used to eliminate or greatly reduce the amount of seed-borne fungi and bacteria. Organisms such as Xanthomonas campestris in Brassica seeds and Septoria in celery have been shown to be eliminated within seed lots as a by-product of priming (Mel Bachman, personal communication). In the case of Xanthomonas campestris in Brassica sp., zero infection in 50,000 seeds is commonly reported. The mechanisms responsible for eradication may be linked to the water potentials that seeds are exposed to during prim-
ing, differential sensitivity to priming salts, and/or differential sensitivity to oxygen concentrations.

SEED-LOT UPGRAWDING

Conditioning upgrades the quality of a seed lot by eliminating immature and damaged seeds. Conditioning can also be used to remove non-viable and low vigor seeds by exploiting differences in seed weight, seed size, and seed volume. The influence of seed size and density on germination and emergence has been well documented for cotton (Krieg and Bartee, 1975) and soybeans (Hoy and Gamble, 1985). Hydrated seeds may also be sorted by density (Hill et al., 1989).

Commercial exploitation of these principles has led to the development and marketing of products like New Density® and the start-up of companies that commercially separate seed into different density fractions as their major service (e.g., Pacific Grading Service). One purpose of seed-lot upgrading is to further improve the uniformity and vigor of a particular seed lot so stand establishment is improved (as in the case of Pacific Grading Service). The other purpose is to eliminate non-viable seeds from existing lots so that the seed-lot utilized for planting has the potential for nearly 100% emergence (as in the case of New Density®).

With the availability of seed lots that have nearly 100% viability combined with the faster emergence and disease control of priming, uniform and near perfect stands of vegetables can be attained. Seed technology advancements will continue to enhance agricultural production as land availability decreases and competitive demand for maximum production increases.

REFERENCES


