Scientia Horticulturae 184 (2015) 85–92

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Development of seed agglomeration technology using lettuce and tomato as model vegetable crop seeds

Potjana Sikhao[a,b], Alan G. Taylor[a,*], Edward T. Marino[a], Catharine M. Catranis[a], Boonmee Siri[b]

[a] Department of Horticulture, New York State Agricultural Experiment Station, Cornell University, Geneva, NY 14456, USA
[b] Agronomy Division, Faculty of Agriculture, Department of Plant Science and Agricultural Resources, Khon Kaen University, Khon Kaen 40002, Thailand

ARTICLE INFO

Article history:
Received 27 August 2014
Received in revised form 9 December 2014
Accepted 19 December 2014
Available online 14 January 2015

Keywords:
Tomato seed
Lettuce seed
Seed agglomeration
Seed pelleting
Seed coating
Multiple seeds

ABSTRACT

Seed agglomeration is a coating technology with the purpose to sow multiple seeds of the same seed lot, or multiple seeds of different seed lots, varieties or species. The objective of this study was to develop agglomeration technology by producing single agglomerates or pellets using lettuce and tomato as model vegetable crop seeds. Physical properties of dry and wet pellets were measured and seedling emergence assessed. Pellets were formed by a molding technique with a mixture of filler, binder, and seeds. Diatomaceous earth (DE) was used as the filler, and two binders were tested: polyvinyl alcohol (PVA) and a commercial organic binder. Each binder solution was mixed with DE, and seeds were added during the agglomeration process. Oval and cylindrical pellets were molded with known compression forces. Cylindrical pellet strength increased, as PVA binder concentration increased from 8% to 16% and pellet strength was greater for pellets produced with 3 kg than with 1 kg compression. The percent seedling emergence and speed of emergence were not affected by a compression force of 1 kg and 3 kg for PVA-pelleted lettuce and tomato, respectively compared to the non-pelleted control. Cylindrical pellets formed using the commercial organic binder at 1 and 3 kg force without lecithin showed significantly less seedling emergence and speed of emergence for lettuce seed; no significant differences were observed for tomato seed. Seedling emergence and speed of emergence for lettuce seed from oval pellets formed with the commercial organic binder and lecithin at 1 kg and 3 kg compression grouped with the non-pelleted control. Cylindrical pellets made without lecithin and with the commercial organic binder using 3 kg compression force containing three tomato seeds produced plants with greater combined leaf area, fresh and dry weight than plants grown from single non-pelleted seeds, 26 days after being sown in the greenhouse.

1. Introduction

Seed treatment and coating technologies are used worldwide for the application of materials to seeds including seeds sown in planter boxes, as well as conventional liquid treatments, film coating and pelleting (Taylor, 2003). The goal of these seed coating technologies is to apply materials uniformly over the surface of seed in the same lot while maintaining singulation during the coating process. An alternate coating technology is required to sow multiple seeds of the same seed lot, or multiple seeds of different seed lots, varieties or species. Agglomeration is a technology that combines particles of different sizes and shapes into a single unit; seeds are examples of particles that can be formed into agglomerates with the purpose of sowing multiple seeds into a single dispersal unit. The seed agglomeration technology has broad applications for many crop seeds including vegetable, flower, grass, cover crop, and biofuel species.

A review of agglomeration and coating technologies to produce propagules with multiple seeds is largely found in patents. Three patents were issued for making seed capsules (Adams, 1971; Brink, 1971; Clifford, 1971), using a two step process that positioned a seed in the depression of a lower, partially compressed pellet volume then covered the seed with a top layer of the pelleting material and compressed the entire mass into one pellet. Mechanized seed pelleting incorporated advances of seed coating technologies to produce seed pellets 'comprising a core of at least two seeds, an organic substrate such as loess, organic fertilizer, fungicides, and a wetting agent enclosed by a water permeable coating' (Gerber, 1988). Later versions of the multi-seed pellet addressed problems with pelletizing very small seeds such as flower seeds and methods have been patented that use an inert core (e.g., glass bead, perlite,

* Corresponding author. Tel.: +1 315 787 2243; fax: +1 315 787 2216.
E-mail addresses: potja_noi@hotmail.com (P. Sikhao), agt1@cornell.edu (A.G. Taylor).

http://dx.doi.org/10.1016/j.scienta.2014.12.028
0304-4238/

bentonite granules), surrounded by an intermediate layer (e.g., clay, vermiculite, polyvinyl acetate) around which 'at least two seeds of the same or different species were distributed in an adhesive layer formulated from a combination of binders and fillers (e.g., polyvinyl alcohol, clay, gypsum)' (Legro, 1997). Recently, Conrad (2012) submitted a patent application for a method of producing 'a cast pellet comprising a mixture of one or more plant seeds'. As multi-seed pelletizing processes were being developed, a process was proposed to encapsulate multiple seed units utilizing pharmaceutical capsules composed of hard gelatin to contain one or more seeds (Trias and Takahashi, 2014). However, a molding technique that incorporates multiple seeds within a pellet comprised entirely of organic materials (US Government Printing Office, 2014) has not been reported.

Rotary pan technology has been adapted to make agglomerates using a solution of polyvinyl alcohol as the binder and diatomaceous earth as the filler material on bluebunch wheatgrass (*Pseudoroegneria spicata* (Pursh) Á. Love) seeds (Madsen et al., 2012). Based on the same planting density, the agglomerated treatment had greater seedling emergence than the non-coated control under simulated soil crusting (clay soils) and non-crusting (sandy soil) conditions in greenhouse studies. Focused research conducted on agglomeration seed coating technology (Kavak and Taylor, unpublished) examined the effect of pelletizing on seed germination. Pellets were formed by compressing lettuce seeds in a mixture of 85% red clay thoroughly mixed with 15% liquid binder (Spectrum 100, Germains Seed Technology, Gilroy, CA, USA) at 3 kg compression force; a 5 kg compression force was used for onion seeds. Pelleting decreased the seedling emergence rate but did not affect total emergence, based on the total seeds sown in both crops seeds. Additionally, when using compressive force to produce seed containing pellets, ease of removal of the compressed pellet from the molding form is a critical component of efficient manufacture. Soy lecithin, a plant based extract with amphipathic molecules aligning the nonpolar fatty acid portion facing the surface provides a "non-sticking" property (Xu et al., 2011). To our knowledge, the effect of incorporating soy lecithin in multi-seed pellets on seed pellet three-dimensional strength, seed germination and seedling growth has not been reported. Overall, the effect of mechanical aspects used to form multi-seed compressed pellets, as well as the possible inhibitory or stimulatory effects of formulation components on seedling germination and growth, must be considered as critical design features during the development of multi-seed pellets.

The goal of this study was to produce agglomerates using a molding technique to form single pellets containing multiple seeds of lettuce or tomato, the model vegetable crops used in this study. The objectives of this study were: (1) the production of a pellet of uniform size and shape which is three-dimensionally strong for use in mechanical planter; (2) the development of a formulation and pelletizing process that permits more than one seed per pellet; and (3) proposal of a multi-seed process that has no negative effect on germination and seedling growth under greenhouse conditions. The optimum compression force for producing multi-seed lettuce and tomato seed pellets without negative growth effects was determined from data on three-dimensional strength, dissolution period, germination, and seedling growth.

2. Materials and methods

2.1. Seed agglomeration materials

Single seed lots of two vegetable crops were used in all laboratory and greenhouse experiments. Lettuce (*Lactuca sativa* L.), 'Jupiter' was provided by Nunhems USA, Inc., Parma, ID, USA, and tomato (*Solanum lycopersicum* L.), 'Talladega' was provided by Syngenta Seeds, Inc., Boise, ID, USA. Diatomaceous earth (DE) obtained from Perma-Guard, Inc., Albuquerque, NM, USA was used as the filler material for all pellet formulations. SELVOL™ polyvinyl alcohol (Selvol-205®), a water-soluble copolymer was provided from Sekisui Specialty Chemicals America, LLC, Dallas, TX, USA. A commercial organic binder, SOL034 was provided by Incotec, Salinas, CA, USA. Natural Soya Lecithin (Rite Aid Pharmacy, Camp Hill, PA, USA) was used in selected experiments as a non-sticking agent, to prevent sticking of the seed containing filler material to the molding tips.

2.2. Agglomeration methods and physical properties of pellets

Two properties are essential to the production and utility of agglomerated seeds: (1) a suitable concentration of binder sufficient to provide adequate mechanical strength for dry pellets used in mechanized planting, and (2) water permeability allowing pellet dissolution and seed germination. To examine pellet three-dimensional strength, pellets were prepared with one of two binders over a range of compression forces without the addition of seeds. Polyvinyl alcohol (PVA) crystals were dissolved in water at a range of concentrations from 8% to 16% (w:v) in 2% increments, to prepare the non-organic binder. The commercial organic binder, SOL034 was prepared by diluting the concentrate with water to 12.5%, 25%, 50% (v:v) and by using undiluted, 100% SOL034. Each binder solution was thoroughly mixed with diatomaceous earth, DE filler at ratio 5:4 (w:w) to form a moist, friable powder.

Two 6.3 mm × 100 mm × 100 mm plates composed of ultra high molecular weight (UHMW) polyethylene were used for molding the pellets. The first plate was solid with a smooth hard surface and served as the base during molding process (Fig. 1A, right). The second plate was drilled with 16 holes of 5 mm diameter and equidistantly spaced (Fig. 1A, left); the holes served to contain the friable binder–filler powder during pellet formation under pressure. To form pellets, the second plate was placed on top of the first plate and the holes were filled with binder–filler. The binder–filler mixture in the holes was compressed at specific force measured in kg with an Extech "Fruit Hardness Tester" (model FHT200, Extech Instruments Corp., Waltham, MA, USA; www.extech.com) (Fig. 1B). The 5 mm tip of the Extech fruit hardness tester had a flat end that produces a cylindrical pellet. After compression, the pellets were removed by pressing the pellet from the mold using the flat top of a drill bit shank. After removal from the mold, all compressed pellets were dried in forced air oven at 30 °C for 4 h.

Physical properties, including three-dimensional strength and dissolution period of the pellets were determined. Ten pellets were placed on the undrilled, solid base plate and the three-dimensional mechanical strength of individual pellets was assessed by applying force on the top (height of cylinder) or side (diameter of cylinder) of the pellet with the Extech fruit hardness tester. The dimensional force required to crush each pellet was recorded. An additional ten pellets from each production batch were individually dissolved in 30 ml of water contained in weigh boats; the total dissolution period for the pellets to dissolve was recorded with a laboratory timer.

2.3. Effect of compression forces on seedling emergence

Lettuce and tomato seed pellets were prepared with 8% PVA binder and DE filler (binder:filler, 5:4, w:w) at different compression forces; 250 seeds of either crop were mixed with the binder–filler mixture in a single batch. The lettuce mixture was filled into the holes of the mold plate and compressed at 0 kg, 0.5 kg, 1 kg, 2 kg or 3 kg. The same procedure was conducted for tomato seeds using compression forces of 0 kg, 1 kg, 3 kg, 5 kg or 7 kg. The