General comments

Thinned trees had fruit with better quality attributes than unthinned trees. Fruit color in all treatments that included hand thinning was improved compared to those without hand thinning (data not shown) because of less fruit-to-fruit contact and better light distribution around the fruit.

Time and temperature are important factors influencing the effectiveness of blossom thinning in apple and peach. It is essential that hydrogen cyanamide is applied when some, but not all, flower fertilization has occurred. Also, the severity of freeze damage must be considered before applying or determining rates of any chemical blossom thinner. Temperature affects bee activity and, subsequently, the number of fertilized flowers. Temperature also affects the chemical characteristics and the effectiveness of blossom thinners, including hydrogen cyanamide. Therefore, the effect of these blossom thinners should be tested for each geographical region and for each cultivar.

The University of Idaho has conducted hydrogen cyanamide residue tests through IR-4 Program for 2 years. No detectable residue has been found in apple, plum, prune, or peach fruit. This chemical is not registered for blossom thinning at this time, but it is in the process of registration under D.K. International, Georgia, and SKW Germany.

Conclusion

Under conditions of this study, hydrogen cyanamide was an effective blossom thinner for 'Early Spur Rome', 'Law Rome', and perhaps 'Gala' and 'Delicious' apples and 'Flavorcrest' peach. Based on this commercial-scale test and previous reports (Fallahi, 1997; Fallahi et al., 1997), hydrogen cyanamide should be applied at rates of 4 to 5 pts formulation per 200 gal/acre, depending on the level of thinning desired. Application of a postbloom fruit thinner or hand thinning, in addition to a full-bloom spray of hydrogen cyanamide, is recommended in apples. Application of hydrogen cyanamide reduces time and labor needed for hand thinning in apple and peach. A complete coverage of the whole fruiting surface throughout the tree canopy is advised. Fruit marking or major phytotoxicity is unlikely if hydrogen cyanamide is sprayed at the recommended rates.

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Seed Treatment and Cultural Practices Influence Seedling Growth of Hydroponic Lettuce

Ahmet Korkmaz,¹
Wallace G. Pill,² and
Bruce B. Cobb³

ADDITIONAL INDEX WORDS. *Lactuca sativa*, fluid drilling, pregerminated seed, pelleted seed, nutrient film technique

SUMMARY. Raw, pelleted or germinated seeds of 'Cortina' lettuce (*Lactuca sativa* L.) were sown in phenolic foam cubes preplant soaked in water or full-strength nutrient solution (2 mmho·cm⁻¹, 2 dS·m⁻¹). The seeds were left uncovered or covered with fine vermiculite (grade 5), and seedling emergence characteristics were subsequently determined. Shoot fresh masses and their coefficients of variation (cv) by 9 days after planting (1 or 2 true leaves) and by 31 days after planting (4 or 5 true leaves) also were determined. Soaking the cubes in nutrient solution rather than water increased seedling emergence percentage and rate, and increased shoot fresh masses by 9 or 31 days after planting. This increased shoot fresh mass was accompanied by lower cv of shoot fresh mass by 9 days after planting, but not by 31 days after planting. Covering seeds with vermiculite decreased

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¹Graduate research assistant. Current address: Department of Horticulture, Clemson University, Clemson, S.C. 29634.

²Professor, Delaware Agriculture Experiment Station, Department of Plant and Soil Sciences, University of Delaware, Newark, DE 10717-1303. To whom reprint requests should be sent.

³Owner and operator of ARC Greenhouses, Shiloh, N.J.

emergence from 99% to 93%, but increased shoot fresh mass by 9 and 31 days after planting when cubes were soaked in water, but not in nutrient solution. Seed treatments influenced shoot fresh mass at 9 and 31 days after planting in the order germinated > pelleted > raw. Germinated seeds resulted in lower cv of shoot fresh mass (24%) than raw or pelleted seeds (29%) by 31 days after planting. Thus, sowing germinated seeds into foam cubes soaked in full-strength nutrient solution, with or without covering the seeds with vermiculite, produced the heaviest and most uniform seedlings.

Most literature concerning hydroponic culture is focused on postplant establishment considerations such as the design, mechanics, and operation of various production systems, and the manipulation of the edaphic and aerial environments (Food and Agriculture Organization, 1990; Schwarz, 1995). Factors involved in the establishment of seedlings to be transplanted into a soil-less culture systems have received much less attention.

The production of hydroponic lettuce may be divided into four stages. Stage 1 is involved in germination and seedling emergence (one or two true leaves). Stage 2 is involved in early seedling growth up to four or five true leaves. Both stages occur in nursery or propagation areas with plants closely spaced, as in cubes of phenolic foam. Subsequently, individual plants are transferred to the hydroponic system such as troughs in which roots are continuously wetted by a flowing film of nutrient solution, the nutrient film technique (NFT) (Cooper, 1979). In such a system, the plants are closely spaced for Stage 3 [e.g., 3 × 3 inches (7.5 × 7.5 cm) for 3 weeks] then provided more spacing for Stage 4 [e.g., 6 × 6 inches (15 × 15 cm) for 4 weeks].

Lettuce emergence rate, seedling growth and head size were correlated positively with seed vigor (Smith et al., 1973). Wurr and Fellows (1983) confirmed that field-grown lettuce head mass variability was positively related to variability in seedling emergence time. Other recent work (Korkmaz et al., 1998) showed that shoot fresh mass of 'Cortina' lettuce at the end of stages 1 and 2 were inversely and linearly related to day of seedling emergence from phenolic foam cubes. This work showed further that seedling size at the end of

stage 2 was related positively to head weight and was related inversely to the coefficient of variation (cv) of head weight at the end of stage 4 (after 44 d culture in NFT). Thus, procedures that increase seedling shoot mass and reduce its variability during stages 1 and 2 will lessen the time to harvest of marketable heads and reduce the extent of plant culling. A commercial hydroponic lettuce grower (B. Cobb) reported that single sowings of high-quality pelleted seeds typically can result in 18% culling of small plants at the end of stage 2, 5% culling at the end of stage 3, and a further culling of ≈22% (largely due to low-weight heads) at the end of stage 4.

In hydroponic lettuce production, pelleted seeds typically are sown in phenolic foam cubes. However, there is an opportunity to sow germinated (pregerminated) seeds using the fluid drilling technique (Pill, 1995). Sowing quickly germinated seeds compared with raw or pelleted seeds resulted in the fastest and most synchronous emergence, and the heaviest and most uniform shoots at the end of stage 2 (Korkmaz et al., 1998).

Most reports suggest use of water during stage 1 of hydroponic lettuce production (Allison and McKay, 1987; Bres and Weston, 1992; Kratky, 1993; Schwarz, 1995). Knight and Mitchell (1987), however, reported using one-half strength Hoagland's solution during stage 1 hydroponic lettuce production. Korkmaz (1996) reported that soaking phenolic foam cubes in full-strength nutrient solution rather than water had no effect on emergence percentage, but increased emergence rate and synchrony, and increased the fresh mass and uniformity of lettuce shoots at the end of stage 2. The manufacturer of phenolic foam cubes recommends that the cubes be saturated with water before seeding, and that a regular feeding program should follow germination (Smithers-Oasis U.S.A., 1994).

Smithers-Oasis U.S.A. also recommends that seeds not be covered with media after their placement in the prepunched holes of the phenolic foam cubes. Korkmaz (1996), however, found that covering the pelleted lettuce seeds sown in these cubes with very fine vermiculite increased shoot fresh mass by 23% by the end of stage 1, but had no effect on emergence percentage, rate or synchrony, or the variability of shoot fresh mass.

The purpose of this study was to

determine whether various treatments could increase the mass and uniformity of hydroponic lettuce shoots during stages 1 and 2. Reported here are the effects of sowing raw, pelleted or germinated seeds in phenolic foam cubes, soaking the cubes in full-strength nutrient solution or water, and then either covering or not covering the seeds with fine vermiculite.

Materials and methods

STAGE 1. Phenolic foam cubes [LC-1 Horticultures, 0.9 inches (22 mm) square × 1.5 inches (37 mm) deep] arrive from the manufacturer (Smithers-Oasis U.S.A., Kent, Ohio) in sheets containing 338 cubes. The sheets were cut to provide 81 (9 × 9) cubes per experimental unit. The cubes were soaked either in water or full-strength nutrient solution. The nutrient solution was prepared from four salts: Hydrosol (5N-4.7P-22K; Grace-Sierra, Milpitas, Calif.), calcium nitrate, magnesium sulfate, and iron chelate (Sprint 330; Ciba-Geigy, Greensboro, N.C.) at 1.0, 1.0, 0.1, and 0.04 g·L⁻¹, respectively. This provided (in mg·L⁻¹) N 200, Ca 129, P 48, K 210, Mg 20, S 66, Fe 4, Mn 0.5, Zn 0.15, Cu 0.15, B 0.50, and Mo 0.10. Solution electrical conductivity was 2 mmho·cm⁻¹ (dS·m⁻¹) and pH was 5.9.

Seeds of 'Cortina' lettuce were acquired from Leen de Mos (Gravenzande, The Netherlands) in late 1997. Half of the seeds from this seedlot were pelleted commercially (Shamrock Seed Co., Salinas, Calif.). To produce germinated seeds for sowing, raw seeds were placed on a water-saturated double layer of germination paper (Seed Germination Blotter N. 385; Seedburo, Chicago) within a 14 × 9 × 2-inch (36 × 23 × 5-cm) plastic growth box that was then sealed with its transparent plastic dome (Stewart Plastics, Croydon, U.K.). Following 24 h in darkness at continuous 68 °F (20 °C), sufficient seeds had radicles 0.04 to 0.08 inches (1 to 2 mm) long. Single germinated, raw or pelleted seed were transferred with forceps to the central 0.3 inch (7.5 mm) diameter × 0.4 inch (10 mm) deep depression of each cube. The seeds either were left uncovered or were covered with fine vermiculite (Grade 5; W.R. Grace, Cambridge, Mass.) level with the cube surface. Thus, the study was a three (raw, germinated or pelleted seeds) × two (seeds covered or noncovered) × two (cubes soaked in water or nutrient solution) factorial with 81 seeds per treat-

ment within each of four replications.

The cubes, arranged on a mist bench as randomized complete blocks, received 10 s of mist every 6 min during daylight hours, with no supplemental irradiation (January). Seedling emergence (hypocotyl arch visible) was counted daily for 9 d, by which time emergence had ceased and the most advanced seedlings had fully expanded first true leaves (end of Stage 1). From these counts, final emergence percentage (emergence) and its angular transformation (arcsine $\sqrt{\text{emergence}}$), days to 50% emergence (E_{50}), and days between 10% and 90% emergence (E_{10-90}) were calculated. At 9 d after planting, the shoots from each plant in two adjacent rows of cubes were cut at the cube surface (maximum 18 shoots per treatment-replication combination), and their shoot fresh masses determined individually. Shoot fresh masses and their cv, emergence, E_{50} and E_{10-90} were subjected to analysis of variance (ANOVA).

STAGE 2. At 10 d after planting, the remaining phenolic cubes (63 per treatment-replication combination) were transferred, without separation of the

cubes, from the mist bench to a greenhouse bench lined with white polyethylene. The same randomized complete block arrangement used for stage 1 was retained. The lined bench was flooded with nutrient solution to 0.4 inch (1 cm) depth. The solution was replaced on alternate days. The greenhouse was maintained at an average 73/68 °F (23/19 °C, day/night) with 400 W high-pressure sodium lamps 79 inches (2 m) above the cubes, spaced 79 inches (2 m) apart.

At 31 d after sowing, 3 weeks after removal from the mist, the most advanced seedlings had reached the 4 to 5 true leaf stage (end of Stage 2). Each shoot was cut at the cube surface and weighed. The shoot fresh masses and associated cvs were subjected to ANOVA.

Results and discussion

STAGE 1. The influence of seed state and cultural practices on seedling emergence and shoot fresh masses and their cvs at 9 d after planting are shown in Table 1. Soaking the cubes in nutrient solution rather than water before seed sowing increased emergence (97

vs. 94) and increased shoot fresh mass by $\approx 100\%$. Raw and pelleted seeds had faster emergence (lower E_{50}) when cubes were soaked in nutrient solution rather than water. The E_{50} of germinated seeds, although lower than that of raw or pelleted seeds, was uninfluenced by cube soak solution. Thus, seed and cube treatments that increased seedling emergence rate also increased shoot fresh mass at 9 d after planting. Emergence synchrony was increased (lower E_{10-90}) by soaking the cubes in nutrient solution rather than water, and by sowing pelleted or germinated seeds rather than raw seeds. The similar ranking by treatments by E_{10-90} and cv of shoot fresh masses indicated that variability in emergence time was associated with variability in shoot fresh mass, as reported by Wurr and Fellows (1983).

Covering seeds with fine vermiculite increased shoot fresh mass but decreased the cv of shoot fresh mass only from raw seed. The significant interaction of soak solution with seed covering (Table 1) revealed that covering the seed increased shoot fresh mass from 12 to 15 mg/shoot when cubes were soaked in water, but had no effect when the

Table 1. Final emergence percentage (emergence) and its angular transformation, days to 50% of emergence (E_{50}), days between 10% and 90% of emergence (E_{10-90}), shoot fresh mass (SFM) and coefficient of variation (CV) of SFM at 9 d after sowing raw, germinated or pelleted 'Cortina' lettuce seeds, with or without covering the seeds with fine exfoliated vermiculite, into phenolic foam cubes preplant soaked in water or nutrient solution.

Cultural practice	Seed state	Emergence % (deg.)	E_{50} (d)	E_{10-90} (d)	SFM (mg/shoot)	SFM cv (%)
Cube soak						
Water	Raw	94 (77)	4.2	2.4	10	27
Pelleted		96 (80)	3.9	2.0	13	26
Germinated		95 (79)	2.9	1.7	16	20
Nutrient solution	Raw	97 (81)	3.5	2.0	22	22
Pelleted		97 (81)	3.6	1.2	26	20
Germinated		97 (82)	2.8	1.1	30	17
LSD _{0.05}		(4)	0.2	0.4	2	4
Seed covering						
Noncovered	Raw	99 (84)	3.8	1.4	13	29
Pelleted		99 (84)	3.5	1.2	18	23
Germinated		99 (87)	2.9	1.0	21	17
Covered	Raw	92 (74)	3.9	3.0	19	24
Pelleted		94 (77)	4.1	2.0	21	23
Germinated		92 (74)	2.8	1.8	25	14
LSD _{0.05}		(4)	0.2	0.4	2	4
Significance						
Water vs. nutrient solution (WNS)		*	***	***	***	**
Seed state (SS)		NS	***	**	***	**
WNS $\times$ SS		NS	*	***	*	*
Covered vs. noncovered seed (CNC)		***	***	***	**	*
WNS $\times$ CNC		NS	NS	NS	**	NS
SS $\times$ CNC		NS	**	**	***	*
WNS $\times$ SS $\times$ CNC		NS	NS	NS	NS	NS

ns,*,***,****Nonsignificant or significant at $P \leq 0.001$, 0.01, 0.05, respectively.

Table 2. Shoot fresh mass (SFM) and coefficient of variation (CV) of SFM at 31 d after sowing raw, germinated or pelleted 'Cortina' lettuce seeds, with or without covering the seeds with fine vermiculite, into phenolic foam cubes soaked in water or nutrient solution.

Treatment	Seed covering	SFM (mg/shoot)	SFM cv (%)
Cube soak			
Water	Noncovered	1182	33
	Covered	1773	26
Nutrient solution	Noncovered	2082	26
	Covered	2180	25
LSD _{0.05}		163	4
Seed state			
Raw		1616	29
Pelleted		1825	29
Germinated		1962	24
LSD _{0.05}		130	4
Significance			
Water or nutrient solution (WNS)		***	*
Seed state (SS)		***	*
WNS × SS		NS	NS
Covered or noncovered seed (CNC)		***	**
WNS × CNC		***	*
SS × CNC		NS	NS
WNS × SS × CNC		NS	NS

ns, ***, **** Nonsignificant or significant at $P \leq 0.001, 0.01, 0.05$, respectively.

cubes were soaked in nutrient solution (average 25 mg/shoot). The seed covering reduced emergence from 99 to 92, reduced emergence synchrony, and increased the E_{50} of raw and pelleted seeds, but had no effect on the E_{50} of germinated seeds. The covering increased postemergence seedling growth rate of raw and pelleted seeds since it delayed emergence and yet increased shoot fresh mass.

For pelleted seeds, preplant soaking of cubes in nutrient solution rather than water increased the fresh mass and uniformity of shoots, but covering them with vermiculite reduced emergence. For noncovered pelleted seeds, preplant soaking of cubes in nutrient solution rather than water increased shoot fresh mass by 50% and decreased the cv of shoot fresh mass by 71% (three-way interaction means). These responses may be attributed to increased emergence rate and synchrony, respectively. Seedling responses for germinated seeds were greatest when the seeds were covered with vermiculite and the blocks were soaked in nutrient solution. Covered germinated seeds sown in cubes soaked in nutrient solution had 150% greater shoot fresh mass and 36% lower cv of shoot fresh mass than noncovered germinated seeds sown in cubes soaked in water (three-way interaction means).

However, these benefits occurred at the expense of reduced emergence, from 99% to 94%.

In this study, seeds were germinated at 68 °F (20 °C). Earlier work (Korkmaz et al., 1998) showed that incubation at 50 °F (10 °C) spread germination over 2 d. Seeds germinated on the first day having greater vigor than those germinated on the second day. Thus, lowering the incubation temperature in the present study and selecting quickly (first day) germinated seeds may have led to even greater magnitude and uniformity of shoot fresh masses. Finch-Savage and McQuistan (1988) reported that seed selection on the basis of newly emerged radicles can be used to improve the seedlot vigor since germination rate and subsequent seedling performance are positively correlated.

STAGE 2. Shoot fresh mass and its cv following removal from the mist bench and subirrigation with nutrient solution for 3 weeks, to the end of stage 2, are shown in Table 2. As at the end of stage 1, greater shoot fresh mass at the end of stage 2 resulted from soaking cubes in nutrient solution rather than water. Covering the seeds increased shoot fresh mass when cubes were soaked in water, but had no effect when they were soaked in nutrient solution. The vermiculite covering over seeds sown in

water-soaked cubes decreased cv of shoot fresh mass, to a level similar to that achieved in nutrient solution-soaked cubes. The influence of seed treatment on shoot fresh mass at the end of stage 1 (Table 1) was retained to the end of stage 2, being in the order germinated > pelleted > raw (Table 2). Sowing germinated seeds rather than pelleted seeds increased shoot fresh mass by 8% and decreased cv of shoot fresh mass by 17% by the end of stage 2 (Table 2).

Gray (1976) noted that sowing germinated seeds rather than raw seeds resulted in greater head weight uniformity of field-produced lettuce at final harvest. Seeds are pelletized primarily to facilitate planting (Allison and McKay, 1987); however, equipment to fluid drill singulated and germinated seeds is available commercially (Pill, 1995).

Conclusions

Soaking phenolic foam cubes in nutrient solution rather than water before planting increased emergence rate, and increased shoot fresh mass by the end of stage 2. This increased shoot fresh mass was accompanied by decreased cv of shoot fresh mass by the end of stage 1, but not by the end of stage 2. Although covering seeds with vermiculite increased shoot fresh mass by the end of stage 1, this benefit was smaller than was achieved by soaking the cubes in nutrient solution. Sowing germinated seeds, compared with pelleted seeds, produced heavier and more uniform seedling shoots by the end of stage 2. Thus, sowing germinated seed and soaking cubes in nutrient solution would lessen production time and reduce the amount of culling necessary at the end of stage 2.

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Evaluating Leonardite as a Crop Growth Enhancer for Turnip and Mustard Greens

John R. Duval,¹

Frank J. Dainello,²

Vincent A. Haby,³ and

D. Ron Earhart⁴

ADDITIONAL INDEX WORDS. humic acid, humates, leonardite, soil fertility, mineral nutrition

SUMMARY. The objectives of this study were to determine if the use of leonardite as a fertilizer supplement improved crop growth and if there was a residual effect from previous applications. Three planting sequences were established and leonardite applied at 0, 50, 100, 200, and 400 lb/acre (0, 56.1, 112.1, 224.3 and 448.6 kg-ha⁻¹). Subplots were treated at the first, the first and second, or all at three planting sequences. 'Purple Top White Globe' turnip (*Brassica rapa* L.) and 'Florida Broadleaf' mustard greens (*Brassica hirta* L.) were used as the indicator crops in the first two and last sequences, respectively. No differences in plant growth were observed among number of applications or treatment rate. Differences in soil potassium and iron were observed.

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¹Former graduate student, Department of Horticultural Science, Texas A&M University, College Station TX, 77843. Current address: Department of Environmental Horticulture, University of Georgia, Athens GA, 30602.

²Professor and extension vegetable specialist, Department of Horticultural Science, Texas A&M University, College Station TX, 77843.

³Professor of soil and crop sciences, Texas Agricultural Experiment Station P.O. Drawer E, Overton TX, 75684.

⁴Senior research scientist, Texas Agricultural Experiment Station P.O. Drawer E, Overton TX, 75684.

The benefit of organic matter in soils is well known. Early agricultural systems relied on recycling plant residues and composting to increase soil fertility (Obrezza et al., 1988). As the world demand for food increases, practices that lead to increased yields on existing farm lands will continue to be important. Humates are reported to increase crop yields and reduce drought and high temperature stress (Russo and Berlyn, 1990). However, these compounds have not been researched extensively.

Humates occur in three chemical forms: humic acids, fulvic acids, and humins (Choudry, 1983). Humic acid is soluble in dilute alkaline solutions and is precipitated by acidification. Fulvic acid is the fraction that remains soluble after acidification, and cannot be precipitated. Humins are insoluble in dilute acid or base.

Commercial humate products are either mined or extracted from naturally occurring sources. Extracted humates are derived from peat moss, kelp and seaweed, from shale and oxidized coal (leonardite) deposits in Texas, Wyoming, New Mexico, North Dakota, Idaho, and Florida. The humic acid contents of these deposits usually range from 30% to 60%.

Hydroponic experiments have shown that when equal amounts of essential nutrients are supplied from humates or traditional sources, tomato (*Lycopersicon esculentum* Mill. 'Mountain Pride') seedlings grown with the nutrients supplied by humates outperform those receiving the same nutrient levels supplied by traditional sources (David et al., 1994). Conover and Poole (1979) suggested that the beneficial effects of humates in foliage plants could not be solely attributed to their fertilizer value.

Humates can have beneficial effects on plant growth by stimulating the plant to absorb greater quantities of nutrients and by inducing a more efficient use of the absorbed nutrients. Hydroponic experiments have shown that low concentrations of humic acids had a positive effect on nitrate and ammonium uptake in olive (*Olea europaea* L. 'Maurino') (Tattini et al., 1990). Potatoes (*Solanum tuberosum* L.) (Kunkel and Holstad, 1968) and teak (*Tectona grandis* L.f.) seedlings (Fagbenro and Agboola, 1993) have responded similarly to humic acid applications. Increased levels of phospho-