and McMurtry, 1971). All five concentrations of sodium hypochlorite tested produced axenic mites at all three treatment durations. There were no significant differences between treatments with respect to surface disinfestation of mites. No differences in mite disinfestation were observed with the different time and concentration treatments. However, the higher concentrations of sodium hypochlorite and longer time periods were more lethal to the mites.

A modified version of the slip-dip technique was used to confirm mortality levels. Highly significant differences in mite mortality were observed between time and concentration treatments. Significant differences were not observed in the interaction response. All three time periods differed from each other significantly (Table 1). As the time in the sodium hypochlorite concentrations increased from 5 to 15 min, mite mortality increased. A linear response was observed for time; as time increased mite mortality increased (Fig. 2). The percentage of mite survival also decreased as the sodium hypochlorite concentration increased from 0.05 to 0.25%. The concentration having 0.05% sodium hypochlorite differed significantly from the rest of the concentrations having the highest survival rate. A linear response was observed with concentration and survival; the higher the concentration of sodium hypochlorite, the higher the mite mortality (Fig. 3). Croughan and Quisenberry (1989) reported of similar relationships when working with fall armyworm (*Spodoptera frugiperda* J.E. Smith).

From the results of this study, we conclude that the concentration of 0.05% sodium hypochlorite and 0.05% Tween-20 for a time period of 5 min is adequate for surface sterilization of mites without causing excessive mortality of mites before they are introduced in vitro. The technique allows surface-disinfested mites to be introduced into culture. Once this is accomplished, plant material can be evaluated for resistance, thereby offering the ability to evaluate plant material in vitro and possibly reducing considerable time, space, and expense as opposed to a field evaluation.

Most of the progress in the area of plant resistance to insects has been due to conventional insect evaluation and plant breeding techniques. In the future, accurate and economical techniques of plant and insect evaluations developed from biotechnology will prove useful as molecular plant technologies are developed for use in crop protection. However, problems inherent in the development of resistant cultivars will most likely follow the development of resistant cultivars, whether by conventional or transgenic means. New techniques to identify plant resistance to insects using all available technologies will be a main element of future crop insect pest management systems.

Literature cited

Bussivine, J.R. 1980. Recommended methods of measurement of pest resistance to pesticides. FAO Plant Proc. Protec. Paper 21.

Croughan, S.S. and S.S. Quisenberry. 1989. Evaluation of cell cultures as a screening technique for determining fall armyworm (Lepidoptera: noctuidae) resistance in bermuda grass. J. Econ. Entomol. 82:232–235.

Hadi, M. and M.P. Bridgen. 1996. Somaclonal variation as a tool to develop pest resistant plants of *Torenia fournieri* 'Compacta Blue.' Plant Cell Tissue Organ Cult. 46:43–50.

Klein, R.M. and D.T. Klein. 1970. Research methods in plant science. Natural History Press, New York.

Kreider, J.W. 1968. Some practical aspects of the use of a laminar air-flow system for tissue culture manipulations. Appl. Microbiol. 16:1804–1805.

Murashige, T. and F. Skoog. 1962. A revised medium for rapid growth and bioassay with tobacco tissue culture. Physiol. Plant. 15:473–497.

SAS Institute, Inc. SAS/STAT users guide. release 6.03 ed. SAS Inst., Cary, N.C.

Scriven, G.T. and J.A. McMurtry. 1971. Quantitative production and processing of Tetranychid mites for large scale testing of predator production. J. Econ. Entomol. 64:1255–1257.

Voss, G. 1961. Ein neues akarizid-Austestungsverfaher fur spinnmilben. Anzeiger fuer Schaedlingskunde 34:76–77.

Walker, W.F., A.L. Boswell, and F.F. Smith. 1973. Resistance of spidermites to acaricides: Comparison of slip dip and leaf dip methods. J. Econ. Entomol. 66:549–50.

Seeding Uniformity of Precision Seeders

Regina P. Bracy and Richard L. Parish[1]

ADDITIONAL INDEX WORDS. seeding, seed metering, planters, cabbage, carrot, cucumber, onion, spinach

SUMMARY. Stanhay, Carraro, and Gaspardo precision vegetable seeders were evaluated for seeding uniformity with seeds of five vegetable crops—cabbage (*Brassica oleracea* L. Capitata group), carrot (*Daucus carota* L.), cucumber (*Cucumis sativus* L.), onion (*Allium cepa* L. Cepa group), and spinach (*Spinacia oleracea* L.). Five measurements [mean, percentage of misses, percentage of multiples, quality of feed, and precision (defined as the coefficient of variation after misses and multiples were discarded)] were used to evaluate seeder uniformity. Using all five measurements provided a more complete determination of the metering uniformity of the seeders than was possible in prior work when only mean and coefficient of variation were used. The belt seeder (Stanhay) was effective at singulating spherical seeds (cabbage) and nearly spherical seeds (onion)as the most precise vacuum seeder (Carraro). Seeding uniformity of all seeders with elongated (carrot and cucumber) or angular (spinach) seeds was inadequate for precision seeding.

Seed spacing uniformity is very important when direct-seeding vegetable crops. Plant spacing can affect growth and yield (Thornley, 1983; Willey and Heath,

[1]Associate Professor and Professor, Louisiana State University Agricultural Center, Louisiana Agricultural Experiment Station, Hammond Research Station, 21549 Old Covington Highway, Hammond, LA 70403.

Approved by the director of the Louisiana Agricultural Experiment Station as manuscript number 97-68-0185. Use of trade names does not imply endorsement of the products named nor criticism of similar ones not named. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

1969), and plant spacing uniformity begins with seed spacing uniformity. Quantifying seed spacing uniformity is challenging, and a number of measures including mean and standard deviation of spacing between plants, percent of multiples and misses, and scores based on indexed values have been used (Kachman and Smith, 1995).

Kachman and Smith (1995) compared alternative measures of accuracy in seed placement for planters and, based on the theoretical seed spacing, recommended using four measures for evaluating seeding uniformity. Their recommended measures (based on International Organization for Standardization, 1984) included multiple index (MULT), miss index (MISS), quality of feed index (QFI), and precision (PREC). MULT indicated multiple seed drops and was the percentage of seed spacings that were less than or equal to one-half of the theoretical seed spacing. MISS indicated missed seed locations or skips and was the percentage of spacings >1.5 times the theoretical spacing. QFI indicated single seed drops and was the percentage of spacings that were more than half but no more than 1.5 times the theoretical spacing. QFI was an alternative way of presenting the information contained in MISS and MULT. PREC was the coefficient of variation of the spacings after omitting the missed and multiple seed drops (outliers). PREC was a measure of the uniformity of spacings classified as singles, whereas MULT, MISS, and QFI were measures of singulation or lack thereof. A more complete discussion of these terms and examples of calculations are given by Kachman and Smith (1995).

Although the mean and CV have been used in research publications to describe spacing uniformity (Bracy et al., 1993, 1995; Hudspeth and Wanjura, 1970; Parish, 1972; Parish et al., 1991; Wilkins et al., 1992), Kachman and Smith (1995) judged the mean and CV as inappropriate measures of seeder accuracy. The mean does not reflect variation in spacing, and CV does not identify the types of nonuniformity (e.g., misses, multiples, or nonuniform basic spacing).

Parish et al. (1991) used the mean and CV to quantify the uniformity of seed spacing of belt and vacuum precision seeders in the laboratory. Parish et al. (1991) reported that a belt-type seeder resulted in the most uniform seed spacing of spherical seed (cabbage), but spacing of elongated seeds (cucumber) was more uniform with a vacuum seeder.

The objective of this study was to evaluate the seeding accuracy (singulation and spacing uniformity) of three precision seeders (previously reported by Parish et al., 1991) using the measures of accuracy as described by Kachman and Smith (1995).

Materials and methods

Spacing measurements of five vegetable crops (cabbage, onion, spinach, carrot, and cucumber) from three seeders (belt-type Stanhay model S870, Hestair Farm Equipment, Suffolk, England; vacuum-type Carraro model Omega Mark 4, Carraro, Campodarsego, Italy; and vacuum-type Gaspardo SV255, Gaspardo, Pordenone, Italy) were used in this study. The seeders were operated over a 20-ft (6-m) greased board at a ground speed of 1.5 mph (2.4 $km \cdot h^{-1}$) with seed spacing measurements recorded over a center distance of 10 ft (3 m). The board was coated with grease to prevent seed bouncing and to retain exact placement of the seed. Seed spacings from four replications of each combination of seeder and seed were recorded.

The seed spacings were analyzed using the methods (MULT, MISS, QFI, and PREC) described by Kachman and Smith (1995). Acceptable QFI values with precision seeders were established at ≥85%, indicating that ≥85 of every 100 drops were singulated seed. Researchers have indicated that >95% accuracy with agronomic planters, indicating the metering accuracy (ACCU) to be within 5% of the theoretical seeding population (Bateman, 1972; Halderson, 1983; Synder and Hummel, 1985). ACCU, like the mean, indicates total seed metering but does not measure singulation. Precision seeders for vegetables should have at least as much, if not more, accuracy as typical agronomic planters (Parish, 1972).

Kachman and Smith (1995) reported a practical upper limit of 29% for the value of PREC, since a 29% value would be obtained with any random scattering of seeds within the target range. An acceptable PREC for seed measurements taken in the lab should fall below 10%, which would mean that the standard deviation of spacings within the target region would be ≤10% of the theoretical spacing.

Although not considered a valid measure of uniformity by Kachman and Smith (1995), the mean is the only measure that a grower has to readily determine seeder performance. It was included to illustrate fallibility of the typical seeder calibration checks (catching the seed while the drive tire is rotated) for determining seeding uniformity of the seeder.

MISS, MULT, QFI, and PREC were analyzed using the GLM statistical procedure and the mean was calculated using PROC MEAN procedure (SAS, 1995).

Results and discussion

Cabbage. The Stanhay and Carraro seeders had an equivalent number (15% and 13%, respectively) of MISS, but no multiple drops were recorded with the Stanhay compared with 13% with the Carraro and 16% with the Gaspardo (Table 1). A significantly higher number of MISS was recorded with the Gaspardo (39%) than with the other seeders. Because seeding uniformity of cabbage seed was good with the Stanhay and Carraro seeders, the mean was very close to theoretical spacing for these two seeders. The QFI values with the Stanhay and Carraro (85% and 74%, respectively) were higher than with the Gaspardo (45%), indicating better singulation with the Stanhay and Carraro.

The seed spacing uniformity of cabbage within the target region (after misses and multiples were removed) was more uniform with the Stanhay, as indicated by 7% PREC compared with 21% PREC obtained with the Carraro. The belt seeder (Stanhay) metered cabbage seed more uniformly than either of the vacuum seeders (based on the low percentage of MISS, no multiple seed drops, and higher PREC). Since cabbage seed was the most spherical seed used in this study, seed spacing uniformity was expected to be better than for the other vegetable seed (Parish et al., 1991). If uniformity of the seeders was not good with cabbage seed, better seeding uniformity was not expected with the other less spherical seeds.

Onion. The QFI with the Stanhay (85%) was similar to the Carraro (76%) but significantly higher than with the Gaspardo (34%) (Table 1). The Stanhay had a higher percentage of MISS than the Carraro, but multiple seed drops were nil with the Stanhay. PREC with the Stanhay (8%) was significantly lower than with either vacuum seeder (21%), indicating good seed spacing uniformity within the target area. Mean values were less than theoretical seed spacing with the Carraro and greater than theoretical with the Stanhay and the Gaspardo seeders. Since the onion seed was nearly spherical but angular, seeder uniformity was expected to be better with the vacuum seeders than with the belt seeder (Parish et al., 1991); but results here indicate that better seeding uniformity occurred with the belt seeder.

SPINACH. Even though the spinach seed was non-spherical and angular, the percentage of missing seed (MISS) was low with the Stanhay and Carraro, and the percentage of MULT was equivalent with all three seeders (Table 1). QFI ranged from 71% for the Gaspardo to 88% for the Carraro. The mean was close to the theoretical spacings for all seeders. Seed spacing uniformity within the target range (PREC) was unacceptable with all seeders (≥17%).

CARROT. Seeding uniformity was poor with all seeders when seeding elongated carrot seed (Table 1). MISS was no greater than 11% for all seeders, but the lowest percentage of MISS was recorded with the Stanhay (1%) and Gaspardo (6%). All of the seeders had a high number of multiples, but the Stanhay seeder had a greater percentage of MULT than the vacuum seeders. The excessive multiples with the Stanhay were due to using round holes in the seed belt to meter elongated seed. Selecting a hole size to accommodate the long dimension of the elongated seeds resulted in multiple seeds per drop. Although significant differences occurred in the QFI among seeders, QFI values (≤52%) were too low to be acceptable for precision seeders. Spacing within the target range (PREC) was better for the Stanhay than for the vacuum seeders but unacceptable with all seeders (≥18%). The performance of the two vacuum seeders with carrot seed was similar except for a higher QFI with the Gaspardo. The mean was considerably less than the theoretical spacing with all seeders.

CUCUMBER. Seeding uniformity of flat, elongated cucumber seed and elongated carrot seed was similar. Percentage of MISS was low and percentage of MULT was high with the vacuum seeders. Because multiple elongated seeds filled each round hole in the metering belt, the percentage of MULT was very high with the Stanhay. QFI was better with the vacuum seeders than with the belt seeder, but no QFI was as high as would be desired with precision seeders. Although the Stanhay spaced seed within the target area better than the vacuum seeders, PREC was unacceptable for all seeders. Due to the large number of multiple seed drops, the mean was less than theoretical for all seeders.

These results augmented results in an earlier study by Parish et al. (1991), who relied on the mean and cv to analyze seeding uniformity. Parish et al. (1991) reported that the Stanhay belt seeder seeded spherical seed (cabbage) more uniformly than the vacuum seeders, but the seeding uniformity of vacuum seeders was greater than the belt seeder for elongated cucumber seed. No difference in seeding uniformity of carrot was discerned among seeders. Results were mixed on the seeder uniformity with onion and spinach. Using the criterion proposed by Kachman and Smith (1995), a more discriminating analysis was possible, and areas of nonuniformity were identified.

Price and Taylor (1994) reported that snap bean seedling emergence revealed a large tendency for the

Table 1. Seeding uniformity of three precision seeders with five vegetable seeds.

Seed type and seeder	Theoretical spacing inches (mm)	Measures[z]				
		Mean inches (mm)	MISS (%)	MULT (%)	QFI (%)	PREC (%)
Cabbage						
Stanhay	3.5 (89)	3.7 (94)	15 b[y]	0 b	85 a	7 c
Carraro	2.4 (61)	2.4 (60)	13 b	13 a	74 a	21 b
Gaspardo	3.5 (88)	4.5 (114)	39 a	16 a	45 b	26 a
Onion						
Stanhay	3.1 (79)	1.9 (49)	15 b	0 b	85 a	8 b
Carraro	3.1 (79)	1.9 (49)	5 c	19 a	76 a	21 a
Gaspardo	3.0 (77)	3.5 (88)	50 a	16 a	34 b	21 a
Spinach						
Stanhay	1.6 (41)	1.3 (34)	7 b	16 a	77 ab	17 b
Carraro	1.9 (48)	1.6 (42)	2 b	11 a	88 a	17 b
Gaspardo	3.0 (77)	3.2 (80)	16 a	14 a	71 b	23 a
Carrot						
Stanhay	1.9 (48)	0.6 (14)	1 b	79 a	20 c	18 b
Carraro	1.9 (48)	1.3 (33)	11 a	48 b	41 b	26 a
Gaspardo	1.9 (48)	1.1 (29)	6 ab	41 b	52 a	25 a
Cucumber						
Stanhay	12.0 (305)	4.4 (112)	1 b	65 a	34 b	13 b
Carraro	6.0 (152)	5.0 (128)	4 ab	19 b	77 a	19 a
Gaspardo	6.0 (152)	5.6 (141)	11 a	19 b	69 a	23 a

[z]MISS = missed seed locations (skips), MULT = multiple seed drops, QFI = quality of feed index (single seed drops), PREC = precision (variation of the spacings within target range).
[y]Means within a group followed by same letter are not significantly different at $P = 0.05$ by Duncan's multiple range test.

vacuum seeders tested to drop multiple seeds, with less errors made in the form of misses or skips. Visual observation by the authors of the vacuum plates during operation of the vacuum seeders indicated that the seed was being singulated with few misses and multiples. The loss in uniformity must have occurred as the plate rotated down to the release point, with seed not being released or being released erratically, resulting in nonuniform spacing. Further testing must be done to pinpoint where precision is being lost with the vacuum seeders.

Conclusions

The Stanhay belt seeder uniformly seeded spherical (cabbage) and nearly spherical (onion) seeds but could not singulate elongated seeds (carrot and cucumber) as well as the vacuum seeders. Although the vacuum seeders singulated elongated seed better than the belt seeder, none of the seeders singulated or spaced cucumber and carrot seed adequately. Seeding uniformity of all seeders with spinach seed was also insufficient.

The belt seeder had the lowest PREC value with all seeds tested, indicating that the belt seeder was more effective than the vacuum seeders at spacing the seeds uniformly within the target area when outliers were removed. Evaluating the data using Kachman and Smith's (1995) criteria cast doubt on our previous assumptions that vacuum seeders were effective at seed singulation and precision seed spacing.

Overall, the belt seeder was the most uniform and precise of the seeders tested. Seeding uniformity of the belt seeder was good when seeding spherical and nearly spherical seed. When seeding elongated or angular seeds with the belt seeder, multiple seed drops and reduced seed spacing uniformity should be expected.

Literature cited

Bateman, H.P. 1972. Planter metering, soil and plant factors affecting corn ear populations. Trans. Amer. Soc. Agr. Eng. 5:1013–1020.

Bracy, R.P., R.L. Parish, P.E. Bergeron, E.B. Moser, and R.J. Constantin. 1993. Planting cabbage to a stand with precision seeding. HortScience 28:179–181.

Bracy, R.P., R.L. Parish, and E.B. Moser. 1995. Planting cauliflower to a stand with precision seeding. HortScience 30:484–486.

Halderson, J.L. 1983. Planter selection accuracy for edible beans. Trans. Amer. Soc. Agr. Eng. 26:367–371.

Hudspeth, E.B. and D.F. Wanjura. 1970. A planter for precision depth and placement of cottonseed. Trans. Amer. Soc. Agr. Eng. 13:153–154.

International Organization for Standardization. 1984. Sowing equipment—Test methods—Part 1: Single seed drills (precision drills). 7256/1.

Kachman, S.D. and J.A. Smith. 1995. Alternative measures of accuracy in plant spacing for planters using single seed metering. Trans. Amer. Soc. Agr. Eng. 38:379–387.

Parish, R.L. 1972. Development of a narrow-row, vertical-plate planter. Trans. Amer. Soc. Agr. Eng. 15:636–637.

Parish, R.L., P.E. Bergeron, and R.P. Bracy. 1991. Comparison of vacuum and belt seeders for vegetable planting. Appl. Eng. 7:537–540.

Price, H.C. and A.G. Taylor. 1994. Precision seeding studies on snap beans. HortScience 29:485 (Abstr.)

SAS. 1995. SAS system for windows, release 6.11. SAS Inst., Cary, N.C.

Snyder, K.A. and J.W. Hummel. 1985. Low pressure air jet seed selection for planters. Trans. Amer. Soc. Agr. Eng. 28:6–10.

Thornley, J.H.M. 1983. Crop yield and planting density. Ann. Bot. 52:257–259.

Wilkins, D.E., F. Bolton, and K. Saxton. 1992. Evaluating seeders for conservation tillage production of peas. Trans. Amer. Soc. Agr. Eng. 8:165–170.

Willey, R.W. and S.B. Heath. 1969. The quantitative relationships between plant population and crop yield. Adv. Agron. 21:281–321.

Evaluating Biorational Pesticides for Controlling Arthropod Pests and their Phytotoxic Effects on Greenhouse Crops

Fredric Miller[1] and

Susan Uetz[2]

Additional index words. greenhouse pests, horticultural oils, insecticidal soap, neem extract (Margosan-O and Azatin), phytotoxicity, plant growth

Summary. Horticultural oil and insecticidal soap were as effective as conventional insecticides and miticides in controlling a variety of sap-feeding insects and mites on common greenhouse crops. Neem extract (Margosan-O or Azatin) was less consistent and provided intermediate to good control of a variety of sap-feeding insects and mites on common greenhouse crops. Except for purple heart (*Setcreasea purpurea* K. Schum. & Sydow) and wax ivy (*Hoya carnosa* R. Br.), repetitive sprays of horticultural oil, insecticidal soap, and neem extract (Azatin) did not seem to cause any noticeable phytotoxicity or effect the growth of 52 species or cultivars of bedding plants and 13 species of foliage plants examined in this study. Repetitive sprays of horticultural oil and insecticidal soap significantly affected plant height and final quality of some poinsettia cultivars evaluated in this study.

[1]Extension educator, Urban IPM, University of Illinois, Countryside Extension Center, Countryside, IL 60525.

[2]Research assistant, The Morton Arboretum, 4100 Route 53, Lisle, IL 60532.

Mention of a proprietary product does not constitute an endorsement or a recommendation for its use by the Univ. of Illinois Cooperative Extension Service or by the USDA. We thank B. Corr, Ball Seed Co., and A. Spomer, Univ. of Illinois, for their helpful review of an earlier draft of this manuscript. Special thanks to J. Granrath, E. Britt, J. Fitzpatrick-Cooper, and J. Burkholzer, Dept. of Horticulture, College of DuPage, and P. Lisner, the Morton Arboretum, for providing greenhouse space, plant material, and consultation. A personal note of gratitude is extended to M. Miller for her support in all aspects of this project. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.