Turtle' x 'Pinto' F_2 (χ^2 = 1.81) and 73:17 for the 'Pinto' x 'Black Turtle' F_2 (χ^2 = 1.79). Chi-square tests indicated no significant deviation from the expected 3:1 ratio and Chi-square tests for heterogeneity (0.38 for BT1 and 0.04 for P1) also were nonsignificant.

The presence of both BT1 and P1 in the F_1 progeny of the 'Black Turtle' x 'Pinto' crosses and the 3:1 segregation in the F_2 progeny suggests: 1) that each band is under the control of a single, dominant Mendelian gene; 2) that the loci for these genes are unlinked; and 3) that the parental cultivars are homozygous for their respective bands. In addition, the absence of segregation differences between the F_2 reciprocal families suggests no maternal influences with regard to BT1 and P1. The simple extraction procedure used was adequate for this study.

Literature Cited

1. Bliss, F.A. and J.W.S. Brown. 1982. Genetic control of phaseolin protein expression in seeds of common bean, *Phaseolus vulgaris* L. Qual. Plant. Plant Foods Hum. Nutr. 31:269–279.
2. Brown, J.W.S., J.R. McFerson, F.A. Bliss, and T.C. Hall. 1982. Genetic divergence among commercial classes of *Phaseolus vulgaris* in relation to phaseolin pattern. HortScience 17(5):752–754.
3. Brown, J.W.S., T.C. Osborn, F.A. Bliss, and T.C. Hall. 1982. Bean lectins. Part 1: Relationships between agglutinating activity and electrophoretic variation in the lectin-containing G2/albumin seed proteins of French bean (*Phaseolus vulgaris* L.). Theor. Appl. Genet. 62:263–271.
4. Buishand, T.J. 1956. The crossing of beans (*Phaseolus* spp.). Euphytica 5:41–50.
5. Fairbanks, G., T.L. Steck, and D.F.H. Wallach. 1971. Electrophoretic analysis of the major polypeptides of the human erythrocyte membrane. Biochemistry 10:2606–2617.
6. Juo, P. and G. Stotzky. 1970. Changes in protein spectra of bean seed during germination. Can. J. Bot. 48:1347–1350.
7. Laemmli, U.K. 1970. Cleavage of structural proteins during assembly of the head of bacteriophage T4. Nature 227:680–685.
8. Ma, Y. and F.A. Bliss. 1978. Seed proteins of the common bean. Crop Sci. 18:431–437.

HortScience 19(6):866–868. 1984.

Propagation Methods Influence Asparagus Transplant Quality and Seedling Growth

Robert J. Dufault[1] and Luther Waters, Jr.[2]

Department of Horticultural Science and Landscape Architecture, University of Minnesota, St. Paul, MN 55108

Additional index words. *Asparagus officinalis*, crown, bud, container, media, bareroot

Abstract. **In 3 separate experiments, the effects of container types, transplant age, and growing media on asparagus (*Asparagus officinalis* L.) transplant quality were determined. These transplants then were field planted to determine the effects of propagation methods on plant growth after one growing season. Transplants grown for 10 weeks in deep peat pots (10 cm deep, 177 cm^3, and 364 plants/m^2) produced crowns and fern of higher fresh and dry weight than other containers (ranging in depth from 5.5 to 7.6 cm, in volume from 53 to 186 cm^3, and plant density/m^2 from 277 to 1624). Shoot and root growth of 7-, 8.5-, and 10-week-old transplants (grown in identical containers) were similar, but crown fresh and dry weight were reduced for 6-week-old transplants. Ten-week-old transplants originally broadcast-seeded in flats of 1 vermiculite: 1 peat medium (v:v) produced more roots, buds, shoots and fern and crowns of greater fresh and dry weight than those grown in 1 peat : 1 perlite or 1 perlite : 1 vermiculite media. At the end of the growing season, plants originally grown in deep peat pots were superior in number of shoots and fleshy roots, and crown and fern dry weight to those grown in other container types, to transplants of various ages, and to bareroot transplants.**

Traditionally, new asparagus acreage is established using one-year-old nursery grown crowns. Since the digging of crowns and replant operations require a high labor input (4), the use of 10- to 12-week-old transplants reduces costs. Other benefits associated with transplant use are reduced seed usage (3), improved stands (6), reduced disease (3) and yield potential equivalent to crowns (4, 7).

Various methods of propagating asparagus transplants have been described. Containers constructed of plastic (1, 6), peat (7), and paper (7), differing in depth, volume, and plant density/m^2 have been evaluated. Container size had been found to influence transplant growth in previous studies. Increasing container volume increased shoot and root dry weight and the number of buds, but intensifying plant density/m^2 had no effect on these variables (2). Container depths less than 7.5 cm restricted transplant growth rates (3). Benson and Fisher (2) reported that transplants grown in cylindrical containers had higher shoot dry weight and more roots and shoots than those grown in inverted pyramidal containers. The types of media used in previous research included mixtures of 1 peat : 1 sand : 1 vermiculite (2, 6) and 1 peat : 1 sand (3). Age of transplants ranged from 8- to 10 weeks (1), 9-weeks (3), and 9- to 12-weeks (6).

In this study, container type, growing media, and transplant age were evaluated in 3 separate experiments. Our objectives were to determine the influence of container type, growing media, and transplant age on transplant quality. In a 4th experiment, the transplants grown by these different methods were field planted to determine any differences in plant growth related to transplanting method(s).

Expt. 1. Effect of container types on transplant quality. Five container types, differing in volume, depth, and plant density/m^2, were evaluated (Table 1). 'Green Giant Select' asparagus seeds were germinated in moist, standard-weight, paper germination towels in a 25°C incubator. After 5 days, the containers were filled with a 1.5 vermiculite : 1.5 perlite : 7 peat (v:v:v) (pH 6.7) (Sunshine Mix Basic Blend No. 2, Western Peat Moss LTD, Vancouver, B.C.) and the germinated seeds were immediately sown. The transplants were watered daily with tap water and fertilized 1, 4, 8, and 10 weeks after seeding with a solution of 42N–14P–14K mg/liter of H_20. The plants were grown for 10

Table 1. Size characteristics of container types use to evaluate asparagus transplant quality.

Container type	Depth (cm)	Volume (cm^3)	Density (plants/m^2)
Paper pot[z]	7.6	53.0	1624
Rose tube[y]	7.0	77.2	796
Cell pack[x]	5.5	163.4	416
Deep peat pot[w]	10.0	177.0	364
Shallow peat pot[w]	5.5	186.1	277

[z]Cylinders constructed of biodegradable paper, style BS208, Lännen Co., Finland.
[y]Plastic cones, style No. 72, TLC Polyform Inc., Minn., MN.
[x]Plastic rectangles, style No. 606, Brighton Inc., New Brighton, PA.
[w]Constructed of sphagnum peat moss (70%) and wood fiber (30%).

Received for publication 3 Jan. 1984. Journal article no. 13,512 of the Minnesota Agricultural Experiment Station. Partial financial assistance was provided by the Governor's Council for Rural Development. The authors wish to thank David Bedford, Horticulture Research Center., Univ. of Minnesota, Excelsior, for growing the plant material in this study.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.

[1]Present address: Assistant Professor, Texas A&M Univ., Agricultural Research and Extension Center, 2415 East Hwy 83, Weslaco, TX 78596.
[2]Associate Professor.

Table 2. Influence of container type on transplant quality of 10-week-old asparagus.

Container type[z]	Shoot no.	Fern wt/plant (g)		Root no.	Bud no.	Crown wt (g)	
		Fresh	Dry			Fresh	Dry
Paper pot	1.9 c[y]	0.18 c	0.04 c	3.5 b	1.3 a	0.51 c	0.09 d
Rose tube	2.3 c	0.19 c	0.04 c	4.3 b	1.3 a	0.75 b	0.15 bc
Cell pack	2.1 c	0.17 c	0.04 c	3.8 b	1.5 a	0.54 c	0.11 cd
Deep peat pot	4.3 a	1.15 a	0.25 a	5.5 a	1.6 a	1.23 a	0.21 a
Shallow peat pot	3.1 b	0.64 b	0.14 b	6.3 a	2.3 a	0.91 b	0.16 b

[z]All container types grown in a media mixture of 1.5 vermiculite : 1.5 perlite : 7 peat.
[y]Mean separation within columns by Duncan's multiple range test, 5% level.

weeks in a greenhouse maintained at 24°/18° ± 3°C (day/night) from March through May of 1982.

Expt. 2. Effect of transplant age on asparagus transplant quality. Germinated seeds were sown in cell packs (Table 1) on 5, 15, 25 April and 4 May 1982, using the same medium as in Expt. 1. Greenhouse environment, watering, and fertilization practices were the same as in Expt. 1. At the time the plants were field planted and growth measurements had been taken, 10, 8.5, 7, and 6 weeks had passed since seeding, respectively.

Expt. 3. Effect of growing media on transplant quality. Three media were evaluated: a) 1 vermiculite : 1 peat (v:v), b) 1 peat : 1 perlite (v:v), and c) 1 perlite : 1 vermiculite (v:v). These media were placed into 45 × 25 × 8 cm metal flats. Germinated seeds (150) were planted into the media about 2 cm deep at a density of 1300 seeds/m^2 and were grown under the same conditions as in the Expt. 1.

Before transplanting, asparagus transplant shoot and crown growth measurements were taken from 40 plants (10 plants/rep) selected from each propagation method. The transplants in Expt. 1 and 3 were 10-weeks-old at data collection. In this study, "crown" included rhizome, buds, and fleshy and fibrous roots; "fern" included stems and cladophylls.

Expt. 4. Influence of propagation methods on seedling growth in the field. The 5 container types in Expt. 1, 4 transplant ages in Expt. 3, and the 3 media treatments in Expt. 2 were evaluated for field performance. Plants from media treatments were pulled by hand and planted as bareroot transplants. One week prior to field planting, all transplants were acclimatized in a lath house. On 4 June, 15 plants from each of the 12 treatments tested in Experiments 1, 2, and 3 were field planted in a randomized complete block design, in 4 replications, at the Horticulture Research Center, Excelsior. The plants were transplanted on level ground and were spaced 0.3 cm apart within single rows spaced 0.9 m apart. About 120 ml of a starter solution containing 54N–270P–90K mg/liter of H_20 were added to each plant at transplanting. The soil texture was a clay loam with 3.4% organic matter and a pH of 7.0. Prior to transplanting, 11N–14P–40K kg/ha were broadcasted and disked, followed by an application of linuron at 2.2 kg/ha. Sprinkler irrigation was applied when needed.

In mid-September, 5 randomly selected plants from each replication were dug by hand, thoroughly washed, and growth measurements were determined.

Effect of container type on transplant quality. Asparagus transplants grown in deep peat pots (DP) had more shoots with fern and crowns of higher fresh and dry weight than shallow peat pots (SP), paper pots (PP), rose tubes (RT), and cell packs (CP) (Table 2). Fleshy root production was similar between DP and SP transplants, but PP, RT, and CP transplants had fewer fleshy roots in comparison. Bud production did not differ among any of the containers. SP transplants had fewer shoots and lower fern fresh and dry wt than DP transplants, yet the shoot growth of SP transplants was higher in comparison to PP, RT, and CP transplants. Shoot number, and fern fresh and dry weight were equivalent among PP, RT, and CP transplants.

Stepwise regression analysis indicated the best models describing the effects of container volume, depth, and plant density on plant growth (Table 3). A substantial portion of the variation (R^2) in shoot growth could be assigned to container volume and depth, but not to plant density. As volume and depth increased, shoot number and fresh and dry fern weight increased. Crown growth models, however, accounted for reduced variation. About half the variation in fleshy root production was assigned to container volume; as volume increased, root number increased. Bud production was influenced minimally by container volume. About 56% to 66% of the variation in crown fresh and dry weight was due to container depth and density; as depth increased, these weights increased. Increasing density decreased crown fresh and dry weight. This evidence suggests that the "ideal" container to enhance asparagus transplant growth should be deep, of large volume and have low plant densities. The depth, density, and large volume of DP containers partially explained their superiority over other containers. Other explanations for enhanced growth in deep peat pots may relate to nutrient and moisture relationships. Peat containers permit water and oxygen to enter from all sides; however, essential growth factors only can enter through the tops of nonporous containers. As water moves out of porous containers, soluble salts move with water and are deposited and retained within the container's walls; however, nutrients in nonporous containers are lost due to leaching (5). The enhancement of growth in DP may be due to nutritional effects, to spatial effects, and to minimal damage to root systems, promoting uninterrupted growth.

Effect of transplant age on transplant quality. Transplants 8.5-week-old (8W) produced more shoots than those 6-(6W) and 7-weeks-old (7W) (Table 4); however, shoot production was similar between transplants 8W to 10-weeks-old (10W). Fern fresh weight of 8W was higher than that of all others, with 7W and 10W intermediate and 6W lower in comparison to 8W. Fern dry weight and root and bud numbers were unaffected by transplant age. Even though the crown fresh weights of 7W and 8W were similar, the 8W crowns weighed more than the 10W. The crown fresh and dry weight of 6W were lower than those 7W to 10W. These data suggested that 6W plants generally were less vigorous and of lower quality than older transplants. Using transplants ranging in age from 7W to 8W showed as much commercial potential as the conventional 10W transplant.

Effect of growth media on transplant quality. Transplants grown in vermiculite + peat medium (VP) produced more shoots, roots and buds and fern and crowns of greater fresh and dry weight than those grown in either peat + perlite (PP) or perlite + vermiculite (PV) media (Table 5). Bud and root production in PV and PP media were similar.

Influence of propagation methods on seedling growth in the field. In the 3 separate experiments described, transplants grown in DP containers, as 7W to 10W transplants, or in a VP medium enhanced transplant growth and quality. Thus, it was important to ascertain if any propagation method would continue to enhance growth even after field planting.

The growth superiority of DP transplants at transplanting was still evident by the end of the 1st growing season. The number of shoots and fleshy roots, fern dry weight and

Table 3. Models describing the relationship among container volume, depth and plant density/m^2 on the growth of 10 week-old asparagus transplants.[z]

Variable	Model	R^{2y}	Probability[x]
Shoot no.	$\hat{Y} = -1.61 + 0.01$ volume $+ 0.40$ depth	0.46	0.0001
Root no.	$\hat{Y} = 2.89 + 0.01$ volume	0.24	0.0001
Bud no.	$\hat{Y} = 1.02 + 0.004$ volume	0.07	0.04
Shoot fresh wt	$\hat{Y} = -1.52 + 0.005$ volume $+ 0.19$ depth	0.57	0.0001
Shoot dry wt	$\hat{Y} = -0.33 + 0.001$ volume $+ 0.04$ depth	0.56	0.0001
Crown fresh wt	$\hat{Y} = 0.14 - 0.004$ density $+ 0.13$ depth	0.44	0.0001
Crown dry wt	$\hat{Y} = 0.05 - 0.0001$ density $+ 0.02$ depth	0.31	0.0001

[z]Derived from stepwise regression analysis.
[y]Coefficient of determination.
[x]Probability that computed F value is greater than the tabled F value.

Table 4. Influence of transplant age on asparagus transplant quality.[z]

Age (weeks)	Shoot no.	Fern wt/plant Fresh	Fern wt/plant Dry	Root no.	Bud no.	Crown wt (g) Fresh	Crown wt (g) Dry
6	1.5 c[y]	0.09 c	0.03 a	2.5 a	0.8 a	0.21 c	0.04 b
7	1.6 bc	0.12 b	0.02 a	2.8 a	0.8 a	0.41 ab	0.08 a
8.5	2.1 a	0.14 a	0.03 a	3.2 a	0.9 a	0.50 a	0.09 a
10	2.0 ab	0.10 bc	0.02 a	3.1 a	1.1 a	0.39 b	0.08 a

[z]All transplants grown in plastic cell packs (5.5 cm deep, 163.4 cm^3 and 416 plants/m^2) using a media mixture of 1.5 vermiculite : 1.5 perlite : 7 peat.
[y]Mean separation within columns by Duncan's multiple range test at 5% level.

Table 5. Influence of growing media on transplant quality of 10-week-old asparagus.

Media[z]	Shoot no.	Fern wt (g) Fresh	Fern wt (g) Dry	Root no.	Bud no.	Crown wt (g) Fresh	Crown wt (g) Dry
Vermiculite + peat	3.4 a[y]	0.84 a	0.21 a	4.9 a	2.2 a	0.79 a	0.14 a
Peat + perlite	2.3 b	0.16 b	0.05 b	3.5 b	1.0 b	0.41 b	0.09 b
Perlite + vermiculite	1.9 b	0.16 b	0.04 b	3.0 b	1.0 b	0.46 b	0.10 b

[z]All media components in a 1:1 (v/v) ratio. Transplants grown in flats (45 × 25 × 8 cm) at a density of 1300 seeds/m^2.
[y]Mean separation within columns by Duncan's multiple range test at 5% level.

Table 6. Influence of propagation methods on asparagus seedling growth at the end of the first season after transplanting.[z]

Propagation method	Shoot no.	Fern wt/plant (g) Fresh	Fern wt/plant (g) Dry	Root no.	Bud no.	Crown wt (g) Fresh	Crown wt (g) Dry
Container[y,x]							
Paper pot	10.1 b[w]	82 bcd	15 bc	35 bcd	18 a	58 bc	7.7 b
Rose tube	13.0 b	95 bc	19 b	48 bc	22 a	66 bc	10.6 b
Cell pack	10.1 b	82 bcd	15 bc	38 bcd	20 a	58 bc	7.7 b
Deep peat pot	20.0 a	131 a	26 a	67 a	23 a	118 a	15.8 a
Shallow peat pot	11.1 b	104 ab	19 b	49 b	24 a	74 b	9.4 b
Transplant age (wks)[y,v]							
6	8.1 b	54 d	10 c	34 cd	18 a	43 c	5.8 b
7	10.9 b	72 bcd	15 bc	42 bcd	21 a	53 bc	7.8 b
8.5	9.8 b	73 bcd	14 bc	45 bc	22 a	64 bc	9.5 b
10	10.1 b	82 bcd	15 b	38 bcd	20 a	58 bc	7.7 b
Bareroot media[u,x]							
Vermiculite + peat	12.6 b	78 bcd	14 bc	30 d	25 a	43 c	6.7 b
Peat + perlite	9.0 b	77 bcd	15 bc	38 bcd	19 a	56 bc	9.0 b
Perlite + vermiculite	12.5 b	60 cd	11 bc	45 bc	20 a	61 bc	9.3 b

[z]Transplants field-planted 4 June and dug 12 September.
[y]Grown in a media mixture of 1.5 vermiculite : 1.5 perlite : 7 peat.
[x]Transplanted as 10-week-old seedlings.
[w]Mean separation within columns over propagation methods by Duncan's multiple range test at 5% level.
[v]All transplants grown in plastic cell packs.
[u]All media components in a 1:1 (v/v) ratio. Seed broadcasted at 1300 seeds/m^2 in a flat, hand pulled 10 weeks after seeding, and planted as bareroot transplants.

crown fresh and dry weight were increased significantly in DP transplants (Table 6). Apparently, the initial growth advantage, minimal transplant shock and uninterrupted growth, container size and nutrient relationships of the DP containers contributed to this effect.

Although the 6W transplants were inferior in growth to 7W and 10W at the time of field planting, crown fresh and dry weight and root and bud numbers of 6W were lower, but not significantly different than 7W, 8W, and 10W by the end of the 1st growing season (Table 6). Shoot number and fern fresh weight were similar among 6W to 10W plants, but fern dry weight was significantly reduced in 6W. Since the growth potential of 7W to 10W was increased, their use is appropriate. Although this study did not evaluate container types, transplant age and media factorially, we suggest that growing young transplants (7W to 8W) in DP containers may reduce greenhouse use and cost and still produce a transplant of acceptable quality.

The growth advantage of transplants grown in VP media at transplanting time diminished by the end of the 1st season (Table 6). Growth essentially was the same among media treatments. Planting the significantly larger VP transplants as bareroot transplants, thus increased transplant shock reduced any growth advantage. This medium may be beneficial in containers, such as DP containers, where minimal transplant shock is expected.

Based on their initial enhancement of plant growth, and the long term advantage in improving seedling growth, DP containers have the best potential of all propagation methods in improving growth of new asparagus plantings. Subsequent evaluations of yield and stand establishment must warrant their use economically in comparison to other conventional methods.

Literature Cited

1. Benson, B., F. Souther, F. Takatori, and R. Mullen. 1978. Establishing asparagus plantations with seedling plants. Calif. Agr. 32:10–11.
2. Benson, B. and K.J. Fisher. 1983. Effect of cell volume, plant density and nitrogen on asparagus seedling growth. Scientia Hort. 21:105–112.
3. Fisher, K.J. 1982. Comparison of the growth and development of young asparagus plants established from seedling transplants and direct seeding. N. Z. J. Expt. Agr. 10:405–408.
4. Garrison, S.A. 1977. New planting method for asparagus. Amer. Veg. Grower 25:16.
5. Jones, L.H. and H.D. Haskins. 1935. Distribution of roots in porous and nonporous plant containers. Plant Physiol. 10:511–519.
6. Ombrello, T. and S. Garrison. 1978. Establishing asparagus from seedling transplants. HortScience 13(6):663–664.
7. Williams, J.B. 1979. Studies on the propagation and establishment of asparagus. Expt. Hort. 31:50–58.