Establishment of Vegetables in the Field

M.D. Orzolek

Additional index words. seeding, soil physical conditions, seed quality

Summary. Optimization of crop production can be accomplished only if successful stand establishment is achieved first, since each plant contributes to the total crop yield. Reduction of plant populations after planting will reduce yield and/or quality, even though plants compensate to some degree for stand losses. Successful stand establishment is achieved if factors that affect establishment are known, evaluated, and modified appropriately at the time of field planting. The factors that affect stand establishment are biotic and/or **abiotic**. Biotic factors are generally pathogens that attack plants as parasites, while **abiotic** factors are the environmental and physical conditions to which the plant or seed is exposed at the time of planting. **Abiotic** factors can be classified under three headings: soil, planting requirements, and environmental stress.

Abiotic

Soil. Soil parameters include: type, fertility and tilth. Soil type has a significant influence on establishment because of its inherent characteristics of composition, porosity, water infiltration, organic matter content, and drainage. In general, soils with higher clay content have greater water-holding capacity, cation exchange capacity, and the potential for soil crusting (capping), but have slower water infiltration rates and are slower to warm in the spring. Soils with a high sand content have a low water-holding capacity, lower cation exchange capacity, lower potential for soil crusting, increased water infiltration rates, and faster soil warming in the spring than clay soil types. Soil fertility is important for stand establishment because pH affects nutrient availability and

uptake, seed germination, and root growth. An annual soil testing program will provide guidelines for adjusting soil fertility for crop(s) to be established each year. If soil nutrient levels or pH are not in the optimum range, modification of soil nutrient content is accomplished most successfully prior to or at planting.

Soil tilth is defined as the physical condition of soil as related to its ease of tillage, fitness as a seedbed, and impedance to seedling emergence and root penetration (Donahue et al., 1971). Soils with poor tilth must be modified (i.e., increased organic matter, deeper tillage, waiting for soil to dry before working it, etc.) before attempting to direct-seed or transplant a crop if stand establishment is to be successful. Soil compaction will reduce the emergence of direct-seeded vegetables and establishment and growth of transplanted crops, especially in fine-textured soils (Table 1, Daum and Orzolek, 1987; Orzolek and Daum, 1988).

Planting factors. The quality of the seed or transplant will affect initial stand establishment and final yield (Daniello, 1988). Seeds with a reduced germination and/or vigor often result in reduced plant stands that are not uniform and are slow to emerge under stress conditions such as cold or excessively high soil temperatures, low or excessive soil moisture, soil crusting, attack by parasitic fungi, bacteria, or insects at planting (Karlen, 1989). Stand establishment (regeneration of new roots and resumption of top growth) may be delayed with transplants that have been hardened-off excessively (withdrawal of water or nutrients, exposure to low temperatures) or that are very succulent. These plants may have a difficult time becoming established in the field after transplanting. Planting depth affects both seeded and transplanted crops, since deeper-than-optimum planting will delay or prevent seedling emergence or transplant establishment. Deep planting in spring will expose the seed/plant to cold soil temperatures and compacted soil. Also, with deeper-than-normal planting, seeds have a more difficult time breaking through the soil crust.

Commercially available soil anticrustant materials tended to alleviate the reduction of plant populations due to crusting and rate of seed emergence (Table 2). To test the effects

Upcoming Themes for HortTechnology

- Water in horticultural production
- Human issues in horticulture
- Postharvest horticulture
- The role, impact, and propriety of patenting in horticulture
- Sustainability of horticultural production
- Plasticulture
- Protected culture
- Successes in integrated pest management
- Pest resistance
- Education and employment opportunities
- Marketing horticultural products
- Food safety, diet, and health

Department of Horticulture, The Pennsylvania State University, University Park, PA 16802.

Table 1. *Effect of soil compaction on the yield of vegetables grown on compacted soil (Hagerstown silt loam), Horticulture Research Farm, Russell E. Larson Research Center—1987–88 (nonreplicated observational trial).*

Crop	Yield (lb/20-ft row)	
	Compacted soil	Noncompacted soil
Snap bean	3.9	15.5
Cucumber	33.4	98.4
Cabbage	52.6	153.1
Eggplant	4.2	13.3
Pepper	48.2	74.0
Squash	49.6	166.8
Sweet Corn	9.6	21.4
Tomato	63.1	144.4
Watermelon	185.6	212.2
Pentrometer reading	465 psi	220 psi

of anticrustants, the soil was disced purposely several times to encourage a soil crust before planting lettuce (Table 3).

A partial solution to soil crusting can be achieved by seeding a high plant population. The germinating seeds act in concert to penetrate the soil crust effectively; this results in a plant population required for optimum yields. One disadvantage of high populations of seeds is the additional seed costs. In addition, labor-intensive and expensive thinning often is required.

Environmental stress. After seeding or transplanting in the field, environmental stresses are a chief reason for stand failure. Soil moisture levels may be too low or high for adequate water imbibition by seeds or root development of seedlings/plants. In ad-

dition, soil temperatures may be excessively low (<55F) or high (>90F) for active germination or root growth. Both soil moisture and temperature interact, and their combined effect is generally greater on seeds or plants than either factor considered alone (Wagenvoort et al., 1981). There is a 5- to 14-day period after seeding or transplanting when plants are susceptible to sun-scalding (especially stems of plants), sandblasting, or mechanical damage of young plants caused by high, constant winds. Low night temperatures in the spring may not kill plants, but will slow growth and extend the time to crop maturity. Although not occurring often in most areas, hail will cause extensive damage that can result in severe stand loss and delayed crop maturity.

Biotic

Insects. Small populations of insects can destroy small seedlings and newly set transplants in the spring. Severe insect damage can occur on the foliage, stems, or roots of plants within 24 h of planting in the field (Ferretti et al., 1990). Monitoring for insect problems is critical because insect damage such as early flea beetle damage on broccoli or Colorado potato beetle damage on tomato can result in plant death or parasitism by a secondary pest. Early feeding of cucumber beetle on muskmelon, if left unchecked, will result in bacterial wilt transmission and plant collapse later when fruit are just beginning to ripen. Early insect damage can lead to stand reduction and loss of early plant growth and vigor. Cutworm damage can be

Table 2. *Effect of anticrustant treatments at planting on the emergence of gel-seeded 'Heins 1350' tomato planted 26 May 1987 at the Horticulture Research Farm, Russell E. Larson Research Center.*

Treatment	Rate*	Plant stand (days after planting)				Early emergence (%)
		10	13	15	20	
Check-dry	---	24	63	102	144	44
Check-water	---	25	53	85	114	47
SprayAide	2.0%	22	82	139	182	45
ML 2812	5.0%	20	42	64	81	59
Soiltex L	1.5%	25	58	71	94	59
Blk Mulch Coat	50.0%	8	35	75	119	31
Nalco 2190	10.0%	36	93	118	161	62
Enersol-gran	15 g·m ⁻²	17	52	74	112	50
Foam	3.8 cm	52	98	126	149	67
Enersol-liq	20.0%	23	56	80	126	48
LSD _{0.05}		22	45	56	50	

*Volume of water applied equaled 3.2 liters per 30 m of row.

Table 3. *Effect of anticapping materials on the emergence of 'Ithaca' lettuce direct-seeded, Horticulture Research Farm, Russell E. Larson Research Center, June 1989.*

Treatment	Rate*	Plant stand (days after planting)		
		8	14	17
Check-dry	---	136	136	130
Check-water	---	145	134	127
ML 2812	4%	87	117	106
Soiltex L	2%	187	166	156
Nalco 2190	10%	140	131	125
Foam	3.8 cm	82	150	145
Enersol	10%	184	184	175
LSD _{0.05}		75	NS	NS

*Volume of water applied equaled 3.2 liters per 30 m of row.

severe with newly transplanted crops such as peppers.

Disease. Infection of seeds or plants after planting can occur from the soil. Organisms can attack seeds, stems or roots in or above the soil, and can infect stems and foliage (Ferretti et al., 1990). Fungi, bacteria, and viruses can attack plants when present if given the optimal environmental conditions for their multiplication and growth. Seed treatments help to reduce stand loss due to fungal or bacterial infection before emergence. Even after emergence, plants can be infected by fungi such as *Pythium* on snap beans or early blight on tomatoes, which can be carried on transplants.

Weeds. Because weeds are reservoirs for insects and diseases, initial control of weeds is necessary for successful stand establishment. In addition, weeds compete for the same nutrients, water, and light required for sustained plant growth under field conditions (Weston and Jones, 1990). Seeded crops that are planted under cool soil conditions may have a reduced plant stand if weed seeds germinate faster than the crop and produce a solid mat of grass or broadleaved weed seedlings that are not controlled after emergence.

Planting method

Direct-seeding. Crops that can be grown under optimum growing conditions and a long growing season are direct-seeded most easily, since this can be done mechanically with very little labor input. However, the cost of seed, especially hybrids, which are becoming more prevalent, is high and

Table 4. *Effect of planter type on the plant stand and yield of direct-seeded onions at the Horticulture Research Farm, Russell E. Larson Research Center, 1985.*

Planter	Type	Stand count (plants/10 ft)	Bulb yield/10 ft of row	
			No.	lb
Nibex	Cup planter	27.8	31.9	7.2
Fluid Drilling Ltd.	Gel seeder	62.9	57.7	8.9
John Deere 33	Plate planter	30.3	30.4	5.6
Stan Hay	Belt planter	31.2	39.9	7.1
LSD _{0.05}		5.2	5.5	0.9

some growers find it prohibitive to seed at high densities and thin to a final expected plant stand. To reduce seed cost and still plant to a final stand, many growers are using precision planters. A precision planter systematically dispenses a seed or a group of seeds at some selected spacing. Precision-seeding may eliminate the need for thinning and greatly reduce the amount of seed needed to plant a given area. Seeds may be coated to produce a uniform seed shape and enhance the performance of precision seeders. Several materials are used in the seed coating process, but all break down in contact with water and are generally permeable to gas exchange (Taylor et al., 1990). Some precision seeders are designed with a series of cells or orifices (under vacuum) moving through the seed supply to collect the desired number of seeds for each drop. These cells are sized and sometimes shaped to match the specific seeds to be planted. Once seeds are collected, they are carried to a furrow opener, where they are deposited into the soil. A nontraditional method of direct-seeding is gel-seeding or fluid-drilling (Table 4). In this planting system, the seed is not handled directly, but rather is suspended in a gel that is metered and dispensed into the soil (Ward, 1981). One advantage of gel-seeding is that fungicides, insecticides, growth regulators, and nutrients can be mixed into the gel and placed in direct contact with the seed as planting is completed (Pill, 1990; Orzolek and Daum, 1984).

Because of seed cost, growers are offered several options from seed companies to ensure the highest-quality seeds. For a slight additional cost, growers can purchase seed that has been primed (osmoconditioned), coated, or graded. Priming seeds increases the rate, percentage, and uniformity of germination by initiating germination under controlled conditions through

treatment with polyethylene glycol, various salts, solid matrix priming, water, temperature, growth regulators, or a combination of several treatments (Bennett, 1988; Kubik et al., 1988). Graded seed offers the grower a seed lot that is generally uniform in size, weight, and seed maturity. Graded seed often results in higher germination and greater uniformity of emergence than nongraded seed.

Transplanting. Transplants are used for crop production because they result in earlier harvesting, enable warm-season crops to be grown in regions too cold for direct-seeding, and develop better root systems (Watts, 1929).

Many vegetable growers purchase either field-grown bare-root or greenhouse-grown plug plants. Field-grown bare-root transplants are generally less costly to buy than tray-grown plants and may establish more rapidly in the field than over-hardened tray plants. However, the disadvantage of bare-root plants is that they tend to have a high rate of mortality in the field after planting (Orzolek, 1986). Bare-root transplants should be inspected carefully before planting because they may be infested with diseases, insects, or weeds. Greenhouse-grown plug plants generally have very high survival rates once planted in the field. However, plug plants may take longer to become established after planting because they may have been hardened-off (withdrawal of nutrients, water, and/or grown under cool temperatures) and undergone stresses during shipment. This is especially true of transplants being shipped from Florida or Georgia to northern states. Growers in Pennsylvania purchase >75 million transplants per year. In any given year, it has been difficult to predict which type of transplant will be of higher quality and will establish rapidly in the field under the cool, wet springs of Pennsylvania. As important as the

type of transplant is the age, handling, and storage conditions to which transplants have been exposed before planting. Generally, the 5- to 7-week-old solanaceous and cruciferous transplants were long considered at the optimum age for transplanting (Fletcher, 1975). Recently, Vavrina and Orzolek indicated that there was no significant difference in the growth and yield of greenhouse-grown plug tomato and watermelon plants ranging in age from 3 to 11 weeks (Orzolek et al., 1990; Vavrina et al., 1990). However, delay in establishment, especially in northern climates, of the 3- and 4-week-old transplants resulted in delayed fruit maturity. After plants are received from southern growers they should be placed in a cool (55 to 65F) and dry storage area until planted so that disease and extreme wilting do not stress the plant beyond recovery potential.

While many factors affect the establishment of vegetables in the field, careful planning of necessary inputs, accurate record-keeping, and planting under optimum field conditions will help reduce establishment problems and ensure success.

Recommendations for successful stand establishment

- 1) Do not work soil while too wet.
- 2) Initiate a soil testing-program that will help manage soil nutrient requirements.
- 3) Use legumes and small grains in the rotation program when possible to help build soil organic matter, increase soil nitrogen reserves, reduce the potential for soil crusting, and help manage weed problems.
- 4) Buy quality treated seed or certified plants.
- 5) Consider previous planting conditions and use primed, coated, and/or graded seed when necessary.
- 6) Always calibrate the planter in the spring for accurate seed count and placement.
- 7) Use environmental modification techniques in the spring to ensure emergence and complete stands (row covers, organic mulch, soil anti-crustants, drip irrigation, frost nozzles, etc.).
- 8) Keep accurate field records to help identify potential soil insects, diseases, weeds, and other problems from year to year. Implement programs to manage these pests. This also will help

to develop better crop rotation systems for individual farms.

Summary

Successful establishment of vegetables in the field will eliminate unnecessary and expensive inputs in order to rescue stressed, nonestablished plant stands and also will ensure scheduled harvests during the growing season. Healthy, vigorous plants generally will not develop serious disease problems or become infested with insect pests. Whether transplanting or direct-seeding, scheduling and planning for contingencies in the field will ensure successful stand establishment of vegetable crops. Good record-keeping will help emphasize the correct management decisions from year to year and help change those decisions that were wrong and that affected either crop yield or quality negatively.

Literature Cited

- Bennett, M.A. 1988. Evaluation of seed coatings and priming treatments for stand establishment of processing tomatoes. Proc. Intl. Conf. on Stand Establishment for Hort. Crops. p. 51-62.
- Daniello, F.J. 1988. Overview of stand establishment methods of vegetable crops in Texas. Proc. Intl. Conf. on Stand Establishment for Hort. Crops. p. 201-202.
- Daum, D.R. and M.D. Orzolek. 1987. Soil compaction demonstration. Veg. Res. Rpt., Dept. of Horticulture, The Pennsylvania State Univ. Hort. Mimeo Ser. 11:173, p. 95-96.
- Donahue, R.L., J.C. Shickluna, and L.S. Robertson. 1971. SOILS-An introduction to soils and plant growth. 3rd ed. Prentice-Hall, Englewood Cliffs, N.J.
- Ferretti, P.A., M.D. Orzolek, A.A. MacNab, Z.A. Smilowitz, R. Cole, W.K. Hock, D.R. Daum, and C.H. Collison. 1990. Pennsylvania commercial vegetable production recommendations. The Pennsylvania State Univ. Publ. U.Ed. 90-562.
- Fletcher, R.F. 1975. Growing vegetable transplants. The Pennsylvania State Univ. Publ. U.Ed. 84-707.
- Karlen, D.L. 1989. Tillage and planting system effects on corn emergence from Norfolk loamy sand. 1989. Applied Agr. Res. 4(3):190-195.
- Kubik, K.K., J.A. Eastin, J.D. Eastin, and K.M. Eskridge. 1988. Solid matrix priming of tomato and pepper. Proc. Intl. Conf. on Stand Establishment for Hort. Crops. p. 86-96.
- Orzolek, M.D. 1986. Use of growth retardants for tomato transplant production. Applied Agr. Res. 1(3):168-171.
- Orzolek, M.D., C.S. Vavrina, and R. Scott. 1990. Tomato transplant age study. Proc. 21st Annu. Mid-Atlantic Veg. Workers Conf. p. 47-48.
- Orzolek, M.D. and D.R. Daum. 1988. Soil compaction study. Veg. Res. Rpt., Dept. of Horticulture, The Pennsylvania State Univ. Hort. Mimeo Ser. 11:188, p.72-73.
- Orzolek, M.D. and D.R. Daum. 1984. Effect of planting equipment and techniques on seed germination and emergence: A review. J. Seed Technol. 9(2):99-113.
- Pill, W.G. 1990. Seedling emergence and yield of 'Champion' collard from hydrated seeds fluid drilled in high-phosphorous gel. Proc. Natl. Symp. on Stand Establishment for Hort. Crop Prod. p. 71-82.
- Taylor, A.G., T-G. Min, G.E. Harman, and X. Jin. 1990. Liquid coating formulations to increase efficacy of biological seed treatments. Proc. Natl. Symp. on Stand Establishment for Hort. Crop Prod. p. 119-124.
- Vavrina, C.S., K. Ambrester, and T.B. Cole. 1990. Watermelon production as influenced by transplant age. Proc. Florida State Hort. Soc. Paper 115.
- Wagenvoort, W.A., A. Boot, and J.F. Bierhuizen. 1981. Optimum temperature range for germination of vegetable seeds. Gartenbauwissenschaft 46:97-101.
- Ward, S.M. 1981. Performance of a prototype fluid drill. J. Agr. Eng. Res. 26:321-331.
- Watts, R.L. 1929. Vegetable gardening. Orange Judd, New York.
- Weston, L.A. and R.T. Jones. 1990. Tolerance of transplanted bell peppers (*Capicum annum*) to clomazone and diethatyl applied preemergent. Applied Agr. Res. 5(1):13-16.