Table 3. Cumulative marketable yields of deep- and shallow-cultivated 'TAMBel-2' bell peppers transplanted by cotyledon orientation or at random.

Cultivation method	Orientation	Yield ($t \cdot ha^{-1}$) 13 Nov.	20 Nov.	27 Nov.	4 Dec.
Deep	N–S	2.6	6.1	10.3	14.5
	E–W	4.6	7.9	12.5	16.9
	Random	4.0	7.9	12.2	17.5
Shallow	N–S	2.6	6.0	13.0	15.0
	E–W	6.2	13.3	19.4	25.8
	Random	2.9	6.5	11.0	17.6
Significance					
N–S vs. random		NS	NS	NS	**
E–W vs. random		*	**	**	**
Deep vs. shallow		NS	*	**	**
E–W vs. N–S		**	**	**	**

^{*,**,NS}Significant at the 5% and 1% levels, or nonsignificant, respectively.

Influence of transplant orientation and cultivation practices on yield. Of the cultural systems evaluated, the method combining E–W cotyledon orientation and shallow cultivation increased early and overall marketable yields (Table 3). These increased yields were due to a significant increase in the number of pods produced and not to an increase in individual pod weight (data not shown). The deeply cultivated E–W cotyledon system yielded less No. 1 pods in all four harvests as compared to the E–W shallow-cultivated system.

The orientation of the cotyledons affected yield in contrast to random transplanting, which was considered the commercial standard. Orthogonal contrasts indicated that orienting transplants N–S by cotyledons significantly limited overall yields in contrast to the randomly transplanted control. Conversely, orienting transplants E–W significantly increased early and overall yields in contrast to random transplanting (Table 3). Because the rows in the field were established in a N–S orientation, we assumed that the plants with E–W cotyledon orientation had roots growing predominantly perpendicular to the row for the growing season. All sidedressings were applied as a band in the N–S direction and furrow irrigation flowed N–S. Also, roots that were perpendicular to the bed were distant from the center of the bed, where salts accumulated and concentrated as a result of evaporation and soil wetting and drying patterns. This observation may explain yield suppressions that occurred with N–S orientations.

Orthogonal contrasts indicated that deep cultivation limited overall yields but did not affect production on first harvest (Table 3). Although the system combining E–W orientation and shallow cultivation increased yields in contrast to N–S orientation with shallow cultivation, deep cultivation in E–W plots negated any benefit to orientation.

The strong correlations between root and cotyledon orientation in direct-seeded peppers suggests a greater use of "orienting" seedlings to increase yields. Direct-seeded peppers could be oriented by thinning all seedlings except those in an E–W cotyledon direction in N–S rows, but this practice may be laborious and cost-prohibitive commercially. Further work is needed to document yield potential of oriented direct-seeded peppers. Also, it is important to document whether root patterns persist through plant maturity. Deep cultivation, independent of seedling orientation, was detrimental to yields.

Literature Cited

1. Awoleye, F. 1985. The genetics and anatomy of lateral root patterns of *Capsicum annuum* L. cultivars. PhD Diss., Texas A&M Univ., College Station.
2. Krylov, A.V. and G.A. Tarakonova. 1960. Magnetotropism of plants and its true nature. Soviet Plant Physiol. 7:156–160.
3. Millory, T.E., S. Chiang, E.G. Cutter, and E.M. Gifford, Jr. 1970. Sequence and pattern of lateral root formation in five selected species. Amer. J. Bot. 57:800–809.
4. Pittman, U.J. 1962. Growth reaction and magnetotropism in roots of winter wheat. Can. J. Plant Sci. 42:430–436.
5. Pittman, U.J. 1963. Magnetism and plant growth—effect of germination and early growth of cereal seeds. Can. J. Plant Sci. 43:513–518.
6. Schrieber, K. 1958. An unusual tropism in feeder roots in sugar beets and its possible effects on fertilizer response. Can. J. Plant Sci. 38:124.
7. Street, H.E. 1957. The physiology of plant growth. Biol. Rev. 32:117–155.
8. Thimann, K.V. 1936. Auxins and the growth of roots. Amer. J. Bot. 23:561–569.
9. USDA. 1960. United States standards for grades of sweet peppers. Washington, D.C.
10. Ware, G. and J.P. McCollum. 1968. Producing vegetable crops. Interstate, Danville, Ill.
11. Weaver, J.E. and W.E. Bruner. 1927. Root development of vegetable crops. McGraw-Hill, New York.

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Inoculation of Sweet Potato with *Azospirillum*

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Abstract. **The response of sweet potato (*Ipomoea batatas* Lam.) to inoculation with *Azospirillum* with and without fertilizer N was evaluated in a greenhouse and field study. In the greenhouse study, storage root N concentration of 'Centennial' and 'Jewel' were higher with 34 mg N/pot + inoculant (Cd strain) than with 34 mg N/pot without inoculant. In the field study, the marketable and total root yields and root N contents of 'Centennial' for the 0 kg N/ha + Cd inoculant and 0 kg N/ha + TI-sp-(7+11) inoculant treatments were higher than for the 0 kg N/ha control and were not different from or higher than the 67 kg N/ha treatments with or without the inoculants.**

The N_2-fixing bacteria *Azospirillum* has been isolated from a range of grass, grain, cereal, and orchard crop rhizospheres in tropical and temperate regions (1, 11, 13–16). A survey of rhizosphere soil of 14 crops in Brazil indicated that *Azospirillum*-like bacteria were associated with a number of crops, including sweet potato (5). Iswaran et al. (10) reported the isolation of N_2-fixing bacteria from several tubers and roots of nonleguminous plants, including sweet potato. Hill et al. (7–9) isolated and characterized strains of *A. brasilense* and *A. lipoferum* associated with the roots of six sweet potato cultivars. Inoculation of forage grass, grain, and cereal crops with *Azospirillum* has produced increases in plant growth, dry weight, total N content, and yield, although responses have not always been consistent (2–4, 12). The objective of this study was to determine if *Azospirillum* inoculation influenced storage root and foliage production and nitrogen content of sweet potato.

Experiment 1. Slips of three sweet potato cultivars ('Centennial', 'Jewel', and 'Rojo

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Table 1. Response of three sweet potato cultivars to inoculation with *Azospirillum brasilense*, Cd strain (greenhouse study).

	Plant wt (g/pot)						N concn (%)						Total N content (mg/pot)					
	Foliage			Storage roots			Foliage			Storage roots			Foliage			Storage roots		
Treatment	C[z]	J	RB	C	J	RB	C	J	RB	C	J	RB	C	J	RB	C	J	RB
0 mg N/pot	11	13	17	6	25	20	0.9	1.6	1.5	0.5	0.6	0.7	27	36	48	8	26	31
34 mg N/pot	13	14	15	13	23	25	0.9	1.7	1.3	0.6	0.5	0.4	22	34	32	19	25	31
0 mg N/pot + inoculant	14	12	14	12	21	22	1.2	1.3	1.5	0.6	0.7	0.6	38	28	40	23	28	41
34 mg N/pot + inoculant	15	11	14	7	28	23	1.1	1.6	1.5	0.8	0.9	0.5	38	28	42	14	48	36
LSD 5%	4	3	3	10	6	3	0.7	0.9	0.9	0.2	0.4	0.3	29	18	31	21	23	16

[z] C = 'Centennial', J = 'Jewel', and RB = 'Rojo Blanco'.

Table 2. Response of 'Centennial' to inoculation with several strains of *Azospirillum* (field study).

Treatment		Foliage wt ($t \cdot ha^{-1}$)		Storage root yield ($t \cdot ha^{-1}$)		N concn (%)		Total N ($kg \cdot ha^{-1}$)	
N rate ($kg \cdot ha^{-1}$)	Inoculant strain	Fresh	Dry	Marketable	Total	Foliage	Storage root	Foliage	Storage root
0	No inoculant	7.6	1.1	10.1	17.4	2.4	0.7	27	13
0	TI-Sp-7	10.4	1.8	15.2	26.0	2.3	0.9	42	25
0	TI-Sp-11	14.3	2.2	1.3	12.1	2.5	1.1	52	16
0	TI-Sp-(7+11)	16.9	2.5	24.0	36.4	2.3	1.0	58	42
0	Cd	12.5	1.9	25.2	34.8	2.5	1.1	45	41
67	No incoulant	9.7	1.8	21.2	35.6	2.6	1.2	47	50
67	TI-Sp-7	33.0	4.8	25.2	38.4	2.7	1.2	125	54
67	TI-Sp-11	21.0	3.3	7.1	16.2	2.7	1.2	86	22
67	TI-SP(7+11)	26.6	2.5	27.3	40.1	2.5	1.1	86	53
67	Cd	15.3	3.8	10.1	19.9	2.7	1.2	63	28
	LSD 5%	13.0	2.4	8.6	9.3	0.7	0.2	45	15

Blanco') were transplanted into 5.5-liter pots (one plant per pot) containing 1000 g of Norfolk sandy loam (fine-loamy, siliceous, thermic, typic paleudult) at pH 6.5 and were grown for 3 months. Treatments consisted of 0 mg N/pot, 34 mg N/pot, 0 mg N/pot + inoculant (*A. brasilense*, Cd strain), and 34 mg N/pot + inoculant. The Cd strain is a red-pigmented strain that was isolated initially from *Cynodon dactylon* (6) and has been used in several inoculation studies of cereal and grass crops. The experimental design was split plot with the inoculant and N treatments as main plots, cultivars as subplots, and three replications.

Experiment 2. A field study was carried out using 'Centennial' to evaluate the response of sweet potato on Norfolk sandy loam (pH 6.5) to four inoculation treatments with or without 67 kg N/ha. The inoculant treatments were: TI-sp-7 (ATCC 35629), an *A. brasilense* isolate; TI-sp-11 (ATCC 35630), an *A. lipoferum* isolate; a mixed inoculant of TI-sp-7 and TI-sp-11; and *A. brasilense* Cd. The TI-sp-7 and TI-sp-11 strains were isolated initially from sweet potato fibrous roots (8). The experimental design was a randomized complete block with three replications. Slips were transplanted in early July 1983 into 1.2 × 4.2 m rows with plants spaced 30 cm apart. Total foliage weights of the center three plants from each row were determined 103 days after transplanting. At harvest (120 days after transplanting), storage roots of the remaining plants in each row were graded and weighed.

In Expts. 1 and 2, the inoculants were applied at 2, 4, and 6 weeks after transplanting, and P and K were applied prior to transplanting based on soil test. Each inoculation consisted of the application of 5 ml of 10^8 to 10^9 cells per ml of the bacterial suspension per plant. The N contents of foliage and roots from Expts. 1 and 2 were determined by semimicro-Kjeldahl procedure.

In Expt. 1, the foliage weight of 'Centennial' at 34 mg/pot was not different from 0 mg N/pot, but the foliage weight at the 34 mg N/pot + inoculant treatment was higher than for 0 mg N/pot (Table 1). The foliage weight of 'Jewel' was lower for the 34 mg N/pot + inoculant treatment than for 34 mg N/pot. 'Rojo Blanco' foliage weights for the two inoculant treatments were lower than for 0 mg N/pot. The N and Cd inoculation treatments did not influence foliage dry weights (data not shown) or percent N content for any of the cultivars. The storage root weight of 'Jewel' was higher for the 34 mg N/pot + inoculant treatment than the 0 mg N/pot + inoculant treatment, but differences in storage root weights of 'Rojo Blanco' for the same treatments were not different. The 34 mg N/pot treatments with and without inoculant gave higher storage root weights of 'Rojo Blanco' than for 0 mg N/pot. The storage root weights of 'Centennial' tended to be higher for the 0 mg N/pot + inoculant and 34 mg N/pot treatments than for the 0 mg N/pot treatment. The storage root N concentration of 'Centennial' was higher for the 34 mg N/pot + inoculant treatment than for all other treatments. The storage root total N content of 'Jewel' was higher for the 34 mg N/pot + inoculant treatment than the 34 mg N/pot treatment.

In Expt. 2, application of fertilizer N at 67 $kg \cdot ha^{-1}$, compared to the 0 kg N/ha control, did not increase foliage fresh or dry weight, N concentration, or total N content, but did increase marketable and total yield, percent N, and total N in storage roots (Table 2). When 67 kg N/ha was combined with the TI-sp-7 or TI-sp-(7 + 11) inoculant, a higher foliage yield was produced than with 67 kg N/ha without inoculant. The 67 kg N/ha + TI-sp-7 inoculant treatment resulted in a higher foliage dry weight and total N content than the 67 kg N/ha treatment. The foliage dry and fresh weight were higher for the 67 kg N/ha + Cd inoculant treatment than for the 0 kg N/ha control. Although storage root yields were not increased by the 67 kg N/ha + Cd inoculant treatment, when compared to the 0 kg N/ha control, the storage root percent N and total N contents were higher. Root yields with the 0 kg N/ha + Cd inoculant treatment were higher than for the 0 kg N/ha control and tended to be higher than the 67 kg N/ha + Cd inoculant treatment; similar trends were found for Expt. 1 with 'Centennial'. The marketable and total root yields, percent N, and total N content in roots for the 0 kg N/ha + Cd inoculant and 0 kg N/ha + TI-sp-(7 + 11) inoculant treatments were higher than for the 0 kg N/ha control and not different from or higher than the 67 kg N/ha treatment with or without inoculants. The results suggest that inoculation of sweet potato with *Azospirillum* spp. does influence sweet potato nitrogen content, storage root yield, and/or foliage weight, depending on cultivar and inoculant strain used.

Literature Cited

1. Balandreau, J. 1986. Ecological factors and adaptive process in N_2-fixing bacterial populations of the plant environment. Plant & Soil 90:73–92.
2. Boddy R.M. and J. Dobereiner. 1982. Association of *Azospirillum* and other diazotrophs with tropical graminae. Proc. 12th Intl. Congr. Soil Sci. New Delhi, India, 8–16 Feb. 1982. Symp. Papers I. p. 28–47.
3. Boddy R.M. and J. Dobereiner. 1984. Nitrogen fixation associated with grasses and cereals, p. 277–313. In: N.S. Subba Rao (ed.). Current perspectives in biological nitrogen fixation. Oxford and IBH, New Delhi.

4. Dart, P.J. 1986. Nitrogen fixation associated with non-legumes in agriculture. Plant & Soil 90:303–334.
5. Dobereiner, J. 1978. Influence of environmental factors on the occurrence of *Spirillum lipoferum* in soils and roots. Ecol. Bul. (Stockholm) 26:343–352.
6. Eskew, D.L., D.D. Focht, and I.P. Ting. 1977. Nitrogen fixation denitrification and pleomorphic growth in a highly pigmented *Spirillum lipoferum*. Applied Env. Microbiol. 582–585.
7. Hill, W.A. and P. Bacon. 1984. Fertilizer N use efficiency and associative N_2-fixation with nonlegumes, p. 533–542. Proc. 6th Intl. Symp. Tropical Roots Crops, Intl. Potato Center (CIP), Lima, Peru, 21–26 Feb. 1983.
8. Hill, W.A., P. Bacon-Hill, S.M. Crossman, and C. Stevens. 1983. Characterization of N_2-fixing bacteria associated with sweet potato roots. Can. J. Microbiol. 29:860–862.
9. Hill, W.A., P.B. Rodney, and L.A. Graham. 1981. Root associated N_2-fixation of sweet potato, p. 489. In: A.H. Gibson and W.E. Newton (eds.). Current perspectives in nitrogen fixation, Austral. Acad. Sci. Canberra.
10. Iswaran, V., B.D. Patil, K.S. Jaubri, and A. Sen. 1980. A study of nitrogen fixation by bacteria in some non-leguminous plants. Zbl. Bakt. II. Abstr. 135:392–395.
11. Neyra, C.A. and J. Dobereiner. 1977. Nitrogen fixation in grasses. Adv. Agron. 29:1–38.
12. Okon, Y. 1984. Response of cereal and forage grasses to inoculation with N_2-fixing bacteria, p. 303–309. In: C. Veeger and W.E. Newton (eds.). Advances in nitrogen fixation research. Martinus Nijhoff, The Hague, Netherlands.
13. Okon, Y. and Y. Kapulnik. 1986. Development and function of *Azospirillum*-inoculated roots. Plant & Soil 90:3–16.
14. Subba Rao, N.S. 1983. Nitrogen-fixing bacteria associated with plantation and orchard plants. Can. J. Microbiol. 29:863–864.
15. van Berkum, P. and B.B. Bohlool. 1980. Evaluation of nitrogen fixation by bacteria in association with roots of tropical grasses. Microbiol. Rev. 44:491–517.
16. Vose, P.B. 1983. Developments in non-legume N_2-fixing systems. Can. J. Microbiol. 29:837–850.

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Use of Growth Retardants to Improve Ripening Uniformity and Yield of Processing Tomatoes

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Additional index words. *Lycopersicon esculentum*, growth regulators, dikegulac, ancymidol, maleic hydrazide, RSW 0411

Abstract. **After the major fruit set period was completed, aqueous sprays of 1000 ppm dikegulac, 66 ppm ancymidol, 1000 ppm maleic hydrazide (MH), and 1 kg·ha^{-1} RSW 0411 were applied to processing tomato (*Lycopersicon esculentum* Mill) plants. Dikegulac, RSW 0411, and ancymidol visually reduced vegetative growth, whereas MH had no apparent influence. None of the compounds reduced the number of flower clusters or flowers per cluster on the late-season growth, but dikegulac and RSW 0411 did reduce the percentage of fruit set in the terminal regions. The partial reductions in late vegetative and/or reproductive growth from the chemical treatments did not enhance uniformity of fruit maturity. Only the dikegulac treatment decreased the yields and percentage of green fruit from the harvest. Chemical names used: 2,3:4,6-bis-*O*-(1-methylethylidene-d-L-*xylo*-2-hexulofuranosonic acid (dikegulac); α-cyclopropyl-α-(4-methoxyphenyl)-5-pyrimidinemethanol (ancymidol); 1,2-dihydro-3,6-pyridazinedione [maleic hydrazide (MH)]; and β-(cyclohexylmethylene-α-(1,1-dimethylethyl)-1*H*-1,2,4-triazole-1-ethanol (RSW 0411).**

A proper balance of growth is necessary throughout the entire season to ensure high, early, concentrated yields of processing tomatoes for machine harvest. Once the majority of fruit has set, subsequent reproductive growth produces fruit that does not contribute to usable yield. The late vegetative and reproductive growth competes with the maturing fruit for assimilates and delays the maturity of the early set fruit (5, 6, 10). We have conducted preliminary field research removing late vegetative growth by hand, but it was very laborious and was uneffective in improving ripening uniformity. A growth regulator could provide a cost-effective method to reduce late-season growth. This study was conducted to evaluate the effectiveness of several growth regulators in decreasing late-season growth and improving ripening uniformity. Four levels of N fertilizer were used to promote different levels of late-season growth.

Six-week-old greenhouse-grown seedlings of 'Heinz 722', a determinate cultivar, were transplanted on 27 May 1983 at the Ohio Agricultural Research and Development Center, Wooster. The soil was a fine-loamy, mixed, mesic Typic Fragiudalf with 3% organic matter and a pH of 6.8. The experimental design was split-plot with N as the main plots and chemical treatments as subplots using four replications.

The seedlings were planted with a single-row commercial transplanter in plots 9 m long and 1.5 m wide with plants spaced 0.3 m within the rows. Seventy-nine kg P/ha and 186 kg K/ha were broadcast and incorporated prior to planting. Four rates of N (0, 84, 140, and 224 kg·ha^{-1}) as NH_4NO_3 were applied broadcast as the main plots. The recommended N application for this soil type is 50–85 kg·ha^{-1}.

A preliminary greenhouse and field experiment suggested the application rates of each growth regulator that would give the best plant response. Treatments and application dates used in this study were: a) control; b) dikegulac at 1000 ppm (5 Aug.); c) RSW 0411 at 1.0 kg·ha^{-1} (5 Aug.); d) ancymidol at 66 ppm (12 Aug); and e) maleic hydrazide (MH) at 1000 ppm (12 Aug). The major fruit set period was completed by the time of treatment applications. The chemi-

Table 1. Influence of growth regulators on the flowers per cluster, clusters per terminal, and fruit set on late-season growth of 'Heinz 722' tomato.

Treatmet	No. flowers/ cluster	No. clusters/ terminal	Late-season fruit set (%)
Control	3.5	1.5	17.0
Ancymidol (66 ppm)	3.4	1.4	10.8
Maleic hydrazide (1000 ppm)	3.2	1.5	18.2
Dikegulac (1000 ppm)	3.5	1.4	4.1
RSW 0411 (1 kg·ha^{-1})	3.3	1.4	9.0
LSD, 5%	NS	NS	6.3

^{NS}Not significant.

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