same sieve size, a delay in harvest usually results in higher percentages of seed and fiber and probably will be more accelerated under conditions of moisture stress (5, 6, 10). Our results also suggest that 'Galamor' is better adapted to greater soil water stress conditions than is 'Oregon 1604'. 'Oregon 1604' was developed in the Oregon State University snap bean breeding program in which the irrigation regime was similar to the high irrigation treatment used in this study. Gabelman and Williams (5) reported differential responses of cultivars to irrigation treatments and suggested that it is highly desirable to test new cultivars under both good and poor irrigation conditions.

Earlier work (1, 2, 7, 9, 11) indicated that higher yield can be obtained with increases in population and/or changes in plant arrangement which is confirmed by the present results. Population density and plant arrangement effects on yield were additive in Expt. 4. Increased yields of high over low populations in Expts. 1, 2, and 3 were likely the result of both increased density and improved arrangement through use of narrow rows (more toward achieving a 1:1 rectangularity). Results from this study reinforce the concept that an integrated, broad-based approach in which many factors are considered is needed to obtain optimized cropping systems for bush snap beans.

Literature Cited

1. Atkin, J. D. 1961. Row spacing influences yield of snap and dry beans. N. Y. Agr. Expt. Sta. Farm Res. 27(3):13.
2. Bleasdale, J. K. A. 1973. Some problems and prospects in plant spacing. J. Royal Agr. Soc. England 134:89–100.
3. Crandall, P. C., M. C. Jensen, J. D. Chamberlain, and L. G. James. 1971. Effect of row width and direction, and mist irrigation on the microclimate of bush beans. HortScience 6:345–347.
4. Evans, D. D., H. J. Mack, D. S. Stevenson, and J. W. Wolfe. 1960. Soil moisture, nitrogen, and stand density effects on growth and yield of sweet corn. Ore. Agr. Expt. Sta. Tech. Bul. 53.
5. Gabelman, W. H. and D. D. F. Williams. 1960. Developmental studies with irrigated snap beans. Wisc. Agr. Expt. Sta. Res. Bul. 221.
6. Kattan, A. A. and J. W. Fleming. 1956. Effect of irrigation at specific stages of development on yield, quality, growth, and composition of snap beans. Proc. Amer. Soc. Hort. Sci. 68:329–342.
7. Mack, H. J. and D. L. Hatch. 1968. Effects of plant arrangement and population density on yield of bush snap beans. Proc. Amer. Soc. Hort. Sci. 92:418–425.
8. Mack, H. J., L. L. Boersma, J. W. Wolfe, W. A. Sistrunk, and D. D. Evans. 1966. Effects of soil moisture and nitrogen fertilizer on pole beans. Ore. Agr. Expt. Sta. Tech. Bul. 97.
9. Nichols, M. A. 1974. Effect of sowing rate and fertilizer application on yield of dwarf beans. N. Z. J. Expt. Agr. 2:155–158.
10. Robinson, W. B., D. E. Wilson, J. C. Moyer, J. D. Atkin, and D. B. Hand. 1964. Quality versus yield of snap beans for processing. Proc. Amer. Soc. Hort. Sci. 84:339–347.
11. Rogers, I. S. 1976. The effect of plant density on the yield of three varieties of French beans (*Phaseolus vulgaris* L.). J. Hort. Sci. 51:481–488.
12. Shearer, M. N. 1963. Electrical resistance gypsum blocks for scheduling irrigations. Ore. State Univ. Coop. Ext. Ser. Ext. Bul. 810.
13. Smittle, D. A. 1976. Response of snap bean to irrigation, nitrogen fertilization, and plant population. J. Amer. Soc. Hort. Sci. 101:37–39.
14. Stansell, J. R. and D. A. Smittle. 1980. Effects of irrigation regimes on yield and water use of snap bean (*Phaseolus vulgaris* L.). J. Amer. Soc. Hort. Sci. 105:869–873.
15. Steadman, J. R., D. P. Coyne, and G. E. Cook. 1973. Reduction of severity of white mold disease on Great Northern beans by wider row spacing and determinate plant growth habit. Plant Dis. Reptr. 57:1070–1071.

J. Amer. Soc. Hort. Sci. 107(2):290–295. 1982.

Effect of Gibberellic Acid and Seed Rates on Pepper Seed Germination in Aerated Water Columns[1]

Jorge Sosa-Coronel[2] and J. E. Motes
Department of Horticulture, Oklahoma State University, Stillwater, OK 74078

Additional index words. Capsicum annuum, fluid drilling

***Abstract*. Seed germination of pepper (*Capsicum annuum* L.) in aerated water columns was accelerated and germination uniformity improved by using gibberellic acid (GA_3) at 6 μg/mg seed with 50 to 75 mg seed/ml of solution. Higher GA_3 rates in the aerated columns reduced germination percentage in some cultivars. Detrimental effects for GA_3 up to 6 μg/mg seed were not observed and in some cultivars speed of emergence and seedling growth was stimulated. GA_3 is economically feasible for use in germinating pepper seeds for sowing using the fluid drilling technique.**

Rapid and uniform germination is difficult to achieve with most pepper seed. Cultivars which usually have a high total percent germination do not exhibit uniformity in germination. Kanchan (9) reported that soaking pepper seed for 5 to 10 hr in GA_3 solutions stimulated germination. Other workers have reported stimulation of pepper seed germination using various techniques including polyethylene glycol and sodium hypochlorite treatments (6, 7, 14). GA_3 has been shown to stimulate seed germination in many species (1, 2, 10, 11, 12, 13).

It is essential to have a high percentage of germinated seed with uniform radicle length for fluid drilling (3, 4). Within a seed lot a few seeds produce radicles first and these often develop long radicles before the remaining seeds are at the proper stage of germination for fluid drilling. Long radicles (>4mm) on early germinat-

[1]Received for publication July 7, 1981. Oklahoma Agricultural Experiment Station Journal Article No. 4007. This research was supported in part by CONACYT (Consejo Nacional de Ciencia y Tecnologia, Mexico).

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.

[2]Present address: Campo Agricola Experimental de Mexicali. CIANO. Apartado Postal 3-1019, Mexicali, Baja California.

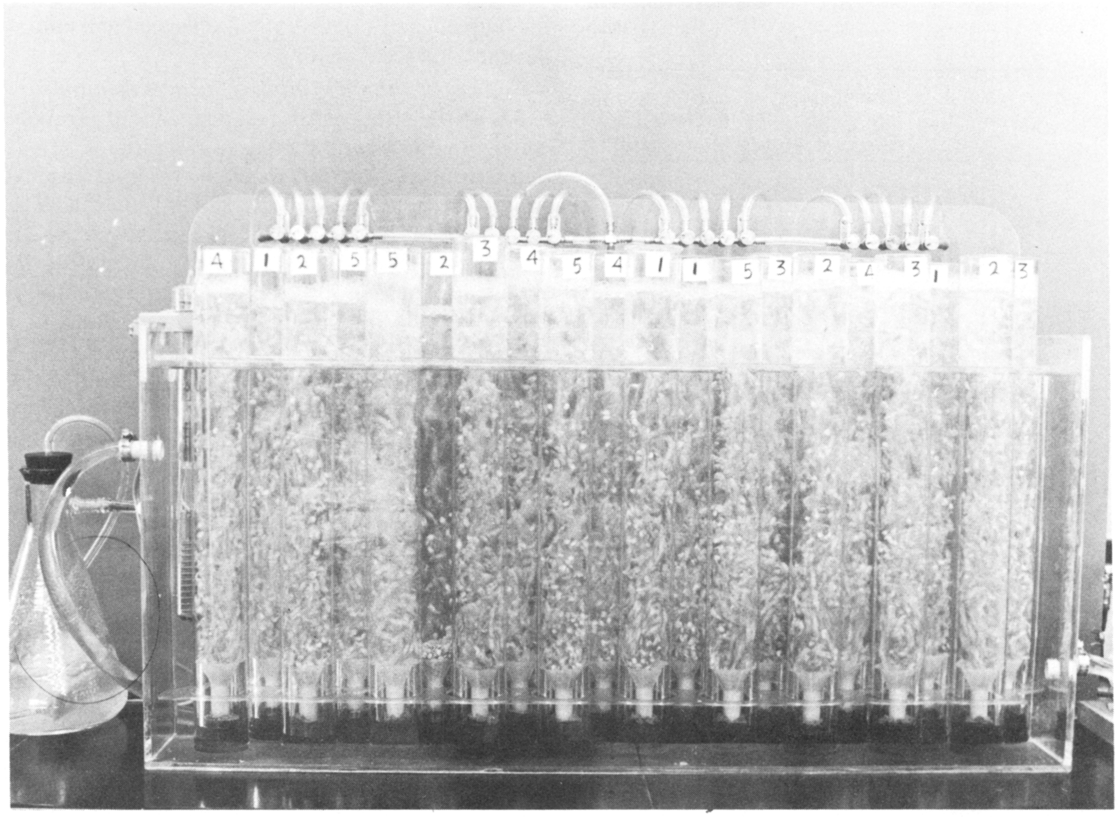

Fig. 1. Constant temperature water bath germinator with aerated water columns.

ing seeds are easily broken during handling and can clog fluid drilling planters. Uniform radicle emergence and length is essential for proper planter operation and to produce uniform seedling emergence and crop maturity (8).

This study was undertaken to develop a technique to germinate pepper seeds in aerated water columns that would produce rapid and uniform radicle emergence for use in fluid drilling of germinated pepper seeds.

Materials and Methods

Seed germination in aerated distilled water. Seeds of cultivars 'California Wonder Select' (bell), 'Bahemian Hot Chili', 'Kalspice #1' (paprika), 'Papaloapan' (jalapeno) and 'Tampiqueno 74' (serrano) were surface disinfested with a 1% solution of sodium hypochlorite for 5 min and rinsed immediately for 10 min with distilled water (7). After disinfestation, 100 seeds of each cultivar were placed in an aerated glass water column (39.5 cm in length and 4.5 cm in diameter) filled with 550 ml distilled water.

Germination columns were tapered at the bottom and fitted with an aeration stone. The flow of humidified air was adjusted to agitate the seeds throughout the height of the column (Fig. 1). The columns were immersed in a constant temperature water bath maintained at 30°C. Water in the columns was changed every 24 hr.

Seeds were counted daily as soon as the first radicle was observed. Seeds were considered germinated when the radicles were visible. Seeds with radicles exposed were discarded so that only non-germinated seeds remained in the column. The experiment was continued until germination ceased. Percent germination, daily cumulative germination, germination rate, days to 50% germination (T50) and uniformity of germination for each cultivar were calculated.

Seed germination in gibberellic acid solutions. GA_3 (MW 346.4) solutions at concentrations of 0, 200, 400, 600, 800, and 1000 ppm were prepared using distilled water. Germination conditions were the same as in the experiment with distilled water.

One hundred disinfected seeds of each of the 5 cultivars were placed in columns with 150 ml of GA_3 solution. The solutions were changed every 24 hr. The experiments were terminated after 2 or 3 days depending upon the cultivar. Each cultivar was treated independently with GA_3 treatments. GA_3 treatments were replicated 3 times in a randomized complete block design.

Gibberellic acid rate and seed rate. The germination conditions were the same as in the experiments described above. GA_3 rates were 0, 2, 4, 6, and 8 μg/mg seed in factorial combination. Seed rates were 25, 50, 75, and 100 mg/ml solution. The experiments were carried out separately for each cultivar. Two replications were used for each treatment combination in a randomized complete block design.

Previous experiments indicated that it was not necessary to keep the seeds in the GA_3 solutions continuously till radicle emergence to promote germination. After imbibition in distilled water, seeds will respond to the application of GA_3 in the subsequent 24 hr. Imbibition time was determined for each cultivar by noting the time to first radicle emergence. Imbibition times were 24 hr for 'California Wonder Select', and 'Papaloapan', 48 hr for 'Bahemian Hot Chili' and 'Tampiqueno 74' and 60 hr for 'Kalspice #1 Sweet Paprika'.

Table 1. Percent germination, germination rate, T50, and uniformity for seeds of five pepper cultivars germinating in aerated columns using distilled water.[z]

Cultivar	Total germination (%)	Germination rate (seed/day)	T50[y] (days)	Uniformity[x] (days)
California Wonder Select	96	13.7	5.7	5.6
Bahemian Hot Chili	95	20.7	4.0	3.7
Kalspice #1	97	29.4	3.0	2.6
Papaloan	100	45.5	1.9	1.7
Tampiqueno 74	90	26.4	2.8	4.1

[z]The germination period was 10 days with 100 seed/column.
[y]No. of days to 50% radicle emergence.
[x]No. of days between 10 and 90% radicle emergence.

After the germination data were obtained, 20 germinating seeds from each treatment were sown in a tray of peat and vermiculite. Trays were placed in an incubator at 30°C and 12 hr light. Seedling emergence data was determined every 24 hr. After no more seedlings emerged, the trays were transferred to room conditions (29° to 30° and daylight) in the laboratory. The seedlings were grown for 20 days and the tops harvested and dried at 100° for three days before determining dry weight per seedling.

Total percent emergence, emergence rate, days to 50% emergence (T50), uniformity of emergence and the emergence value (5) were calculated and analyzed. The emergence rate was calculated by adjusting the daily emergence data to fit a linear trend. The peak value was calculated in the manner described by Czabator (5). Once the peak value for each observation was found, the peak day (days from sowing corresponding to the day of peak value) was determined. In order to calculate the emergence rate which corresponds to the slope of the line in the linear equation, only the daily emergence data collected up to the peak day were used in the calculations. The emergence rate was expressed as the number of seedlings emerged per day. The T50 and uniformity (the span of time between days to 10% emergence and 90% emergence) were calculated from the linear equation, after calculating the emergence rate.

Results and Discussion

Seed germination in distilled water. Germination in aerated distilled water showed that seeds of all cultivars germinated 90% or higher (Table 1). Days from 10 to 90% germination (uniformity) and days to 50% germination (T50) exceeded 2 for all cultivars except 'Papaloapan'. Most of the radicles on the early germinating seeds of the other four cultivars would have been too long (>4mm) to be sown without radicle breakage and planter clogging by the time 50% radicle emergence was attained. Except for 'Papaloapan', the germination speed and uniformity were undesirable for fluid drilling.

Seed germination in gibberellic acid solutions. No information exists on the effect of GA_3 on pepper seed germination in aerated water columns, therefore the concentration of GA_3 at which seeds of different pepper cultivars would respond was investigated. Results of these studies are presented in Table 2. GA_3 concentrations above 200 or 400 ppm did not increase germination percentage appreciably. Even rapidly germinating seeds of 'Papaloapan' responded to the GA_3 treatment. For cultivars 'California Wonder Select' and 'Tampiqueno 74', concentrations of 1000 ppm decreased germination compared with lower GA_3 rates although still increasing germination above the controls. Radicle length was uniform in all cultivars at all the GA_3 rates (data not shown). The GA_3 treatments improved germination speed and all cultivars reached their maximum percent germination in a period of only 2 to 3 days.

These preliminary experiments with GA_3 indicated it was possible to accelerate pepper seed germination and attain uniformity in radicle length. Results indicated no need for GA_3 concentrations greater than 400 ppm to significantly increase the germination rate. However, even the lowest GA_3 concentration would be uneconomical since the seed quantity was very small compared to the quantity and cost of GA_3 used in the solutions.

Gibberellic acid rates and seed rates. The next procedure was to determine the minimum quantity of GA_3 needed for a given seed weight to improve the germination rate and uniformity and still be economical for use in the fluid drilling system. Another factor considered was the seed quantity in the GA_3 solution. Seed quantity will modify other factors in the germination environment due to competition for oxygen, water and accumulation of inhibitors leached from the seed during germination.

Percent germination generally increased as GA_3 increased from 0 to 6 μg/mg seed (Table 3). In cultivars 'California Wonder Select' and 'Tampiqueno 74' the highest germination was obtained with 8 μg GA_3/mg seed. For the other cultivars, 8 μg/mg seed was less effective in stimulating germination than 6 μg/mg seed.

Percent germination of 'Bahemian Hot Chili' and 'Tampiqueno 74' decreased as the quantity of seeds in the column increased from 25 to 100 mg/ml solution. The number of seeds/g (Table 3) in 'Bahemian Hot Chili' and 'Tampiqueno 74' was greater than in other cultivars. A greater number of viable seeds in the same volume of solution, regardless of the GA_3 rate, apparently modified the conditions for germination in the column. Competition for oxygen was increased, and more inhibitors may have been leached into the same volume of solution, thus creating

Table 2. Effect of gibberellic acid concentrations on percent seed germination in aerated water columns of 5 pepper cultivars.

	Seed germination (%)									
	GA_3 concn (ppm)						Significance			
Cultivar	0	200	400	600	800	1000	Linear	Quadratic	R^2	CV (%)
California Wonder Select[z]	2.7	60.7	81.0	79.0	79.7	71.3	.01	NS	.97	8.4
Bahemian Hot Chili[z]	7.0	87.3	91.0	87.7	85.0	87.7	.01	.01	.99	5.4
Kalspice #1[z]	40.3	94.3	91.0	92.0	94.7	93.0	.01	.01	.99	1.9
Papaloapan[y]	78.0	100.0	99.7	99.3	99.7	100.0	.01	.01	.97	1.9
Tampiqueno 74[y]	16.0	73.3	70.7	74.7	70.0	54.3	.01	.01	.69	28.2

[z]Experiments were terminated after 3 days.
[y]Experiments were terminated after 2 days.

an environment less favorable for germination. Oxygen supply was the same for all the columns in the germinator since the variability due to other factors was low. There was no significant interactions between GA_3 and seed rates. Results of GA_3 experiments on pepper seed germination generally agree with the findings of other researchers (1, 2, 9, 10, 11, 12, 13).

Seedling emergence results are presented in Table 4 and Fig. 2. Depending upon cultivar, speed of seedling emergence was unaffected or improved when seeds were treated with up to 6 μg GA_3/mg seed (Table 4). Eight μg GA_3/mg seed appeared to delay seedling emergence, except for cultivars 'Bahemian Hot Chili' and 'Papaloapan' which emerged faster at that rate than at lower rates. Eight μg GA_3/mg seed delayed the start of seedling emergence in all cultivars, but after the seedlings started to emerge the rate of emergence was high, as illustrated in Figure 2 for 'California Wonder Select'. For all cultivars except 'Califor-

Table 3. Effect of gibberellic acid rates and seed rates on the percent germination of 5 pepper cultivars germinating in aerated water columns.

	Germination (%)				
Variables	California Wonder Select	Bahemian Hot Chili	Kalspice #1	Papaloapan	Tampiqueno 74
GA_3 rates (μg/mg seed)					
0	11.3	73.3	33.8	60.8	48.4
2	26.7	77.6	39.8	70.1	55.7
4	39.2	77.0	43.6	72.0	62.5
6	48.3	80.2	44.8	78.1	61.1
8	52.9	79.7	37.5	75.5	72.7
linear	**[z]	*	*	**	**
quadratic	**	NS	**	**	NS
cubic	NS	NS	NS	NS	NS
Seed rates (mg/ml sol.)					
25	31.4	84.3	41.7	70.5	65.3
50	35.2	80.2	40.9	73.0	59.3
75	40.0	74.4	37.6	69.7	58.3
100	36.0	70.5	39.3	72.1	57.4
linear	*	**	NS	NS	**
quadratic	*	NS	NS	NS	NS
cubic	NS	NS	NS	NS	NS
Seed size (no. seed/g)	122	253	159	148	191

[z]NS,*,**Nonsignificant (NS), or significant F values at 5% (*) or 1% (**).

Table 4. Effect of gibberellic acid rates and seed rates on the days to 50% emergence and seedling dry weight (mg/seedling) from germinated seed of 5 pepper cultivars.

	California Wonder Select		Bahemian Hot Chili		Kalspice #1		Papaloapan		Tampiqueno 74	
Variable	Days to 50% emergence	Seedling dry wt (mg)	Days to 50% emergence	Seedling dry wt (mg)	Days to 50% emergence	Seedling dry wt (mg)	Days to 50% emergence	Seedling dry wt (mg)	Days to 50% emergence	Seedling dry wt (mg)
GA_3 rates (μg/mg)										
0	4.5	8.5	3.2	7.8	3.2	6.4	3.4	13.8	3.5	11.4
2	3.2	12.0	3.1	8.1	3.2	6.7	3.5	15.2	3.5	11.2
4	3.2	12.5	3.1	8.6	3.2	6.8	3.5	13.9	3.4	10.6
6	3.3	12.0	3.1	8.9	3.1	6.9	3.2	14.4	3.5	9.7
8	4.4	13.8	2.7	5.6	3.9	6.5	3.0	14.3	3.5	8.0
linear	NS[z]	**	**	**	**	**	*	NS	NS	**
quadratic	**	**	*	**	**	*	NS	NS	NS	*
cubic	NS	**	**	**	**	*	NS	NS	NS	NS
Seed rates (mg/ml sol.)										
25	3.8	11.1	2.8	6.7	3.4	6.5	3.2	14.7	3.2	10.6
50	3.8	11.6	3.1	8.1	3.2	7.3	3.3	15.5	3.5	10.5
75	3.7	12.6	3.1	8.3	3.4	7.3	3.4	14.7	3.6	10.0
100	3.7	11.8	3.2	8.0	3.3	7.2	3.5	12.4	3.5	9.6
linear	NS	NS	**	**	NS	*	**	*	**	*
quadratic	NS	NS	*	*	NS	*	NS	*	*	NS
cubic	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	8.7	10.7	6.3	10.0	7.0	9.8	8.9	17.3	8.3	13.1
R^2	0.86	0.83	0.78	0.87	0.82	0.87	0.62	0.48	0.47	0.67

[z]NS, *, **Nonsignificant (NS), or significant F values at 5% (*) or 1% (**).

nia Wonder Select' there were no significant differences among the GA_3 rates regarding the total percent emergence (data not shown).

Higher seed rates for cultivars 'Bahemian Hot Chili', 'Tampiqueno 74' and 'Papaloapan' slowed seedling emergence (Table 4). Emergence speed for 'California Wonder Select' and 'Kalspice #1' was not affected by seed rate.

Cultivar 'Tampiqueno 74' had higher seedling dry weight when no GA_3 was applied during germination. Other cultivars, except 'Papaloapan', increased in seedling dry weight when intermediate GA_3 rates were used during germination. The 8 μg GA_3/mg seed rate was detrimental to seedling growth for 3 of the 5 cultivars evaluated (Table 4). Although seedling height was not measured, no apparent height differences were observed when seedlings were harvested.

Seedling dry weight decreased as the seed rate increased from 25 to 100 mg seed/ml solution for cultivar 'Tampiqueno 74'. For the other cultivars, the trend was for 50 or 75 mg seed/ml solution to produce greater seedling dry weights compared with the other rates evaluated.

GA_3 stimulation of germination in the aerated columns did not always increase speed of seedling emergence. The highest percent germination for 'California Wonder Select' was obtained with 8 μg GA_3/mg seed (Table 3), but excluding the control, this treatment was the slowest in emergence (Table 4). The control (0 μg GA_3/mg seed) gave the lowest percent germination in the columns and the speed of emergence was generally poorer than for GA_3 rates up to 6 μg/mg seed. There were no significant interactions between GA_3 and seed rates for speed of emergence or seedling dry weight.

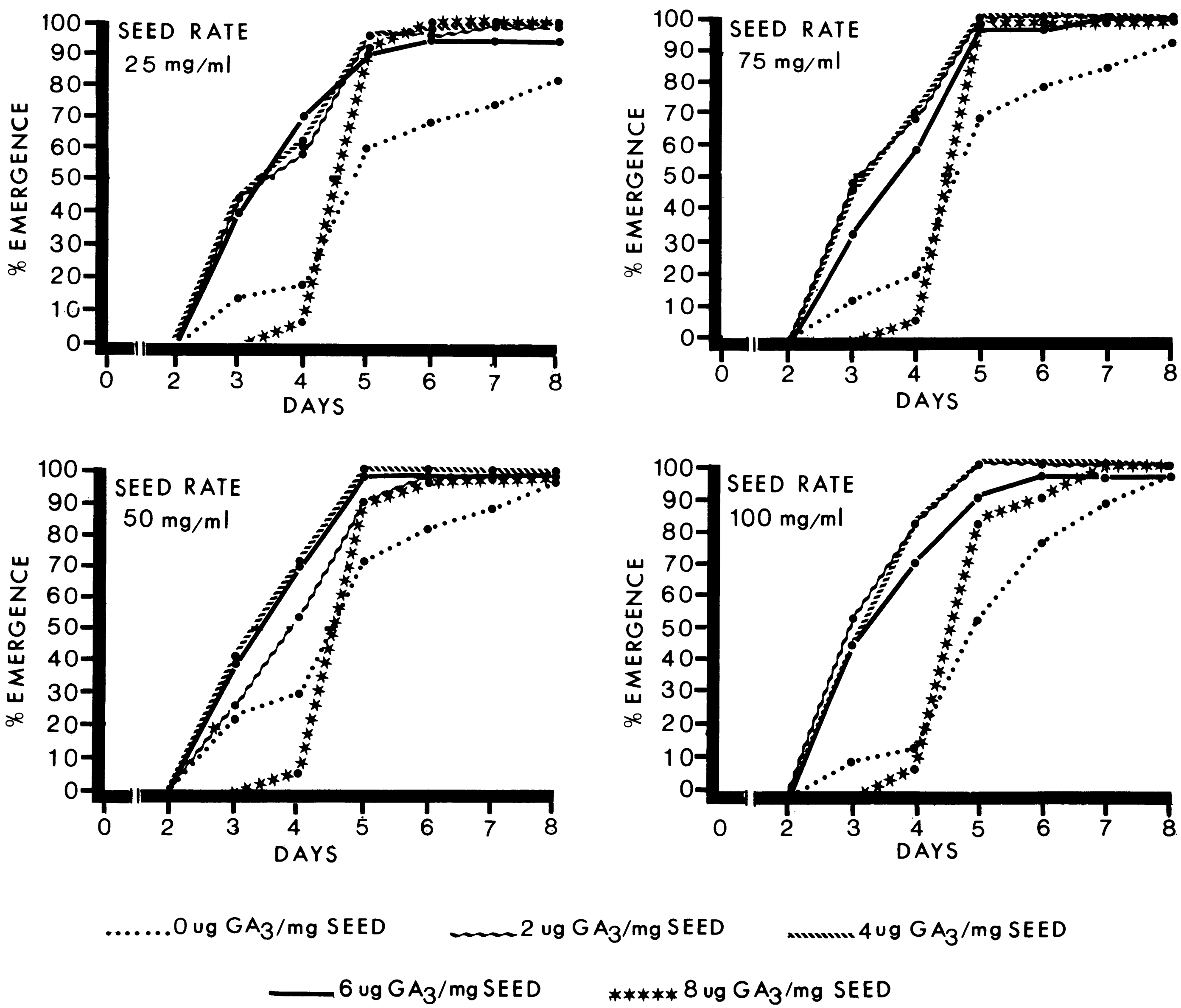

Fig. 2. Effect of gibberellic acid rates and seed rates on the cumulative daily emergence from germinated pepper seed (cultivar 'California Wonder P.S.').

Speed and uniformity of pepper seed germination can be enhanced by providing GA_3 in the germination water during the 24 hr subsequent to radicle emergence. All cultivars tested responded with more rapid and uniform germination. Detrimental effects from suitable GA_3 treatments were not observed and some cultivars were stimulated in speed of emergence and seedling growth. Using GA_3 for germinating pepper seeds for use in fluid drilling would increase seed germination costs $15 to $20/ha (6 to 8 μg GA_3/mg of dry seed and 50 to 75 mg of seed/ml of solution). This additional cost is justified to avoid planter clogging and to gain uniformity in radical emergence, seedling emergence and possibly in crop maturity.

Literature Cited

1. Bretzloff, L. V. and N. E. Pellett. 1979. Effect of stratification and gibberellic acid on the germination of *Carpinus caroliniana* Walt. HortScience 14:621–622.
2. Buxton, D. R., P. J. Melich, L. L. Patterson, and C. A. Godinez. 1977. Evaluation of seed treatment to enhance Pima cotton seedling emergence. Agron. J. 69:672–676.
3. Currah, I. E., D. Gray, and T. H. Thomas. 1974. The sowing of germinating vegetable seeds using a fluid drill. Ann. Appl. Biol. 76:311–318.
4. Currah, I. E. 1978. Plant uniformity at harvest related to variation between emerging seedling. Acta Hort. 72:57–67.
5. Czabator, F. J. 1962. Germination value: an index for combining speed and completeness of pine seed germination. For. Sci. 8:386–396.
6. Darby, R. J. and P. J. Salter. 1976. A technique for osmotically pretreating and germinating quantities of small seed. Ann. Appl. Biol. 83:313–315.
7. Fieldhouse, D. J. and M. Sasser. 1975. Stimulation of pepper seed germination by sodium hypochlorite treatment. HortScience 10:622.
8. Gray, D. 1976. The effect of time to emergence on head weight and variation in head weight at maturity in lettuce (*Lactuca sativa*). Ann. Appl. Biol. 82:569–575.
9. Kanchan, S. D. 1973. Effect of hardening on emergence and seedling growth in sweet pepper (var. 'California Wonder'). Current Sci. 42(21):762–763.
10. Ketring, D. L. and P. W. Morgan. 1970. Physiology of oil seeds. I. Regulation of dormancy in Virginia-type peanut seeds. Plant Physiol. 45:268–273.
11. Nagao, M. A. and W. S. Sakai. 1979. Effect of growth regulators on seed germination of *Archontophoenix alexandrae*. HortScience 14:182–183.
12. Nagao, M. A., K. Kanegawa, and W. S. Sakai. 1980. Accelerating palm seed germination with gibberellic acid, scarification and bottom heat. HortScience 15:200–201.
13. Puls, E. E. and V. N. Lambeth. 1974. Chemical stimulation of germination rate in aged tomato seeds. J. Amer. Soc. Hort. Sci. 99:9–12.
14. Yaklich, R. W. and M. D. Orzoleck. 1977. Effect of polyethylene glycol-6000 on pepper seed. HortScience 12:263–264.

J. Amer. Soc. Hort. Sci. 107(2):295–298. 1982.

Effects of Mechanical and Hand Pruning, Tree Spacing, and Limb Bending on Tree Development and Yield of Hedgerow 'Delicious' Apples on Malling Merton 106 Rootstock[1]

W. A. Dozier, Jr., C. C. Carlton, and K. C. Short[2]
Auburn University Agricultural Experiment Station, Auburn University Agricultural Experiment Station, Auburn University, AL 36849

Additional index words. Malus domestica

Abstract. **A combination of mechanical and hand pruning each year from 1971–1976 reduced pruning time over that of hand pruning alone for 'Delicious' apple (*Malus domestica* Borkh.). Yield was not significantly affected by pruning method with one exception in 1975. The use of the mechanical pruner destroyed the framework of the tree by inducing a thick canopy and reducing light penetration. Yield was increased by limb positioning at both the 2.3- and 3.0-m spacings. In 1974, higher yields were obtained with the 1.5-m spaced trees and in 1979 with the 3.0-m spaced trees. Average fruit weight was less for the 1.5-m spaced trees than for the 3.0-m spaced trees.**

Two major problems of the apple industry are increasing costs of production and a lack of qualified workers, particularly for pruning and harvesting operations (1, 2, 7). Kelsey et al. (11) reported in 1971 that pruning accounted for over 30% of apple production cost. In 1979, Smith and Ferree (14) reported that training of trees accounted for 43% of preharvest labor requirements. In an effort to improve pruning efficiency and reduce cost, research with various mechanical pruners has been conducted by a number of research workers (1, 2, 4, 9, 13). Even though the use of mechanical cutter bars to hedge and top trees reduces time necessary to prune orchards, such pruning results in a dense periphery of vigorous shoot growth. This dense growth reduces light penetration into the canopy, which results in suppressed spur formation, spur death, and poorly colored, small fruit (1, 2, 7).

[1]Received for publication Aug. 29, 1980.
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.
[2]Associate Professor, Department of Horticulture, and Superintendent and Assistant Superintendent, Chilton Area Horticulture Substation, respectively.