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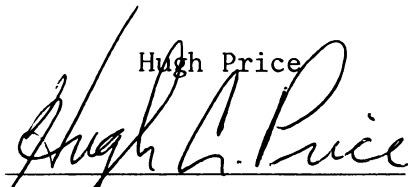
The Effect of Sowing Pregerminated and
Other Pretreated Vegetable Seed in a
Fluid Gel on Seedling Emergence and
Growth

presented by

Alan George Taylor

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THE EFFECT OF SOWING PREGERMINATED AND OTHER
PRETREATED VEGETABLE SEED IN A FLUID GEL ON
SEEDLING EMERGENCE AND GROWTH

By

Alan George Taylor

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ABSTRACT

THE EFFECT OF SOWING PREGERMINATED
AND OTHER PRETREATED VEGETABLE
SEED IN A FLUID GEL ON SEEDLING
EMERGENCE AND GROWTH

BY

ALAN GEORGE TAYLOR

Seed of various vegetable crops were pregerminated to improve earliness and uniformity of seedling emergence. Seed was germinated in aerated water, suspended in gel, then sown. Seed that germinates slow, especially at low temperatures, benefit most from pregermination.

Pregerminated tomato and pepper seed sown in the field emerged faster and with greater uniformity than dry seed. Pregermination resulted in an increase in fresh weight of plant in pepper and a greater percentage of ripe fruit in tomato.

Germinated seed was separated from non-germinated seed by density differences. Separation permitted elimination of over 95% of non-germinated seed and increased the rate and percent of seedling emergence for celery and pepper.

Germinated seed of certain species were stored for six days at low temperatures without loss in vigor. Earliness of emergence and increase in dry weight resulted from high humidity pretreatment of asparagus, celery, pepper and tomato in the greenhouse.

ACKNOWLEDGMENTS

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INTRODUCTION

In today's agriculture, economics and quality dictate the efficient production of crops. Direct seeding is an important practice to increase efficiency for the grower. Direct seeding provides the following advantages over transplanting: 1) lower cost per acre, 2) less need for labor, 3) more flexibility in choice of variety and plant population, and 4) more disease-free seedlings. (26).

A major problem in direct seeding is the failure to obtain an adequate and uniform stand (36) due to cold, wet conditions during planting. There exists a need for uniform crop emergence (31) to enhance the uniformity of maturity for machine harvesting.

The review of physiological predetermination by Kidd and West (24) cited information on the effect of presoaking of seeds on germination and subsequent growth of plants. Seed soaked in water and slowly dried imbibe water and germinate faster than untreated seed. Seed soaked in water and sown in a moist condition also germinate more quickly than untreated seed. Presoaked seeds show an increase in initial growth, but this advantage is not evident in later development.

The process of soaking seeds for twenty-four hours and then drying them for twenty-four hours is known as "hardening". This cycle may be repeated three or four times. Austin et al. (2) and Hegarty (19) have shown that carrot seeds which were hardened had a higher rate of germination than did the untreated seed. Hegarty reported that two corn cultivars had a significant improvement of germination by hardening seeds over the untreated seed. However, Waisel (43) showed that hardening of



wheat had no effect on growth, drought, frost or heat resistance as compared to untreated seed.

Inorganic salts and growth regulators have been used to improve seed germination. Ells (13) reported that K_3PO_4 and KNO_3 treatment stimulated germination in tomatoes when seeds were exposed to $10^{\circ}C$ night temperatures. Mayer and Poljakoff-Mayber reported (30) on the use of thiourea, gibberellin and KNO_3 to overcome seed dormancy and increase germination of seed. Oyer and Koehler (32) reported a method of treating tomato seed with aerated nutrient solutions to increase germination rate. The study indicated the effect of maintaining an osmotic potential to prevent germination during treatment.

Heydecker et al. (21) showed a method of accelerating germination by osmotic pretreatment. Seed are placed under an aerobic condition for a specified period and temperature with a solution of polyethylene glycol 6000. The polyethylene glycol, PEG, maintains an osmotic potential, thus at low concentrations the seed will germinate in the solution but at high concentrations imbibition will be prevented. The proper concentration will allow partial imbibition and initial processes of germination without radicle emergence.

Heydecker et al. (20) found with onion an increase in rate and earliness of germination by soaking seed in 296 grams of PEG per liter of water for 23 days at $10^{\circ}C$ compared to untreated seed. Salter and Darby (38) have also shown similar response with the synchronization of germination of celery seed by soaking in PEG.

The concept of extruding pregerminated seeds suspended in a gel was first described by Elliot (12). The gel acts as a carrier to facilitate planting and prevent damage to the exposed radicles. The



seed is first germinated in aerated water (11) and then suspended in a fluid gel which is extruded behind the furrow opener of a conventional planter as described by Gray (14).

Currah et al. (10) reported that germinated carrot seed, sown in a fluid gel, emerged earlier and with greater uniformity than dry seed. Field studies also indicated a significant increase in yield after 64 days from planting but not after 77 days. Biddington et al. (4) showed that germinated celery seed sown in a fluid gel gave an earlier and increased emergence and increased final yield as compared to sowing dry seed.

Uniformity of seedling emergence is important for uniformity of growth and time of harvest. Gray reported (15) the major factor influencing uniformity of mature head weight and the date of head maturity in lettuce was the uniformity in the time of emergence. He also illustrated that sowing pregerminated seed increased the uniformity of lettuce emergence compared with size graded seed sown in a conventional manner.

The period of germination is very crucial for subsequent development of the plant. Seed of certain species are most susceptible to chilling injury and seedling rot caused by exudates during imbibition. Dormancy also must be overcome before seed will germinate. This indicates the advantage of germinating the seed under ideal conditions prior to planting under field conditions.

Highkin and Lang (22) reported on the residual effect of germination temperatures on the growth of peas. Seed germinated at 23°C resulted in a significant increase in final height as compared to those germinated



at 3° or 7° C. Gray (16) has shown that light requirements and thermodormancy of lettuce can be overcome by germinating the seed in ideal conditions before fluid drilling. Bussel and Gray (6) have reported on low temperature germination requirement of tomato. Tomato seed do not germinate below 10° C. If dry seed are sown at 10° C they require 41 days for emergence. Seed that are pregerminated emerged after 17 days.

Nutrients and carbohydrates are exuded during seed germination. These exudates leach into soil and stimulate microbial activity (40). There is a direct correlation between the amount of exudate and seedling rot. Short and Lacy (39) have shown that in germinating pea seed, a significant increase in exudate occurs at 10° C. Short and Lacy (40) also showed seed soaked for 48 hours prior to planting had less incidence of seedling rot than the control.

Work by Pollock and Toole (33) on lima beans has shown the most critical period for the induction of chilling injury occurred during imbibition. Seeds that imbibed water at 25° C then followed by low temperature were observed to have no injury. Christiansen (8) found similar results with cottonseed. Seed imbibed at 5° C were seriously injured or killed, however, seed that were imbibed for four hours at 31° C, then dried, retained immunity to chilling.

Pollock (34) has shown that embryonic axes of lima bean seed with 20 percent initial seed moisture are more resistant to chilling injury than axes of less than 20 percent moisture. Roos and Manalo (37) have shown that snap bean seed with higher than 12 percent moisture gave a significant increase in field emergence than lower moisture seed.



Dry seed separators have been used to clean and upgrade seed quality of commercial seed lots (9, 23). Flotation in ethanol or pentane allows separation of full from empty pine seed (3). Green (17) has reported that a float-sink method in water is effective in determining the viability of tea seed. A method is necessary to separate germinated (radicles emerged) from non-germinated and non-viable seed without damage to emerged radicles.

Taylor et al. (42) developed a method to separate seed germinated from non-germinated or non-viable seed by density difference obtained by using a solution of sucrose in water. The separation procedure allowed elimination of over 95 percent of the non-germinated seed from the seed lot. The top fraction (germinated) of both celery and pepper resulted in significant increase in both rate and percent of emergence compared to non-separated or the bottom fraction.

This thesis reports results of research conducted on fluid drilling of vegetable seed. The method of density difference separation of germinated seed will be described. Greenhouse and field data will be reported comparing pregerminated, high moisture and dry seed. Cold storage studies are included with the greenhouse experiments.



MATERIALS AND METHODS

Section I and II

Crop response to pregermination and high humidity pretreatment

Cold storage of pregerminated seed

Six different vegetable crop seed were used to evaluate the effect of pregermination and high humidity pretreatment on seedling emergence and growth. The three treatments before sowing were pregerminated (radicles emerged), high humidity storage and dry seed stored at 60 percent relative humidity.

To obtain pregerminated seed, four replications of 100 seed of each species were germinated in the laboratory at 25°C. Germination took place in glass columns 40 x 4 cm filled with distilled water and aerated by an airstone at the base of each column. Water was changed daily. The following time in hours was required for pregermination of each species before they were removed from the columns.

<u>Crop</u>	<u>Species</u>	<u>Time in hrs.</u>
Asparagus	<u>Asparagus officinalis</u> cv. Mary Washington	120
Carrot	<u>Daucus carota</u> cv. Gold Pak	48
Celery	<u>Apium graveolens</u> var dulce cv. Florida 683	96
Onion .	<u>Allium cepa</u> cv. Bronze Age	48
Pepper	<u>Capsicum annuum</u> cv. California Wonder	96
Tomato	<u>Lycopersicon esculentum</u> cv. Chico III	72



To obtain high moisture seeds, four replications of 25 seeds of each species were counted and placed in 3 cm x 3 cm plastic weigh boats. The plastic boats were then placed in a closed desiccator with 400 ml of water in the base. Seeds were pretreated in this manner for one week at 25 °C before planting. Seeds for the dry treatment were stored at 25 °C and 60 percent relative humidity prior to sowing.

All treatments were sown on February 20, 1977, in the Plant Science Greenhouse range at Michigan State University. Seeds were planted with tweezers in flats filled with #3 vermiculite using a randomized complete block design. Rows were 32 cm long and 4 cm apart. Seeds were planted at a depth of 1 cm, 25 seeds were planted per row. Flats were watered as needed, and fertilized weekly with a 1/2 Hoagland's solution. Daily emergence was recorded and dry weight per plant was determined 30 days after sowing.

The days to 50 percent emergence (T50), days for 10 to 90 percent emergence (T10-90), and percent emergence were determined. The symbols T50 and T10-90 will be used throughout this thesis. The smaller the numbers the shorter the period of time to 50% emergence and the time between 10 to 90% emergence. The coefficient of germination (C.G.) is a mathematical expression for determining the speed of germination of seed. (25).

$$C.G. = \frac{(100) (A_1 + A_2 \dots + A_x)}{A_1 T_1 + A_2 T_2 + \dots + A_x T_x}$$

A=Number of seeds germinating



T=Time corresponding to A

X=Number of days to final count

The symbol C.G. will be used throughout this thesis. The larger the number the faster the germination.

In section II seed of the same species and pregermination procedure as section I were used to determine storage ability of seeds with emerged radicles. Asparagus, carrot, celery and onion pregerminated seed were stored at 1°C. Pepper and tomato pregerminated seed were stored at 5°C. The seeds of all species were stored in 10 cm petri dishes with a moistened piece of 9 cm diameter Whatman #3 filter paper in each.

Seed was stored for 0, 3, and 6 days before sowing. Four replications of 25 seeds of each were planted in the greenhouse with the same procedure as in section I and data also was collected as described in section I. No appreciable growth of radicles occurred during storage nor was any browning of radicles noted after storage before planting.

MATERIALS AND METHODS

Section III

Separation of pregerminated seed

Celery, Apium graveolens var dulce, cv Florida 683, and pepper, Capsicum annuum cv California Wonder seed were used to evaluate the sucrose separation technique. Five replications of 100 seeds of each species were germinated in the laboratory at 25°C as described in Section I. Radicle emergence was noted after 86 and 89 hours for celery and pepper, respectively. After 96 hours, seeds were removed from aerated columns.

A 22/78 and 25/75 wt./wt. sucrose/water solution was found to be optimal for celery and pepper separation, respectively. The specific gravity of these solutions are 1.091 and 1.105.

Seed and approximately 500 ml of sucrose solution were mixed in a beaker then poured into the separation column (Figure 1a). After 30 seconds, the bottom fraction was removed, and contained essentially all non-germinated seed (Figure 1b). The top fraction contained germinated seed (with emerged radicles). Fractions were collected on sieves and rinsed with distilled water. Germinated and non-germinated seed were counted before separation and in each fraction after separation.

After separation, 25 seed samples from each fraction were planted in flats filled with #3 vermiculite using a randomized complete block design. Flats were placed in growth chambers at 20°C and daily emergence was recorded for ten days.

The rate of emergence was evaluated using the technique of Maguire (29).



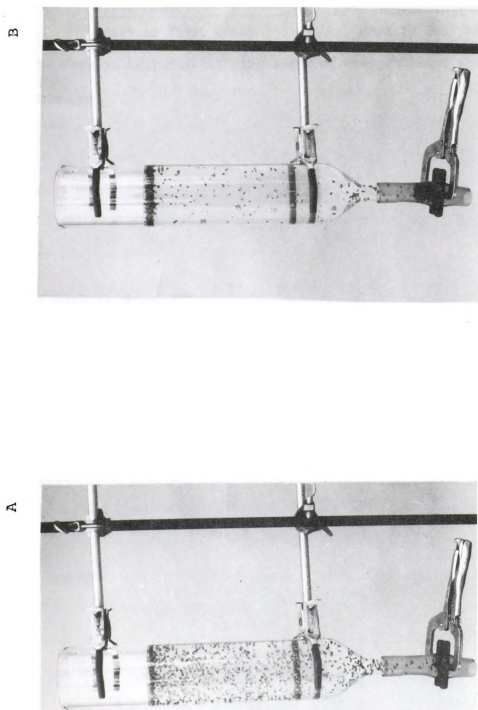
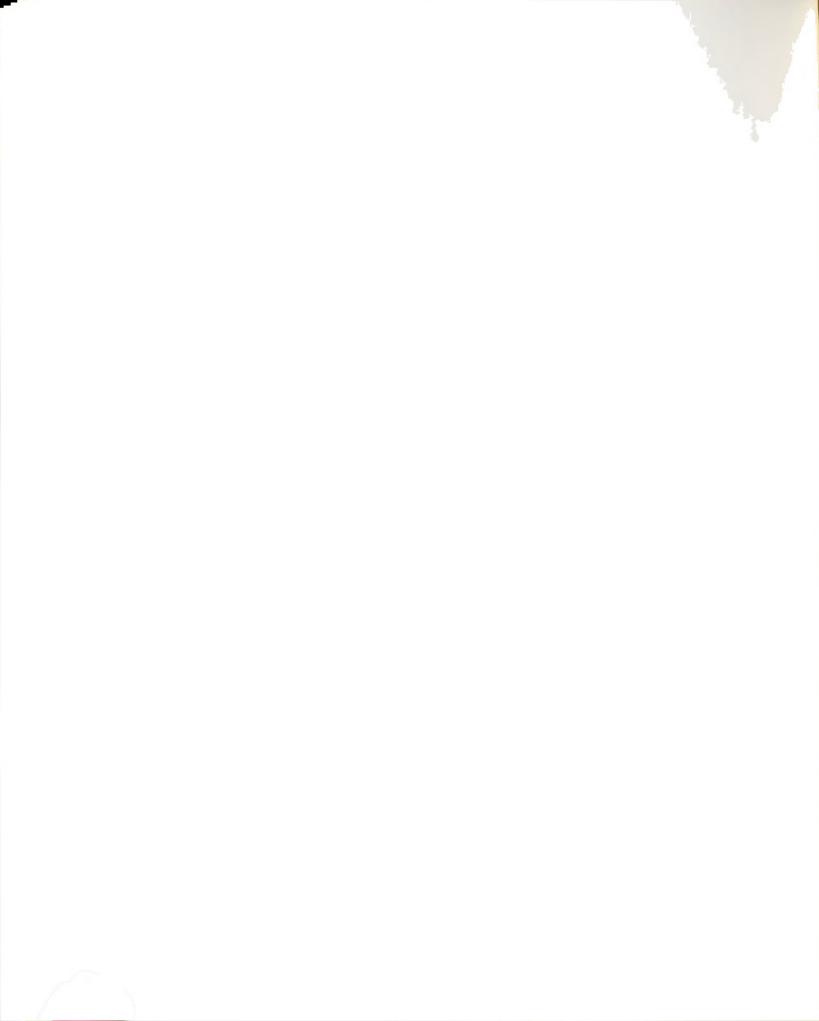


Figure 1. Separation of pregerminated seed by sucrose solution (A, initial placement of seed in sucrose solution) (B, top (floating) and bottom fractions after 30 seconds)

$$\text{Rate} = \frac{\text{no. of normal seedlings (first count)}}{\text{days to first count}} + \dots + \frac{\text{no. of normal seedlings (last count)}}{\text{days to last count}}$$

The formula includes both the speed of emergence and the total emergence.



MATERIALS AND METHODS

Section IV

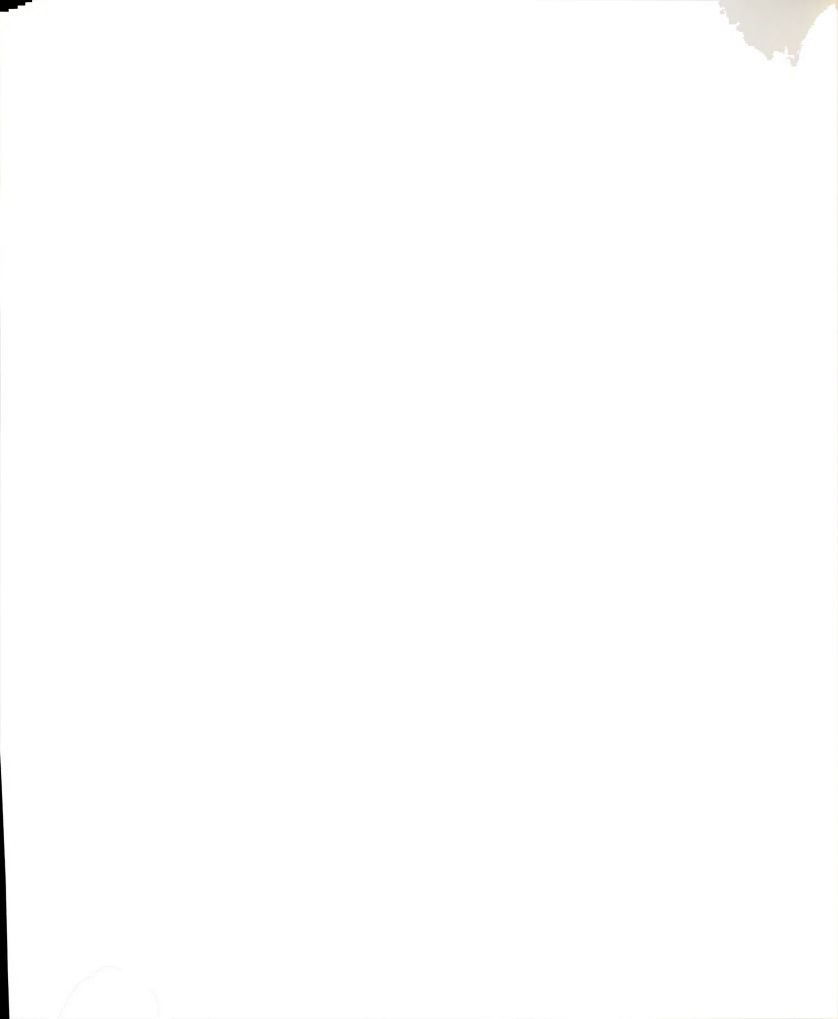
Field evaluation of pregerminated sown seed

Tomato, Lycopersicon esculentum, cv. Campbell 28 and pepper, Capsicum annuum cv. Yolo Wonder L were used for evaluating seedling emergence and growth of pregerminated and dry sown seed in the field. Seeds were germinated in a similar manner as described in section I, except 250 ml beakers were used instead of glass columns. There were four replications per treatment.

The pregerminated and dry seed were dispersed in 2 liter plastic bags containing 250 ml of gel. The gel used for fluid drilling was a starch based polymer, hydrolyzed starch polyacrylonitrile, H-SPAN. (available from General Mills Chemicals, Inc.). The proper viscosity needed to support seed was obtained by adding 3.5 g of H-SPAN to 1 liter of distilled water in a wareing blender. The gel and seed mixture was then sown with a bulk loading caulking gun in the field.

Seeding was done on June 18, and July 2, 1976, for tomato and pepper, respectively, at the Horticulture Research Center at Michigan State University. The soil was a Conover sandy loam and soil temperatures recorded at times of planting were 23°C and 19°C at the 5 cm level.

Tomato seed was sown in clumps .5 m apart with the caulking gun. The gun delivered 6.9 ml per clump which contained approximately 8 seed per clump. Rows were 6 m long and 1.5 m apart. Clumps were thinned to 3 plants 4 weeks after seeding. Pepper seed was sown in rows with the caulking gun. Approximately 40 ml per meter of row of gel was extruded. Rows were 6 m long and 1 m apart. Plants were thinned to .4 m



between plants 4 weeks after seeding. Seed for both species was planted at a depth of 1.5 cm in a randomized complete block design. Daily emergence and fresh weight of plants and fruit were recorded. Yield data was taken on September 21, 1976.



MATERIALS AND METHODS

Section V

Field evaluation of pregerminated and other pretreated seed

The effect of dry, high humidity stored, pregerminated and separated pregerminated sown parsnip, Pastinaca sativa cv. Hollow Crown, and tomato, Lycopersicon esculentum cv. Chico III seed were evaluated in the field. Seed of both species were germinated in the laboratory as described in section I. Parsnip seed required 144 hours for adequate radicle emergence for fluid drilling. Pregerminated seed were separated from non-pregerminated as described in section III. A 25/75 and 22/78 wt./wt. solution of sucrose to water was optimal for parsnip and tomato seed separation, respectively. The specific gravity of these solutions were 1.105 and 1.091. High moisture and dry sown seed pretreatments are described in section I. There were four replications per treatment.

Each replicate of all treatments was dispersed in 2 liter plastic bags as described in section IV. The only alteration was that another gel was used instead of H-SPAN. A blend of Xanthangum and Guar (available from Hercules Inc.) was used. The new material required 10 g per liter of water to form a suitable gel. An addition of 50 ppm of Captan, N-dichlormethylthiotetrahydrophthalimide, was mixed with the gel (1).

Seeding was done on June 7, and June 9, 1977, for parsnip and tomato seed, respectively, at the Horticulture Research Center. The soil was a Conover sandy loam and soil temperatures recorded at times of planting were 17°C and 19°C at 5 cm level.

The method of sowing tomato seed was the same as described in section IV. Parsnip seed was sown in rows with the caulking gun. Approximately 30 ml per meter of row of gel was extruded. Rows were 6 m long and 1 m apart. Plants were thinned to 8 cm between plants 4 weeks after seeding. Seed was at a depth of 1.0 cm and a randomized complete block design was used. Emergence and yield data was recorded for both crops. Yield data was taken on October 6 and 7, 1977.



RESULTS AND DISCUSSION

Section I

Crop response to pregermination and high humidity pretreatment

Sowing pregerminated seed reduced the T50 and increased the C.G. for all species (Table 1). High humidity treated seed were intermediate in response. The dry weight per plant thirty days after seeding of the pregerminated treatment was significantly greater than those of the other treatments for all crops except onion.

Asparagus seedlings sown from pregerminated seed emerged with less time for T10-90 than high moisture seed which was better than dry seed. There was a higher dry weight and higher percent emergence for pregerminated seed than the other treatments. The emergence of pregerminated asparagus seed was much more uniform than the other treatments (Figure 2).

The T10-90 of carrots was not affected by treatments. The effect of high moisture was observed to decrease the T50 over dry seed. Pregerminated carrot seed had a greater percent emergence and dry weight than the other treatments (Table 1). The days to final emergence of seedlings was the same for the high moisture and dry sown seed (Figure 3).

The effects of high humidity pretreatment of celery seed showed significant increases in T50, C.G. and dry weight per plant as compared to dry sown seed. The mean dry weight of plants sown from pregerminated seed was 2.5 mg compared to 1.4 mg for dry sown seed. The dry sown celery seed had a maximum value for daily emergence of 36 percent as compared to 27 percent for pregerminated seed (Figure 4).

Onion seed emerged erratically (Figure 5) and seedlings from



Table 1
The effect of high moisture and pregermination treatments of asparagus, carrot, celery, onion, pepper, and tomato seed on T50, T10-90, total percent emerged, C.G., and dry weight per plant

Species	Treatment	Emergence		C.G.	Dry wt. per plant in mg
		T50	T10-90		
Asparagus	Dry Seed	15.7c*	4.0c	6.0a	5.1a
	High Moisture	14.4b	3.1b	7.0b	6.4a
	Pregerminated	7.8a	2.2a	11.7c	11.3b
Carrot	Dry Seed	7.2c	2.8a	13.0a	3.5a
	High Moisture	6.1b	3.2a	14.3a	3.6a
	Pregerminated	3.6a	2.7a	22.8b	4.6b
Celery	Dry Seed	11.0c	2.8a	8.7a	1.4a
	High Moisture	8.9b	3.6a	10.6b	1.8b
	Pregerminated	4.8a	3.6a	17.6c	2.5c

* Mean separation within columns within species by Duncan's multiple range test at 5% level



Table 1 (cont'd)

Species	Treatment	Emergence		C.G.	Dry wt. per plant in mg
		T50	T10-90 Percent of total		
Onion	Dry Seed	7.2c*	3.2a	13.3a	6.0a
	High Moisture	6.1b	3.2a	15.0a	6.4a
	Pregerminated	2.4a	2.3a	32.9b	6.2a
Pepper	Dry Seed	15.9c	4.0ab	5.6a	4.0a
	High Moisture	13.6b	4.5b	7.2b	4.9b
	Pregerminated	7.5a	3.5a	12.4c	6.7c
Tomato	Dry Seed	9.0c	4.5b	10.0a	7.6a
	High Moisture	7.4b	4.1b	12.3b	10.4b
	Pregerminated	2.7a	2.1a	30.7c	17.2c

* Mean separation within columns within species by Duncan's multiple range test at 5% level

Figure 2. Effect of high humidity and pregermination treatments of asparagus seed on the daily percentage of seedlings emerged

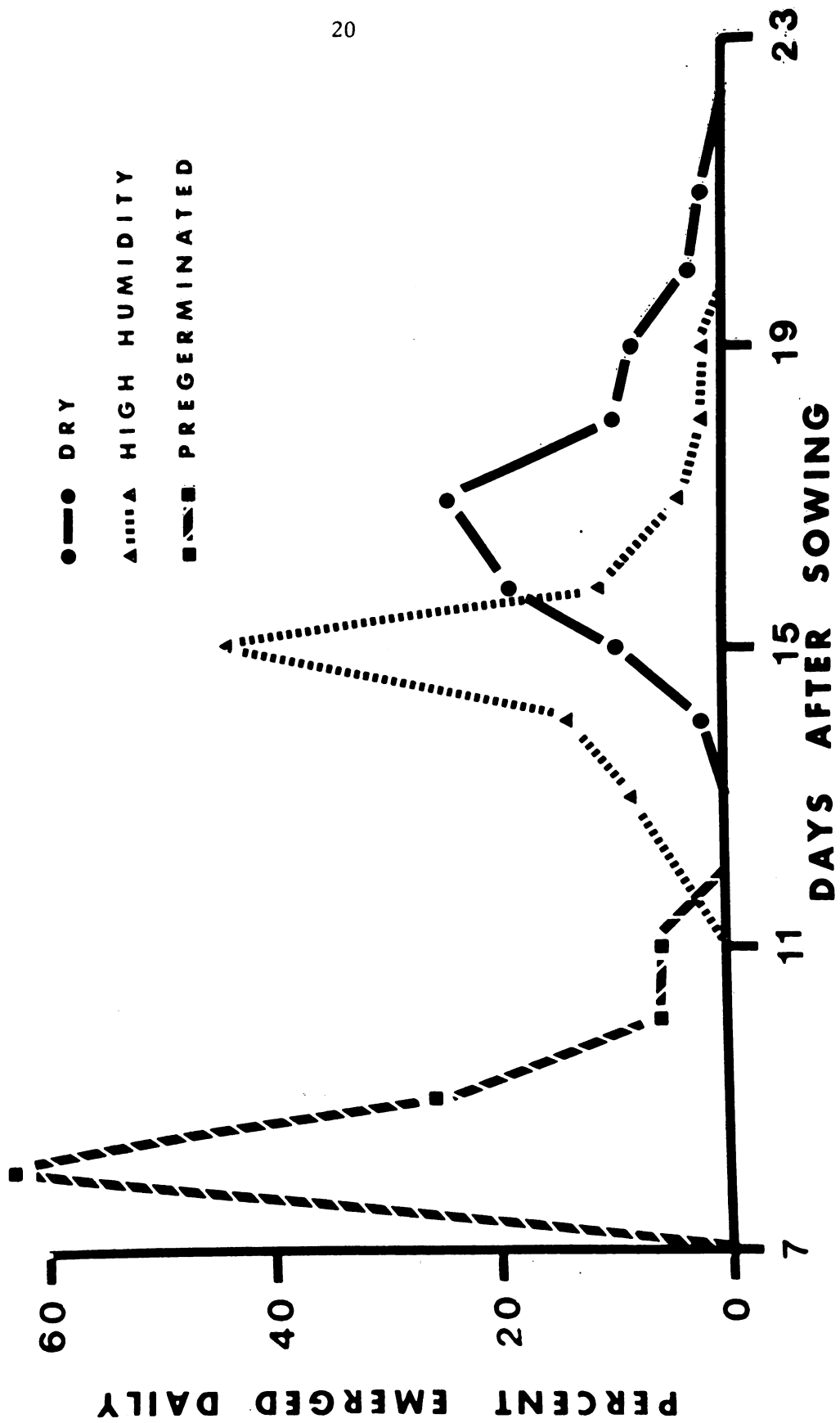




Figure 3. Effect of high humidity and pregermination treatments of carrot seed on the daily percentage of seedlings emerged

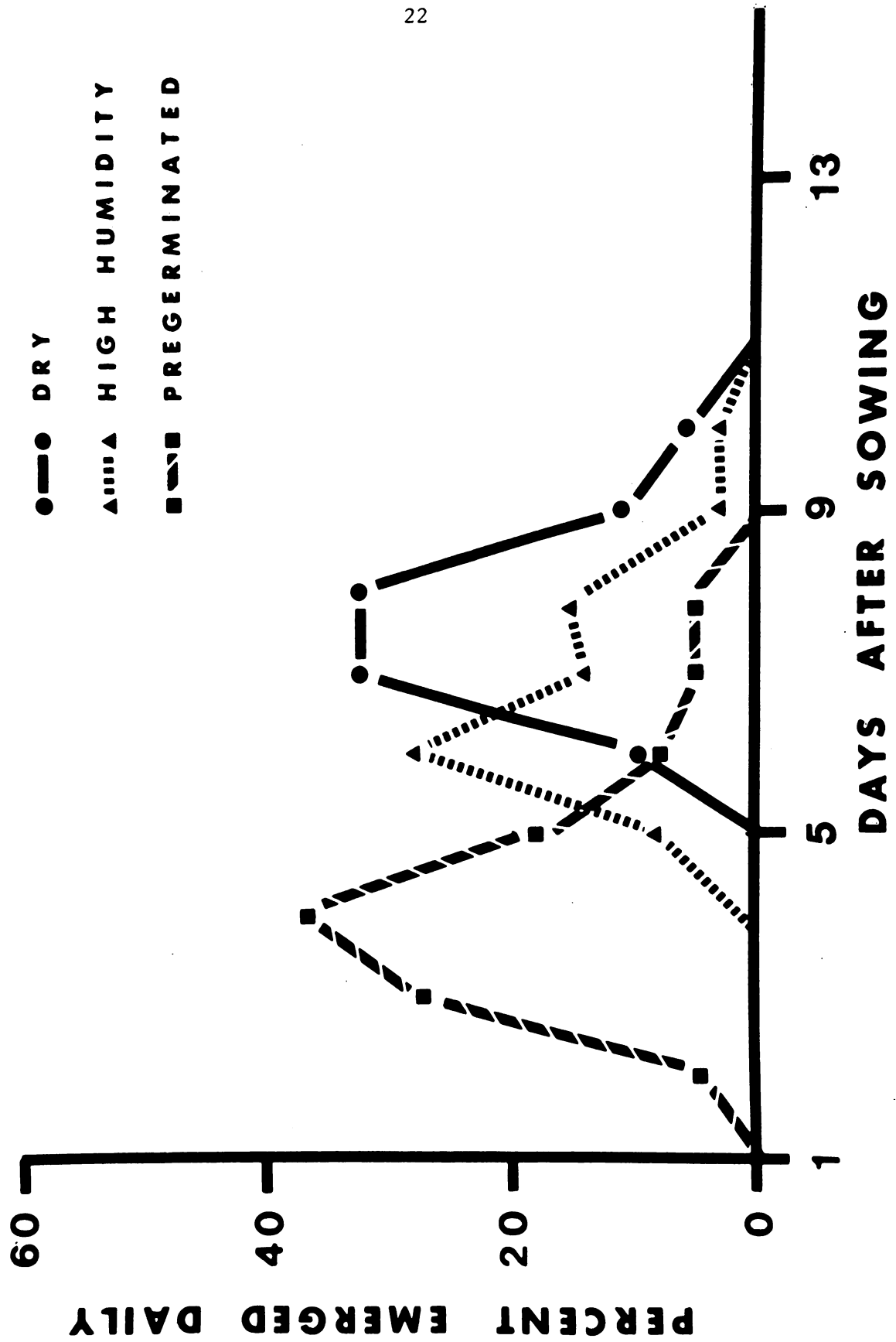


Figure 4. Effect of high humidity and pregermination treatments
of celery seed on the daily percentage of seedlings
emerged

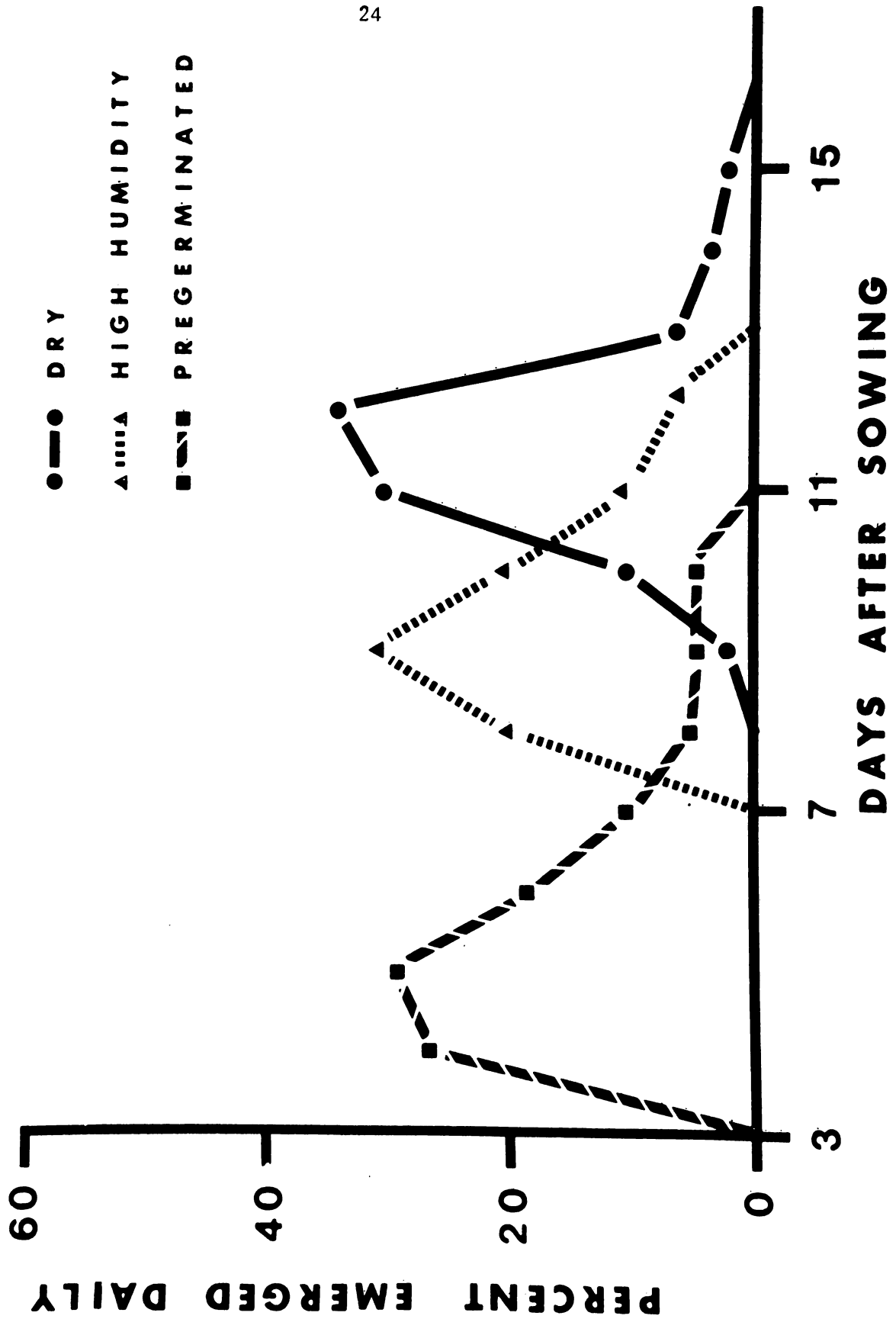
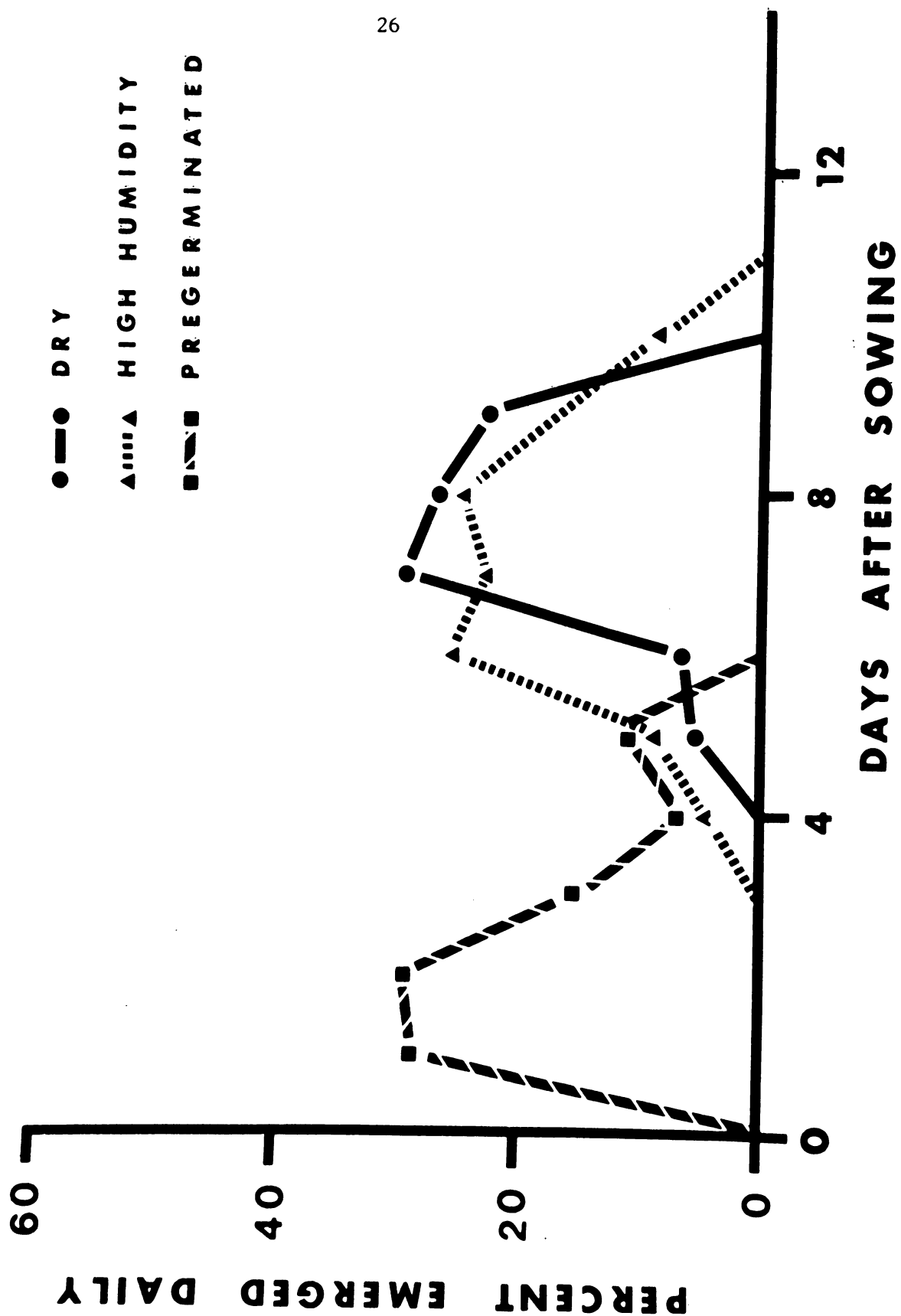




Figure 5. Effect of high humidity and pregermination treatments of onion seed on the daily percentage of seedling emerged





pregerminated sown seed did not develop properly. There was a 10 percent decrease in percent emergence for pregerminated seed as compared to other treatments (Table 1). There was no difference in T10-90 for all treatments.

Pregerminated sown pepper seed required only 7.5 days as compared to 15.9 days for dry seed for T50 (Table 1). Plants sown from pregerminated seed were greater in dry weight 30 days after sowing than the other treatments. Pregermination of pepper seed indicates an increase in C.G. as compared to the other treatments. There was no difference between the total percent emerged for all treatments. The effect of high moisture was observed to decrease the T50 and increase the C.G. as compared to the control. The emergence data illustrates that all pregerminated sown seed emerged before dry seed (Figure 6).

Tomato seed also responded very favorably to pregermination. Pregerminated sown seed required less time for T10-90 than did the other treatments. An increase in both dry weight and C.G. was also noted. High humidity treated seed emerged with less time for T50 and had an increase in dry weight compared to dry seed. The 'tailing' effect of emergence was greatly diminished by planting pregerminated seed than either high moisture or dry seed (Figure 7).

It appears that those seeds which will benefit most from fluid drilling are those that require long periods of time for germination, especially in cool soil temperatures. Tomato, pepper and asparagus respond well to pregermination and exhibit an increase in uniformity and earliness. Seeds that germinate very fast in cool soils would not gain an appreciable advantage over dry sown seed. High humidity pretreatment appears to be of some benefit to early emergence, especially



Figure 6. Effect of high humidity and pregermination treatments of pepper seed on the daily percentage of seedlings emerged

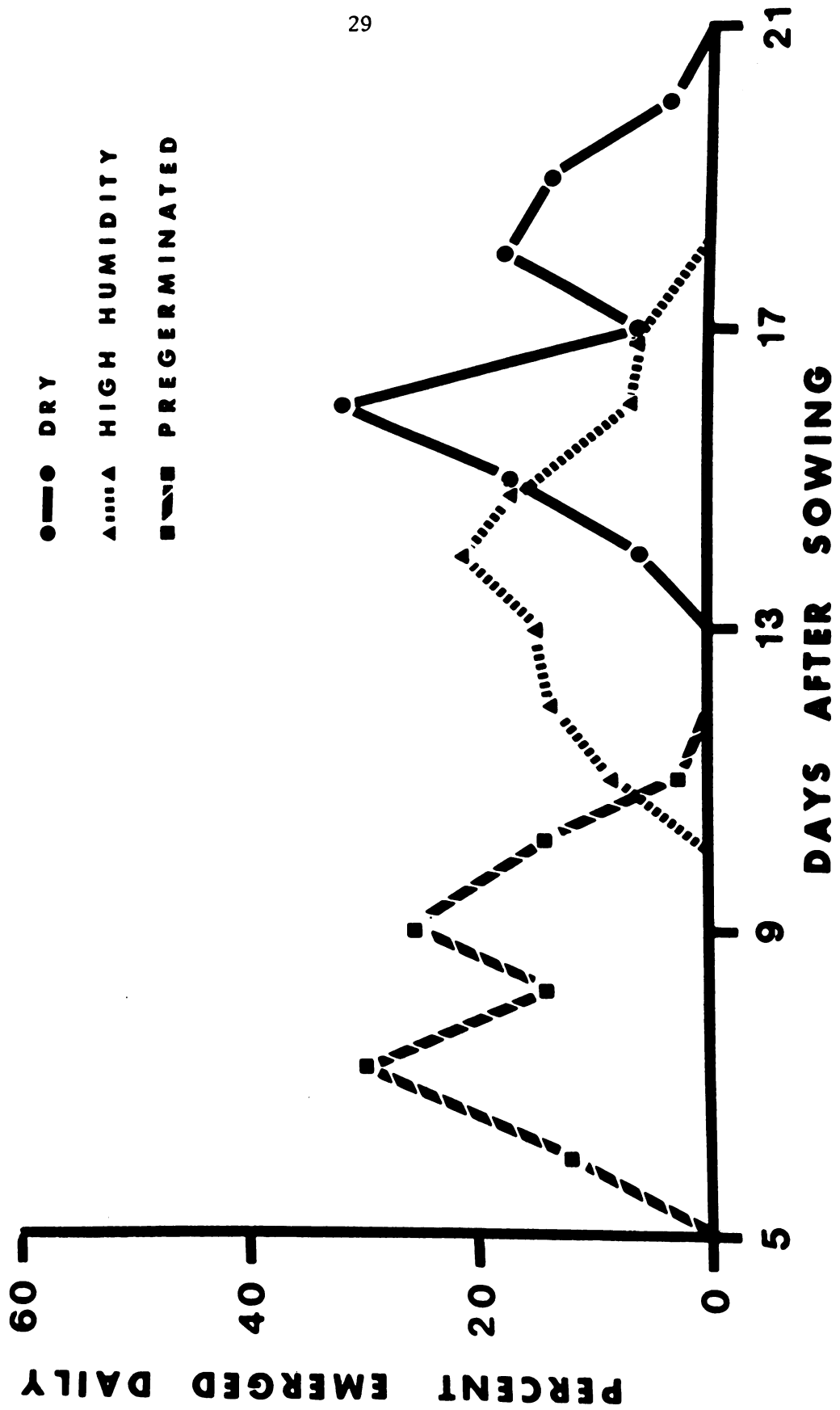
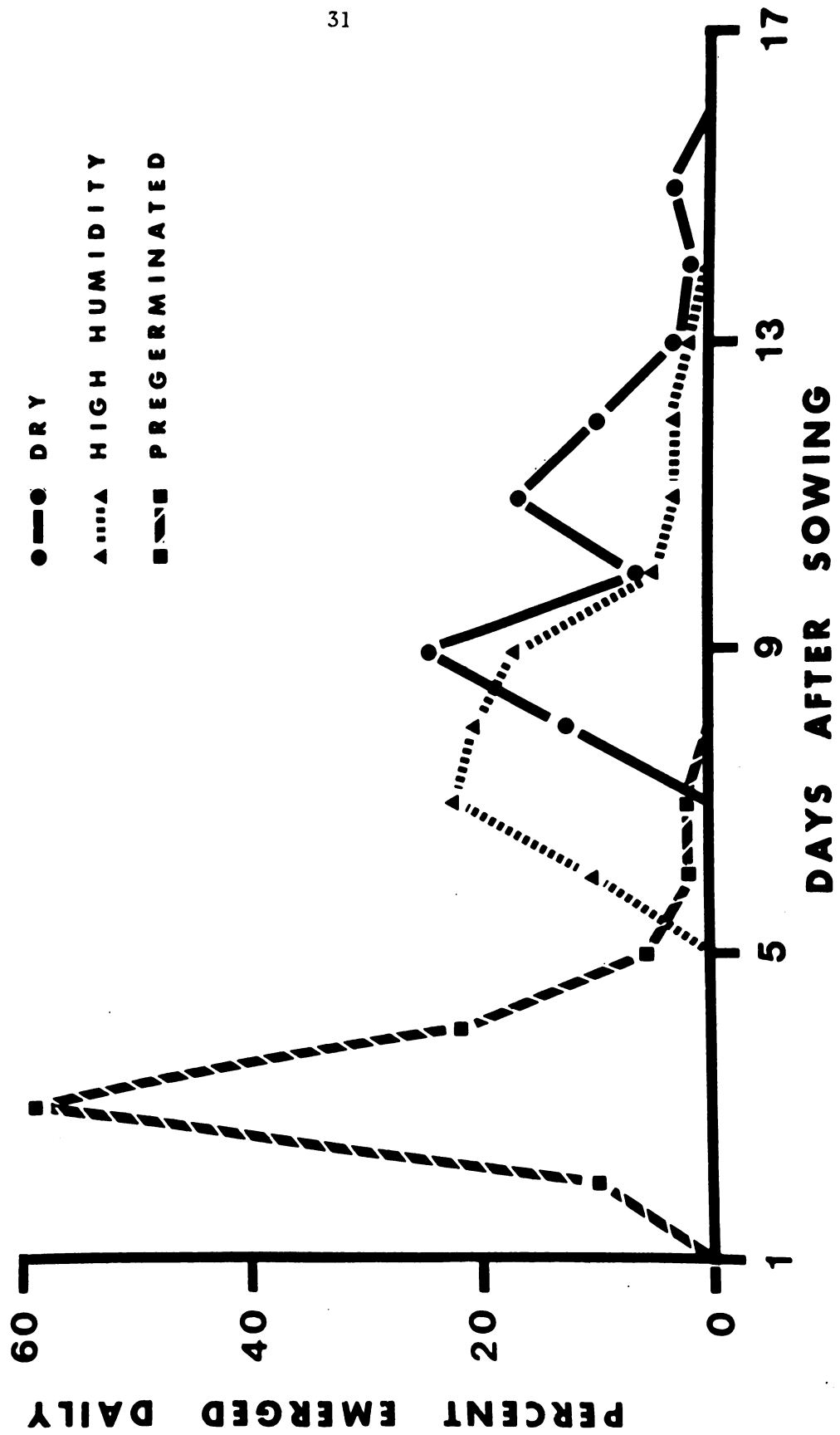




Figure 7. Effect of high humidity and pregermination treatments
of tomato seed on the daily percentage of seedlings
emerged



under cool conditions.



RESULTS AND DISCUSSION

Section II

Cold storage of pregerminated seed

Seed of asparagus, carrot, celery, and onion performed well after storage of up to 6 days. The T50, T10-90 and dry weight per plant after 30 days were not significantly different from the no storage treatment after storage of 3 or 6 days (Table 2). The percent emergence of carrot, celery and onion was not different after 3 or 6 days of cold storage. The C.G. was not significantly different for all storage times of asparagus, carrot and onion. Celery seed had a significant increase in C.G. after 6 day as compared to 3 day treatment.

The tomato and pepper seed, however, did not store as well. The T50, T10-90 and C.G. were not different for pepper and tomato after storage. After 3 and 6 days of storage, however, there was a significant decrease in total percent emergence of pepper. There was no significant difference in dry weight for the treatments. Storage of peppers for 6 days had 79.0 percent of the seedlings emerged as compared to 92.7 for the 0 day storage.

Pregerminated tomato seed held for 6 days had a significantly lower percent emerged than did 0 or 3 day storage. There was also a decrease in dry weight per plant after 6 days as compared to 0 and 6 days cold storage.

The storage of pregerminated seed is an important aspect of fluid drilling. If field conditions are not adequate or machinery breakdown occurs, seed must be kept without continued growth of radicles and must remain viable and vigorous. Pregerminated seed sown at suboptimal soil temperatures must retain their vigor until temperatures and growth can proceed.



Table 2

The effect of 0, 3, and 6 day cold storage of pregerminated sown asparagus, carrot, celery, onion, pepper and tomato seed on T50, T10-90, total percent emerged, C.G., and dry weight per plant

Species	Treatment (days in cold storage)	Emergence		C.G.	Dry wt. per plant in mg
		T50	T10-90		
Asparagus	0	8.1a*	2.7a	11.2a	12.2a
	3	8.0a	2.3a	11.5a	12.2a
	6	8.2a	2.9a	11.1a	12.1a
Carrot	0	4.5a	3.4a	19.6a	5.1a
	3	4.2a	3.3a	21.7a	4.7a
	6	4.1a	3.5a	22.5a	5.3a
Celery	0	4.3a	2.5a	19.8ab	2.7a
	3	4.4a	3.1a	18.6a	2.7a
	6	3.9a	2.5a	21.2b	2.6a

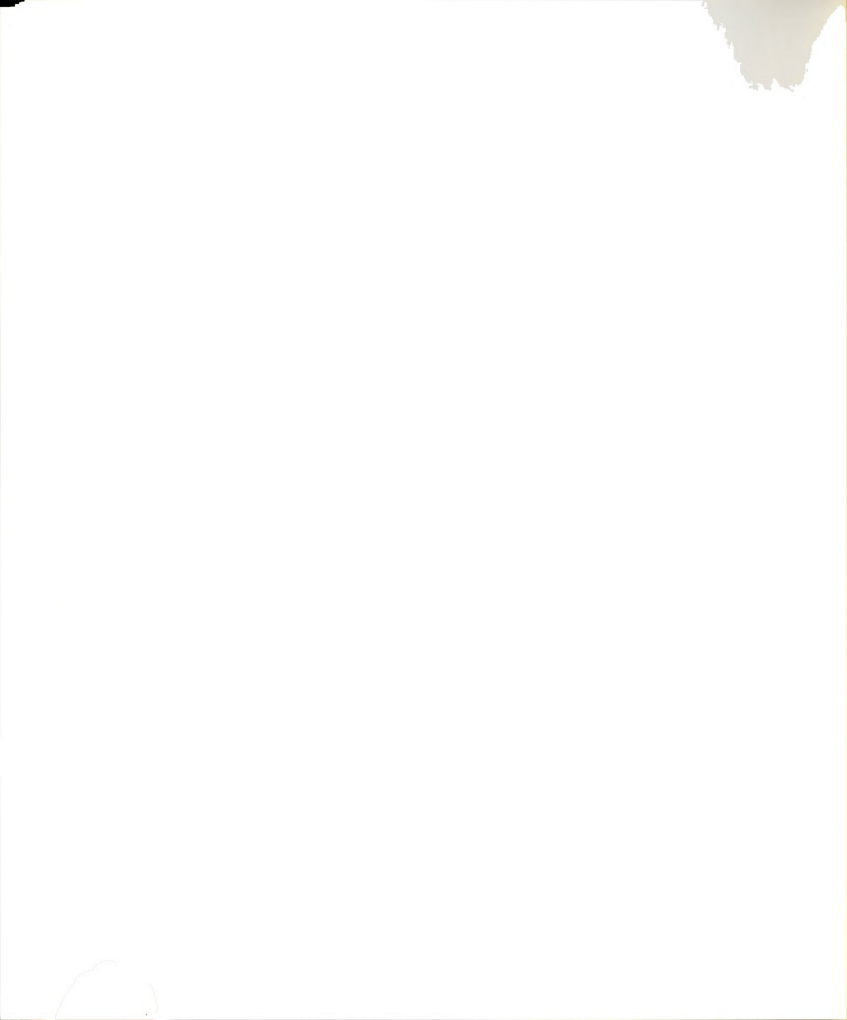
* Mean separation within columns within species by Duncan's multiple range test at 5% level



Table 2 (cont 'd)

Species	Treatment (days in cold storage	Emergence		C.G.	Dry wt. per plant in mg
		T50	T10-90 Percent of total		
Onion	0	3.5a*	3.0a	26.5a	5.4a
	3	3.3a	3.2a	26.0a	5.3a
	6	2.8a	3.5a	28.0a	5.5a
Pepper	0	6.9a	2.9a	13.6a	6.1a
	3	7.1a	3.6a	12.9a	6.0a
	6	6.9a	3.8a	13.1a	5.9a
Tomato	0	2.7a	2.7a	26.8a	13.0b
	3	2.7a	2.8a	28.3a	12.3b
	6	3.0a	3.4a	27.1a	10.5a

* Mean separation within columns within species by Duncan's multiple range test at 5% level



RESULTS AND DISCUSSION

Section III

Separation of pregerminated seed

The top fraction of celery contained 74.1 percent of the germinated (radicle emerged) seed and only 4.9 percent of the non-germinated seed (Table 3). The ratio of seed with radicles to seed without radicles, 37.7, is greatest in this fraction. The bottom fraction of celery seed contained 25.9 percent germinated seed and 95.1 percent non-germinated seed. The T50 of this top fraction of celery seed was significantly less than the bottom fraction and non-separated seed (Table 4). There was no difference between time for 10-90 percent emergence of the seedlings for all treatments.

The top fraction of celery had a significant increase in percent emergence as compared to the other treatments. Dry seed sown at the same time resulted in 83.2 percent seedling emergence. There was a significant increase in the rate of emergence of the top fraction compared to the non-separated and bottom fractions. Figure 8 illustrates the increase in both rate and percent of emergence of the top fraction of celery seed as compared to the non-separated and bottom fractions (Figure 8).

The top fraction of pepper retained only 4.6 percent of the non-germinated seed and had the greatest ratio of seed with radicles to seed without radicles (Table 3). The bottom fraction contained 95.4 percent of the non-germinated seed. There were no significant differences between T50 and T10-90 for all treatments of pepper (Table 4). The top fraction had the highest percentage of seedling emergence, 97.6 percent, and the greatest rate of emergence. Figure 9 illustrates increase in the percent of seedlings sown from the top fraction of pepper

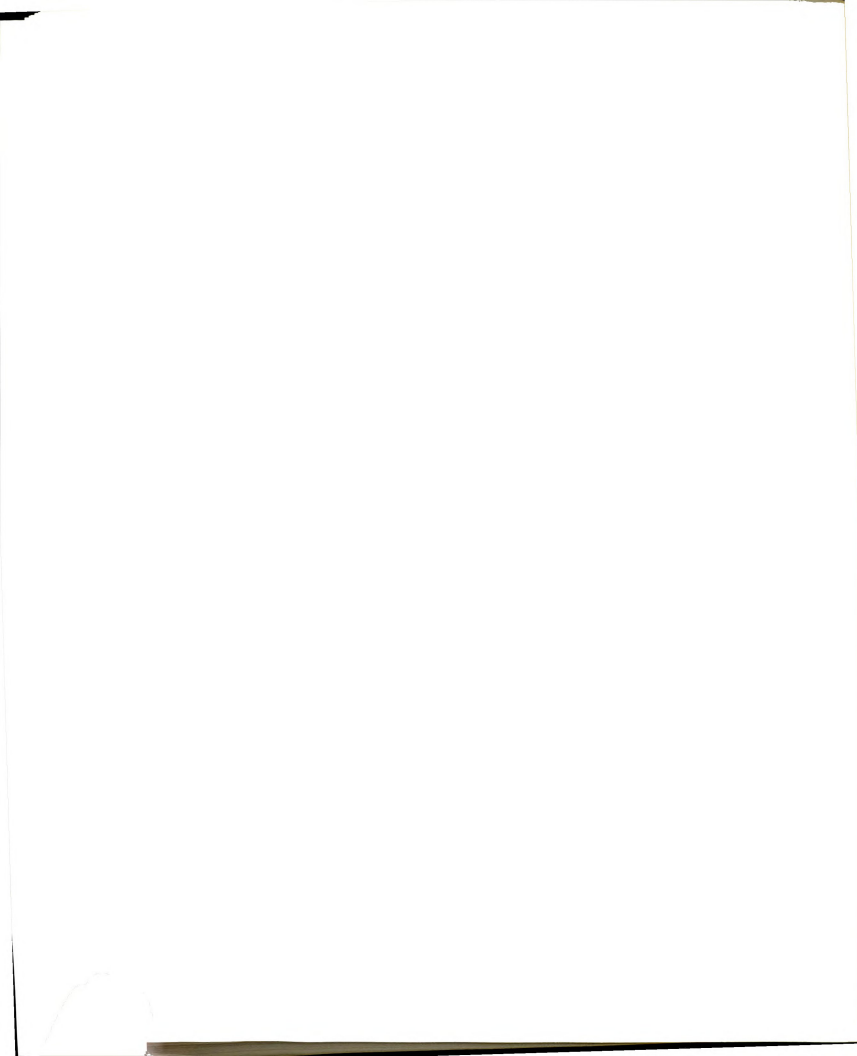


Table 3 The ratio, number, and percent of total seed with and without radicles for the top and bottom fractions and non-separated seed of celery and pepper

Species	Treatment	With Radicles		Without Radicles		Ratio ^x
		No.	% of Total	No.	% of Total	
Celery	Not Separated	71.2		28.8		2.5
	Separated					
	Top Fraction	52.8	74.1	1.4	4.9	37.7
	Bottom Fraction	18.4	25.9	27.4	95.1	.7
						37
Pepper	Not Separated	51.8		48.2		1.1
	Separated					
	Top Fraction	32.4	62.5	2.2	4.6	14.7
	Bottom Fraction	19.4	37.5	46.0	95.4	.4

^x $\frac{\text{No. with radicles}}{\text{No. without radicles}}$



Table 4 The T50, T10-90, total percent and rate of emergence for the top and bottom fractions and non-separated seed of celery and pepper

Species	Treatment	Emergence		
		T50	T10-90	Percent of Total Rate
Celery	Not Separated	4.9a*	2.2a	83.2b 15.1b
	Separated			
	Top Fraction	4.8a	2.1a	95.2c 17.6c
	Bottom Fraction	5.1b	2.7a	72.8a 12.7a
Pepper	Not Separated	5.3a	4.3a	76.0a 13.8a
	Separated			
	Top Fraction	5.4a	3.9a	97.6b 17.9b
	Bottom Fraction	5.6a	4.0a	73.6a 12.8a

* Mean separation within columns within species by Dunca's multiple range test at 5% level



Figure 8. Effect of sowing the top and bottom fractions and
non-separated seed on celery seedling emergence

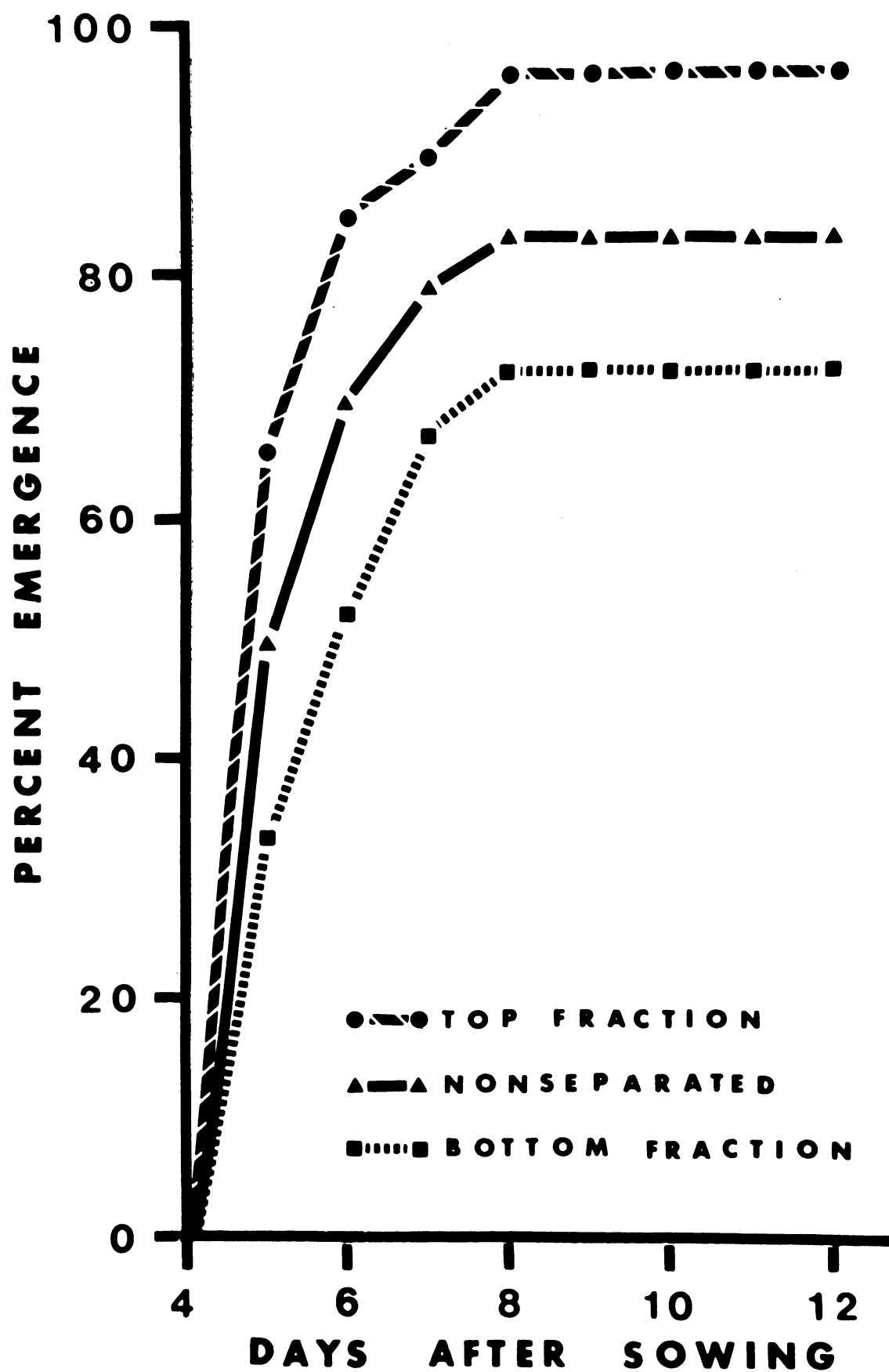
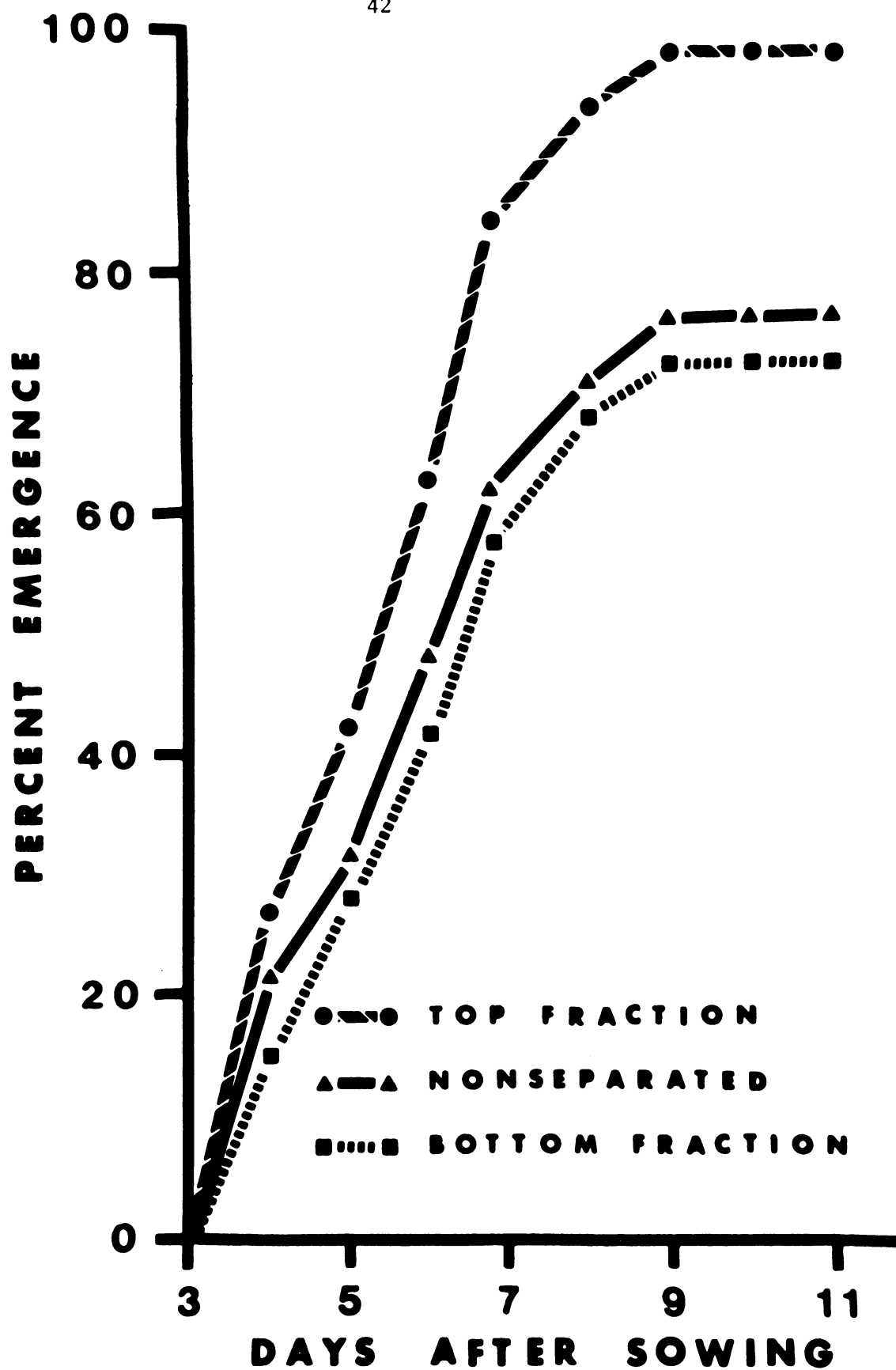




Figure 9. Effect of sowing the top and bottom fractions and non-separated seed on pepper seedling emergence





seed compared to other treatments.

The specific gravity method of separating germinated from non-germinated seed appears to be a valuable compliment to fluid drilling. The separation process is rapid and could be utilized on a large scale to separate quantities of seed.



RESULTS AND DISCUSSION

Section IV

Field evaluation of pregerminated seed

The T50 of pregerminated pepper seed was significantly faster than dry seed (Table 5). The C.G. also reflected the earliness and uniformity of emergence in the pregerminated as compared to dry seed. The fresh weight of plants was 1.0 kg per 6 m row for pregerminated in contrast to 0.3 kg for the control. No yield data was taken as plants had not reached sufficient maturity at time of harvest. The total spread in time of emergence for pregerminated sown seed was less than dry seed (Figure 10).

The C.G. and T50 was not significantly different for either of the treatments of tomato (Table 5). There was a decrease in the T10-90 by sowing pregerminated seed. Figure 11 illustrates the decrease in time to total emergence of pregerminated seed as compared to dry sown treatment. Fresh weight of plant and fruit at time of harvest were not different.

The fact that the T50 was reduced with pregerminated pepper seed, but not tomato seed indicates that soil temperatures were not limiting to tomato seed germination. Both crops have an optimum germination temperature of 30°C according to Knott (28), however, peppers require a greater accumulation of heat units than tomatoes. Bierhuizen and Wagenvoort (5) have demonstrated that peppers have a heat sum constant of 182 for emergence compared to only 88 for tomato.

Although soil temperatures were close to optimum for this field test, pregermination of the pepper seed appears to facilitate the accumulation of sufficient heat units for rapid emergence.



Table 5 The effect of pregermination of pepper and tomato seed on T50, T10-90, C.G., and fresh weight of plants and fruit.

Species	Treatment	Emergence		C.G.	Fresh wt. of plants in kg per 6m row	Fresh wt. of fruit in MT per ha
		T50	T10-90			
Pepper	Dry Seed	15.8b*	9.9b	12.0b	.3a	
	Pregerminated	7.6a	4.5a	6.3a	1.0b	
Tomato	Dry Seed	6.7a	6.8b	12.9a	27.3a	24.2a
	Pregerminated	6.2a	3.1a	15.4a	29.0a	28.6a

* Mean separation within columns within species by Duncan's multiple range test at 5% level



Figure 10. Effect of pregermination of pepper seed on daily percentage of seedlings emerged

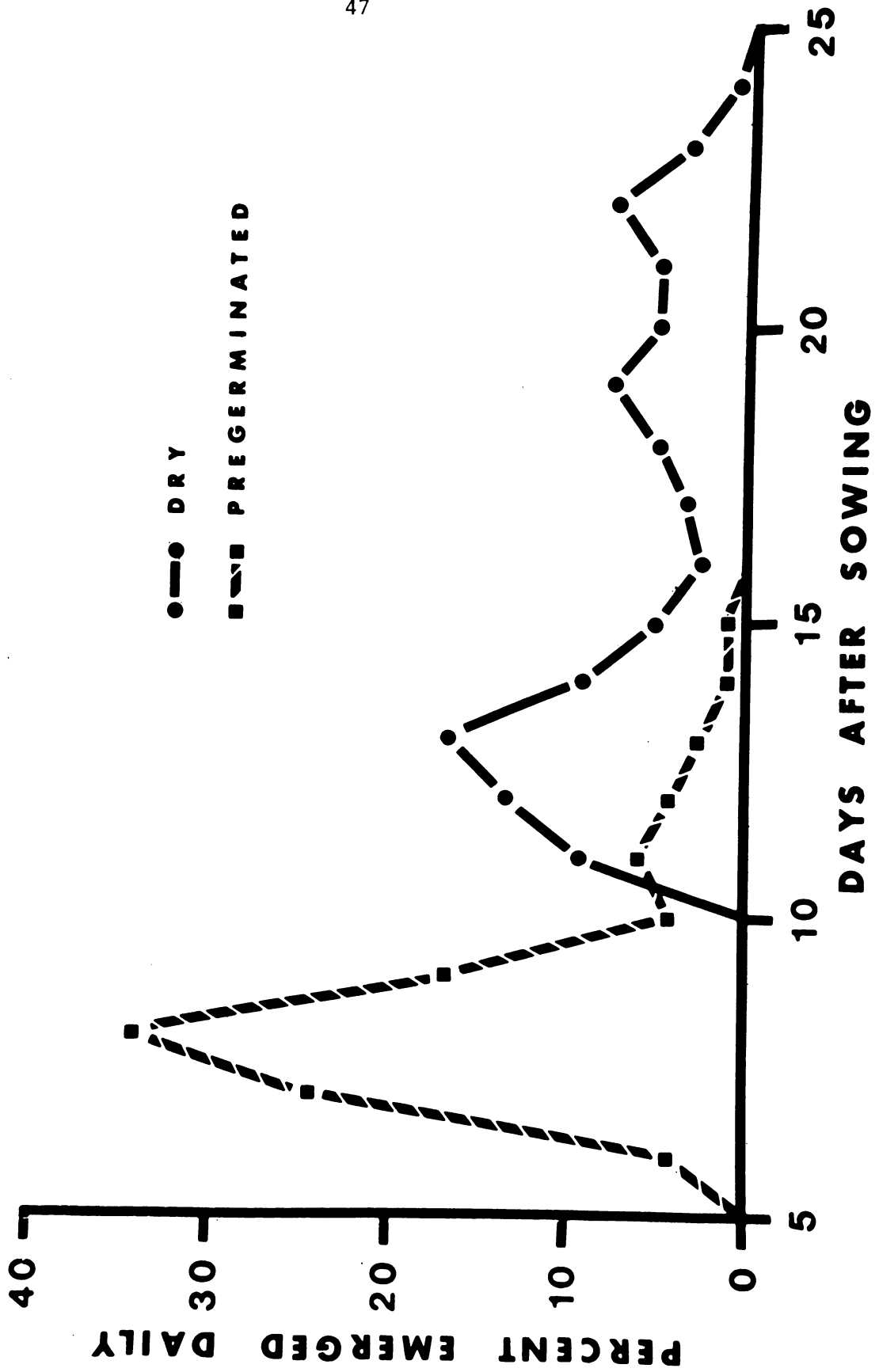
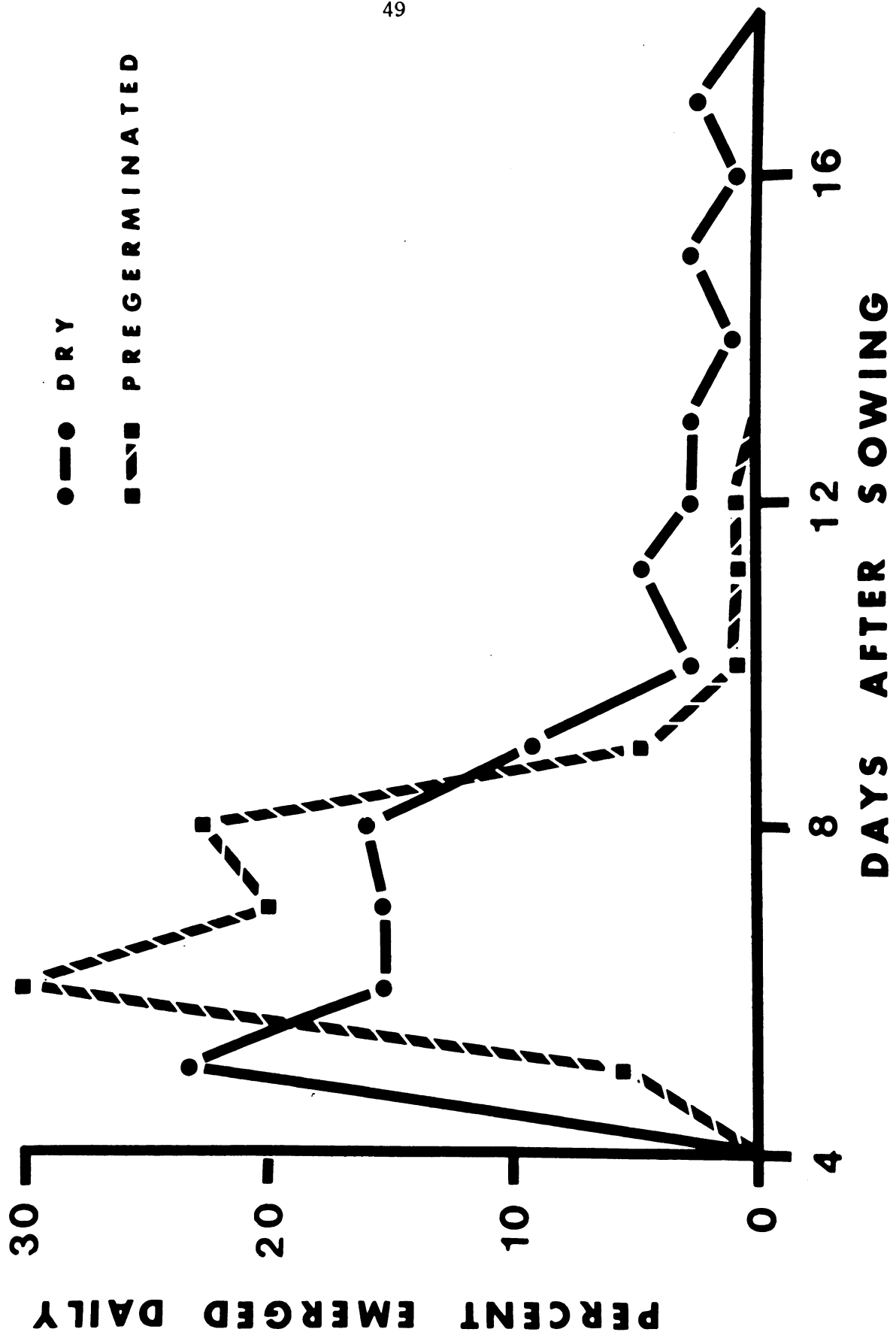


Figure 11. Effect of pregermination of tomato seed on daily percentage of seedlings emerged





RESULTS AND DISCUSSION

Section V

Field evaluation of pregerminated and other pretreated sown seed

The T50 of parsnips was significantly longer for dry seed than either high moisture or pregerminated treatments (Table 6). The pregerminated seed treatment also greatly enhanced the uniformity of emergence by reducing the T10-90 from 6.1 for dry seed to 3.8 days for the pregerminated seed. Separation of pregerminated seed did not decrease the T50 or T10-90 compared to sowing only pregerminated seed. Sowing separated pregerminated seed resulted in 39 percent of the seedlings emerged as compared to 23 percent for the pregerminated treatment 5 days after sowing (Figure 12). The C.G. was significantly different for each treatment with separated pregerminated having the greatest rate followed by pregerminated, high moisture and dry.

The yield data indicates a significant increase in weight of total harvested roots in the pregerminated treatments as compared to the high humidity or dry treatments. The poor stand in the dry and high humidity plots, resulted in fewer harvestable roots, but of much larger size. Adjusting yields to a uniform stand gave no difference between treatments, thus the initial stand is the primary factor affecting yield in this experiment.

Both pregerminated tomato treatments emerged in less time for T50 and T10-90 than high moisture and dry sown seed (Table 7). Only 5.2 days were required for T50 of the separated pregerminated seed as compared to 13.6 for dry seed. Although separated pregerminated seed did not affect T50 or T10-90 the C.G. was increased. Pregerminated sown seed required



Table 6 The effect of high moisture, pregermination and separated pregermination of
parsnip seed on T50, T10-90, C.G. yield and adjusted yield

Treatment	Emergence		C.G.	Yield		
	T50	T10-90		MT per ha	# of roots harvested	MT per ha adjusted
Dry Seed	18.4c*	6.1b	5.4a	5.6a	(34.2)	9.9a
High Moisture	14.5b	5.3b	6.8b	6.7a	(34.5)	11.8a
Pregerminated	7.2a	3.8a	13.6c	11.2b	(54.2)	11.9a
Separated Pregerminated	6.7a	3.5a	15.5d	11.5b	(59.7)	12.4a

*

Mean separation within columns by Duncan's multiple range test at 5% level



Figure 12. Effect of high humidity, pregermination and separated
pregermination of parsnip seed on the daily percentage
of seedlings emerged

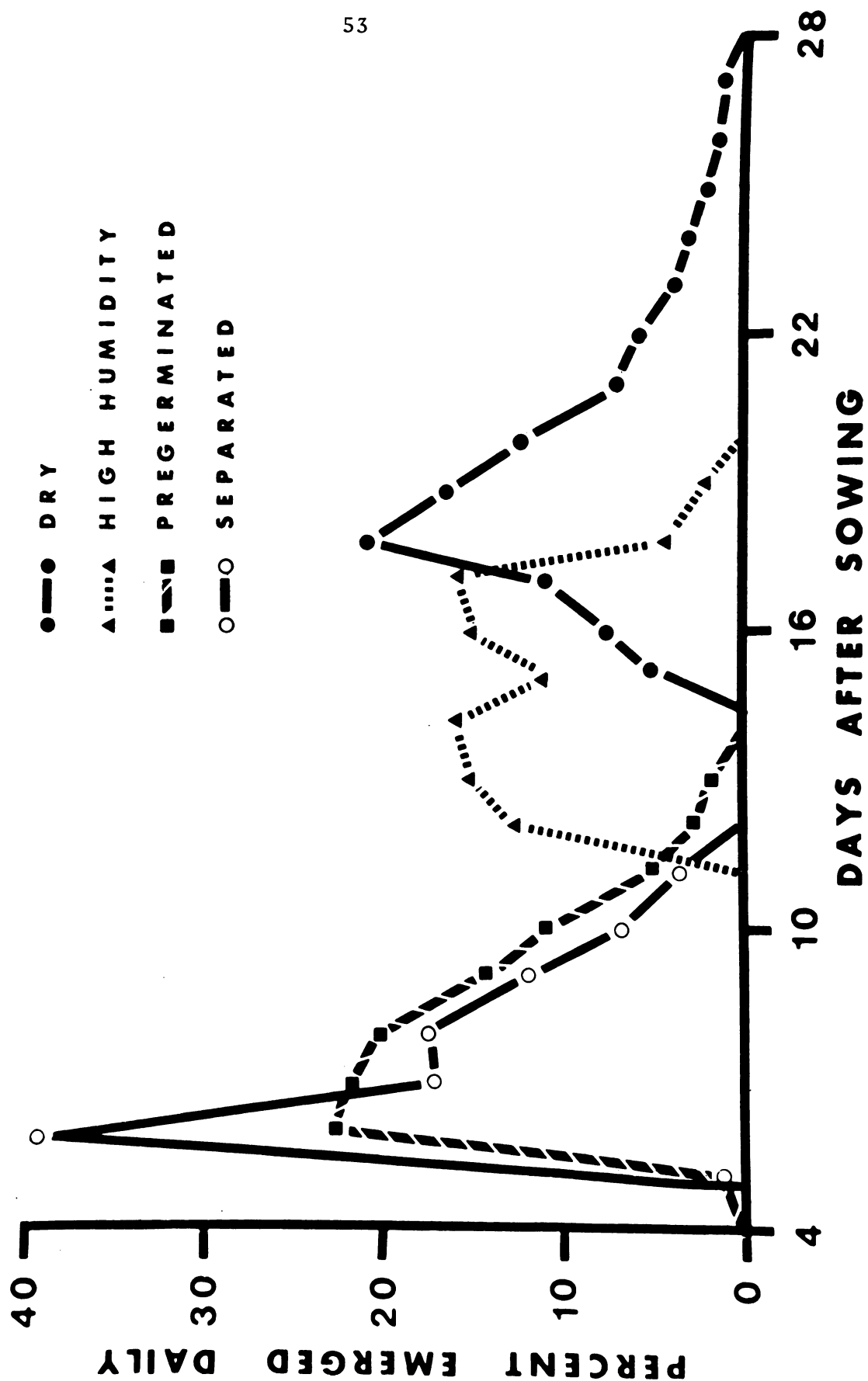


Table 7 The effect of high moisture, pregermination and separated pregermination of tomato seed on T50, T10-90, and C.G.

Treatment	Emergence		C.G.
	T50	T10-90	
Dry Seed	13.6b*	6.9c	7.3a
High Moisture	12.4b	6.2b	7.8a
Pregerminated	5.4a	3.7a	15.6b
Separated Pregerminated	5.2a	3.5a	17.3c

* Mean separation within columns by Duncan's multiple range test at 5% level



Figure 13. Effect of high humidity, pregermination and separated pregermination of tomato seed on daily percentage of seedlings emerged

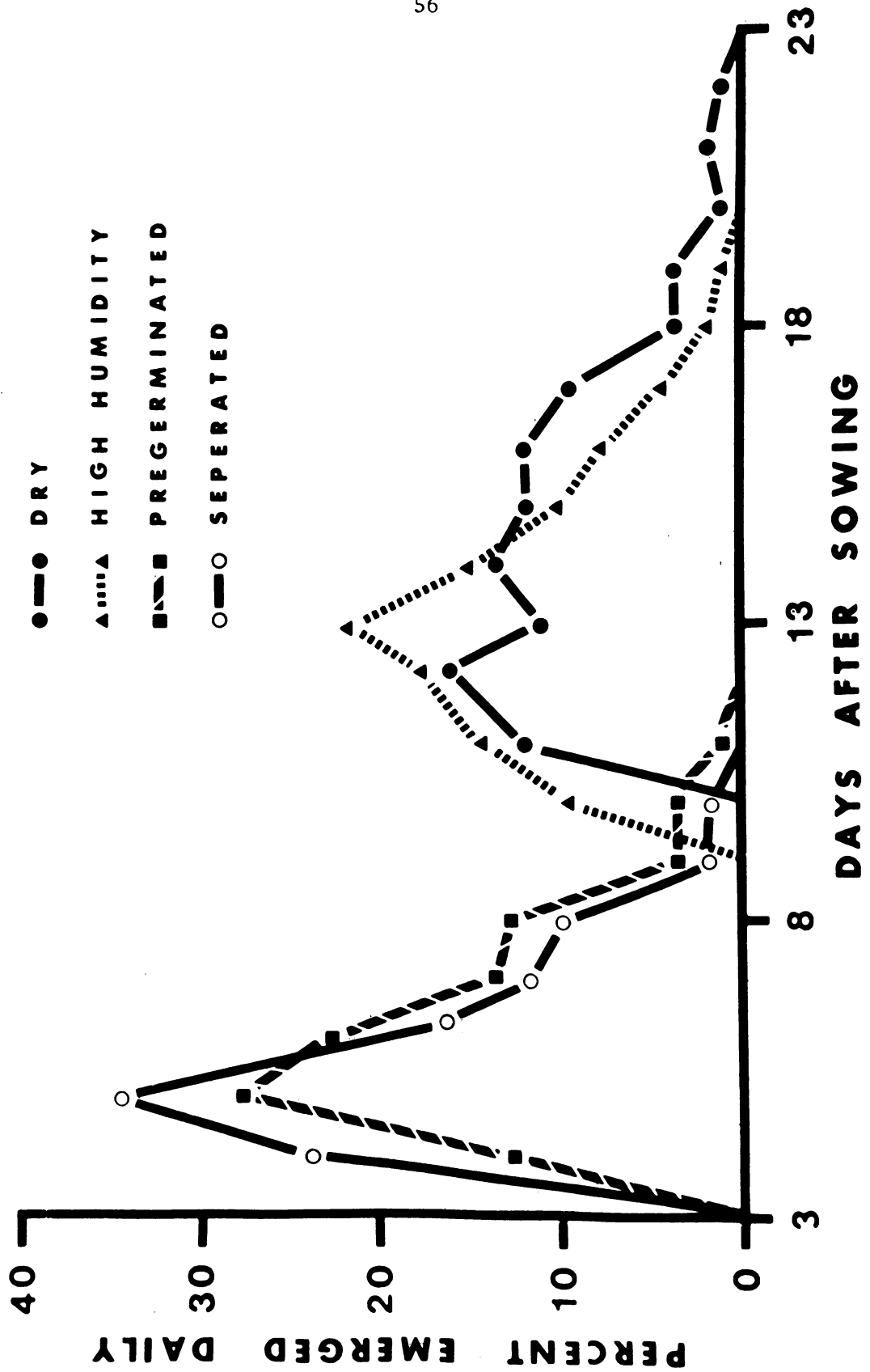




Table 8 The effect of high moisture, pregermination, and separated pregermination of tomato seed on yield of red, green, and total fruit weight and percent red of total yield

Treatment	Yield			Percent red of total wt.
	MT per ha of red fruit	MT per ha of green fruit	MT per ha for total wt.	
Dry Seed	12.6a*	53.5a	66.1a	19.0a
High Moisture	14.5a	49.5a	64.0a	22.7a
Pregerminated	23.8b	49.0a	72.8a	32.2b
Separated Pregerminated	24.3b	47.7a	72.0a	33.5b

* Mean separation within columns by Duncan's multiple range test at 5% level



3.7 days for T10-90 as compared to 6.9 for dry sown seed. The total time spread of emergence for the dry and high moisture treatments was greater than both pregerminated treatments (Figure 13).

There were no significant differences between the yield of green and total weight for all treatments (Table 8). The yield of red and the percent red fruit, however, was significantly greater for both pregerminated treatments. Tomato yield data indicates that the significant increase in percent of ripe fruit of total weight was due to the earliness of emergence and growth of pregerminated seed as compared to the other treatments.



SUMMARY AND CONCLUSION

The earliness and speed of emergence was greatly enhanced by sowing pregerminated seed of the crops evaluated. Biddington, et al. (4) has reported similar responses by sowing pregerminated celery seed in the field resulting in an earlier and greater seedling emergence and increased final crop yield. Currah, et al. (10) has stated that thermodormancy of lettuce can be eliminated by germination in optimum conditions in the laboratory before they are sown in the field where the seeds may become exposed to high temperatures which would normally induce thermodormancy.

The earliness and uniformity of emergence of pregerminated tomato seed in the field resulted in a greater percent of ripe fruit at time of harvest as compared to dry seed (Table 7,8). Gray (15) has shown that the major factor for uniformity of mature head weight and date of head maturity in lettuce was directly correlated with uniformity in the time to emergence.

Tomato seed sown in the field showed no effect on earliness of emergence when soil temperatures were at 23°C (Table 5). Bussel and Gray (6) have reported on the effects of sowing pregerminated seed at different soil temperatures, concluding that the major advantage of pregermination occurs when soil temperatures are cool. Pepper seed, however, did respond well though soil temperatures were elevated (Table 5).

The benefit of high humidity pretreatment was observed in asparagus, celery, pepper and tomato in the greenhouse. An increase in C.G. and dry weight of plant was measured as compared to dry seed. Roos, et al. (37) and Pollock, et al. (35) have shown that bean seed having initial



seed moisture above 12 percent had higher field emergence than lower moisture seed, particularly at soil temperatures below 10°C. It would appear that increasing the initial moisture of the seeds which are either very slow to germinate or are subject to low temperature injury would provide for better germination.

Separation of pregerminated seed by specific gravity differences is a fast and easy method to eliminate non-viable or non-germinated seed. The percent and rate of emergence was higher for the top floating fraction of pepper and celery which combined the highest proportion of germinated seed (Table 4). Krieg and Bartee (27) and Cameron, et al. (7) have shown that seed density is an important aspect of seed vigor. Further studies to evaluate separation for different densities of seed are needed.

Cold storage of pregerminated seed of asparagus, carrot, celery and onion crops is very effective. No injury or appreciable radicle growth had occurred after 6 days at 1°C (Table 2). Tomato and pepper storage at 5°C resulted in decreased percent of emergence and dry weight of plants. Chilling injury may have occurred after storage at 5°C.

Fluid drilling provides a method to sow germinated seed with radicles without damage. The gel provides moisture during early development and may also act as a carrier for other amendments. Crops that will benefit most are those which require a long period of time for emergence and those that germinate poorly or erratically at low temperatures.

Pregermination overcomes the time for normal germination processes



to occur in the soil. It has been shown by Bierhuizen and Wagenvoort (5) that germination is the result of heat sums in degree days. Therefore, the effect of pregermination is greatest at low soil temperatures which are below optimal for normal germination.

Sowing germinated seed would reduce the time to 50 percent emergence, thus, seed are emerged and can begin photosynthesis earlier and grow faster than dry seed. Dormancy can be overcome then fluid drilled. The result is a more predictable stand.

Uniformity of emergence is necessary for uniformity of crop development and growth. With a high plant density and once over machine harvest, uniformity is very critical for optimum yields.

Separation of pregerminated seed will be valuable in precision seeding. Planting nearly 100 percent germinated seed provides the potential for nearly 100 percent stand.

Short term storage of seed can be accomplished by cold storage. Seeds that are sensitive to chilling injury present a problem in prolonged storage at low temperatures. Research to understand chilling and avoid injury should be continued. Possible uses of controlled atmosphere or hypobaric storage may prolong storageability of pregerminated seed.

The future of fluid drilling is very promising. The concept of first germinating seed and then sowing in a fluid gel has many applications for early emergence and stand of crops. Nutrients, growth regulators and symbiotic bacteria could conveniently be added to the gel at time of planting (18, 41).

This research is the beginning of work on a new cultural practice.

This system takes advantage of and integrates several disciplines of research. Fluid drilling can be an effective tool for the entomologist, pathologist, physiologist, plant breeder and herbicide physiologist. Fluid drilling can also lend itself to planting of agronomic, ornamental and tree seed.



LIST OF REFERENCES

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1. Agrawal, P. S. and M. N. Khare. 1975. Presowing treatment of mustard seeds with fungicides for improving germination. *Seed Res.* 3:57-58.
2. Austin, R. B., R. C. Longden, and J. Hutchinson. 1969. Some effects of 'hardening' carrot seeds. *Ann. Bot.* 33:883-895.
3. Baldwin, H. I. 1932. Alcohol separation of empty seed, and its effect on the germination of red spruce. *Amer. J. Bot.* 19:1-11.
4. Biddington, N. L., T. H. Thomas and A. J. Whitlock. 1975. Celery yield increased by sowing germinated seeds. *Hort-science* 10:620-621.
5. Bierhuizen, J. F. and W. A. Wagenvoort. 1974. Some aspects of seed germination in vegetables. 1. The determinations and application of heat sums and minimum temperature for germination. *Scientia Horticulturae.* 2:213-219.
6. Bussel, W. T. and D. Gray. 1976. Effects of presowing seed treatments and temperatures on tomato seed germination and seedling emergence. *Scientia Horticultura* 5:101-109.
7. Cameron, J. W., A. Van Maren and D. A. Cole. 1961. Seed size in relation to plant growth and time of ear maturity of hybrid sweet corn in a winter planting area. *Proc. Amer. Soc. Hort. Sci.* 80:481-484.
8. Christiansen, M. N. 1968. Induction and prevention of chilling injury to radicle tips of imbibing cottonseed. *Plant Physiol.* 43:743-746.
9. Copeland, L. O. 1976. Principles of Seed Science and Technology. Burgess Pub. Co., Minneapolis, Minnesota. pp. 239-250.
10. 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.
11. Darby, R. J. and P. J. Salter. 1976. A technique for osmotically pre-treating and germinating quantities of small seeds. *Ann. Appl. Biol.* 83:313-315.

12. Elliott, J. G. 1966. The sowing of seeds in aqueous fluid.
Report of the Weed Research Organization for 1965-66. p.31-32.
13. Ells, J. E. 1963. The influence of treating tomato seed with
nutrient solutions on emergence rate and seedling growth.
Proc. Amer. Soc. Hort. Sci. 83:686-687.
14. Gray, D. 1974. Some developments in the establishment of drilled
vegetable crops. XIX th. Intern. Hort. Congr.
15. _____. 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.
16. _____. 1977. Temperature sensitive phases during the germina-
tion of lettuce (Lactuca sativa) seeds. Ann. Appl. Biol.
86:77-86.
17. Green, M. J. 1968. Flotation as a rapid test for tea seed
viability. Trop. Agr. 45:133-139.
18. Hardwick, R. C. and J. M. Hardaker. 1976. Fluid carrier for
Rhizobium bacteria. Nat. Veg. Res. Sta. Ann. Rep. for 1976.
p. 68-69.
19. Hegarty, J. W. 1970. The possibility of increasing field
establishment by seed hardening. Hort. Res. 10:59-64.
20. Heydecker, W., J. Higgins and Y. J. Turner. 1975. Invigoration
of seeds? Seed Sci. & Technol. 3:881-888.
21. _____, J. Higgins, R. L. Gulliver. 1973. Accelerated germi-
nation by osmotic seed treatment. Nature Lond. 246:42-44.
22. Highkin, H. R. and A. Lang. 1966. Residual effect of germination
temperature on the growth of peas. Planta. 68:94-98.
23. James, E. and D. C. Clark. 1970. A convenient high-capacity seed
blower. Crop. Sci. 10:154-155.
24. Kidd, F. and C. West. 1918. Physiological predetermination:
the influence of the physiological condition of the seed upon
the course of subsequent growth and upon the yield. I. The
effects of soaking seeds in water. Ann. Appl. Biol. 5:1-10.
25. Kotowski, F. 1926. Temperature relations to germination of vege-
table seeds. Proc. Amer. Soc. Hort. Sci. 23:176-184.
26. Johnson, P. E. and G. E. Wilcox. 1972. Tomato seeding for commer-
cial production. Purdue Univ. Agric. Expr. Station.



27. Krieg, D. R. and S. N. Bartee. 1975. Cottonseed density: Associated germination and seedling emergence properties. *Agron. J.* 67:343-347.
28. Knott, J. E. 1957. Handbook for vegetable growers. John Wiley and Sons. New York.
29. Maguire, J. D. 1962. Speed of germination aid in selection and evaluation for seedling emergence and vigor. *Crop Sci.* 2:176-177.
30. Mayer, A. M. and A. Poljakoff-Mayber. 1963. The Germination of Seeds. The Macmillan Company, New York.
31. Nonnecke, J. L. 1972. Precision seeding vegetable crops. Ministry of Agriculture and Food, Ontario.
32. Oyer, E. B. and D. E. Koehler. 1966. A method of treating tomato seeds to hasten germination and emergence at suboptimal temperatures. *Proc. XVIII. Intern. Hort. Congr. I.* p. 626.
33. Pollock, B. M. and V. K. Toole. 1966. Imbibition period as the critical temperature sensitive stage in germination of lima bean seeds. *Plant Physiol.* 41:221-229.
34. _____. 1969. Imbibition temperature sensitivity of lima bean seeds controlled by initial seed moisture. *Plant Physiol.* 44:907-911.
35. _____, E. E. Roos and J. R. Manalo. 1969. Vigor of garden bean seeds and seedlings influenced by initial seed moisture, substrate oxygen and imbibition temperature. *J. Amer. Soc. Hort. Sci.* 94:577-584.
36. Robinson, F. E. and K. S. Mayberry. 1976. Seed coating, precision planting, and irrigation for optimum stand establishment. *Agron. J.* 68:694-695.
37. Roos, E. E. and J. R. Manalo. 1976. Effect of initial seed moisture on snap bean emergence from cold soil. *J. Amer. Soc. Hort. Sci.* 101:321-324.
38. Salter, P. J. and R. J. Darby. 1976. Synchronization of germination of celery seeds. *Ann. Appl. Biol.* 84:415-424.
39. Short, G. E. and M. L. Lacy. 1976. Carbohydrate exudation from peas seeds: Effect of cultivar, seed age, seed color and temperature. *Phytopathology.* 66:182-187.



40. _____. 1976. Factors affecting pea seed and seedling rot in soil. *Phytopathology*. 66:188-192.
41. Singh, A. and H. N. Singh. 1973. Note on the effect of pre-soaking seeds in N soln. on germination and early seedling growth in pumpkin. *Ind. J. Agr. Sci.* 43:973.
42. Taylor, A. G., J. E. Motes and H. C. Price. (1978). Separating germinated and non-germinated seed by specific gravity. *Hortscience* (in press).
43. Waisel, Y. 1962. Presowing treatments and their relation to growth and to drought, frost and heat resistance. *Physiol. Plant.* 15:43-46.





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