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THE RESPONSE OF TOMATO TO NITROGEN AND PHOSPHORUS IN
THE SEEDLING STAGE

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THE RESPONSE OF TOMATO TO NITROGEN AND PHOSPHORUS IN THE SEEDLING STAGE

by

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ABSTRACT

Plants of tomato (*Lycopersicon esculentum* Mill.) cv. Walter, were grown in Speedling planter flats at day temperatures in excess of 110 degrees (F), under various nitrogen and phosphorus treatments. Significant increases in stem height and fresh weight were observed when the phosphorus levels reached 20 ppm. There was no corresponding increase in dry weight. By the use of a dry weight to fresh weight ratio, it was possible to develop a qualitative value for tomato transplants grown under high temperature conditions.

INTRODUCTION

Since man began growing crops, he has been faced with having to wait until after the ground had thawed in the spring to plant his seed. He then was confronted with the problem of getting his crops harvested before a killing frost in the fall. In such cases a solution to this age old problem has been transplanting. By definition, transplanting is the moving of a plant from one place and planting it is another. However, this does not take into consideration the quality of the plant at time of transplanting; the amount of disturbance to the rootball during transplant; or how well the plant will do after it has been transplanted.

The coming of the Plastic Age has allowed the development of commercially affordable greenhouses, transplanting equipment and supplies for almost all types of horticultural crops. Under greenhouse conditions, growers are able to control heat, cooling, light and humidity to at least some extent. All this has led to the development of a transplant industry which is just now reaching its potential. With controlled environments, growing seasons in the cold northern growing regions can be effectively lengthened by the use of transplants. The use of transplants also allow more growers to compete for the early market. A ready supply of plants can be maintained for replants, with a long delay, if a planting is damaged or destroyed by a natural disaster.

Not only do greenhouse grown transplants offer the grower plants which grow and yield better, but also show the following advantages:

1. Young plants are protected from wind and rain.
2. Reasonable control over temperature and light during germination and early stages of growth.
3. Favorable environment for root growth.
4. Effective and efficient control of water and nutrients for young plants.
5. Prevention and control of diseases and insects in early stages of development.
6. Savings on seeds.
7. Continuous availability of plants, for replanting after periods of adverse weather.

During the winter months, West Mexico provides about one half of the fresh vegetables consumed in the United States. These winter crops are planted in August and September, a period during which West Mexico experiences high temperatures, heavy rains and strong winds which frequently damage or even wipe out field plantings.

In 1972, Dr. Ellsworth Shaw of Canelos Brothers, in the Culiacan Valley, Sinola Mexico, first demonstrated the merits of using greenhouse grown transplants in field production in this area. Since this introduction, the use of transplants has escalated to the point where in 1976 approximately one half of all peppers and tomatoes shipped from Mexico were from greenhouse grown transplants.

Transplants are produced by several different methods in West Mexico. Of concern in this paper is the Speedling technique. This method was developed in Florida and utilized the Speedling planter flats as the key to the system. These flats are molded from polystyrene (EPS) and are strong and lightweight. The flats, which have tapered, open-bottom, inverted pyramid-shaped cells are suspended on aluminum T-rails allowing air flow below the flats which air prunes the roots. The downward root growth prevents the plants from becoming rootbound, a problem often associated with typical flat techniques. A soil-less medium comprised of Canadian peat moss and vermiculite is recommended in the use with the Speedling planter flats. This medium allows for good drainage, acceptable nutrient exchange, and is sterile. Irrigation and nutrient application are generally combined and accomplished by overhead or mobile boom sprayers.

The cultural program developed for tomato production, using the Speedling planter flats has not proven entirely satisfactory for use in West Mexico, although it has been used with success in Florida for tomato production. When used in West Mexico, under high temperatures, the Speedling transplants have incurred some difficulty in the field. They became severely desicated and growth ceases. Usually two weeks or so is necessary for the resumption of growth if the plants do in fact survive the transplant. The question is then, why does system work in Florida and not in Mexico? Is it possible that the difference in temperature is causing a change in the rate of nutrient uptake?

The objectives of this study are:

1. To investigate the effect of nitrogen and phosphorus on vegetative growth during the seedling stage, at high temperatures.
2. To investigate any interaction between the effects of nitrogen and phosphorus on vegetative growth during this seedling stage of growth, at high temperatures.
3. To develop, if possible, a better nutrient program for tomato seedling production under a high temperature environment.

4. To determine a better understanding of how seedlings grow under high temperatures.
5. To develop a measure of quality for transplants of tomatoes under high temperature conditions.

REVIEW OF LITERATURE

In the northern states and Canada, the growing season for many vegetables such as the tomato is short. Hence, to produce earlier and greater total yields, plants are started under protective cover, then transplanted to the field when temperatures are warmer. This practice, in effect, can increase the growing season from three to eight weeks (Schales and Massey Jr. 1969). In areas of winter tomato production, such as Mexico, transplants were found to enable the grower to shorten the effective growing season and thus avoid direct seedling during a period of extreme high temperatures and heavy rainfall (Oebker 1977). The growers also realize a savings in irrigation cost and a more uniform production.

However, transplanting does not always guarantee earliness (Kilbert, Evertte, Overman, Geraldson, Kelsheimer 1966). Severe disturbance of the root system by transplanting can also slow down plant growth (Thompson and Kelly 1957). The type of hardening used before transplanting can also have a definite effect. Hardening of tomato plants under a cold-frame, even to a moderate degree, has a stunting effect and does not make the plants better able to survive under early spring conditions (Brasher and Westover

1938). Tipping of tomato seedlings reduces the early yield by delaying the first harvest but has little effect on the total yield (Knott 1955). Since improper hardening could lead to a loss or a reduction in benefits gained from transplanting, it is necessary that tomato plants be hardened so as to derive maximum benefits.

Transplants for winter production of plants face a different set of environmental factors than do the traditional spring transplants. Rather than having to go from a warm, humid greenhouse to a cool or cold environment, the winter transplants are germinated in a relatively high temperatures, and are grown in greenhouses where the day time temperatures may range from 38-52 degrees (C), and the night temperatures vary from 21-32 degrees (C) (Speedling Corporation 1979).

Little work has been done on the increase in growth of transplants of tomato under high temperature conditions (Oebker 1977). Many factors affect this problem but the major ones which must be considered are:

Photoperiod

The photoperiodic response of the tomato were shown to be modified by temperature. An appraisal of the tomato cultivars to photoperiods, therefore must also consider the temperature conditions under which they are grown. In general all cultivars tested demonstrated a greater total plant height, distance to first infloresence, and stem fresh weight (under long day and temperatures of 22-26 degrees(C)) (Aunt 1976).

Humidity and Soil Moisture

Low ambient humidity reduced the growth and increased the water consumption by seedlings of tomato. Shielding the root medium with a thin, flexible plastic sleeve prevented the growth reduction, which appeared to be largely the result of root zone evaporative cooling. Of various growth papameters observed, root growth was most dramatically improved by shielding at any humidity level tested (Mitchell and Hoff 1977). When growing in flats this can be eliminated by rotating the perimeter flats every other day (Speedling Corp. 1979).

The uptake of nitrogen, phosphorus and potassium is not significantly effected by a decrease in the relative humidity. However, a decrease in nitrogen or phosphorus will result in an increased resistance to water flow (Isu 1978).

Method of Nutrient Application

The method of nutrient application must be considered as it might be a definite variable effecting nutrient uptake. In a paper (Ain Shams University 1976) it was reported that foliar spray with a complete nutrient solution with no soil fertilization has of effects, if compared to foil fertilization, on the content of nitrogen in tomatoes. However, for phosphorus, the results show that foliar spray significantly effective, particularly if urea plus super mixture was used (El-Leboudi, El-Cala, Sakr 1976).

Nitrogen

Plants take up nitrogen either as the NO_3 or NH_4^+ ION. It is believed that the nitrate taken up by the plant is reduced to ammonium before further synthesis by an enzyme containing molybdenum. The ammonium ions are utilized in the synthesis of amino acids and proteins, resulting in a larger amount of leaf tissue. In the presence of high levels of nitrogen in the plant, the ratio of cell protoplasm to cell-wall material tends to produce leaf tissues with large, but relatively thin-walled cells. The larger-celled tissues have a higher water content; excessive nitrogen th-refore results in the so-called soft growth which is more susceptible to frost, disication, and pathogens (Habbock, 1952).

Phosphorus

Phosphorus is closely associated with utilization of starch and sugar. The element is a constituent of the cell nucleus, is essential for cell division, the formation of lat albumen, and the development of meristematic tissue (Ghoddoussi 1965). Phosphorus is a mobile nutrient and is readily translocated within the plant and may move from older tissues into the younger tissues under conditions of reduced phosphorus availability. As the plant matures most of the phosphorus within it is translocated in the seeds and fruit.

Phosphorus exists in plants in both organic and inorganic forms. The inorganic fraction is largely concentrated in the vascular sap as orthophosphate ions. The concentration of phosphorus in the sap varies in different crops, the plant part tested and the stage of plant growth, as well as the type of soil and fertilization program. The content of organic phosphorus is uneffected by the amount of available phosphorus except at extremely high levels, while that of inorganic phosphorus increased regularly in step with the treatment (Mather 1965). In young tomato plants the rate of phosphorus absorption is not directly proportional to the phosphate concentration of the nutrient solution. However, the amount of phosphorus found in the leaves and stems closely correlates with the supply of phosphorus in the nutrient solution. The leaves containing more phosphorus than the stems regardless of the amount of phosphorus in the nutrient solution (Kalin 1943).

Interaction of Nitrogen and Phosphorus

The interaction of nitrogen and phosphorus is very complex, but several things are clearly evident. First a low level of NO_3 may cause inorganic phosphates to accumulate in the plant and conversely a low level of phosphates may cause an accumulation of NO_3 (Gilbert 1927). Also the rate of nitrogen addition was found to have no significant effect on the percentage of phosphorus taken up by plants from residues (Hannapel 1955). It has also been shown, in a study (Polach 1975) of tomatoes grown in peat culture, that when nitrogen, phosphorus and potassium are applied in varying ratios, but at the same total rate, the seedling growth was not markedly effected by the N:P:K ratio but was improved by higher calcium.

Method of Transplant

The method of planting; direct seeding, containerized, or bare-root transplanting, appeared to have no effect on the total yield potential for varieties tested (Long 1975). However, earlier yield and larger size fruit were stimulated by planting methods giving the least amount of disturbance to the root system. In this experiment direct seeding of containerized transplants accomplished this. Plug-mix seedlings offered no added benefit over conventional seeding. Both Jiffy J-7 and Speedling brand transplants increased early yields (Sterrett et al. 1983).

MATERIALS AND METHODS

Tomatoes (Lycopersicon esculentum Mill.) cv. Walter were planted in #155-3 Speedling brand planter flats, having a cell volume of 52.73 cubic centimeters (3.7 cm square tapered to 7.5 cm in depth) containing Redi-Earth brand potting mix. Flats were filled with potting mix, seeds planted, and the flats were capped with a thin layer of fine vermiculite. The trays were watered three times daily until germination had occurred. After germination was achieved the flats were thinned to one plant per cell. Treatments (see Table 1) were then applied each morning at the rate of 125 ml/call. Subsequent daily irrigations were with water only, at the rate of 125 ml/cell. After 21 days the seedlings were examined for stem height (measured from top of median to terminal bud). The plants were then harvested, by cutting them at the soil level, and the fresh weight taken. After 72 hours in a drying oven the dry weight was taken.

The treatments were levels were selected based on the recommended rate of 10 ppm nitrogen and 10 ppm phosphorus by the Speedling Corporation. A matrix was designed to include a 0 ppm nitrogen and 0 ppm phosphorus treatment as a control; a 10 ppm nitrogen and 10 ppm phosphorus

Table 1. A list of the various treatments used on tomato seedlings grown under high temperature conditions

Treatment	PPM (N:P)
1	0:0
2	5:5
3	5:10
4	5:20
5	10:5
6	10:10
7	10:20
8	20:20

treatment level, and a 20 ppm nitrogen and 20 ppm phosphorus treatment level.

To determine what, if any, effect temperature had on the trials, the testing was conducted in mid-summer when the diurnal temperature fluction ranged from 60 degrees (F) to 125 degrees (F), and in mid-winter when the greenhouse temperature was maintained between 65 degrees (F) and 85 degrees (F).

Initial work indicated a reduction in growth in the seedlings located along the margins of the flats. It was therefore decided to avoid this problem by not including the plants in the trials. As a check against other variables due to location in the planter flats, each replicate was extracted from a different row in the planter.

The analysis of data was done using a SPSS program, based on eight blocks and eight treatments in a Random Complete Block Design.

RESULTS AND DISCUSSION

The main effect and interaction F-test values for stem height, fresh weight, dry weight and the dry weight/fresh weight ratio are shown in Table 2. The T-test values between individual treatments are shown for stem height, fresh weight and the dry weight/fresh weight ratio in Tables 3, 4, and 5 respectfully. The T-test values for dry weight are not shown since the residual value was zero which would have the effect of causing all values to be undefined.

Stem Height

The stem height varied with various treatments (Figure 1). There was no significant difference between successive treatments 1-6 or between treatments 7 and 8. However, there was a very significant difference between treatments 6 and 7. Other significant differences noted were between treatment 1 and treatments 4 through 8; treatment 2 and treatments 7 and 8; treatment 3 and treatments 7 and 8; treatment 4 and treatments 7 and 8; treatment 5 and treatments 7 and 8; treatment 6 and treatments 7 and 8. The increase of the stem height between 0 ppm nitrogen and 5 ppm nitrogen was not significant until the level of

Table 2. F-Test values for stem height, fresh weight, dry weight, and DW/FW ratio of tomato seedlings grown under high temperature conditions, at time of transplant

ANALYSIS OF VARIANCE

Source of Variation	Mean Square	F.	Significance of F.
STEM HEIGHT			
Main Effect	9.578	109.807	≤ .001
Residual	.087		
FRESH WEIGHT			
Main Effect	17.785	193.702	≤ .001
Residual	.092		
DRY WEIGHT			
Main Effect	.003	83.461	≤ .001
Residual	.000		
DW/FW RATIO			
Main Effect	.030	57.225	≤ .001
Residual	.001		

Table 3. T-Test values of stem height, under increasing levels[z] of N and P in tomato seedlings, grown under high temperature conditions, at time of transplant

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
T_1	0.0[y]	.6	1.6	2.68	4.38	3.64	14.23	13.47
T_2		0.0	.21	.60	1.66	1.21	8.80	8.21
T_3			0.0	.14	.69	4.15	6.24	5.79
T_4				0.0	.21	.07	4.56	4.14
T_5					010	.04	2.82	2.49
T_6						0.0	3.48	3.11
T_7							0.0	.01
T_8								0.0

[z]See Table 1.

[y]Mean separation by T-Test at 1% level.

Table 4. T-Test values of fresh weight, under increasing levels[2] of N and P in tomato seedlings, grown under high temperature conditions, at time of transplant

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
T_1	0.0[y]	.45	.65	1.03	2.30	2.53	17.76	23.20
T_2		0.0	.02	.12	.72	.85	12.46	17.21
T_3			0.0	.04	.50	.61	11.49	18.13
T_4				0.0	.25	.33	10.14	14.46
T_5					0.0	.01	7.19	10.88
T_6						0.0	6.79	10.40
T_7							0.0	.38
T_8								0.0

[2]See Table 1.

[y]Mean separation by T-Test at 1% level.

Table 5. T-Test value of DW/FW ratio, under increasing levels[z] of N and P in tomato seedlings, grown under high temperature conditions, at time of transplant

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
T_1	0.0[y]	22.5	28.9	32.4	44.1	48.4	67.6	72.9
T_2		0.0	.4	.9	3.6	4.9	12.1	14.4
T_3			0.0	.1	1.6	2.5	8.1	10.0
T_4				.0	.9	1.6	6.4	8.1
T_5					0.0	.1	2.5	3.6
T_6						0.0	1.6	2.5
T_7							0.0	.1
T_8								0.0

[z]See Table 1.

[y]Mean separation by T-Test at 1% level.

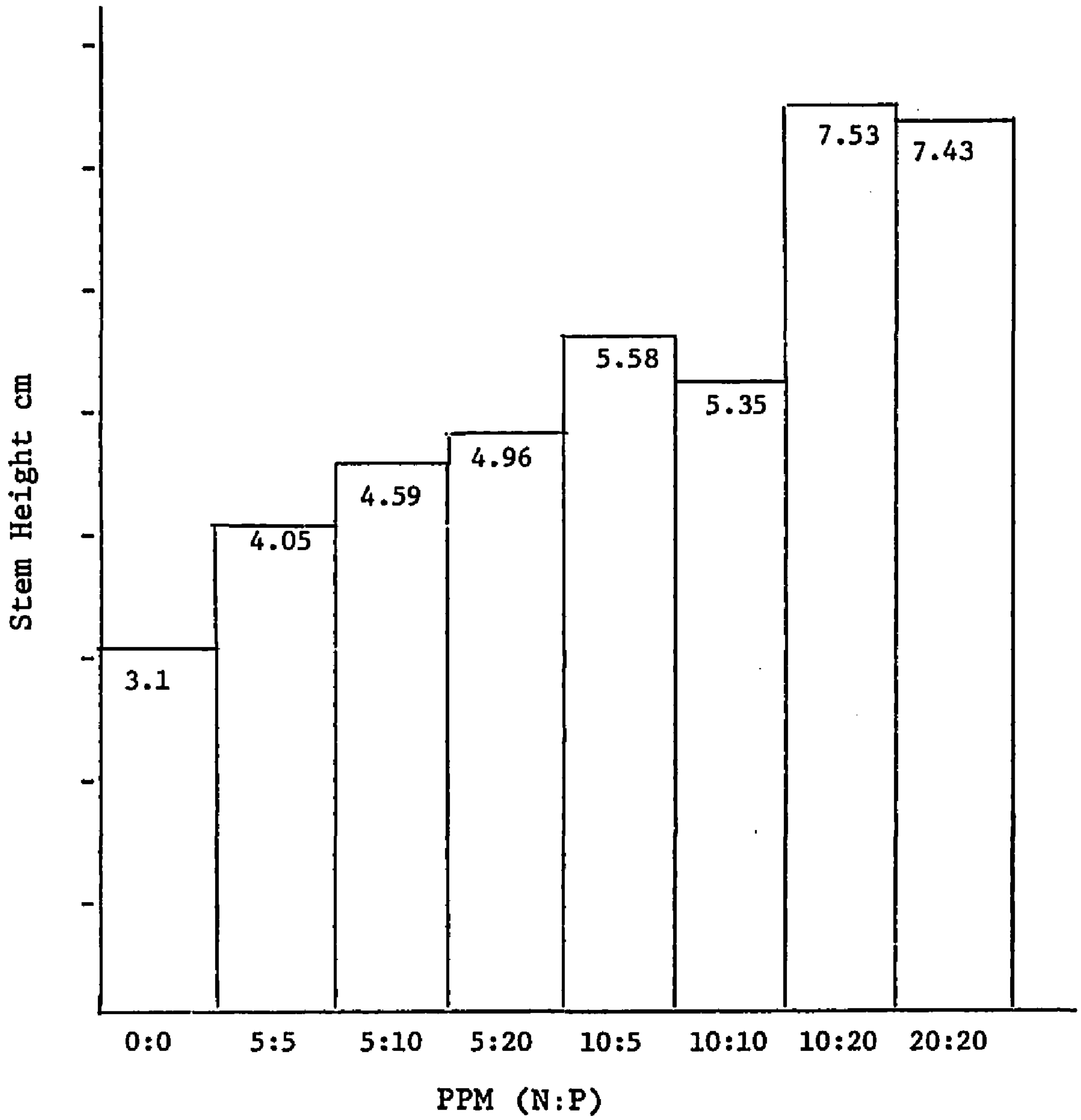

Figure 1. Stem height of 'Walter' tomato seedlings, grown under changing ratios of N & P and high temperature, at time of transplant

phosphorus being applied reached 20 ppm. This would suggest that the phosphorus has an effect on the utilization of nitrogen when the phosphorus is above a certain level. When nitrogen was held constant there was no real increase in stem height regardless of the quantity of phosphorus applied. When nitrogen was increased to 10 ppm, no real increase was observed until phosphorus reached 20 ppm, once again suggesting a threshold value of phosphorus. After the level of 10 ppm nitrogen and 20 ppm phosphorus, the addition of more nitrogen made no significant difference in the stem height.

Fresh Weight

Figure 2 illustrates the results of an increase in fresh weight over the range of treatments. At nitrogen levels less than or equal to 5 ppm, no significant difference was noted in fresh weight regardless of the level of phosphorus applied. When nitrogen was increased to 10 ppm, no significant differences occurred until the phosphorus level applied reached a rate of 20 ppm, at which point the fresh weight more than doubled. Additional nitrogen applied at phosphorus levels of 20 ppm yielded an increase in fresh eight but not a significant one. If phosphorus levels were held at 5 ppm and the nitrogen level is increased from 5 ppm to 10 ppm, no real increase is noted. If phosphorus

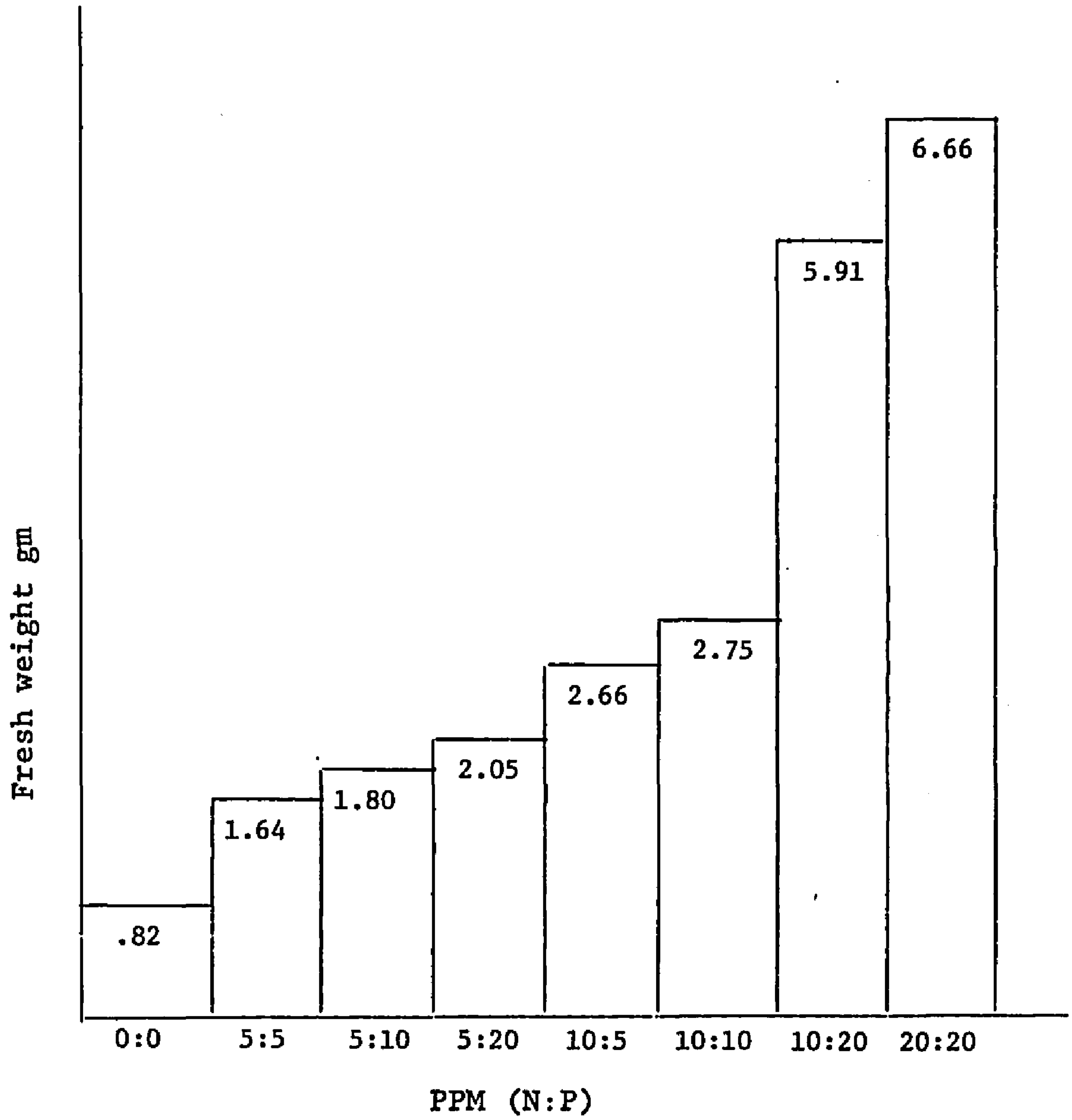

Figure 2. Fresh weight of 'Walter' tomato seedlings, grown under changing ratios of N & P and high temperature, at time of transplant

was held at 10 ppm, no real increase in fresh weight was noted when nitrogen was increased from 5 ppm to 10 ppm.

Dry Weight

The production of dry weight (Figure 3) was not affected significantly by any of the treatments under consideration. This is extremely significant when the reaction of stem height and fresh weight under the same treatments are taken in consideration.

Dry Weight/Fresh Weight Ratio

This ratio fell into four distinct groupings (Figure 4); Group 1--those treatments with 0 ppm of nitrogen; Group 2--those treatments having 5 ppm of nitrogen; Group 3--those treatments having 10 ppm nitrogen but less than 20 ppm of phosphorus; Group 4--those treatments with 10 or 20 ppm of nitrogen and 20 ppm of phosphorus. Group 1 would indicate a very low moisture content. Groups 2 and 3 represent an intermediate moisture content. Group 4 is indicative of a very succulent plant with very high moisture content. The significance of these levels of moisture content will be discussed in the general discussion.

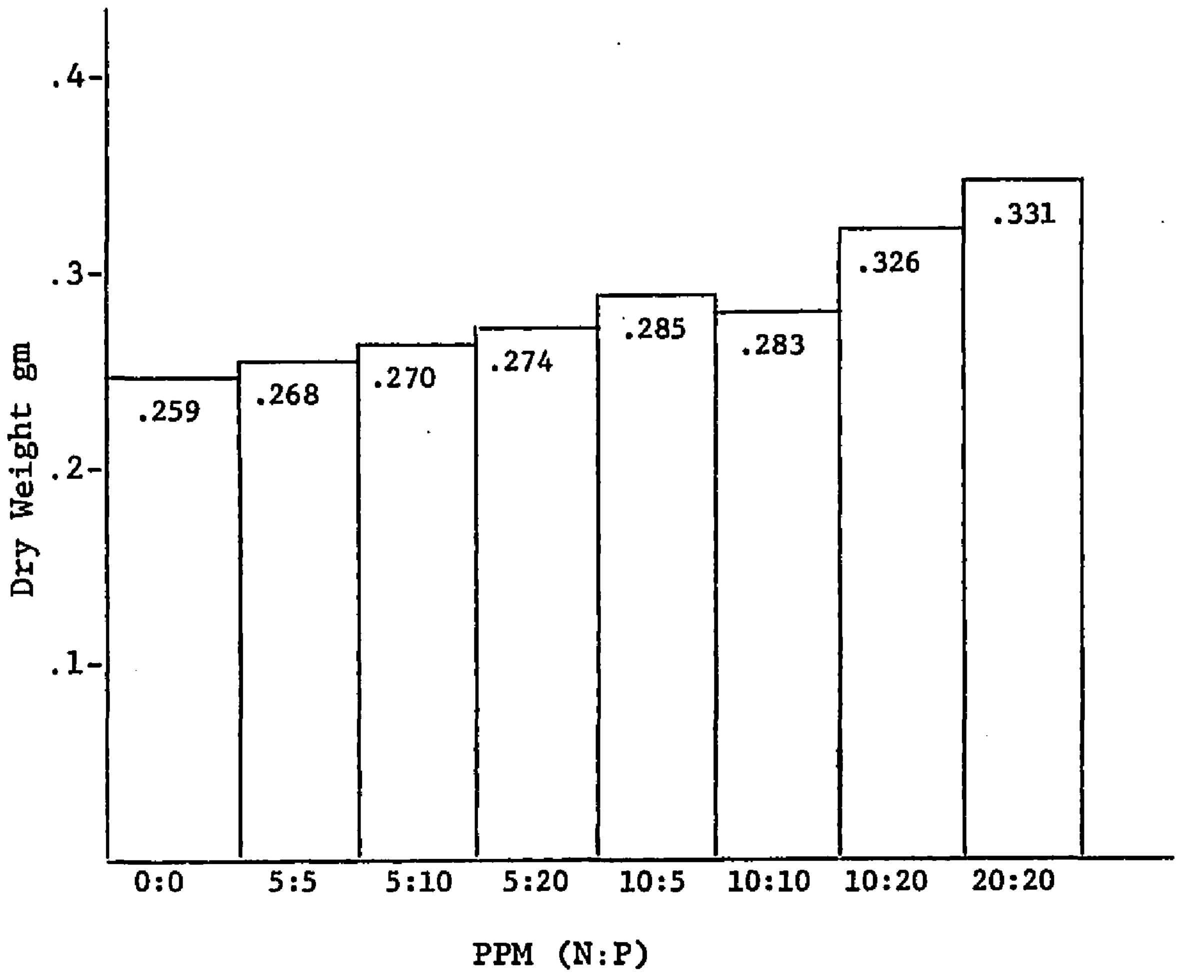

Figure 3. Dry weight of 'Walter' tomato seedlings, grown under changing ratios of N & P and high temperature, at time of transplant

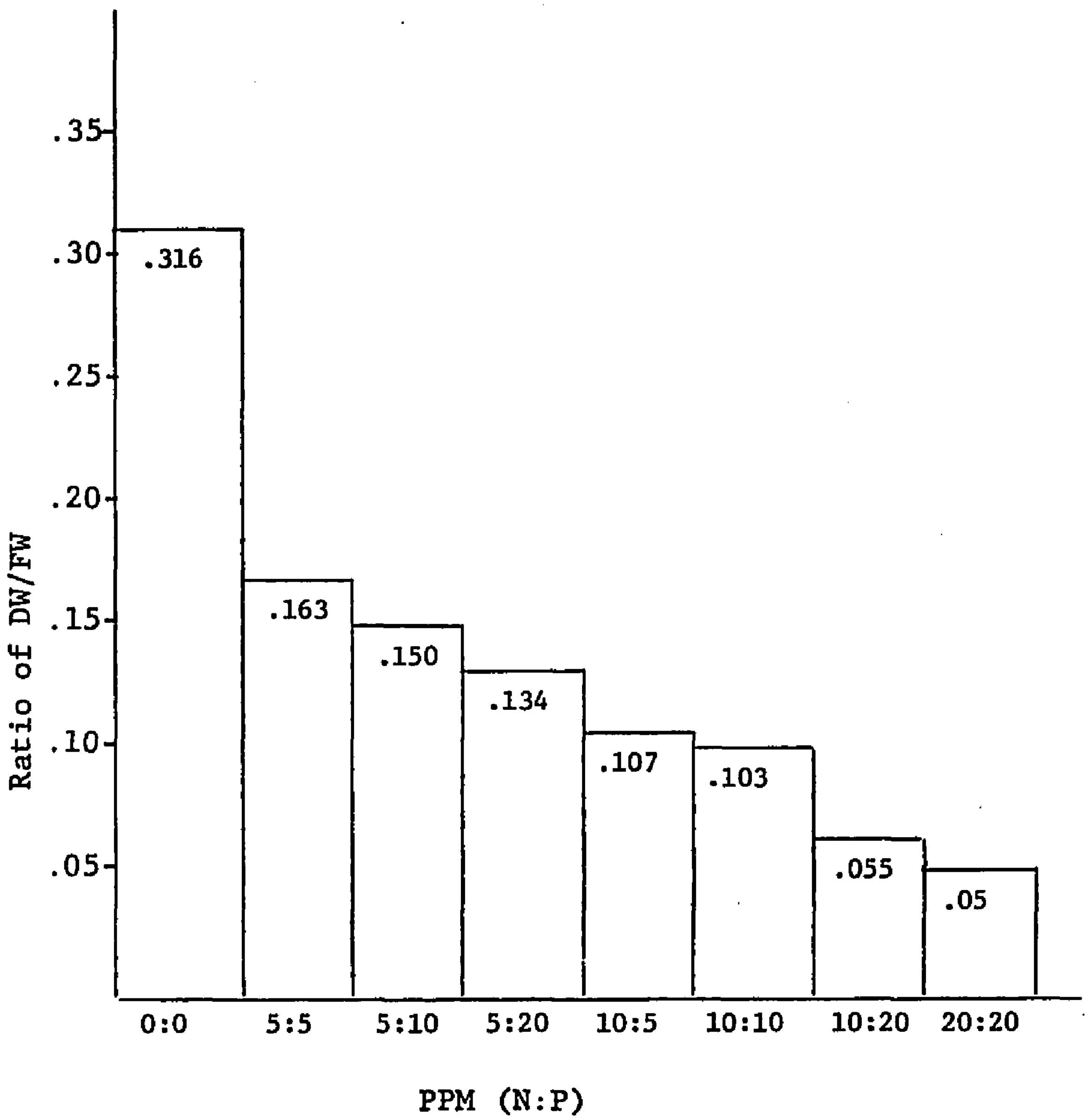

Figure 4. Ratio of dry weight to fresh weight in 'Walter' tomato seedlings, grown under changing ratios of N & P and high temperature, at time of transplant

CONCLUSION AND GENERAL DISCUSSION

The large differences that occur between treatments 6 and 7 in both stem height and fresh weight must be viewed in terms of the dry weight to be fully understood. The failure of the treatments to yield any increase in dry weight means that there was no real production of plant material. This bit of information means that all the increase in stem height and fresh weight came from the uptake of water, not from the production of more plant material. Therefore, all increases in stem height and fresh weight are from an increase in the uptake of water by the plant.

Then the comparisons between treatments are examined, it is clearly noticed that it is the phosphorus which limits the effect of the nitrogen. This finding would be in accordance with the findings of Gilbert (1927). However, it must be noted that this does not rule out the possibility of some limiting action by nitrogen on phosphorus utilization. It does mean that the effect of nitrogen on phosphorus either occurs at different levels than those tested or that the results of the interaction occur at a later stage of development.

A dry weight to fresh weight was established in an attempt to develop a qualitative value for tomato seedlings which would allow the evaluation of the nutrient program being used with respect to development of seedlings for transplant. The result of this ratio is that six of the eight treatments yielded a transplant which fell into the intermediate range (Figure 4), being neither too hard nor too succulent. These five treatments fell into two categories; those with 5 ppm nitrogen and those with 10 ppm nitrogen. It would be impossible to determine which of these groups would actually be best without carrying the study out to include the effect on yield. However, since the nitrogen utilization and not the nitrogen uptake is being effected, it would appear better to select the seedlings at 10 ppm nitrogen so that more nitrogen would be available to the plant when it was planted in the field.

In conclusion this study has shown:

1. That under high temperature conditions, phosphorus, when applied to the tomato seedlings at levels between 10 and 20 ppm, will cause an increase in fresh weight without a corresponding increase in dry weight.
2. That when applied at levels less than 20 ppm nitrogen and phosphorus have no effect on the increase in dry weight.

3. That a tomato seedling grown for transplant into the field, under high temperatures, should have a dry weight to fresh weight ratio of about 1.0.

A personal communique with Dr. Cecil Thomas of the Speedling Corporation, Sun City, Florida, verified that these findings were in agreement with theirs. At Speedling the technique is to grow the tomato transplants with very low levels of nitrogen and phosphorus until a few days prior to transplant. Then the phosphorus concentration in their nutrient mix is increased, so that the phosphorus is just beginning to take effect when the plants are in the field. Dr. Thomas also stated that a trip to the tomato growing region in Culiacan, Mexico, to study the problem with Speedling systems being used there, showed a deviation in the nutrient program from the recommended Speedling program to using Peters (20-20-20), since the recommended nutrients were not available.

Likewise in a trial done on transplant methods by the University of Florida, Long (1975), the fresh and dry weights were taken and the Speedling grown plants yielded a dry weight to fresh weight ratio of .20. This would seem out of line with the finding of this study, however there are two variables which must be taken into consideration. One, Speedling uses a straight peat moss and vermiculite mix without any fertilizer added, and in this study Redi-Earth was used. Redi-Earth contains some low levels of nutrients. This would tend to inflate the values assigned to the treatments in the study. Secondly, the trials at the University of Florida dealt with transplants grown for spring planting and not for winter planting, which would make a difference in temperature and photoperiod. So if these adjustments were made, the results of the trials at the University of Florida would be very similar to those of this study.

It is therefore seen that growers wishing to raise tomato seedlings under high temperature conditions, should develop a nutrient program that would yield a dry weight to fresh weight ratio of 1.0. Such a nutrient program would be nitrogen at 10 ppm and phosphorus at 10 ppm until a few days prior to the date that the seedlings are to be planted into the field. The phosphorus level should then be increased to 20 ppm.

Further studies in this area need to be conducted to determine the effects of this type of nutrient program on the earliness of yield and total yield.

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