T H E S I S

A STUDY OF THE FACTORS AFFECTING THE RESERVE FOOD SUPPLY IN CARNATIONS

Submitted by

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY RICHARD E. ODOM

ENTITLED A STUDY OF THE FACTORS AFFECTING THE RESERVE FOOD SUPPLY IN CARNATIONS

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

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Chapter I

INTRODUCTION

The market value of the 1948-1949 carnation crop in the United States has been estimated by Fossum (7) at 20 million dollars. This represents a tremendous number of cut flowers which are second only to roses in value. Under present day marketing conditions, a grower must time his crop to reach a peak in production at the time when the market for carnations or the demand for a specific color or variety is the most favorable. To do this, he must have uniformly well rooted cuttings for planting at a specified time so that the crop is in production when desired. Any difficulty encountered in the propagation of cuttings, such as non-uniformity of rooting or delay in rooting, not only causes considerable loss in time and money, but delays the planting operation. This delay, in some cases, throws the flowering period of that planting into a less favorable market, resulting in considerable loss of money for the grower.

Commercial propagators who supply rooted cuttings to growers on a regular schedule are also confronted with the problem of having good, uniformly rooted cuttings at a time specified by the grower. Any difficulties or delays in delivery cause the grower to delay his planting, creating dissatisfaction between grower and propagator.

Carnation growers have frequently encountered such problems as uneveness of rooting, delay in rooting, the production of a weak root system, and sloughing of the roots, and in some instances, a complete failure to root. The relationship between these problems and the food supply of the carnation cutting has not been investigated. It is believed that such a study would lead to a better understanding of the difficulties encountered in the propagation of cuttings.

<u>The problem</u>

What effects do certain environmental factors and handling processes have on the food supply in carnation cuttings?

<u>Problem analysis</u>.--Before answering the major question, it will be necessary to answer the following sub-problems:

1. What effect does the average daily light intensity one to several days preceding the taking of cuttings have on the food supply?
2. What is the hourly and day to day fluctuation of the food supply in cuttings?
3. How is the food supply in cuttings affected by mineral nutrition?

4. How is the food supply in cuttings affected during the time they are in the rooting medium?

5. How is the food supply in cuttings affected by cold storage prior to rooting?

Delimitations.--This investigation has been limited to Miller's Yellow and Sim varieties of carnations grown in the Colorado A & M Greenhouses, Fort Collins, Colorado. This experiment was conducted from September, 1952 to June, 1953.

Definition of terms.--1. Food supply, as used in this experiment, refers to the total non-protein, soluble solids as measured by a Spencer refractometer. It also refers to percentage of dry weight or to the hydrochloric acid hydrolizable material found in the carnation cuttings.

2. Cold storage is defined as storage at 34 to 36° F.

Chapter II
REVIEW OF LITERATURE

In vegetative propagation, the portion to be propagated is severed from the parent plant. The amount of stored food and the changes that take place until the cutting is rooted are very important. No attempt will be made to review all the factors involved in the synthesis and utilization of the food material in plants for these are adequately covered by most plant physiology books. Pertinent literature concerning the effects of light, temperature and nutrition on the food supply will be reviewed.

Accumulation of stored foods

It is common knowledge that most plant food is produced in the leaves. Priestly and Swingle (18) discussed the function of the leaves of herbaceous stem cuttings. They concluded that leaves were necessary for root formation, and while the leaves were in light they continued to accumulate a considerable amount of food in the cutting. Von Overbeck (20) found later that a combined action of auxin and some substance produced in the leaves was necessary for root formation. Working with hibiscus, he showed that the influence of the leaves could be replaced by sucrose and nitrogenous material.

In addition to other factors, Bonner and Galston (1) pointed out that in plants at zero light intensity, only respiration was taking place and as light was increased a point was reached where photosynthesis and respiration were balanced. With still further increases in light intensity, the manufacture of food exceeded the breakdown allowing some food to be stored.

Curtis (3) studied dry weight accumulation in alfalfa. A June cutting made an average daily gain in dry weight during the day of 8.5 per cent and lost 4.5 per cent at night. An August cutting gained 8.2 per cent during the day with a nightly loss of 5.1 per cent. If the alfalfa was cut in the afternoon of a clear day following a cloudy day, the gain for that day was greater than normal. The loss on the night following a single clear day was also greater than the loss following several clear days. Curtis found that the carbohydrate content of alfalfa was 83 per cent higher and the dry weight 19 per cent higher in late afternoon cuttings than in morning cuttings.

Denny (5) studied both herbaceous and woody plants, and measured overnight changes in dry weight, nitrogen, and carbohydrates. He found that the dry weight of herbaceous plants decreased markedly overnight but in woody plants, the decrease was relatively small.

Overnight changes in carbohydrates in most species were large. In some species overnight loss of carbohydrates amounted to more than one-half that accumulated in hours of daylight.

Bushnell (2), in an experiment measuring the losses of carbohydrates in potato plants between 6:30 p.m. and 5:00 a.m., found that at 20° C the percentage loss due to respiration was 53.5 and at 29° C 93.9 per cent.

An important factor in the accumulation of food in plants is temperature. Holley (11), in determining the photosynthetic efficiency of three varieties of carnations, measured dry weight accumulation under different conditions of light and temperature. His findings indicated that there were varietal differences in photosynthetic efficiency. As the light intensity decreased the importance of temperature became apparent. Under conditions of low light intensity and high temperature the utilization of food exceeded the synthesis.

Using a range of temperatures from 4° to 40° C, Hewitt and Curtis (10) measured the overnight loss of dry weight and carbohydrates from leaves of tomato, bean and milkweed. Matched leaves, one removed and one left on the plant, were held for 13 hours in dark, temperature controlled chambers. The temperatures were maintained at 4°, 10°, 20°, 30° and 40° C. At the end of the dark period, the differences in dry weight and carbohydrates between the excised leaves and the intact leaves were attributed to translocation. Their conclusions were that the respirational loss of dry matter and carbohydrates (soluble sugars and starch) increased with each increment of temperature, and the translocation losses increased with temperature to approximately 30° C then diminished. The reduction of translocation at the higher temperatures was believed to be due to the amount of material for transport becoming limiting.

Nutrition, as pointed out by Curtis and Clark (4), affects the accumulation of dry weight in plants. Haun and Cornell (9) tested the rooting responses of geranium cuttings as influenced by the mineral nutrition of the stock plants. Stock plants were grown at 3 levels of nitrogen, 3 levels of phosphorus, and 3 levels of potassium in all combinations. Their low level was considered deficient, the medium level normal, and the high level excessive. They found that low and medium nitrogen levels resulted in a significantly higher percentage of rooting than high nitrogen. In testing the leaves and stem for total carbohydrates, the authors found significant differences due to nitrogen, with higher nitrogen giving lower total carbohydrates. Phosphorus and potash gave no significant differences in total carbohydrates or in rooting responses.

Working with poinsettias, Shanks and Link (19) tested the effect of nutrition of stock plants on the production, rooting, and growth of cuttings. Using 3 levels of nitrogen, 3 levels of phosphorus, and 3 levels of potash, ranging from normal to deficient, they obtained significant differences in number of cuttings and in percentage of cuttings that rooted. High levels of all 3 elements produced the most cuttings, and high levels of nitrogen and high and medium levels of phosphorus gave the highest percentage of rooting.

Kenworthy and Mitchell (12), in a study of the effects of soil management practices on the soluble solids of Montmorency cherries at harvest, concluded that the use of mulches, fertilizers, clean cultivation, or any other soil management practice, which promoted vigor and supplied nutrients and moisture to the plants, appeared to result in a reduction of soluble solids.

Respiration of stored food

It is common knowledge that plant tissue continues to respire when placed in cold storage. No food is being produced so the net result is a loss of dry weight and carbohydrates. If the respiration is allowed to continue long enough complete breakdown of the tissue occurs. Meyer and Anderson (16) state that the temperature coefficient of respiration, within the temperature range of

0° to 30° C appears to be about 2.0 to 2.5; i.e., respiration approximately doubles with each 10° rise in temperature.

Platenius (17) measured the effect of temperature on the rate of deterioration of fresh vegetables. Using green peas, asparagus, and sweet corn stored at 35°, 50°, and 80° F, he measured the storage time which had elapsed when the vegetables had lost 30 per cent of their total sugars. A portion of his data showed that asparagus stored at 50° F lost 30 per cent of the total sugars in 275 hours, and at 35° lost an equivalent amount in 1000 hours. Similar differences were also shown for green peas and sweet corn.

<u>Measurement of stored food</u>

Curtis and Clark (4) describe the various methods that have been used to measure the amount of photosynthate produced and respired. One such method is the change in dry weight of the plant material. The authors point out that dry weight is a means of measuring the amount of photosynthate accumulated or lost from a given tissue over a period of time, but changes in dry weight do not account for the amount used in respiration or translocated to other tissues. Curtis and Clark also point out that day by day changes in food content of various crops and the nightly loss due to respiration will vary with the crop and its stage of development, and with several environmental factors. The nightly loss is especially influenced by temperature, water supply and the supply of certain minerals. During the day, in order for the plant to produce food, these factors, plus light, are important.

Light refractometers have been used by many workers to determine the amount of soluble solids in plant tissue. Mann and Hoyle (15) and Faskett and Peterson (6) successfully used the refractive index to select onion bulbs with high dry matter content.

Webb, Miller, and Edmond (21) found no correlation between the total soluble solids and the dry weight of sweet potatoes. They did find a high correlation between the total soluble solids and the total sugars.

To determine the dilution of different samples of honey, Fulmer, Bosch, Park and Buchanan (8) compared the refractive index of samples with known water content to the refractive index of known percentage solutions of sucrose. From the data obtained they were able to prepare refractive index tables that could be used to determine the water content of samples of honey by use of a refractometer. They found that the factors affecting the refractive index were the kinds of material in solution, their concentration, and the temperature.

According to Loomis and Shull (14), some of the non-soluble reserves can be used for respiration under starvation conditions. The reducing substances formed by acid hydrolysis give an indication of the amount of the hemi-reserves in the plant. Since these materials are a heterogeneous mixture, Loomis and Shull suggests that they be called substances hydrolyzed by dilute acids.

Chapter III

METHODS AND MATERIALS

All carnation cuttings used in this experiment were taken from mother blocks of stock plants grown in the Colorado A & M Greenhouses. These plants were grown at 50° F night temperature. Day temperatures varied from 56° F on cloudy days to a maximum of approximately 80° F on sunny days. Since light was variable, light records were kept during the entire period of the experiment. Where light was a factor in the changes of the food supply of cuttings, daily light intensities are included with the results.

In preliminary studies, it was found that turgidity of the cuttings caused extreme variability in both the non-protein soluble solids and the dry weight measurements. To overcome this variability, uniform cuttings were selected and the basal ends of all cuttings were placed in water and set in a refrigerator until the cuttings were completely turgid. The cuttings were then handled as described in the following procedures.

GENERAL PROCEDURES

Non-protein soluble solids determination.--In determining the non-protein soluble solids, the turgid cuttings were divided into samples of 5 cuttings each, tagged for identification, wrapped in paper and frozen. The cuttings were then thawed and the juice extracted by squeezing. Vials of the juice from each lot were placed in a wire basket and set in boiling water for 1 to 2 minutes to coagulate the proteins. The juice was filtered through Whatman No. 1 filter paper, cooled to room temperature, and readings of the non-protein soluble solids were made on a Spencer refractometer. In reading the per cent concentration of the soluble solids, one drop of the extracted juice was placed in the instrument. Five or more readings were taken on each sample and the average value used as the reading for that sample. If the samples could not be read immediately after being filtered and cooled, they were frozen until such time as they could be read. No attempt was made in this experiment to determine the types of sugars and other organic compounds in the extracted juice.

Dry weight determinations.--Cuttings collected for dry weight determinations were also placed in water until completely turgid. The cuttings were then divided into lots of 5 cuttings each, the excess water clinging to the basal end of the stem wiped off with a dry cloth, and each replication weighed to the nearest tenth of a gram on a triple beam balance. The cuttings were then wrapped in paper, tagged for identification, and placed in a forced air oven for 48 hours at 100° C. They were removed, cooled, and weighed to the nearest hundredth of a gram on a torsion balance and percentage dry weight determined.

Acid hydrolizable material determinations.--The dried material from the dry weight determinations was ground to pass a 40 mesh screen and placed in closed vials. Duplicate samples of approximately one gram each were weighed to the fourth decimal place and placed in a 150 ml beaker. One hundred ml of 10 per cent HCl was added, a watch glass placed over each beaker, and the solutions were boiled for 2½ hours. Approximately every 30 minutes, the material clinging to the sides of the beakers was washed down with 10 per cent HCl solution. While still hot, the material not hydrolized was filtered out in a weighed Gooch crucible with an asbestos filter. The crucibles were placed in an electric oven until dry, cooled in a desiccator and weighed to the fourth decimal place. The amount of material hydrolized was converted to a percentage basis.

HOURLY CHANGES IN THE FOOD SUPPLY IN CARNATION CUTTINGS

Non-protein soluble solids.--Three replications of 5 cuttings each of the Miller's Yellow variety were taken every hour from 8 a.m. to 4 p.m. on March 4. Three replications of 5 cuttings each of the Crowley's Pink Sim variety were taken every hour from 8 a.m. to 4 p.m. on March 5. Determinations were made of the non-protein soluble solids.

Dry weight.--Cuttings of the Crowley's Pink Sim variety were taken on May 14, 27 and 28, 1953. Three replications of 5 cuttings each were taken every 2 hours from 8 a.m. to 6 p.m. and the percentage dry weight determined.

DAY TO DAY CHANGES IN THE FOOD SUPPLY IN CARNATION CUTTINGS

Non-protein soluble solids.--Three replications of 5 cuttings each were taken from Miller's Yellow and Crowley's Pink varieties at 8 a.m. and 5 p.m. each day from March 30 to April 15, 1953 for measurements of non-protein soluble solids.

Dry weights.--Five replications of 5 cuttings each of the Miller's Yellow variety were taken at 8 a.m. and 5 p.m. each day from January 26 to January 30, 1953 for determination of percentage dry weight.

NUTRITIONAL EFFECTS ON THE FOOD SUPPLY IN CARNATION CUTTINGS

Carnation stock plants of the White Sim variety were grown at 3 levels of nitrogen, 2 levels of phosphorus, and 3 levels of potassium in all combinations. Ammonium nitrate applied at the rate of 1 pound per 100 square feet of bench area was used as the source of nitrogen. The nitrogen levels were maintained from normal to deficient by varying the number of applications in a ratio of 3:2:1. Phosphorus levels were maintained at high and normal by incorporation of treble superphosphate, at the rate of 5 pounds per 100 square feet of bench area, in the soil of the high plots before planting. Potassium chloride applied at the rate of 1 pound per 100 square feet of bench area, was used to maintain the potassium levels from high to deficient by varying the number of applications in a ratio of 3:2:1.

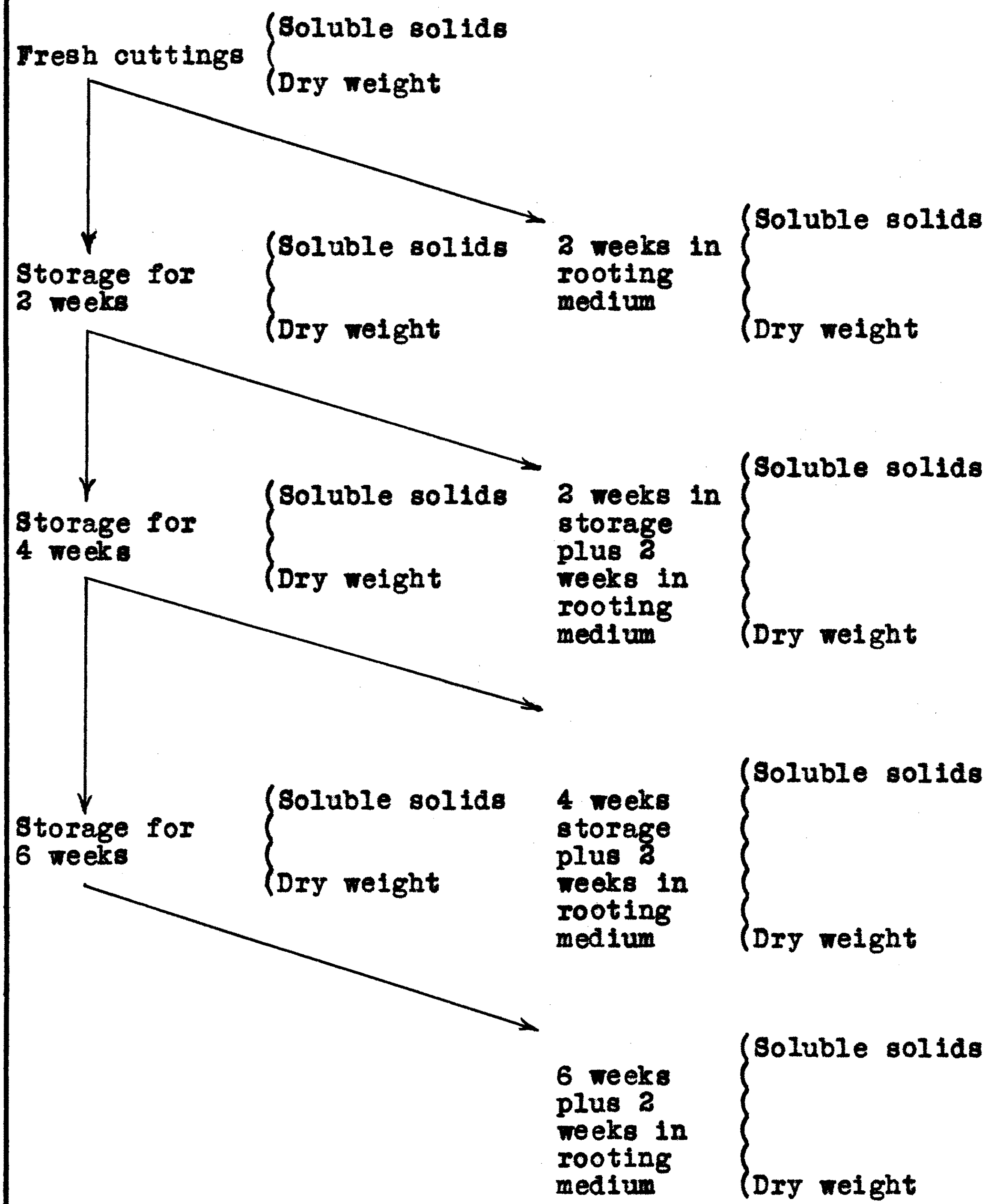
Cuttings were taken March 9, April 21, and May 16 from all plots and the non-protein soluble solids and dry weights determined. Dried materials from dry weight determinations made on February 9 were analyzed by acid hydrolysis.

CHANGES IN THE FOOD SUPPLY IN CARNATION CUTTINGS IN STORAGE AND IN THE ROOTING MEDIUM

This phase of the study was designed to determine the changes in the food supply of carnation cuttings while in storage at 34-36° F and while in the rooting medium. The rooting medium used was sharp sand. Eighty samples of 5 cuttings each were taken and placed in water until turgid. The samples were weighed to the nearest tenth of a gram, placed in a cellophane bag, misted lightly with water and the bag stapled at the top with an identifying number attached. Five samples were selected at random for non-protein soluble solids determinations, and 5 for dry weight determinations of the fresh cuttings. Ten samples were placed in the rooting medium for 2 weeks at which time they were removed and tested for non-protein soluble solids and dry weight. The time was limited to 2 weeks in the rooting medium due to the difficulty of measuring the dry weight of cuttings after they had formed roots. When rooted, some of the roots were lost in removing the cuttings from the medium. The sand particles were difficult to remove from the root mass.

Every two weeks, 20 more samples were selected. Ten were tested for effects of the storage period, and 10 were placed in sand for 2 weeks.

The following is a graphic representation of the plan:



Cuttings of the White Sim variety were taken on March 1 for the first series. The Miller's Yellow variety was used for the second series, which was started March 21. The dried material from the dry weight measurements of the first series was used to determine the acid hydrolizable material.

CORRELATION OF THE NON-PROTEIN SOLUBLE SOLIDS MEASUREMENTS AND THE DRY WEIGHT DETERMINATIONS

Measurements of the non-protein soluble solids and the per cent dry weight from 54 comparable samples of carnation cuttings were correlated by use of the following formula (13):

$$r = \frac{S\,(xy) - N\,\bar{x}\bar{y}}{\sqrt{(Sx^2 - N\bar{x}^2)\,(Sy^2 - N\bar{y}^2)}}$$

The t-test for significance was applied to the correlation coefficient by use of the formula (13):

$$t = \frac{r\sqrt{N - 2}}{\sqrt{1 - r^2}}$$

Chapter IV

PRESENTATION OF DATA

The data presented in this experiment are the average percentages of all determinations of all replications used in each test. The per cent non-protein soluble solids represents the per cent concentration of such substances found in the juice of the carnation cuttings as measured by a Spencer refractometer. The per cent dry weight includes the soluble and non-soluble materials in the cuttings. The per cent acid hydrolizable material is the portion of the dried material that is usually designated as the hemi-reserves or substances hydrolyzed by dilute acids.

HOURLY CHANGES IN THE FOOD SUPPLY IN CARNATION CUTTINGS

Non-protein soluble solids.--Measurements of the non-protein soluble solids in cuttings of the Miller's Yellow variety, taken March 4, are shown in Fig. 1. The values shown are averages of readings from 3 replications of 5 cuttings each taken each hour from 8 a.m. to 4 p.m. The average light intensity in the greenhouse for each increment of time for March 4 and the previous day, March 3, is also included. The per cent concentration of the

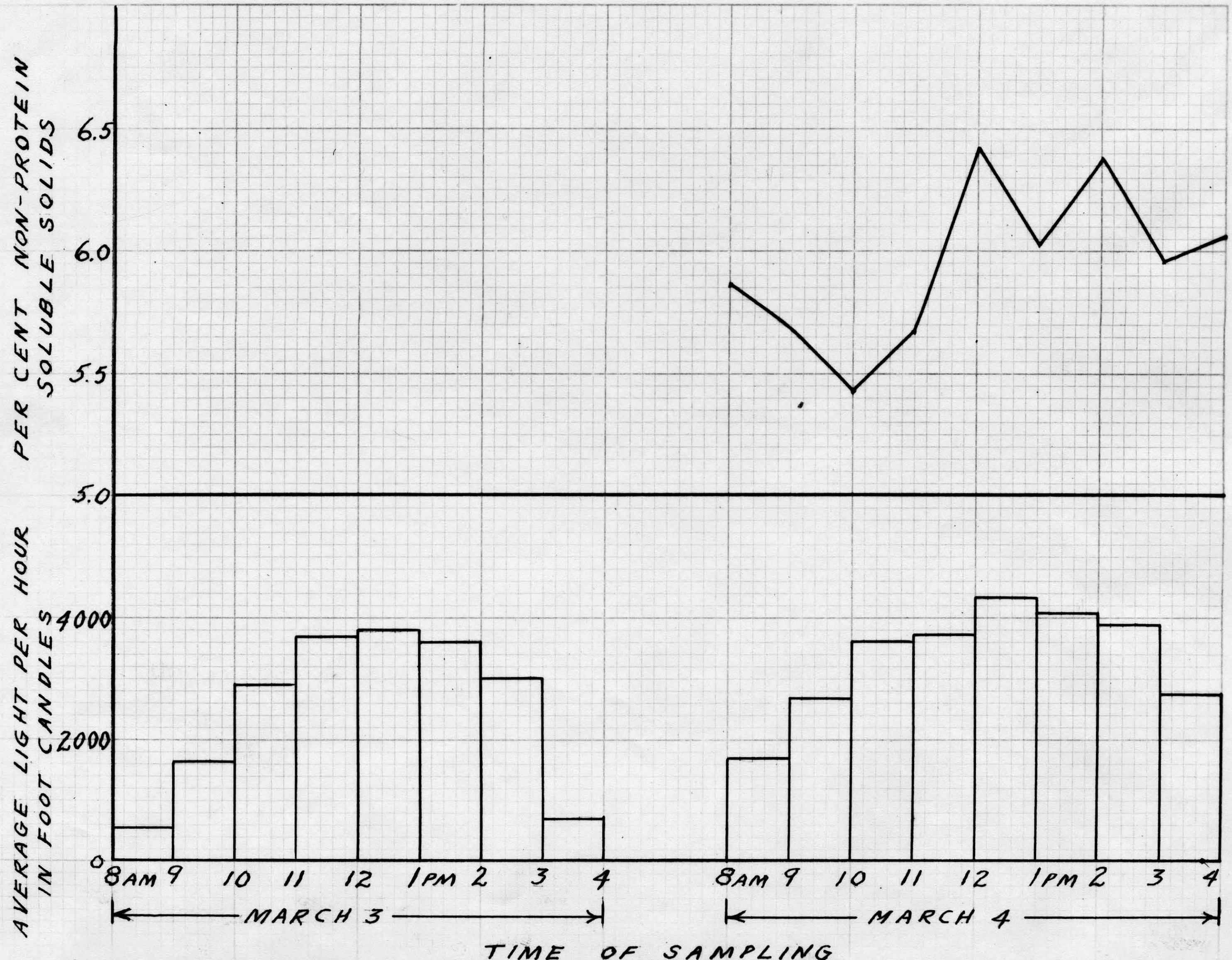


Fig. 1 Hourly measurements of non-protein soluble solids in Miller's Yellow carnations taken on March 4, 1953.

soluble solids varied from a low of 5.43 at 10 a.m. to a high of 6.40 at 12 noon and 2 p.m.

Similar measurements of the White Sim variety taken March 5 are shown in Fig. 2. These values varied from a low of 5.07 per cent at 8 a.m. to a high at 2 p.m. of 5.80 per cent. March 4 was a clear day following a day that was cloudy after 2:30 p.m. March 5 was a clear day following a clear day.

Dry weight.--Fig. 3 is a graph of the changes in the per cent dry weight of cuttings of the Crowley's Pink Sim variety taken every 2 hours from 8 a.m. to 6 p.m. on May 14. The values shown are the averages of 2 determinations. The corresponding 2-hour increments of light in the greenhouse for that and the preceding day are also shown. There was a gradual increase from 8 a.m. to 12 noon, a sharp increase from 12 noon to 2 p.m., after which there was a gradual decrease until 6 p.m. The dry weight decreased overnight from 14.93 at 6 p.m. to 12.14 per cent at 8 a.m. May 14 was a partially cloudy day with heavy clouds after 2 p.m. preceded by a cloudy day with the sun breaking through between noon and 2 p.m.

Fig. 4 includes the measurements for 2 consecutive days, May 27 and 28, 1953, of the changes in dry weight of the Crowley's Pink Sim variety plus the corresponding light measurements for each period and for the preceding day. Percentages shown on the graph are averages

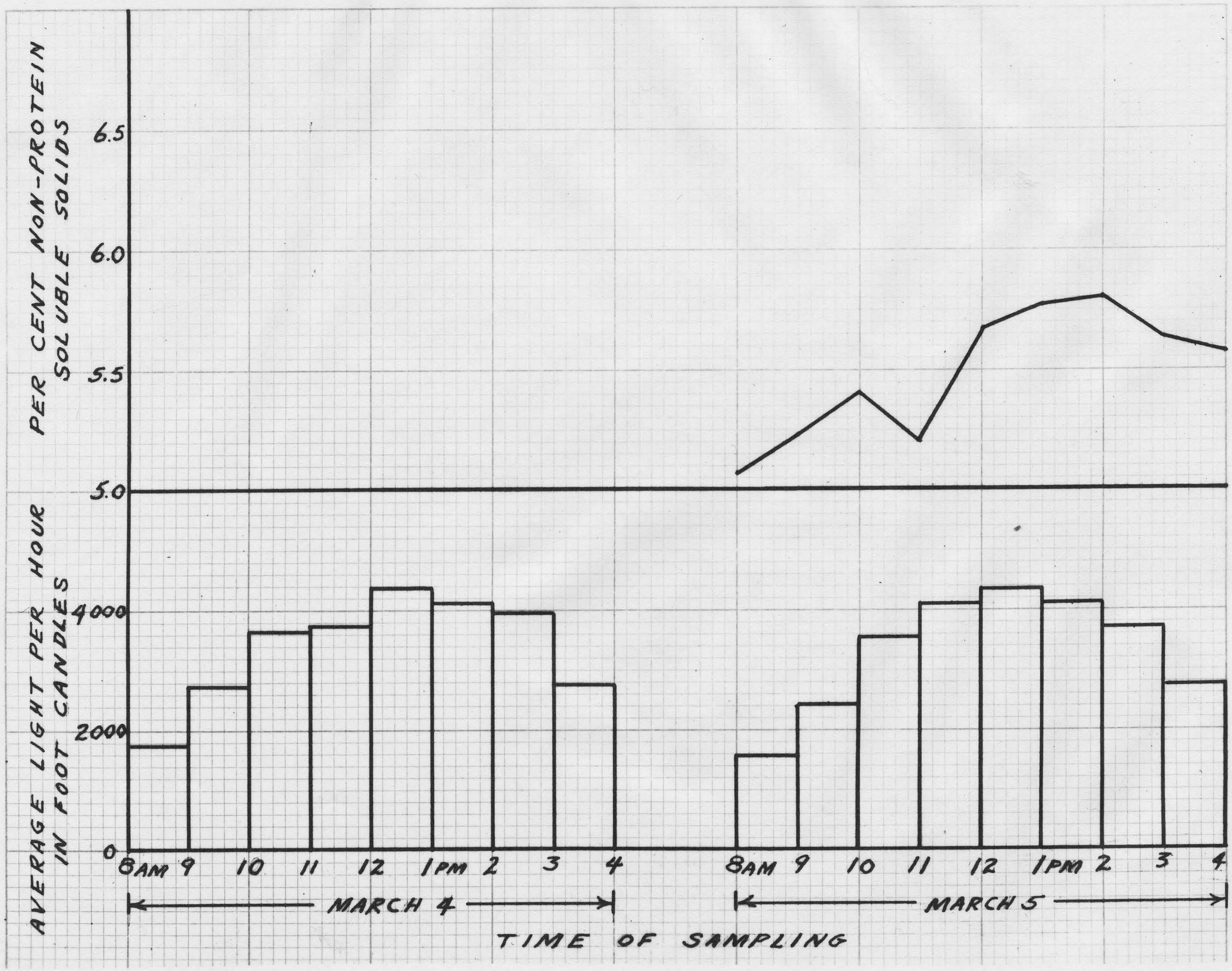


Fig. 2 Hourly measurements of non-protein soluble solids in White Sim carnations taken on March 5, 1953.

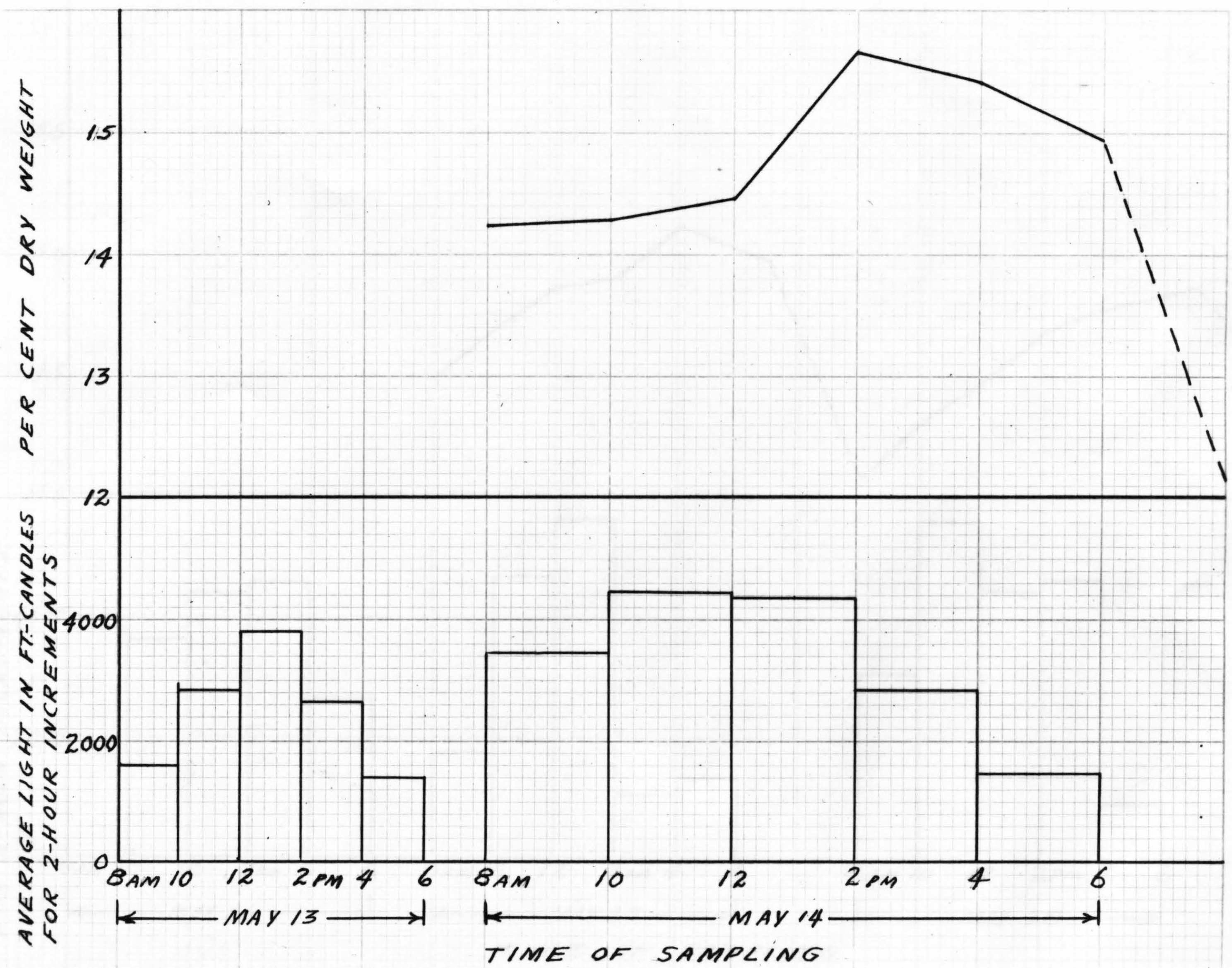


Fig. 3 Changes in the percentage of dry weight of cuttings from Crowley's Pink Sim (May 14).

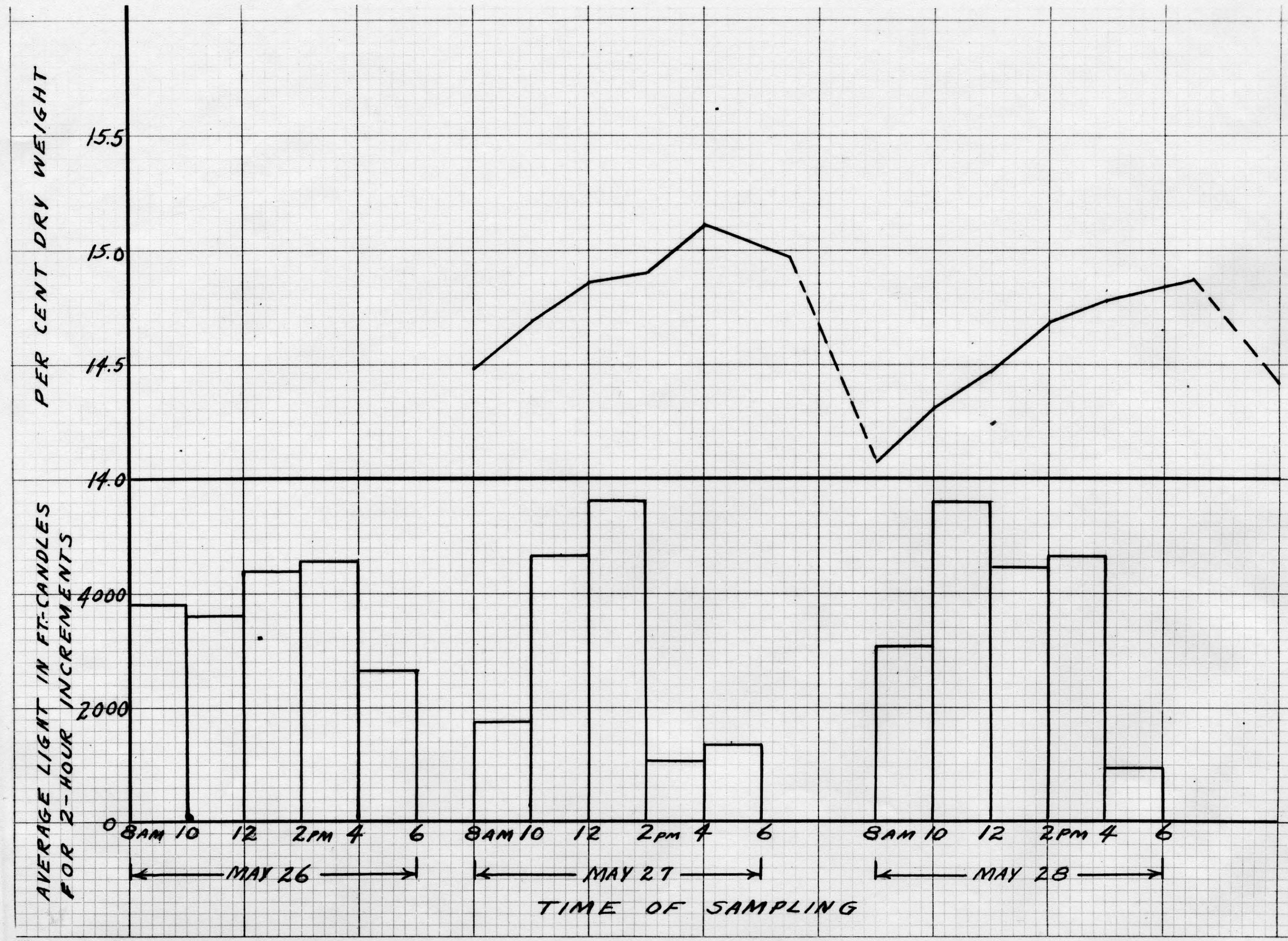


Fig. 4 Dry weight percentages of cuttings from Crowley's Pink Sim for May 27 and 28, 1953.

of 3 determinations. The percentages of dry weight increased on both days until 4 p.m. or later. The decrease in dry weight was greater during the night following May 27. May 26 was a partially cloudy day with floating clouds and fairly high light intensity throughout the day. May 27 and 28 were partially cloudy days with heavy clouds after 2 p.m. on May 27 and after 4 p.m. on May 28.

In both Figs. 3 and 4 the higher light intensities preceded the maximum accumulation of dry weight.

DAY TO DAY CHANGES IN THE FOOD SUPPLY IN CARNATION CUTTINGS

Non-protein soluble solids.--The measurements of the changes in the non-protein soluble solids from day to day are shown graphically in Figs. 5 and 6. The values used represent averages of 3 replications of 5 cuttings each taken at 8 a.m. and 5 p.m. each day from March 30 to April 15. The light measurements shown are the values of the average light intensity from 7 a.m. to 6 p.m. Fig. 5 pictures the changes in the Miller's Yellow variety. The non-protein soluble solids increased during the day and decreased overnight, except that on March 30, April 2, 4, 10 and 13 there was no change or a decrease during the day and on the night following April 5 there was an increase. When the average light intensity was less than approximately 1500 foot candles per day, the soluble solids decreased or

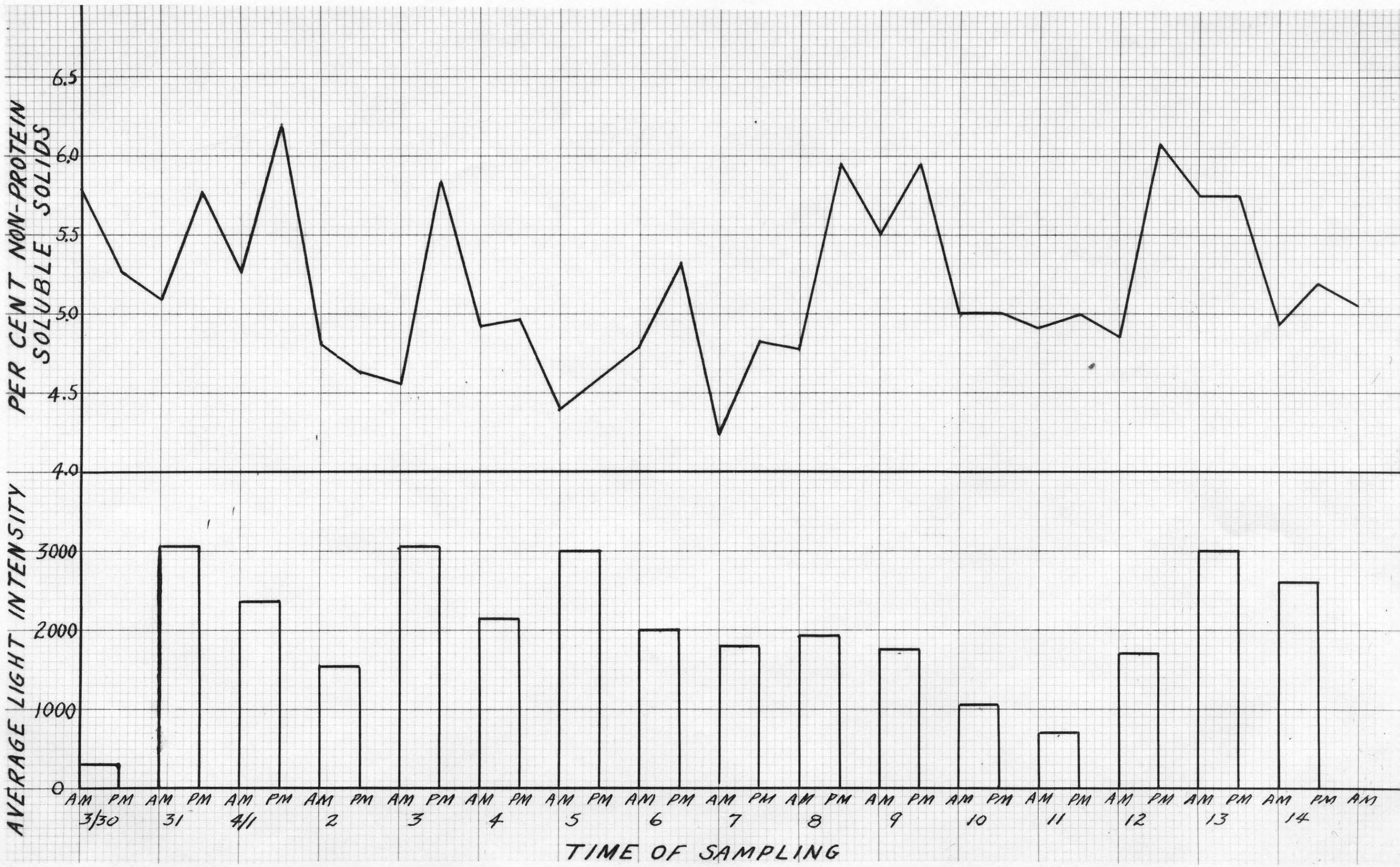


Fig. 5 Morning and afternoon measurements of non-protein soluble solids in Miller's Yellow carnations from March 30 to April 15, 1953.

remained the same. The greatest accumulation did not follow the highest light intensity.

Fig. 6 shows the changes in the Crowley's Pink Sim variety. This variety also showed an increase during the day and a decrease at night, except on March 30, April 7 and 13 there was a decrease or no change during the day, and on the nights following March 30, April 2, 4, 8 there was no change or an increase. The readings varied from a low of 5.07 to a high of 7.17 per cent, and in general, tended to increase during the test period. The greatest accumulation did not follow the highest light intensity.

Dry weight.--In Fig. 7 the day to day changes in the per cent dry weight are graphed. The values used represent the averages of 5 replications of 5 cuttings each of the White Sim variety. The cuttings were taken at 8 a.m. and 5 p.m. from January 26 to 31. The graph shows a definite downward trend over the period which follows a slight decrease in the light intensity. The dry weight varied from a high of 13.17 per cent to a low of 11.76 per cent. The light intensity for the period was low with January 27 being a clear day and the others partially cloudy.

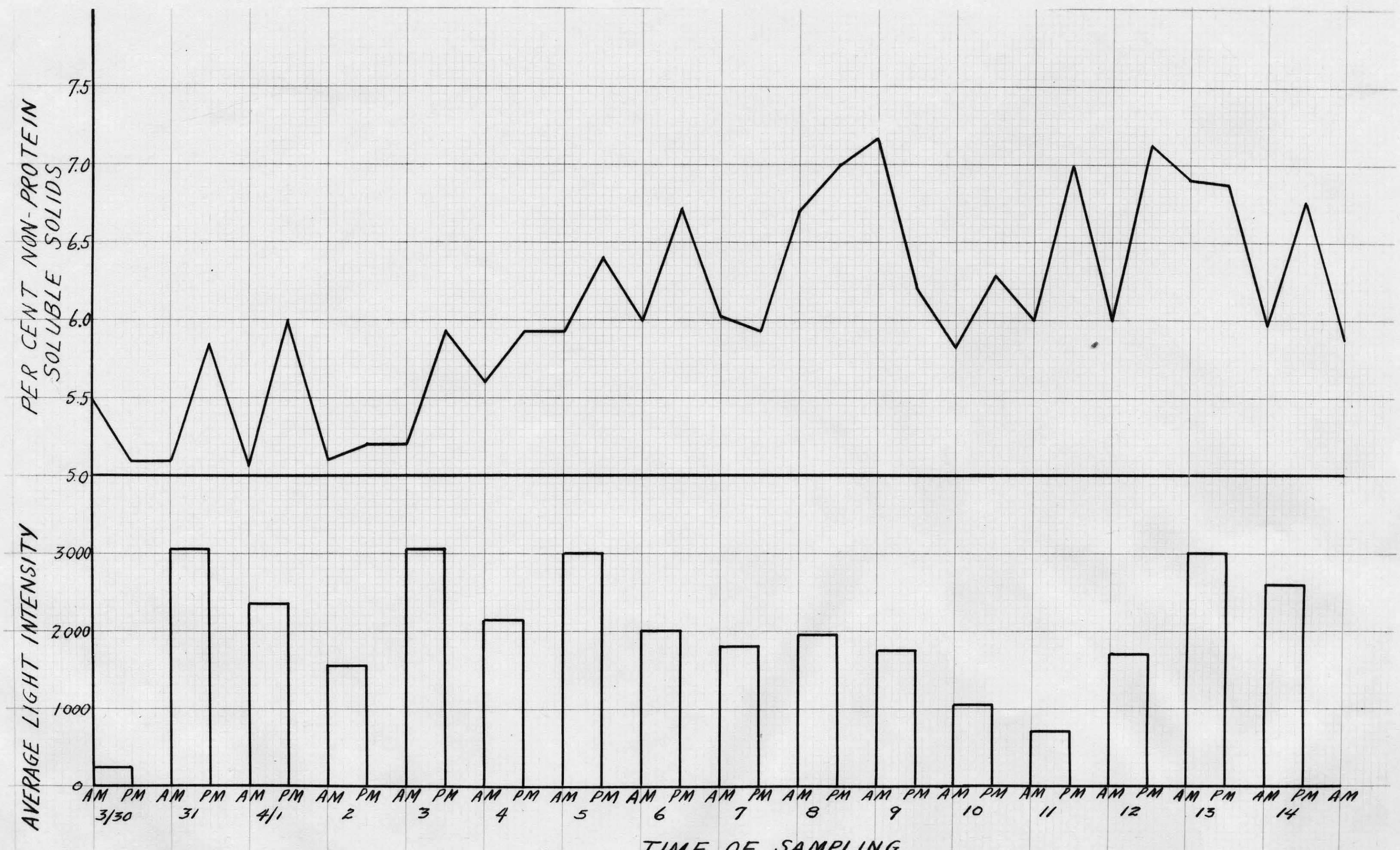


Fig. 6 Morning and afternoon measurements of non-protein soluble solids in Crowley's Pink Sim carnations from March 30 to April 15, 1953.

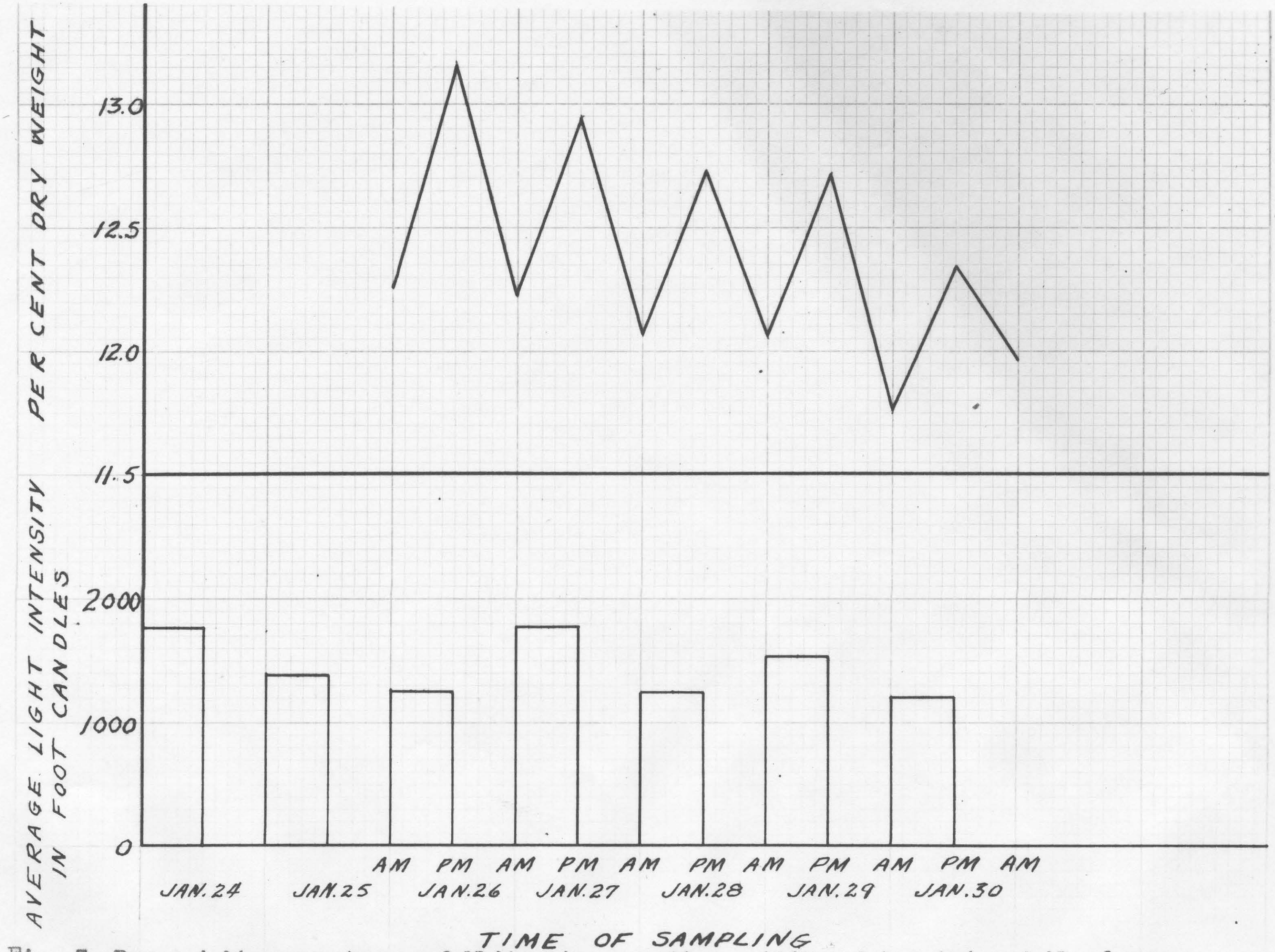


Fig. 7 Dry weight percentages of White Sim carnation cuttings taken twice daily from January 26 to January 31, 1953.

NUTRITIONAL EFFECTS ON THE FOOD SUPPLY IN CARNATION CUTTINGS

Non-protein soluble solids.—Table 1 gives the averages of the readings of non-protein solids in cuttings taken from the nutrient plots on March 9, April 21, and May 16. The values shown are based on an average of 18 measurements. The soluble solids varied inversely with the nitrogen levels, but were not affected by differences in potassium or phosphorus levels. It was found that the lower the nitrate level at which the stock plants were grown the higher were the soluble solids. The high nitrogen plots gave a reading of 5.95 while low plots gave an average of 6.81 per cent. These differences were highly significant. All levels of potash and phosphorus gave an average of approximately 6.35 per cent, with differences between treatments not significant.

Table 1. The effect of nutrient levels on percentage non-protein soluble solids in White Sim carnation cuttings.

		Per cent soluble solids			Per cent soluble solids		Per cent soluble solids
Nitrogen	High	5.95	Potash	High	6.38	High	6.33
	Medium	6.29		Medium	6.33	Phosphorus	
	Low	6.81		Low	6.34	Low	6.37
L.S.D. at one per cent level		0.31			N.S.		N.S.

Dry weight.—The dry weight determinations of cuttings from the nutrient plots taken on March 9, April 21 and May 16 are shown in Table 2. Values are based on an average of 18 determinations. The per cent dry weight varied inversely with nitrogen but there were no real differences attributable to potassium or phosphorus. The average per cent dry weight for cuttings from high nitrogen plots was 14.43 and for the low plots 16.17. The average for all potassium and phosphorus plots was approximately 15.40.

Table 2. The effect of nutrient levels on percentage dry weight of White Sim carnation cuttings.

		Per cent of dry weight			Per cent of dry weight		Per cent df dry weight
	High	14.43		High	15.43	High	15.34
Nitrogen	Medium	15.40	Potash	Medium	15.42	Phosphorus	
	Low	16.17		Low	15.34	Low	15.46
L.S.D. at one per cent level		0.61			N.S.		N.S.

Acid hydrolizable material.—The percentage of acid hydrolizable material found in cuttings taken from nutrient plots on February 9 was determined. Table 3 summarizes these data. The values represent the percentages of acid hydrolizable material found in the cuttings and are averages of 12 determinations per category. There were no real differences obtained from the various levels of nitrogen, potassium or phosphorus. All nutrient treatments gave an average of approximately 74.00 per cent.

Table 3. The effect of nutrient levels on percentage acid hydrolizable material in White Sim carnation cuttings and the corresponding dry weights.

		Per cent dry weight	Per cent acid hydrolizable material
	High	15.73	73.88
Nitrogen	Medium	17.49	74.00
	Low	18.26	74.00
	High	17.47	73.96
Potassium	Medium	17.58	73.99
	Low	16.42	74.04
	High	17.19	73.90
Phosphorus			
	Low	17.13	74.09

CHANGES IN THE FOOD SUPPLY IN STORAGE AND IN THE ROOTING MEDIUM

Series 1.--Cuttings of the White Sim variety were taken on March 1 and handled as described in Methods and Materials. The data for the changes in the non-protein soluble solids and percentage dry weight for the entire series are shown graphically in Fig. 8. The values used are averages of 5 determinations each. The average daily light intensity (7 a.m. to 6 p.m.) is also shown for the test period. It should be noted that any changes in storage were not affected by light intensity since the cuttings were stored in the dark. The dry weight and the

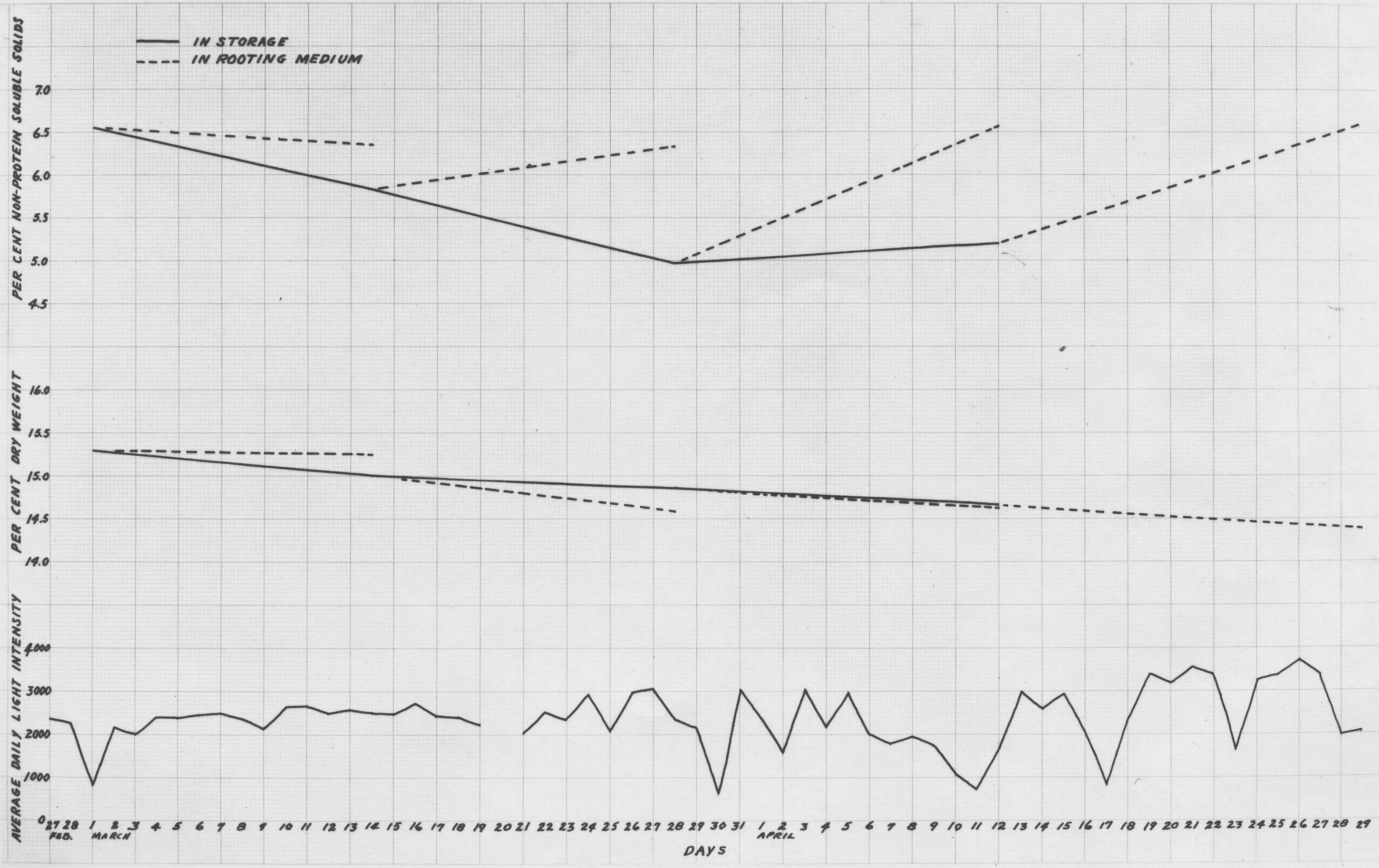


Fig. 8 The effects of cold storage and the rooting environment on non-protein soluble solids and dry weight in White Sim carnation cuttings.

soluble solids gradually decreased throughout the storage period. The non-protein soluble solids showed a slightly larger decrease than the dry weight. The dry weight continued to decrease when the cuttings were placed in the rooting medium, while the non-protein soluble solids increased. In storage the dry weight decreased from 15.30 to 14.65 per cent and the soluble solids decreased from 6.54 to 5.20 per cent (Table 4).

The dried materials from the dry weight determinations were hydrolized, and the percentages of acid hydrolizable materials are shown in Table 4. The percentages shown represent an average of 10 determinations each. There were no real differences in the acid hydrolizable materials, due to treatments given in this experiment. The amount of acid hydrolizable material was found to average between 72.5 and 74.0 per cent.

Table 4. Trends in (A) per cent non-protein soluble solids, (B) per cent dry weight and (C) per cent of acid hydrolizable material in the White Sim carnation cuttings while in storage and in the rooting medium.

Fresh March 1	A 6.54 B 15.30 C 74.22		
2 weeks storage	A 5.84 B 15.01 C 72.99	2 weeks in sand	A 6.36 B 15.24 C 73.20
4 weeks storage	A 4.98 B 14.87 C 73.69	2 weeks in storage plus 2 weeks in sand	A 6.34 B 14.58 C 73.67
6 weeks storage	A 5.20 B 14.65 C 72.48	4 weeks in storage plus 2 weeks in sand	A 6.56 B 14.62 C 72.51
		6 weeks in storage plus 2 weeks in sand	A 6.58 B 14.37 C 73.72

Series 2.—Cuttings of the Miller's Yellow variety were taken on March 21 and handled in the same way as Series 1, except that no test was made for acid hydrolizable material. Fig. 9 pictures the changes due to time in storage and in the rooting medium. The performance of this series (Table 5) very closely parallels that of Series 1, except that, when the cutting were placed in the

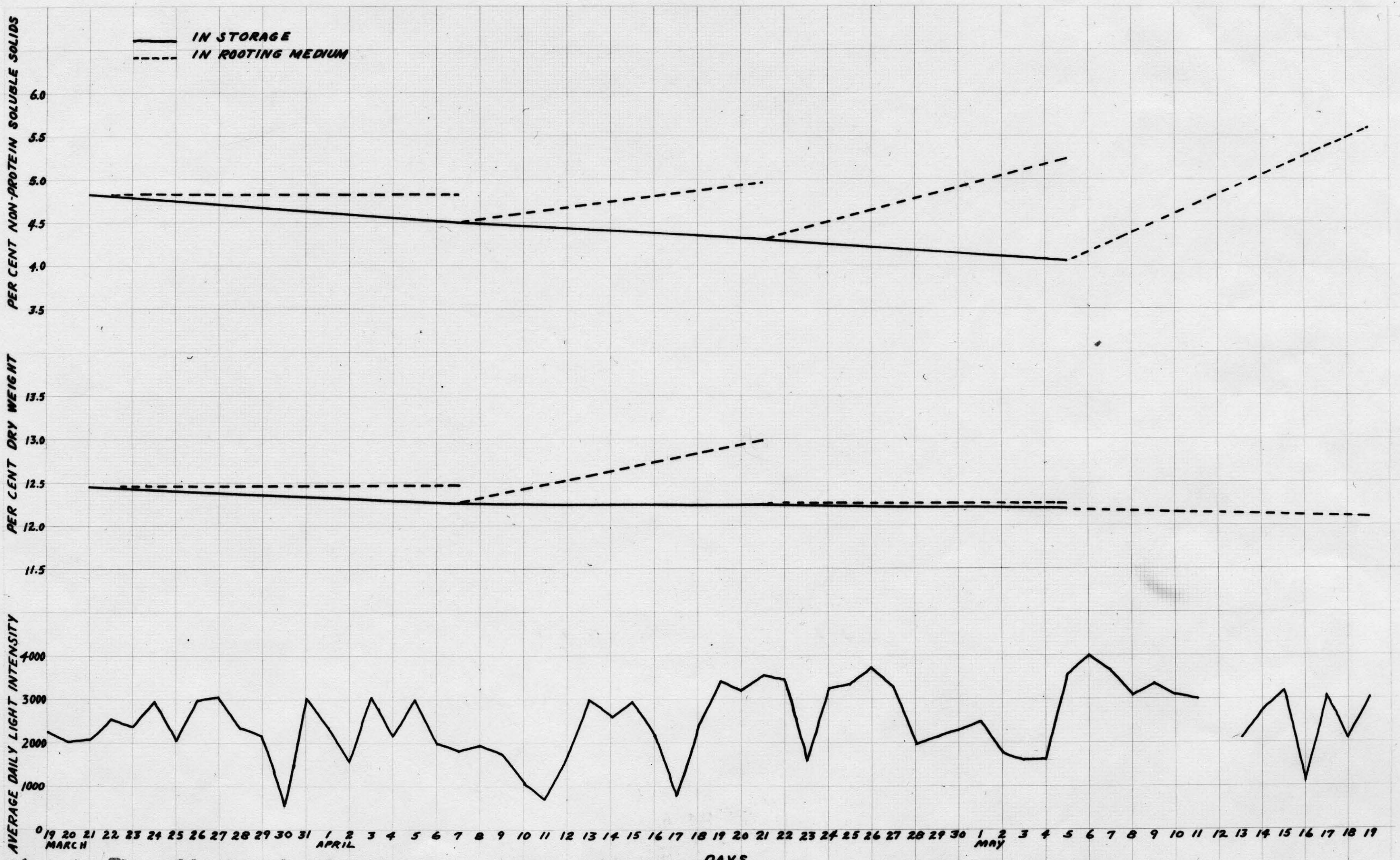


Fig. 9 The effects of cold storage and the rooting environment on non-protein soluble solids and dry weight in Miller's Yellow carnation cuttings.

rooting medium the dry weight remained approximately the same or increased slightly. In storage the dry weight decreased from 12.45 to 12.17 per cent and the soluble solids decreased from 4.82 to 4.04 per cent.

Table 5. Trends in (A) per cent non-protein soluble solids and (B) per cent dry weight in the Miller's Yellow carnation cuttings while in storage and in the rooting medium.

Fresh March 21	A 4.82	B 12.45			
2 weeks storage	A 4.50	B 12.27	2 weeks in sand	A 4.82	B 12.47
4 weeks storage	A 4.30	B 12.26	2 weeks in storage plus 2 weeks in sand	A 4.96	B 12.98
6 weeks storage	A 4.04	B 12.17	4 weeks in storage plus 2 weeks in sand	A 5.24	B 12.23
			6 weeks in storage plus 2 weeks in sand	A 5.58	B 12.09

CORRELATION OF THE NON-PROTEIN SOLUBLE SOLIDS MEASUREMENTS AND THE DRY WEIGHT DETERMINATIONS

Using 54 comparable measurements of the non-protein soluble solids and per cent dry weight on fresh samples of carnation cuttings, a correlation coefficient was found to be 0.508. Using the t-test this value was found to be highly significant.

Chapter V
DISCUSSION OF RESULTS

Changes in the food supply in carnation cuttings were measured by 3 methods: 1) percentage dry weight, 2) non-protein soluble solids, and 3) percentage of acid hydrolizable material.

The measurement of dry weight in the carnation cuttings apparently gave an accurate picture of the amount of reserve food in the cuttings at the time of the determination. In most cases the changes found could be attributed to certain environmental factors or handling processes. The ability of the carnation plants to accumulate dry weight varied with the varieties tested. From the data shown in Figs. 3, 4, 7, 8 and 9 and from preliminary studies, the Miller's Yellow variety normally accumulated less dry weight than the Sim varieties under comparable growing conditions. The dry weight of cuttings from the Miller's Yellow variety fluctuated within a range lower than the range of the Sim varieties. Under no treatment given in this experiment or in other trials, did the dry weight of cuttings fall below 11 per cent. This may indicate the approximate lower limit of the food reserve at which carnation cuttings will survive.

The accumulation of dry weight during a single day tended to follow the light intensity for the day (Figs. 3, 4 and 7). In all tests, the higher light intensities preceded the maximum accumulation of dry weight. The overnight loss in dry weight was high following days with cloudy afternoons. During the time of year when the average light intensity was low (Fig. 7), any reduction of light by cloudy weather tended to give a downward trend in the level of food reserves in the cuttings. For the time of year covered in Fig. 7, a reduction in the average daily light intensity below approximately 1700 foot candles reduced the synthesis of food below that utilized.

The nitrogen nutrition of stock plants affects the accumulation of stored foods in carnation cuttings (Table 2). Plants grown in a soil deficient in nitrogen produced hard, thin cuttings that were high in dry weight. Various levels of phosphorous and potassium did not appreciably affect the dry weight.

Carnation cuttings placed in storage gradually decreased in dry weight (Figs. 8 and 9). When the cuttings were removed from storage and placed in the rooting medium, the dry weight remained the same or decreased slightly, which indicates that sufficient photosynthesis occurred to balance respiration. Since there were no roots on the cuttings and no translocation out of the stems, all the loss was due to respiration.

The results of this experiment indicate that the environmental conditions of one or more preceding days may have as much or more effect on the stored foods in cuttings as the conditions immediately prior to sampling. Fig. 7 illustrates the effect of several partially cloudy days on later determinations.

In evaluating the dry weight method of detecting changes in the food supply in carnation cuttings, the data obtained points up several limitations. It is satisfactory for comparing treatments of a particular variety grown under the same environmental conditions. Unless nutrition, light, temperature and other environmental factors are under control, this method would be unsatisfactory for comparing samples from different greenhouse ranges, or for samples taken at different times of the year.

In the data presented and in other trials, the range of the non-protein soluble solids of the Miller's Yellow variety was normally lower than the range of the Sim varieties tested under comparable conditions. The range for all tests varied from 4.0 to 8.85 per cent. Under no conditions of stress did the soluble solids go below a reading of 4.0 per cent, which indicates the lower limit at which other stored foods break down to maintain the soluble solids.

The non-protein soluble solids increased during the day and decreased at night in a manner similar to dry weight. The accumulation normally followed the light intensity but tended to fluctuate more than the dry weight (Figs. 1, 2, 5 and 6). When the average daily light intensity was below approximately 1700 foot candles there was little or no accumulation. Several exceptions to this (Figs. 5 and 6) could possibly have been due to conversion from other materials in the plant.

The non-protein soluble solids varied inversely with the nitrogen level at which the stock plants were grown. Cuttings from the low nitrogen plots gave high soluble solids readings, which would indicate a high reserve of carbohydrates. Potassium and phosphorus levels apparently did not affect the soluble solids in the cuttings.

The non-protein soluble solids decreased in storage due to continued respiration. When the cuttings were taken from storage and placed in the rooting medium the soluble solids increased. Since the dry weight did not increase proportionally, the increase in the soluble solids was likely due to a conversion of reserves within the cuttings.

This procedure for measuring the changes in the non-protein soluble solids, although easily made, has definite limitations. It could be used on samples taken from plants given the same growing conditions and handling processes, but it is not suitable for testing material grown or handled in different ways. Possibly the factor that causes the most fluctuation in the soluble solids content is the continual synthesis and breakdown of proteins in the plant.

The acid hydrolysis test used in this experiment did not detect changes in the food supply in the cuttings. This would indicate that differences produced by various treatments were changes in the more soluble fraction of the food reserve.

SUGGESTION FOR FURTHER STUDY

1. A procedure for measuring the total soluble solids should be devised. This test would take into account the proteins as well as the carbohydrates. It should give a more accurate measurement of the reserve foods than dry weight percentage, especially under variable environmental conditions.
2. For studies leading to work on the keeping quality of cut carnation flowers, measurement of the food supply in the plant should be made over an entire growing season. These data could then be correlated with climatic conditions as well as with the other environmental factors.

3. The performance of the cuttings should be compared with the food supply in the cutting at the time they are taken from the stock plant. Data needed would be a measurement at the time cuttings are taken, their rooting performance, the number of breaks produced per cutting, the timing of the growth of the resulting plants and the quality and quantity of production.

Chapter VI

SUMMARY

Changes in the food supply in carnation cuttings, due to certain environmental factors and handling processes, were determined by three methods. Acid hydrolysis tests detected no changes. This would indicate that changes in the food supply were in the more soluble portion of the material in cuttings. The changes detected by dry weight and non-protein soluble solids measurements were as follows:

1. The food supply in cuttings was affected by the average daily light intensity of one to several days preceding the test. Several days of cloudy weather reduced both the dry weight and non-protein soluble solids. When the average light intensity was high the dry weight and soluble solids fluctuated within a fairly constant range. This range varied slightly with the varieties tested. The range of food supply in the Sim varieties was normally higher than the range of the Miller's Yellow variety.

2. In the hourly measurement of changes in the food supply, dry weight and non-protein soluble solids increased with the light intensity for that day. The greatest accumulation of food followed the maximum light intensity by 1 to 2 hours.

3. In measurements of the day to day changes in the food supply, dry weight and soluble solids increased and decreased with the light intensity. Normally there was a build up of the food supply during the day and a decrease overnight. When the average daily light intensity was below approximately 1700 foot candles the utilization of the food slightly exceeded the synthesis. The overnight loss was high following a day with a cloudy afternoon.

4. The nitrogen level at which the stock plants were grown affected the dry weight and the non-protein soluble solids. The percentage of dry weight and non-protein soluble solids were inversely proportional to the nitrogen available to the plants. Potassium and phosphorus levels did not appreciably affect the dry weight or the soluble solids.

5. When cuttings were placed in storage the food reserve, as measured by both the dry weight and the non-protein soluble solids test, decreased throughout the storage period.
6. When removed from storage and placed in the rooting medium, cuttings maintained approximately the same level of food reserves. Apparently sufficient photosynthesis took place to balance respiration.

The correlation coefficient of the two methods of measuring the food supply was 0.508. The t-test showed this value to be highly significant. The changes in non-protein soluble solids normally followed the changes in dry weight. The non-protein soluble solids fluctuated more than the dry weight, which was probably caused by the synthesis and breakdown of proteins in the plant.

The dry weight method appears to be more satisfactory than the non-protein soluble solids method for the measurement of the food reserves in the cuttings. It would be unsatisfactory for comparing samples grown under different environmental conditions or for samples from different varieties of carnations. It is possible that a total soluble solids measurement might be more accurate in reflecting changes on the soluble fraction of the food supply.

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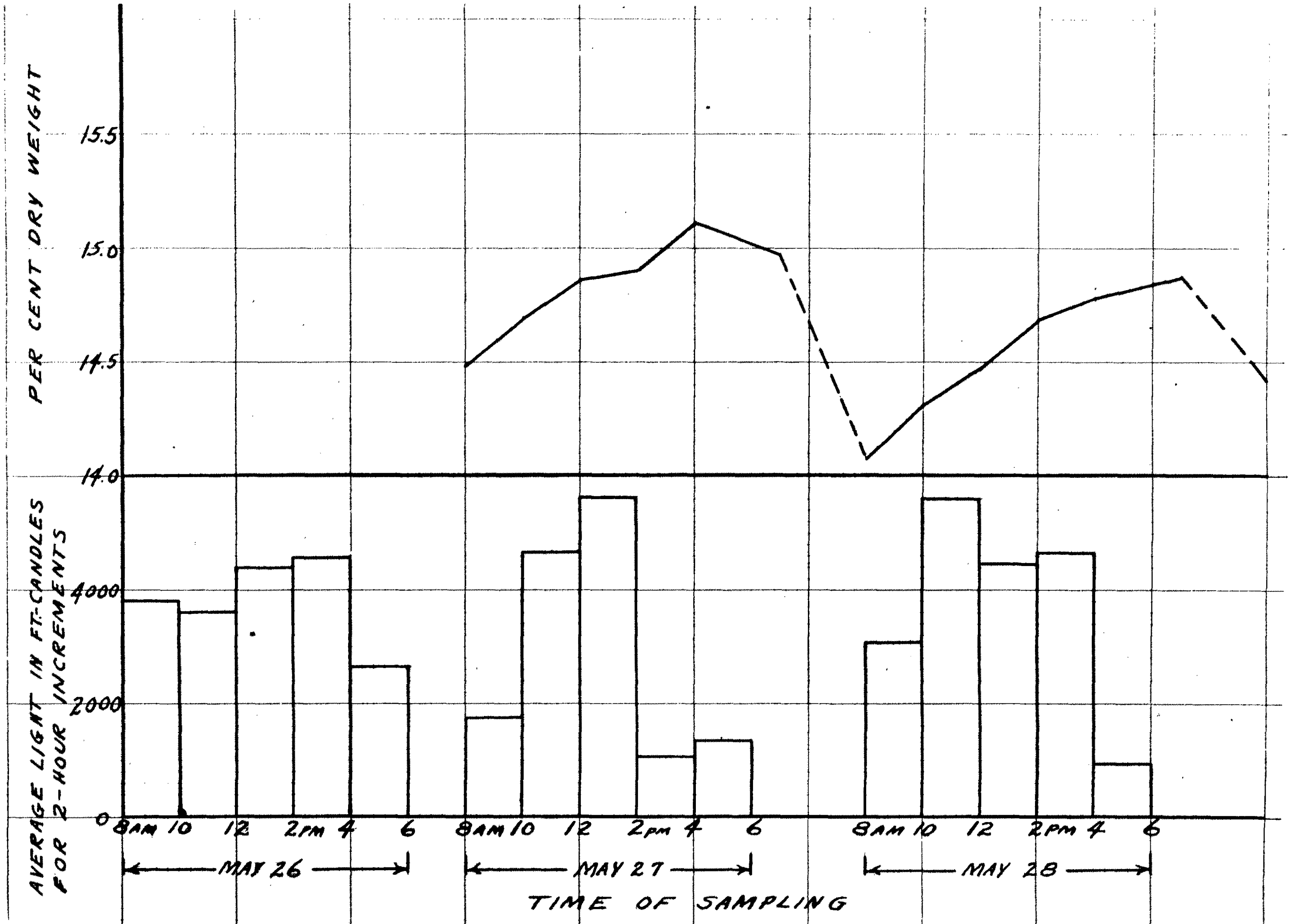

Fig. 4 Dry weight percentages of cuttings from Crowley's Pink Sim for May 27 and 28, 1953.