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Physiology of Reproduction in Horticultural Plants

I. Reproduction and Metabolic Efficiency in the Tomato

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Physiology of Reproduction in Horticultural Plants

Through detailed studies of plant nutrition, growth and development, the technical horticulturist has definitely entered the field of plant physiology. His most logical and effective tool so far developed has been found to be chemistry, particularly organic. Hence a large amount of chemical data are being rapidly accumulated as a basis for future generalizations. Much of this information is, however, of current value in explaining certain definite responses of a plant to its environment, both external and internal. Some of it has been of immediate practical application in fruit growing.

While thus the vegetative development of many of our more important horticultural plants is being carefully interpreted, so far very little attention has been paid to the physiology of reproduction. Yet from both theoretical and practical points of view there is pressing need for information on the physiological effect of flowering, fruit setting and development, especially in perennial plants, such as our fruit trees. This has become particularly urgent due to our interest in the carbohydrate-nitrogen relation concept and the recently disclosed striking correlation between reproductive and vegetative activities.

The present series of papers on the Physiology of Reproduction in Horticultural Plants is initiated with the object in mind of not only accumulating more definite knowledge but also of stimulating further inquiry on this subject. Wherever and whenever possible strictly horticultural plants will be used for this study. If necessary, however, other more conventionally botanical material will be drawn upon.

A. E. M.

I. Reproduction and Metabolic Efficiency in the Tomato

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Abstract.—Tomato plants grown in sand cultures absorbed the greatest quantities of soil nutrients and synthesized the largest amounts of organic substances when fertilization (gametic union) was permitted, but fruit was not allowed to develop. The highest metabolic efficiency, however, was exhibited by normal fruiting plants. Stimulation due to sexual reproduction seems to extend beyond the reproductive organs. The development of embryos and accessory tissues is marked by a decrease in concentration of nitrogen and phosphorus and a corresponding increase in sugars, starch, and crude fiber. Some practical applications of the results are suggested.

As a result of extensive investigations on the effects of correlation between vegetative and reproductive functions in the tomato^{19, 20, 21} the writer has demonstrated a striking physiological control exerted by the developing fruit on the synthesized food supply. Under certain conditions of nutrition even a single fruit is able to monopolize practically all of the incoming or elaborated nitrogenous substances, resulting in disturbances in metabolism and in a marked curtailment or complete cessation of further vegetative development. Generally these effects can be neutralized neither by extreme changes in nutrition nor by drastic alterations in the length of daily exposure to light (photo-periodic effect), provided that reproduction is kept at a maximum. The mechanism of correlation, whatever it may ultimately be, is clearly of a fundamental nature.

An attempt is herewith made to throw further light on the subject. It is of particular interest to know whether the extraordinary metabolic activity of organs comprising the developing fruit is initiated by gametic union and hence is due solely to sexual reproduction or has some connection with the ontogenetic development of the plant as a whole. Accepting for the time being as a working hypothesis the theory of Child^{5, 6} that sexual reproduction is the primary cause of rejuvenescence in tissues connected with the developing embryos, resulting in the establishment of a metabolic gradient, the question naturally arises as to the general effect of such localized gradients on the total metabolism of the plant. In other words, does a plant, whose energy is confined largely

to the development of fruit, utilize more efficiently its environment than one whose activities are concentrated primarily or exclusively in vegetative extension? This question is of fundamental significance in studies of nutrition and development of higher plants.

EXPERIMENTAL METHODS

The present experiment was conducted during the winter months with 108 tomato plants grown under greenhouse conditions.

Having reached the proper stage of development a uniform lot of plants of a pure strain of the Bonny Best variety were transferred from rich soil to sand cultures. At the time of transplanting all of the specimens were in an excellent state of vegetation, approximately 25 cm. in height, and showed the first flower buds. Usually three plants were set in each earthenware container of 12-liter capacity.

A six salt solution of the following concentration served as the soil nutrient for all cultures: $MgSO_4$ - 2%, KH_2PO_4 - 2%, KNO_3 - 2%, $CaCl_2$ - 3%, $CaSO_4$ - 2%, and $Ca(NO_3)_2$ - 4%. The two stock solutions, each containing three salts in the respective order, were diluted with six volumes of tap water before using. The general care of the plants, including application of soil nutrients, watering, training to a uniaxial type of growth, and pollination of flowers, was similar in scope and method as detailed by the writer in a previous publication for "nitrogen high" plants¹⁹.

The experimental treatment was as follows:

Group 1. (Control)—All plants were artificially pollinated and permitted to develop fruit normally.

Group 2.—Fertilization allowed, but fruit was removed when .5 to 1.0 cm. in diameter.

Group 3.—Flower buds removed immediately preceding the normal opening of flowers (anthesis).

In all instances specimens representing the respective groups were grown side by side in the same containers, thus insuring a uniform edaphic environment.

The rate of growth, based on increase in height, was measured at weekly intervals from a fixed point at the base of the stem.

After 50 days in the sand cultures, when some of the fruits on control plants began to show signs of maturity, all specimens were cut, separated into the requisite parts and prepared for chemical analysis by drying at 75°C to constant weight.

Chemical Analysis.—The material was ground to a fine powder and analysed for ash, potassium, phosphorus, soluble and insoluble nitrogen, total sugars, starch, hemicellulose, and crude fiber.

Determinations of ash, potassium, phosphorus, nitrogen and crude fiber were made by the department of agricultural chemistry of the Experiment Station. In all cases either one of the official or else an approved standardized method was used. Potassium is expressed as K, *not* as K_2O and phosphorus as P, *not* as P_2O_5 . Under "soluble" nitrogen is understood nitrogen in the water-soluble fraction obtained by protracted washing the sample with 200 c.c. distilled water over quantitative filter paper. Figures for total nitrogen were secured by adding the respective amounts in both the soluble and insoluble portions of each sample.

Presence of nitrates was determined microchemically by means of the diphenylamine reaction, using the modified and improved technique of Harvey¹².

Sugars, starch and hemicellulose were determined on 2-gram samples. The material was washed repeatedly over quantitative filter paper with cold distilled water. The soluble fraction was cleared with neutral lead acetate, delead with a mixture of sodium sulphate and sodium carbonate, and the total sugar values obtained from 50 c.c. aliquots, using the official hydrochloric acid method. Starch was determined on the residue left from sugar extraction by complete gelatinization and subsequent digestion with freshly collected saliva for 10 min. at 38°C. The filterable portion was hydrolyzed as usual for determination of reducing power. By hemicellulose is understood the digestible portion of the final residue under the following conditions: It was brought to a volume of 90 c.c. Then 10 c.c. of HCl (sp. gr. 1.125) was added, and the mixture digested under a reflux condenser for 2 hours. After thorough separation of the soluble portion with hot distilled water, the reducing power was determined as usual.

Reducing sugars in all cases were analyzed on 50-c.c. aliquots of a cleared fraction by Shaffer and Hartman's method²⁹.

Under "total carbohydrates" is understood the sum total of sugars, starch, hemicellulose and crude fiber.

RESULTS

Growth.—In general, growth and development of all plants used for this investigation proceeded almost in an ideal way under the existing conditions. They were free from disease or insect pests of any kind.

Control plants carried the usual quantity of fruit. This resulted in the characteristic inhibition of farther vegetative extension in a manner described in detail by the writer elsewhere^{19, 20}. The rate of growth of this group of plants, measured as weekly increments in height, is repre-

sented in Fig. 1. It is evident that the type of the graph suggests the so-called "autostatic" phase of the normal S curve²⁶. The total amount of foliage produced by these plants, expressed by dry weight of leaves, was less than half of that of any other group (Table 2). Moreover the normal

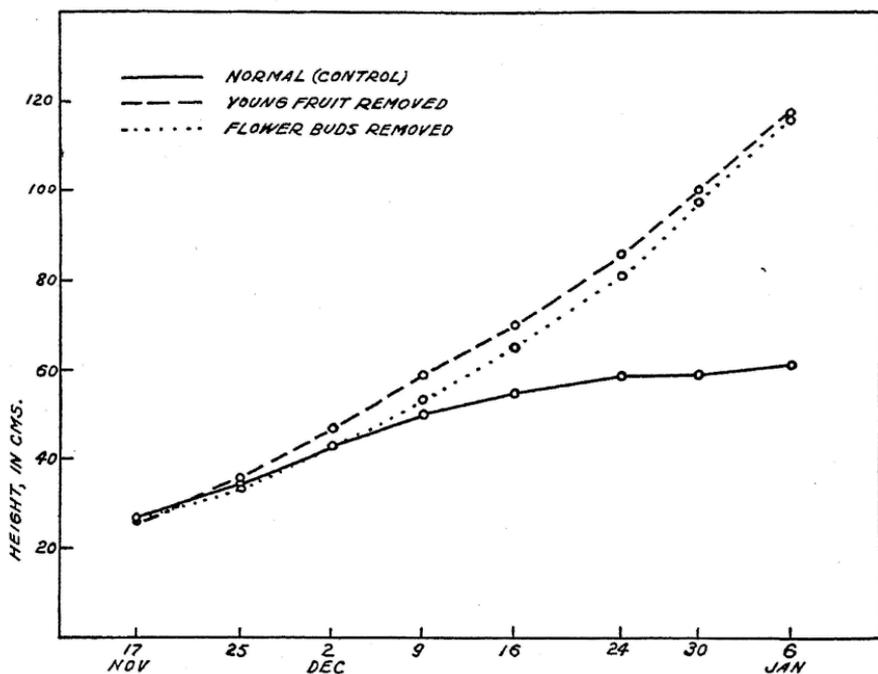


Fig. 1.—Graphs showing rate of growth of normal, defruited and deflorated plants.

yellowing and defoliation of the basal leaves was considerably more extensive in this group,—6.94% of the total foliage of the control plants, and 5.38% and 4.57% respectively for the other two groups. Thus the presence of fruit resulted not only in decreased growth, but as a natural consequence, also in a marked reduction of the photosynthetic mechanism.

When fertilization was permitted but the subsequently developing fruits were promptly removed soon after setting, the plants grew at an even or slightly accelerated rate. The graphic representation of growth rates resembles the "autokinetic" phase of an S curve (Fig. 1). Throughout the growth period all specimens in this group were incomparably more vegetative than control plants. This is clearly evident when the total fresh and dry weights of various organs of these plants are compared.

The removal of flower buds resulted in an external response quite similar to that produced by defruiting. In general appearance and character and rate of growth these two treated groups were very much

alike, excepting that growth of the deflorated plants was somewhat slower, particularly at the beginning of the experiment, and that the total fresh and dry weights of various parts of these plants was approximately 10% less. This difference, however, does not in any sense express a definite metabolic comparison, as will be seen from what follows.

Metabolism.—The metabolic efficiency of a plant may be estimated either by the concentration of the intermediate substances of metabolism at certain stages of development or by the total end products obtained. The logical method to be used in either case is chemical analysis. Hence all chemical determinations in connection with this investigation have been calculated not only on the basis of percentage composition but also as total amounts of the different substances found in various organs of the plants.

A summary of chemical analysis expressed as percentages on dry weight basis is presented in Table 1. The data indicate that not only flower buds but also fruits of various stages of development, when compared with other organs of the tomato, are rather low in ash and crude fiber but comparatively high in phosphorus, nitrogen, starch and hemicellulose.

The exceedingly high values for phosphorus, starch, but especially for soluble nitrogen in the reproductive organs seems to be of particular significance. The importance of phosphorus in the development of the tomato fruit has recently received considerable emphasis^{13, 17}. Accumulation of starch is considered by some as the inevitable result of retarded growth¹¹, while others believe it to be a direct cause of growth inhibition¹⁴. The significance of the presence of comparatively high concentrations of soluble nitrogen in plant metabolism has recently been pointed out by several investigators^{24, 19, 20, 10}. In this connection it is of interest to note that nitrates were present everywhere in the plants, save the fruit, thus corroborating the results of previous work^{19, 3}.

When the chemical composition of normal specimens is compared with that of either the defruited or deflorated ones, the following general differences may be worth emphasizing: a decrease in concentration of ash in all vegetative parts of the treated plants, but a considerable increase in phosphorous, nitrogen and starch (excepting leaves).

Considering three developmental stages of tissues associated with reproductive functions, a sharp decrease in concentration of phosphorus and nitrogen and an equally marked increase in sugars, starch and crude fiber are evident (Fig. 2). The somewhat different character of the starch curve, contrasting with those for other carbohydrates, is naturally due to a rapid hydrolysis of starch to sugars coincident with the develop-

TABLE 1.—CHEMICAL COMPOSITION OF VARIOUS PARTS OF THE TOMATO. PERCENTAGES, ON DRY WEIGHT BASIS

	Ash	K	P	Total N	Sol. N	Ins. N	Sugar	Starch	Hemi-cellulose	Crude fiber	Total carbo-hydrates	Presence of Nitrates
<i>Normal (Control)</i>												
Fruit—all stages	10.79	4.55	.226	2.53	1.30	1.23	11.50	8.38	13.57	16.70	50.15	-
Leaves—Green	26.99	4.67	.165	2.64	.56	2.08	1.60	1.75	11.34	10.47	25.16	+
Leaves—Yellow	38.60	2.21	.173	1.59	.47	1.12	1.33	.68	8.55	7.15	17.71	+
Stems	18.02	4.69	.061	1.06	.46	.60	7.35	.87	13.02	28.71	49.95	+
Roots	21.68	2.91	.158	1.77	.35	1.42	5.10	.35	14.45	25.99	45.89	+
<i>Young Fruit Removed</i>												
Fruit—young	12.06	4.70	.504	4.08	1.70	2.38	4.11	9.98	26.87	12.18	53.14	-
Leaves—Green	19.50	4.93	.193	3.04	.66	2.38	1.90	1.65	14.40	12.15	30.10	+
Leaves—Yellow	37.00	4.26	.265	2.05	.64	1.41	.70	.90	10.48	8.30	20.38	+
Stems	13.75	4.31	.100	1.23	.55	.68	6.05	2.40	15.55	29.71	53.71	+
Roots	15.70	2.63	.159	1.83	.38	1.45	4.15	2.05	17.05	26.97	50.22	+
<i>Flower Buds Removed</i>												
Flower buds	11.76	4.29	.800	5.44	1.34	4.10	2.44	1.56	19.91	11.90	35.81	+
Leaves—Green	19.75	5.30	.188	3.03	.61	2.42	2.20	1.78	11.98	11.80	27.76	+
Leaves—Yellow	36.24	4.68	.300	2.06	.60	1.46	.70	.37	7.92	8.05	17.04	+
Stems	13.53	4.56	.110	1.25	.56	.69	6.55	2.83	13.25	29.31	51.94	+
Root	17.97	2.78	.174	1.94	.39	1.55	4.90	1.27	14.07	25.20	45.44	+

TABLE 2.—TOTAL DISTRIBUTION OF VARIOUS SUBSTANCES IN ORGANS OF THE TOMATO—IN GRAMS PER 100 PLANTS.

	Fresh Weight	Dry Weight	Ash	K	P	Total N	Sol. N	Ins. N	Sugar	Starch	Hemi-cellulose	Crude Fiber	Total Carbohy- drates
<i>Normal (Control)</i>													
Fruit—all stages	9555.8	732.10	79.04	33.32	1.653	18.54	9.54	9.00	84.19	61.19	99.35	122.63	367.36
Leaves—Green	5919.3	547.66	147.42	25.58	.904	14.46	3.06	11.40	8.76	9.58	62.08	57.33	137.75
Leaves—Yellow	-----	40.89	15.29	.91	.090	.65	.17	.48	.54	.28	3.50	2.91	7.23
Stems	2710.8	234.46	42.28	10.90	.143	2.48	1.09	1.39	17.25	2.04	30.55	67.34	117.18
Roots	1504.2	153.55	33.30	4.48	.244	2.72	.55	2.17	7.83	.54	22.20	39.89	70.46
Total	19690.1	1708.66	317.83	75.19	3.034	38.85	14.41	24.44	118.57	73.63	217.68	290.10	699.98
<i>Young Fruit Removed</i>													
Fruit—young	251.8	73.95	8.92	3.48	.374	3.02	1.28	1.74	1.80	7.38	19.87	9.00	38.05
Leaves—Green	12360.7	1252.8	244.47	61.77	2.418	38.10	8.26	29.84	23.80	20.68	180.50	152.25	377.03
Leaves—Yellow	-----	71.34	26.40	3.04	.186	1.46	.46	1.00	.50	.64	7.48	5.92	14.54
Stems	8155.9	791.0	108.7	34.10	.792	9.73	4.33	5.40	47.87	19.00	123.00	234.94	424.81
Roots	2884.0	251.86	39.54	6.62	.400	4.61	.96	3.65	10.42	5.16	42.92	68.00	126.50
Total	23652.4	2440.95	428.03	109.01	4.170	56.92	15.29	41.63	84.39	52.86	373.77	470.11	981.13
<i>Flower Buds Removed</i>													
Flower buds	25.9	16.09	1.91	.70	.130	.88	.23	.65	.66	.25	3.20	1.91	6.02
Leaves—Green	12351.8	1234.96	243.73	65.42	2.323	37.40	8.73	28.67	27.20	21.96	147.98	137.59	334.73
Leaves—Yellow	-----	59.16	21.4	2.78	.178	1.22	.35	.87	.41	.22	4.68	4.74	10.05
Stems	6592.4	688.60	93.18	31.41	.758	8.61	3.87	4.74	45.12	19.50	91.18	201.84	357.64
Roots	2962.3	263.20	47.28	7.26	.457	5.11	1.02	4.09	12.90	3.34	37.07	66.08	119.39
Total	21932.4	2262.01	407.54	107.57	3.846	53.22	14.20	39.02	86.29	45.27	284.11	412.16	827.83

ment of fruit—a fact well known from physiological studies of a number of plants, including the tomato^{28, 27}.

Table 2 gives the total distribution of various substances in organs of the three groups of tomatoes. The figures are expressed in grams per

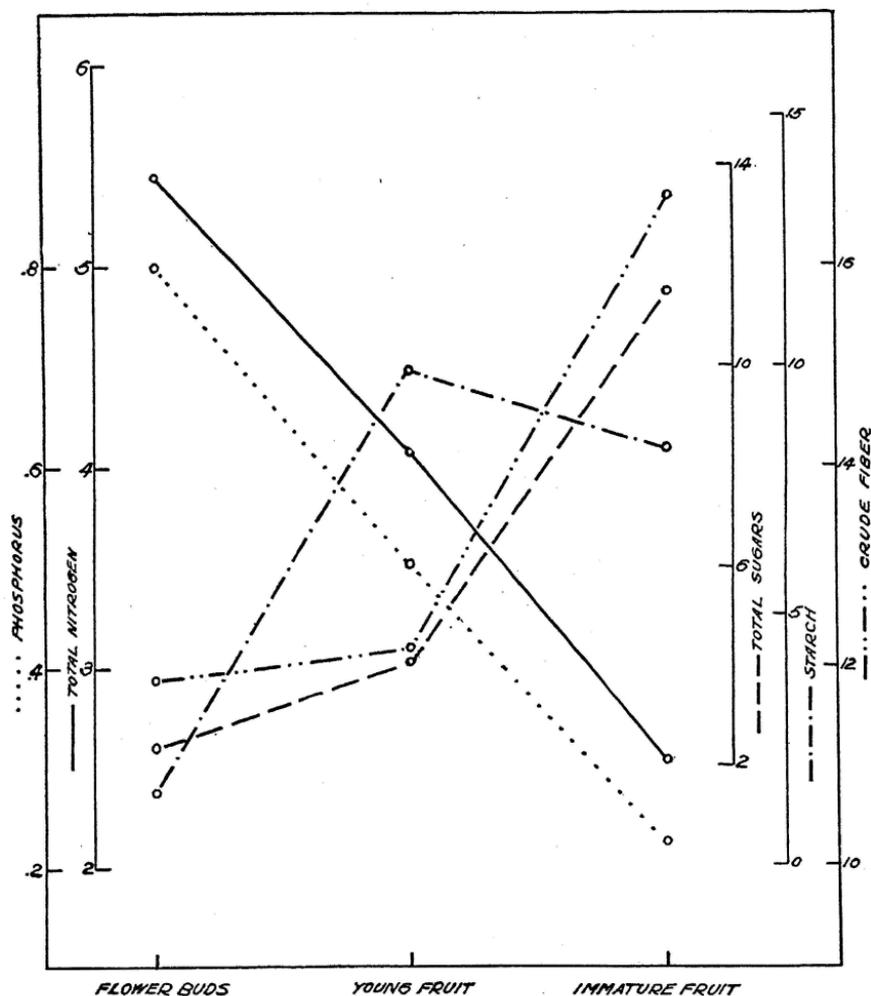


Fig. 2.—A graphical representation of percentage composition of phosphorus, nitrogen, total sugars, starch and crude fiber in flower buds, young fruit and immature fruit.

100 plants. An examination of the data will show that the lowest total fresh and dry weights were obtained from normal fruiting or control plants, next highest from deflorated, and most from defruited ones.

Barring slight differences, the three groups fall in the same relative positions as regards the total amounts of ash, potassium, phosphorus, nitrogen, hemicellulose, and crude fiber. This, however, is not true with intermediate products of metabolism, such as soluble nitrogen, sugars and starch. Here the figures differ much less significantly or else are completely reversed.

It is worth pointing out that approximately 50 per cent of the total phosphorus and nitrogen, 71 per cent of sugar, and 83 per cent of starch were concentrated in the fruit of the control plants. Thus while there is a sharp decreasing gradient in percentage composition of nitrogen and phosphorus, and an equally rapid increasing gradient of sugar and a fluctuating condition of starch during the development of the flowers and fruit, as may be seen from Fig. 2, the total amounts of these substances show an ever increasing accumulation in the fruits of normally developing plants. Hence when fruits are not permitted to develop, as in Groups 2 and 3, not only higher percentages are obtained, but the total augmentation of these substances is greater in all vegetative portions, but particularly in the stems and leaves.

In this connection it is worth while to recount the results of a careful and complete analysis of a number of plants at various stages of development by Wilfarth and his co-workers³⁸ and by Ulbricht³³. Their data show that in the case of most field crop plants—barley, oats, corn, wheat, peas and mustard—the maximum amount of nutrients is absorbed and incorporated into the plant by the time of flowering and setting of fruit, the only exception being the potato—usually a non-flowering and practically always a non-fruiting plant. In the potato the maximum absorption continued clear to the end of growth and development.

DISCUSSION

Much of the evidence secured from this investigation has a bearing on the general subject of the effects of correlation between reproductive and vegetative functions in the tomato, which has been discussed in detail elsewhere^{19, 21} and therefore need not be stressed here. As stated before, the central feature of the present inquiry is the influence of sexual reproduction on metabolic efficiency.

The highest values for all substances which may be considered as end products of metabolism were obtained from plants in Group 2, when fertilization was permitted, but the fruits were removed soon thereafter. Because of the treatment, these plants set the largest number of fruits, when the whole period of growth is taken into account. If gametic union is the main or primary cause of increased metabolism or rejuvenation

nescence, one should expect the greatest amount of stimulation and hence the highest average metabolic efficiency in this group, were it not for the fact that the fruit was removed soon after inception.

An analysis of the data on the basis of the total root and foliage systems, obtained under the specific conditions, will make this point clear. If absorption of mineral substances is considered the primary function of the roots, and if the total dry weight of these organs is considered a comparative index of the extent of the root system, then it is apparent from Fig. 3 that the metabolic efficiency of the roots was highest during the post-fertilization period of reproduction. The deflorated plants fall short very markedly in this regard. Likewise, if synthesis of carbohydrates is the main activity of the foliage, an analysis on a similar basis shows (Fig. 4) that the efficiency of carbohydrate synthesis is affected in the same manner by certain stages of reproduction.

In either consideration the normal plants excel the defruited ones. This probably was due to the fact that the embryos remained attached to the plant and therefore exerted their influence over a much longer period.

Most likely stimulation due to fertilization extends to an appreciable degree beyond the tissues immediately adjoining the developing embryos, for how else could one explain a greater efficiency of the defruited tomato plants when contrasted with those of Group 3, where the same stage of development was permitted, but fertilization was prevented.

These results throw some new light upon the interpretation of the probable causes of the exceptionally high yields of hay secured by cutting certain field crops either in the full bloom²³ or the early fruiting stages^{25, 31, 30, 39}. According to the investigations referred to here, the highest total dry weights and the most efficient utilization of soil nutrients by various sexually reproducing plants was secured when the crop was harvested soon after flowering of the plants or during the early stages of seed development, while much smaller returns were obtained by cutting either before or after this period. Hence it is more than probable that the act of fertilization was one of the main contributing causes of this efficiency in production of dry matter. This evidence, acquired from field investigations with such diverse plants as timothy, alfalfa and soybeans, is identical with the results obtained from the tomato.

The above conceptions have an interesting parallel in animal physiology. Recent investigations in metabolism during pregnancy have shown that not only those organs closely associated with the embryo but the whole body of the mother becomes more efficient during the prenatal period, resulting in increased storage of nitrogen, phos-

phorus and various mineral substances⁹. Such a parallel, however, should not be carried too far. Plants naturally do not possess an efficient circulatory system, which one would expect to be of great service in this regard.

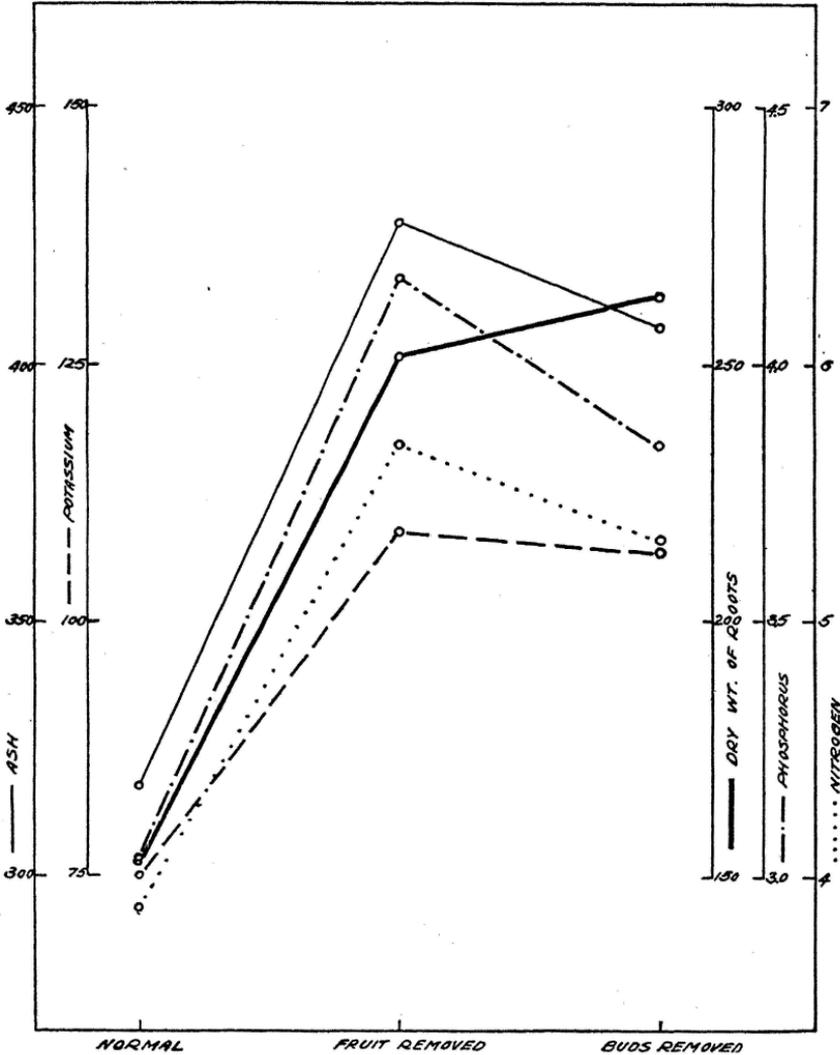


Fig. 3.—Graphs showing the relation of the root system to total absorption of ash, nitrogen, phosphorus and potassium. In grams per 100 plants.

Though a general stimulation may accrue from gametic union, the characteristic behavior of normal fruiting plants makes it quite clear that the reproductive organs, particularly the developing fruits,

receive an incomparably greater benefit from it. In fact, once the largest number of embryos have been formed under the particular conditions of environment, practically all of the synthesized and a large part of the directly absorbed substances are incorporated into the fruit^{38, 33, 8, 19}. Under normal conditions of a maximum crop, as in the present control

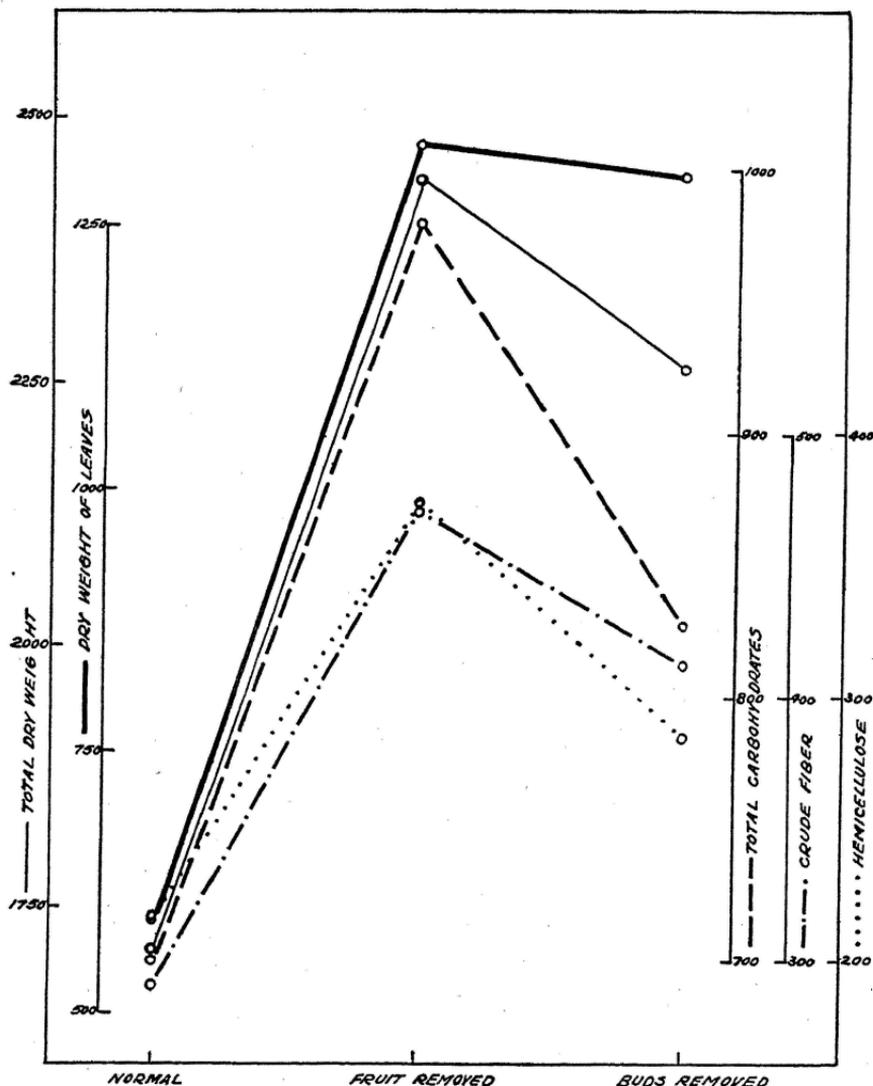


Fig. 4.—Graphs showing the relation of foliage to synthesis of various carbohydrates. In grams per 100 plants.

plants, this establishment of localized metabolic gradients and the resulting tremendous draft on the total available food supply goes so far as to lead to striking inhibition and even destruction of the vegetative

parts. Thus the very mechanism by means of which the embryo and its accessory tissues are supplied with food is disarranged^{19, 20, 21, 7, 36}. Naturally one must assume that such a situation is being obtained only when the need of the reproductive organs for certain nutrients is either equal to or else exceeds the current supply. Under the first condition none would be available for farther vegetative extension; under the latter the existing vegetative organs would be torn down to make available the necessary ingredients. Analogous instances may be found in the destruction of parental tissues by the animal embryo in case of certain metabolic deficiencies¹⁶.

It is necessary to emphasize at this point that the two effects of reproduction on metabolism, as differentiated and discussed here, should be clearly recognized. In the first place, *as a result of the act of gametic union, and hence immediately following fertilization, there is a marked increase in metabolism at the embryonic points, and this increase in a measure extends throughout the body of the plant.* In the second place, *if a maximum number of embryos and their accessory tissues (seeds or fruits) under the particular conditions of nutrition are permitted to develop, the inevitable result is a retardation in or destruction of further vegetative development, leading under extreme circumstances to death of the plant.* Hence the immediate beneficial effects that accrue from fertilization may, and under conditions of excessive fecundity usually do, result in a negative value, when the sum total of metabolism is taken into account, if the seeds or fruits are permitted to come to full maturity.

To accomplish such results a definite and powerful mechanism must certainly be available to the reproductive organs. At present we are entirely ignorant as to its nature beyond the mere conjecture that it may be either of enzymatic, hormonal, and generally specific character. To be sure, various hypotheses have been advanced regarding the existence of such a mechanism in the animal body, the discussion of which, however, would lead one too far afield.

APPLICATION

If the ideas advanced here should be found of value in the interpretation of metabolic activities of many other plants beside the tomato, which it is reasonable to suppose, then a number of points of application suggest themselves. It is hoped that the following will not be considered as definite recommendations for practice, but merely as stimulating and possibly helpful suggestions.

The importance of harvesting certain hay crops at the time when the plants are just past flowering, in order to secure the highest yields, has already been referred to. Likewise in the cutting of various crops for silage purposes one may be guided in a large measure by the reproductive

activities of the plants. Of course such factors as the digestibility and palatability of the product must always be evaluated.

In the utilization of green manure or cover crops in the orchard, the operations may be so timed, other factors being favorable, as to obtain the maximum benefit from a certain stand. Here too it would probably be of value to take a strict account of the stage of flowering or seed development of the particular plants. In many instances not only the greatest total manurial value may be secured from plants in certain stages of reproduction, but the readiness with which the benefit would accrue to the soil and ultimately to the permanent crop, which they are to serve, may also be of consequence.

That the effects of reproduction on the development of plants with an indeterminate type of growth have been recognized by the truck grower, and the greenhouse man, may be judged from the care often exercised in harvesting such crops as melons, cucumbers, tomatoes, peas and beans. Empirical as this knowledge may be, one may observe frequently the practice of removing the first fruit as soon as possible, in order that the plants should not be checked in their future development. So, too, in the cutting of flowers from plants with a prolonged season of blossoming one may be guided to a considerable degree by the reproductive state.

The adverse effects of seed or fruit development in many plants have been appreciated, but the effects of stimulation due to fertilization, being more obscure to the casual observer, have not been evaluated. One can not help emphasizing that the recognition of this fact may be of considerable benefit in the culture and handling of a number of field and horticultural crops.

A somewhat more remote point suggests itself in connection with flowering and fertilization of fruit trees. While proper pollination has long been recognized as an important factor in securing high yields of fruit, the act of fertilization itself, or gametic union, because of its stimulating effect on metabolism, may be of considerable benefit to the tree, even if a large proportion of the fruit drops soon after flowering. While the effects of fruit on vegetative development of the tree have recently received considerable emphasis^{25, 2, 15, 4, 22}, the stimulating influence of fertilization has been appreciated only as far as it tends to increase the development of tissues immediately associated with the embryos or seeds—the pulp of the fruit^{37, 18}. In this regard it is of utmost interest to note that very commonly cross-fertilization results in a higher degree of stimulation than self-fertilization, as shown by the rate and amount of development of the pulp of some of our pomaceous fruits^{34, 1, 32}. May not this extra stimulation of metabolism due to cross-fertilization

extend farther back into other tissues of the plant? Looking at the situation from this point of view, proper pollination of the orchard would have an additional value.

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