Sex Expression in Cucumbers

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Thesis submitted to the Faculty of the Graduate School, University of Maryland, in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

June, 1933.

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Introduction

The effect of certain environmental conditions, particularly the photoperiod and nutrient supply, on the vegetative and reproductive growth of horticultural crop plants has been extensively investigated within recent years. The work of Garner and Allard (15), and Laurie Poesch (37), and others indicates that, in many cases, the photoperiod controls the vegetative or reproductive growth periods, while the work of Kraus and Kraybill (36), Nightingale (46) and many others shows that the nutrient supply profoundly affects vegetation and reproduction. These workers have shown that these environmental effects have induced marked changes in metabolism, which in some cases has been determined by differences in chemical composition, in others by differences in catalase activity. However this work has been done largely on plants bearing hermaphroditic flowers. Very little has been done on plants bearing unisexual forms. Cucumbers present an example of a unisexual crop plant in which changes in the environment produce striking changes in the production of staminate and pistillate flowers. Since the photoperiod and nutrient supply exert profound effects on the metabolism, chemical composition and catalase activity in other plants, they may induce corresponding changes in cucumbers which may be associated with, if not directly related to, changes in sex expression. Furthermore knowledge of factors controlling sex expression in unisexual plants is essential not only in breeding work but also in the production of satisfactory crops. The results of certain experiments to show the relation of sex expression to certain environmental and physiological factors are presented.

Review of Literature

Schaffner (56) observed that the majority of plants of *Arisaema triphyllum* and *Arisaema dracontium* growing in rich moist soil bore both pistillate and staminate flowers, while the majority of the plants growing in dry soil bore staminate flowers only. He varied the nutrient and water supply and found that monoecious and pistillate plants grown in dry soil became staminate, while monoecius and staminate plants grown in heavily manured soil became pistillate. The behavior of these plants led Schaffner to conclude that a delicate nutritional balance that is easily influenced by environmental conditions, exists in certain plants, and that this nutritional balance may be associated with, if not directly related to the change in sex expression. He concluded that sex reversal is due to physiological conditions within the plant and not primarily to hereditary factors.

Autenrieth and Maux (5) found that female plants of hemp, nettle, spinach and red capion grown in dry soil in sunny exposures became hermaphroditic. They state that sandy or dry soil combined with "the free influence of sunlight" favors the development of maleness, while rich or freshly manured soils combined with "the more feeble influence of sunlight" favors the development of femaleness.

McPhee (40) found a distinct vegetative difference and sexual dimorphism in hemp. Plants grown during the long days of summer produced either staminate or pistillate flowers only, both forms never occurring together on the same plant. He believed that the most important factor affecting a change in sex expression is the relative length of day and night.

Allard (1) studied the influence of the photoperiod on the flowering behavior of the hog peanut (Falcatu comosa L). The blue aerial perfect flowers developed only when the days were not less than $13\frac{1}{2}$ hours long while the greenish aerial and extremely rudimentary flowers developed during a shorter photoperiod, varying from 5 to $13\frac{1}{2}$ hours. He concluded that seasonal changes in length of day, in some instances at least, exert a profound effect not only upon the initiation of flowering, but also upon the type of flower and inflorescence produced.

Schaffner (57) studied the seasonal variation in sex expression in hemp. Seed planted at semi-monthly intervals from May 1 to July 15 at Columbus, Ohio, produced staminate plants while seed planted from November 1 to November 15 produced pistillate plants. He concluded that sex in hemp is not determined by chromosome differences, but that it is due to the development of different physiological states in the egg or vegetative body or both.

In certain monoecious plants marked changes in the ratio of staminate to pistillate flowers have been observed. Boswell* grew

Personal conversation with the writer 1929 plants of Cucumis sativus L. of the Windermoor Wonder variety in the horticultural greenhouses of the University of Maryland during the early spring of 1927. Although the plants produced pistillate flowers abundantly they failed to develop sufficient staminate flowers for necessary pollination. Plants raised from the same source of seed and grown outdoors later in the season developed the expected number of staminate forms. Zimmerley noticed differences in the staminate-pistillate ratio between plants of the Arlington White Spine variety grown in the field and in the greenhouse at the same time.

Autenrieth and Maux (5) concluded that the staminate-pistillate ratio is markedly affected by environmental conditions. They state in part as follows: "A melon in a pot, for example, little watered, much exposed to the sun and several times pruned will not form female flowers but several hermaphroditic and some male ones; another melon in a larger pot, watered a great deal and never pruned will carry some perfect and female flowers".

Tiedjens (61) worked with strains of Arlington White Spine and concluded that both genetic and environmental factors were responsible for variations in the staminate-pistillate ratio. He isolated strains which produced wide ratios and others which produced relatively narrow ratios. These strains of wide ratios produced staminate flowers only during the summer months and very few pistillate forms during the winter. On the other hand the strains of narrow ratios produced a relatively greater number of pistillate flowers in both summer and winter. He found that high light intensity combined with long days widened the staminate-pistillate ratio considerably, largely by increasing the production of staminate flowers. Despite this environmental effect, he concluded that genetic factors are more influential in changing the staminate-pistillate ratio of cucumbers than any effect of the environment.

Whitaker (66) studied the sex expression of certain species of the cultivated cucurbitaceae grown in the field. Although in all cases the staminate flowers greatly out-numbered the pistillate forms, varieties within any given species varied in the staminate-pistillate or perfect-pistillate ratio. In Cucumis melo L. the Henderson Bush variety possessed a relatively high ratio (22.4:1), while the Vine Peach and Lake Champlain varieties possessed a relatively low ratio (8.5:1 and 9.6:1) respectively.

Erwin and Haber (12) observed that plants of the Des Moines squash produced a large number of staminate and a comparatively small number of pistillate flowers during the early part of the growing season (July 11 to August 31, 1929). In fact, five plants developed an average of 50 staminate flowers per plant before any pistillate forms appeared. However during the first part of September the production of staminate flowers declined rapidly, while the production of pistillate flowers markedly increased. From July 11 to September 23, staminate flowers constituted 92.5 per cent and pistillate forms 7.5 per cent of the total flowers produced, resulting in an approximate 12.0:1 ratio. From September 18 to 23, only one staminate flower was produced to 14 pistillate resulting in a markedly low 0.071:1 ratio. The fact that the production of staminate flowers declined and that of pistillate forms increased concomitantly with plant development and with the season, indicates that the staminate-pistillate ratio of both cucumbers and pumpkins are similarly influenced.

Schaffner (58) grew the Evergreen variety of sweet corn in highly fertile soil during various seasons of the year. During the short days of winter from a total of 28 plants, 21 produced silks and ears on the terminal inflorescence, while during the long days of summer the normal sex expression occurred. He observed marked differences in vigor of the plants grown during the short and long days respectively. Plants grown during the short days of winter were extremely small and weakly vegetative, while those grown during the long days of summer were larger and vigorously vegetative. He obtained similar results with the variety, Country Gentleman. He observed that with the decreasing photoperiod of autumn, the base of the tassel produced pistillate flowers, while the middle portion produced staminate forms. With the increasing photoperiod of early spring the pistillate flowers occurred in no definite part of the tassel, but they were interspersed among the staminate forms.

Reid (50) grew squash plants in quartz sand with and without nitrogen. She found that although nitrogen accelerated growth during any season of the year its effect was more pronounced in June than in December. Observations on plants shaded in June showed a great similarity in vegetative vigor with those grown without shade in December, indicating that differences between the unshaded June and unshaded December plants are brought about largely by light differences, presumably due to differences in intensity and length of the day in the two periods. The author concluded that seasonal differences in growth and utilization of reserve nitrogen are largely determined by the amount of total carbohydrates present.

Gardner (14) observed changes in the sex expression of a normally perfect flowered variety of strawberry -- Senator Dunlap. Plants grown in sand cultures became weakly vegetative and produced pistillate flowers only, while those grown in fertile soil remained moderately vegetative and perfect flowered. He attributed this change in sex expression to the low carbohydrate supply at the time of fruit bud differentiation. He states in part: "with carbohydrate accumulation", (presumably at time of fruit bud differentiation), "just above the point to make the plant reproductive, femaleness is developed. With greater accumulation, maleness appears and the plant becomes hermaphroditic. With still greater accumulation, femaleness is suppressed and maleness alone develops. When the carbohydrate reserves decrease a similar series of changes in sex takes place but in reverse order. ------Fundamentally, the initiation of the reproductive condition in higher plants is nothing more or less than the differentiation of sexual states from tissues in a neuter state. Some plants are reproductive within comparatively wide limits of carbohydrate supply, while others are reproductive within narrow limits". Thus this assumption suggests that low carbohydrate content is associated with female differentiation, high carbohydrate content with male, and intermediate carbohydrate content with hermaphroditic differentiation. However, Gardner (14) points out that changes in sex expression cannot be explained on the basis of carbohydrate content alone. He suggests that factors other than carbohydrate content may be equally important and should be considered also.

Murneek (44) succeeded in shortening the characteristic normal cyclic sterility of the spider flower (Cleome spinosa L.) by cutting off the perfect flowers or immature fruit pods. When the pistils were removed immediately after their formation hermaphroditic flowers developed instead of the staminate forms. When the fruits were allowed to develop, extreme cyclic sterility was initiated. Murneek concluded that the developing fruit and seeds monopolize certain substances, particularly nitrogen, which prohibit the development of femaleness in adjacent flowers.

Atkinson (3) grew plants of Arisaema triphyllum L. in the greenhouse in pots containing rich soil and observed that neuter and staminate forms became pistillate. In addition he found that removing the basal portion of the bulb at the time of flower development changed pistillate into staminate plants. Urbain (63) found that removal of the albumen of the seed of the castor bean, fennel flower and poppy during germination modified subsequent development. Plants raised from seed from which the albumen had been removed were shorter in stature, possessed smaller leaves and produced flowers relatively early. Urbain noticed a change in the sex organs of some of the flowers. In most cases, though the pistillate flowers were normal the staminate flowers produced pistils. He concluded that removal of albumen in the seed during the process of germination influences subsequent development.

Pritchard (49) working with hemp found that the removal of the flowers from either staminate or pistillate plants induced changes in sex expression and that the injection of certain chemical compounds into the stem or bagging of the tops had little effect. The removal of the pistillate flowers induced a greater change in the staminate-pistillate ratio than the removal of the staminate forms. Pritchard believed that the removal of the pistillate flowers made nutritive conditions within the plant favorable for the production of the staminate forms.

Malhotra (41) presents evidence of an interesting case of the effects of variously treated pollen on the sex ratio of Asparagus officinalis L., a dioecious plant. At Rio Vista, California, he collected mature pollen from 800 plants of the Mary Washington variety and subjected certain lots of it to periods of dessication of 6, 12 and 24 hours; other lots to quantities of pollen distillate; and other lots to distilled water until they had absorbed ten, thirty and sixty per cent of the original dry weight. Flowers pollinated with the dessicated pollen matured seed which produced a larger number and percentage of female plants. The longer periods of dessication produced the larger number of female plants. Flowers pollinated with pollen treated with the pollen distillate matured seed which produced a larger number of staminate plants, while flowers pollinated with pollen sprayed with distilled water matured seed which produced the normal sex ratio. He believed that in asparagus at least, the environment may induce certain changes in the pollen, presumably physiological, of sufficient magnitude to modify the chromosome equipment or gene balance of the zygote.

Part I

Cultural Studies

Seasonal Variation in Sex Expression of Certain Varieties

Varieties

Windermoor Wonder, Early Fortune, Deltus, Extra Long White Spine and Arlington White Spine cucumber were used. Seed of Windermoor Wonder and Early Fortune was secured from Francis C. Stokes and Company, Philadelphia, Pennsylvania, that of Arlington White Spine and Extra Long White Spine from Joseph Harris Company, Inc., Coldwater, New York and that of Deltus from Alexander Forbes and Company, Newark, New Jersey. Seed from the same package was used throughout. A brief description of each variety follows:

Windermoor Wonder

This variety was developed by Mr. J. V. Sheap, of Jackson, Michigan. It was produced from a cross between Isbell's Perfected Davis Perfect and Rollison's Improved Telegraph, an English variety. The green-mature fruits are long and slender averaging 12 by 3 inches. The rind is emerald green, smooth and thin. The suture lines are indistinct and gray at the blossom end. The flesh is fine in texture, creamy white and crisp. During the normal growing season the vines are usually vigorous, possess long internodes and large leaves. In comparison to many other varieties, growers consider the Windermoor Wonder a poor yielding sort. The originator named this variety Dark Wonder, but Stokes renamed it Windermoor Wonder and introduced it in

1916. The Vaughan and Longfellow bear more or less resemblance to Windermoor Wonder in vigor of the plant and characteristics of the fruit.

Early Fortune

This variety was developed by Mr. George E. Starr at Grass Lake, Michigan. It is a selection from Davis Perfect, a variety belonging to the White Spine group. In general the fruit is moderately long and slender (9 by $2\frac{1}{2}$ inches) and tapers slightly at the blossom end. The rind is thin, dark green and smooth. The suture lines are white at the blossom end. The flesh is firm, crisp and fine in texture. During the normal growing season the vine is vigorous, possesses relatively short internodes, moderately large leaves and it is very productive.

Extra Long White Spine

This variety is a long fruited selection of some unknown variety of the White Spine group. It is particularly adapted to forcing. During the normal growing season the vines are vigorous and possess long internodes. The fruit is cylindrical, dark green and very long and slender (14 by $3\frac{1}{2}$ inches). The Evergreen White Spine is similar to Extra Long White Spine in vigor of the plant and in characteristics of the fruit.

Deltus

Although this variety can be grown successfully under field conditions it is particularly adapted to forcing. According to Jones and Rosa (31) this variety was introduced in 1920 by Hart and Vick, of Rochester, New York. During the normal growing season it is very vigorous and reasonably productive. Fruits are long and cylindrical (11 by 3 inches). The rind is dark green and smooth; the suture lines are somewhat indistinct and greenish gray at the blossom end.

Arlington White Spine

This variety belongs to the Early White Spine group. Its parentage and time of introduction are uncertain. Tiedjens* states that this variety is a grower's selection of the White Spine type. It is particularly adapted to forcing. In general the fruit is moderately short ($7\frac{1}{2}$ by $2\frac{1}{2}$ inches), and pointed at the blossom end. The rind is thin, green and reasonably smooth. The suture lines are moderately distinct and white. The flesh is firm, crisp, and fine in texture. The vine is moderately vigorous; the internodes are short; the leaves are medium sized and it is very productive. Since many glass house growers, particularly in the Boston, Massachusetts area, have endeavored to improve the quality of the fruits, presumably by individual fruit or plant selection, numerous strains of this variety adapted to indoor culture exist.

Growing Periods

The effect of season upon the staminate-pistillate ratio was determined on plants grown from June 27 to September 6, from December 15 to April 15 and from February 17 to May 25. In the latitude of College Park, Maryland, from June 27 to September 6, the length of the day gradually declines from 15.0 to 13.0 hours, from December 15 to April 15 it gradually increases from 9.5 to approximately 13.0 hours, and from February 17 to May 25 from

*Personal correspondence

about 11.0 to 14.5 hours.

Cultural Practices

The plants were grown in an experimental greenhouse of the Department of Horticulture, College Park, Maryland. The house is 50 feet long and 18 feet wide and is of the even span type equipped with two rows of discontinuous vents opening at the ridge. The sash bars are 16 inches apart. The orientation is north and south and the north end abuts the service house.

The temperatures varied with the season of the year. During late spring and summer excessively high temperatures frequently occurred despite the presence of whitewash on the greenhouse roof applied to give partial shade and to lower the temperature. During late fall and winter temperatures were regulated by manipulation of steam heat. In this way reasonably uniform temperatures were maintained. Ventilation was given whenever necessary.

Four to six seeds per pot were planted in $2\frac{1}{2}$-inch clay pots containing soil composed of equal quantities of sand and compost. The pots were plunged in sand in a greenhouse bench. To insure good germination, bottom heat was supplied when necessary, maintaining a temperature of 65 to 75 degrees F. The seedlings were thinned to one per pot, later transferred to 4-inch clay pots, and finally set in a greenhouse bed of a moderately fertile clay loam. They were spaced 20 inches apart in 36-inch rows and the vines were supported by jute twine attached below the cotydons and to overhead wires.

Pruning and Pollination

Since two of the objects of the investigation were to determine the influence of the nitrogen supply and the season on the staminate-pistillate ratio without other disturbing influences, particularly those induced by removal of terminal growth and by fruit setting and seed development, neither pruning nor artificial pollination was practiced. Normal terminal and lateral growth was allowed to take place. Honey bees and an occasional bumblebee were observed among the flowers during the summer months only. They pollinated some female blossoms which resulted in the development of fruit. When fruit formed they were removed before they had attained a length of four to six inches.

Control of Pests

Red spider, powdery mildew, white fly and aphids were the most troublesome pests.. Red spider and powdery mildew were particularly prevalent during late fall, winter and early spring months. Since the humidity requirements for the control of these pests are opposed, absolute control of either was difficult.

Frequent sprinkling of the foliage combined with the use of standard applications of Volck partially controlled red spider, while sulphur sifted through a 40-mesh sieve and applied in early afternoon of sunny days with the greenhouse vents closed was utilized to control powdery mildew.

Occasional fumigation with hydrogen cyanide and with nicotine controlled white fly and aphids respectively.

The seed was treated with corrosive sublimate previous to planting to facilitate control of anthracnose, angular leaf spot and "damping off".

Recording of Data

Each plant was given a definite number and place on the data sheet to facilitate recording the kind and number of flowers occurring at each node. The data were recorded at the end of, rather than at frequent intervals, during each growing period to avoid counting the same blossoms twice.

Observations showed that the staminate flowers either developed to and remained in the bud stage or completely expanded their corollas. Since only those male flowers showing complete corolla expansion produce pollen averages and ratios based on these flower counts are presented and they should give an index to functional maleness, while the ratios based on total staminate flowers, opened and unopened, should indicate the tendency toward maleness of the plant as a whole. All pistillate flowers observed showed complete corolla expansion.

Individual plants showing either scant or abundant vigor of growth or an unusual sex expression were discarded. For example, certain plants of Early Fortune, Extra Long White Spine and Arlington White Spine grown from February 17 to May 25 were too stunted and lacking in vigor of growth to be included in the experiment.

Probable errors of the means were calculated by the formula $PE. \pm 0.6745 \frac{S.D.}{\sqrt{n-1}}$ for numbers less than 25 and by the standard formula for numbers greater than 25. Probable errors of the difference were determined according to the formula $PE_{diff} = \sqrt{(PE)_1^2 + (PE)_2^2}$

Presentation of Results

Seasonal Differences in Growth Characteristics

Although no measurements of growth were made marked differences were observed between the period of long days (June 27 to September 6) and that of short days (December 15 to April 15). During the period of long days (June 27 to September 6) the plants were comparatively more vigorous, possessed longer internodes and larger leaves, while during the period of short days (December 15 to April 15) they were weakly vegetative, possessed shorter internodes and relatively smaller leaves.

Varietal Differences in Staminate-Pistillate Ratio

The data for the period June 27 to September 6 (Table 1) show that the varieties differed widely in the number of staminate and pistillate flowers. The variation was greatest in the number of open staminate and the least in the number of total staminate flowers. Arlington White Spine and Evergreen White Spine produced significantly fewer opened staminate flowers than Deltus, Extra Long White Spine and Early Fortune. In most cases the data show, in terms of average production per plant, a direct association between the number of open and total staminate flowers. Varieties producing a large number of open staminate flowers correspondingly produced a large number of total staminate forms. However this relation on a per node basis failed to exist in all cases. Although Evergreen White Spine produced a relatively small number of open and total staminate flowers per plant, it produced a small number of open and a large number of total staminate flowers per node. On the other hand, Deltus produced a large number of both classes of staminate flowers per plant and a large number of open and a small number of totalstaminate flowers per node. Evidently varieties differ not only in the production of staminate

Table 1.--Varietal Differences in Production of Staminate and Pistillate Flowers of Cucumber Plants for Period June 27 to September 6, 1930. Photoperiod 15 to 13 Hours.

Variety	Average Number Flowers[1]						Staminate Pistillate Ratio		Total-open Staminate Ratio
	Per Plant			Per Node					
	Staminate		Pistillate	Staminate		Pistillate			
	Open	Total	Total	Open	Total	Total	Open	Total	
Evergreen White Spine	69.4±15.22	442.8±54.57	1.4±0.36	1.08±.008	6.83±.010	0.02±.004	50.63	316.1	6.3
Windermoor Wonder	104.1±8.86	488.4±26.15	2.7±0.63	1.24±.003	5.50±.003	0.03±.005	39.29	180.8	4.6
Arlington White Spine	16.1±4.69	229.3±30.12	1.9±0.43	0.36±.001	4.92±.073	0.04±.001	8.58	120.6	14.2
Deltus	236.7±16.63	738.3±49.14	8.8±1.20	1.80±.030	5.44±.051	0.07±.001	26.96	83.9	3.1
Extra Long White Spine	154.4±20.14	602.7±48.90	7.3±0.89	1.66±.037	6.47±.058	0.08±.001	21.15	82.5	3.9
Early Fortune	216.6±8.63	669.4±55.78	8.1±1.96	2.03±.038	6.24±.059	0.08±.001	26.74	82.6	3.1

[1] Eight to ten plants.

flowers but also in their ability to develop them to the functional stage. In other words, though functional maleness and total maleness were usually positively associated, this was not always the case.

Variation in the number of pistillate flowers is striking. Evergreen White Spine, Windermoor Wonder, and Arlington White Spine developed fewer pistillate flowers per plant and per node than Deltus, Early Fortune, and Extra Long White Spine. With the exception of Arlington White Spine, the ratio of open staminate flowers to pistillate varied from 50.6:1 to 21.2:1 in the order named and the total staminate-pistillate ratio varied from 316:1 to 82.6:1. Evergreen White Spine and Windermoor Wonder produced not only a wide staminate-pistillate ratio, but also a small number of pistillate flowers which if allowed to develop would undoubtedly result in low yields. Since pollination was not practiced, the results indicate that certain varieties may produce, at least during the long days of summer, a relatively large number of staminate flowers even in the absence of developing fruit. On this basis Evergreen White Spine and Windermoor Wonder may be considered lower yielding varieties than Deltus, Extra Long White Spine and Early Fortune.

The data for the period December 15 to April 15 (Table 2) show that though all varieties produced a relatively smaller number of staminate and a larger number of pistillate flowers than during the preceding period, varietal standings were not maintained. From June 27 to September 6 Extra Long White Spine, Early Fortune and Windermoor Wonder produced more staminate flowers per node than Deltus and Arlington White Spine, whereas, from December 15 to April

Table 2.--Varietal Differences in Production of Staminate and Pistillate Flowers of Cucumber Plants for Period December 15 to April 15, 1929-30. Photoperiod 9.5 to 13 Hours.

Variety	Average Number Flowers[1]						Staminate Pistillate Ratio		Total-open Staminate Ratio
	Per Plant			Per Node					
	Staminate		Pistillate	Staminate		Pistillate			
	Open	Total	Total	Open	Total	Total	Open	Total	
Windermoor Wonder	3.6±0.50	70.0±10.79	61.4±3.72	0.074±.0050	1.45±.083	1.27±.054	0.059	1.140	19.5
Deltus	0.5±0.21	50.0±5.69	94.0±2.08	0.007±.0025	0.69±.047	1.31±.036	0.005	0.531	100.0
Extra Long White Spine	0.7±0.18	41.0±7.41	93.7±1.99	0.014±.0033	0.85±.081	1.95±.046	0.007	0.438	58.6
Arlington White Spine	0.8±0.27	30.8±1.44	101.8±2.49	0.018±.0054	0,66±.058	2.21±.066	0.008	0.303	38.5
Early Fortune	2.0±1.67	16.5±6.46	104.8±8.79	0.054±.0186	0.44±.059	2.82±.103	0.019	0.157	8.3

1 Six plants

15, Windermoor Wonder, Extra Long White Spine and Deltus produced the greater number.

Varietal response in the total-open staminate ratio for the two periods was dissimilar also. Deltus and Extra Long White Spine possessed a comparatively narrow ratio during the period of long days and a comparatively wide ratio during the period of short days. On the other hand Early Fortune produced a narrow ratio during both periods. This indicates that varieties developing a large proportion of staminate flowers at one season of the year may or may not produce a correspondingly large proportion at another season of the year.

The data for February 17 to May 25 (Table 3) show that varietal differences in the number of staminate flowers were again inconsistent. Arlington White Spine and Extra Long White Spine produced significantly fewer open staminate blossoms per node than Windermoor Wonder, Deltus, or Early Fortune, and Extra Long White Spine developed significantly larger numbers of total staminate flowers followed by Windermoor Wonder, Deltus, Early Fortune and Arlington White Spine in the order named. This variation in the production of open and total staminate forms is brought out strikingly by the data on open-total staminate ratio. Though total maleness, as determined by the total number of staminate flowers, was decidedly greater in Extra Long White Spine than in the other varieties, actual maleness, as determined by the number of open staminate flowers, was decidedly less. Evidently with increasing light intensity and length of day varieties differ in the ability to develop staminate flowers to the blossoming stage.

Table 3.--Varietal Differences in Production of Staminate and Pistillate Flowers of Cucumber Plants for Period February 17 to May 25, 1930. Photoperiod 11.0 to 14.5 Hours.

Variety	Average Number Flowers[1]						Staminate Pistillate Ratio		Total-open Staminate Ratio
	Per Plant			Per Node					
	Staminate		Pistillate	Staminate		Pistill ate			
	Open	Total	Total	Open	Total	Total	Open	Total	
Extra Long White Spine	1.7±0.02	205.0±14.84	134.0 ± 8.82	0.01±.003	1.39±.030	0.91±.018	0.01	1.53	120.5
Windermoor Wonder	55.3±10.98	126.3±18.76	161.3±21.97	0.35±.021	0.81±.033	1.03±.014	0.35	0.78	2.3
Deltus	27.0±8.58	117.8±20.13	201.7±35.15	0.19±.015	0.81±.034	1.38±.023	0.14	0.58	4.4
Arlington White Spine	1.5±0.42	29.5±0.31	123.2 ± 8.34	0.02±.001	0.35±.009	1.44±.006	0.01	0.24	19.7
Early Fortune	15.0±6.29	37.2±12.20	165.8±18.67	0.17±.019	0.42±.031	1.88±.047	0.09	0.22	2.5

[1] Six plants.

Varietal standings in the average production of open and total staminate flowers per plant and per node were more closely associated for the periods December 15 to April 15 and February 17 to May 25 than for the period June 27 to September 6. For the former periods varieties producing a large number of flowers per plant likewise produced a large number per node. These relative differences in plant and nodal production are probably associated with the differences in the number of nodes produced during the two periods. The plants grown during the long days of summer attained a greater length of stem and developed correspondingly more internodes than those grown during the short days of winter.

The data for February 17 to May 25 (Table 3) show a lesser nodal production of pistillate flowers than for the December 15 to April 15 period. In this respect varietal differences are again evident. Extra Long White Spine and Windermoor Wonder produced significantly fewer pistillate flowers per node than Deltus, Arlington White Spine or Early Fortune. Here again varietal standings varied. From December 15 to April 15 Extra Long White Spine produced more pistillate flowers than Deltus and Windermoor Wonder, while from February 27 to May 25 it produced fewer quantities. Though varietal response was in the same direction it was not always of the same magnitude.

The association between the number of pistillate flowers and the total staminate-pistillate ratio is noteworthy. For the three periods varietiessproducing a small number of pistillate flowers per node produced a high staminate-pistillate ratio. This was not always the case in the production of staminate flowers. For example from June 27 to September 6, Extra Long White Spine and Early Fortune produced a relatively large number of staminate and pistillate flowers per node and a low staminate-pistillate ratio. Apparently changes in the total staminate-pistillate ratio correspond more closely to changes in the production of pistillate flowers than to differences in the development of staminate forms.

Seasonal Differences in Staminate-Pistillate Ratio

The data for the periods June 27 to September 6 (Table 1) and for December 15 to April 15 (Table 2) show marked differences in the number of total staminate flowers produced during the two periods. For the period June 27 to September 6 the varietal range varied from 229.3 to 738.3 and from 4.92 to 6.83 per plant and per node respectively, while for the period December 15 to April 15 it varied from 16.5 to 70.0 and from 0.44 to 1.45 per plant and per node respectively. In fact, during the former period certain plants of Evergreen White Spine, Arlington White Spine and Windermoor Wonder produced staminate flowers only. Evidently long length of day combined with high light intensity is more favorable for the production of staminate flowers than short length of day combined with low light intensity. These results, in general, agree with those obtained by Tiedjens (61) who found that short length of day markedly decreased the production of staminate forms.

The proportion of staminate flowers which developed to the functional stage varied greatly for the three periods. For the period June 27 to September 6, the proportion is relatively narrow, varying from 3.1:1 to 14.2:1, while for the periods December 15 to April 15 and for February 17 to May 25 it is relatively wide, varying from 8.3:1 to 100:1 and from 2.3:1 to 120.5:1 respectively. Apparently short length of day combined with low light intensity not only decreases the number of staminate flowers, but it is also unfavorable for the complete development of those that are initiated.

The data show marked differences in the number of pistillate flowers produced during the three periods. The differences between the period June 27 to September 6 and that of December 15 to April 15 are especially striking. For the former period the varietal range varied from 1.4 ± 0.36 to 8.8 ± 1.20 and for the latter period from 61.4 ± 3.92 to 104.8 ± 8.79. In fact, during the short days some plants of Early Fortune and Arlington White Spine produced pistillate flowers only. Tiedjens (61) reported similar results. Plants grown during the winter months produced greater numbers of pistillate flowers than plants grown during the summer months.

The effect of an increasing length of day is shown by the figures in Table 3. In all instances on a per node basis, a lesser number of pistillate flowers were produced than during the short days. Obviously short length of day combined with low light intensity and low temperature is more favorable for the production of pistillate flowers than long length of day combined with high light intensity and high temperature.

Since the long days of summer were more favorable for the production of staminate flowers than for the development of pistillate forms, and since the short days of winter were more favorable for the development of pistillate than for the development of staminate flowers, the staminate-pistillate ratio varied greatly with the season. During the long days it was relatively wide, while during the short days, it was relatively narrow.

The influence of Season and Soil Fertility on Sex Expression

Since cucumbers are raised during various seasons of the year and on soils varying greatly in mineral and organic matter, studies were made to determine the combined effects of season and soil on the staminate-pistillate ratio.

Varieties

The varieties Windermoor Wonder and Arlington White Spine, previously described on pages 10, 11 and 12, were grown. The results of the preceding experiment show that under similar conditions the Windermoor Wonder possesses a relatively wide staminate-pistillate ratio, while the Arlington White Spine possesses a relatively narrow ratio. A comparison of these varieties may give an index of varietal response to soils varying widely in fertility and during seasons of the year differing widely in the photoperiod, light intensity and temperature.

Growing Periods

The plants were grown from July 31 to November 15 and from November 15 to March 6, March 28 and April 18 respectively. In the latitude of College Park, Maryland, from July 31 to November 15 the photoperiod gradually declines from 14 to 10 hours and from November 15 to April 18 it declines from 10 to 9.5 hours on December 21, after which it gradually increases to 13.0 hours. The Windermoor Wonder was the only variety grown from July 31 to November 15, while from November 15 to April 18 both the Arlington White Spine and the Windermoor Wonder varieties were grown.

Soils

The soils used were (1) a mixture of three parts of coarse sand and one part of decomposed manure and (2) a mixture of equal parts of garden loam and manure. Each soil received, as a basic application, 1000 pounds per acre of 16 per cent superphosphate.

Cultural Practices

The plants were grown in an experimental house of similar dimensions and adjacent to the one previously described on page 13. The house is equipped with two central benches 47 feet by 4 feet and two side benches 50 feet by 2 feet. To minimize variations in light intensity, temperature and humidity, the plants were grown in the central benches only. Each treatment was duplicated, one in the north and the other in the south half of the house. The plants were set in 3 rows. The center row was approximately 27 inches and the side rows were about 10 inches from the sides of the bench.

Methods of growing, pruning and pollinating the plants and of controlling pests are described on pages 13 and 14.

Presentation of Results

Differences in Growth Characteristics

Marked differences in growth characteristics similar to those reported in the preceding experiment were observed between the plants grown during the long and short days respectively. The plants grown from July 31 to November 15 were vigorously vegetative, and they possessed longer internodes, thicker stems, longer petioles and larger leaves than those grown from November 15 to April 18. Data showing differences in the amount of growth, as measured by the length of the main axes are presented in Table 4. From July 31 to November 15 (77 days) the main axes of the plants grown in the loam-manure mixture was 121.5±1.84 inches, while that of the plants grown from November 15 to April 18 (154) days was 41.3± 2.69 inches. Similar results were obtained for the sand-manure mixture. Since the average daily rate of elongation of the main axes was much greater from July 31 to November 15 (1.58 inches) than from November 15 to April 18 (0.26 inches), undoubtedly light was the most important factor in growth during the latter period. Tiedjens (61) reported similar results. He found that plants of the Granite State variety grown during the short days of winter were weakly vegetative. Their internodes were extremely short or of a characteristic rosette type of growth. Other workers, notably Garner and Allard (15), reported loss of apical dominance in plants subjected to relatively short photoperiods. They pointed out that with certain plants the length of the photoperiod markedly influences the length of the internode and the rate of stem elongation.

Influence of Soil Fertility on Growth

The data in Tables 4 and 5 show the differences in the lengths of the main axes of plants grown in the sand-manure and in the loam-manure mixtures. Although the foliage of the plants grown on the loam-manure mixture was darker, the differences in the length of the main axes were not significant and cannot be ascribed to differences in fertility in the two mixtures. In fact, in 3 out of 7 cases the plants grown in the sand-manure mixture

Table 4.--Average length (inches) of main axes of Windermoor Wonder cucumber plants grown from July 31 to November 15 and from November 15 to April 18, 1929-30.

Growing period	Soil mixture		Difference
	Loam-manure	Sand-manure	Loam minus sand
July 31 to November 15 (77days)	121.5 ± 1.84	127.6 ± 2.94	-6.1 ± 3.47
November 15 to April 18(154 days)	41.3 ± 2.69	39.9 ± 1.19	1.4 ± 2.94
Difference	*80.2 ± 3.26	*87.7 ± 3.17	

*Differences are considered significant

Table 5.--Average length (inches) of main axes of Arlington White Spine and Windermoor Wonder cucumber plants grown during periods between November 15 to April 18, 1929-30

Variety	Sand-manure	Loam-manure	Difference (Loam minus sand)
November 15 to March 6 Photoperiod 10.0 to 11.5 Hours			
Arlington White Spine	14.1 ± 0.99	11.8 ± 0.34	-3.2 ± 1.05
Windermoor Wonder	21.6 ± 0.98	28.3 ± 2.65	6.7 ± 2.82
Difference(W.W.minus A.W.S.)	* 7.5 ± 1.39	*16.5 ± 2.67	
November 15 to March 28 Photoperiod 10.0 to 12.5 Hours			
Arlington White Spine	18.3 ± 0.72	23.7 ± 1.93	5.4 ± 2.06
Windermoor Wonder	27.1 ± 1.71	38.3 ± 3.84	11.2 ± 4.21
Difference(W.W.minus A.W.S.)	*8.8 ± 1.85	*14.6 ± 4.30	
November 15 to April 18 Photoperiod 10.0 to 13.0 Hours			
Arlington White Spine	32.5 ± 1.98	29.8 ± 1.72	-2.7 ± 2.62
Windermoor Wonder	39.9 ± 1.19	41.3 ± 2.69	1.4 ± 2.94
Difference (W.W.minus A.W.S.)	* 7.4 ± 2.31	*11.5 ± 3.19	

*Differences are considered significant

attained longer stems than those grown in the loam-manure. Apparently the sand-manure mixture was sufficiently fertile for vigorous growth.

Varietal Differences in Vigor

Varietal differences in vigor, as measured by the length of the main stem,are evident and significant. The data show that the main axes of the plants of the Windermoor Wonder were longer than those of Arlington White Spine. On this basis plants of Windermoor Wonder may be considered more vigorous than those of Arlington White Spine

Seasonal Variations in Sex Expression

The data (Table 6) show that the plants grown from July 31 to November 15 produced a large number of staminate and a small number of pistillate flowers. The staminate flowers occurred in clusters of 2 to 12 flowers per node and the pistillate flowers occurred singly, usually on the primary and secondary branches. Staminate and pistillate flowers, in no instance, developed at the same node.

The nodes of the main axes produced a larger number of open and of total staminate flowers, and the lower primary laterals, the upper primary laterals, and the lower secondary laterals in the order named produced a decreasing number of both. The decrease in the production of total staminate forms was less rapid than the decrease in the production of open staminate flowers. In fact the branches which developed during the latter stages of growth produced a preponderance of undeveloped forms. The proportion of open staminate

Table 6.--Staminate and Pistillate Flower Production of Windermoor Wonder Cucumber Grown in Sand-manure and Loam-manure Mixtures July 31 to November 15, 1929. Photoperiod 14 to 10 Hours.

Plant Part	Average Number of Flowers						Staminate-Pistillate Ratio		Total Open Staminate Ratio
	Per Plant			Per Node					
	Staminate		Pistillate	Staminate		Pistillate			
	Open	Total	Open	Open	Total	Open	Open 3/	Total 3/	
Loam-manure 1/									
Main	162.2±5.94	273.6 ± 9.12	6.7±0.59	4.23±0.010	7.26±0.101	0.18±0.018	24.2	40.8	1.68
Lower Lats	574.4±35.4	1009.6±43.5	56.2±7.21	3.35±0.058	5.91±0.058	0.33±0.001	10.2	18.0	1.75
Upper Lats	164.5±14.8	362.9 ± 9.68	37.0±3.33	1.74±0.038	4.35±0.072	0.40±0.014	4.4	9.8	2.21
Secondary Lats	132.3±4.01	420.2 ± 7.89	120.9±6.85	0.89	2.84	0.82	1.1	3.5	3.17
Sand-manure 2/									
Main	155.7 ± 2.3	266.4 ± 7.47	5.1±0.80	4.09±0.105	6.89±0.107	0.14±0.046	30.5	52.2	1.71
Lower Lats	579.7±18.3	1050.5±16.10	44.0±2.13	3.14±0.043	5.76±0.061	0.24±0.010	13.2	23.9	1.81
Upper Lats	174.6±11.1	399.4 ± 7.10	47.9±5.14	1.69±0.043	3.88±0.096	0.45±0.005	3.6	8.3	2.29
Secondary Lats	45.6 ± 2.4	178.4 ±3.27	41.7±0.96	0.75	2.94	0.69	1.1	4.3	3.91

1/ Eleven plants   2/ Seven Plants   3/ Staminate flowers to total staminate flowers of plants grown in the soil-manure mixture was 1.68:1 on the main axes and 3.17:1 on the secondary laterals. The ratios for the plants grown in the sand-manure mixture are similar. These data substantiate the results secured in the preceding experiment that declining length of day is not only unfavorable for the production of staminate flowers, but that it is also unfavorable for the development of those that are initiated.

The number of pistillate flowers per node increased progressively with each succeeding branch. The main axes produced the least number of pistillate flowers, followed by the lower primary laterals, the upper primary laterals and secondary laterals in the order named. This concomitant decrease in the production of staminate flowers and increase in the production of pistillate forms resulted in a marked decrease in the staminate-pistillate ratio with the advancing season and with plant maturity. For the loam-manure mixture the open staminate-pistillate ratio varied from 24.2:1 to 1.1:1, and for the sand-manure mixture it varied from 30.5:1 to 1.1:1. The total staminate-pistillate ratio varied similarly. On the loam-manure mixture it varied from 40.8:1 to 3.5:1 and on the sand-manure mixture from 52.2:1 to 4.3:1.

The data presented in Tables 7 to 12 inclusive show the production of staminate and pistillate flowers for the periods between November 15 to April 18. The more marked decrease in the number of staminate flowers and increase in the number of pistillate forms than in the previous period is striking. In fact during the period of short days very few staminate flowers were produced and

Table 7.--Production of Staminate and Pistillate Flowers on Windermoor Wonder Cucumber for November 15 to March 6, 1929-30

Photoperiod 10.0 to 11.5 Hours

Plant Part	Average Number Flowers				Staminate Pistillate Ratio
	Per Plant		Per Node		
	Staminate[1]	Pistillate	Staminate	Pistillate	
Loam-Manure Mixture[3]					
Main Axes	1.3 ± 0.31	24.2 ± 1.19	0.08 ± 0.021	1.50 ± 0.021	0.053
Lower Laterals[2]	3.5 ± 0.91	27.7 ± 2.42	0.50 ± 0.082	*3.95 ± 0.103	0.126
Upper Laterals	--- ----	2.2 ± 0.60	--- -----	2.67 ± 0.078	-----
Sand-Manure Mixture[4]					
Main Axes	1.3 ± 0.35	31.2 ± 2.82	0.08 ± 0.019	1.94 ± 0.169	0.041
Lower Laterals[2]	3.0 ± 0.78	32.6 ± 3.34	0.28 ± 0.059	*3.03 ± 0.107	0.092
Upper Laterals	0.4 ± 0.17	3.3 ± 1.09	0.29 ± 0.131	2.50 ± 0.241	0.116

*Differences are considered significant between corresponding parts

1/ No staminate flowers opened

2/ First 10 nodes

3/ 7 Plants

4/ 11 Plants

Table 8.--Production of Staminate and Pistillate Flowers on Arlington White Spine Cucumber for November 15 to March 6, 1929-30

Photoperiod 10.0 to 11.5 Hours

Plant Part	Average Number Flowers				Staminate Pistillate Ratio
	Per Plant		Per Node		
	Staminate[1]	Pistillate	Staminate[1]	Pistillate	
Loam-manure Mixture[3]					
Main Axes	2.1 ± 0.86	32.5 ± 2.08	0.12 ± 0.029	1.79 ± 0.717	0.065
Lower Laterals[2]	1.9 ± 0.47	47.0 ± 4.62	0.13 ± 0.031	*3.28 ± 0.154	0.040
Upper Laterals	0.3 ± 0.35	6.9 ± 1.68	*0.13 ± 0.044	3.06 ± 0.369	0.043
Sand-manure Mixture[4]					
Main Axes	2.7 ± 0.85	32.3 ± 2.50	0.14 ± 0.025	1.72 ± 0.934	0.083
Lower Laterals[2]	1.8 ± 0.27	30.3 ± 4.01	0.13 ± 0.026	*2.17 ± 0.065	0.059
Upper Laterals	0.9 ± 0.46	7.1 ± 1.85	*0.28 ± 0.029	2.17 ± 0.190	0.127

*Differences are considered significant between corresponding parts
1/ No staminate flowers opened
2/ First 10 nodes
3/ 7 plants
4/ 11 plants

Table 9.--Production of Staminate and Pistillate Flowers on Windermoor Wonder Cucumber for November 15 to March 28, 1929-30

Plant Part	Average Number Flowers Per Plant Staminate[1]	Per Plant Pistillate	Per Node Staminate[1]	Per Node Pistillate	Staminate Pistillate Ratio
			Photoperiod 10.0 to 12.5 Hours		
			Loam-manure Mixture[3]		
Main Axes	2.3±0.43	44.1±0.17	0.10±0.019	1.86±0.138	0.052
Lower Laterals[2]	1.6±0.65	36.9±1.25	0.16±0.061	3.67±0.223	0.043
Upper Laterals	----	* 2.1 0.85	----	3.00 0.000	----
			Sand-manure Mixture[4]		
Main Axes	5.6±1.27	53.3±2.99	0.24±0.036	2.26±0.048	0.105
Lower Laterals[2]	3.5±1.36	32.1±3.97	0.31±0.084	2.75±0.123	0.109
Upper Laterals	2.6±0.74	*17.2±3.49	0.47±0.105	3.14±0.150	0.151

*Differences are considered significant between corresponding parts

1/ No staminate flowers opened

2/ First 10 nodes

3/ 7 plants

4/ 11 plants

Table 10.-- Production of Staminate and Pistillate Flowers on Arlington White Spine Cucumber for November 15 to March 28, 1929-30

Plant Part	Average Number Flowers				Staminate Pistillate Ratio
	Per Plant		Per Node		
	Staminate[1]	Pistillate	Staminate[1]	Pistillate	
Photoperiod 10.0 to 12.5 Hours					
Loam-manure Mixture[3]					
Main Axes	2.1 ± 1.12	48.1 ± 3.49	0.10 ± 0.026	2.17 ± 0.157	0.045
Lower Laterals[2]	3.6 ± 1.21	49.1 ± 3.50	0.25 ± 0.048	*3.42 ± 0.134	0.073
Upper Laterals	----	8.3 ± 3.93	----	*3.05 ± 0.151	----
Sand-manure Mixture[4]					
Main Axes	3.6 ± 1.26	48.1 ± 3.49	0.14 ± 0.026	1.80 ± 0.037	0.075
Lower Laterals[2]	3.6 ± 1.72	43.0 ± 9.71	0.18 ± 0.040	*2.06 ± 0.073	0.083
Upper Laterals	4.2 ± 1.19	33.7 ± 8.30	0.27 ± 0.049	*2.16 ± 0.066	0.124

*Differences are considered significant between corresponding parts
1/No staminate flowers opened
2/ First 10 nodes
3/ 7 plants
4/ 11 plants

Table 11.- Production of Staminate and Pistillate Flowers on Windermoor Wonder Cucumber for November 15 to April 18, 1929-30

Plant Part	Average Number Flowers Per Plant Staminate[1]	Per Plant Pistillate	Per Node Staminate[1]	Per Node Pistillate	Staminate Pistillate Ratio
		Photoperiod 10.0 to 13 Hours			
		Loam-manure Mixture[3]			
Main Axes	*5.2 ± 1.54	34.6 ± 2.57	*0.21 ± 0.038	*1.39 ± 0.032	0.150
Lower Laterals[2]	*3.4 ± 1.12	50.0 ± 7.82	*0.13 ± 0.020	*1.87 ± 0.044	0.068
Upper Laterals	1.6 ± 0.64	21.4 ± 6.47	*0.19 ± 0.049	*2.50 ± 0.132	0.075
		Sand-manure Mixture[4]			
Main Axes	*50.0 ± 6.96	26.8 ± 2.46	*1.79 ± 0.112	*0.97 ± 0.045	1.867
Lower Laterals[2]	*37.8 ± 9.23	40.8 ± 4.74	*1.25 ± 0.108	*1.32 ± 0.044	0.926
Upper Laterals	12.2 ± 6.25	13.0 ± 3.99	*1.27 ± 0.172	*1.42 ± 0.118	0.894

*Differences are considered significant between corresponding parts
1/ No staminate flowers opened
2/ First 10 nodes
3/ 7 plants
4/ 11 plants

Table 12 - Production of Staminate and Pistillate Flowers on Arlington White Spine Cucumber for November 15 to April 18, 1929-30

Photoperiod 10.0 to 13.0 Hours					
	Average Number Flowers				
Plant Part	Per Plant		Per Node		Staminate Pistillate Ratio
	Staminate[1]	Pistillate	Staminate[1]	Pistillate	
Loam-manure Mixture[3]					
Main Axes	*1.8 ± 0.48	40.0 ± 2.16	*0.07 ± 0.019	1.55 ± 0.059	0.045
Lower Laterals[2]	*5.1 ± 1.81	73.9 ± 8.32	*0.11 ± 0.024	*1.63 ± 0.062	0.069
Upper Laterals	2.6 ± 0.69	*44.5 ± 5.75	0.17 ± 0.034	2.91 ± 0.124	0.058
Sand-manure Mixture[4]					
Main Axes	*13.0 ± 1.59	32.7 ± 1.47	*0.56 ± 0.067	1.38 ± 0.068	0.398
Lower Laterals[2]	*25.0 ± 2.25	67.2 ± 5.34	*0.69 ± 0.066	*1.87 ± 0.059	0.372
Upper Laterals	5.7 ± 1.79	*13.7 ± 3.13	1.04 ± 0.294	2.50 ± 0.238	0.416

*Differences are considered significant between corresponding parts

1/ No staminate flowers opened

2/ First 10 nodes

3/ 7 plants

4/ 11 plants

they developed to the bud stage only, while many pistillate flowers developed and occurred at practically every node, sometimes in clusters varying in number from 2 to 15 but more frequently in groups of 2, 3 or 4: (Figures 1a-1b). In many plants staminate and pistillate flowers occurred together at the same node; in others pistillate flowers only developed at all nodes. Plants of Windermoor Wonder grown in the loam-manure from November 15 to March 6 (Table 7) produced on the main axes 1.3 0.31 and 0.08 0.021 unopen staminate flowers per plant and per node respectively, while those grown from July 31 to November 15 (Table 6) produced 162.2 5.94 and 4.23 0.010 open staminate and 273.6 9.12 and 7.26 0.101 total staminate flowers per plant and per node respectively. From July 31 to November 15 (Table 6) plants similarly treated developed on the main axes 6.7 0.59 and 0.18 0.018 pistillate flowers per plant and per node respectively, while from November 15 to March 6 (Table 7) plants of the same variety grown in the same mixture produced 24.2 1.19 and 1.50 0.021 per plant and per node respectively. The results are similar for the primary laterals. Since these data show that a larger number of staminate and a smaller number of pistillate flowers were produced during the period of long days than during the period of short days the staminate-pistillate ratio varied considerably for the two periods. From July 31 to November 15 (Table 6) the total stamihate-pistillate ratio of the main axes of Windermoor Wonder grown in the loam-manure was 40.8:1 and from November 15 to March 6 (Table 7) it was 0.053:1.

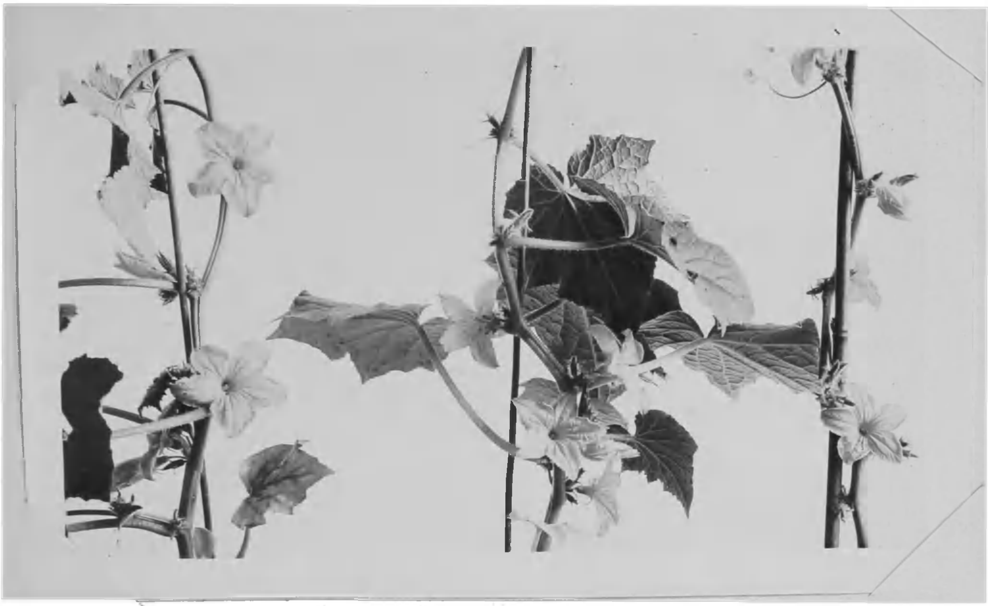
The data for November 15 to April 18 (Tables 11 and 12) again show the effect of an increasing length of day. In all cases the

Predominately staminate plants

Predominately pistillate plant

Arlington White Spine

Fig. 1-a



Predominately staminate plants

Predominately pistillate plant
Windermoor Wonder
Fig 1-b

lateral branches produced a relatively greater number of staminate and a lesser number of pistillate flowers than did the main axes. They developed during days of longer photoperiod, higher light intensity and higher temperature. These results substantiate those of the previous experiment. Apparently long length of day combined with high light intensity and high temperature is more favorable for the production of staminate than for the production of pistillate flowers resulting in a wide ratio. Conversely short length of day combined with low light intensity and low temperature is more favorable for the production of pistillate forms resulting in a narrow ratio.

The fact that plants grown from November 15 to April 18 produced for the most part undeveloped staminate flowers only and a large number of fully developed pistillate forms emphasizes the important connection between environmental effects and certain forms of sterility in horticultural plants. The plants grown during the short days (November 15 to April 18) were functionally entirely female and therefore sterile, while those grown during the long days (July 31 to November 15) were functionally both male and female and therefore fertile. These data combined with the fact that the staminate flower of the cucumber is potentially hermaphroditic, Heimlich (25), indicate that the long days of summer may promote the development of one type of reproductive organ and retard the development of the other. Short length of day combined with low light intensity and low temperature was decidedly favorable for the development of the pistillate flowers, while long length of day combined with high light intensity and high temperature was favorable for the production of large numbers of staminate forms. In other words, either the male or female organs may first show the effects of certain environmental conditions. Murneek (45) has shown that when the tomato plant is induced to bear maximum crops symptoms of disturbed metabolism are indicated by (1) an inhibition of fertility, (2) a decrease in size of the pistils and (3) a reduction in vegetative development. He believes that the terminal position of the ovary and the large quantities of foods necessary for its development make it more susceptible to metabolic disturbances than the stamens or the leaves, leading to one sided sterility and unfruitfulness. However, the results indicate that the male organs may show the effects of a disturbed metabolism also. Watts (65) observed that tomatoes grown during late fall and winter produced very thick and distinctly fasciated pistils and malformed stamens bearing thin walled imperfect pollen which either aborted or produced nubbins.

Since in many plants the development of both male and female organs is essential for the production of satisfactory crops the lack of development of either type of organ is extremely undesirable. In cucumbers an excessive production of either type of flower is likewise undesirable. Even in parthenocarpic varieties, where staminate flowers are necessary for seed development only, the heavy production of female flowers is undesirable since their development makes for the production of a large number of illshaped, undersized, unmarketable fruit.

In certain other plants variations in the season are effective in changing the sex expression. Geddes and Thompson (16) report that the water soldier bears pistillate flowers only north of 52° lat. and staminate flowers only south of 50° lat. Valleau (64) found that some varieties of strawberries often produce pistillate flowers early in the season and hermaphroditic forms later. McClelland (39) found that a 15-hour exposure delayed maturity, decreased yields, increased vegetative vigor and hastened the appearance of the staminate flowers of corn. Woodruff (67) andIsbell (30) found that the staminate flowers of the pecan differentiate in the spring and summer, while pistillate flowers differentiate in the spring only. Autenrieth and Maux (5) state that certain seasons of the year are more favorable for the development of one sex organ than the other. The middle of winter favors the development of pistils; spring, early summer and late autumn favor the development of both pistils and stamens; and late summer favors the development of stamens in both monoecious and dioecious plants.

Since in these studies temperature, light intensity, and the photoperiod operated simultaneously, the specific effect of each factor on the sex expression of cucumbers is difficult to determine. In certain plants temperature seems to be quite effective in modifying sex expression. Higgins and Holt (28) observed that though the pistils on the so-called male trees of the papaya remain in a rudimentary state in the tropics they frequently develop and produce fruit in cooler regions. Richey and Sprague (51) grew different strains of

Indian corn in a warm and in a cool greenhouse during the winter of 1929-30 and 1930-31. Temperatures varied from 70-80° F. in the warm house and from 60-70° F. in the cool house. In both houses some plants were subjected to a long photoperiod by additional light from 4:30 to 9:00 P. M., while others were subjected to an increased light intensity from 7:30 to 12:00 A. M. They found that though strains differed considerably in the percentage of plants producing silks in the tassel, some strains failed to respond, while others responded markedly to these differences in the environment. Light intensity was less effective in inducing changes than was temperature and photoperiod. In fact the low temperature was as effective as 4½ hours of additional illumination.

Knight cited from Geddes and Thompson (16) observed that watermelon plants grown in a greenhouse maintained at high temperatures grew luxuriantly and produced staminate flowers only. He states: "this result did not in any degree surprise me, for I had many years previously succeeded, by long continued very low temperature, in making cucumber plants produce female flowers only and I entertain but little doubt that the same fruit stalks might be made, in this and the preceding species, to support either male or female flowers in obedience to external causes". These observations seem to indicate that the seasonal differences in temperature of the periods studied may have had some effect on the staminate-pistillate ratio of the varieties studied.

Vigor of Growth and Sex Expression

The marked association between sex expression and vigor of growth is striking. During the long days of summer the plants were predominantly staminate and vigorous and they possessed long internodes and large leaves. This was especially true of the Windermoor Wonder. During the short days of winter the varieties were predominantly pistillate and weakly vegetative and they possessed shorter internodes and smaller leaves. In fact many plants of Arlington White Spine, the more pistillate variety, exhibited the rosette type of growth.

The results show that a wide staminate-pistillate ratio and vigorous vegetative growth were positively associated. Conversely a comparatively narrow ratio and weak vegetative growth were also positively associated. Others have reported marked associations between sex expression and vigor of growth. Tiedjens (61) found that heavy production of pistillate flowers of plants grown during the winter months was associated with short internodes, short petioles and small leaves in certain strains and varieties of cucumbers of the White Spine type. However he also reported that though certain plants produced abundant female flowers, one or two at practically every node, their vines were sufficiently vigorous for the production of satisfactory crops. Hawthorn and Wellington (24) observed that though certain plants of the second generation of a cross between Arlington White Spine and Rochford Market produced pistillate flowers abundantly the vines were vigorous and productive. Schaffner (57) and Autenreith and Maux (5) observed that staminate hemp plants were taller and possessed longer internodes than pistillate plants. Stout (59) observed a correlation between vegetative vigor and flower abortion in Brassica pekinensis and Brassica chiloensis. Gardner (14) found that the production of pistillate flowers in plants of the Senator Dunlap strawberry is associated with small size and lack of vigor. Robbins and Jones (52) and Tiedjens (60) found that staminate plants out-yield pistillate plants of Asparagus officinalis.

On the other hand Meehan cited from Gardner (14) observed that the pistillate flowers of certain species of Pinus and Thuja are borne at the ends of the most vigorous main and lateral branches, while staminate flowers are borne on the weakest branches. In addition he records that moderately vegetative plants of certain species of Rumex are hermaphroditic and that excessively vigorous plants are pistillate. Gardner (14) states that frequently young vigorous trees of certain species of Japanese persimmon and of maple bear a preponderance of pistillate flowers. Schaffner (56) found vigorous vegetative growth and femaleness positively associated in Arisaema. McPhee (40) and Pritchard (49) reported that female hemp plants possess larger leaves than male hemp plants. Rosa (53) found that male spinach plants produce either scant or abundant leaf growth, while female or monoecious plants always produce abundant leaf growth.

From the evidence in the literature, Gardner (14) concluded that vigor of growth is associated with femaleness, while non-vigorous growth is associated with maleness. Apparently vigor of growth may be associated with either maleness or femaleness. With cucumbers excessive femaleness, as indicated by a relatively narrow staminate-pistillate ratio, is associated with scant vegetative growth; excessive maleness, as indicated by a relatively wide staminate-pistillate ratio, is associated with vigorous vegetative growth; while moderate maleness or femaleness is associated with moderate vegetative growth.

Effect of Soil Treatments on Sex Expression

The data in Tables 7 to 12 inclusive show that though the differences due to the soil treatments are less striking than those due to the season the loam-manure mixture usually produced more pistillate flowers and fewer staminate forms than the sand-manure mixture. Accordingly its influence on the staminate-pistillate ratio was of the same order. In all cases except one, the sand-manure mixture produced a wider ratio than the loam-manure mixture. These data indicate that highly fertile soils tend to produce a relatively narrow ratio while poor soils tend to produce a relatively wide ratio. Tiedjens (61) obtained similar results for the production of pistillate flowers only. He found that plants of the Granite State variety of cucumbers grown in fertile soil (garden loam) produced a larger number of both staminate and pistillate flowers than plants grown in infertile soil ($\frac{1}{2}$ garden loam and $\frac{1}{2}$ sand). Heyer cited from Whitaker (66) grew cucumbers and pumpkins in rich soil in the greenhouse and in poor soil outdoors. Plants grown in the poor soil produced a larger per cent of staminate flowers. Schaffner (56) and Atkinson (3) observed that monoecious and staminate plants of Arisaema grown in heavily manured soil became pistillate. Murneek (44) found that though low nitrogen had little effect on the length of the fruiting cycle of the spider flower it produced a predominance of staminate flowers.

Varietal Differences

Varietal differences in the nodal production of staminate and pistillate flowers for November 15 to March 6 (Tables 13 and 14) are small, inconsistent and in 5 out of 8 cases insignificant, while for November 15 to April 18 they are larger, more consistent and in 6 out of 8 cases significant. During the latter period in all instances except one Windermoor Wonder produced the larger number of staminate and the smaller number of pistillate flowers on both the main and on the lateral branches. In all instances except two, the differences are significant. These results, similar to those reported in Experiment I, indicate that varietal response varies with the season. In this instance with an increasing length of day combined with increasing light intensity and higher temperature, the production of staminate flowers increased, while that of pistillate flowers decreased more rapidly in Windermoor Wonder than in Arlington White Spine resulting in a wider staminate-pistillate ratio.

Table 13 -- Varietal Differences in Production of Staminate and Pistillate Flowers of Cucumbers Grown in Sand-manure Mixture

Variety	Average Number of Flowers Per Node				Staminate Pistillate Ratio	
	Staminate		Pistillate			
	Main	Lats.	Main	Lats.	Main	Lats.
November 15 to March 6 - Photoperiod 10.0 to 11.5 Hours						
Arlington White Spine	0.14± .025	0.13± .026	1.72± .934	2.17± .065	0.083	0.059
Windermoor Wonder	0.08 ± .019	0.28 ± .059	1.94± .169	3.03± .107	0.041	0.092
W.W.minus A.W.S.	-0.06 ± .031	0.15± .064	0.22± .949	*0.86± .125		
November 15 to April 18 - Photoperiod 10.0 to 13.0 Hours						
Arlington White Spine	0.56 ± .067	0.69± .066	1.38± .068	1.87± .059	0.398	0.372
Windermoor Wonder	1.79 ± .112	1.25 ± .108	0.97± .045	1.32± .044	1.867	0.926
W.W.minus A.W.S	*1.23± .130	*0.56± .127	*- 0.41± .082	*-0.55± .074		

* Differences are considered significant

Table 14 -- Varietal Differences in Production of Staminate and Pistillate Flowers of Cucumbers Grown in Loam-manure Mixture

Variety	Average Number Flowers Per Node				Staminate Pistillate Ratio	
	Staminate		Pistillate			
	Main	Lats.	Main	Lats.	Main	Lats.
November 15 to March 6 - Photoperiod 10.0 to 11.5 Hours						
Arlington White Spine	0.12 ± .029	0.13 ± .031	1.79 ± .717	3.08 ± .154	0.065	0.04
Windermoor Wonder	0.08 ± .021	0.50 ± .082	1.50 ± .021	3.62 ± .058	0.053	0.126
W.W. minus A.W.S	-0.04 ± .036	*0.37 ± .088	-0.29 ± .718	*0.67 ± .155		
November 15 to April 18 - Photoperiod 10.0 to 13.0 Hours						
Arlington White Spine	0.07 ± .019	0.11 ± .024	1.55 ± .059	1.63 ± .062	0.045	0.069
Windermoor Wonder	0.21 ± .038	0.14 ± .022	1.39 ± .032	1.87 ± .044	0.15	0.068
W.W. minus A.W.S.	*0.14 ± .043	-0.03 ± .032	-0.16 ± .068	0.24 ± .076		

* Differences are considered significant

Influence of Nitrate Supply and Supplementary Illumination on Sex Expression

Varieties

The varieties grown were Windermoor Wonder and Arlington White Spine previously described on pages 10, 11 and 12.

Growing Periods

The plants were grown from December 27 to April 15 and from May 22 to July 24 respectively. In the latitude of College Park, Maryland, from December 27 to April 15, the length of day gradually increases from 9.5 to 13.0 hours and from May 22 to July 24 it varies from 14.5 to 15.0 hours. During the latter period additional light was supplied by means of 50 watt Mazda lamps suspended 24 inches apart above the center of the greenhouse bench. These lamps were turned on at 7:00 P. M. and automatically switched off at 10:00 P. M. The light duration was approximately 16.5 hours on May 22. It increased slightly with the earlier rising of the sun to a maximum of approximately 17.0 hours on June 21, after which time a slight decrease took place.

Nutrient Supply

Since the loam-manure and sand-manure mixtures utilized in the preceding experiment failed to produce the desired differences in vigor of growth, the use of some highly infertile medium was necessary to facilitate regulation of the nitrate supply. In this experiment the medium utilized was river bank sand and the nitrogen was applied in solution. Basic applications of superphosphate and potassium chloride were made in the form of commercial fertilizers at the rate of 2000 and 400 pounds per acre respectively and thoroughly incorporated into the sand.

The nitrogen was applied in the form of calcium nitrate and potassium nitrate. The following stock solution was used:

Potassium nitrate (KNO_3)	1000 grams	Water to make 40 liters
Calcium nitrate ($Ca(NO_3)_2$)	4000 grams	

To facilitate applying practically the same volume of solution to each plant and to prevent washing of the sand from the roots a three-inch clay pot was plunged at the base of each plant. A sprinkling can with the rose detached was used to make applications. It contained 100 c. c. of the stock solution in six liters of tap water. Though measurements showed that the pots varied in capacity from 130 to 141 c. c., uniformity in vigor within each treatment was maintained.

The high nitrogen plants received applications twice weekly until the main stem was 6 to 8 inches long when the nitrogen was supplied on alternate days. During the later stages the nitrogen was supplied daily. The low nitrogen plants received the first application on January 27, 12 days after they were set in the bench. Succeeding applications were made at weekly intervals thereafter. Whenever plants receiving nitrates were watered with the solution those not so treated were given the same volume of tap water.

Furthermore an optimum amount of water was supplied at all times so that differences in vigor which developed would be due to differences in nitrogen supply alone.

The plants grown from December 27 to April 15 were started in $2\frac{1}{2}$-inch clay pots as described on page 14. Just before they were transplanted in the bench the roots and soil were removed carefully by gentle hand pressure and finally by washing. The plants grown from May 22 to July 24 were started directly in the bench to avoid the injury and subsequent check in growth incident to transplanting. Planting distances, pollinating and pruning practices were the same as those described on pages 13 and 14.

Presentation of Results

Seasonal, Nutritional and Varietal Differences in Growth

The data presented in Table 15 show that differences in growth, as determined by differences in length of the main axes, were effectively secured through control of the nitrogen supply. From December 27 to April 15 the main axes of the high nitrogen plants attained the average length of 17.2 0.71 and 25.6 1.07 inches, while the low nitrogen plants attained the average length of 7.5 0.36 and 9.0 0.37 inches. From May 22 to July 24 the main axes of the high nitrogen plants averaged 32.1 0.69 and 36.3 1.07 inches, while those of the low nitrogen plants averaged 12.9 0.41 and 12.7 0.28 inches. The data show that though the seasonal differences were less wide than in the preceding experiment,

Table 15.--Average Length (inches) of Main Axes of High and Low Nitrogen Cucumber Plants grown from December 27 to April 15 and from May 22 to July 24, 1930-1931.

Variety	Dec. 27 to April 15 Photoperiod 9.5 to 13 hrs		May 22 to July 24 Photoperiod 16.5 to 17 hrs		Seasonal Difference (Long minus short days)		Nutritional Difference (High minus low N.)	
	High N.	Low N.	High N.	Low N.	High N.	Low N.	Long day Period	Short day Period
Arlington White Spine	1/ 17.2±0.71	2/ 7.5±0.36	5/ 32.1±0.69	6/ 12.9±0.41	*14.9±0.99	*5.4±0.55	*19.2±0.80	*9.7±0.80
Windermoor Wonder	3/ 25.6±1.07	4/ 9.0±0.37	7/ 36.3±1.07	8/ 12.7±0.28	*10.7±1.51	*3.7±0.47	*23.6±1.11	*16.6±1.13
Varietal Difference (W.W.minus A.W.S.)	*8.4±1.29	1.5±0.52	*4.2±1.35	-0.2±0.50				

1/ 30 plants, 2/ 30 plants, 3/ 28 plants, 4/ 19 plants, 5/ 22 plants, 6/ 40 plants, 7/ 30 plants,

8/ 34 plants.

*Differences are considered significant.

the plants grown from May 22 to July 24 attained greater vegetative vigor than those grown from December 27 to April 15. In fact the low nitrogen plants grown from May 22 to July 24 developed marked symptoms of nitrogen deficiency in a relatively shorter time than those grown from December 27 to April 15. This substantiates the results of the previous experiment that light was undoubtedly the most important factor in growth from December 27 to April 15.

The high nitrated plants grew rapidly while the low nitrated plants grew slowly. Leaf size was influenced correspondingly. For example the first leaves of the high nitrogen plants of Arlington White Spine grown from December 27 to April 15 averaged 7.4 centimeters in width, while those of the low nitrogen lots averaged 6.0 centimeters. Since nitrogen supply induced greater differences in vigor of growth, as determined by stem length, from May 22 to July 24 than from December 27 to April 15 the greatest differences in vigor of cucumbers may be expected between plants grown in soils varying widely in fertility during the long days of summer. Since varietal differences in vigor were significant for the high nitrogen plants only, adequate supplies of nitrogen are necessary when varietal comparisons are made.

<u>Seasonal Differences in Sex Expression</u>

The data in Table 16 show that the nodal production of open staminate flowers in both varieties varied from 0.75 ± 0.044 to 1.70 ± 0.091 from December 27 to April 15 and from 0.91 ± 0.056 to 1.25 ± 0.051 from May 22 to July 24. A similar variation trend

Table 16.--Staminate and Pistillate Flower Production on Main Axes of Arlington White Spine and Windermoor Wonder Cucumber Plants Grown Under High and Low Nitrogen from December 27 to April 15 and from May 22 to July 24, 1930-31

Treatment	Average Number Flowers						Staminate-Pistillate Ratio		Total Open Staminate Ratio
	Per Plant			Per Node					
	Staminate		Pistillate	Staminate		Pistillate			
	Open	Total	Open	Open	Total	Open	Open 9/	Total 9/	
	December 27 to April 15 Photoperiod 9.5 to 13.0 Hours								
	Arlington White Spine								
High Nitrogen 1/	7.9±1.21	36.1±2.61	12.0±0.59	0.75±0.044	3.25±0.111	1.08±0.043	0.66	3.01	4.57
Low Nitrogen 2/	8.4±1.53	37.8±2.56	7.5±0.62	1.09±0.081	4.94±0.185	0.98±0.061	1.12	5.04	4.50
	Windermoor Wonder								
High Nitrogen 3/	19.1±2.13	49.8±3.14	9.3±0.58	1.70±0.091	4.55±0.143	0.85±0.034	2.05	5.35	2.61
Low Nitrogen 4/	11.3±1.09	38.2±1.58	3.5±0.47	1.46±0.077	4.91±0.117	0.45±0.047	3.23	10.91	3.38
	May 22 to July 24 Photoperiod 16.5 to 17.0 Hours								
	Arlington White Spine								
High Nitrogen 5/	15.9±1.16	60.7±3.40	1.9±0.03	1.25±0.051	4.80±0.097	0.15±0.001	8.36	31.94	3.82
Low Nitrogen 6/	9.7±0.75	42.8±1.49	0.8±0.05	0.97±0.048	4.23±0.077	0.08±0.006	12.13	53.50	4.41
	Windermoor Wonder								
High Nitrogen 7/	11.7±0.89	46.1±2.73	0.8±0.09	0.98±0.043	3.84±0.092	0.07±0.012	14.62	57.63	3.94
Low Nitrogen 8/	8.8±0.58	40.6±1.53	0.6±0.08	0.91±0.056	4.19±0.078	0.06±0.015	14.66	67.67	4.61

1/ 30 plants, 2/ 30 plants, 3/ 24 plants, 4/ 30 plants, 5/ 22 plants, 6/ 40 plants, 7/ 19 plants, 8/ 34 plants, 9/ staminate flowers existed for the total staminate forms. From December 27 to April 15 and from May 22 to July 24 the variation range was from 3.25± 0.111 to 4.94±0.185 and from 3.84±0.092 to 4.80±0.097. These seasonal differences were relatively smaller than those secured in the preceding experiments. Plants grown from May 22 to July 24 failed to develop the expected number of staminate forms. In fact the upper nodes of certain plants, particularly in Windermoor Wonder, were observed to develop neither staminate nor pistillate flowers. Rudimentary buds were formed only. Probably the supplementary illumination exerted an injurious effect on flower development.

The seasonal differences in the production of pistillate flowers were more pronounced and significant in most cases. The nodal production varied from 0.45±0.047 to 1.08±0.043 from December 27 to April 15 and from 0.06±0.015 to 0.15±0.001 from May 22 to July 24. During the former period both staminate and pistillate flowers developed at the same node, even though the pistillate flowers occurred in smaller clusters and the internodes were somewhat longer than in the preceding experiment. During the latter period (the long days) the pistillate flowers occurred singly. The staminate-pistillate ratio was influenced similarly. From December 27 to April 15 the open staminate-pistillate ratio of Arlington White Spine receiving high and low nitrogen was 0.66:1 and 1.12:1 respectively, while from May 22 to July 24 this ratio was 8.36:1 and 12.13:1. Although the ratio was higher for Windermoor

Wonder the seasonal change is similar to that of Arlington White Spine.

Seasonal differences in the total-staminate ratio are more striking than the differences in the open-staminate ratio. From December 27 to April 15 plants of Arlington White Spine receiving high and low nitrogen possessed the ratios 3.01:1 and 5.04:1 respectively, while from May 22 to July 24 they possessed the ratios 31.94:1 and 53.50:1.

Since the seasonal differences were more pronounced for the production of pistillate flowers than for the production of staminate forms, the results indicate that under the particular nutrient and light conditions of this experiment seasonal variations in light intensity and duration are more effective in modifying the production of pistillate flowers than that of staminate flowers.

Influence of Nitrogen Supply

The data show that though nitrogen supply was less effective in changing the staminate-pistillate ratio than the season, in most cases low nitrogen produced the greater number of staminate flowers, while high nitrogen produced the greater number of pistillate forms. Accordingly the influence of the nitrogen supply on the sex ratio was of the same order. Though in many cases the differences are not wide, high nitrogen supply always produced the more narrow ratio regardless of the variety or the season. These results, substantiating those of the previous experiment, indicate that soils abundantly supplied with nitrogen should produce a relatively more narrow ratio than soils lacking in nitrogen.

High nitrogen also increased the production of a proportionately greater number of opened staminate flowers. On both per node and per plant basis its effect was largely due to the development of a larger number of open staminate forms. Apparently abundant nitrogen is favorable for the development of staminate flowers to the functional stage. Tiedjens (61) obtained similar results. He found that abundant nitrogen stimulated the development of staminate flowers of the Granite State variety. However, the figures show that the variation in sex ratio due to nitrogen supply was less wide than that due to the season. This was particularly true of the total staminate ratio. From December 27 to April 15 this ratio varied from 3.01:1 to 10.91:1 and from May 22 to July 24 it varied from 31.94:1 to 67.67:1. Seasonal changes are manifestly more effective in changing the sex ratio in cucumbers than nitrogen supply.

<u>Varietal Differences</u>

The figures show that though varietal differences were inconsistent in the production of staminate flowers, they were consistent in the production of pistillate forms. Arlington White Spine always produced the greater number and the differences secured are significant in all cases, except for the low nitrogen plants grown from May 22 to July 24. As indicated previously, since the upper nodes of certain plants grown from May 22 to July 24, particularly of Windermoor Wonder, failed to develop flowers, the inconsistent behavior may have been due to differential response to the supplementary light. Despite this inconsistency Arlington White Spine always produced the more narrow ratio, regardless of the nitrogen supply or the growing period. The results indicate that for the periods studied and for these particular light conditions varietal differences in the staminate-pistillate ratio were determined more largely through the production of pistillate flowers than through the production of staminate forms.

Discussion

A most significant fact brought out by these experiments is that seasonal changes in the growing period markedly influence the type of flower production. Days of long photoperiod combined with high light intensity and high temperatures are favorable for the production of staminate flowers, while days of short photoperiod combined with low light intensity and comparatively low temperatures are favorable for the production of pistillate forms. This is important in connection with seasonal responses of plants in general and of cucumbers in particular. Many investigators, notably Garner and Allard (15) have shown that certain species of plants flower during the short days only (short day plants); others flower during the long days only (long day plants); while others flower during both short and long days (continuous flowering plants). However this classification is based, for the most part, on the response of plants bearing perfect flowers only. It does not consider the response of plants bearing unisexual forms. Seasonal differences in the photoperiod, temperature and light intensity not only influence the time of flowering but also the type of flowers produced.

The results show that cucumbers are predominantly staminate during the long days of summer and predominantly pistillate during the short days of winter -- thus indicating a marked tendency toward one-sided sterility and unfruitfulness. This marked response to seasonal differences explains why the same variety or the same strain may produce satisfactory crops at one season of the year and unsatisfactory crops at another. Cucumbers grown during the short days of fall or early spring are likely to produce an excessive number of pistillate flowers resulting in the production of a large number of small sized fruits, irregular in shape and low in quality. On the other hand plants grown during the long days of summer may be unproductive due to the excessive production of staminate forms. Since productivity depends on the development of maximum quantities of high grade fruit and since in many varieties staminate flowers are necessary for the pollination of pistillate flowers, the relative production of pistillate and staminate flowers is important. Undoubtedly some varieties are better adapted to forcing during the late spring and summer months, while others are likely to be better adapted to forcing during late fall and early spring. In the selection of any variety its specific response to the season should be considered.

This effect of the season on the staminate-pistillate ratio is important in connection with the breeding of cucumbers at various periods of the year. Plants should not be raised during the winter months when insufficient staminate flowers are likely to be produced for necessary pollination. In case plamts are raised in late fall or early spring in the greenhouse, to obtain a large number of generations in a relatively short time, a comparatively narrow sex ratio should be expected.

The results show that pistillate flowers are not always borne on definite branches or on definite nodes of any particular branch. Plants of one variety may bear pistillate flowers on the lateral branches only during the summer months and on both the main axes and laterals during the late fall and early spring, while plants of another variety may bear pistillate flowers on all branches during any season of the year. Undoubtedly fruiting habit varies with the season and with the variety.

Though the effect of nitrogen supply was less potent than the season, high nitrogen supply generally produced a more narrow ratio than low nitrogen. Apparently nitrogen supply is more associated with the development of female organs than with the development of male organs. This emphasizes the important connection between nitrogen supply, vegetative and reproductive growth and cultural practices. Modifications in soil fertility, through variations in the nitrogen supply, may be expected to influence the yield in instances in which other factors produce a ratio that approaches a non-productive condition. Since Murneek (45) has shown that large quantities of nitrogen are necessary for fruit and seed development, plants grown on poor soil will require more applied nitrogen than those grown in highly fertile soil.

Conclusions and Summary

1. Cucumber plants of the varieties Windermoor Wonder, Extra Long White Spine, Deltus, Early Fortune and Arlington White Spine were grown from June 27 to September 6, from September 15 to April 15 and from February 17 to May 25, 1930-31 under greenhouse conditions. In another experiment plants of the varieties Windermoor Wonder and Arlington White Spine were grown from July 29 to November 15 and from November 15 to April 15, 1929-30 respectively in soil mixtures consisting of (1) one-third barnyard manure and two-thirds sand and (2) equal parts of manure and garden loam. Later cultures were grown from December 27 to April 15 and from May 22 to July 24, 1930-31 respectively in sand with phosphorus and potassium applied in the form of commercial fertilizers and with nitrogen applied in solution in the form of calcium and potassium nitrate.

2. Although varietal standings varied somewhat, plants of Windermoor Wonder, Extra Long White Spine and Deltus generally produced a higher staminate-pistillate ratio than Early Fortune and Arlington White Spine.

3. Periods of long days combined with high light intensity and high temperatures favored the production of staminate flowers. Conversely periods of short days combined with low light intensity and comparatively low temperatures favored the production of pistillate forms.

4. The production of a large number of staminate flowers combined with a relatively small number of pistillate forms was associated with vigor of growth, comparatively long internodes and relatively large leaves, while a preponderance of pistillate forms was associated with short internodes and comparatively small leaves.

5. Although high nitrogen supply accelerated vegetative growth and generally produced a more narrow ratio than low nitrogen supply, its effect on the staminate-pistillate ratio was less marked than that of light and temperature during the growing period.

Part II

Catalase Studies

Many investigators have obtained close associations between certain phases of plant development and catalase activity. Most striking associations between catalase activity, vigor of vegetative growth and yield of reproductive growth have been found, positive in some cases, negative in others. In most instances differences in vegetqtive and reproductive growth have been induced by varying the nutrient, particularly the nitrate supply, and corresponding differences in catalase activity have been noted in the leaves. There is comparatively little information upon the association between seasonal or varietal differences in vegetation and reproduction and on the catalase activity of the reproductive as well as the vegetative organs. Since the staminate-pistillate ratio of cucumbers is known to vary with the season and with the variety, and since vigor of growth is known to vary with the nutrient supply, corresponding differences in catalase activity may occur also.

Review of Literature

Tyson (62) found a distinct positive correlation between the catalase activity of the leaves and the yield of roots of the sugar beet. The highest catalase activity was found in the leaves of the plant producing the highest yields. Auchter (4) secured a much greater catalase activity of leaves on the side of apple trees receiving nitrogen than on the side receiving no nitrogen, even though chemical analyses failed to show a significant increase in nitrogen content. MacDaniels and Curtis (38) determined the catalase activity and the nitrogen content of the leaves in the mid-portion of vigorous twigs of closed ringed and spirally ringed apple trees receiving nitrate and no nitrate, respectively. Their data show a high positive correlation between catalase activity and nitrogen content. The leaves of trees receiving nitrogen increased in percentage of nitrogen content and in catalase activity, while those of trees receiving no nitrogen decreased in percentage of nitrogen and in catalase activity. Heinicke (26) found that the leaves of apple trees growing on sandy soil had less active catalase than those of trees growing on clay. On either type of soil, leaves of trees cleanly cultivated were higher in catalase activity than were those growing on sod. Nitrate of soda applied to non-vigorous trees either cleanly cultivated or growing in sod greatly accelerated vegetative growth and greatly increased catalase activity. These results led Heinicke to believe that the application of nutrients promoting vegetative growth, particularly nitrates, favor catalase activity and conversely substances inhibiting vegetative growth retard catalase activity. Harding (23) found a similar association in the fruits of the Grimes Golden apple. Immediately after harvesting he placed one lot of fruit in cold storage and another lot in a room maintained at approximately 50 degrees F. In both cases nitrogen fertilization of the trees and catalase activity of the fruits were closely associated. Gourley and Hopkins (17) secured similar results. Their data show a positive correlation between percentage of nitrogen in the fruit and catalase activity in the leaves and in the fruit.

Certain investigators have shown a negative correlation between growth and catalase activity. Chance (11) found no direct relation between catalase activity and the fresh weight of the seedling plant of corn. Haber (22) working on the effect of soil reaction on the catalase activity and yield of the tomato plant obtained a negative correlation between the vegetative mature leaves, green mature fruit and ripe fruit as measured by yield of fruit and dry weight of roots, stems and leaves, undoubtedly due to the fact that high catalase activity was associated with an excessively vegetative condition which is not easily produced in many other plants.

Pope (48) found that though catalase activity was roughly proportional to the reciprocal of the growth rate of barley, it was lowest during the stages of most active growth, as measured by length of the stem and rate of deposition of dry matter. Catalase activity was highest during the first stages of germination of the seed, during the development of the crown roots and during early jointing. Ezell and Crist (13) obtained correlations between catalase activity and growth of radish, spinach and leaf lettuce, as measured by fresh weight. The coefficient of correlation for radish and spinach was low, negative and insignificant (0.03±0.301) and (0.08±0.253) respectively, while that for leaf lettuce was high, negative and significant (0.50±0.061). These authors postulated that catalase activity is primarily associated with the catabolic phase of metabolism -- respiration, and that since growth is determined by the excess of the processes of anabolism over catabolism catalase must be more directly concerned with the latter process rather than with the former. They cite many cases showing that catalase activity is high in organs in which the catabolic processes predominate as in the germination of seed, the sprouting of potato tubers, the appearance of flowers, and the formation of roots.

The results of certain investigators show that temperature influences catalase activity. Burge and Burge (7) determined the catalase activity of one year old needles of *Pinus strobus L.* at weekly intervals during 1927. They found that the enzyme was most active during the summer months and least active during the winter months. Despite the seasonal differences in length of day these authors attribute the difference obtained largely to the seasonal differences in temperature. Green et al (18) working with the same plant found that cold weather decreased and warm weather increased catalase activity of the needles. Later Burge and Burge (8) found that though light increased the catalase activity of Spirogyra porticalis its effect was not as marked as that of temperature. Miller (43) found a greater catalase activity in the tissue of cabbage plants grown at relatively high temperatures (approximating 65°F) than in that of plants growh at relatively low temperatures (approximating 32°F).

Harding (23) found that catalase activity was lower in Grimes Golden apples placed immediately in cold storage at 32°F. than in fruits held at 50°F. At the comparatively low temperatures (30 - 36°F) he found no close association with respiration rate and catalase activity, although at 50°F. a rather closely direct association existed.

There is some indication that light influences the catalase activity of certain tissues. Knott (35) abruptly subjected December grown spinach plants of the Virginia Savoy and Old Dominion varieties to an additional 5.5 hours of illumination. He determined catalase activity of the reproductive apical buds at 2.5, 16.5 and 40.5 hours after exposure. His data show an increase in activity of the enzyme following the change from short to long photoperiods. In all cases except one, the longer the period of exposure, the greater the activity. These differences were more marked in Virginia Savoy than in Old Dominion and the rate of development of the seed stalk was also greater, indicating a positive correlation between catalase activity and rate of seed stalk development. Gustafson et al (21) found that high catalase activity accompanied rapid growth and respiration rate of the fruits of the John Baer variety of tomato. In three out of four experiments, they obtained "a general, though irregular, increase in amount of oxygen liberated as the rate of growth increased". Their data show some indication that catalase activity was higher in fruit maturing during the summer months than in fruit maturing during winter months even though the plants were grown under the same nutritive conditions. Gustafson is inclined to think that "catalase increase precedes increased growth rather than follows or accompanies it".

Heinicke (27) found marked seasonal variations in the catalase activity of tissue in various parts of McIntosh apple trees. High catalase activity occurred during June, July and August and a corresponding low activity occurred during late fall and early spring. Biennial bearing trees showed a higher catalase activity and a corresponding greater increase in trunk circumference during the non-bearing year than during the bearing year, while annual bearing trees were more uniform in catalase activity and in increase of trunk circumference from year to year.

Haber's (22) results indicate that catalase activity may be more active during the short days of winter. He grew tomato plants in acid, (pH 4.0 - 4.5) neutral, (pH 6.5 - 7.0) and alkaline (pH 8.5 - 9.0) soil from October 1 to February 1 and from February 20 to April 27. The vegetatively mature leaves of the spring crop showed less catalase activity than those of the fall crop. For a reaction time of 3 minutes leaves of the spring crop displaced from 2.9 to 6.1 c.c. of water, while those of the fall crop displaced from 4.4 to 9.7 c.c. of water.

Tyson (62) has reported that high light intensity produced a greater activity of catalase in leaves of the sugar beet than low light intensity.

The reproductive and vegetative phases of growth in the same plant have shown differences in catalase activity. For example, Knott (33) obtained striking differences in the catalase activity between the vegetative and reproductive apical buds of Virginia Savoy spinach. In one instance, the vegetative buds liberated 3 c.c. of oxygen in 53 seconds, while the reproductive buds required 256 seconds. As the seed stalk elongated respiration intensity and catalase activity decreased. With a return to the vegetative type of growth, induced by shortening the length of the day, catalase activity increased markedly. He found also that within any particular treatment or within either the reproductive or vegetative phase of growth the most vigorous plants possessed the most active catalase activity. The same author in collaboration with Anthony (35) compared the catalase activity of fruit and leaf buds of weak and of vigorous specimens of 19 year old Stayman Winesap trees growing in sod receiving applications of nitrate of soda, and of those growing on cleanly cultivated land receiving applications of barnyard manure. Though their data show little differences in catalase activity of the fruit buds of trees differing widely in vigor, the figures show marked differences in the vegetative buds. Close agreement within either type of vigor was secured. Vegetative buds of vigorous trees receiving either treatment had equal catalase activity. Similarly fruit and leaf buds of non-vigorous trees produced identical results.

Camp (9) compared the catalase activity of various organs of male and female plants belonging to 12 species. In all cases he found that the leaves and stems of staminate plants possessed a higher catalase activity than those of pistillate plants. Furthermore, within plants of each sex the floral parts showed higher catalase activity than the vegetative parts. Later Camp (10) determined the catalase activity of plants of <u>Arisaema triphyllum L.</u> He found that size and catalase activity of the corm and the sex expression of the inflorescence varied with the maturity of the plant. During the early stages of development the corms were small and the inflorescences bore staminate flowers only, during the intermediate stages the corms were intermediate in size and the inflorescences bore both staminate and pistillate flowers, while during the later stages the corms were large and the inflorescences bore pistillate flowers only. The corms bearing staminate flowers only produced the greatest catalase activity, followed by those producing both types of flowers and pistillate flowers in the order named. Camp concluded that the six expression of Arisaema triphyllum L. is relatively unstable and can be easily modified by fluctuations in the environment which in turn may induce metabolic changes within the plant.

The sexes within the same species have shown differences in substances other than in catalase. Satina and Demeric (55) reviewed a publication by Manoilov (42) on the identification of the sexes in dioecious plants by differential reaction to various chemical substances. This investigator obtained alcoholic extracts of chlorophyll from leaves of Acer nejundo, Lychnis diocia L., Urtica spp., and Cannabis spp. To a definite quantity of the extract he added small quantities of dilute solutions of papayotin, methylgreen, potassium permanganate, hydrochloric acid, and thiosinamin and observed the color change taking place. In all cases extracts of plants bearing staminate flowers became colorless while those of plants bearing pistillate flowers retained a reddish violet color. Grünberg (20) tested Manoilov's method and obtained similar results with plants of Vallisneria spp., Urtica dioica L., Cannabis sativa L., Papulus spp., Hippophae rhamnoides, Begonia spp. and Eucephialartes villosus and longifolius. Satina dn Demerec (55) report especially interesting results obtained with plants belonging to the genus Begonia. Extracts of male flowers gave the characteristic male reaction; those of female flowers gave the characteristic female reaction; while those of leaves gave an intermediate reaction between the male and female tissues. They point out that the precautions advanced by Manoilov that the chlorophyll extract used should be not greater than 60 per cent and that the tests should be made within 24 hours after extraction; otherwise enzyme activity is likely to be impaired.

Satina and Blakeslee (54) showed that within the same species differences exist in the reducing power of the sap of staminate and pistillate plants. The extracted juice of plant tissue bearing pistillate flowers possessed a greater capacity to reduce potassium permanganate than that from comparable parts of plants bearing staminate flowers. They suggested that the reducing substances concerned are not as complex as ensymes, but that they are the more staple substances, possibly carbohydrates and fats which are widely distributed in plants. In another experiment these investigators made comparative tests for differences in enzymatic activity between male and female races of 10 species of mucor. Their data failed to reveal any measurable differences between the sexes in trehalase, maltase, amylase, glycogenase and emulsin activity.

The Bouillennes (6) reported an interesting sase showing a direct relation between plant growth, sex expression and respiration rate. They planted seed of Mercurialis annua L. in the winter of 1929 and in the spring and summer of 1930 and observed that certain plants grew quickly and possessed long internodes and dark green foliage, while others grew slowly and possessed short internodes and grayish green foliage. Since these investigators found that the majority of the tall vigorous plants possessed staminate flowers only (80 out of 120) and that most of the dwarf forms possessed pistillate flowers only (50 out of 80), they believed that the marked differences in plant characteristics were indicative of a difference in metabolism between plants of the two sexes. An average of five respiration measurements of a single plant of each sex showed that the plant bearing staminate flowers emitted 0.053 milligrams of carbon dioxide per gram of fresh weight per hour, and that bearing pistillate flowers emitted 0.043 milligrams. They concluded that respiration of male plants is more intense than that of female plants for the period of flowering at least.

Experiment I

Materials and Methods

Determination of Catalase Activity

The apparatus used was similar to that described by Knott (33). The water bath was maintained at 30 degrees C., fluctuations not exceeding 2 degrees C and the hydrogen peroxide(unneutralized)and the tissue preparations were mixed in standard Bunzell catalase reaction tubes. The oxygen was collected in a burette by the displacement of water. Three per cent hydrogen peroxide was used. A stationary pivot was employed for supporting and swinging the reaction tubes. This pivot is a rectangular frame consisting of two horizontal and two vertical bars. The lower bar is mounted on a wire bearing and serves as a support for the reaction tubes. To the upper bar is attached an arm from an eccentric wheel operated by a small electric motor. Clamps were soldered to the horizontal bars to hold the reaction tubes in place. (Figure 2)

Leaf Preparations

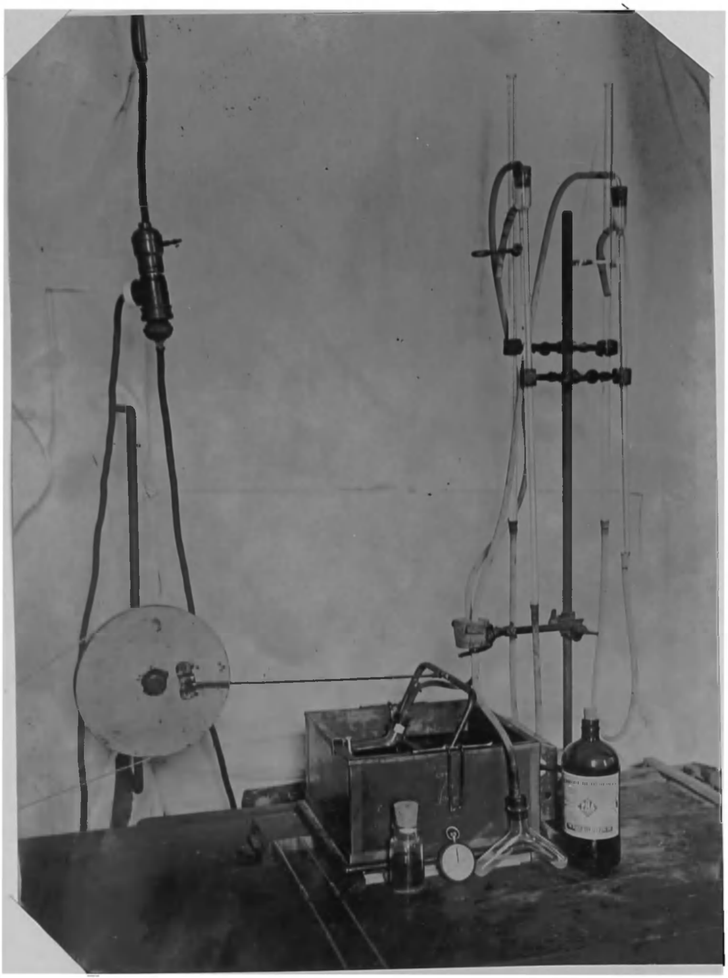
In general the method of preparation was similar to that used by Knott (33) in his work with spincah and celery. Four to six disks of tissue, one centimeter in diameter, were taken from the opposite side of the midribs and transferred immediately to a stoppered vial, weighed, and placed in a small mortar containing powdered calcium carbonate which had been previously moistened with 2 to 3 c.c. of distilled water. Usually one gram of tissue and one gram of the carbonate was used. The mixture was ground with a small amount of acid-treated quartz sand for 2 to 3 minutes and transferred to a small sample bottle with sufficient distilled water to make a dilution of 1 to 50.

Flower Preparations

The method of preparation was identical to that used for the leaf tissue. The opened or unopened staminate flowers were taken from axils of leaves sampled for catalase determinations, while the pistillate flowers were taken from the bearing nodes nearest these sampled leaves. In this way comparative uniformity between leaf and flower tissue was obtained. In all cases samples were secured between one and five o'clock in bright sunshine.

Measurement of Oxygen Evolution

Since Knott (33) pointed out that the supernatent liquid in



Apparatus used to determine catalase activity
Fig. 2

catalase preparations is low in activity and that the lower portion is high in this respect, the following procedure was employed to secure uniformity in mixing and drawing of the samples. The sample bottle was shaken in a rotary manner for about 10 seconds and allowed to stand for 15 seconds before the sample was drawn. In this way close agreement between duplicates was obtained. The 1 to 50 preparation was pipetted into one arm of the reaction tube and the hydrogen peroxide into the other. The tube was placed in the bath, allowed to stand for 3 minutes and then shaken at the rate of 136 excursions per minute. Quantities of water, less than one c.c., in the tube were considered as without disturbing effect since Knott (33) has shown that water, unless present in large quantities, neither accelerates nor retards the reaction.

While making determinations the leveling tube was gradually lowered to maintain a pressure of approximately one atmosphere in the burette.

Data are recorded in time (seconds) required to liberate a definite quantity of oxygen rather than in volume obtained in a definite period of time, since Osterhaut (47) has shown that the latter method is an unsafe basis for comparison for rates of biological reactions.

Preliminary Tests

Since different organs of the same plant and the same organs of different plants are known to vary in catalase activity, some preliminary tests were conducted to determine the effect of certain environmental conditions on catalase activity of the organs and to ascertain any variation in activity among the organs themselves.

The data in Table 17 show that dark green leaves are far more active in catalase than yellowish green leaves. Obviously in sampling the stage of maturity of the leaf is important. In this study leaves just attaining vegetative maturity and usually from those at comparable nodes, except in a few instances which are noted, were used.

Table 17 -- Catalase Activity of Young and Old Leaves of Arlington White Spine Cucumber, August 1930

	Seconds for evolution of oxygen	
–	5 c.c.	10 c.c.
Young Leaves	32.0	88.0
Old Leaves	63.0	419.0

Dilution 1-50, Hydrogen Peroxide 3 c.c., preparation 5 c.c.

Since the catalase activity of samples prepared at the same time could not be determined within a relatively short time, preliminary tests were made to show the effect of high and low storage temperatures. The figures in Tables 18 and 19 show that storing at temperatures approximating 5 degrees C for a period of 24 hours failed to significantly change the catalase activity of the tissue. On the other hand, exposure to high temperatures approximating 30 degrees C even for a short time was decidedly detrimental.

Table 18 -- Effect of High Temperature (30°C) on Catalase Activity of Unopened Staminate Buds of Arlington White Spine Cucumber August 1930

Storage Period (Minutes)	Seconds for evolution of oxygen 5 c.c.	10 c.c.
None	82	269
15	105	321
30	105	345
45	119	435
60	137	555
75	151	802

Dilution 1-50, Hydrogen Peroxide 3 c.c., Preparation 5 c.c.

Table 19 -- Effect of Low Temperature (4°C) on Catalase Activity of Unopened Staminate Buds of Arlington White Spine Cucumber August 1930

	Seconds for evolution of oxygen			
Storage Period	Sample I		Sample II	
(Hours)	5 c.c.	10 c.c.	5 c.c.	10 c.c.
None	80	271	81	275
1	81	246	75	233
6	85	272	73	201
18	89	300	80	240
24	83	276	76	234

Dilution 1-50, Hydrogen Peroxide 3 c.c. Preparation 5 c.c.

On this basis, samples were run immediately or within 24 hours after preparation. Whenever storing was necessary they were placed in a refrigerator maintained at 3 to 5 degrees C.

Table 20 -- Effect of Various Amounts of Hydrogen Peroxide on Catalase Activity of Unopened Staminate Buds of Deltus Cucumber August 1930

Hydrogen Peroxide Added (cubic centimeters)	Seconds for evolution of oxygen			
	Sample I		Sample II	
	5 c.c.	10 c.c.	5 c.c.	10 c.c.
1	231	---	233	---
2	96	369	92	388
3	73	221	72	220
4	67	197	73	232
5	75	216	70	207

Dilution 1-50, Preparation 5 c.c.

Varying quantities of peroxide were added to 5 c.c. of the preparation to obtain some indication of the amount required to yield the most consistent results. Though the data in Table 20 indicate that three cubic centimeters is sufficient for measuring the catalase activity of staminate buds, the use of a larger amount was deemed advisable for subsequent determinations, since other material might be higher in catalase activity. For any set of determinations the amounts used are indicated at the bottom of the tables.

Presentation of Results

Influence of Nitrogen Supply

The data presented in Tables 21 and 22 and in graphic form in Figures 3 and 4 show wide differences in catalase activity for the nitrate treatments. In all cases the high nitrogen plants possessed

Table 21.--Influence of Nitrate Supply on Catalase Activity of Arlington White Spine Cucumber for Periods January 15 to April 15 and May 22 to July 24, 1931.

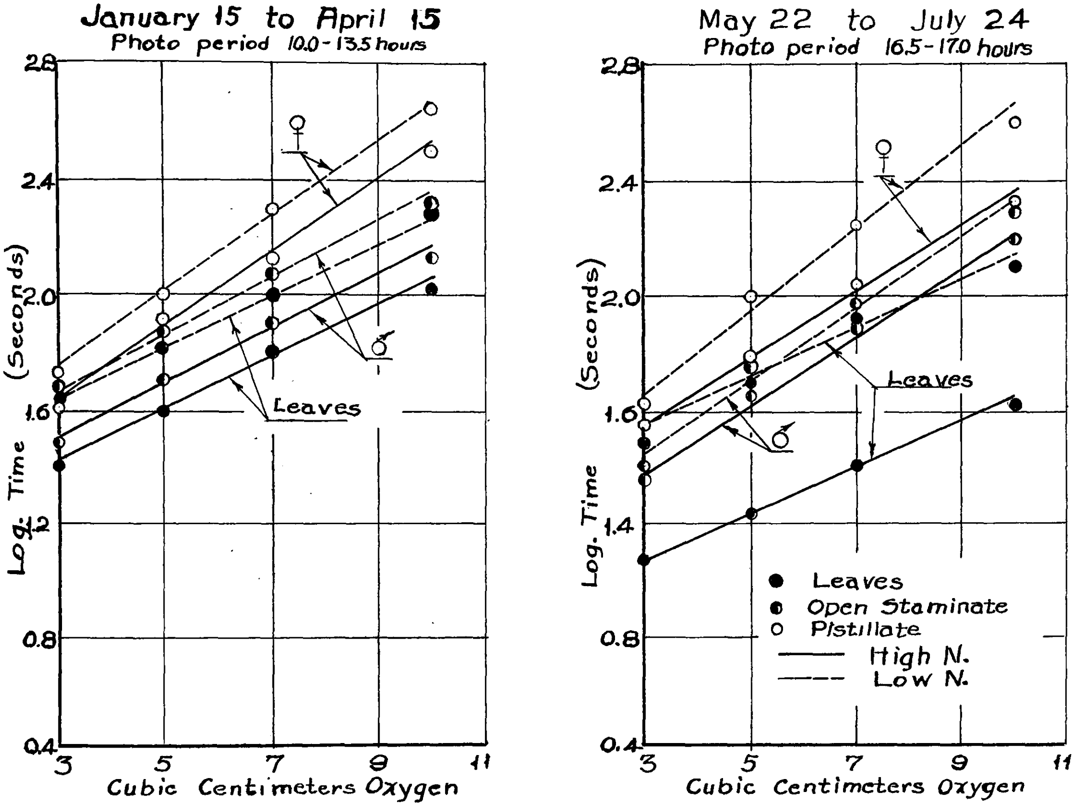
Plant Part	Date of Determination	High Nitrogen: Seconds for evolution of oxygen[1] (cc) 3	5	7	10	Low Nitrogen: Seconds for evolution of oxygen (cc) 3	5	7	10
January 15 to April 15. Photoperiod 10 to 13 Hours.									
Leaves	Feb. 14	28.0	41.5	65.0	100.5	46.0	76.0	109.3	214.0
Unopened Staminate	Jan. 23	23.3	43.0	62.0	110.7	37.7	73.7	132.7	255.3
Opened Staminate	March 21	33.3	53.3	81.0	138.0	42.7	69.7	125.7	242.7
Opened Pistillate	March 21	43.0	80.0	139.3	295.3	50.7	101.3	211.7	461.7
May 22 to July 24. Photoperiod 16.5 to 17.0 Hours.									
Leaves	June 22	12.3	18.3	26.0	41.0	33.0	51.0	79.3	133.0
Opened Staminate	July 19	24.3	53.3	83.0	149.0	25.7	60.0	101.7	191.7
Opened Pistillate	July 19	37.3	68.0	112.0	215.0	45.0	101.3	186.0	420.0

[1] Average of three determinations -- Dilution 1-50, Preparation 10 cc., Hydrogen Peroxide 10 cc.

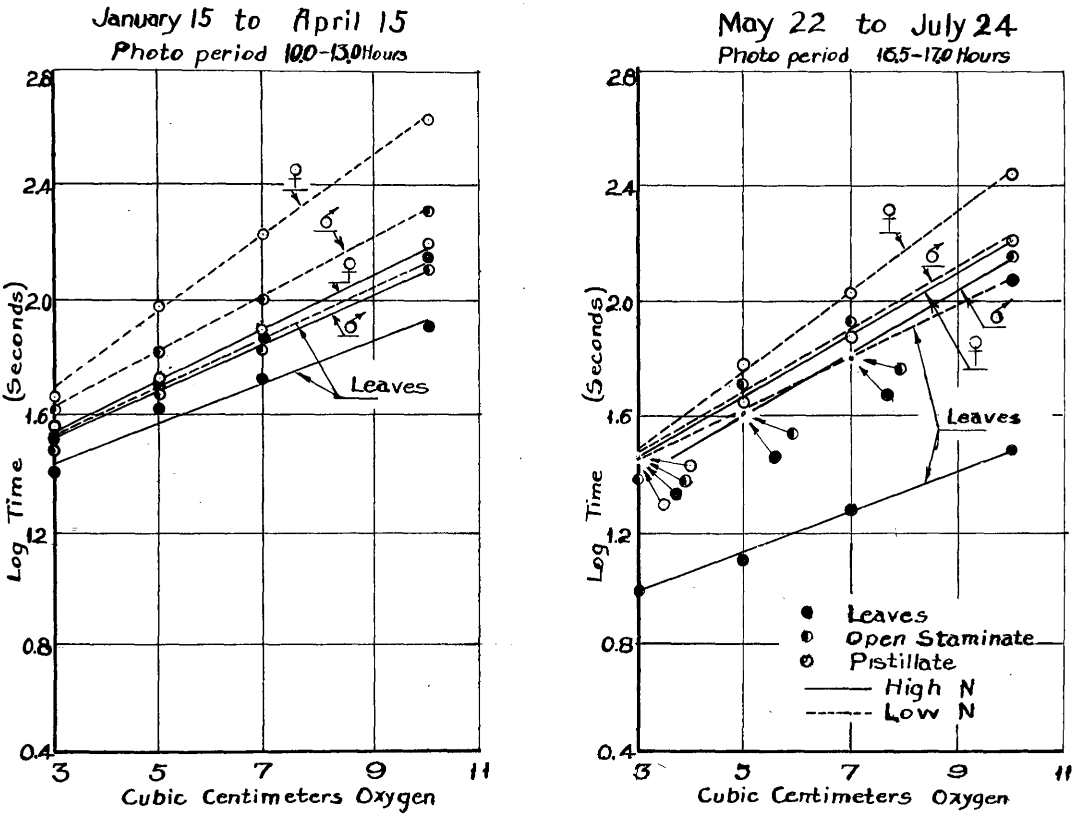
Table 22.--Influence of Nitrate Supply on Catalase Activity of Windermoor Wonder Cucumber for Periods January 15 to April 15 and May 22 to July 24, 1931

Plant Part	Date of Determination	High Nitrogen Seconds for evolution of oxygen (cc)				Low Nitrogen Seconds for evolution of oxygen (cc)			
		3	5	7	10	3	5	7	10
January 15 to April 15. Photoperiod 10 to 13 Hours									
Leaves	Feb. 14	28.3	42.5	56.5	82.0	33.0	52.0	76.0	134.0
Unopened Staminate	Jan. 23	23.7	37.0	58.0	92.7	28.3	55.3	85.3	152.0
Opened Staminate	March 21	32.0	49.3	75.7	128.3	40.0	66.6	106.6	195.3
Opened Pistillate	March 21	30.7	57.3	93.3	163.7	44.0	98.3	175.0	405.7
May 22 to July 24. Photoperiod 16.5 to 17.0 Hours									
Leaves	June 22	9.7	14.5	20.0	32.7	26.7	42.5	60.0	116.3
Opened Staminate	July 19	22.7	43.7	76.0	132.0	21.3	50.0	84.7	162.7
Opened Pistillate	July 19	23.0	45.3	81.3	147.7	28.0	62.0	115.3	351.3

Average of three determinations -- Preparation 10 cc., Hydrogen Peroxide 10 cc.



Catalase activity of Arlington White Spine
Fig. 3



Catalase activity of Windermoor Wonder
Fig. 4

greater catalase activity than the low nitrogen plants. Since high nitrogen supply promoted vigor of growth and catalase activity, while low nitrogen supply retarded growth and catalase activity, nitrate supply, vigor of growth and catalase activity are closely associated. Many investigators have reported similar associations. Heinicke (27), Auchter (4), MacDaniels and Curtis (38) found that applications of nitrogen in the form of nitrate of soda markedly increased vigor of growth and catalase activity in the leaves of the apple. Tyson (62) reported that applications of the same material induced a close positive correlation between catalase activity of the leaves and vigor of growth of the sugar beet. Knott (35) found a similar association between catalase activity and vigor of growth in Virginia Savoy spinach. On the other hand, Ezell and Crist (13) found that though nitrogen applied in the form of calcium nitrate increased growth, it failed to increase catalase activity in the leaves of radish, spinach and lettuce. In fact a negative correlation was secured between catalase activity in the leaves of lettuce and growth, as measured by fresh weight.

Influence of Season

Though seasonal differences in catalase activity are less marked than the nutritional or the varietal differences, the data show, in most cases, a greater catalase activity during the long days (May 22 to July 24) than during the short days (December 27 to April 15). This greater activity may have been due to the greater temperature and the greater light intensity during the former period than during the latter which, in turn, induced greater vigor of growth. Knott (33) has shown that an increase in temperature correspondingly increases catalase activity. He interchanged potted celery plants from a cool to a warm greenhouse differing by 10 degrees F. He found that the leaf tissue of plants transferred from the cool to the warm house gradually increased in catalase activity, while those transferred from the warm to the cool house gradually decreased in catalase activity. Burge and Burge (7) considered that seasonal differences in temperature were mainly responsible for the greater catalase activity in needles of Pinus strobus L. during the summer than during the winter. Miller (43) secured higher catalase activity in cabbage grown at temperatures approximating 65 degrees F. than that grown at temperatures approximating 32 degrees F. Tyson's (62) data indicate a positive correlation between light intensity, vigor of growth and catalase activity in the sugar beet, while Ezell and Crist's (13) work with lettuce indicates that supplementary illumination during the short days of winter had little effect.

Varietal Differences

In most cases varietal differences are evident and consistent. In general the leaves and floral organs of Windermoor Wonder were greater in catalase activity than those of Arlington White Spine. The greater divergence between varieties was secured in the low nitrogen treated lots. In fact, high nitrogen produced similar rates of catalase activity in the leaves and staminate flowers of both varieties during the first part of the reaction, thus illustrating the necessity to allow the reaction to proceed for a relatively long time, particularly when comparisons are made of tissue relatively high in catalase.

Since the data indicate a higher rate of catalase activity for Windermoor Wonder, and since this variety possessed a wider staminate-pistillate ratio than Arlington White Spine which is independent of the season and nitrogen supply, varieties possessing a wide ratio are likely to show greater catalase activity than those possessing a comparatively narrow ratio.

Camp (9) has presented additional evidence to show that catalase activity and sex expression may be associated. In 12 species of dioecious plants, he found a higher catalase activity in the staminate plants than in the pistillate plants.

Plant Part Differences

Differences in the catalase activity of the various tissues, though not very wide in some instances, are evident. The leaves possessed the greatest activity followed by the unopened staminate, opened staminate and pistillate flowers in the order named. If catalase activity is considered as an index to metabolic activity, the leaves should be most active metabolically, with the pistillate flowers the least active and the staminate flowers intermediate in activity. On this basis in dioecious species staminate plants should be more active metabolically than pistillate plants.

Other investigators have secured differences in the catalase activity of various tissues within the same plant. Knott (35) found striking differences between the leaf and flower buds of Virginia Savoy spinach. Knott and Anthony (34) secured similar differences between the fruit and leaf buds of the Winesap apple.

Experiment II

In this experiment, certain modifications were made in the apparatus used for making determinations. The position of the fulcrum of the reaction tube carrier was changed to permit the tube to swing through a wider arc and the arm on the eccentric was changed to swing the reaction tubes at the rate of 213 excursions per minute, thus facilitating thorough mixing. Furthermore since pistillate flowers, particularly from low nitrogen plants were extremely low in catalase activity, some means to accelerate the rate of the reaction seemed advisable. Preliminary tests showed that this effect was secured by adding a small quantity of powdered calcium carbonate to the hydrogen peroxide. Consequently in subsequent determinations the hydrogen peroxide was neutralized by adding a small quantity of powdered calcium carbonate.

The plants were grown from May 22 to July 24 under a short and a long photoperiod. Light was partially excluded from the plants subjected to the short photoperiod through the use of a layer of black muslin and black sateen and by a single layer of muslin placed on the sides and top of the enclosure respectively. The cloth was removed at 12 o'clock noon and returned at 7 o'clock at night, thus permitting a seven hour exposure to full day light. Though the light was not entirely excluded by the cloth, measurements made with the Watkins Beemeter failed to show any appreciable light intensity. The methods used in the application of supplementary light for the plants exposed to the long photoperiod and in the application of nitrogen to both lots have been described.

Description of Plants

The plants grown under the cloth were etiolated, possessed relatively long internodes, thin spindling stems and small sized leaves. Floral development was poor and consisted entirely in the development of unopened staminate flowers which were too small to permit securing data on the staminate-pistillate ratio. Data in Table 23 show the average length of the main axes of plants of both varieties receiving high and low nitrogen respectively.

Table 23 -- Average height (inches) of Main Axes of Plants of Windermoor Wonder and Arlington White Spine Cucumber for Seven Hour Photoperiod, May 22 to July 24, 1931

Variety	Treatment		Difference
	High Nitrogen	Low Nitrogen	(High minus Low)
Arlington White Spine[1]	9.8 ± 0.23	7.6 ± 0.27	2.2 ± 0.36
Windermoor Wonder[2]	12.2 ± 0.23	9.4 ± 0.11	2.8 ± 0.26
Difference W.W. minus A.W.S.	2.4 ± 0.32	1.8 ± 0.29	

[1] 59 plants high N. 44 plants low N.

[2] 48 plants high N. 44 plants low N.

Differences are considered significant

Presentation of Results

Influence of Nitrogen Supply

The data presented in Tables 24 and 25 and in graphic form in Figures 5 and 6 show marked similarities and variations in the catalase activity of leaves taken from the same and adjacent nodes of plants subjected to an extremely short photoperiod. The catalase activity of leaves from either the third or fourth node were similar regardless of the nitrogen supply, while that of third and fourth node leaves within either treatment was quite wide. Third node leaves of plants receiving high and low nitrogen respectively required only 89.0 and 87.8 seconds to liberate 15 cubic centimeters of oxygen whereas the fourth node leaves required 219.7 and 252 seconds respectively. Similar though less striking results were obtained with the variety Arlington White Spine. In either case the leaves of the lower node showed marked symptoms of nitrogen deficiency, while those on the higher node did not. The low catalase activity of the leaves in the lower node combined with the observed nitrogen starvation indicates that the seven hour photoperiod of comparatively intense sunlight was insufficiently long to permit adequate nitrogen absorption, even in the presence of a high nitrogen supply.

The data upon the opened staminate flowers are similar to those presented in Tables 21 and 22. For the two treatments the rate of the reaction is similar during the initial stage but less rapid during the latter for the flowers of plants receiving low nitrogen. As in other comparisons, the leaves of plants receiving high and low nitrogen

Table 24.-- Catalase Activity of Leaves and Staminate Flowers of Plants of Windermoor Wonder Cucumber Grown Under Short and Long Photoperiods from May 22 to July 24, 1931

Plant Part	Date of Determination	High Nitrogen Seconds for evolution of oxygen (cc)					Low Nitrogen Seconds for evolution of oxygen (cc)				
		3	5	7	10	15	3	5	7	10	15
Short Photoperiod 7 Hours											
Leaves[1]	July 24	8.3	18.7	29.3	48.7	89.0	8.5	17.0	26.5	43.8	87.8
Leaves[2]	July 24	14.7	27.7	49.3	83.0	219.7	15.7	30.3	47.3	83.7	252.0
Long Photoperiod 16.5 to 17 Hours											
Leaves[1]	July 24	3.7	5.7	8.7	12.5	22.3	10.2	16.7	25.5	44.4	76.5
Opened Staminate	July 19	22.7	50.7	76.0	132.0	----	21.3	50.0	84.7	162.7	----

[1]Third Node   Preparation 5 cc. Neutralized Hydrogen Peroxide 5 cc.

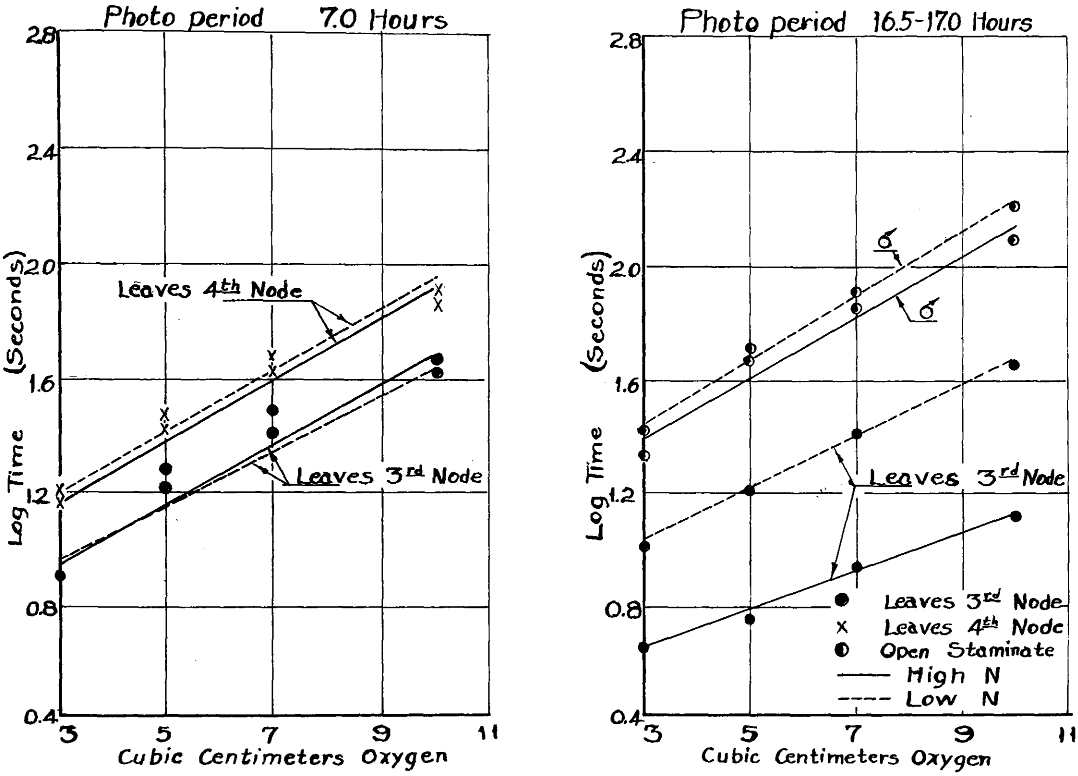
[2]Fourth Node

Table 25.-- Catalase Activity of Leaves and Staminate Flowers of Plants of Arlington White Spine Cucumber Grown Under Short and Long Photoperiods from May 22 to July 24, 1931

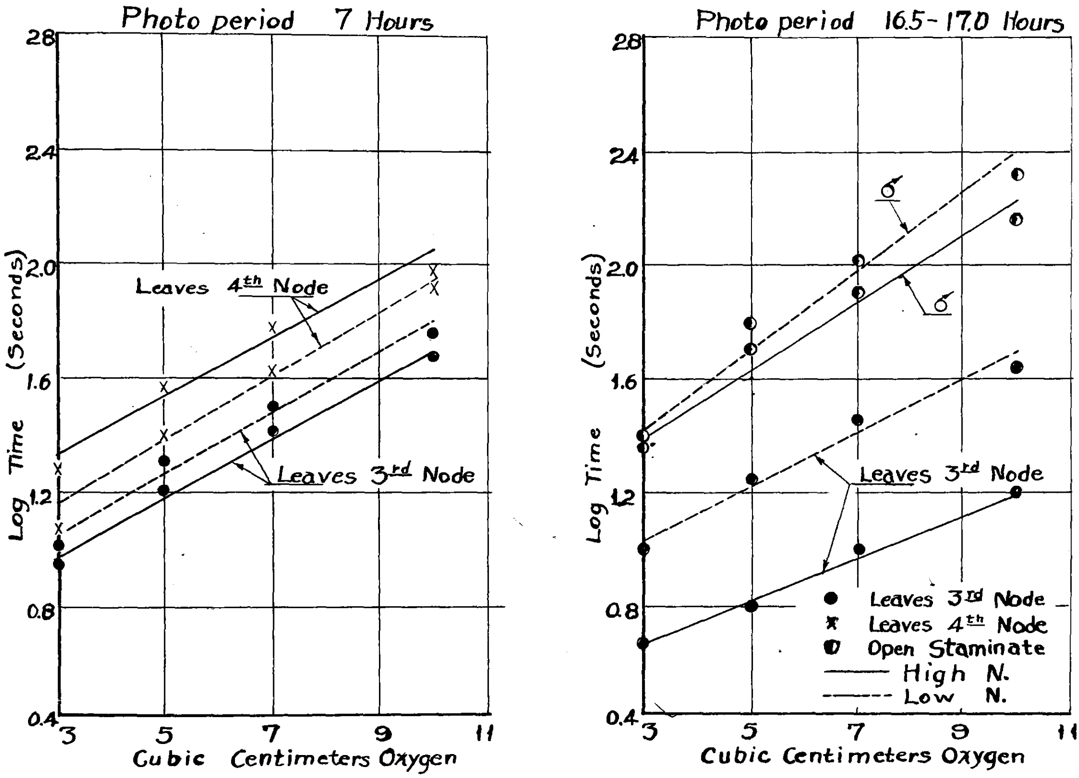
Plant Part	Date of Determination	High Nitrogen Seconds for evolution of oxygen (cc)					Low Nitrogen Seconds for evolution of oxygen (cc)				
		3	5	7	10	15	3	5	7	10	15
Short Photoperiod 7 Hours											
Leaves[1]	July 23	9.3	17.3	27.3	47.0	90.3	10.7	21.0	32.7	54.3	110.3
Leaves[2]	July 23	19.7	38.7	59.3	97.0	261.0	14.5	26.8	43.0	85.0	249.5*
Long Photoperiod 16.5 to 17 Hours											
Leaves[1]	July 23	4.5	6.5	10.7	15.8	29.8	10.3	18.5	28.3	44.5	87.5
Opened Staminate	July 19	24.3	53.3	83.0	149.0	----	25.7	60.0	101.7	191.7	----

[1]Third Node   Preparation 5 cc.   Neutralized Hydrogen Peroxide 5 cc.   * 12.5 cc.

[2]Fourth Node



Catalase activity of Arlington White Spine
May 22 to July 24
Fig. 5



Catalase activity of Windermoor Wonder
May 22 to July 24
Fig 6

respectively showed by far the greater divergence.

Influence of the Photoperiod

The catalase activity of the leaves was more rapid for the plants grown during the long photoperiod than for those grown during the short photoperiod. In the case of Windermoor Wonder, receiving high nitrogen, the leaves of the third node required 22.3 seconds to liberate 15 cubic centimeters of oxygen, while those of plants during the short photoperiod required 89.0, 87.8 and 76.5 seconds respectively. Similar results were obtained with the leaves of the fourth node and for Arlington White Spine with the leaves of both nodes. These data similar to those obtained in the preceding experiment indicate that catalase activity is markedly associated with nitrogen supply. Probably the influence of the photoperiod is indirectly associated with the activity of the enzyme largely through its influence on nitrogen absorption.

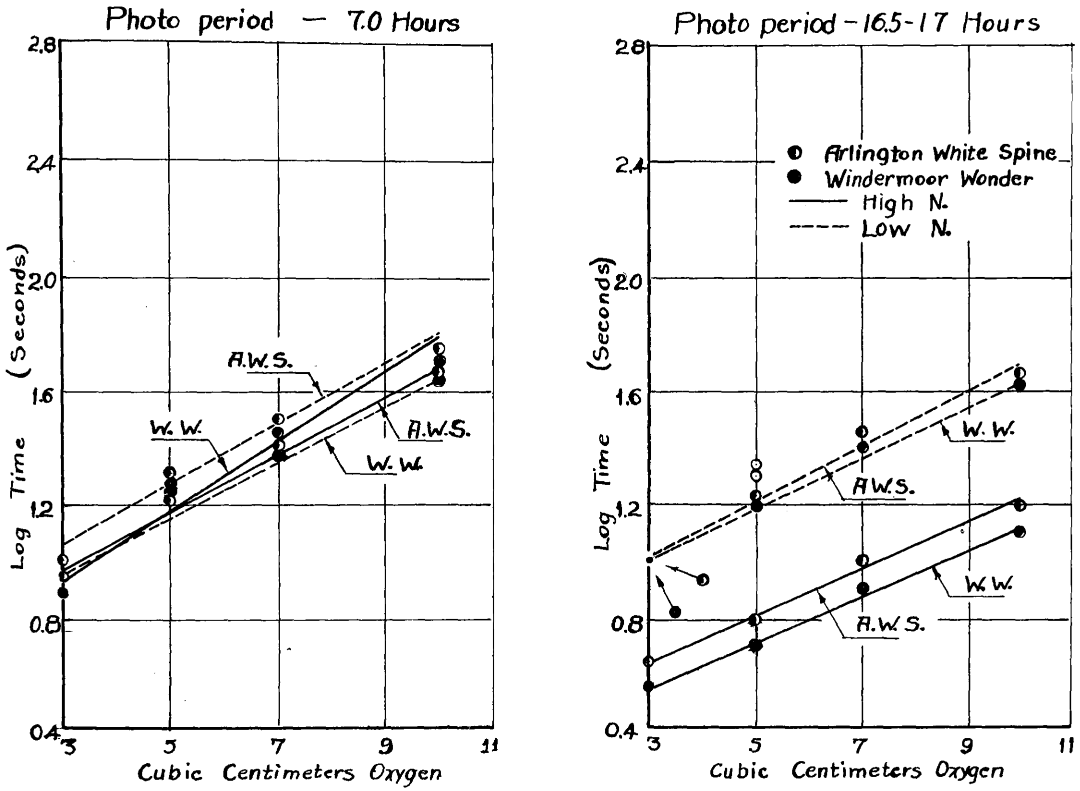
Varietal Differences

The data presented in Table 26 and in graphic form in Figure 7 show that, with the exception of the leaves of plants receiving high nitrogen during the short photoperiod, the leaves of Windermoor Wonder possessed greater catalase activity than those of Arlington White Spine. The greatest difference occurred between the leaves receiving low nitrogen supply and the least between those of plants receiving high nitrogen supply. These results, similar to those in Tables 21 and 22, indicate that the varietal differences are independent of the nitrogen supply and the length of the day.

Table 26.-- Varietal Differences in Catalase Activity of Leaves[1] of Cucumber Plants Grown Under Short and Long Photoperiods - May 22 to July 24, 1931

Variety	Date of Determination	High Nitrogen Seconds for evolution of oxygen (cc)					Low Nitrogen Seconds for evolution of oxygem (cc)				
		3	5	7	10	15	3	5	7	10	15
Short Photoperiod 7.0 Hours											
Arlington White Spine	July 23	9.3	17.3	27.3	47.0	90.3	10.7	21.0	32.7	54.3	110.3
Windermoor Wonder	June 24	8.3	18.7	29.3	48.7	89.0	8.5	17.0	26.5	43.8	87.5
Long Photoperiod 16.5 to 17 Hours											
Arlington White Spine	July 23	4.5	6.5	10.7	15.8	29.8	10.3	18.5	28.3	44.5	87.5
Windermoor Wonder	June 24	3.7	5.7	8.7	12.5	22.3	10.2	16.7	25.5	44.4	76.5

[1]Third Node   Preparation 5 cc.   Neutralized Hydrogen Peroxide 5 cc.



Varietal differences in catalase activity
May 22 to July 24
Fig. 7

Discussion

The results show that associations may be established between nitrogen supply, vigor of growth and catalase activity. Abundant nitrogen supply, abundant vigor of growth and high catalase activity were positively associated. Similarly, scant nitrogen supply, weak vegetative growth and low catalase activity were positively associated. In other words, growth expressed in terms of rapid development in size, volume or area, particularly of the vegetative organs and high catalase activity are undoubtedly closely associated, whereas slow vegetative extension and low catalase activity are correspondingly closely associated. Since large quantities of energy are necessary for the growth of rapidly developing organs, rapid vegetative growth, a high rate of respiration and high catalase activity are positively associated. Similarly slow vegetative growth, a low rate of respiration and low catalase activity are also positively associated.

A marked association between sex expression and catalase activity is evident in most cases. A wide staminate-pistillate ratio, indicating a high degree of maleness, and high catalase activity were positively associated. Conversely, a narrow staminate-pistillate ratio, indicating a high degree of femaleness, and high catalase activity were negatively associated. These associations obtained in all the factors studied except that of nitrogen supply. Windermoor Wonder always produced the wider staminate-pistillate ratio and generally possessed the greater catalase activity than Arlington White Spine. Within either variety, the male tissues always produced greater catalase activity than the female tissues.

They were intermediate in activity between the leaves and female organs, regardless of the period of growth, regardless of the nitrogen supply. Days of long photoperiod combined with high light intensity and high temperature were favorable for the production of a wider staminate-pistillate ratio and a higher catalase activity than days of short photoperiod combined with low light intensity and low temperature. On the other hand, although high nitrogen supply greatly increased catalase activity, it favored the development of femaleness. This paradoxical effect of nitrogen, favoring vigorous vegetative growth on the one hand and femaleness on the other, is difficult to explain. Its role in the development of either type of organ probably induces the formation of compounds which respond differently to catalase.

Conclusions and Summary

1. Varietal, seasonal and nutritional effects on the catalase activity of the leaves, staminate and pistillate flowers of Windermoor Wonder and Arlington White Spine were determined on plants grown from January 15 to April 15 and from May 22 to July 24, 1931, under a high and a low nitrogen supply.

2. Windermoor Wonder possessed a wider staminate-pistillate ratio and a greater catalase activity than Arlington White Spine.

3. The vegetative leaves produced the greatest catalase activity, followed by the unopened staminate, opened staminate and opened pistillate flowers in the order named. The male flowers always produced greater catalase activity than the female tissue, regardless of the nitrogen supply or the season.

4. For any treatment or variety the catalase activity was greater during the period of long days than during the period of short days.

5. High nitrogen supply greatly increased catalase activity. Conversely, low nitrogen supply greatly decreased catalase activity. Its effect was decidedly more potent than the temperature and light during the growing period.

Part III

Chemical Studies

The association of the relative carbohydrate and nitrogen content with the vegetative and reproductive phases of plant growth is well known to plant physiologists and to horticulturists. In many plants vigorous growth of stems and leaves combined with little or no flowering and fruiting are associated with relatively low carbohydrate and high nitrogen content, while the production of flowers and fruit combined with moderate growth of stems and leaves are associated with a relatively high carbohydrate and low nitrogen content. Since vigor of growth and the staminate-pistillate ratio of cucumbers are associated and vary with the season, corresponding changes may occur in carbohydrate and nitrogen content. In other words, tissue bearing predominately staminate flowers might show different relative proportions of carbohydrates and nitrogen than that bearing predominately pistillate flowers. Hence the object of these studies was to determine any possible association between the carbohydrate and nitrogen content and the staminate-pistillate ratio.

Methods

Preparation of Samples

In most cases a composite sample of eight to ten plants was used, the sex expression of which had been previously recorded. The leaf blades of the plants were cut off and the petioles and stems were cut into thin sections, mixed, weighed and immediately transferred to Mason jars containing 0.2 grams of powdered calcium carbonate and hot alcohol mixed with water sufficient to give a final concentration of 80 per cent. The jars were then placed in a water bath and the contents boiled for three to five minutes. Duplicate samples of each lot were taken during the same afternoon in bright sunshine. The weights varied from 60 to 100 grams.

Treatment of alcohol insoluble residue

The alcoholic solution was decanted from the insoluble residue through a coarse sieve into a volumetric flask. The residue was then rinsed with 80 per cent alcohol and transferred to an evaporating dish, dried in an oven maintained at 65 to 70 degrees centigrade for 48 hours, cooled in a dessicator and finally ground without sand to pass through a 40-mesh sieve.

Free Reducing Substances

A suitable aliquot of the ground residue was extracted in a Soxhlet apparatus with an equal portion of the preserving alcohol for two and one-half to three hours. The extract was then freed from alcohol by means of a heated sand bath and a blast of air and finally cleared with neutral lead acetate and deleaded with potassium oxalate. The Bertrand-Munson-Walker method was used to determine the reducing value of the free reducing substances and they were calculated as glucose.

Total Sugars

An aliquot of the cleared solution was hydrolized with two and one-half per cent hydrochloric acid at room temperature for twenty-four hours and neutralized with sodium hydroxide. The reducing power determined was calculated as glucose and is reported as total sugars.

Sucrose

The differences between the total sugars and the free reducing substances are reported as sucrose.

Acid Hydrolyzable Substances

The extracted residue was refluxed with two and one-half per cent hydrochloric acid for two and one-half hours. After neutralization with sodium hydroxide the reducing value of the solution was determined as starch and is reported as acid hydrolyzable material.

Starch

An aliquot of the extracted residue was ground with fine sand to pass through a 100-mesh sieve. After the addition of 50 cubic centimeters of boiling water the beaker containing the mixture was placed in a bath of boiling water for one hour, allowed to cool to 50 degrees centigrade, mixed with 10 cubic centimeters of saliva in water (proportion of one part of salive to two of water) and incubated for one hour in an oven maintained at 50 degrees centigrade. The material was removed and placed in the boiling water bath for 15 minutes, cooled to 50 degrees centigrade and the incubation repeated. The solution was cleared with 70 per cent alcohol, freed from alcohol and finally hydrolized with two and one-half per cent hydrochloric acid under a reflux condensor for two and one-half hours.

The reducing power of the solution was determined as glucose.

Alcohol-Soluble and Alcohol-Insoluble Nitrogen

In each case the Kjeldahl method, modified to include nitrates, was used. Nitrogenous substances soluble in the preserving alcohol are presented as soluble nitrogen, while those contained in the insoluble residue are listed as insoluble nitrogen.

Total Nitrogen

Total nitrogen was calculated by combining the percentage of the soluble and insoluble fractions.

Presentation of Results

Seasonal Differences

The data presented in Tables 27 and 28 show that the plants grown from May 22 to July 24 possessed a greater percentage of sucrose, total sugars and total carbohydrates than those grown from December 15 to April 15. The differences in sucrose content were rather marked. In fact the greater total carbohydrate content of the plants grown from May 22 to July 24 was chiefly due to the greater percentage in this constituent. For the period May 22 to July 24 it varied from 0.225 to 0.295 per cent and for the period December 15 to April 15 from 0.131 to 0.167 per cent.

The greater sugar content of plants grown during the long days appears to be positively associated with vigor of growth, catalase activity and sex expression. The plants grown during the long days were more vigorous, possessed wider staminate-pistillate ratios and

Table 27.-- Carbohydrate and Nitrogen Content of Windermoor Wonder Cucumber Receiving High and Low Nitrogen [1]

Treatment	Free Reducing substances	Sucrose	Total sugars	Starch	Acid Hydrolyzable substances	Total carbohydrates	Soluble Nitrogen	Insoluble Nitrogen	Total Nitrogen	C/N Ratio [2]	TS/N Ratio [3]	Flowers per Node		Total Staminate-Pistillate Ratio
												Staminate	Pistillate	
December 27 to April 15 Photoperiod 9.5 to 13.0 Hours														
High N.	0.299	0.154	0.454	0.165	0.721	1.175	0.073	0.139	0.213	5.52	2.13	1.75	0.89	1.97
Low N.	0.248	0.167	0.415	0.301	0.815	1.230	0.026	0.135	0.161	7.65	2.58	3.10	0.53	2.91
May 22 to July 24 Photoperiod 16.5 to 17.0 Hours														
High N.	0.317	0.225	0.572	0.076	0.671	1.238	0.054	0.152	0.206	6.01	2.77	3.71	0.084	44.3
Low N.	0.308	0.295	0.603	0.205	0.859	1.462	0.024	0.121	0.145	10.07	4.16	4.97	0.092	54.2

[1] Per cent fresh weight

[2] Total carbohydrates

[3] Total sugars

Table 28.-- Carbohydrate and Nitrogen Content of Arlington White Spine Cucumber Receiving High and Low Nitrogen[1]

Treatment	Free reducing Substances	Sucrose	Total sugars	Starch	Acid Hydrolizing substances	Total Carbohydrates	Soluble Nitrogen	Insoluble Nitrogen	Total Nitrogen	C/N Ratio[2]	TS/N Ratio[3]	Flowers Per Node		Total Staminate-Pistillate Ratio
												Staminate	Pistillate	
December 27 to April 15 Photoperiod 9.5 to 13.0 Hours														
High N.	0.286	0.131	0.417	0.156	0.776	1.193	0.082	0.179	0.262	4.52	1.59	0.49	1.12	0.44
Low N.	0.235	0.157	0.392	0.184	0.897	1.289	0.034	0.172	0.206	6.26	1.90	0.87	0.85	1.02
May 22 to July 24 Photoperiod 16.5 to 17.0 Hours														
High N.	0.297	0.232	0.528	0.051	0.690	1.218	0.067	0.141	0.208	5.85	2.54	4.62	0.106	43.6
Low N.	0.224	0.238	0.462	0.160	0.969	1.432	0.028	0.124	0.158	9.35	2.92	4.93	0.092	53.5

[1] Per cent fresh weight

[2] Total Carbohydrates

[3] Total sugars

greater catalase activity than the plants grown during the short days. Apparently abundant vigor of growth, a high degree of maleness, high catalase activity and comparatively high soluble carbohydrate content are positively associated, while weak vegetative growth, a high degree of femaleness, low catalase activity and low sugar content are also positively associated. The results show that no marked accumulation of insoluble carbohydrates occurred in the plants making poor growth. Certain investigators have shown that poor growth of other plants is accompanied by excessive carbohydrate accumulation. For example, Hooker (29) found marked accumulation of insoluble carbohydrates in the twigs of comparatively non-vigorous apple trees.

The comparatively high sugar content of plants with a high staminate-pistillate ratio substantiates the hypothesis advanced by Gardner (14). His work with the Senator Dunlap variety of strawberry led him to believe that vigorous vegetative growth and high carbohydrate content is associated with either hermaphrodism or maleness and that scant vegetative growth and low carbohydrate content is associated with femaleness. He cites many instances in which a high and low carbohydrate content are associated with maleness and femaleness respectively. Arthur, Guthrie and Newell (2) obtained results similar to those reported in this work. Though these investigators found no correlation between chemical composition and flowering in many species of plants, their data show that cucumbers grown during a comparatively short photoperiod were lower in total sugars and total carbohydrates and higher in soluble and insoluble nitrogen than those grown during a long photoperiod. The short day plants possessed a correspondingly lower carbohydrate nitrogen ratio. However, these workers failed to note any differences in sex expression of the plants grown during the two periods.

Despite the great difference in nitrogen supply the data show that both high and low nitrogen plants grown during the period of long days possessed lower percentages of nitrogen than corresponding lots grown during the period of short days. The total sugar and total carbohydrate ratios were influenced accordingly. Undoubtedly the high sugar and total carbohydrate content and the correspondingly lower nitrogen content of the long day plants was due to the greater opportunity for carbohydrate manufacture and for nitrogen utilization from May 22 to July 24 than from December 15 to April 15. Gregory (19) has shown that the rate of growth of the cucumber plant varies with the season of the year. He found that leaf area and stem elongation increased at a greater rate in March and June than in December and Nanuary. During the former period, growth followed the compound interest law; during the latter, though it was proportional to the leaf area at first, a gradual decline in growth took place. Gregory concluded that the low light intensity and the low temperature of the winter months militate against photosynthetic activity. However, the short photoperiod of the winter probably produces as great or even greater militating effects than low temperature or low light intensity.

<u>Influence of Nitrogen Supply</u>

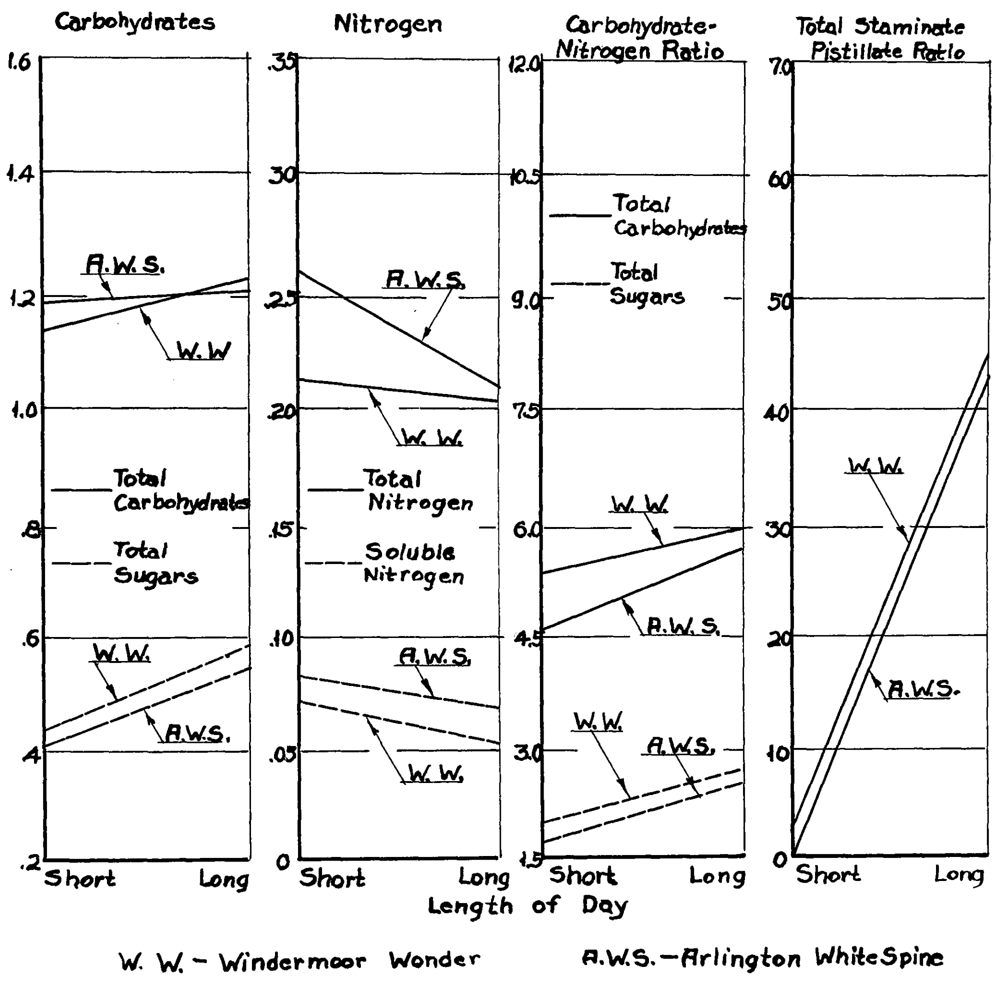
The figures show that the plants receiving high nitrogen possessed, in three of four comparisons, a greater percentage of total sugars and a lesser percentage of insoluble carbohydrates than those receiving low nitrogen. As would be expected, they had the greater percentage of both soluble and insoluble nitrogen. For both periods these high nitrogen plants also possessed the lower carbohydrate-nitrogen ratio. The lower carbohydrate-nitrogen ratio of the high nitrogen plants was largely due to their higher nitrogen content. This was more pronounced for the plants raised from May 22 to July 24. Since this period was characterized by longer days, higher light intensity, and higher temperature, it afforded greater opportunity for both carbohydrate manufacture and nitrogen utilization than the period from December 15 to April 15.

The results of experiments reported in Part I show that high nitrogen supply induced the development of a greater number of pistillate flowers than low nitrogen. In this connection the figures on chemical composition show that the more pistillate plants had a lower carbohydrate-nitrogen ratio than the more staminate plants in any comparison of two comparable lots. High nitrogen plants had a lower staminate-pistillate ratio and a lower carbohydrate-nitrogen ratio than low nitrogen plants for any one growing period. Similarly plants grown during the short days had lower sex and carbohydrate-nitrogen ratios than those grown during the long days.

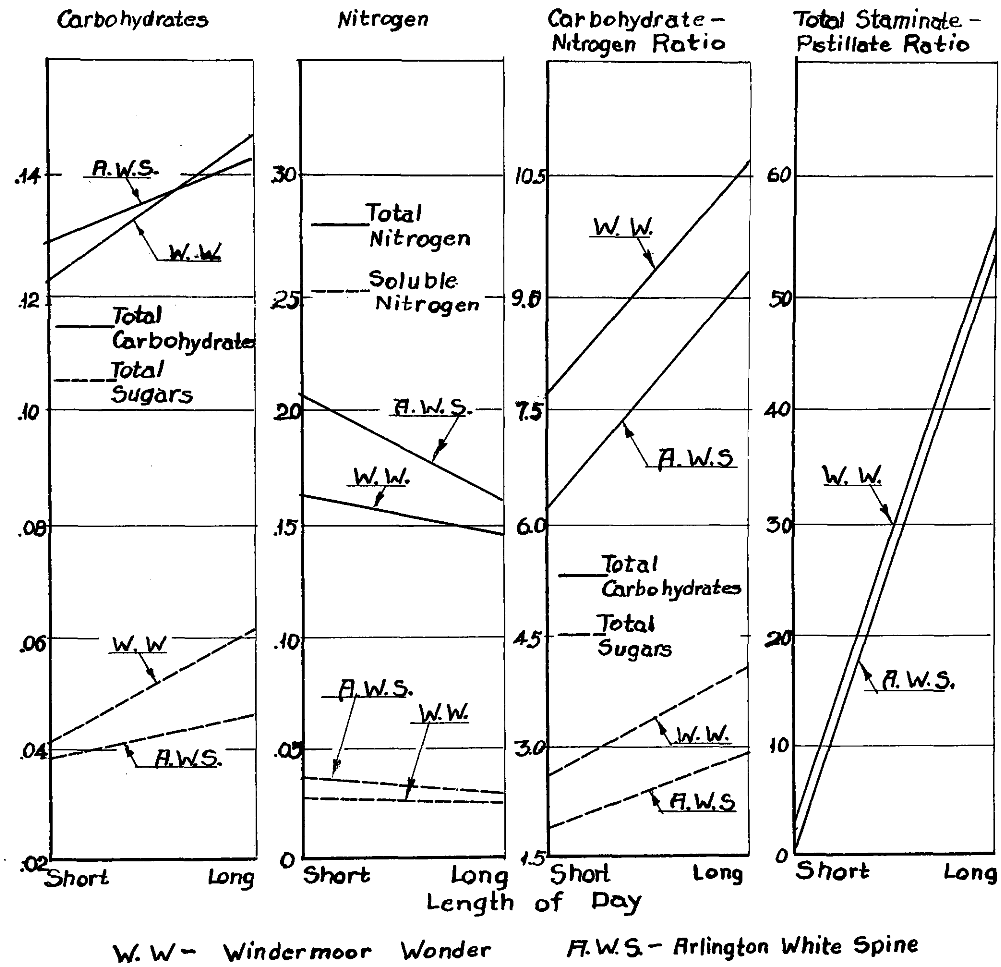
Many investigators believe that a greater abundance of nitrogen is necessary for the development of the female organs than for the development of the male forms. Murneek (44) found that the most conspicuous effect from the lack of nitrogen was a general increase in maleness in Cleome spinosa L. He believes that comparatively large quantities of nitrogen are necessary for the development of the ovarian tissue.

Varietal Differences

The varietal differences in total carbohydrate and nitrogen content, though small, are in most cases consistent. Arlington White Spine possessed a greater percentage of acid hydrolizable materials, soluble and total nitrogen, and a lesser percentage of free reducing substances, sucrose and starch. Its total sugar and total carbohydrate nitrogen ratio was correspondingly lower than than of Windermoor Wonder (Figures 8 and 9). These differences, particularly in total sugars, suggest a positive association with sugar content and with vigor of growth, sex expression, and catalase activity. Arlington White Spine always possessed lesser vigor, greater femaleness and lesser catalase activity than Windermoor Wonder. It also possessed a lesser total sugar content. In general, these results agree with the observation made by Tiedjens (61). He reported that varieties or strains predominately staminate were high in sugars and low in nitrogen, while varieties or strains predominately pistillate were both high in sugars and in nitrogen. On this basis, varieties predominately staminate would



Varietal differences in carbohydrates and nitrogen
High nitrogen supply
Fig. 8



Varietal differences in carbohydrates and nitrogen
Low nitrogen supply
Fig. 9

possess a wider carbohydrate-nitrogen ratio than those predominately pistillate.

Discussion

The differences in the carbohydrate and nitrogen constituents combined with the marked differences in catalase activity between tissue predominately male and that predominately female indicate that a different rate of metabolism exists between the sexes. Predominately male tissue always possessed the greater catalase activity and the greater percentage of carbohydrates, particularly total sugars. Since catalase is considered an index to metabolic activity, predominately male tissue should possess a greater metabolic rate. In these studies Windermoor Wonder possessed the greater sex ratio, the greater amount of total sugars, and the greater catalase activity than Arlington White Spine. On this basis, varieties or strains predominately staminate should possess a higher metabolic rate than those predominately pistillate and within any variety staminate tissue should possess a higher rate than pistillate tissue. Many investigators have noted a difference in metabolic rate between the sexes. Geddes and Thompson (16) cite many cases where the rate is higher in males than in females.

Practical Applications

The results show that the cucumber plant is rather sensitive to certain environmental conditions. Obviously the combined effects of light, both in terms of duration and intensity, and nitrogen supply determine, within limits, vigor of growth, sex expression and yield. For the maximum production of high grade fruit,growth should be continuous and at least moderately vigorous, since scant vegetative growth is associated with an excessive production of female flowers which will in turn produce a large number of nubbins. In the greenhouse fall crops are started under better light conditions than spring crops. They are likely to be the more vigorous and to possess a lesser number of female flowers. In this way though lesser numbers of fruits will develop they will be higher in yield, quality and market value. On the other hand spring crops are started under poorer light conditions than fall crops. Conversely they are likely to be the less vigorous and to possess relatively greater quantities of female flowers. Plants started in the fall can utilize more nitrogen than those started in the spring. This does not mean that nitrogen supply and the amount of light available are the only factors affecting vegetative growth, sex expression, and fruitfulness. It does mean, however, that applications of nitrogen should vary from season to season within the year and with the maturity of the plants.

General Conclusions and Summary

1. Experiments were conducted under greenhouse conditions from 1929 to 1931 to study the effects of season and nitrogen supply on the vigor of growth, sex expression, catalase activity, and carbohydrate and nitrogen content of certain varieties of cucumbers.

2. The varieties Windermoor Wonder, Extra Long White Spine, Deltus, Early Fortune and Arlington White Spine were grown from June 27 to September 6, from September 15 to April 15 and from February 17 to May 25, 1930-31. Windermoor Wonder and Arlington White Spine were

grown from July 29 to November 15 and from November 15 to April 15, 1929-30 in fertile and infertile soil and from December 27 to April 15 and from May 22 to July 24, 1930-31 in sand with phosphorus and potassium applied in the form of commercial fertilizers and with nitrogen applied in solution.

3. Although varietal standings were not the same within all growing periods, Windermoor Wonder, Extra Long White Spine and Deltus generally produced a higher staminate-pistillate ratio than Early Fortune and Arlington White Spine.

4. Periods of long days combined with high light intensity and high temperature favored the development of vigorous vegetative growth, a wide staminate-pistillate ratio, high catalase activity and a comparatively high total sugar and total carbohydrate-nitrogen ratio.

5. Periods of short days combined with low light intensity and low temperature favored the development of weak vegetative growth and the production of a narrow staminate-pistillate ratio. This type of growth and sex expression was associated with low catalase activity and a comparatively low sugar and total carbohydrate-nitrogen ratio.

6. In most cases differences between Windermoor Wonder and Arlington White Spine were significant. Windermoor Wonder generally possessed greater vegetative vigor, a wider staminate-pistillate ratio, greater catalase activity and a somewhat wider total sugar and total carbohydrate ratio than Arlington White Spine, regardless of the nitrogen supply and the growing period.

7. Evidently, vigorous vegetative growth, a relatively wide staminate-pistillate ratio, high catalase activity and a relatively wide carbohydrate-nitrogen ratio are positively associated. Conversely, weak vegetative growth, a relatively narrow staminate-pistillate ratio, low catalase activity and relatively narrow carbohydrate-nitrogen ratio are also positively associated.

8. High nitrogen supply greatly accelerated vegetative growth and greatly increased catalase activity. It generally produced more female flowers than low nitrogen. However, its effect on sex expression was less potent than that of the season.

9. On any one plant the leaves showed the greatest catalase activity followed by the unopened staminate, opened staminate and opened pistillate flowers in the order named. Male flowers always produced greater catalase activity than the female flowers regardless of the season and the nitrogen supply.

LITERATURE CITED

1. Allard, H. H. Flowering behavior of the hog peanut in response to length of day. Jour. Agr. Res. 44:127-137. 1932.

2. Arthur, J. M., Guthrie, J. D. and Newell, J. M. Some effects of artificial climate on the growth and chemical composition of plants. Am. Jour. Bot. 17: 416-482. 1930.

3. Atkinson, G. T. Experiments on the morphology of Arisaema triphyllum L. Bot. Gaz. 25:114. 1898.

4. Auchter, E. C. Is there normally a cross transfer of foods, water and mineral nutrients in woody plants? Md. Agr. Exp. Sta. Bul. 257. 1923.

5. Autenreith and Maux. Change of sex in Begonia. Gardeners' Chronicle (London) 3rd Series 26: 243. October 7, 1899.

6. Bouillenne, R. and M. La sexualite er les oxydations cellulaire chez Mercuriales annua. Bul. Acad. Roy de Belgeque. Class des Sci.:16 Ser. 5, 1047-1051. 1930.

7. Burge, W. E. and Burge, E. L. Effect of temperature and light on catalase content of Spirogyra. Bot. Gaz. 77:220-224. 1924.

8. Burge, W. E. and Burge, E. L. A study of the effect of hot and cold weather on the catalase of plant and animal in their relation to their respiratory metabolism. Am. Jour. Bot. 15:412-415. 1928.

9. Camp, W. H. Catalase activity and sex in plants. Amer. Jour. Bot. 16:221-224. 1929.

10. Camp, W. H. Sex in Arisaema triphyllum L. Ohio Jour. of Sci. 32:147-151. 1932.

11. Chance, H. L. The relation between catalase activity and vigor in inbred strains and crosses of corn seedlings. Amer. Jour. Bot. 18:696-703. 1931.

12. Erwin, A. T. and Haber, E. S. Species and varietal crosses in cucurbits. Iowa Agr. Exp. Sta. Bul. 263. 1928.

13. Ezell, B. D. and Crist, J. W. Effect of certain nutrient conditions on the activity of oxidase and catalase. Mich. Agr. Exp. Sta. Tech. Bul. 78. 1927.

14. Gardner, V. R. Studies in the nutrition of the strawberry. Mo. Agr. Exp. Sta. Res. Bul. 57. 1923.

15. Garner, W. W. and Allard, H. A. Effect of relative length of day and night and other factors of the environment on growth and reproduction in plants. Jour. Agr. Res. 18:553-606. 1919.

16. Geddes, P. and Thomson, J. A. The evolution of sex. Contemporary Science Series Res. Ed. Chas. Scribners Sons, New York.

17. Gourley, J. H. and Hopkins, E. F. Some relations of nitrogen to keeping quality of fruit. Proc. Am. Soc. Hort. Sci. 26:167-173. 1929.

18. Green, F. C., M' Endarfer, M. E., Orth, O. S., and Burge, W. E. Further study on the effect of summer and winter temperatures on the catalase of pine needles. Proc. Roy. Irish Acad. 39. 1929.

19. Gregory, F. G. The increase in area of leaves and leaf surface of Cucumis sativus. Ann. Bot. 35: 93-123. 1921.

20. Grünberg, O. An addition to the paper of Dr. Manoilov - Identification of the sexes in dioecious plants by chemical action. Bul. App. Bot. and Plant breeding 13(2): 1922-23.

Cited from Satina, S. and Demerec, M., Manoilov's reaction for the identification of the sexes. Science 62: 225-226. 1925.

21. Gustafson, F. G., Clark, I., Shaw, D. A., and Warweg, E. Catalase activity in tomato fruits at different stages of development. Plant Physiol. 7:155-160. 1932.

22. Haber, E. S. Catalase and oxidase of the tomato as influenced by soil reaction. Iowa State Coll. Jour. Sci. 3:29-39. 1929.

23. Harding, P. L. Relation of catalase activity to temperature, respiration, and nitrogen fertilization of Grimes Golden Apples. Proc. Am. Soc. Hort. Sci. 27: 37-41. 1930.

24. Hawthorn, L. R. and Wellington, R. Geneva, a greenhouse cucumber that develops fruit without pollination. Geneva (N. Y.) Agr. Exp. Sta. Bul. 580. 1930.

25. Heimlich, L. F. The development and anatomy of the staminate flower of cucumbers. Am. Jour. Bot. 14:227-237. 1927.

26. Heinicke, A. J. Catalase activity in dormant apple twigs; its relation to the condition of the tissue, respiration and other factors. Cornell Agr. Exp. Sta. Memoir 74. 1924.

27. Heinicke, A. J. Seasonal variation in the nutrient condition of apple trees, as indicated by catalase activity. Proc. Am. Soc. Hort. Sci. 25:234-239. 1928.

28. Higgins, J. E. and Holt, V. S. The Papaya in Hawaii. Hawaii Agr. Exp. Sta. Bul. 32. 1914.

29. Hooker, H. D., Jr. Certain responses of apple trees to nitrogen applications of different kinds and at different seasons. Mo. Agr. Exp. Sta. Res. Bul. 50. 1922.

30. Isbell, C. L. Growth studies of the Pecan. Ala. Agr. Exp. Sta. Bul. 226. 1928.

31. Jones, H. A. and Rosa, J. T. Truck crop plants. McGraw-Hill Book Co. 441. 1928.

32. Knight, T. A., cited from Geddes, P. and Thomson, J. A. The evolution of sex. Walter Scott Publishing Co., London and New York. 1908.

33. Knott, J. E. Catalase in relation to growth and to other changes in plant tissue. Cornell Univ. Agr. Exp. Sta. Memoir 106. 1927.

34. Knott, J. E. and Anthony, R. D. Catalase as an indication of fruit tree response to soil treatment. Proc. Am. Soc. Hort. Sci. 24:188-190. 1927.

35. Knott, J. E. Rapidity of response of spinach to changes in photoperiod. Plant Physiol. 7:125-130. 1932.

36. Kraus, E. J. and Kraybill, H. R. Vegetation and reproduction with special reference to the tomato. Oregon Agr. Exp. Sta. Bul. 149. 1918.

37. Laurie, Alex. and Poesch, G. H. Photoperiodism. The value of supplementary illumination and reduction of light on flowering plants in the greenhouse. Ohio Agr. Exp. Sta. Bul. 512. 1932.

38. MacDaniels, L. H. and Curtis, O. F. The effect of spiral ringing on solute translocation and the structure of the regenerated tissues of the apple. Cornell Agr. Exp. Sta. Memoir 133. 1930.

39. McClelland, T. B. Studies of the photoperiodism of some economic plants. Jour. Agr. Res. 37:590-603. 1928.

40. McPhee, H. C. The influence of environment on sex in hemp, Cannabis sativa L. Jour. Agr. Res. 28:1067-1080. 1924.

41. Malhotra, R. C. Can sex ratios be altered in dioecious plants? Am. Nat. 64: 470-473. 1930.

42. Manoilov, E. O. Identification of the sexes by chemical action. Bul. App. Bot. and Plant Breeding (Russian) 13. 1922-23.

43. Miller, J. C. A study of some factors affecting seed stalk development in cabbage. Cornell Agr. Exp. Sta. Bul. 488. 1929.

44. Murneek, A. E. Physiology of reproduction in horticultural plants. II. The physiological basis of intermittent sterility with special reference to the spider flower. Mo. Agr. Exp. Sta. Res. Bul. 106. 1927.

45. Murneek, A. E. Growth and development as influenced by fruit and seed formation. Plant Physiol. 7: 79-90. 1930.

46. Nightingale, G. T. The chemical composition of plants in relation to photoperiodic changes. Wis. Agr. Exp. Sta. Res. Bul. 74. 1927.

47. Osterhout, W. J. V. Note on measuring the relative rates of life processes. Science 48: 172-174. 1918.

48. Pope, M. N. Catalase activity in relation to the growth curve of barley. Jour. Agr. Res. 44:343-355. 1932.

49. Pritchard, F. J. Change of sex in hemp. Jour. Hered. 7:325-329. 1916.

50. Reid, M. E. Growth and nitrogen metabolism of squash seedlings. Amer. Jour. Bot. 16: 847-849. 1929.

51. Richey, F. D. and Sprague, G. F. Some factors affecting the reversal of sex in the tassels of maize. Am. Nat. 66: 433-443. 1932.

52. Robbins, W. W. and Jones, H. A. Further studies on sex in Asparagus. Proc. Am. Soc. Hort. Sci. 25: 13-16. 1928.

53. Rosa, J. T. Sex expression in Spinach. Hilgardia 1: 259-274. 1925.

54. Satina, S. and Blakeslee, A. F. Further studies on biochemical differences between sexes in plants. Proc. Nat. Acad. Sci. 13:115. 1928.

55. Satina, S. and Demeric, M. Manoilov's reaction for the identification of the sexes. Science 62:225-226. 1925.

56. Schaffner, J. H. Control of the sexual state of *Arisaema triphyllum* and *Arisaema dracontium*. Ohio Jour. Sci. 9:72-76. 1922.

57. Schaffner, J. H. The influence of relative length of daylight on the reversal of sex in hemp. Ecol. 4:323-334. 1923.

58. Schaffner, J. H. Control of sex reversal in the tassel of Indian corn. Bot. Gaz. 84:440. 1928.

59. Stout, A. B. Cyclic manifestations of sterility in *Brassica pekinensis* and *B. chiloensis*. Bot. Gaz. 73:110-132. 1922.

60. Tiedjens, V. A. Some physiological aspects of *Asparagus officinalis*. Proc. Am. Soc. Hort. Sci. 21:129-139. 1924.

61. Tiedjens, V. A. Sex ratio in cucumber flowers as affected by different conditions of soil and light. Jour. Agr. Res. 36: 721-746. 1928.

62. Tyson, J. The influence of soil conditions, fertilizer treatments, and light intensity on growth, chemical composition and enzyme activities of sugar beets. Mich. Agr. Exp. Sta. Tech. Bul. 108. 1930.

63. Urbain, J. A. Modifications morphologeques et anomalies florales consecutive a la suppression de l' albumen chez quelques plantes. Academie des Sciences Comples Rendus. 157:450-451. 1913.

64. Valleau, W. D. Sterility in the strawberry. Jour. Agr. Res. 12: 613-670. 1918.

65. Watts, V. M. Some factors which influence growth and fruiting of the tomato. Ark. Agr. Exp. Sta. Bul. 267. 1931.

66. Whitaker, T. W. Sex ratios and sex expression in the cultivated cucurbits. Amer. Jour. Bot. 18:359-366. 1931.

67. Woodruff, J. G. The development of pecan buds and the qualitative production of pollen. Ga. Agr. Exp. Sta. Bul. 144. 1924.

Acknowledgements

The writer is pleased to acknowledge his indebtedness to Dr. V. R. Boswell, U. S. Department of Agriculture, for suggesting the problem and for criticism of the manuscript; to Director J. R. Ricks, Mississippi Agricultural Experiment Station, for the privilege of organizing the experimental data and preparing the manuscript at the Mississippi Station; and to Professor R. V. Lott, Department of Horticulture, Mississippi State College, for reading certain portions of the manuscript.

Many thanks are also due Dr. H. B. Cordner, Department of Horticulture, College Park, Maryland, for assistance in setting up the catalase apparatus, and to Mr. J. B. Blandford, Superintendent of the Horticultural Experiment Station Grounds and Greenhouses, for the use of liberal space in the greenhouse.