Proceedings of the Iowa Academy of Science

Volume 25 | Annual Issue Article 29

1918

A Study of the Formation and Development of the Flower Buds of Jonathan and Grimes Golden in Relation to Diferent Types (Clover Sod, Blue Grass Sod, Clover Crop, and Clean Tillage) of Soil Management

R. S. Kirby
Iowa State College

A STUDY OF THE FORMATION AND DEVELOPMENT OF THE FLOWER BUDS OF JONATHAN AND GRIMES GOLDEN IN RELATION TO DIFFERENT TYPES (CLOVER SOD, BLUE GRASS SOD, COVER CROP, AND CLEAN TILLAGE) OF SOIL MANAGEMENT.

R. S. KIRBY UNDER THE DIRECTION OF J. N. MARTIN.

SUMMARY.

The data so far obtained are insufficient to warrant conclusions as to what is true as a rule. This summary simply states briefly what was found during 1916 and 1917 concerning the formation and development of flower buds in these two varieties of apples, growing on plots representing four types of soil management in the Council Bluffs orchard humus Experiments of the Sections of Pomology and Soils of the Iowa Experiment Station.

1. Flower buds were formed, that is, differentiated from leaf buds, earlier on sod plots than on plots receiving some cultivation each year.

2. The earliest time at which flower buds were formed occurred on clover sod, with a low percentage of soil moisture. Flower buds formed earlier on a clover sod than on a blue grass sod having slightly less soil moisture. On the other hand, flower buds formed earlier on a blue grass sod than on a clover sod having about 2½ per cent more soil moisture. These facts indicate two things: *first*, that the addition of nitrates in the clover sod causes the flower buds to form earlier; and *second*, that the amount of soil moisture is a very important if not the chief external factor in determining the time at which flower buds form.

3. The formation of flower buds began about the first of July on the plots where it occurred earliest and extended until the middle of September on the plots where it occurred latest, thus occupying a period of about two and one-half months. The time occupied by each tree in forming flower buds was about four weeks.

4. Trees in sod produced the largest proportion of flower buds and those in clover sod, which supposedly contained the most nitrates, produced a much larger proportion of flower buds than those in blue grass sod.

5. The period covering the time during which the different trees formed and developed their flowers extended from about the first of July, 1916, to May 17, 1917, thus being about ten months in length.

6. Apple flowers have two periods of rapid growth. The first one immediately follows the differentiation of the flower bud from the leaf bud, and during this period, which is about six weeks in length, the floral organs are differentiated. During the second period, which begins about six weeks previous to the opening and ends with the full expansion of the flower, the floral organs increase their size many times. During the time intervening between the two periods of rapid growth, growth continues but is slow.

INTRODUCTION.

This series of apple fruit bud investigations was started as graduate work under the direction of the senior author by F. M. Harrington of the Horticultural staff at the suggestion of S. A. Beach, Chief in Horticulture of the Iowa Experiment Station. The collection of material for this purpose was begun by T. J. Maney, now Chief of Pomology of the Station. Later the work passed into the hands of the junior author, R. S. Kirby, as a fellow in horticulture.

These investigations were inaugurated as a phase of the orchard humus project which is being carried on by the Pomology Section with the co-operation of the Soils Section of the station. This project was inaugurated in 1910 in an orchard near Council Bluffs which has been leased till 1925 for this purpose. It was initiated by and has remained under the general supervision of Professor Beach with the immediate management in charge of Chief Laurenz Greene for the horticultural staff. In 1917 Chief Maney succeeded Professor Greene in this work.

This orchard humus investigation is a modified continuation of the orchard humus project initiated by Professor Beach at the State Experiment Station, Geneva, New York, in 1903 and carried forward by him for three years before coming to Iowa. The results of that work have been reported by Hedrick (17) in New York Station bulletins 314 (1909), 375 (1914), and 376, (1914), and in other publications.

Owing to the close relation between the formation of flowers and the production of fruits, a good knowledge of the factors affecting the development of fruit buds is essential to a scientific

determination of the best methods of orchard management to secure regular and abundant crops. To add to our scientific knowledge of such factors has been the purpose of these investigations.

The Pomology Section is keeping very careful records of the soil moisture in the different plots of the orchard humus experiment and of the annual yield of each individual tree. These records have been open to the use of the authors in their interpretative study of the results of the different methods of soil management in the experiment plots on the development of fruit buds in the varieties of apple trees under observation.

REVIEW OF LITERATURE.

Of the many publications on bud formation only those most closely related to the work reported in this bulletin are reviewed.

Vincent (33) in 1884 studied the development and formation of flower buds of a number of common orchard fruits. He reported the relative development of flower buds as shown by measurements of floral organs, at different times from March 6 to July 24.

Goff (10, 11, 12, 13), one of the first to make a systematic study of the formation and development of apple flowers, reports as a result of his work in 1898 that in case of the Hoadley Apple flower and leaf buds were differentiated as early as June.

As a result of the second investigation, Goff found that flower buds may form in September as well as in July and suggests that flowers are formed as a result of a check in growth which may be caused by drought in summer or the cool nights of autumn. He further states that the flower buds are not structurally different from leaf buds but that they probably never revert back to leaf buds.

The results of his third series of investigations are summarized by the statement that embryo flowers may form on any tree from the time vegetative growth ceases till the middle of September.

In his fourth report which summarizes the results of his previous investigations on bud formation, the following conclusion should be noted: *First,* that the sap that goes to the undifferentiated buds must contain a certain amount of nutriment before it can form flowers; *second,* that the sap may become rich in nutriment by girdling below the bud or by the concentration

Most of the work here reported was done by the junior author while a fellow in the Department of Horticulture. Its success must be attributed to the immense amount of time and energy which he gave to the problem and to his cytological skill and excellent technique.—J. N. M.

of the sap due to the evaporation of the water through dry weather; and *third,* that, since every bud of the apple tree is a potential flower bud, the weather must have much to do in determining the number of flowers formed.

Drinkard (8), in 1909 to 1910, working in Virginia, studied in detail the development of the flower buds of three varieties of apples. He notes the following facts concerning the Oldenburg (Duchess) apple. The date of leaf and flower bud differentiation was as early as June 20. This was immediately followed by a period of active growth in which all floral organs except the pistil were formed by July 7 and all of the flower parts were formed by the first of November. In the following spring pollen grains were completely formed and the flowers were ready to open by April first. In conclusion the following statement is made: "The proper development of the fruit bud would therefore be influenced by factors which are brought to bear upon the tree prior to and during the period at which fruit-bud formation takes place. In the practice of such orchard operations as are designed to influence or control fruit-bud formation, it appears that such operations should be more effective in the spring and early summer than at other stages of development."

The truth of the last statement was verified by later experiments. In 1913 and 1915 Drinkard (9) conducted experiments to determine the effects of pruning, ringing, and stripping on the formation of fruit buds on the dwarf apple trees. The results indicated that spring pruning at the time of the resumption of growth retards the formation of fruit buds, while summer pruning the last of June greatly stimulated the formation of fruit buds. Fall pruning in November had little effect on bud formation. Stripping in June acted the same as pruning at that time. Ringing also stimulated bud formation when done after the leaves matured.

Remy (29) in 1911 studied relations existing between the fertilizers applied to the soil and the amount of nutritive substances in the various organs of the tree. One row of trees received a fertilizer containing all of the necessary elements while in the other rows nitrogen, potash, phosphoric acid, and lime, respectively, were withheld.

It was observed that a certain amount of nitrogen is necessary for the abundant development of fruit buds and that the ratios

between the various nutritive elements appear to exert some influence on fruit bud development.

Pickett investigated the effect of soil management on formation of fruit buds of the Baldwin apple. The results of the first paper (27) which were largely drawn from macroscopic study indicate that clean tillage induces the formation of many more fruit buds than sod culture. The two most important factors stimulating fruit bud production were, moisture and nitrogen, the nitrogen being added to the soil in the form of a cover crop.

Kraus (20) in his investigations on the morphology of the apple, in 1913 carefully worked out the development of the flower parts. In the summary he states that "All parts of the flower are cyclic in arrangement and that the succession of cycles is acropetal."

Kraus (21 and 22) describes the manner in which flower buds may be borne, in regard to the type of branch or spur. He further explains the injury to the fruit-bearing power of a tree caused by heading back in winter or thinning out and advocates summer pruning to increase the number of fruit buds. Considering the factors causing fruit bud formation he states, "Fruit bud formation is directly induced and the buds are dependent upon the conditions existing within the tree, and not by any system that may be hotly agitated today and abandoned tomorrow."

Bradford (4) in 1914 conducted investigations to determine the relation between the development and the position of buds on the tree of Yellow Newton. He found that fruit buds were differentiated earlier on spurs than on sprigs. The buds of old spurs that produced no flowers the spring of the current year showed the most uniformity in development. On those spurs which produced flowers the current year the buds showed much variation in development, but most variation in cases where the flowers failed to produce fruit.

A short consideration of the variation in the varieties was undertaken with the result that a wide range in the development of fruit buds was discovered, and attributed to varietal and individual factors.

Gourley (14) after his investigation to determine the response of the Baldwin apple tree to cultural treatments, states that the plots in the experiment where the moisture ran the lowest during the period of fruit bud formation, coupled with good growing

conditions earlier in the season, produced the largest number of buds and also that the yield in the "off" years of Baldwin apple trees can be materially improved by good cultural methods.

Magness (24) in 1916 conducted an extensive series of experiments to determine the influence of summer pruning upon the development of fruit buds in Oregon. He found that heading back in early summer had no influence on the number of fruit buds on spurs, but reduced the number of fruit buds formed on the one year wood. Also axillary leaf and fruit buds differentiated one month later than spur buds on the same tree.

Black (3) investigated the development of the Baldwin apple from the incipient shoot to the subsequent formation of the fruit. It was found that fruit buds may be anticipated by their position on the fruit spur, but are identified with certainty only by dissection.

Butler (5) has recently published a paper in which he divides branches on which fruit is developed into four classes, fruit branches, sprigs, darts, and spurs. A fruit branch is a leader in which the terminal and axillary buds in the upper two-thirds or thereabouts of its length become flower buds during the season of its development. The sprig is a shoot about a foot in length developing from two year old wood. The sprig not infrequently produced a flower bud the year of its formation. The dart is a very short spinelike branch with smooth bark. In some cases it may produce a terminal flower bud the first year but normally it does not produce flowers till the end of three years. The spur is a short, thick, brittle branch with much wrinkled bark and breaking readily with a smooth fracture. The spur usually develops from a bud formed during the previous season, that is. from two year old wood, and requires two season's growth to form a flower bud.

THE PURPOSE OF THE WORK AND METHODS EMPLOYED.

A microscopical study of buds from apple trees subject to different types of soil management should, if extended over a number of years and including a number of varieties, afford some data helpful in judging the influence of different types of soil management on the formation and development of fruit buds and thereby be of service in determining the merits of the different types of soil management in relation to the production of fruit.

The immediate purpose of the work reported in this bulletin, was to discover the ways in which different trees of the Jonathan and Grimes Golden growing on plots representing four types of soil management, (clover sod, blue grass sod, tillage and cover crop and clean tillage) differed in the time of forming flower buds, in the number of flower buds formed and in the rate of the development of flowers. In addition to the difference in the management of the soil, also such factors as the amount of soil moisture of the different plots and the growth and production of the different trees during previous years were considered in relation to the differences in the formation and development of flower buds.

At the time the orchard was leased it was eighteen or nineteen years old. It was perhaps in a little better condition than the ordinary neglected orchard of similar size and age. The soil of this orchard is known as Missouri loess. It has a texture almost as fine as clay but is very porous and affords excellent drainage and aeration. This soil is very deep and since it holds moisture well, it is an ideal orchard soil.

The part of the orchard included in the experiment was divided into six plots. These plots have received the following treatment since 1910.

Plot One (clover sod) has an east slope. Beginning with 1910 it was seeded to red clover but a poor stand resulted then and in the three next years; in the spring of 1914 it was seeded to white sweet clover. A very heavy stand was obtained in 1915 but the clover failed to reseed itself and in 1916 the plot was well covered with a good growth of weeds.

Plot Two (cover crop) is situated above plot one on the same east slope. Each year it receives weekly cultivations between May first and the last of July. Between July 25 and August 3 a leguminous or nonleguminous cover crop is sown. The leguminous crop is sown on even years. In 1915 rape and buckwheat were sown while in 1916 vetch was substituted for the buckwheat.

Plot Three (clean tillage) receives a weekly cultivation from early spring till late in July. The part of the plot on which the trees included in the experiment were located was near the top of the ridge on a southwest slope.

Plot Four (blue grass) was plowed in 1910 and seeded to blue grass. It required two or three years to get a blue grass

sod established. The grass is mowed and allowed to remain on the soil as a mulch. The trees in this plot from which the buds were studied are located on a southwest slope.

Plot Five (cover crop) receives same treatment as plot two. It has a southwest slope.

Plot Six (clover sod) receives the same treatment as plot one.

This work was a continuation of the bud study inaugurated by F. M. Harrington. The same trees which he had selected were chosen with the idea that his work could be used as a check on our results. These trees, consisting of one tree of the Jonathan and one of the Grimes Golden from each of the six plots. were carefully selected as representing the average growth and production of the trees of the respective plots.

In order to eliminate as much error as possible, due to a lack of uniformity in buds, all buds were collected from old spurs which bore no flowers in the spring of the current year. Also since the flowers of a cluster differ in development according to position in the cluster, only the terminal flower of the cluster was used in making comparisons.

Despite these precautions there still remains much chance for error. Buds on different spurs vary in time of formation and in rate of development. Hence the buds studied at successive collections, unless a large number of buds are included, vary so much in the proportion of backward and forward buds, that their average time of formation and rate of development may be far from the average of all the buds of a tree. Then there are a number of factors other than soil conditions, such as the health of trees, exhaustion from previously bearing a heavy crop, and individual characteristics that cause variation and make it impossible to draw conclusions except from a large amount of data.

At each collection ten buds were chosen from each of the twelve trees. The first collection was made on July 6, 1916, and during the following forty-two weeks, nineteen similar collections were made at intervals of approximately two weeks during active growth of summer, fall, and spring and at intervals of two to four weeks during winter when growth was inactive.

As soon as the buds were removed from the trees they were placed in labeled vials and immediately sent to the laboratory where all of the cutinized scales were removed, leaving only the vital parts of the bud and a very short peduncle to be killed.

Of the various reagents tried a modification of Drinkard's (8) formula for Gilson's mixture gave the best results in killing and fixing the material and was used throughout. The modification consisted of increasing the percentage of alcohol from ten to twenty-five to facilitate penetration through the pubescence of the buds. The material was left in the killing fluid from ten to twenty hours, the length of the period depending upon the size of the buds.

Dehydrating or the removing of all traces of water from the tissues was accomplished by means of increasing strengths of alcoholic solutions. Two hours was taken as the minimum time allowed for the material to remain in each solution.

In the 50 per cent, 60 per cent, and 75 per cent alcohols iodine was added to remove the mercury from the tissues, while the 85 per cent and 95 per cent alcohols contained 10 per cent of glycerine in which the buds were left for twenty-four hours to toughen the tissues and prevent brittleness, after which they were removed to absolute alcohol. The material was removed from absolute alcohol and run two hours in each of six solutions of different percentages of xylol which cleared the tissues and also prepared them for infiltration with paraffin.

The last two sets of buds were run through 25 per cent, 50 per cent, 75 per cent, and 100 per cent solutions of cedar oil for clearing, with the result that the material handled in this way was not nearly so brittle as the material cleared in xylol and could therefore be sectioned much thinner. This point was observed in running up material where thin sections were desired for the study of heterotypic mitosis.

It was found best to very gradually infiltrate the flower tissue with soft paraffin which was later replaced with medium and then hard paraffin (56°—58°C). The best results were obtained by imbedding the material in blocks of paraffin which were composed of four parts Leitz best grade of hard paraffin and one part Parowax. This mixture gave a grade of paraffin with a melting point of about 55°C. and with a toughness that the hard paraffin alone did not afford.

During the eight to ten hours that the material was in the paraffin oven the temperature of the oven was not allowed to rise over three degrees above the melting point of the paraffin used. This was very important because if the temperature was

allowed to go higher than three degrees above the melting point of the paraffin, the tissues of the buds became hardened and brittle and could not be sectioned.

By being very careful in running up the material, it was found possible to get good sections in paraffin from buds taken at any time during the year. By using cedar oil in clearing and dehydrating, the material was more easily sectioned and by the use of cedar oil it is probable that all could have been sectioned on the rotary microtome, whereas without the use of the cedar oil it was necessary to cut some of the buds during the winter with the slide microtome. In tracing the differentiation of flower buds from leaf buds and in studying the development of the floral organs the sections were cut from 10μ to 25μ. In studying the formation of sporogenous tissues the material was sectioned as thin as 8μ.

In general all but the last two sets were stained with Delafield's haematoxylin according to the procedure recommended by Chamberlin (6). It was found that ten minutes staining gave the tissues a heavy overstain which gave excellent differentiation to the different flower tissues when destained in 70 per cent acid alcohol. In the last two sets the iron alum haematoxylon facilitated the study of mitosis which was taking place at that time.

In order to make a detailed comparative study of the various stages of development shown by the slides, at first it was thought best to make camera lucida drawings (x60) of the various stages. After about two hundred different stages had been drawn and studied, it was found that measurements could be used quite well in comparing the relative development of buds. The floral organs develop acropetally and their primordia appear when the primordia of organs preceding them have reached a certain length. The width of the crown of leaf buds was found to be less than .14 mm. during the period that flower buds were being differentiated. When the crown of a flower bud attained a width of practically .27 mm., then the differentiation of the individual flowers began. From the time of its differentiation until the primordium of the calyx appeared, the terminal flower increased in width from .16 mm. to .24 mm. When the calyx primordium attained a height of .11 mm. and the receptacle a width of .34 mm. then appeared the primordium of the corolla closely followed by that of the stamens. The

primordia of the carpels appeared when the corolla and stamens had attained a height of about .10 mm. and the sporogenous tissue was differentiated in the upper anthers when the carpels were from .19 mm. to .24 mm. in height above the center of the torus. These measurements were found to be practically the same in both varieties of apples and no noticeable variations due to the different types of soil managements were observed. Since these measurements were found quite reliable, they were chosen in preference to drawings as a means of comparison. More than a thousand slides containing median longitudinal sections of as many flower buds were made and the measurements of each bud recorded.

RESULTS.

The results obtained from the microscopical study of the buds are given in tables I to IV inclusive. In these tables are recorded the measurements of the least and most advanced flowers found in the collections from July 20, 1916; to November 13, 1916. The number in the upper part of the square is the measurement of the least advanced bud in the collection made on the date designated at the left of the table, while the number at the bottom of the square is the measurement of the most advanced bud in that collection. The measurement of the floral organ last formed is the one recorded. For example, in the column under plot 1 of clover sod the terminal flower in the bud showing the least development had a width of only .16 mm., which is much less than the width of the flower at the time the calyx appears, while in the bud most advanced not only the calyx had appeared but the corolla was .02 mm. in height. In all of the flower buds collected on November 13, the carpels had appeared, and the sets of floral organs were thus complete. The empty squares at the top of Tables I and III, excepting the column under plot 5 of Table III, indicate that flower buds were not sufficiently advanced to be told from leaf buds. In a few squares there is only one number in which case only one flower bud was found among the ten collected or all were in practically the same stage of development. The measurements in table I show that on plot 1 of clover sod, the flower buds formed earlier and were more advanced on November 13 than were those on either of the other plots. In all of the other plots, including plot 6 of clover sod, the measurements show that flower buds were not formed until August and hence nearly a month later than on

TABLE I.

FORMATION AND DEVELOPMENT OF FLOWER BUDS IN THE JONATHAN.

Method of Management	Clover Sod								Cover Crop								Clean Tillage				Blue Grass			
Plot	1					6			2					5			3				4			
Date	I	K	C	O	I	K	C	O	I	K	C	O	I	K	C	O	I	K	C	O	I	K	C	O
July 20 1916	16		2																					
Aug. 2 1916	16	9																						
Aug. 18 1916		8	3		16 21								15 16				17				18	3		
Aug. 30 1916			6		18		1						19		6				6			2		
Sept. 15 1916			5 6			7 11			16 18					5 6			19	4				4 5		
Oct. 3 1916			11 16				2 4		4 6						4	5			4 5			5		2
Nov. 13 1916			16 22				3 16				2 6				10 16				2 13					3 19

The unit of measurement is .01 mm.
I—Width of the terminal flower.
K—Height of the calyx primordia.
C—Height of the corolla.
O—Height of the carpel primordia above the center of the torus.

TABLE II.

FORMATION AND DEVELOPMENT OF FLOWER BUDS IN THE JONATHAN.

Method of Management	Clover Sod		Cover Crop		Clean Tillage	Blue Grass
Plot	1	6	2	5	3	4
Date	0	0	0	0	0	0
December 9 1916	22 26	13 14	10 11	14 16	 11	13 21
January 11 1917	14 24	16 24	 12	12 14	12 13	17 24
January 30 1917	21 28	 29		11 21	17 21	 24
February 19 1917	12 27	16 24	11 21	12 22	6 20	13 22
March 23 1917	40 53	24 30	21 29	34 38	19 24	36 38
April 10 1917	86 Mother Cells Lose	80 Mother Cells		134 Tetrad	72 Synapsis	77 Mother Cells
Date of Blooming	May 9–17	May 9–17	May 10–17	May 9–17	May 10–17	May 10–17

The unit of measurement is .01 mm.
O—Height of the carpel primordia above the center of the torus.

TABLE III.

FORMATION AND DEVELOPMENT OF FLOWER BUDS IN THE GRIMES GOLDEN.

Method of Management	Clover Sod								Cover Crop								Clean Tillage				Blue Grass			
Plot	1				6				2				5				3				4			
Date	I	K	C	O	I	K	C	O	I	K	C	O	I	K	C	O	I	K	C	O	I	K	C	O
July 20 1916					16																			
Aug. 2 1916					22	3																		
Aug. 18 1916	24				17		1		22													19		
Aug. 30 1916		6			23		10			7	5						21				23	10		
Sept. 15 1916			4			4	10			4	6						16		6				6	
Oct. 3 1916				5			6	6												4				5
Nov. 13 1916				10 19				13 19												18				19

The unit of measurement is .01 mm.
I—Width of the terminal flower.
K—Height of the calyx primordia.
C—Height of the corolla.
O—Height of the carpel primordia.

TABLE IV.

FORMATION AND DEVELOPMENT OF FLOWER BUDS IN THE GRIMES GOLDEN.

Method of Management	Clover Sod		Cover Crop		Clean Tillage	Blue Grass
Plot	1	6	2	5	3	4
Date	0	0	0	0	0	0
December 9 1916	18 19	22 27	19		13 19	19 27
January 11 1917	18 22	18 20	13 19		19 21	16 20
January 30 1917	22	20 21	14		16 18	19 21
February 19 1917	16 22	24 30	21		20	24
March 23 1917	21 24	21 29	30			27 30
April 10 1917	80 Mother Cells	152 Tetrad			85 Mother Cells	63 Synapsis
Date of Blooming	May 9–16	May 9–18	May 9–18		May 9–18	May 9–18

The unit of measurement was .01 mm.
O—Height of the carpel primordia above the center of the torus.

Plot I. According to the measurements the flower buds were slightly more advanced on blue grass sod than on other plots excepting Plot 1 of clover sod.

In Table II, the relative development of the flower buds of the Jonathans from December 9 to April 10 of 1917, is shown by the relative lengths of the carpels of the terminal flowers. When the different plots are compared as to the shortest and longest carpels recorded on the different dates, it will be noted that with two exceptions this table is in accord with what is shown in Table I in reference to the relative development of buds on the different plots. The exceptions referred to occurred on April 10 on plat 5 cover crop, and plot 3 clean tillage. The bud containing a flower with some stamens in synapsis and recorded under clean tillage was an exceptional bud, for the bud least advanced was less developed than the buds least advanced on the other plots and the buds on the average were less developed than the buds on the other plots. But on plot 5 cover crop the buds collected on April 10 were on the average more developed than buds collected from other plots. Either the buds on this plot developed more rapidly than buds on other plots, during the latter part of March and early part of April, or the buds of this collection happened to be exceptional. Unfortunately no flower buds, which would have served as a check on plot 5, were found in the collection from plot 2, cover crop, on April 10. The dates of blooming were practically the same on all plots. The cool spring which retarded blooming and thereby afforded an opportunity for the flowers least advanced to catch up may account for this. It may be that there is a difference in the rate of development just preceding the blooming period due to different methods of soil management, and it is also possible that buds backward in development surpass other buds in rate of development just preceding the blooming period. From the two tables it is seen that the flower buds of the Jonathan developed most rapidly from the time of their formation to November, and from February till time of blooming. During the remainder of the season development was slow.

In tables III and IV are given the measurements of the least and most advanced buds of the Grimes Golden on the different plots. The trees of the Grimes Golden formed fewer flower buds than the Jonathan on the plots where there was cultivation and the measurements are less complete. The tree on plot

5, cover crop, formed no flower buds at all, and in two collections from plot 2 cover crop and in one collection from clean tillage all buds were leaf buds. According to the measurements flower buds formed earliest and led in development on sod the blooming period on plot 6 clover sod. On the remaining plots the flower buds formed slightly earlier and were slightly more advanced up till April 10 on the blue grass sod. These tables are in accord with those of the Jonathan showing that the flower buds formed earliest and lead in development on sod and also that there are two periods at which growth is more rapid. It should be noted, however, that in contrast to the Jonathan which formed flowers earliest on plot 1, the Grimes Golden on plot 6 formed flowers earliest. This shows that there is some other factor which is as potent as soil management in its effects on the time of the formation of flower buds.

The formation of sporogenous tissue began about November 13 and continued until February 19. The mother cells of the anthers began to form about April first. The order of the formation of sporogenous tissue in the different trees was as follows:

Grimes Golden, blue grass sod.
Jonathan, blue grass sod.
Grimes Golden, clover sod, plot six.
Jonathan, clover sod, plot one.
Grimes Golden, clover sod, plot one.
Grimes Golden, clean tillage.
Grimes Golden, cover crop, plot two.
Jonathan, clover sod, plot six.
Jonathan, cover crop, plot five.
Jonathan, clean tillage, plot three.
Jonathan, cover crop, plot two.

With the exception of the Jonathan on clover sod, plot 6, the sporogenous tissue appeared earliest on the sod plots.

From a study of the slides it was ascertained that the formation of flowers for the two varieties of trees took place in the various plots in the order as shown below.

Jonathan	Grimes Golden
1. Clover sod. Plot one.	1. Clover sod. Plot six.
2. Blue grass sod.	2. Blue grass sod.
3. Clover sod. Plot six.	3. Clover sod. Plot one.
4. Cover crop. Plot five.	4. Cover crop. Plot two.
5. Clean tillage.	5. Clean tillage.
6. Cover crop. Plot two.	6. Cover crop. Plot five (no flowers)

The number of flower buds in each collection was recorded and from these data the percentages of flower buds formed by

the two varieties on plots in sod and in cultivation were determined. The percentages are recorded in Table V and show with some exceptions that the percentages of flower buds were higher on sod.

TABLE V. PERCENTAGES OF FRUIT BUDS.

Kind of Soil Management	Clover Sod	Blue Grass Sod	Clover Sod	Cover Crop	Clean Tillage	Cover Crop
Number of plot.....	1	4	6	5	3	2
Percentage of flowers formed by the Jonathans	81	51	95	92	41	36
Percentage of flowers formed by the Grimes Goldens	100	72	92	0	20	38

SOIL MOISTURE CONSIDERED IN REFERENCE TO THE FORMATION AND DEVELOPMENT OF FRUIT BUDS IN THE JONATHANS.

Determinations of soil moisture made at different places show that there is considerable difference in the amount of soil moisture in different regions of the same plot. It so happened, however, that determinations were made within a few feet of the Jonathans during the summer of 1916. The results of these determinations are given in Table VI and are interesting when considered in connection with the formation and development of flower buds. It will be observed that the sod plots, 1 and 4, which are the plots where flower buds formed earliest and most abundantly, had the lowest percentage of soil moisture. Also on plot 6 where flower buds formed later than on plot 1 the percentage of soil moisture was relatively high. Thus on the plots where the soil moisture was low, the flower buds formed earliest and also most abundantly with the exception of the Jonathan on plot 5.

TABLE VI. PERCENTAGE OF SOIL MOISTURE ON THE DIFFERENT PLOTS IN THE REGION OF THE JONATHAN.

Method of Management	Clover Sod		Cover Crop		Clean Tillage		Blue Grass		Cover Crop		Clover Sod	
Plot	1		2		3		4		5		6	
Date	S	SS	S	SS	S	SS	S	SS	S	SS	S	SS
June 25, 1916	10.8	10.7	15.6	14.0	13.5	13.2	10.6	9.6	16.1	15.1	15.7	14.7
July 14, 1916	8.0	8.3	16.9	16.5	15.4	16.9	7.6	8.4	15.4	13.2	13.3	12.9
July 31, 1916	6.7	7.0	16.5	15.4	14.3	9.3	5.6	7.0	11.9	11.5	9.5	8.7
August 15, 1916	11.1	7.3	14.0	10.8	14.5	10.6	10.5	6.5	16.1	14.8	9.4	7.2
Average per cent	9.1	8.3	15.0	14.2	14.4	12 8	8.5	7.8	14.8	13.4	11.9	10.8

S—Surface soil.
SS—Suosoil.

GROWTH OF THE TREES AS RELATED TO THE SOIL MOISTURE AND FORMATION OF FRUIT BUDS.

In Table VII is recorded the growth of the trees in diameter and the average percentage of soil moisture for the different plots. It will be noted from a study of this table that growth

TABLE VII. RELATION OF SOIL MOISTURE TO GROWTH.

Method of Soil Management	Circumference Increase of the trees in inches 1916	Average Soil water content June 18 to Aug. 22 Per cent
Blue Grass Sod	.63	8.1
Clover Sod, Plot 1	.68	8.7
Clover Sod, Plot 6	.88	11.3
Clean Tillage	1.	13.6
Cover Crop, Plot 5	1.25	14.1
Cover crop, Plot 2	1.63	14.6

was directly related to the percentage of soil moisture. With the exception of the Grimes Golden on plot 6 as shown by Table III, the trees making the least growth were ahead in the formation and the development of fruit buds. It will be noted that although the flower buds formed earliest on clover sod, the blue grass sod had less moisture. This fact suggests that the amount of nitrates in the soil may affect the time of bud formation.

THE FRUIT CROP OF PREVIOUS YEARS AS RELATED TO THE GROWTH OF THE TREES AND THE FORMATION OF FRUIT BUDS.

In Tables VIII and IX are recorded the growth and crop of the individual trees on the different plots during the years of 1915 and 1916, the percentage of fruit buds which each tree produced in 1916 and the order in time of forming fruit buds.

TABLE VIII. RECORDS OF THE JONATHAN.

Method of Management	Clover Sod		Blue Grass		Clover Sod		Cover Crop		Clean Tillage		Cover Crop	
Plot	1		4		6		5		3		2	
	G	P	G	P	G	P	G	P	G	P	G	P
1916	.68	292	.63	13	.88	109	1.25	340	1.00	65	1.63	109
1915	1.44	848	1.44	252	.94	178	2.33	786	2.25	1058	2.56	614
Percentage of Flower Buds	81.		51.		95.		92.		41.		26.	
Order of Forming Buds	1		2		3		4		5		6	

G—Circumference increase of the tree in inches.
P—Production of the tree in pounds.

TABLE IX. RECORDS OF THE GRIMES GOLDEN.

Method of Management	Clover Sod		Blue Grass		Cover Crop		Clover Sod		Clean Tillage		Cover Crop	
Plot	6		4		2		1		3		5	
	G	P	G	P	G	P	G	P	G	P	G	P
1916	.50	84	.81	324	1.50	793	.81	374	.75	579	1.25	451
1915	.44		.50	483	.69	590		270	1.13	592	.75	29
Percentage of Flower Buds	100		72		38		92		20		0	
Order of Forming Buds	1		2		4		3		5			

G—Circumference increase of tree in inches.
P—Production of the tree in pounds.

It will be noted from Tables VIII and IX, that in most cases the trees forming flower buds earliest and most abundantly were those which grew slowly and bore a comparatively small fruit crop during the year 1916. One of the trees which was in part an exception was the Jonathan on plot 5. It formed flower buds late but abundantly, made considerable growth but bore a comparatively small crop of fruit. On the other hand the Jonathan on clean tillage produced a small percentage of flower buds although neither growth nor crop was large. But it will be noted that during 1915 the growth and production of this tree were remarkably high and the tree was probably in a state of exhaustion in 1916.

DISCUSSION.

The data given in the preceding pages show that the formation and development of flower buds in the two varieties of apples subject to four types of soil management were associated with a number of factors. Early formation and high percentage of flower buds were associated with a low percentage of soil moisture, small growth and the production of a small crop. Also the fact that buds formed earlier on clover where the soil moisture was greater than in blue grass suggests that the amount of nitrates may be a factor of considerable importance. It is likely, however, that the most important factor was the amount of soil moisture, which also affects the growth of the tree and probably the size of the crop at the same time it affects the formation and development of flower buds.

BIBLIOGRAPHY.

1. **Beach, S. A.,** Grimes Golden and Jonathan Description: Apples of New York, 1, pp. 153, 172, 1903.

2. **Bessey, C. E.,** The Botany of the Apple Tree: Ann. Rep. Nebr. State Hort. Soc., 1894

3. **Black, Caroline A.,** The Nature of the Inflorescence and Fruit of the Pyrus Malus: New Ham. Technical Bull. 10, pp. 519-546, 1916.

4. **Bradford, F. C.,** Fruit Bud Development of the Apple: Bull. Ore. Agr. Sta. 129, pp. 1-16, 1915.

5. **Butler, O.,** On the Cause of Ultimate Bearing in the Apple: Bull. Torrey Bot. Club, 44, pp. 85-96, Feb., 1917.

6. **Chamberlain, C. J.,** Staining Methods, in Methods in Plant Histology, 3d Revised Edition, 1915.

7. **Cranefield, F.,** Duration of Growth Period in Fruit Trees: Rep. Wis. Exp. Sta., 17, pp. 300-308, 1900.

8. **Drinkard, A. W., Jr.,** Fruit Bud Formation and Development: Ann. Rep. Vir. Exp. Sta., 159-205, 1909-1910.

9. **Drinkard, A. W., Jr.,** Some Effects on Root Pruning and Stripping on the Formation of Fruit Buds on the Dwarf Apple: Vir. Exp. Sta. Tech. Bull. 5, pp 96-120.

10. **Goff, E. S.,** The Origin and Early Development of the Flowers in the Apple: Rep. Wis. Exp. Sta., **16**, pp. 289-303, 1899.

11. **Goff, E. S.,** Investigation of Flower Buds: Rep. Wis. Exp. Sta., **17**, pp. 266-285, 1900.

12. **Goff, E. S.,** Investigation of Flower Buds: Rep. Wis. Exp. Sta., **18**, pp. 304-316, 1901.

13. **Goff, E. S.,** Origin and Development of the Apple Blossom: American Gardening, **22**, pp. 330, 346-347, 1901.

14. **Gourley, J. H.,** Studies in Fruit Bud Formation: New Hampshire Exp. Sta. Tech. Bull. **9**, pp. 1-79, 1915.

15. **Green, W. J., & Ballou, F. H.,** Orchard Culture: Ohio Agri. Exp. Sta. Bull. **171**, pp. 189-210, 1906.

16. **Halsted, B. D.,** Reserve Food Materials in Buds and Surrounding Parts. Mem. Torrey Bot. Club. **2**, p. 26, 1890.

17. **Hedrick, V. P.,** A Comparison of Tillage and Sod Mulch in an Apple Orchard: N. Y. Exp. Sta. Bull. **314**, pp. 76-132, 1907.

18. **Hedrick, V. P.,** The Formation of Fruit Buds: Western Hort. 1906, pp. 28-35.

19. **Jost, T. L.,** Causes of Flower Formation, Lectures on Plant Physiology. Authorized American Translation. pp. 363-365, 1907.

20. **Kraus, E. J.,** Gross Morphology of the Apple: Part 1. Oregon Agr. Col. Exp. Sta. Res. Bull. **1**, 1913.

21. **Kraus, E. J.,** A Study of Fruit Buds: Part 2. Ore. Ag. Exp. Sta. Bull. **130**, pp. 12-21, 1915.

22. **Kraus, E. J.,** Fruit Bud Formation Related to Orchard Practice: Proc. Wash. State Hort. Ass'n 12th Ann. Conv., 1916, pp. 24-29.

23. **Lazenby, Wm. R.,** Development of the Buds in Some of our Common Orchard Fruits: Proc. of Amer. Pom. Soc., 1899, p. 40.

24. **Magness, J. R.,** The Influence of Summer Pruning on the Bud Development of the Apple: Ore. Exp. Sta. Bull. **139**, pp. 46-67. 1916.

25. **Morgan, W. M.,** Studies in the Development of Fruit Buds. An Unpublished Paper Prepared at Cornell Univ. Cited by Drinkard et al., 1902.

26. **Pickering, S. U., & Duke of Bedford,** Effect of Grass on Fruit Trees: Woburn Exp. Fruit Farm. Rep. **13**, 1911.

27. **Picket, B. S.,** Fruit Bud Formation: New Hamp. Exp. Sta. Bull. **153**, pp. 1-37, 1911.

28. **Picket, B. S.,** Factors Influencing Formation of Fruit Buds in Apple Trees: Trans. Mass. Hort. Soc. Part 1, pp. 57-72, 1913.

29. **Remy, T.,** The Application of Nitrogen in Relation to Fruit Bud Formation: Mitt. Deut. Landw. Gessell. Vol. **28**, 416-421, 1913.

30. **Russell, E. G.,** Soil Conditions and Plant Growth, p. 73, 1912.

31. **Sanderson, E. P.**, Conditions which Affect the Time of the Annual Flowering of Fruit Trees: Wis. Exp. Sta. Bull. **137**, pp. 1-7, **1906**.

32. **Sorauer, P.**, A Treatise on the Physiology of Plants, pp. 147-148, **1895**.

33. **Vincent, M.**, Development of Fruit Buds in Some of Our Orchard Fruits, An unpublished thesis written at I. S. C. Ames, Iowa, **1884**.

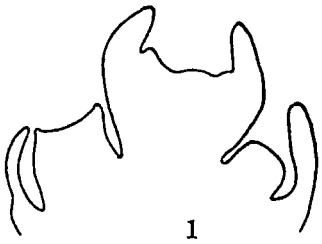
DEPARTMENT OF BOTANY,
IOWA STATE COLLEGE.

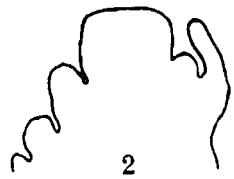
Description of Plate VII.

Camera lucida drawings showing the greatest development found on August 18, 1916.

Buds were in each case taken from,

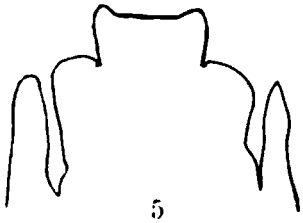
1. Jonathan tree growing in plot one. Clover Sod.
2. Grimes Golden tree growing in plot one. Clover Sod.
3. Jonathan tree growing in plot six. Clover Sod.
4. Grimes Golden tree growing in plot six. Clover Sod.
5. Jonathan tree growing in plot four. Blue Grass Sod.
6. Grimes Golden tree growing in plot four. Blue Grass Sod.
7. Jonathan tree growing in plot two. Cover Crop.
8. Grimes Golden tree growing in plot two. Cover Crop.
9. Jonathan tree growing in plot three. Clean Tillage.
10. Grimes Golden tree growing in plot three. Clean Tillage.
11. Jonathan tree growing in plot five. Cover Crop.
12. Grimes Golden tree growing in plot five. Cover Crop.

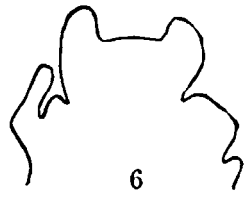

1


2


3

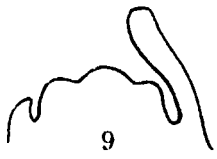

4

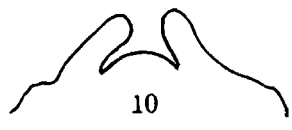

5


6

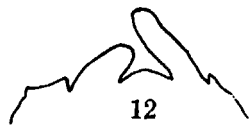

7


8


9


10


11


12