A FLOWERING HORMONE AS RELATED TO BLOOMING IN SWEETPOTATO WHEN GRAFTED ON MORNING GLORY

By

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PREFACE

In this study, Ipomoea tricolor, Cav. (morning glory) was found to be the most effective stock species in inducing flowering with Jersey varieties of sweetpotatoes. This result has not been previously reported. The grafting technique described in this paper is considered to be the most successful method for inducing flowering in Jersey varieties of sweetpotatoes. Undoubtedly, the knowledge gained in this study extends the possibilities for the improvement of sweetpotatoes by breeding.

The writer wishes to express his sincere appreciation to Dr. H. B. Cordner, Professor of Horticulture, for his many suggestions and guidance during the course of this study, and in the preparation of this thesis; to Dr. Frank B. Cross, Head of Horticulture Department, for his constant interest and assistance and to Professor Fred LeCrone, Professor W. R. Kays, Professor F. A. Romshe and all professors of the Horticulture Department for their constructive criticisms and suggestions. He is also sincerely grateful to Professor O. C. Schultz and Dr. A. R. Cooke, Dr. I. V. Holt and Dr. F. B. Struble of the Botany Department, Oklahoma A. & M. College for their invaluable information and suggestions.

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INTRODUCTION

The sweetpotato is an important food crop in all tropical as well as subtropical countries. It ranks next to the Irish potato in importance as a vegetable crop in the United States. The varieties of sweetpotatoes commonly grown in this country may be divided into two groups: (1) "dry fleshed" or Jersey type and (2)"moist fleshed" or "yam" type. The so-called "dry" and "moist" types are based on their cooking quality, particularly baking, not the percentage of water in the storage roots. The leading varieties of the first group are Big Stem Jersey and its sport Maryland Golden, Yellow Jersey (Little Stem Jersey), Orlis, a sport of Yellow Jersey and Nemagold a recently introduced variety developed by Dr. H. B. Cordner at Oklahoma A. & M. College. These varieties are commonly grown in the Northern and Eastern sections of the country. They have more or less uniform shape of roots, clustered close to the main stem of the plant and also high resistance to root knot nematodes. But they are, as a general rule, low in carotene content was well as yielding ability. The second group, is represented by the varieties: Porto Rico, Nancy Hall, Allgold, Redgold and Goldrush. Generally these "yam" type varieties possess the characteristics of high carotene content, high yielding ability and some of them are resistant to fursarium wilt. They also have some defects such as susceptibility to nematodes, irregularity in shape and size of roots. They are not well adapted to the northermost sweetpotato areas.

Unfortunately, most of the Jersey type varieties of sweetpotatoes bloom sparsely if at all under ordinary conditions in the continental United States. Consequently, very few successful crosses have been made

between Jersey and other varieties and breeding lines. This has imposed certain restrictions on the sweetpotato breeding program. The non-flowering characteristics of the Jersey types and certain breeding lines of the "yam" types is a difficult problem confronting present day sweetpotato breeders.

The purposes of this study are (1) to develop a technic of inducing flowering with certain non-flowering varieties and (2) to determine the factors that induce flowering in the grafted scions of non-flowering varieties of sweetpotatoes.

REVIEW OF LITERATURE

In 1926, Stout described flowering in the sweetpotato and pointed out that the non-flowering habit of certain varieties would be a difficult problem in sweetpotato breeding. In 1935, Tioutine (20) reported that considerable effort was made to induce flowering in certain varieties of sweetpotatoes that did not bloom under ordinary conditions but success was not obtained either by restricting the root system, grafting on the other species of Ipomoea or growing them as perennials under glass. He stated that the ability to produce flowers was a varietal characteristic. In 1937 and 1939, Miller (17, 18) described the methods of inducing flowering and seed production in sweetpotatoes developed at the Louisiana Station, where the sweetpotato vines are trained to a trellis under outdoor conditions. This method is not effective for the non-flowering varieties of the Jersey type. Warmke (22) in 1949, reported that Jersey varieties could be induced to bloom in Porto Rico using Miller's method. This is true only under subtropical conditions. Borthwick (1) in 1947, reported that he was unable to induce Jersey varieties to bloom by varying the nutrient supply, the photoperiod, the light intensity and temperature, or by girdling and grafting. In 1948, Hartman (13) likewise reported failure in a study of flower induction with Jersey varieties extending through a peri of eight years. In his study, treatments involving photoperiods, partial girdling of the stem, grafting young branches onto easy-flowering varieties, and other species of Ipomoea such as I. pandurata, and I. hederacea, (wild morning glory) and wide spacing of plants and pruning were all used. In 1948, Mikell, Miller and Edmond (16) reported the production of six flowers by the Jersey variety grown on a trellis out

of doors, but none of the flowers produced seed. In 1952, Mikell (15) reported using such chemical substances as 2,3,5-triiodobenzoic acid, 2,4-dichlorophenoxyacetic acid and alpha-naphthalenacetic acid on plants of Jersey varieties but none of these had any effect on the initiation or retardation of floral primordia formation. However, in 1948, Cordner and Sorensen (6) reported success in inducing flowering and fruit set with Jersey varieties grown in gravel culture. A promising variety--Nemagold* which was tested in cooperative Jersey trials as Oklahoma 46 for three years and is now widely grown in several states, was derived from this cross. In 1950, Culbertson (8) reported that sweetpotatoes in Japan were induced to bloom by grafting them on I. Bona-Nox (moonflower). Recently, Kehr, Ting and Miller (14) in Louisiana and Zobel and Hanna (23) in California also reported success in inducing flowering of Jersey sweetpotato varieties by grafting them on I. carnea and I. purpurea respectively. The success of their efforts was attributed to the accumulation of carbohydrates in the sweetpotato scion which is supported by a root system incapable of forming storage roots.

The literature on flowering in plants in relation to growth substances and flowering hormone is so extensive that it is not possible to present a full review of this field here. However, a few papers vital to the subject at hand should be mentioned.

As early as 1880 the famous German botanist Julius Sachs suggested that flower forming substance existed in plants (as reported by Tukey(21)). This flower forming substance was also tentatively designated by Cajlachjan (2,3) in 1937 as "florigen". At the present time, this flower forming substance has not been completely isolated and identified although reports

* P-47 (yam type) X Orlis (Jersey type)

by Roberts (19) indicate that certain substances extracted from flowering branches may induce flowering in other plants. The possibility of a flower forming substance in plants has more recently been proposed by investigators (4, 9, 10, 11, 12) and some of these refer to this substance or substances as "florigen".

In this paper the term "florigen" will therefore be used to designated this flower inducing substance or substances which presumably originate in the leaves of the morning glory plant and are readily translocated to the sweetpotato scion where they are effective in promoting flower bud initiation.

SPECIAL GRAFTING TECHNIQUE

The cleft graft method was used through the experiment. Briefly the technique used in this experiment consisted of the following steps:

1. Morning glory seeds were sown in vermiculite, and the seedlings transplanted to fertile soil in 3-inch pots 7 to 9 days after sowing.

2. When the seedlings had developed 5 to 7 nodes, they were ready for grafting (Fig. 11).

3. A strong terminal stem of the sweetpotato ½ to 1 inch long was used as a scion and cut to form a triangular wedge necessary in making a cleft graft.

4. In preparing the morning glory seedlings for grafting the stem terminal was cut off and the stem split longitudinally downward about ¼ inch to provide for the insertion of the scion.

5. The scion was then inserted into the stock and the graft union tied tightly with a sisal fiber.

6. The grafted plants were then kept in a propagating box for from 5 to 10 days depending on seasonal conditions.

7. As soon as the graft union had become well established the plants were removed from the propagating box and transplanted to 6-inch pots. At this time the sisal fiber were removed from the graft union.

8. The vines of grafted plants were trained to stakes 2 to 3 feet long and kept under favorable growing conditions on the bench in the greenhouse.

EXPERIMENTAL PROCEDURES AND RESULTS

1. Effect of Root-stock Species

Fifteen related species forming nonstorage roots were used as stocks, eight of which were introduced recently from the Carribean area by the USDA and still await identification. P-47 (easy-flowering variety of *I. batatas*) was also used as a stock. The known species include *I. repens* (chinese water spinach), *I. tricolor*, Cav. (morning glory), *I. purpurea*, Lam., *I. hederacea*, Jacq. (wild morning glory), *I. Nil*, Roth, *I. batatas*, Lam. (sweetpotato), *Quamoclit pennata*, Bojer., (cypress vine), and *Calyonction aculeatum*, House (*I. Bona-Nox*). The eight recent introductions are designated by Oklahoma accession numbers XO-1, XO-2, XO-4, XO-5, XO-8, XO-9, XO-10, XO-19. Orlis (asport of Yellow Jersey) was used as grafted scion and 5 to 10 plants of each species were grafted.

The results of this test (Table 1) suggest that the absence of storage roots in the understock per se will not assure blooming in the sweetpotato scion. All but one of the 16 species used in these grafting tests were of the nonstorage root types. Only four species, *I. tricolor*, *I. purpurea*, *I. Nil* and *I. hederacea* were found effective in inducing flowering. It is interesting to note that when the sweetpotato scions bloomed, ungrafted plants of the stock species were also blooming profusely. However, blooming in the stock species alone will not produce bloom in the sweetpotato scion since Orlis scions failed to bloom on profusely blooming plants of *I. batatas* and *Quamoclit pennata* and moderately blooming plants of *I. repens*.

Table 1. Flowering Response of Orlis Scions as Affected by Grafting on Different Species

Stock used	Date of grafting (1953-54)	Flowering condition of stock species*	Flowering Response in Orlis Scion
Group A. (nonstorage root)			
I. repens	October	moderate	none
I. tricolor	October	many flowers	many
	November	many flowers	many
I. purpurea	September	many flowers	many
I. hederacea	October	many flowers	many
	March	many flowers	none
I. Nil	September	many flowers	many
	March	many flowers	none
Quamoclit pennata	October	many flowers	none
	March	many flowers	none
XO-1 (20916)**	March	none	none
XO-2 (209127)	March	none	none
XO-4 (209130)	March	none	none
XO-5 (207818)	March	none	none
XO-8 (207821)	March	none	none
XO-9 (207822)	March	none	none
XO-10 (207823)	March	none	none
XO-19 (209319)	March	none	none
Group B. (storage root)			
I. batatas (P-47)	October	Many flowers	none

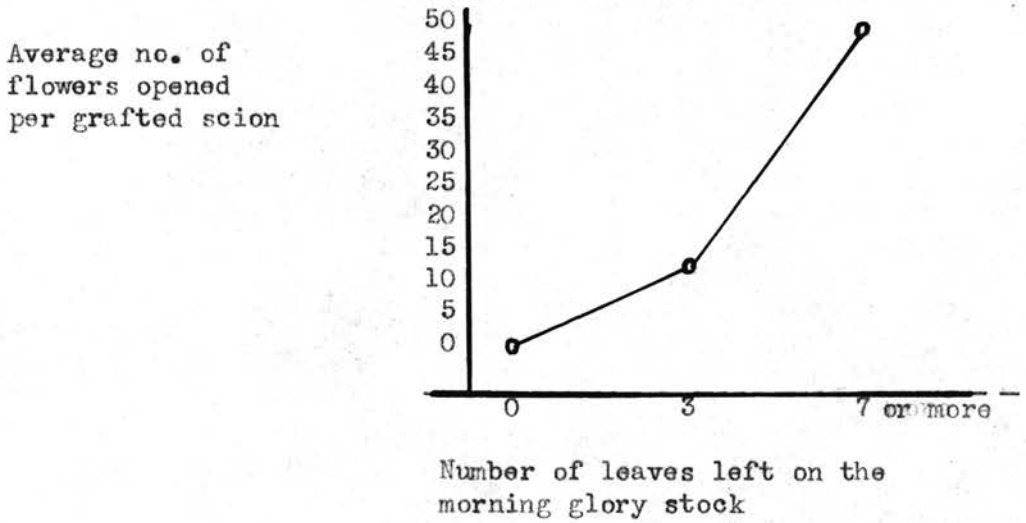
* Extent of flowering in normal (ungrafted) plants grown as control.
** U. S. Plant Introduction Numbers.

2. Effect of Defoliation of Root-stock Plant

In this test Orlis scions were grafted on stock plants of morning glory (I. tricolor, var. Heavenly Blue) with varying number of leaves, that is, none, 3, and 7 or more. Five to ten grafts were made in each group during October and November. Set of fruit on the morning glory stocks was prevented by removal of flower buds. The number of flowers that opened on the sweetpotato scion of each grafted plant was recorded. In this test, the flower buds appeared on the scion about 30 days after grafting and blooms appeared in about 60 days. Flowering usually was initiated in the sweetpotato scion at the seventh node and continued for 3 to 20 nodes, depending on the number and the continued vigor of the leaves on the morning glory stock. As the leaves of the morning glory stock became yellow with age and dropped off, the scion of the non-flowering sweetpotato reverted to the vegetative phase of growth and remained so indefinitely.

The results of this test (Fig. 1) indicate that the number of flowers that appeared on the Orlis scions varied directly with the number of active leaves on the morning glory stocks. No flower buds appeared on the grafted scions in the absence of leaves on the understock. It appears that there may be a chemical substance produced in the leaves of the morning glory which is translocated to the scion of sweetpotato that induced blooming. Since this chemical substance is responsible for flowering in the sweetpotato it may be referred to as a flowering hormone or flower inducing substance. This substance might well be the same type as that which was tentatively designated as "florigen" by Cajlachjan.

Figure 1. Relation Between the Number of Flowers Opened on the Orlis scion and the Number of Leaves on the Morning Glory Stock (grafts made in October and November)



3. Upward and Downward Movement of Flower Inducing Substance in the Plant

In the previous test, it is quite evident that the flower inducing substance or "florigen" moved upward thru the graft union to induce the sweetpotato scion to bloom. In this test a segment of morning glory with 4 to 5 leaves was grafted on a sweetpotato stock. Two weeks after grafting, flower buds appeared on the sweetpotato as shown in figure 2. This indicates that the "florigen" may move downward as well as upward in inducing the sweetpotato to bloom. Other grafts with inter-stocks of morning glory stems were made to demonstrate simultaneous movement of "florigen" in both directions in the grafted plants. When the leaves were cut off from the segment of the inter-stock, no flower buds appeared on the sweetpotato, either above or below the inter-stock (Fig. 3).

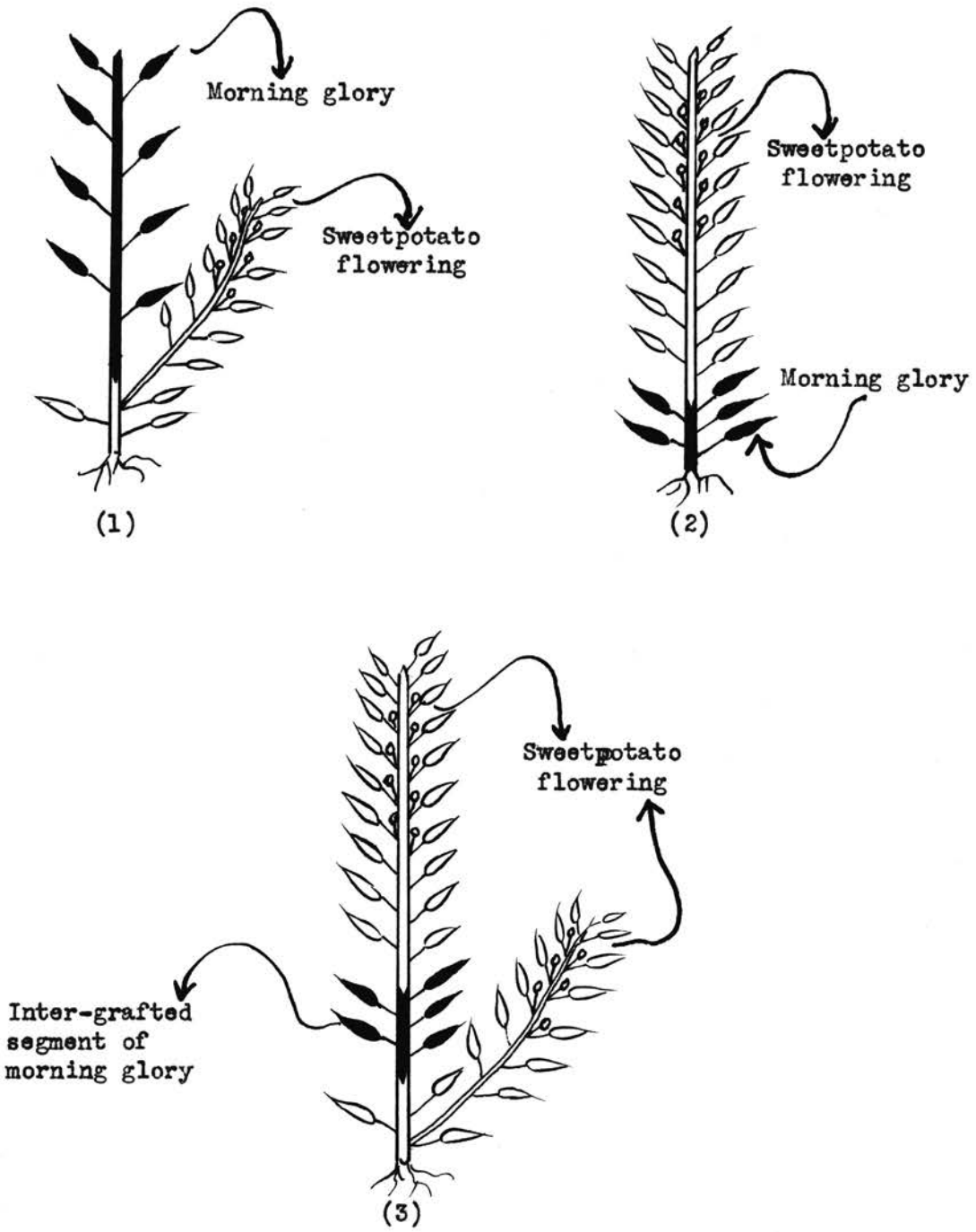


Figure 2. (1) Flowering hormone moved downward into sweetpotato stock
(2) Flowering hormone moved upward into sweetpotato scion
(3) Moved in both directions (grafted in September)

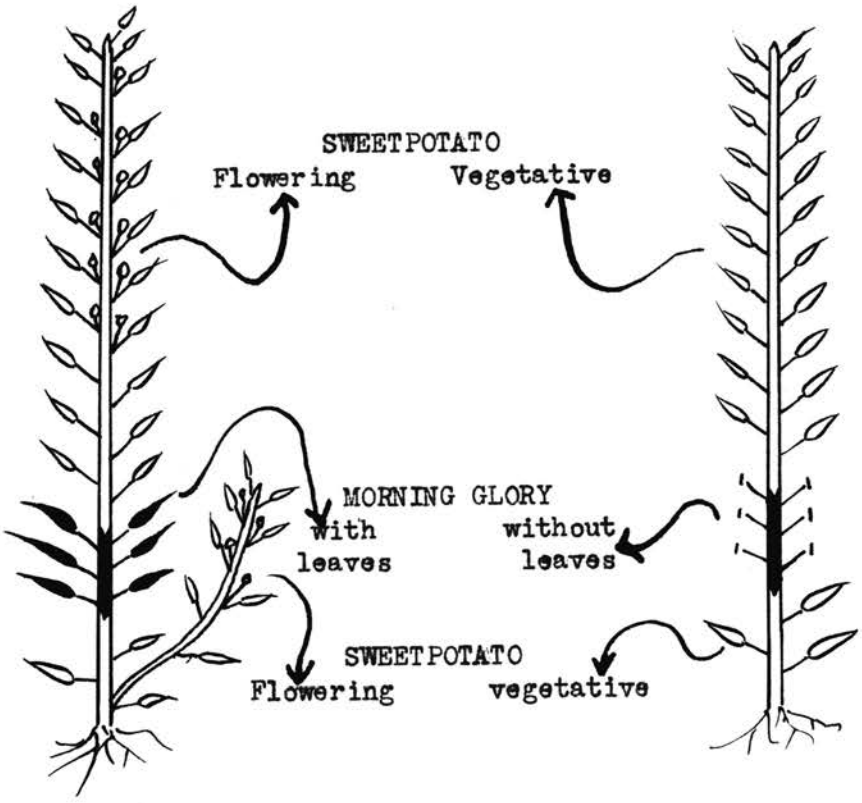


Figure 3. The intergrafted segment of morning glory stem with leaves will induce the sweetpotato to bloom above and below. Without leaves this stem of morning glory is ineffective. (grafted in September)

4. Interference of Translocation of Flower Inducing Substance by Heating and Girdling

The Orlis variety was grafted on the morning glory stock and in this test the leaves of the morning glory were confined to a lateral branch. As soon as the flower buds appeared on the sweetpotato scion, the base of the lateral branch of the morning glory was treated by heating with hot water at approximately 90° C. As a result of this treatment, the sweetpotato scion ceased to initiate flower buds and some of the flower buds which had appeared on the scion aborted gradually after the treatment (Fig. 4). The same result was obtained by girdling the lateral of the morning glory stock.

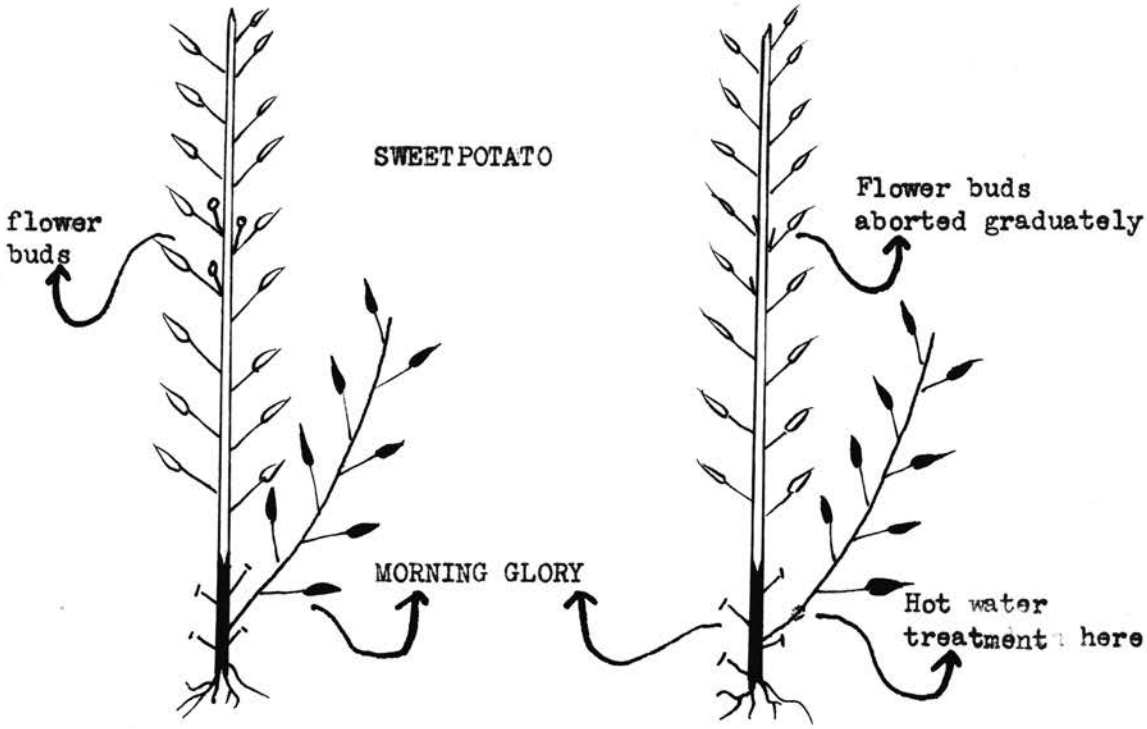


Figure 4. Translocation of flowering hormone can be prevented by hot water treatment. Left; the flower buds began to appear on the sweetpotato scion after grafting. Right; the flower buds aborted graduately after hot water was applied to the stem of morning glory. (grafted in October)

5. Flower Inducing Substance are Monopolized by Fruit Developing on the Morning Glory Stock

The Orlis variety was again used as grafted scion. Fourteen grafts were made and divided into two groups of seven plants each. In one group, fruit set on the morning glory stock was prevented in the other, fruit set was allowed to take place.

The results (Fig. 5) show that flowering of the sweetpotato scion was greatly favored by the defloration of the morning glory stock since an average of 46 opened flowers per scion resulted. When fruit set was permitted on the stocks the scions bloomed sparsely if at all (the average was 5 blooms per scion). Is it possible, therefore, that the growing fruits monopolized the flower inducing substance provided by the foliage of the stock to the extent that flower initiation in the scion was retarded or inhibited entirely?

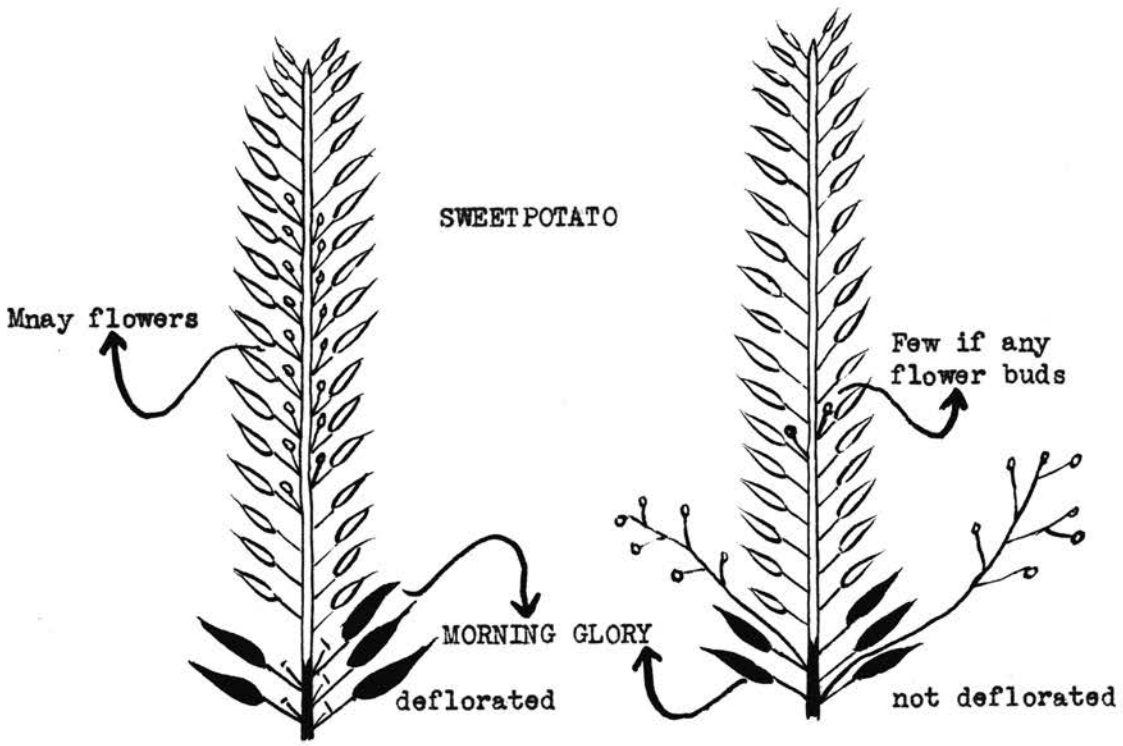


Figure 5. Growing fruits on the morning glory stock monopolized the flowering hormone to the extent that flowering in the sweetpotato scion was reduced or prohibited entirely, (grafted in October)

6. Flower Inducing Substances - Universal or Specific?

In addition to the sweetpotato, several related species of plants were used as scions grafted on *I. tricolor* to note any similarity of flowering response. The normal plants of these related species remained in a nonflowering condition for the duration of this test period. The results (Table 2) indicate that the "florigen" manufactured in the leaves of this species of morning glory would not only induce flowering in sweetpotatoes but also in other related species. To this extent it seems that the flower inducing substance or substances are universal. However, all the species used as grafted scions in this test belong to the same genus *Ipomoea* of Convolvulaceae. Owing to the difficulty of obtaining successful grafts between plants in different families, the present data are not sufficient to justify the conclusion that the "florigen" manufactured in the morning glory leaves will also induce blooming in the plants of other families. Therefore, the question "flower inducing substances- universal or specific" still awaits further investigation.

Table 2. Flowering Response of Different Related species When Grafted on I. tricolor

Species used as scion	Flowering condition on its own root at the time of grafting	Flowering response after grafting on I. tricolor
XO-1 (I. quinquefolia)	not flowering	many flowers
XO-2	not flowering	many flowers
XO-3	not flowering	many flowers
XO-4	not flowering	many flowers

7. Level of Flower Inducing Substance in Morning Glory as affected by the Environmental Conditions

In this test, the morning glory and Orlis were used as grafted stocks and scions respectively. Five to ten grafts were made at about monthly intervals throughout the year (October, 1953 to September, 1954). All grafted plants were kept under favorable growing condition on the bench of the greenhouse throughout the experimental period. The plants were also maintained with as many leaves as possible on the understock. The number of opened flowers per grafted scion, node at which the first flower bud appeared, date of first flower bud and the date of the first blooming on the scion, and the number of the flowering nodes per grafted scion were recorded. These data are shown in Table 3.

The non-flowering varieties of sweetpotatoes could be induced to bloom only when the grafts were made during the period September thru April and no flower buds appeared on scions which were grafted from May thru August. The number of opened flowers on the scions decreased from 58 in September to 3 in April. The first flower buds usually appeared on a node between the 7th to 13th on the grafted scions. The first flower buds appeared on scions about 13 days after grafting when the grafts were made in September and about 35 days on scion grafted in December and January. It appears that during June and August when the temperature in the greenhouse usually rose to 100° F. or higher and the light intensity was very high, "florigen" level was low or was not synthesized under these conditions and therefore, the plants remained vegetative. During October, November and December the temperature ranged between 65° and 85° F. and the light intensity was moderate. Such environmental conditions apparently are favorable for the synthesis of "florigen" in the morning glory leaves. Therefore, the number

of opened flowers per grafted scion during this period was the highest during the years. The number of flowers produced by the grafted scion may by logically used as an index of the amount of "florigen" being synthesized in the morning glory leaves of the stock at different seasons (Fig. 6).

Table 3. Flowering Response of Orlis Scion When Crafted on *I. tricolor* at Different Seasons

Date of grafting	Node on which the first flower buds appeared	No. of days: grafting to first flower bud	No. of days: grafting to first open flower	No. of flowers per scion	No. of flowering nodes per scion
October	7 to 13	30	60	49	21
November	7 to 12	32	70	40	18
December	8 to 14	35	83	34	15
January	9 to 12	35	80	24	11
February	8 to 13	32	70	28	12
March	7 to 12	28	62	21	8
April	7 to 13	18	50	3	5
May	0	0	0	0	0
June	0	0	0	0	0
July	0	0	0	0	0
August	0	0	0	0	0
September	9 to 10	13	37	58	25

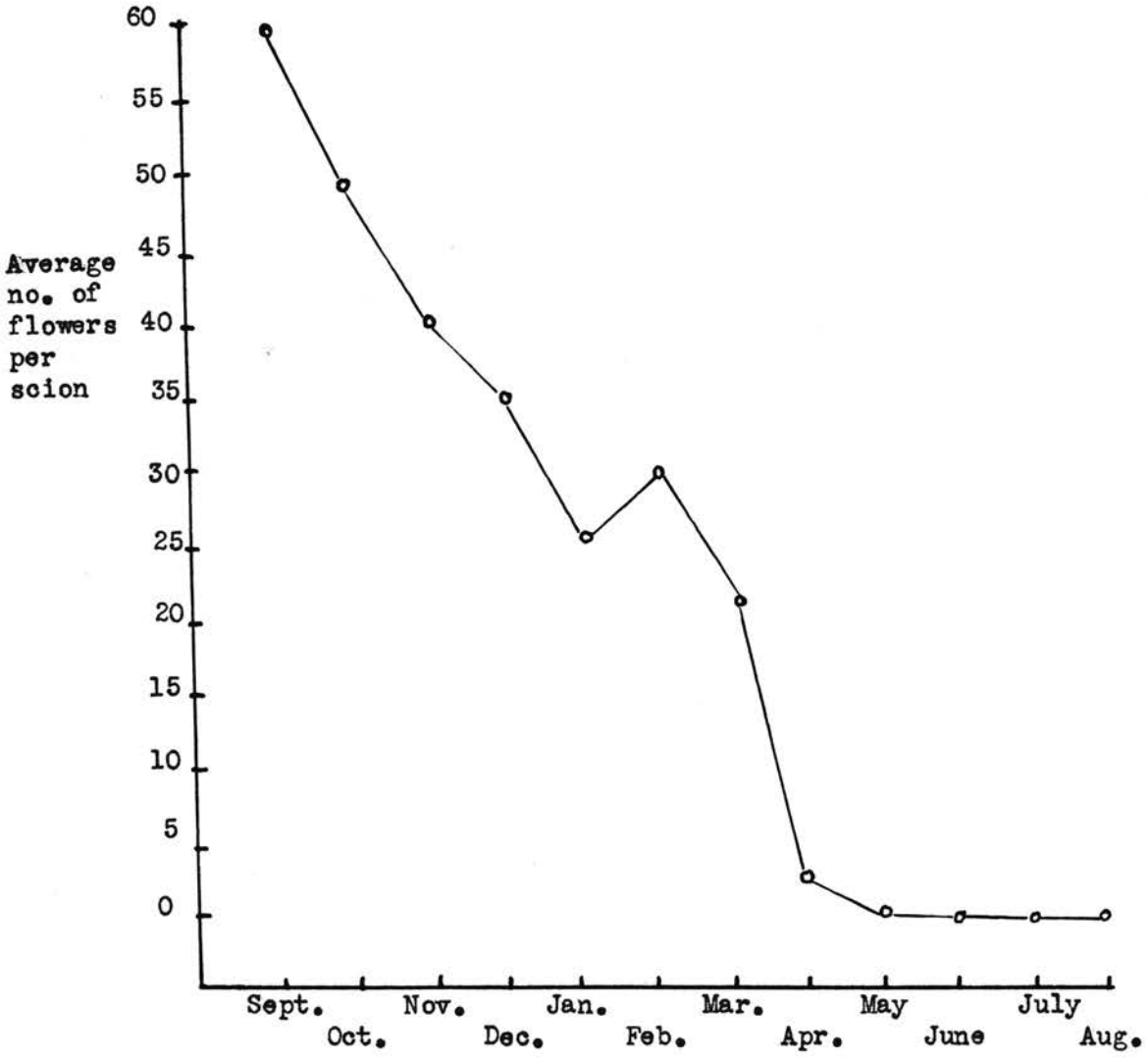


Figure 6. Flowering response of Orlis sweetpotato scions grafted on the morning glory stock at different seasons.

8. Level of Flower Inducing Substances of Morning Glory as Indicated by Its Flowering Behavior

As the morning glory plants were grown for the seasonal grafting tests (described previously), some plants were kept and observed as ungrafted controls. Special attention was given to the mode of flowering of these plants. It was observed that the flowering behavior of the morning glory plants changed with different seasons. During November December and January, the morning glory inflorescences consisted of 6 or more flowers and the plants were strongly determinate with the lateral shoots ending in flower clusters. During April and May and also during late August and early September, these check plants produced only one or two flowers at each node. In the summer (late June, July and early August) they remained entirely vegetative.

As shown by figure 7, the effectiveness of the morning glory stocks in inducing flowering in sweetpotato scions was closely related to the intensity of flowering of the morning glory plants. For example, during the period late September to early April the morning glory stock was effective in inducing blooming in the sweetpotato scion while late April and thru the middle of September it was ineffective. It should be noted that during the period late April to early June, the morning glory plant was blooming only sparsely and at this time it was ineffective in inducing blooming in the sweetpot to. The same relationship was found during the period late August to mid-September. Thus it was apparent that when the morning glory plant was blooming most intensively it was most effective. Conversely, when the morning glory plants bloomed only moderately or were entirely vegetative, they were without influence on the flowering of the sweetpotato scions.

This relationship may help to account for the failure of stocks of free-flowering sweetpotatoes to induce non-flowering sweetpotato scions to bloom. It appears that the level of the "florigen" in the free-flowering variety is inadequate to provide the flower inducing substances to the scion in quantities sufficient to cause flower bud initiation.

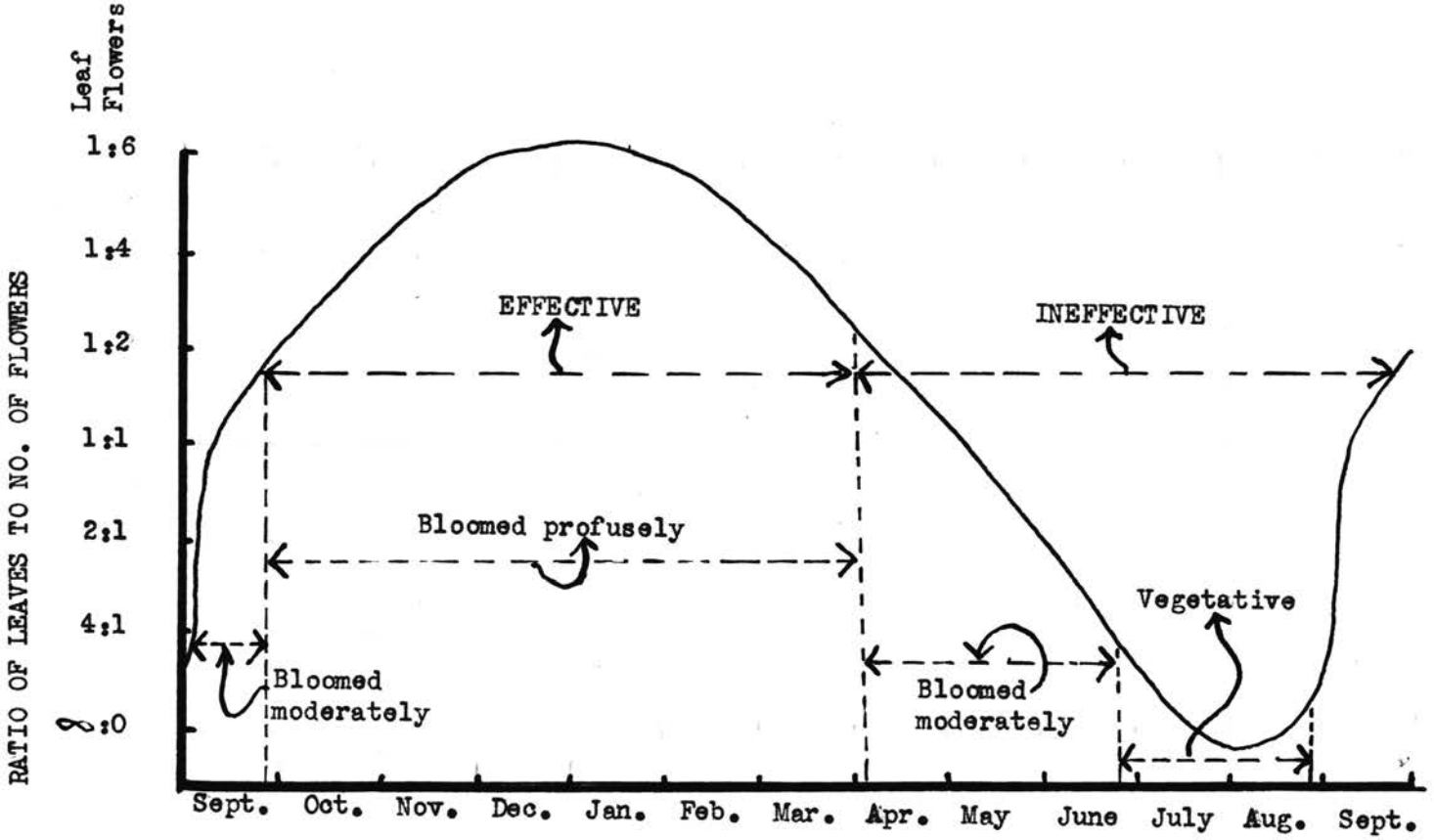


Figure 7. Flowering conditions of morning glory plants as related to their effectiveness in induction of flowering with sweetpotato at different seasons.

9. Flowering Response of Scions of Different Varieties of Sweetpotato When Grafted on I. tricolor

In this test the Orlis, Nemagold and P-114 sweetpotatoes, which are rated as the most difficult to induce to bloom under Oklahoma conditions (7), were used as grafted scions. The morning glory stock plants on which the different varieties were grafted were uniform with reference to the number of leaves and total absence of flowers.

The results (Table 4) show marked varietal differences in the number of opened flowers on the scions when they were grafted on morning glory stocks having a comparable numbers of leaves. Many more flower buds and flowers appeared on scion of Orlis and Nemagold than on those of P-114. It appears that the latter variety is more strongly vegetative than the former variety.

Table 4. Flowering Response of the three Jersey Varieties When Grafted on the Morning Glory Stock (grafted in Oct. and Nov.)

Varieties	No. of grafts made	Ave. no. of flowers per scion	No. of flowering nodes on scion	Node on which the first flower appeared
Orlis	10	46	23	7 to 13
Nemagold	5	38	19	8 to 13
P-114	5	7	12	9 to 13

10. Reactions of Actively Flowering Shoots of Two Sweetpotato Varieties When Used as Scions

In this test, the terminals of Orlis (non-flowering variety), which had been brought to the flowering condition by grafting on morning glory stocks and flowering shoots of P-47 (free-flowering variety) were used as grafted scions. The morning glory plants were used as stocks. Four different graft combinations were made as follows:

a. Flowering shoots of Orlis variety grafted on morning glory stocks which were devoid of leaves.

b. Flowering shoot of Olris variety grafted on morning glory stocks with leaves remaining.

c. Flowering shoots of P-47 variety grafted on morning glory stocks devoid of leaves.

d. Flowering shoots of P-47 variety grafted on morning glory stocks with leaves remaining.

From 2 to 5 successfully grafted plants were observed in each combination. The growing conditions of the sweetpotato scions after grafting were observed carefully. The results are as follows:

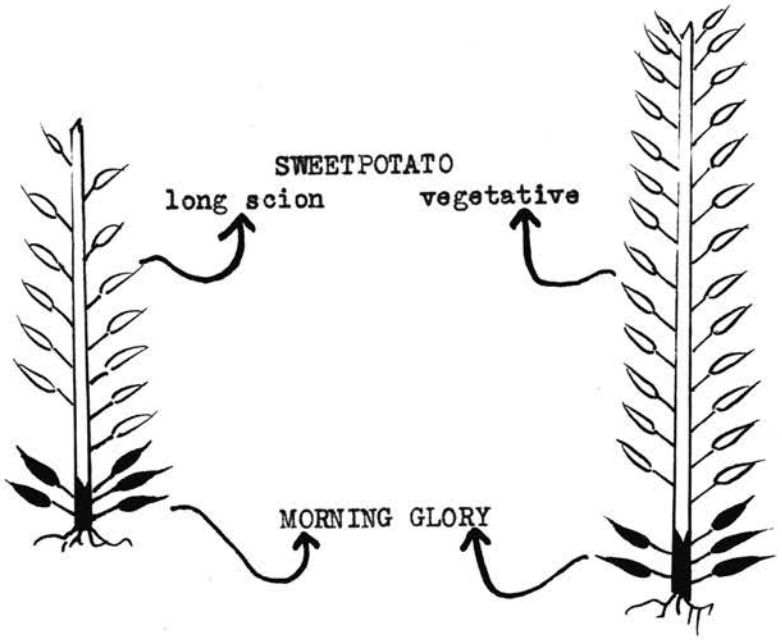
In all cases the flower buds which had previously appeared on the grafted scions gradually aborted. In the absence of leaves on the morning glory stock, no new flower buds appeared on the Orlis scions. The scion remained vegetative indefinitely following the abortion of the flower buds that were present at the time of grafting. Also when the stock had leaves, the flower buds onthe Orlis scions aborted but new flower buds appeared for more than ten nodes and until all of the leaves on the morning glory stocks became yellow with age. In the scions of the P-47, the flower buds

also aborted after grafting but new flower buds appeared on the grafted scions just as would be expected of ordinary plants grown on their own roots.

In the fourth combination, the response of the sweetpotato scions when grafted on the morning glory stock was somewhat different. The internodes of the scions were short, and in 3 to 4 weeks after grafting 3 of the 5 grafted plants died suddenly and without reasonable cause. The remaining two grew normally, the flower buds appeared continuously on the scions.

11. Long Scion of Sweetpotato in Comparison to Short Scion When Grafted on Morning Glory

In this test Orlis sweetpotato scions were grafted on morning glory stocks. Two types of grafts were made, one with scions from 1 to 2 feet in length having 5 to 10 fully developed leaves. The other with scions from $\frac{1}{2}$ to 1 inch length without opened leaves. The long sweetpotato scions failed to bloom while the short scions bloomed profusely. It is possible that the flower inducing substances passed into the long sweetpotato scion and due to the presence of an abundance of sweetpotato foliage was diluted or neutralized to the point that its concentration fell below the level necessary to induce flower bud initiation. It might also have been destroyed by reacting with substances present in the sweetpotato stems and foliage (Fig. 8).



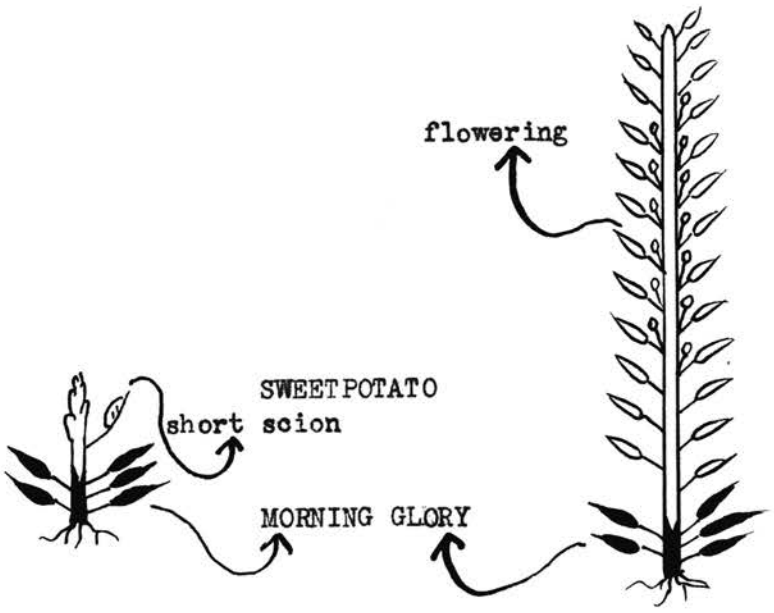


Figure 8. Long scion of sweetpotato in comparison with short scion when grafted on morning glory stock. (grafted in October)

12. Inhibitor can be Removed by Pruning the Main Stem of Sweetpotato Scion

It was shown that the sweetpotato scions grafted on morning glory in August failed to bloom. In the present test, two grafts were made on August 20, the scions remained continuously vegetative until October 28, when the main stem of one of these two with 30 fully developed leaves was cut off leaving only 3 leaves on the scion. After the main stem was removed a lateral shoot developed from the remaining basal portion of the scion and initiated flower buds which became visible November 18 (Fig. 9). The other grafted plant remained vegetative.

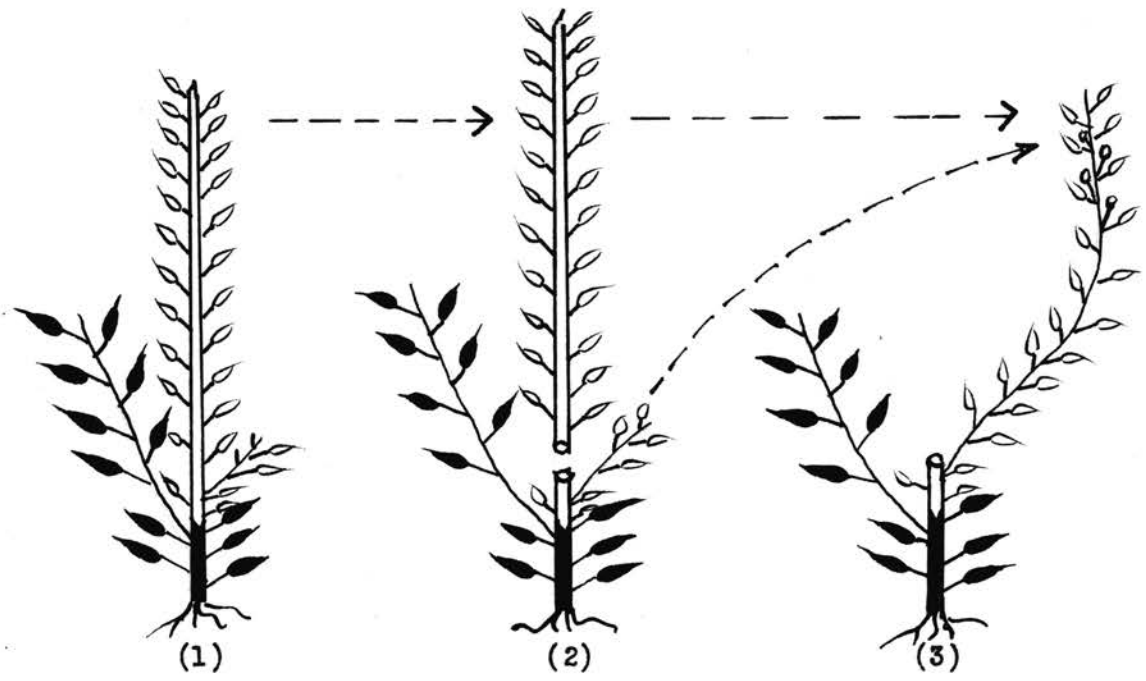


Figure 9. Sweetpotato scions grafted on August 20 were continuously vegetative (1); however, when the foliage of the sweetpotato was reduced by removing the main stem on Oct. 28 (2) a favorable balance of hormone for flowering evidently resulted and flower buds were then initiated and become visible by Nov. 18 (3).

13. Inhibitor can be Removed by Spraying with Anti-auxin

Two types of grafts were made with four grafted plants of each. The first consisted of a sweetpotato scion grafted on a morning glory stock with leaves, and the second, that of a morning glory stock without leaves. The eight grafted plants were divided into four groups of two plants each. The morning glory stock of one plant of each group was defoliated while the other was allowed to retain its leaves. Each froup of grafted plants was given one of the following treatments:

1. Spraying with water (control)
2. Spraying with 100 ppm of 2,3,5-triiodobenzoic acid
3. Spraying with 600 ppm of 2,3,5-triiodobenzoic acid
4. Spraying with 1200 ppm of 2,3,5-triiodobenzoic acid

Three sprayings were made on the 10th, 12th, and 14th of September respectively. One week after the treatments were completed, it was observed that the growth of the terminal shoots of those plants receiving 1200 ppm of 2,3,5-triiodobenzoic acid was retarded. Later the lateral buds of these plants developed into shoots. However, except at the base of the sweetpotato scion, these laterals failed to develop beyond a half inch in length. On November 3 the flower buds became visible on the basal laterals of the sweetpotato scion grafted on morning glory stock with leaves. The sweetpotato scion grafted on morning glory stock without leaves showed no evidence of flower bud initiation. It may be true, as suggested by Cooke (5) that the decrease in auxin level in plants is not responsible for flower bud initiation. The leaves of grafted scions receiving the treatments 2 and 3 showed slight curvature but the terminal shoots continued to grow normally. No flower buds appeared on these treated plants or on the controls(Table 5).

Table 5. Flowering Response of Sweetpotato Scions on Different Types of Morning Glory Stocks and in Relation to Spraying with Varying Concentration of Anti-auxin (2,3,5-triiodobenzoic Acid)

Treatment*	Orlis grafted on Morning glory with leaves	Orlis grafted on morning glory without leaves
Control	no flower	no flower
100 ppm TIBA	no flower	no flower
600 ppm TIBA	no flower	no flower
1200 ppm TIBA	many flowers	no flower

* Scions were sprayed on September 10, 12, 14.

DISCUSSION AND CONCLUSION

In these studies there is no concrete indication of a direct relationship between flower bud initiation and the accumulation of carbohydrates in the grafted scions. When terminal shoots from $\frac{1}{2}$ to 1 inch long were used as scions 6 to 8 leaf buds had already differentiated and the appearance of the first flower bud at the first node differentiated after grafting, (see Fig. 10) usually indicates a very prompt flowering response of the sweetpotato scion to some chemical substances provided by the leaves of the understock. It was observed that more flower buds were initiated by the scion when the leaves of morning glory were in a very active condition. As soon as the leaves of the morning glory stocks became yellow with age the sweetpotato scion reverted to the vegetative phase of growth and remained so indefinitely, Therefore, it seems logical to assume that a flowering hormone (or hormones) is manufactured in the morning glory leaves and translocated to the meristematic regions of the sweetpotato scion where it exerts its morphogenetic effect. The level of this "florigen" not only varied with different species (Table 1), but also in the same species and varieties during different seasons (Fig. 6 and Table 3). It moved upward across the graft union to influence the sweetpotato scion to bloom and also downward to effect a similar response in the sweetpotato stock (Fig. 2). The translocation of the "florigen" can be restricted by heating and girdling (Fig. 4). When the stem were girdled the results suggested that the translocation of "florigen" is confined to the living cells of the phloem tissues. The Orlis scions usually failed to bloom when fruit set was allowed to take place on the morning glory stock. This may be due to the "florigen"

being monopolized by the fruit as it developed on the morning glory to the extent that flower buds were entirely inhibited on the scion. The "florigen" level of the morning glory plant varied considerably with different seasons and this variation was expressed by the intensity of its flowering. The "florigen" level of the morning glory was directly related to its effectiveness in inducing flowering in the sweetpotato scion. Thus, the morning glory was effective in inducing flowering in the sweetpota only when it possessed a high "florigen" level as indicated by its profuse blooming. On the other hand, the morning glory was ineffective when it was at a moderate or low "florigen" level as evidensed by its moderate blooming or its vegetative condition. However, it should be noted that the morning glory stock at a high "florigen" level was also ineffective when the long Orlis scion was used in grafting. It is purely hypothetical but it is possible that some anti-florigen substances were produced in the leaves of the long sweetpotato scions which neutralized the "florigen" provic by the morning glory stock. The condition which prohibited flowering in the sweetpotato scion could be overcome either by removal of most of the foliage by pruning off the main stem or by spraying with anti-auxin. The anti-flowering substance or substances which prevented flower initiation in the scions and caused them to remain in a vegetative condition, may be referred to as a "vegetative hormone". It is possible that this substance is indole-3-acetic acid commonly called "auxin". Although in the present study there is no chemical data available to prove this point. However, this appears to be a reasonable assumption in the light of our knowledge of auxins and their influences on the growth response of plants in general.

These investigations have shown that one species may be induced to

bloom by grafting on another . However, to be effective, the donor species must contribute a sufficient quantity of flower inducing substances to the acceptor species to establish a favorable auxin-florigen balance in the latter.

It appears that the non-flowering characteristics in certain varieties and breeding lines of sweetpotatoes should not be a difficult problem to the sweetpotato breeder, if the relationship disclosed by this research is applied properly. Success in obtaining blooming in the non-flowering types of sweetpotato depends upon:

1. The choice of a donor species producing a high "florigen" level such as I. tricolor and I. purpurea.

2. Graft the sweetpotato at the time that the "florigen" level in the donor species is at a maximum.

3. Prevent fruit setting on the donor species.

4. Maintain the maximum foliage on the donor species and reduce the foliage of the scion of the acceptor species (sweetpotato) to a minimum.

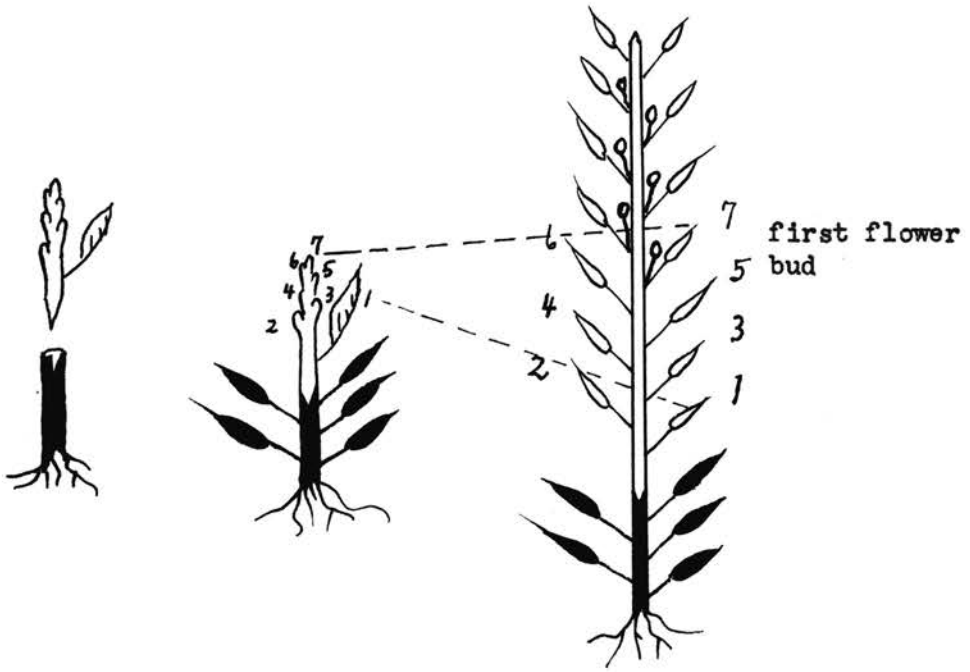


Figure 10. A terminal of a sweetpotato plant about $\frac{1}{2}$ to 1 inch long, consists of 6 to 8 leaf buds. Thirteen days after grafting on morning glory stock, the first flower bud appeared on the seventh node of the sweetpotato scion indicating a very prompt flowering response.

SUMMARY

1. This study of flowering in sweetpotato was initiated in September of 1953 in the experimental greenhouse at Oklahoma A. & M. College.

2. Of the sixteen related species used as understocks in this study only I. tricolor, I. purpurea, I. hederacea and I. Nil were found to be effective in inducing flowering in Jersey varieties of sweetpotatoes under the conditions described.

3. The number of opened flowers on the sweetpotato scion was directly related to the number of leaves remaining on the morning glory stock. This suggests that a flower inducing substance or flowering hormone (florigen) was manufactured in the morning glory leaves and translocated to the sweetpotato scion where it induced blooming.

4. This flower inducing substance can move upward and downward in the grafted plant to influence the sweetpotato to bloom (Fig. 12, 13).

5. The translocation of "florigen" can be prevented by heating and girdling the stem of the plant.

6. The "florigen" was apparently monopolized by the fruit developing on the morning glory stock.

7. It was shown that "florigen" is universal within the genus Ipomoea, but further investigations are needed to prove that it is universal throughout the plant kingdom(Fig. 14).

8. The "florigen" level of the morning glory plant as indicated by its flowering behavior was influenced by environmental conditions (Fig. 15, 16).

9. The number of flowers produced by the grafted scion at different

seasons was also a reflection of "florigen" level in the morning glory stock.

10. Three Jersey varieties, Orlis, Nemagold and P-114 showed some differences in their flowering responses when grafted on the morning glory stocks.

11. The differences in the reactions of flowering shoots of non-flowering and free-flowering varieties when used as scions grafted on morning glory were observed.

12. Fewer flower buds were initiated on long scions with many leaves as compared to short scions.

13. Pruning back the long sweetpotato scions resulted in flower bud initiation.

14. Spraying the long scions of sweetpotato with an anti-auxin (2,3,5-triiodobenzoic acid) also resulted in initiation of flower buds.

15. Success in obtaining flowering on the non-flowering varieties of sweetpotato depends upon: (a) the choice of a donor species with a high "florigen" level; (b) grafting the sweetpotato at the time the "florigen" level in the donor species is of the maximum level; (c) preventing fruit setting on the donor species; (d) maintaining the maximum foliage on the donor species and with the foliage of the scion of the acceptor species (sweetpotato) at a minimum.

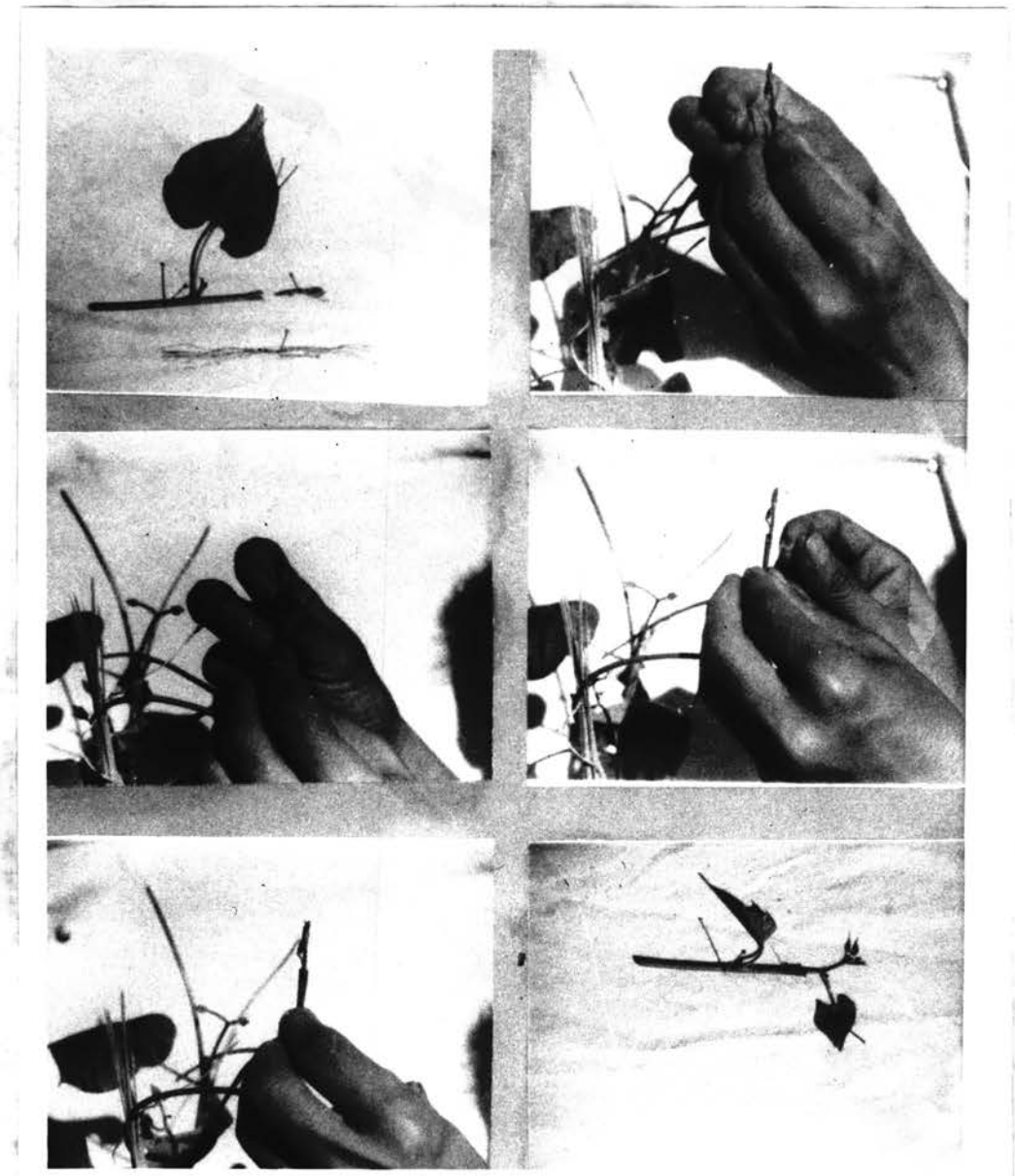


Figure 11. Special Grafting Technique

Figure 12. Orlis scion grafted on morning glory stock, showing upward movement of flowering hormone.

Figure 13. Morning glory scion grafted on sweetpotato stock, showing downward movement of flowering hormone.

Figure 14. Different species of Ipomoea grafted on morning glory. Left: XO-4, Right: XO-1.

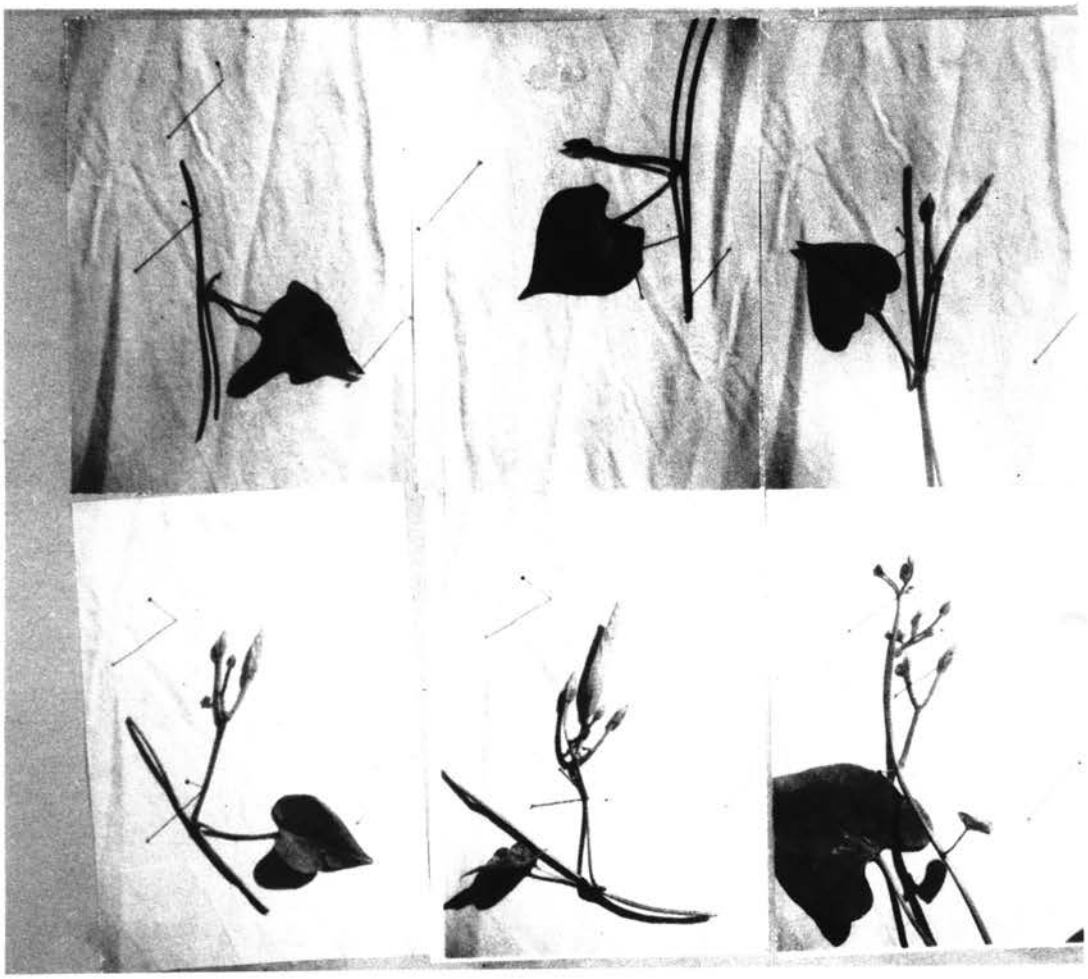


Figure 15. Flowering behavior of morning glory

Figure 16. Blooming of morning glory profuse during period when environmental conditions are favorable indicating high level of flowering hormone.

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