# A STUDY OF SOME FACTORS AFFECTING THE CAPACITY FOR VEGETATIVE REPRODUCTION IN THE IPOMOEA BATATAS LAM WITH SPECIAL REFERENCE TO BEDDED ROOTS

By

MAAMUN S. JAYYOUSSI

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Oklahoma State University

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Thesis Approved:

H. B. Cordner
Thesis Adviser

W R Kays

Robert MacVicar
Dean of the Graduate School

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# CHAPTER I

## INTRODUCTION

The selection and propagation of plants is one of the oldest works of mankind. Plant collecting expeditions were organized and sent to the fartherest points of the known world by the Arabs 5,000 years before the birth of Christ, and intensive plant selection was an integral part of Chinese culture long before Western Civilization, as we know it, came into being. The preservation or prepetuation of desirable horticultural characters by means of vegetative propagation was understood and used by these ancient agriculturists. The centuries of man's slow advances from primeval ignorance, his close attention to all kinds of plants, has been maintained, first from sheer necessity and later from a desire to surround himself with beautiful things. During the Middle Ages, the art of plant propagation and production has already achieved a high degree of excellence and complexity, but had not been organized on a proper scientific basis.

Horticultural knowledge has advanced in the past quarter century, yet nothing has been learned that has changed the basic principles of good growing. Science has presented a number of excellent tools, which can greatly increase efficiency, but in order to use them properly and to the maximum advantage, a thorough background in horticulture, through practical experience must be acquired. There is no substitute for this.

It is now both a duty and a pleasure for me to try to record some of the points which encourage me in working on this subject.

Records of the origin of the sweetpotato species are practically non-existent, other than the sweetpotato was introduced from the tropical sections of North America, especially the West Indies, by the early Spanish and English settlers, and in the recent years by the U.S.D.A. and state experiment stations. From our observation and the natural history records, we can indicate that many of these older varieties were chance seedlings selected in the subtropics. Later, varietal introduction were selected as mutations from these old varieties to fit the need of the American market. An ever present problem is how to efficiently propagate the sweetpotato; how to increase the number of plants from a single hill, or root, in other words the problem is in the potential value of plant production.

The production of sweetpotato plants is expensive. From 400 to 500 pounds of roots are required to produce sufficient shoots to transplant one acre from one pulling of the propagation bed. From this the demand for sweetpotato varieties with a high potential for plant production is understandable. The general practice is to bed fewer roots and make 2, 3, or more pullings. Otherwise 10 to 12 bushels of potato roots are needed to produce plants to set one acre when one pulling is practiced, and from 6 to 8 bushels or more are needed when two pullings are made.

Although individual roots and individual hills of the sweetpotato vary greatly in plant production, there is little definite information to show the degree in which this variation exists. Obviously, the continued success of the sweetpotato varieties widely used in the past was in part due to high plant production by bedded roots or in brief, because of the economy in propagating the crop when these varieties were grown.

In recent times (beginning in the early 1940's) new varieties of sweetpotatoes were placed in commercial production as products of the sweetpotato breeding program which began in the United States during the previous decade. Many of the new varieties proved to have a lower propagation capacity than the old varieties such as Porto Rico and varieties of the Jersey type. The additional cost in propagating some of these new varieties is not compatible with the competitive pressures that vegetable growers must meet in modern-day agriculture.

It is reasonable to assume that the sprout or plant producing capacity in the sweetpotato roots is related to a certain balance or relationship between growth substances which in turn is controlled by genetic factors carried by the variety. This suggests that propagation value is an inherited character and may be controlled to some degree by breeding procedures. However, since the sweetpotato is a hexaploid and on the basis of the experience with the inheritance of other characters, it is to be expected that this inheritance will be complex and difficult to manipulate effectively.

Objectives.

In this experiment our objectives were:

1. To define the range in plant production in the sweetpotato as indicated by the levels found in a great number of seedling individuals and clones.

2. To determine the position of certain selected breeding lines

and varieties in this plant production range.

3. To study the plant production capacity of certain parent lines in relation to the propagation capacity of their off-spring and to observe the genetic influence on this important character in the sweetpotato.

4. To observe the effect of certain auxin-like substances on the origin of vegetative buds and fibrous roots on the sweetpotato and on proximal dominance.

5. To observe the effect of age of root on the sprouting capacity of sweetpotato roots.

## CHAPTER II

## LITERATURE REVIEW

### Early Views on Proximal Dominance in Roots.

The search for a high potential in plant production of sweet-potatoes is by no means new. Many workers have studied the problem from different sides, with various procedures and still to our day these many scientists have not found a completely satisfactory solution.

In 1931, Thompson and Beattie(22) found the main point in the problem is the dominance of the proximal end of the enlarged root of sweetpotato. Proximal dominance in roots of (*Ipomoea batatas Lam.*) strongly inhibits and reduced the production of draws or sprouts.

The inhibiting effect of a terminal bud upon lateral bud development is called apical or proximal dominance and is much more pronounced in some species than in others. The controlling effect of the proximal or apical tissues or buds apparently results from their auxin contents. When agar blocks containing indolacetic acid were applied to broad bean (*Vicia faba*) plants in place of the terminal buds, which has been removed, the block being replaced with fresh ones from time to time in order to maintain the supply of auxin, inhibition of lateral bud development occurred just as if the terminal buds were intact. The lateral buds on check plants, to which only plain agar blocks were applied, developed rapidly.(19)

Studies to Improve Plant Production by Conventional Methods.

These investigations(22) suggested the removal of the tip of the proximal end or other cutting techniques, but in such practices, the result was costly, because the sweetpotato roots decayed readily. However, they insisted that, from a practical standpoint, the breaking of the dominance of the proximal end of the root is of great importance in plant production. In 1932, Beattie and Thompson(2) concluded that cutting the roots into two or more equal portions will increase the number of plants but reduce their size. From the point of view of the farmer, it is better to use whole roots of small size and maintain an optimum temperature in a heated hotbed to produce the highest number of plants.

Edmond(8), in 1934 indicated that small whole roots were more economical than large ones halved crosswise due to the decay factor, or with proximal end removed. In his work in 1937, he noticed that there were significant variations in relation to plant production between the individual roots, and the individual hills of Porto Rico sweetpotatoes(7). This variation was greater in terms of individual roots than in terms of individual hills. At the time, a strong possibility was indicated for selecting high plant producing strains. After this work, many research workers started with keen observation, to test for new lines, but no one fully established such variations to be related to genetic factors.

Edmond(11) reported with Anderson in 1946, that roots harvested during the early part of the season produced a greater number of plants per bushel than those harvested in the later part. Such cause they related to the low soil temperature of the latter part of the season, and chilling of the roots. The age-of-root factor was not considered in this report.

Edmond also indicated(10) that crowded bedding increased the number of plants produced per unit area of bedding space but decreased the number of plants produced per root and per bushel. The crowded bedding consisted of 300 roots per 18 square feet; while the regular bedding consisted of 150 roots in an identical area. Temperatures ranging from 68 to 80°F were maintained, but the data show that the roots at the higher temperature produce more plants(10). Other work done by Edmond in 1943(10), related to the determination of the effect of exposure to storage temperatures below the optimum range (below 50°F) for relatively long periods on lowering the plant producing capacity of the roots.

Introduction of Plant Growth Substances.

Failure of the research workers to find a satisfactory solution to the plant production problem leaves the field open and a strong demand for a better solution. The Growth regulators or Growth substances and their relation to plant life was previously discovered and that proximal dominance may be related to some of these materials was predicted. The study of chemical proximal dominance in the sweetpotato was started in 1935 by Frank Horsefall(14). He used thiourea as a major chemical. He indicated that further work may bring a positive result by producing a given number of slips with less bedding stock. It was the opening of a new era, and a new hope to achieve satisfactory results with chemicals.

In 1950, extensive experiments were conducted by Hernandez and associates(13) to determine the various effects of chemical treatments on the plant production of the sweetpotato. The roots treated with 10 ppm. of 2,4-D produced significantly larger number of plants per root, and per 50 pound bushel than did the controls. All other treatments except Semesan Bel and 2,4-D at 2.6 ppm gave an increase over the control in the number of plants produced per root, and per bushel in four pullings, although these differences lacked statistical significance. Michael and Smith(20) in 1952 supported past work in that the use of 2,4-D, 10 ppm as momentary dips did increase the sprouting capacity per root. They also indicated that ethylene chlorohydrin was the most promising chemical when used at the rate of 20 ml/100 pound of roots. They reported that thiourea must be modified before this chemical can be effectively applicable to the sweetpotato. In the same manner, Hall and Greig(12) in 1956, mentioned that ethelyene chlorohydrin as an instant dip was effective in reducing proximal dominance, and little or not proximal dominance was observed in Nemagold roots.

Inheritance in the Sweetpotato.

At the hexaploid level (2n = 90) the sweetpotato plant exhibits mostly complex inheritance. The quantative type of inheritance is readily observed and generally reported by breeders as e.g. in the segregations for disease resistances and leaf shapes, etc. Quantative inheritance in the Carotene and Ascorbic acid contents of sweetpotatoes has been reported by Cordner, Reder, and Odell(5).

# CHAPTER III

## MATERIALS AND METHODS

Two major experiments were designed, the first was conducted in the laboratory with chemicals and/or other growth regulators. The other was conducted in the greenhouse to observe plant production in the leading varieties, in seedling individuals, and in some breeding lines. These had been obtained through selection, and normal breeding procedures.

### Laboratory Experiments.

The major objective in this experiment was to determine the effect of various chemicals and auxin-like materials on the proximal dominance of the sweetpotato root which limit the production of adventitious buds. The following varieties and seedlings were used: Tanhoma, Nemagold, Bx, and 5-170. The roots were kept under optimal storage conditions until they were selected for study.

First test - The first study was a preliminary one started in 1962, for the purpose of developing satisfactory procedures in setting up the experiment and the type of data needed as a general study of proximal dominance.

The selected roots varied in weight from .15 to 20 pounds. To prepare the roots for chemical treatment, the distal end was sliced off and the root placed upright in a pint jar with the cut end in the solution of the chemical or in water. The first chemical used was 2,4-D at a concentration of 10 ppm with exposures of 12, 24, and 48 hours. In this case roots in certain treatments were exposed to the vapors of 2,4-D in a desiccator. Untreated roots served as controls in this study. After the treatment period, the roots were placed in jars filled with water and allowed to sprout. Sprouts which arose from the proximal, middle, and distal thirds or sections of the roots were recorded separately. At the conclusion of the experiment the data included the total number of breaks or buds for each root and section by treatments and the control, and the weight of the vegetative parts and fine roots which had developed.

Second test - In the second part of the experiment, the effect of Duraset* on the reduction of the proximal dominance in sweet-potato was studied. One year old roots and newly harvested roots were used. Solutions containing this chemical were used for different soak times and concentrations. Containers were prepared with Duraset at concentrations of 50, 100, 150, 200, ppm. Roots were soaked for periods of 12, 24, and 48 hours. One jar containing water was the control. The same treatments were also applied to the newly harvested roots.

Greenhouse Experiments.

First test - In this test, seedling individuals as first year

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*N-meta-tolyl phthalamic acid supplies by the Naugatuck Chemical Division of the United States Rubber Co.

hills and commercial varieties were evaluated for plant production. Tests were conducted under uniform conditions in the experiment station greenhouses. Seedlings included 91 individual hills of 1960 series, propagated in spring of 1961. Other tests included 23 leading breeding lines and varieties including Nemagold, Allgold, and Redgold. These were included as commercially grown standards.

The roots were obtained from the Horticultural Irrigation Field Station at Blair, Oklahoma, cured, and stored under standard conditions until used in the tests. The only chemical treatment was the fungicide, Semesan-Bel, at a rate of 1 pound per 7½ gallons of water, to control the usual root-borne diseases. The seed roots were dipped momentarily in the solution, drained and then planted immediately in beds of sterilized sand on April 1, 1962.

Two raised benches about 2 feet high were used. They extended from north to south in the greenhouse. In 1961 a single bench located midway between the center walk and the east side of House No. 4 was used. In the spring of 1962, the two benches on either side of the center walk of House No. 4 were used. In the fall, 1962-63, the benches were next to the center walk and to the east of this position. The greenhouse temperature was thermostatically controlled. Both benches were supplied with bottom heat from steam pipes which kept the temperature reasonably constant. Each bench was divided into 120, 12"x13" compartments, using 1"x4" wood dividers. See Figure 1. In the case of seedling hills, the space needed for each, fluctuated in order to fit the various sizes and numbers of roots.

A randomized block design was used with the clones, each plot consisted of 10 medium sized roots selected so that replicates were represented by equal weights. The average weight of the 10 roots was approximately three pounds. The total weight of the 4, 10 root replicates for each variety or clone range from 10 to 12 pounds. The roots were uniformly spaced in the compartment on fresh, heat-sterilized sand with the proximal ends lying on a uniform side, then covered with fresh, sterilized sand to a depth of two inches. Large size roots were set lower to keep a uniform depth of sand over all the roots. The benches were watered immediately to settle the sand about the roots. (See Figure 2).

The beds were maintained at a temperature of 80°F, before planting and continued at this approximate level while the roots were in the bed. The temperature observed daily averaged 84°F in both benches throughout the experiment. Careful attention was given to the maintenance of a satisfactory moisture level in the sand. This was checked daily and held at what was considered optimum.

The dates of emergence of sweetpotato plants were recorded for each plot and the overall average from the time of bedding to the time the plants were ready for pulling was 33 days.

Four pullings were made at about 10-day intervals. The time required for four pullings was 28 days. The plants were pulled when they were 6 to 8 inches in length which was considered the optimal size for transplanting. Data on fresh weight, and numbers of plants were recorded at each pulling. The data were analyzed as randomized blocks. The plants were utilized in the usual ways in the breeding program after the sprouting data were obtained.

Second test - In Test Number 2, the procedures in testing the clones and seedling individuals were similar to those described for

Figure 1. The bench was divided into sections with 1" x 4" pine boards. For the 10-root plots shown an area of 12" x 13" was provided.

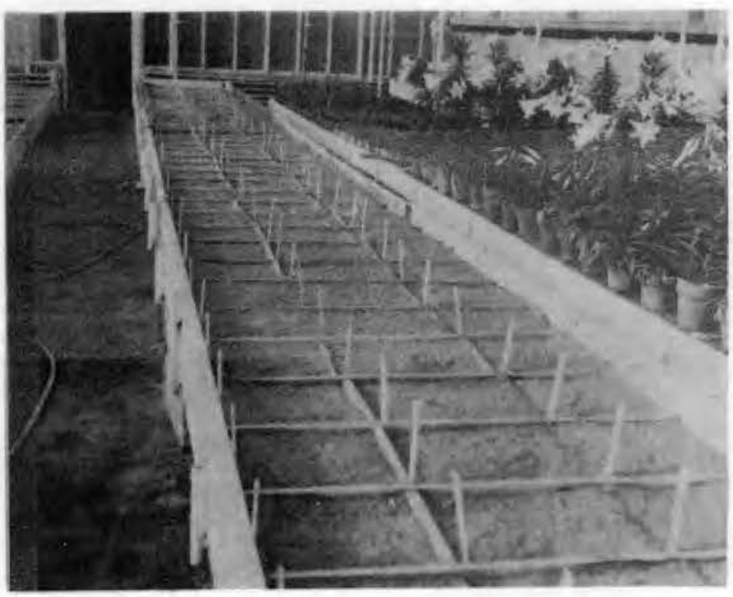

Figure 2. The greenhouse bench after the bedding operation was completed in April, 1962.

the previous test. In preparation for this test, a selected group of the parent lines were planted in the field of the Irrigation Experiment Station near Blair, Oklahoma, to produce a supply of roots. These were propagated to establish the plant-producing capacity of the respective parents.

It was the objective to obtain the maximum numbers of seedling hills or individuals representing crosses of some of the parent lines, especially those on which the parent producing capacity was known or to be determined. However, at harvest time, the roots of the seedling hills were combined rather than remaining separate, thus, the tests were conducted on 15 root samples of these composite lots. These 15 root samples were replicated one to nine times for the various parent-combinations being studied. It was assumed that the means for these replicates were representative of the average sprouting capacity for a given cross.

The roots were harvested October 29, 1962, cured and stored at Stillwater. They were removed from the storage, treated with Semesan-Bel and bedded November 1st, 1962. For this bedding as many replicates as could be planted in the space available were observed to evaluate this genetic factor. The temperature average was 82°F throughout the experiment, and an optimal supply of moisture was provided by watering the beds from time-to-time. Nemagold roots were obtained from a grower in the Blair area and were used as a reference check. Emergence data were taken.

## CHAPTER IV

## EXPERIMENTAL RESULTS

Laboratory Results. This study included three major tests. The first one was concerned with the effect of 2,4-D. The material was used at a concentration of 10 ppm. There were four exposure intervals with four varieties and/or breeding lines. After sprouting, the vegetative buds were counted and recorded for each of the three sections of the roots. This was also done at the end of the experimental period. No data were collected on the weight of the shoots. The fibrous root growth was about average.

Table I summarizes the results of this test. The roots treated for 24 hours produced the greatest number of shoots, a 30% increase in the sprout production capacity over the control; while the 48 hour soak treatment produced the same number of shoots as the control. Figure 3 shows the relationship between these treatments.

There was a wide variation in proximal dominance among the varieties. That proximal dominance was the controlling factor in plant production is shown by the distribution of buds between the proximal, middle, and distal sections. These comparisons on number of shoots were: 59% at the proximal end, and 30%, 11% respectively for the middle and distal sections. The distribution of the vegetative buds is shown in Figure 3. The varieties also showed a variation in their ranking in sprout production, with a total of


Figure 3. Illustrating the sprouting of roots treated with 2,4-D at the 10 ppm concentration for different exposure period (hrs.). Nemagold above; Okla. 5-170 below.

87 for Nemagold, followed by 67 for Tanhoma; while sprouting in Oklahoma selections 5-170 and Oklahoma Bx were lower.

The second test was with indoleacetic acid (IAA) at 10 ppm for different times of exposure.

Results in Table II report the effect of dominance of proximal-end over the other two sections of the root. Sixty-nine per cent of the buds were distributed on the proximal section, while 28.3% and 2.7% respectively were from the middle and distal areas. (See Figure 4). Of the treatments, the 24 hour soak was greatest with an increase of 45% in the number of shoots, followed by the 48 hour soak with 28.3% over the control. The sprouting for the continuous-exposure treatment was less than that for the control. This indicated that the lower concentration or shorter soak time were nearest the optimum and resulted in higher plant production with the Bx sweetpotato.

In the third test, Duraset was used at various concentrations and times of exposure. A preliminary test of this chemical with Tanhoma roots is illustrated in Figure 5. For this third series, Tanhoma roots harvested from the 1962 crop were tested in comparison with "year-old" roots from the 1961 harvest which, after curing, had been stored at 58°F for approximately one year. The roots came out of storage in a firm condition and were more or less free of sprouts although some buds were evident.

Table III presents the results of the test with the new 1962 roots treated with Duraset. As with previous tests, the breaks or number of buds initiated on the proximal, middle, and distal thirds of the roots were recorded along with the fresh weight of the shoots growing from these buds. The principal results from the test were


**Figure 4.** Illustrating sprouting in roots of Okla. B-X treated with indoleacetic acid for different times 948, 24 hours and continously) in comparison with the non-treated control root at the right.

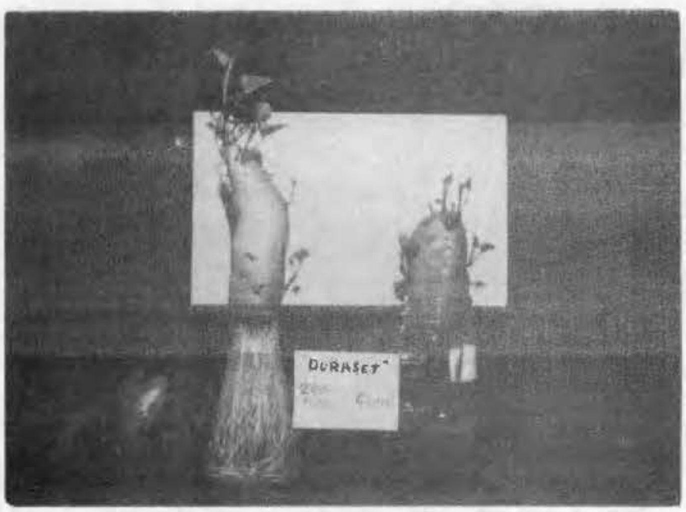


Figure 5. Illustrating the effect of Duraset at a concentration of 200 ppm on the sweetpotato roots. Notice especially the contrast in the fibrous systems of the treated root and the control. (Variety Tanhoma)

the indication of strong proximal dominance in the newly harvested roots of Tanhoma variety. All shoots were initiated in the proximal one-third with an average of only six buds per root after a period of 27 days for growth.

The results for the year-old (1961) roots of Tanhoma potatoes contrast sharply with those just described for the new roots (Table IV). In the first place, the old roots produced from 21 to 43 buds or sprouting points compared with six for new roots. Non-treated old roots averaged 28.7 buds. There was some tendency for the roots treated with 150 ppm of Duraset to show more buds and for the 48-hour exposure to be most effective. Thus the high of 43 buds was from the root treated with 150 ppm and for the 48-hour exposure period. (Figures 6 and 7).

The majority of the buds in the old roots were found within the proximal third, but unlike the new roots some buds were found in the middle and distal thirds of the roots. The important finding is that the plant production capacity of the year old roots was at least five times that of the new roots. In the former, the averages for the various treatments were about 29 to 34 buds as total per root with 14 to 20 of these (about 60%) confined to the proximal third of the root. Three to four buds as the average were found on the distal segment of the root. These represented about 10% of the total number of buds.

On the whole, the results demonstrated that chemicals and age of the root are important factors affecting the sprouting of sweetpotato roots, thus confirming the work of other investigators, and introducing an additional factor, age-of-root, to the plant production complex.


**Figure 6.** Showing the effect of Duraset at the 150 ppm concentration with different time of exposure on sprouting and root development of Tanhoma roots. Control root is at left.

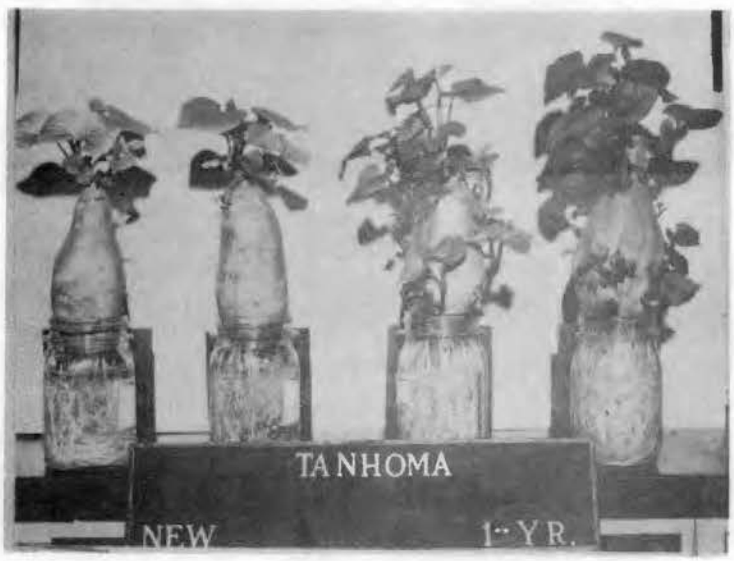


**Figure 7.** Difference in sprouting capacity between old (1961) and new (1962) roots of the Tanhoma variety. The old roots were 13 months from harvest and the new ones one month when they set up in November. Photographed - December 23, 1962.

TABLE I

NUMBER OF VEGETATIVE BUDS PRODUCED ON ROOTS OF VARIOUS VARIETIES AND BREEDING LINES TREATED FOR 24 AND 48 HOURS WITH 2,4-D AT 10 PPM*

| | Tanhoma | | | | Nemagold | | | | Bx | | | | 5-170 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time of exposure | Proximal | Middle | Distal | Total | Proximal | Middle | Distal | Total | Proximal | Middle | Distal | Total | Proximal | Middle | Distal | Total | Variety Average |
| Check | 12 | 8 | 2 | 22 | 18 | 8 | 1 | 27 | 4 | 3 | 4 | 11 | 7 | 4 | 2 | 13 | 18.3 |
| 24 hours | 15 | 7 | 2 | 24 | 21 | 9 | 1 | 31 | 6 | 1 | 2 | 9 | 12 | 8 | 4 | 24 | 22.0 |
| 48 hours | 14 | 5 | 2 | 21 | 15 | 11 | 3 | 29 | 7 | 6 | 2 | 15 | 5 | 2 | 1 | 8 | 18.3 |
| Variety Total | 41 | 20 | 6 | 67 | 54 | 28 | 5 | 87 | 17 | 10 | 8 | 35 | 24 | 14 | 7 | 45 | |

*The number of vegetative buds were recorded from the proximal, the middle, and distal thirds of the roots from the 1961 harvest which were exposed to 2,4-D on March 7, 1962, and the buds counts were made 7 days later.

TABLE II

EFFECT OF INDOLEACETIC ACID UPON SPROUTING OF Bx SWEETPOTATO, TREATED 24, 48 HOURS AND CONTINUOUSLY*

| Time of exposure | Bx Sweetpotato** | | | |
|---|---|---|---|---|
| | Proximal | Middle | Distal | Total |
| Check | 8 | 3 | - | 11 |
| 24 Hours | 13 | 7 | - | 20 |
| 48 Hours | 12 | 4 | - | 16 |
| Continuously | 6 | 2 | 1 | 9 |

*The number of vegetative buds were recorded for the proximal, middle, and distal thirds of the roots, after treating with IAA.

**Roots from the 1961 harvest were exposed to IAA, on February 22, 1962, and the buds count were made during growth and again at the closing day, May 3, 1962.

TABLE III

THE EFFECT OF DIFFERENT CONCENTRATIONS OF DURASET, SOAK-TIME AND ROOT SECTION ON THE NUMBER AND WEIGHT OF SWEETPOTATO SHOOTS FROM NEWLY HARVESTED ROOTS

| Treated hours | Number of Buds: Proximal | Middle | Distal | Total | Weight of Shoot Grams: Oct. 20 | Nov. 7 | Nov. 24 | Dec. 23 | Total* |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Duraset 50 | | | | | |
| 12 | 7 | - | - | 7 | - | - | - | 30 | 30 |
| 48 | 6 | - | - | 6 | - | - | - | 50 | 50 |
| | | | | Duraset 150 | | | | | |
| 12 | 7 | - | - | 7 | - | - | - | 48 | 48 |
| 24 | 5 | - | - | 5 | - | - | - | 42 | 42 |
| 48 | 8 | - | - | 8 | - | - | - | 28 | 28 |
| | | | | Duraset 200 | | | | | |
| 12 | 7 | - | - | 7 | - | - | - | 70 | 70 |
| 24 | 6 | - | - | 6 | - | - | - | 52 | 52 |
| Average treated roots | 6.6 | - | - | 6.6 | - | - | - | 45.7 | 45.7 |
| Average control (3 roots) | 4.7 | - | - | 4.7 | - | - | - | 30.0 | 30.0 |
| Average all new roots | 6.0 | - | - | 6.0 | - | - | - | 41.0 | 41.0 |

Roots from 1962 harvest, treated November 26, 1962. Sprouts were removed and weighed as indicated on December 23, 1962. (27 day growing period).

TABLE IV

THE EFFECT OF DIFFERENT CONCENTRATIONS OF DURASET, SOAK-TIME AND ROOT SECTION ON THE NUMBER AND WEIGHT OF SWEETPOTATO SHOOTS FROM ROOTS STORED 1 YEAR

| Treated hours | Number of buds Proximal | Middle | Distal | Total | Weight of shoots grams Oct. 20 | Total To Nov. 7 | Total To Dec. 23 | Weight roots grams Dec. 23 |
|---|---|---|---|---|---|---|---|---|
| | | | | | Duraset 50 | | | |
| 12 | 14 | 7 | 4 | 25 | 14.3 | 37.5 | 92.7 | 35 |
| 24 | 16 | 8 | 5 | 29 | 18.8 | 39.3 | 101.5 | 13 |
| 48 | 18 | 14 | - | 32 | 18.8 | 31.8 | 89.4 | 22 |
| | | | | | Duraset 150 | | | |
| 12 | 14 | 4 | 3 | 21 | 19.0 | 45.1 | 116.2 | 17 |
| 24 | 22 | 13 | 3 | 28 | 14.3 | 35.2 | 95.5 | 28 |
| 48 | 23 | 12 | 8 | 43 | 10.0 | 30.3 | 68.5 | 15 |
| | | | | | Duraset 200 | | | |
| 12 | 12 | 9 | 3 | 24 | 12.7 | 31.6 | 72.4 | 24 |
| 24 | 13 | 11 | 7 | 31 | 16.3 | 48.8 | 101.7 | 18 |
| 48 | 16 | 14 | 5 | 35 | 11.3 | 30.8 | 81.1 | 21 |
| Average treated roots | 16.5 | 10.5 | 4.2 | 31 | | | | |
| Average control (3 roots) | 17 | 8.3 | 3.3 | 28.7 | | | | |
| Average all old roots | 16.6 | 9.7 | 4.6 | 30.4 | | | | |

**After curing, these 1961 roots were stored at 58°F until treatment on October 3, 1962. Sprouts were removed and weighed as indicated on October 20, November 7, and at close of experiment on December 23, 1962.

Greenhouse Experiments.

In the spring bedding of 1962 as indicated in Table V, the number of plants produced per bushel differed from one clone to another. The clones were divided into three plant production classes: high, medium, and low. Boswell(4) stated that 1,000 to 1,300 plants per bushel is the expected range for the first pulling. In this study about 40% of the plants obtained in four pullings were from the first pulling.

The highest class for plant production of a given variety ranged from 4,000 to 5,300 plants per bushel for the total of four pullings. This is higher than averages reported by other workers. Nemagold was the leading variety in the high category, with breeding lines 0-40 and 0-54 showing a high plant yield.

The medium plant production class ranged from 2,600 to 3,900 plants per bushel with Allgold, Redgold, and Tanhoma, as well as other clones representative of this class. In this case four to six bushels of roots would be required to produce plants for one acre from four pullings; while those in the first class only two to four bushels were required. The lowest class rank produced from 1,000 to 2,500 plants per bushel. Some of the parent lines or clones used in other tests were found in this category (4-105 and 5-195). If we consider the usual practice, followed by the growers in which one or two pullings are made to plant an acreage, it would require from 4 to 10 bushels of these different clones representing all classes, to plant one acre.

In the average production per pulling where a regular interval between the pullings is used, there was an obvious indication that the first pulling produced the highest number of sprouts and the number decreased with each successive pulling. As an average for all clones, 44 per cent of the sprouts were produced at the first pulling with only 14 per cent at the fourth.

The total yield of sprouts was substantially influenced by the time of emergence. Thus, clones in which the sprouts began to emerge early had a larger number of plants in the first pulling, and consequently a higher total number of plants per bushel of roots. When the average number of plants was low the individual plants generally were larger and more vigorous (Figures 8 and 9.

In the overall average for all clones in the three classes, if only one pulling was taken it would require seven bushel for the higher plant makers and 18 bushels for the lowest plant makers to obtain sufficient plants for one acre.

Figure 8. Illustrating differences in time of emergence and abundance of plants in experimental sweetpotato individuals.

Figure 9. Plants from low sprouting lines often have heavy stems and the leaves are thick, rugose and dark green in color.

TABLE V

PLANT PRODUCTION OF SELECTED SWEETPOTATO CLONES IN 1962 TEST, NUMBER OF PLANTS PER BUSHEL FOR FOUR PULLINGS AT SPECIFIED NUMBER OF DAYS FROM BEDDING* AND BUSHELS NEEDED PER ACRE

| Clone | 1st pulling 27 days | 2nd pulling 31 days | 3rd pulling 39 days | 4th pulling 47 days | Total for variety | Bushel needed to plant one acre |
|---|---|---|---|---|---|---|
| | | | High plant producing clones | | | |
| Nemagold | 1378 | 1461 | 481 | 2042 | 5362 | 2.2 |
| Percent** | 25.6 | 27.2 | 8.9 | 38 | - | - |
| 0-47 | 2484 | 1617 | 691 | 368 | 5160 | 2.3 |
| | 48 | 31 | 13.3 | 7.1 | - | - |
| 0-40 | 1440 | 980 | 1360 | 1360 | 5140 | 2.3 |
| | 28 | 19 | 26.4 | 26.4 | - | - |
| 0-54 | 2646 | 986 | 702 | 608 | 4942 | 2.4 |
| | 53 | 19.9 | 14.2 | 12.2 | - | - |
| 0-63 | 1995 | 1578 | 603 | 499 | 4675 | 2.6 |
| | 42 | 33 | 12.9 | 10.6 | - | - |
| 7-41 | 2116 | 1256 | 688 | 327 | 4387 | 2.7 |
| | 48 | 28.6 | 15.6 | 7.4 | - | - |
| 0-58 | 1544 | 1161 | 956 | 485 | 4146 | 2.9 |
| | 37 | 28 | 23 | 11.7 | - | - |

*Roots of 1961 harvest bedded in spring of 1962 and stored at optimal conditions. Experiment started April 1st and closed May 17.

**Percent of the total production for each pulling (four replicates). LSD.05 plants per bushel = 963

TABLE V (continued)

| Clone | 1st pulling 27 days | 2nd pulling 31 days | 3rd pulling 39 days | 4th pulling 47 days | Total for Variety | Bushel needed to plant one acre |
|---|---|---|---|---|---|---|
| Medium plant producing clones | | | | | | |
| Bx | 2341 | 649 | 478 | 438 | 3806 | 3.2 |
| | 61 | 17 | 9.9 | 11.5 | - | - |
| 9-28 | 1713 | 842 | 562 | 562 | 3697 | 3.2 |
| | 46 | 23 | 15.5 | 15.5 | - | - |
| Redgold | 1654 | 515 | 1092 | 390 | 3651 | 3.3 |
| | 45 | 14.1 | 29.9 | 10.6 | - | - |
| 0-25 | 1824 | 845 | 461 | 461 | 3591 | 3.3 |
| | 50.8 | 23.5 | 12.8 | 12.8 | - | - |
| 5-170 | 1500 | 1160 | 480 | 240 | 3380 | 3.6 |
| | 44.3 | 34.4 | 14.2 | 7.1 | - | - |
| Allgold | 1388 | 819 | 587 | 231 | 3025 | 4.0 |
| | 45.8 | 27 | 19.4 | 7.6 | - | - |
| 7-14 | 1540 | 438 | 408 | 393 | 2779 | 4.3 |
| | 55.0 | 15.7 | 14.6 | 14.1 | - | - |
| 8-38 | 952 | 1076 | 374 | 328 | 2730 | 4.4 |
| | 34.8 | 39.4 | 13.7 | 12.0 | - | - |
| Tanhoma | 1601 | 317 | 483 | 317 | 2718 | 5.5 |
| | 58 | 11.6 | 17.7 | 11.6 | - | - |
| 0-1 | 714 | 463 | 714 | 299 | 2690 | 4.5 |
| | 26.5 | 35.8 | 26.5 | 11.1 | - | - |
| S.C. 7-201 | 1373 | 749 | 250 | 229 | 2601 | 4.6 |
| | 52.8 | 28.8 | 9.6 | 8.8 | - | - |

TABLE V (continued)

| Clone | 1st pulling 27 days | 2nd pulling 31 days | 3rd pulling 39 days | 4th pulling 47 days | Total for variety | Bushel needed to plant one acre |
|---|---|---|---|---|---|---|
| Low plant producing clones | | | | | | |
| 8-43 | 1193 | 589 | 347 | 378 | 2507 | 4.8 |
| | 47.5 | 23.4 | 13.8 | 15.0 | - | - |
| 9-9 | 647 | 631 | 481 | 465 | 2224 | 5.4 |
| | 29.1 | 28.3 | 21.6 | 20.8 | - | - |
| 5-195 | 936 | 368 | 485 | 176 | 1965 | 6.1 |
| | 47.3 | 18.7 | 24.8 | 9.0 | - | - |
| 0-28 | 1179 | 183 | 249 | 266 | 1877 | 6.4 |
| | 62.8 | 9.7 | 13.2 | 14.1 | - | - |
| 0-76 | 791 | 361 | 482 | 224 | 1858 | 6.5 |
| | 42.5 | 19.4 | 25.9 | 12.2 | - | - |
| 4-105 | 863 | 400 | 225 | 125 | 1613 | 7.4 |
| | 53.4 | 24.8 | 13.9 | 7.7 | - | - |
| 0-3 | 432 | 199 | 498 | 481 | 1610 | 7.5 |
| | 26 | 12 | 30 | 29 | - | - |
| 0-39 | 518 | 426 | 278 | 222 | 1444 | 8.3 |
| | 35 | 29 | 19.2 | 15 | - | - |
| E. 259 482 | 913 | 213 | 188 | 50 | 1364 | 8.8 |
| | 62.3 | 14.5 | 16.2 | 12.8 | - | - |
| E. 250 487 | 515 | 250 | 390 | 172 | 1327 | 9.0 |
| | 38 | 18 | 29 | 12 | - | - |
| 7-19 | 437 | 374 | 187 | 125 | 1123 | 10.7 |
| | 38.8 | 33 | 16 | 11.1 | - | - |
| Average plants per pulling | 1332.6 | 738.1 | 519.9 | 422.8 | 3000 | 4.0 |
| 90 | 44.42 | 24.6 | 17.3 | 14.09 | - | - |

TABLE VI

PROPAGATION DATA OBTAINED FOR A CERTAIN GROUP OF $F_1$ SEEDLING SWEETPOTATOES AND FOR SOME PARENT LINES - FALL - 1962

| Parentage[1] | Root means: Number per plot | Root means: Average weight (pounds) | Days[2] to emerge | Plants per bushel[3]: For 3 replicates | Plants per bushel[3]: For all replicates | Bushel needed per acre | Sound[4] roots (percent) |
|---|---|---|---|---|---|---|---|
| | | | A. High Plant Production | | | | |
| 134 x 176 | 15.0 | .36 | 12.3 | 3000 | 2786 | 4.3 | 80.0 |
| 107 x 183 | 16.0 | .35 | 17.0 | 2900 | 2960 | 4.1 | 81.5 |
| 176 x 134 | 15.0 | .36 | 13.0 | | 2786 | 4.3 | 78.0 |
| 184 x 183 | 15.0 | .30 | 16.8 | 2583 | 2583 | 3.6 | 60.0 |
| 134 x 129 | 12.7 | .37 | 14.3 | 2496 | 2496 | 4.8 | 86.7 |
| 107 x 178 | 9.0 | .55 | 12.7 | 2470 | 2470 | 4.9 | 88.8 |
| 177 x 183 | 10.0 | .35 | 13.0 | 2383 | 2383 | 5.1 | 100.0 |
| 107 x 179 | 10.0 | .42 | 14.0 | 2373 | 2373 | 5.1 | 80.0 |
| 107 x 184 | 12.0 | .43 | 12.0 | 2316 | 2316 | 5.2 | 83.3 |
| | 12.7 | .39 | 13.9 | 2565 | 2461 | 4.7 | 81.2 |
| | | | B. Medium Plant Production | | | | |
| 134 x 183 | 15.0 | .23 | 16.0 | 2176 | 1456 | 8.3 | 53.3 |
| 129 x 134 | 10.0 | .52 | 16.3 | 2146 | 2146 | 5.6 | 70.0 |
| 179 x 203 | 12.0 | .36 | 15.0 | 2003 | 2003 | 6.0 | 75.0 |
| 176 x 178 | 11.0 | .40 | 17.0 | | 1990 | 6.0 | 72.5 |
| 80 x 184 | 16.0 | .32 | 14.0 | 1986 | 1986 | 6.0 | 62.5 |
| 183 x 184 | 11.0 | .36 | 17.0 | 1936 | 1915 | 6.0 | 63.6 |
| 80 x 179 | 8.0 | .40 | 13.7 | 1906 | 1906 | 6.0 | 87.5 |
| 134 x 177 | 9.0 | .38 | 14.0 | 1846 | 1846 | 6.5 | 88.8 |
| 134 x 175 | 11.0 | .45 | 17.7 | 1803 | 1803 | 6.7 | 63.6 |
| 184 x 179 | 14.0 | .27 | 25.0 | 1718 | 1718 | 7.0 | 65.2 |
| Average | 11.7 | .37 | 16.6 | 1946 | 1876.9 | 6.4 | 70.1 |

TABLE VI (continued)

| Parentage[1] | Root means: Number per plot | Root means: Average weight (pounds) | Days[2] to emerge | Plants per bushel[3]: For 3 replicates | Plants per bushel[3]: For all replicates | Bushel needed per acre | Sound[4] roots (percent) |
|---|---|---|---|---|---|---|---|
| | | | C. Low plant production | | | | |
| 179 x 184 | 14.0 | .27 | 21.0 | 1573 | 1718 | 7.0 | 71.4 |
| 183 x 134 | 13.0 | .35 | 18.8 | 1513 | 1846 | 6.5 | 71.5 |
| 179 x 134 | 13.0 | .30 | 17.3 | 1336 | 900 | 13.3 | 76.9 |
| 80 x 184 | 10.3 | .55 | 16.3 | 1406 | 1406 | 8.5 | 87.1 |
| 81 x 183 | 11.0 | .27 | 17.7 | 1390 | 1390 | 8.6 | 63.6 |
| 134 x 179 | 13.0 | .30 | 18.7 | 1330 | 1581 | 7.6 | 46.2 |
| 134 x 80 | 7.0 | .85 | 18.0 | | 1130 | 10.0 | 48.1 |
| 80 x 178 | 10.0 | .34 | 15.0 | 1020 | 1020 | 11.8 | 60.0 |
| Average | 11.4 | .40 | 18.0 | 1368 | 1374 | 9.2 | 65.6 |
| | | | D. Parents(p) and clones | | | | |
| p - 176 | 9.0 | .50 | 14 | 2880 | 2880 | 4.0 | 88.8 |
| p - 134 | 12.0 | .36 | 17 | 2430 | 2430 | 4.9 | 58.3 |
| p - 107 | 8.0 | .57 | 14 | 1830 | 1830 | 6.5 | 100.0 |
| p - 183 | 9.0 | .40 | 19 | 1766 | 1766 | 6.8 | 66.6 |
| p - 178 | 11.0 | .36 | 15 | 1643 | 1643 | 7.3 | 63.6 |
| p - 184 | 8.0 | .65 | 14 | 752 | 752 | 16.0 | 64.0 |
| p - 154 | 8.0 | .65 | 17 | 703 | 703 | 17.0 | 75.0 |
| p - 185 | 9.0 | .36 | 24 | 233 | 233 | 51.0 | 22.2 |
| 5 - 195 | 9.0 | .61 | 26 | 725 | 725 | 16.5 | 62.0 |
| 0 - 80 | 8.0 | .58 | 15 | 1413 | 1413 | 8.5 | 75.0 |
| 0 - 28 | 8.0 | .50 | 15 | 993 | 993 | 12.0 | 100.0 |
| Tanhoma | 12.3 | .42 | 14 | 1770 | 1770 | 6.8 | 83.3 |
| Nemagold | 7.0 | .54 | 24 | 460 | 460 | 26.0 | 28.6 |
| Average | 9.1 | .50 | 17.5 | 1354 | 1354 | 14.1 | 68.2 |
| | 11.2 | .42 | 16.5 | 1808 | 1767 | 8.6 | 71.2 |

TABLE VI (continued)

[1]Roots of $F_1$ seedlings of the parents as indicated (female parent listed first); harvested at Blair, Oklahoma, October 17, stored at Stillwater

[2]Days from bedding until a significant number of sprouts were showing above the sand.

[3]Plants per 50 pound bushel and for 12,000 plants per acre for four pullings. L.S.D. 01 = 672. (3 replicates)

[4]Percentage of sound roots at the close of the test period.

Table VI summarizes the results for the test of $F_1$'s of specific crosses and some parent clones which were propagated in the fall of 1962. The $F_1$ crosses are shown in high, medium and low plant-production groups in this table. The first or high group ranged from 3,000 to 2,316 plants per bushel with an average of 2565. As an average, 13.7 days lapsed between bedding of the roots and the emergence of the plants. Parents numbers represented prominently in this high plant production group were 176, 134, 107 and 183. Section "D" of Table VI list these parents in descending order in plant production.

In the "B" Section, or medium group, plant production per bushel for the $F_1$ crosses ranged from 2176 to 1718 with an average of 1975. An average of 16.6 days was required for emergence of the plants. The low plant making crosses in Section "C" of Table VI ranged from 1573 to 1920 plants per bushel with an average of 1368 plants per bushel. An average of 18 days was required for the plants to emerge. Parents frequently appearing in the medium and low groups were 178, 184, 179, and 80.

In a brief summary concerning these results it might be pointed out that the maximum plant production of 3,000 plants per bushel for the $F_1$'s (e.g. 134 x 176) agrees quite well with the maximum for the parents (2800 for P - 176). Parents with high plant production capacity produced some progeny with this character.

There was an obvious negative association between the time required for plants to emerge and final yield of plants. About 14 days were required for the high groups compared to 18 days for the low plant producing group. A tendency for root decay in some lines reduce the yield of plants.

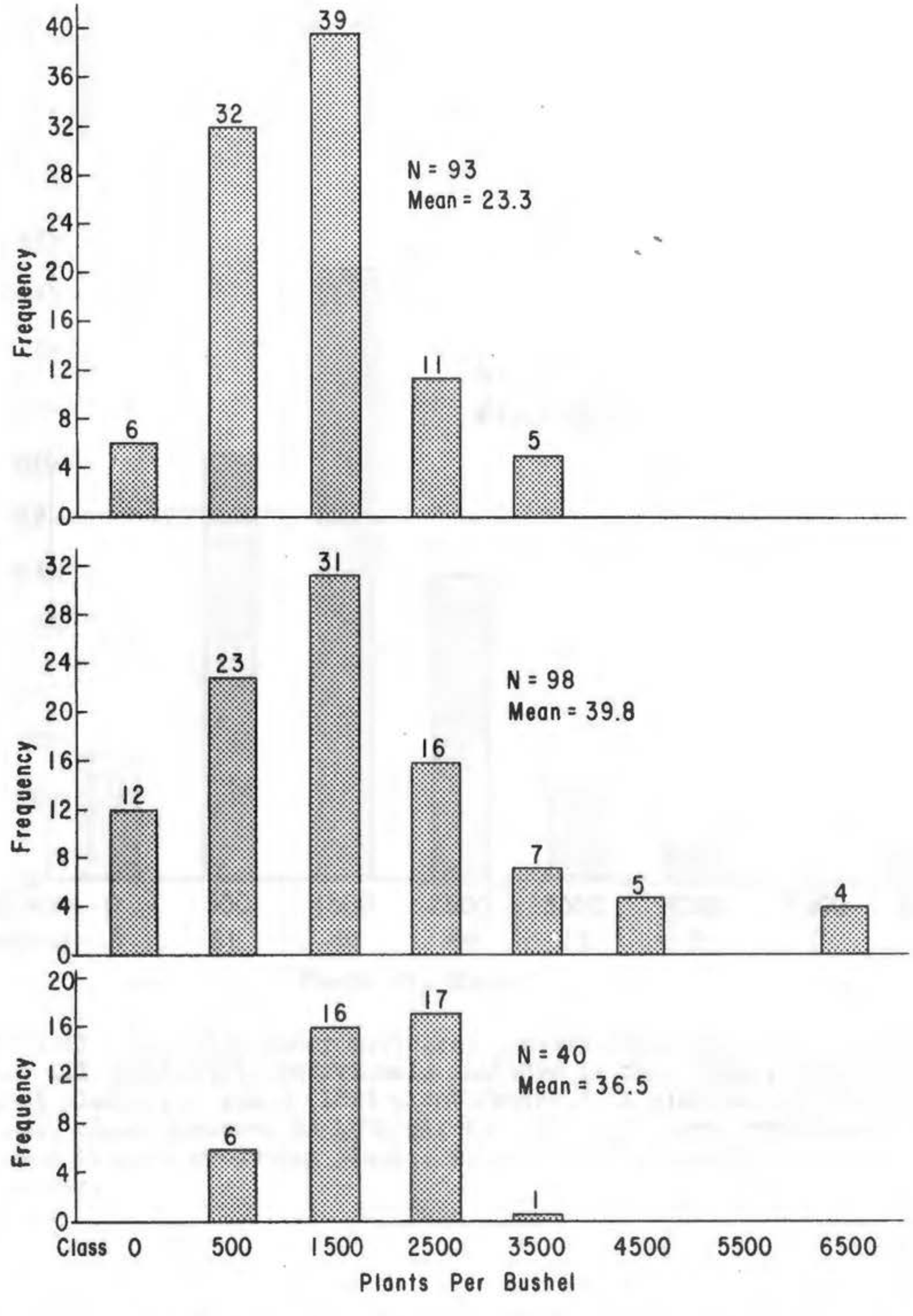


Figure 10. Frequency histograms showing the distribution of sweetpotato individuals in plants/bushel classes: Above, the $F_1$ 1960 seedlings propagated in the spring of 1961. Mid-section, the $F_1$ 1961 individuals and some clones propagated in the spring of 1962 (see table). Lower section $F_1$'s of certain crosses and parent clones propagated in the fall of 1962. The means as given are for plants per pound and must be multiplied by 50 to obtain the value in terms of plants per bushel as given on the abscissa of the graph.

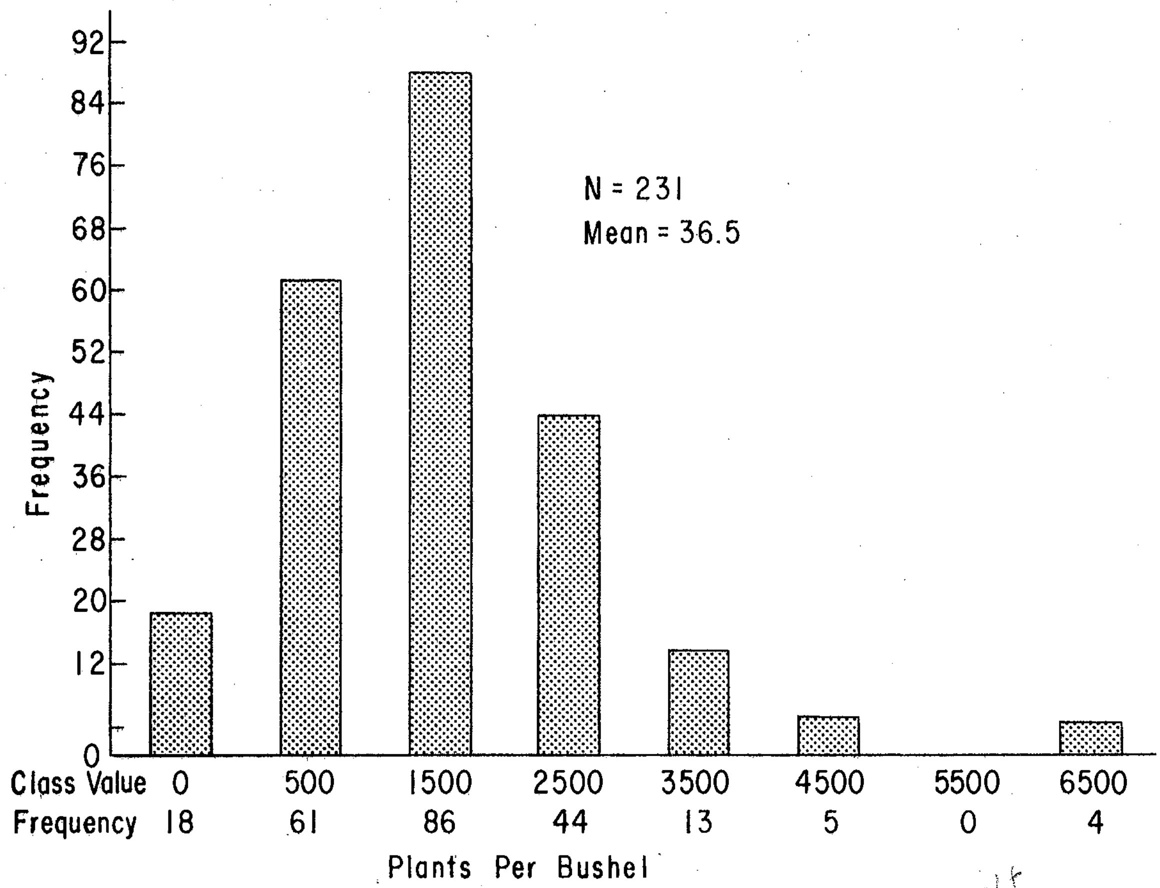


Figure 11. This frequency histogram includes the plant production data for all sweetpotato individuals included in this study. The mean of 36.5 plants per pound (1825 plants/bushel) is slightly left of the model class centered on 1500 plants. Roots of some individuals decayed without producing plants, while others produced high numbers of plants.

During the course of these investigations, the sprouting capacity of over 230 individual sweetpotatoes either as first year seedling hills or in the first clonal generation or as other clones were represented by Oklahoma breeding lines and varieties. These results are summarized on frequency histrograms.

The top histogram in Figure 10 shows the distribution by plant production classes of the 1960 seedlings individuals propagated in the spring of 1961. Although 4 pullings were made these were not at regular intervals and as a result plant production was low with a mean of 23.3 plants per pound of 1165 per bushel.*

The spring 1962 test was conducted more precisely with regular pulling dates and as indicated for this group of 1961 individuals a mean of 39.8 plants per pound which is calculated to 1990 plants per bushel. It should be noted that when populations of first year seedlings were propagated, some individuals failed to produce plants (recorded as 0 in histogram). This appears to be a natural condition in which the roots when bedded decayed without producing plants.

The fall propagation test suggests that with a mean of 36.5 plants per pound or 1825 per bushel, newly harvested (33-day) roots have a lower plant production potential than older (143-day) roots.

The frequency histogram presented in Figure 11 represents the results of all the determination obtained in this study. The fact that this, to some degree, represents the average of tests which varied much with reference to age of root, and intensity of pulling of the beds and in other ways, makes the mean of 1825 plants per bushel more

*These data acquired in 1961 were provided by Dr. H. B. Cordner and Hugh Thomson at Oklahoma State University.

realistic. As indicated by the frequencies to reproduce, while most seedlings may fail to reproduce, while most seedlings are found in the modal class centered on 1500. Extremely high plant production i.e. four times that of the average, was noted for a few individuals.

## CHAPTER V

## DISCUSSION AND CONCLUSION

Apical meristems or buds, to some extent, inhibit the growth and development of buds inferior in position to them. In stems, this phenonenom is described as apical dominance. Much work has been done on this subject and the conclusion usually drawn is that there is a complex relation between the terminal tissues and those below and that plant hormones (of the auxin type) and perhaps plant foods are involved. It is clear that auxins at certain concentrations may replace the terminal bud in the inhibition of other buds. Much emphasis has been given to the levels and distribution of auxin and the presence of auxin inhibitors.

Proximal dominance in the plant root has received less attention, but the general inference is that it basically is similar to apical dominance in the stem. This characteristic of the root becomes of paramount importance in the propagation of sweetpotatoes by bedded roots. Practically, it has been demonstrated that auxins, e.g. those of the 2,4-D type, will increase the development of adventitious buds on the root and hence, the production of plants.

Although only a few roots were used, the laboratory studies carried out confirmed, to some extent, previous reports on the increase in plant production in roots treated with 2,4-D and IAA. In addition, the auxin-like growth substance N-meta-tolyl phthalamic acid (Duraset) was proven to be an effective plant-increasing agent and also stimulated an abundant growth of fiberous roots.

More detailed studies with these plant-increasing chemicals must be performed and especially since they may be quite toxic to some plant tissues. As has been pointed out, if improperly applied they may be quite damaging to the roots and/or the plants.

Unlike most stems, roots do not have a rest period and it might be inferred that in contrast with the sprouting behavior of stems as typified by the Irish potato tuber, maximum sprouting would be attained immediately after the sweetpotato is harvested. In this investigation, the age-of-roots factor was most significant. When year-old (13 mo.) roots were compared with new or 1-month roots, the absence of proximal dominance in the former, resulted in the initiation of around 30 buds or more per root in comparison with about six buds in the latter. The comparison of fall (November) propagation tests (33 day roots) with those conducted in the spring (142-day roots) show similar but less extreme differences. These are interesting observations on the post-harvest physiology of the sweetpotato root.

Some other factors affecting the sprouting potential of sweetpotato roots came to the surface during the course of this study. A genetic basis for plant production is suggested in that parent lines, ranking high in plant production (e.g. parent 176), contributed to the origin of the high $F_1$ seedlings. Similarly, the maximum plant production of 3000 plants/bushel for the parent lines was about equal to that for the $F_1$ crosses.

A significant number of individuals as seedling hills in their first vegetative propagation, failed completely in plant production due to the decay of the bedded roots. This is a natural or inherited character and serves to eliminate a number of individuals that are not adapted to our methods of growing sweetpotatoes just as some individuals are eliminated when roots fail to come through the storage period in a sound condition.

In the course of this study it was noted that the propagation value of the roots was affected by mistreatment after harvesting, e.g. chilling, and also by delay in bedding the roots after they are removed from storage. In either case an increase in root decay in the bed and a proportionate decline in plant production resulted. This situation was demonstrated by the higher percent decay caused by the delay in bedding the roots in the spring of 1962 and by the root decay and low plant production in the Nemagold propagated in the fall of 1962. These results emphasize the importance of harvesting the sweetpotato crop before cold weather and that they should be promptly and properly cured and stored.

The association between early emergence of the sprouts and high plant production was quite evident in the data obtained in these tests.

Four pullings of plants were made in these tests and as indicated in 1962 (Table V) about forty-four per cent of the total plants were produced in the first pulling. Although the size-of-root factor was not a part of this study, when variations in root size were found, it was apparent, as has been previously reported, that large roots produce fewer plants when plant production is expressed on a pound or bushel basis.

When the results of this study, which involved 231 individuals, are summarized (Figure 11) we obtain a good perspective of this problem of vegetative propagation (by roots) of (Ipomoea batatas Lam.)

This frequency histogram includes several groups and population of sweet-potato individuals, some of which were handled under more or less ideal conditions of storage and propagation whereas others were subjected to some unfavorable conditions. Because of this, it is believed that the cardinal points on this histogram are more realistic than those expressed by results of a single test conducted for example, under most ideal conditions.

Thus we might expect a number of seedlings to fail to propagate by roots while the mean of 1800 plants per bushel for four pullings might be expected from a great number of seedlings. This would require about 7 bushels per acre and proportionately more if less than four pullings are made.

The old varieties such as Porto Rico and the Jersey types are good propagators and would be found on the high side of this frequency distribution. High plant production contributed to their continued success as a commercial variety. Varieties of recent breeding or origin are found at various levels in regard to plant production. Unfortunately, some of these are on the low side. Varieties originated at this station rank as follows: Nemagold, Redgold, Allgold, and Tanhoma. All were above the average of about 3000 plants/bushel and would require a maximum of 4 to 5 bushels/acre if four pullings are made.

## Summary

1. Proximal dominance is a deciding factor in plant production of bedded sweetpotato roots.

2. There is a chemical approach to the problem of increased plant production but the use of some chemicals is attended by risk of plant injury and sweetpotato growers have been reluctant to adopt this practice.

3. During the post-harvest period there is a gradual loss of proximal dominance in sweetpotato roots. Thus roots, approximately one year of age, will show little proximal dominance and produce five times as many plants as cured roots of the current harvest.

4. Roots propagated in the fall one month after harvest produced less plants in four pulling test than those propagated in the spring and 143 days after harvest.

5. There is a clear association between early sprouting and emergence of the sprouts and the total number of plants produced by the roots.

6. There is a genetic basis for plant production in the sweet-potato. Thus high plant producing parents give rise to high plant producing $F_1$ seedling individuals. More data in this area would help to more clearly define the parent-seedling relationship.

7. When four pullings of plants were made the percent of the total number of plants was respectively 44 - 24 - 17 - 14.

8. The post-harvest handling and storage of the sweetpotato roots affects their propagation capacity. Chilling roots before and after storage and undue delay in bedding results in decay of bedded roots and low plant production.

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VITA

Maamun S. Jayyoussi

Candidate for the Degree of

Master of Science

Thesis: A STUDY OF SOME FACTORS AFFECTING THE CAPACITY FOR VEGETATIVE REPRODUCTION IN THE OPOMOEA BATATAS LAM WITH SPECIAL REFERENCE TO BEDDED ROOTS

Major Field: Horticulture (Vegetable Crops)

Biographical:

Personal data: Born in Jerusalem, Jordan (Palestine), April 2, 1938, the son of Shakib and Najdia Jayyoussi.

Education: Attended elementary and secondary schools in Tulkarm, Jordan; finished the high school, 1955. Attended Kadoori Agriculture School in 1955 and graduated with agriculture diploma in 1958. Received Bachelor of Science Degree from Oklahoma State University in 1962; completed requirements for the Master of Science Degree in May, 1963.

Professional Organization: Horticulture Club, American Society of Horticulture Science.