A STUDY OF THE GROWTH CYCLE OF SUDAN GRASS

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A STUDY OF THE GROWTH CYCLE

OF SUDAN GRASS

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I. INTRODUCTION

There is considerable evidence suggesting that the change from vegetative to reproductive growth in annual plants takes place principally at the time of the formation of floral primordia. Loehwing (8) states that the first observable indication of this floral inception is a rather abrupt increase in the rate of transpiration which can be measured by the amount of water necessary to maintain pots of soil, and the plants grown in them, at a constant weight. He further states that tissue analyses show a lower moisture content and, consequently, a higher percentage of dry weight at this time. The decrease in the moisture content of the tissues was regarded as a reliable index to the onset of flowering. Loehwing (9) summarizes the published data by stating that "the most profound compositional and developmental changes in the plants' entire existence occur in the brief period of floral differentiation." He goes on to say that these changes are often overlooked because they are localized in certain tissues, are of small numerical magnitude, and occur only during a brief period.

Loehwing (7), in a review of the published data on the nutrition of annuals, summarized the literature concerning the changes in their moisture content, mineral nutrients, proteins, and carbohydrates during the period of transition from the vegetative to the reproductive phases of development.

In view of Loehwing's statement (7) that "as flowering is approached a pre-flowering drop in moisture content is often associated with, and hence a convenient index to, the presence of flower primordia or young buds in many annuals", the present study was carried out in order to determine if this generalization could be applied to Sudan Grass.

Most publications which report data on the dry weight and chemical compositions of various plants are based on examinations at intervals of several days; hence it is obvious that a sudden change in percentages of moisture might have passed unobserved. In order to avoid this possibility, observations were made daily during the growth period of Sudan Grass.

Sudan Grass was used in this experiment because of its agricultural value as a forage crop in the eastern and southwestern areas of the United States. It has been reported that sometimes, during a series of successive cuttings, the grass does not recover vegetatively as it should. There is a possibility that this inability to recover after cutting may be related to the physiological condition of the plant existing at the time of cutting.

At this point a short resumé of the history of Sudan Grass is not out of place to show its agricultural importance. Sudan Grass was introduced into the United States from Africa as a result of a search for a species of wild Andropogon which did not possess rootstocks as does Johnson Grass (20). C. V. Piper (13), of the Office of Forage Crop Investigations, organized the search and on March 16, 1909, obtained a grass called "garawi" from the Director of Agriculture and Lands of the Sudan Government at Khartum. This grass gave considerable promise as a forage crop and in order to assist in its distribution the unique name Sudan Grass was given to it (20). The superiority of Sudan Grass over Johnson Grass, which it closely resembles, lies in the fact that it is easily controlled in the field because of its lack of rootstocks. Hillman (4) and Long (10) discuss the history of these grasses and the distinguishing features between them. Space does not permit a discussion of the subsequent development of the uses of Sudan Grass, but several references are included in the bibliography concerning the agricultural importance of this species (3, 6, 13, 15, 18, 19, 21, 23), a disease resulting in chlorosis of the leaves (22), and the problem of its cyanogen content (2, 5, 11, 12, 16, 17).

II. EXPERIMENTAL METHODS

A. Experiment 1

The greenhouse used for this experiment was large enough to contain a central concrete bench fifty-three feet long and five feet wide. One hundred and forty-seven pots, nine inches in diameter, were filled with a loamy farm soil and spaced six inches apart in four rows running length-wise along the bench. The pots were far enough apart to receive sufficient light to promote the subsequent growth of the plants.

Thirty Sudan Grass seeds were planted in each pot on October 22, 1946. The seeds were spaced so that each was separated from the others by a distance of about one inch. Each pot was lightly watered daily.

The plants were allowed to develop undisturbed for a period of thirty-six days. After this time, they were large enough to begin the daily cuttings. A sufficient number of plants was cut so that about five grams of dried plant material were obtained for chemical analyses. The number of plants in each daily cutting was such that sampling errors were minimized. The plants were cut at noon each day one inch above the surface of the soil. The harvested plants were counted and quickly weighed to the nearest tenth of a gram.

Not more than twenty minutes later, the fresh material was placed in an oven and dried for twenty-four hours at a temperature of 100 degrees Centigrade. The oven-dried plants were weighed and stored in envelopes. From the recorded gross data, the following calculations were made:

1. Average fresh weight per plant.
2. Average dry weight per plant.
3. Average weight of moisture per plant.
4. Percentage dry matter.
5. Percentage moisture.

The percentage of nitrogen in each daily cutting was determined on the dry weight basis by the Kjeldahl method modified to include the nitrogen of nitrates (1). Twenty-three consecutive daily cuttings were analyzed in this manner.

The stubble was allowed to recover after each cutting. On January 30, 1947, the surviving plants were counted and compared with the number of plants originally present. A second survival count was made on February 27, 1947, the results of which did not differ materially from the first. On February 27, 1947, all the plants representing the second growth were cut and the material was labelled to correspond to its previous daily cutting dates. In other words, all the plants recovering from any particular daily cutting were grouped together resulting in twenty-three lots corresponding to the original twenty-three daily cuttings. These groups were weighed immediately, and were then oven-dried for twenty-four hours at 100 degrees Centigrade. As before, the dry weights were taken and the percentage nitrogen was determined. The same calculations were made and recorded as for the daily cuttings.

B. Experiment 2

Sudan Grass, under favorable field growing conditions, can be expected to attain a dry weight per plant of 5.35 grams in 92 days (14). Inasmuch as the dry weight of plants of Experiment 1 did not weigh more than an average of 1.00 gram per plant after 62 days, the growth obviously was subnormal. The temperature of the greenhouse on the dates the cuttings were made varied from 50° F. to 90° F. with lower temperatures at night. Based upon the experience gained from Experiment 1, it appeared advisable to raise the temperature of the greenhouse as well as to increase the length of day artificially. Accordingly, additional steam pipes were laid along the walls of the greenhouse and 300-watt electric bulbs were hung four feet above the plants at intervals of seven feet along the entire length of the bench.

One hundred and eighty-four pots were arranged in four rows, running the length of the bench, on March 12, 1947. There were forty-six pots in each row. Two rows were fertilized with 2.8 grams of ammonium nitrate, which corresponded to 600 pounds per acre, and the other two rows were left unfertilized. Thirty-six seeds of Sudan Grass were planted in each pot. Because of the better growing conditions resulting from increased temperature and the use of an eighteen hour day, the plants thrived much better than those of the previous experiment. This was especially true for the nitrogen-fertilized plants.

The first daily cutting was made on April 7, 1947, when the plants were twenty-six days old. Daily cuttings were made after this date as in Experiment 1 except that there were two sets of daily cuttings--the fertilized and the unfertilized. There were enough pots to permit thirty-three daily cuttings instead of the twenty-three in Experiment 1. The same data and calculations were made and recorded as for the first experiment.

III. EXPERIMENTAL RESULTS

A. Section I. Sudan Grass cut at daily intervals

1. Introduction: Tables 1, 2, and 3 and figures 1 to 8, inclusive, present the data based on the daily cuttings of the Sudan Grass. In the figures, curve 1 represents the data obtained from the first experiment. It should be borne in mind that the growing conditions were very poor because of the low temperature in the greenhouse, the short day length, and the comparatively infertile soil. Yet in spite of these conditions, the plants flowered and ultimately produced normal seeds.

Curves 2 and 3 represent data based on the second experiment. The growing conditions for these plants were much improved since additional steam pipes had been installed in the greenhouse, the installation of a row of electric lights over the bench provided an 18-hour day, and half of the pots were fertilized with ammonium nitrate in amounts corresponding to 600 pounds per acre. The growth of these plants, of course, was very much greater than that obtained in the earlier experiment. But it is important to note that the flowering of these plants was greatly delayed, apparently because of the longer day length. It is apparent that the physiological state of the plants in experiment 2 was fundamentally different from that existing in experiment 1. It should not be inferred that the very rapid growth of the plants of the second experiment was related to the process of flowering. It is more probable that the long day length provided, artificially disturbed the normal reproduction processes of the plants.

2. Fresh weight of the plants: The average fresh weights per plant are presented in tables 1, 2, and 3 and in figure 1. The data are typical of usual growth rates, in as much as the total fresh weight per plant increased as would be expected. The rate of increase was almost constant in experiment 1. In experiment 2, a more rapid growth was initiated after about 45 days. Curve 3 indicates that the addition of ammonium nitrate to the soil significantly increased the total fresh weight of the plants, but this effect became apparent only after 45 days.

3. Amount of moisture per plant: Tables 1, 2, and 3 and figure 2 indicate the average amounts of moisture per plant, during the growth period. The similarity of the curves in figure 2 to those representing the total average fresh weight per plant is apparent. On one hand,

this similarity would be expected since the fresh weight is comprised of such a high percentage of moisture. But on the other hand, a dissimilarity would be expected during a brief period before flowering, if it is true that a general dehydration of the plant preceeds flowering in accordance with the theory of the existence of a "sensitive period" at this stage of development. Careful comparison of the curves in figures 1 and 2 suggest that a period of tissue dehydration did not occur. It is not impossible, however, that small differences in the moisture content of the plants would not be detected by these gross measurements. This possibility will be discussed below.

4. Percentage of moisture in the plants: The percentage of moisture in the plants should give a clearer picture of periods of protoplasmic dehydration than would the total amount of moisture per plant. The data assembled in tables 1, 2, and 3 and in figure 3 were obtained with great care. Their irregularities in magnitude cannot be ascribed to experimental error in the moisture determination.

The less vigorous plants of the first experiment contained a higher percentage of moisture after the 45th day than did any of the vigorously growing plants of the second experiment. Curves 2 and 3 show that the plants fertilized with ammonium nitrate contained conspicuously higher percentages of moisture than the unfertilized plants.

The variations in the percentage of moisture in the plants are difficult to interpret. The less vigorous plants of the first experiment appear to contain increasing percentages of moisture until the

40th day, then a diminishing moisture content appear which reached a minimum on the 43rd day. After this minimum, a second period of increase appeared, followed by the expected gradually lessened moisture content associated with approaching maturity.

The unfertilized plants of the second experiment contained a smaller percentage of moisture than did the other two series. There was a continually decreasing percentage until the 47th day after which there was an increase until the 53rd day. The final decrease was associated with the maturity of the plants. The nitrogen fertilized plants of the second experiment appear to contain a continually decreasing percentage of moisture.

A comparison of the percentages of moisture in the plants of all three series during the early part of their growth suggests certain similarities, although each series varied significantly in the conditions of growth. One might ask the following questions:

In the comparison of curves 2 and 3, do the minima occurring successively in curve 3 at 36, 39, 42, and 45 days correspond to the minima exhibited by curve 2 which occurred at 34, 36, 40, and 47 days? If this be true, then these variations are not only physiologically significant, but the unfertilized plants lag behind the fertilized by 2 or 3 days. These minima could not be caused by differences in the weather since they occur on different days.

If curve 1 is compared to curves 2 and 3, the following questions arise: Is the minimum in curve 1 at 43 days indicative of a period of tissue dehydration, and if so, is it related to the minima in curve 2 on the 47th day and in curve 3 on the 45th day? These questions will be discussed in a later section of this report.

5. <u>Amount of dry matter per plant</u>: The average amounts of dry matter per plant are presented in tables 1, 2, and 3 and in figure 4. The very poor growth obtained in experiment 1 is easily seen from the figure. The maximum dry weight attained by these plants was only about 0.1 gram, while the thriving plants of experiment 2 attained a final dry weight of about 0.8 gram. Nothing of significance is evident in curve 1, but an interesting comparison may be made between curves 2 and 3. It will be noted that maxima appear in the dry weight of the nitrogen fertilized plants on the 30th, 33rd, 37th, 39th, 41st, 43rd, 46th, 49th, 51st, 54th, and 56th days. A similar series of maxima appear in curve 2 representing the unfertilized plants, on the 31st, 33rd, 35th, 38th, 40th, 44th, 47th, 51st, and 57th days. If these maxima have physiological significance, then it is apparent that nitrogen fertilized plants were 1 or 2 days ahead of the unfertilized plants in their rhythmically occurring accumulation of dry material.

It is interesting to note that the actual amount of dry matter in the fertilized plants was less than in the unfertilized, except during the last few days of the observation period.

6. Percentage of dry matter in the plants: The percentages of dry matter in the plants obviously are reciprocally related to the percentages of moisture discussed above. The data are assembled in tables 1, 2, and 3 and in figure 5. Curve 1, in figure 5, shows that the percentage of dry material in the plants of the first experiment decreased to a minimum on the 40th day, then increased to a maximum on the 43rd day, again decreased to a second minimum on the 49th day, and finally rose to a second maximum as the plants approached maturity.

Comparison of curves 2 and 3 indicates that the nitrogen fertilized plants contained a significantly less percentage of dry matter than did the plants of the unfertilized series. This difference was especially evident during the period from the 31st to the 49th day. Again a comparison may be made between the recurrent maxima exhibited by the unfertilized and fertilized plants. The unfertilized series exhibited maxima on the 27th, 29th, 34th, 37th, 40th, 45th, 47th, 52nd, 54th, and 59th days. A similar series of recurrent maxima appeared in the percentages dry weight of the fertilized plants on the 27th, 29th, 33rd, 36th, 39th, 42nd, 45th, 50th, 52nd, 55th, and 60th days. Again it is apparent that if these variations are physiologically significant, the fertilized plants are 1 to 3 days ahead of those in the unfertilized series.

7. Amount of nitrogen per plant: The average amounts of nitrogen, expressed as milligrams per plant, are indicated in tables 1, 2, and 3 and in figure 6. The unthrifty plants of experiment 1 gradually

accumulated nitrogen until about the 54th day. The slight decrease after that time was due to the loss of the lower withered leaf. The maximum nitrogen absorbed per plant in the first experiment was about 3.5 milligrams, while the maximum absorbed from the same soil during the better growing conditions of the second experiment was 10.0 milligrams. The nitrogen fertilized plants of the second experiment absorbed a maximum of almost 18 milligrams. The effect of fertilization on the nitrogen absorbed is not evident during the earlier stages of growth, but it becomes conspicuously great during the later period of growth.

The variability in the amount of nitrogen in the daily cuttings was not due to errors in the nitrogen determination, but represents real differences. A series of recurrent maxima is evident from figure 6, but it is difficult to compare the maxima of curves 2 and 3. In several instances, however, it again appears that these maxima appear 1 or 2 days earlier in the fertilized plants.

8. <u>Percentage of nitrogen in the plants</u>: The data for the percentage of nitrogen in the daily cuttings of Sudan Grass are presented in tables 1, 2, and 3 and in figure 7. The plants of the first experiment exhibited a decreasing percentage of nitrogen throughout their growth period. The minimum which occurred on the 47th day, and the gradual increase until the 49th day should be especially noted in connection with the discussion of the percentage of the plants which survived cutting.

It is noteworthy that the percentages of nitrogen in the more vigorous plants obtained in the second experiment were considerably lower than occurred during the first experiment. This is especially true for the unfertilized plants of the second series. This result is to be expected since the same, rather poor soil was used, and the better growing conditions caused the production of a greater amount of plant material.

The nitrogen fertilized plants of the second series contained greater percentages of nitrogen than the unfertilized plants grown at the same time, but not as great as the percentages of nitrogen in the poorer plants of the first experiment. The minimum which appeared in the unfertilized plants of the second experiment on the 47th day should be especially noted in connection with the discussion of the percentage of the plants which survived cutting.

9. Percentage survival of the plants after cutting: The present study was designed especially to discover if there is a period during the growth cycle of Sudan Grass during which the plant is sensitive to cutting. The amount of recovery was not investigated, but attention was centered on the ability of the plant to merely survive.

The data indicating the percentage survival of the plants, cut on successive days, are presented in tables 1, 2, and 3 and in figure 8. The data for the first experiment are especially interesting when it is recalled that these plants flowered, in spite of their poor

growing conditions and their reduced growth. There seems to be an increasing sensitivity to cutting which became increasingly acute as shown by the minima which occurred on the 40th, 46th, and 49th days. If minor differences are ignored, the sensitivity to cutting began on about the 43rd day and became acute on the 49th day. A decrease in sensitivity to cutting occurred from the 49th to the 55th day. A comparison of figures 1 and 8 shows no relationship between the "sensitive period" during the growth of the Sudan Grass and the fresh weight of the plants. Figure 2 shows that the amount of moisture in the plant also was not related to the sensitive period. Figure 3 shows that the beginning of the sensitive period coincided with a pronounced minimum in the percentage of moisture in the plants, namely, the 43rd day. However, the percentage moisture increased to a maximum on the 49th day, even though the sensitivity to cutting was becoming more acute. The relationship between the period between the maximum dehydration of the tissue and the return to normal, to this "sensitive period" is suggestive.

Figure 4 shows that the average dry weights of the plants of experiment 1 were not related to sensitivity to cutting.

Figure 5 indicates that the relationship between the percentage of dry matter in the plants of experiment 1 was at a maximum on the 43rd day, which was the beginning of the sensitive period. This percentage decreased throughout the development of the sensitive period,

or until the 49th day. After that day, a steady increase in the percentage of dry matter occurred.

Figure 6 shows that the amounts of nitrogen in the plants of experiment 1 were not related to the sensitivity of the plants to cutting. Figure 7 indicates that the percentage of nitrogen also was unrelated to the sensitive period.

The plants studied in experiment 2 did not exhibit any discernible period sensitive to cutting. The minor differences in the percentage recovery of the plants of different ages recorded in tables 2 and 3 and in figure 8 are not related to corresponding variations in any of the observations made during their growth cycle. The absence of a sensitive period in these series of plants is ascribed to the effect of the long day length under which they were grown.

B. Section II. <u>Sudan Grass produced by roots of different age</u>

1. <u>Introduction</u>: The plants of all three series described above were allowed to recover after the daily cuttings described in Section 1 of this report. All plants of each series were harvested at the same time. A group of samples of the top growth for each series was obtained which not only differed in age but which had been produced by roots of different age. For example, at one end of the series the original cutting described in Section 1 was made from young roots. The same roots, therefore, had a longer period for producing the second crop of tops to be described in the present section. At the

other end of the series, the original cutting was made from the oldest roots, and consequently, the tops described in the present Section were the youngest of the group.

The purpose of the observations described in Section 1 was to discover if there was a period in the growth cycle of Sudan Grass during which the cutting of the tops would kill the plants. This was seen to be true for the plants of experiment 1 which were grown under a comparatively short day length. On the other hand, no sensitive period was observed for the 2 series of plants of experiment 2, which were grown under an 18 hour day.

If a true sensitive period occurs during the growth cycle of Sudan Grass, during which recovery after cutting is depressed or impossible, it appears logical to ascribe its physiological basis to some property or condition of the roots, rather than to the tops. If the roots from which the tops had been removed were allowed to produce new tops, in so far as they were able, no sensitive period should be observed when the tops were cut. The reason for this assumption is apparent since the youngest roots which might be presumed to undergo a sensitive period during the period of the second growth of the tops had a comparatively long period before their tops were cut, and any sensitive period would be safely passed. The older roots, which had a short period in which to produce tops would be presumed to have passed their sensitive period while they were producing their first crop of tops.

Although a sensitive period appeared as described in Section 1, a few plants did survive, probably because the physiological age of the individual plants in each pot differed slightly and the few which survived cutting were not in the sensitive stage. The data described in this section are based on all the plants which survived although it seems likely that those few plants which survived the sensitive period would not be completely comparable to the more normal plants. The observations described below were especially directed towards the recovery growth from the roots which were harvested during the sensitive period.

2. Fresh weight per plant: The data representing the average fresh weight per plant of the recovered plants are assembled in tables 4, 5, and 6 and in figures 9 and 10. One base line indicates the actual age of the tops when harvested; the other base line indicates the age of the root at the time when the recovery growth began, in other words, when the first cutting was made.

The plants of the first experiment (figure 1, curve 1) show a very irregular magnitude of the recovery growth. Of course, the amount of recovery growth diminishes as the age of the tops diminishes, but even in view of the erratic data, it appears that the average fresh weight of the tops was more or less the same, in spite of their very different age, until the age of the roots was about 47 days. This age, it will be recalled, is about midway in the sensitive period of these plants described in Section 1. With the exception of this abrupt decrease in the weight of the recovered plants, there seems to be a slight general decrease as the age of the tops lessened and the age of the roots which produced them increased. One may suspect that the older roots which produced the youngest tops were effective in augmenting the speed of recovery.

The unfertilized, long-day plants of experiment 2 (figure 2, curve 1) show a remarkable equality in the average weight of the tops, even though they differed greatly in age. In fact one might even presume a gradual <u>increase</u> in the weight of the tops when the roots were about 49 days old. The effect of the older roots in speeding the rate of top growth again suggests itself.

The nitrogen-fertilized plants of experiment 2 are seen from table 6 and figure 10 to show a much greater difference in the amount of top growth recovery as the tops differed in age. The effect of the older roots in speeding the recovery growth is not apparent. There seems to be a more rapid decline in the amount of recovery growth after the roots were about 49 days old. It is interesting to recall that this age was about when the sensitive period appeared in the reproductive plants of experiment 1.

3. <u>Amount of moisture per plant</u>: The amounts of moisture per plant observed in experiment 1 and recorded in table 4 and in figure 11 show about the same variation with the age of the recovered tops

as did the total fresh weight. The youngest tops contained less moisture per plant.

Tables 5 and 6 and figure 12 show a decrease in the moisture per plant for the plants obtained in experiment. This decrease was very small in the unfertilized series. Even though this decrease is more pronounced for the nitrogen fertilized series, it is less accentuated than was the decrease in the total fresh weight shown in figure 10. There seems to be a more rapid decrease after the roots were 49 days old.

4. <u>Percentage of moisture in the plants</u>: The data in table 4 and in figure 13 show that the percentage of moisture in the plants of experiment 1 increased as the tops were younger. One might assume from the data a period of general tissue dehydration when the tops were from 70 to 75 days old.

The data in tables 5 and 6 and in figure 14 show a gradual increase in the percentage moisture in the tops as they become younger. This increase seems to be more rapid when the tops were less than 48 days old, and the roots were more than 38 days old.

The older fertilized plants contained a smaller percentage of moisture than did the unfertilized plants in their more mature stages, but the percentages of both series were about equal in the younger tops.

5. <u>Amount of dry matter per plant</u>: The data recorded in table 4 and in figure 15 show in grams the average amount of dry matter per

plant for the plants obtained in experiment 1. Comparison of figures 13 and 15 shows that, in general, the amount of dry matter per plant varied inversely, as would be expected, as the percentage of moisture. There was a decrease in the average amount of dry material per plant as the tops became younger.

Tables 5 and 6 and figure 16 show a more rapid decrease in the dry weight per plant for the fertilized group. The older tops of the fertilized plants weighed about twice as much as the unfertilized, yet the weights of the younger plants of both the fertilized and unfertilized group were almost equal. The effect of the ammonium nitrate fertilizer was increasingly greater as the tops became older.

6. Percentage of dry matter in the plants: Table 4 and figure 21 indicate the percentages of dry material in the tops of the plants. These data, of course, are reciprocal to the percentages of moisture. The period of a probable dehydration of the tissue again is apparent, when the tops were from 70 to 75 days old, and were produced by roots from 58 to 53 days old. The general minimum in the percentage of dry matter which appeared when the tops were from 76 to 83 days old and when the roots which produced them were from 52 to 45 days old occurs on the same plants which exhibited the sensitive period described in Section I.

Figure 22 shows the gradual decrease in the percentage of dry matter in the tops of the two groups of plants in experiment 2 with the decreasing age of the tops. In general, the nitrogen fertilized plants contained the greater percentage of dry matter in the more mature stage, but the values were about equal to those of the unfertilized plants when the tops were younger.

7. Amount of nitrogen per plant: The data in table 4 and figure 17 show that the amounts of nitrogen in the tops of the plants of experiment 1 varied from about 9 milligrams in the older tops to about 5 milligrams in the younger tops. The amount was about equal in all tops having an age greater than about 82 days. Tops younger than 82 days showed very irregular nitrogen contents, but in general much lower.

The effect of nitrogen fertilizer on the nitrogen content of the tops is shown strikingly in figure 18. The older fertilized plants contained more than twice as much nitrogen in the tops. The total nitrogen did not vary greatly in the unfertilized series. The effect of the fertilizer is more pronounced in the nitrogen content than in the total growth.

8. Percentage of nitrogen in the plants: The data in table 4 and figure 19 are especially interesting. The percentage of nitrogen in the tops was almost identical during the later stages of growth, when the tops were from about 81 to 92 days old, when the roots which produced the tops were from 36 to 47 days old. There was a sudden maximum in the percentage of nitrogen in the tops when they were from about 81 to 73 days old, and when the roots which produced them were

from 44 to 55 days old. This is especially interesting since these same roots exhibited a "sensitive period" during their original growth, between the ages of 44 and 53 days.

Tables 5 and 6 and figure 20 show that the percentage of nitrogen in the tops was about the same for the plants of the second experiment, after they had attained an age of about 45 days. Tops younger than 45 days exhibited a small progressive increase in percentage of nitrogen with decreasing age. The nitrogen fertilized plants contained a slightly higher percentage of nitrogen throughout their growth cycle. No conspicuous maximum in the concentration of nitrogen occurred, in contradiction to the reproductive plants of the first experiment.

IV. SUMMARY AND CONCLUSIONS

1. Sudan Grass was grown in pots of soil in the greenhouse under the conditions of low and high temperature, short and long days, and low and high nitrogen content of the soil. Daily cuttings were made and the following data were obtained: (1) total fresh weights, moisture, dry matter, and nitrogen; (2) the percentages of moisture, dry matter, and nitrogen; (3) percentage of the plants surviving cutting; (4) the amount of recovery growth and the amount of fresh weight, moisture, dry matter, and nitrogen which it contained.

Effects of nitrogen fertilizer

2. The addition of ammonium nitrate at the rate of 600 pounds per acre did not greatly affect the fresh weight of the plants nor the amount of nitrogen absorbed except in the later stages of growth.

3. Nitrogen fertilization caused a higher percentage of moisture and a lower percentage of dry matter in the plants.

4. Nitrogen fertilization markedly increased the nitrogen concentration of the vigorous, long-day plants.

Effects of short day

5. The percentages of moisture and of nitrogen in the plants grown under unfavorably cool temperatures and short days were greater than in the more vigorous plants grown under favorable temperature and a long day length, even when ammonium nitrate was added to the long day plants at the rate of 600 pounds per acre.

6. A brief sensitive period during the growth of Sudan Grass was detected during which the plants could not survive cutting.

7. The sensitive period existed between the 43rd and 49th days from planting.

8. Increasing the day length to 18 hours eliminated the sensitive period.

9. The sensitive period was not related to the general vigor of the plants, nor to the total fresh weights, dry weights or nitrogen content of the plants.

10. The sensitive period was not related to the percentage of nitrogen in the plants.

11. The sensitive period was preceeded by a well defined period of general tissue dehydration as indicated either by the percentages of moisture or by the percentages of dry matter in the plants.

12. The appearance of the maximum percentage of dry matter and the lowest percentage of moisture occurred at the beginning of the sensitive period.

Recovery growth

13. The amount of recovery growth was about the same for all plants which had been cut before the sensitive period. When the plants were cut after the sensitive period, the amount of recovery growth was related to the actual age of the tops when they were harvested.

14. The amount of recovery growth <u>per day</u> appeared to be greater if it was produced by the older roots, that is, if the original cutting had been made <u>after</u> the sensitive period.

15. The percentage of nitrogen was greater in the recovery growth of the plants which had been cut previously during the sensitive period.

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Table 1. Experiment 1. Data concerning daily cuttings of Sudan Grass.

Age in days	Fresh Weight per Plant (gms.)	Moisture		Dry Matter	
		Wt. per plant (gms.)	Percentage	Wt. per plant (gms.)	Percentage
36	0.18	0.15	85.8	0.03	14.2
37	0.18	0.15	86.5	0.03	13.5
38	0.21	0.18	86.8	0.03	13.2
39	0.25	0.22	87.5	0.03	12.5
40	0.33	0.29	88.4	0.04	11.6
41	0.34	0.30	87.2	0.04	12.8
42	0.34	0.30	87.4	0.04	12.6
43	0.32	0.27	85.5	0.05	14.5
44	0.46	0.40	87.5	0.06	12.5
45	0.49	0.43	87.5	0.06	12.5
46	0.63	0.55	88.0	0.08	12.0
47	0.56	0.49	87.7	0.07	12.3
48	0.61	0.54	88.5	0.07	11.5
49	0.63	0.56	88.6	0.07	11.4
50	0.78	0.68	87.3	0.10	12.7
51	0.75	0.66	87.9	0.09	12.1
52	0.59	0.51	86.6	0.08	13.4
53	0.71	0.61	86.1	0.10	13.9
54	0.99	0.86	86.7	0.13	13.3
55	0.71	0.61	86.4	0.10	13.6
56	0.90	0.78	87.1	0.12	12.9
57	0.77	0.67	86.7	0.10	13.3
58	0.74	0.63	85.6	0.11	14.4

Table 1. Concluded

Age in days	Nitrogen: Amount per plant (mgs.)	Nitrogen: Percentage	Survival after cutting (percentage)
36	0.9	3.56	99.5
37	0.9	3.80	95.6
38	1.0	3.76	96.5
39	1.2	3.87	83.6
40	1.6	4.10	71.3
41	1.7	3.75	90.0
42	1.7	3.88	92.5
43	1.7	3.59	91.6
44	2.2	3.84	78.3
45	2.2	3.63	70.5
46	2.9	3.79	56.2
47	2.3	3.32	73.4
48	2.5	3.58	29.4
49	2.6	3.61	24.7
50	3.2	3.27	32.5
51	2.8	3.04	58.4
52	2.2	2.82	57.1
53	2.9	2.91	61.0
54	3.6	2.75	70.7
55	2.6	2.72	83.2
56	3.3	2.83	75.0
57	2.8	2.78	72.6
58	2.7	2.57	71.3

Table 2. Experiment 2. Data concerning daily cuttings of unfertilized Sudan Grass.

Age in days	Fresh Weight per Plant (gms.)	Moisture		Dry Matter	
		Wt. per plant (gms.)	Percentage	Wt. per plant (gms.)	Percentage
26	0.37	0.33	89.0	0.04	11.0
27	0.37	0.32	86.9	0.05	13.1
28	0.61	0.54	89.0	0.07	11.0
29	0.49	0.44	88.8	0.05	11.2
30	0.80	0.72	89.9	0.08	10.1
31	0.87	0.78	89.2	0.09	10.8
32	0.64	0.56	88.1	0.08	11.9
33	0.83	0.72	87.2	0.11	12.8
34	0.77	0.66	85.9	0.11	14.1
35	0.98	0.84	86.3	0.14	13.7
36	1.12	0.97	86.2	0.15	13.8
37	1.02	0.87	85.3	0.15	14.7
38	1.29	1.10	85.5	0.19	14.5
39	1.30	1.13	86.6	0.17	13.4
40	1.35	1.13	84.1	0.22	15.9
41	1.36	1.15	84.9	0.21	15.1
42	1.22	1.04	85.0	0.18	15.0
43	1.26	1.07	85.0	0.19	15.0
44	1.51	1.28	85.0	0.23	15.0
45	1.18	0.97	82.3	0.21	17.7
46	1.44	1.20	83.6	0.24	16.4
47	1.67	1.37	82.0	0.30	18.0
48	1.59	1.31	82.7	0.28	17.3
49	1.80	1.50	83.4	0.30	16.6
50	2.35	2.00	85.0	0.35	15.0
51	3.01	2.57	85.5	0.44	14.5
52	2.04	1.64	85.3	0.40	14.7
53	2.18	1.86	85.6	0.32	14.4
54	2.21	1.84	83.4	0.37	16.6
55	2.72	2.29	84.2	0.43	15.8
56	3.39	2.86	84.5	0.53	15.5
57	3.75	3.19	85.1	0.56	14.9
58	3.11	2.59	83.4	0.52	16.6

Table 2. Concluded

Age in days	Nitrogen: Amount per plant (mgs.)	Nitrogen: Percentage	Survival after cutting (percentage)
26	1.6	4.10	100.0
27	1.8	3.69	100.0
28	2.9	4.07	95.8
29	1.9	3.85	98.7
30	3.3	4.09	94.2
31	3.3	3.68	100.0
32	2.8	3.51	97.4
33	3.6	3.29	100.0
34	2.9	2.62	100.0
35	4.1	2.94	97.1
36	4.6	2.86	100.0
37	3.8	2.52	95.2
38	4.9	2.56	96.2
39	4.4	2.59	100.0
40	5.0	2.28	98.0
41	4.9	2.31	98.0
42	4.3	2.36	100.0
43	4.0	2.10	100.0
44	6.0	2.61	100.0
45	4.7	2.25	100.0
46	5.2	2.16	100.0
47	3.8	1.27	100.0
48	4.8	1.71	93.3
49	4.3	1.44	95.8
50	6.2	1.76	97.9
51	8.3	1.89	97.5
52	9.4	2.36	94.5
53	7.1	2.21	97.7
54	7.6	2.05	100.0
55	6.0	1.40	100.0
56	7.5	1.42	97.7
57	10.5	1.88	100.0
58	6.4	1.23	97.0

Table 3. Experiment 2. Data concerning daily cuttings of fertilized Sudan Grass.

Age in days	Fresh Weight per Plant (gms.)	Moisture		Dry Matter	
		Wt. per plant (gms.)	Percentage	Wt. per plant (gms.)	Percentage
26	0.30	0.27	88.8	0.03	11.2
27	0.36	0.32	88.1	0.04	11.9
28	0.47	0.42	89.1	0.05	10.9
29	0.58	0.52	89.1	0.06	10.9
30	0.63	0.56	89.6	0.07	10.4
31	0.57	0.51	89.3	0.06	10.7
32	0.56	0.49	88.5	0.07	11.5
33	0.94	0.83	88.3	0.11	11.7
34	0.79	0.70	88.2	0.09	11.8
35	0.88	0.77	87.6	0.11	12.4
36	0.96	0.84	87.5	0.12	12.5
37	1.27	1.11	87.6	0.16	12.4
38	1.25	1.10	88.1	0.15	11.9
39	1.17	1.02	87.2	0.15	12.8
40	1.00	0.88	88.4	0.12	11.6
41	1.74	1.54	88.3	0.20	11.7
42	1.02	0.88	86.1	0.14	13.9
43	1.63	1.42	87.0	0.21	13.0
44	1.39	1.21	87.3	0.18	12.7
45	1.48	1.25	84.5	0.23	15.5
46	2.81	2.42	86.3	0.39	13.7
47	2.59	2.24	86.3	0.35	13.7
48	1.97	1.71	86.8	0.26	13.2
49	2.47	2.13	86.5	0.34	13.5
50	2.36	2.00	84.9	0.36	15.1
51	2.90	2.49	85.8	0.41	14.2
52	2.07	1.76	85.0	0.31	15.0
53	2.95	2.53	85.7	0.42	14.3
54	3.56	3.06	85.9	0.50	14.1
55	3.21	2.73	84.9	0.48	15.1
56	4.10	3.45	84.1	0.65	15.9
57	4.61	3.96	86.0	0.65	14.0
58	5.29	4.51	85.2	0.78	14.8

Table 3. Concluded

Age in days	Nitrogen: Amount per plant (mgs.)	Nitrogen: Percentage	Survival after cutting (percentage)
26	1.3	4.19	95.5
27	1.6	3.95	93.7
28	2.2	4.32	87.3
29	2.5	4.23	94.5
30	3.0	4.33	83.0
31	2.4	3.92	95.7
32	2.7	3.83	97.2
33	4.0	3.59	97.0
34	3.3	3.66	100.0
35	3.9	3.55	96.7
36	4.3	3.55	94.5
37	5.9	3.71	100.0
38	5.9	3.93	84.0
39	5.3	3.54	96.4
40	4.1	3.37	94.2
41	7.5	3.74	91.8
42	4.1	2.90	97.7
43	7.5	3.59	95.5
44	6.2	3.43	98.1
45	6.8	2.96	97.7
46	12.3	3.16	100.0
47	10.4	2.96	100.0
48	6.3	2.43	100.0
49	10.4	3.05	97.5
50	10.2	2.84	100.0
51	11.5	2.81	100.0
52	6.8	2.19	100.0
53	9.1	2.16	91.0
54	10.4	2.08	93.2
55	10.5	2.19	96.5
56	14.6	2.25	100.0
57	15.5	2.38	95.6
58	17.7	2.21	97.4

Table 4. Experiment 1. Data concerning recovery growth of Sudan Grass.

Age of Roots at 1st cutting (Days)	Age of Tops after 1st cutting (Days)	Fresh Weight per Plant (gms.)	Moisture	
			Wt. per Plant (gms.)	Percentage
36	92	1.60	1.23	76.7
37	91	1.76	1.36	77.3
38	90	2.37	1.79	75.6
39	89	2.53	1.93	76.1
40	88	2.70	2.11	78.2
41	87	2.64	2.01	76.1
42	86	2.22	1.66	75.1
43	85	1.61	1.21	75.2
44	84	2.62	2.01	76.5
45	83	2.29	1.81	78.9
46	82	2.91	2.26	77.6
47	81	1.24	0.96	77.4
48	80	1.55	1.24	79.7
49	79	1.20	0.95	79.3
50	78	2.43	1.91	78.5
51	77	1.03	0.82	79.7
52	76	0.87	0.69	79.2
53	75	1.27	0.99	78.1
54	74	1.64	1.26	76.9
55	73	1.30	1.00	76.7
56	72	1.75	1.37	78.2
57	71	1.28	0.99	77.7
58	70	0.87	0.69	78.8

Table 4. Concluded

Age of Roots at 1st cutting (Days)	Age of Tops after 1st cutting (Days)	Dry Matter		Nitrogen	
		Wt. per Plant (gms.)	Per-centage	Amt. per Plant (mgs.)	Per-centage
36	92	0.37	23.3	6.5	1.75
37	91	0.40	22.7	7.1	1.78
38	90	0.58	24.4	9.5	1.64
39	89	0.60	23.9	9.8	1.64
40	88	0.59	21.8	9.6	1.63
41	87	0.63	23.9	9.8	1.56
42	86	0.56	24.9	8.8	1.58
43	85	0.40	24.8	7.1	1.78
44	84	0.61	23.5	9.5	1.55
45	83	0.48	21.1	9.0	1.88
46	82	0.65	22.4	10.4	1.60
47	81	0.28	22.6	5.1	1.83
48	80	0.31	20.3	8.2	2.65
49	79	0.25	20.7	8.0	3.19
50	78	0.52	21.5	12.1	2.33
51	77	0.21	20.3	6.4	3.05
52	76	0.18	20.8	4.2	2.35
53	75	0.28	21.9	6.0	2.13
54	74	0.38	23.1	6.7	1.76
55	73	0.30	23.3	4.6	1.54
56	72	0.38	21.8	8.0	2.12
57	71	0.29	22.3	6.5	2.24
58	70	0.18	21.2	3.3	1.84

Table 5. Experiment 2. Data concerning recovery growth of unfertilized Sudan Grass.

Age of Roots at 1st cutting (Days)	Age of Tops after 1st cutting (Days)	Fresh Weight per Plant (gms.)	Moisture	
			Wt. per Plant (gms.)	Percentage
26	60	4.18	3.46	82.7
27	59	4.35	3.54	81.3
28	58	3.64	2.91	80.0
29	57	3.50	2.89	82.6
30	56	4.05	3.41	81.7
31	55	2.94	2.35	80.1
32	54	3.47	2.87	82.7
33	53	4.46	3.70	83.0
34	52	3.34	2.80	83.7
35	51	4.18	3.45	82.5
36	50	3.70	3.04	82.3
37	49	3.48	2.90	83.2
38	48	3.04	2.49	81.9
39	47	3.45	2.84	82.4
40	46	3.13	2.60	83.1
41	45	3.09	2.56	82.8
42	44	3.87	3.27	84.6
43	43	2.18	1.82	85.3
44	42	3.91	3.27	83.6
45	41	2.87	2.52	87.8
46	40	2.21	1.78	80.5
47	39	1.54	1.30	84.5
48	38	3.44	2.97	86.4
49	37	1.62	1.38	85.2
50	36	1.73	1.47	84.9
51	35	2.47	2.14	86.5
52	34	3.50	3.01	86.1
53	33	2.14	1.81	84.5
54	32	2.72	2.33	85.9
55	31	1.71	1.46	85.4
56	30	1.56	1.32	84.8
57	29	2.98	2.55	85.6
58	28	2.08	1.80	86.5

Table 5. Concluded

Age of Roots at 1st cutting (Days)	Age of Tops after 1st cutting (Days)	Dry Matter		Nitrogen	
		Wt. per Plant (gms.)	Per-centage	Amt. per Plant (mgs.)	Per-centage
26	60	0.72	17.3	9.2	1.28
27	59	0.81	18.7	10.3	1.27
28	58	0.73	20.0	7.3	1.00
29	57	0.61	17.4	8.8	1.44
30	56	0.74	18.3	8.7	1.17
31	55	0.59	19.9	5.7	0.96
32	54	0.60	17.3	8.3	1.38
33	53	0.76	17.0	9.8	1.30
34	52	0.54	16.3	7.8	1.45
35	51	0.73	17.5	8.1	1.11
36	50	0.66	17.7	7.7	1.17
37	49	0.58	16.8	7.6	1.31
38	48	0.55	18.1	5.0	0.91
39	47	0.61	17.6	6.0	0.98
40	46	0.53	16.9	7.6	1.44
41	45	0.53	17.2	6.3	1.19
42	44	0.60	15.4	9.7	1.61
43	43	0.36	16.5	5.0	1.38
44	42	0.64	16.4	9.7	1.52
45	41	0.35	12.2	5.2	1.49
46	40	0.43	19.5	5.8	1.35
47	39	0.24	15.5	3.1	1.30
48	38	0.47	13.6	8.8	1.88
49	37	0.24	14.8	3.4	1.41
50	36	0.26	15.1	3.7	1.41
51	35	0.33	13.5	5.6	1.70
52	34	0.49	13.9	7.9	1.62
53	33	0.33	15.5	5.5	1.66
54	32	0.39	14.1	7.5	1.91
55	31	0.25	14.6	4.5	1.79
56	30	0.24	15.2	4.7	2.01
57	29	0.43	14.4	8.0	1.85
58	28	0.28	13.5	5.6	1.99

Table 6. Experiment 2. Data concerning recovery growth of fertilized Sudan Grass.

Age of Roots at 1st cutting (Days)	Age of Tops after 1st cutting (Days)	Fresh Weight per Plant (gms.)	Moisture	
			Wt. per Plant (gms.)	Percentage
26	60	6.32	5.11	80.8
27	59	7.35	5.86	79.7
28	58	8.09	6.61	81.6
29	57	7.04	5.61	79.7
30	56	7.62	6.11	80.2
31	55	6.65	5.41	81.3
32	54	6.55	5.29	80.8
33	53	8.07	6.55	81.2
34	52	6.34	5.11	80.6
35	51	6.12	4.90	80.1
36	50	6.05	4.82	79.7
37	49	7.70	6.18	80.3
38	48	7.28	5.85	80.4
39	47	5.08	4.15	81.7
40	46	5.07	4.09	80.7
41	45	6.44	5.20	80.7
42	44	5.97	4.90	82.1
43	43	5.73	4.75	82.9
44	42	5.80	4.86	83.8
45	41	7.10	5.91	83.3
46	40	5.48	4.58	83.6
47	39	7.50	6.24	83.2
48	38	6.33	5.35	84.5
49	37	6.27	5.29	84.4
50	36	4.78	3.98	83.3
51	35	4.32	3.61	83.6
52	34	4.70	4.09	86.9
53	33	3.89	3.33	85.6
54	32	3.73	3.21	86.0
55	31	3.30	2.81	85.2
56	30	2.50	2.09	83.7
57	29	3.89	3.34	85.9
58	28	3.80	3.26	85.8

Table 6. Concluded

Age of Roots at 1st cutting (Days)	Age of Tops after 1st cutting (Days)	Dry Matter		Nitrogen	
		Wt. per Plant (gms.)	Percentage	Amt. per Plant (mgs.)	Percentage
26	60	1.21	19.2	19.8	1.64
27	59	1.49	20.3	23.4	1.57
28	58	1.48	18.4	18.4	1.31
29	57	1.43	20.3	19.2	1.34
30	56	1.51	19.8	21.8	1.44
31	55	1.24	18.7	17.6	1.42
32	54	1.26	19.2	22.0	1.75
33	53	1.52	18.8	24.3	1.60
34	52	1.23	19.4	16.0	1.30
35	51	1.22	19.9	18.5	1.52
36	50	1.23	20.3	20.8	1.69
37	49	1.52	19.7	23.3	1.53
38	48	1.43	19.6	14.2	0.99
39	47	0.93	18.3	13.9	1.50
40	46	0.98	19.3	16.5	1.69
41	45	1.24	19.3	12.8	1.03
42	44	1.07	17.9	20.8	1.94
43	43	0.98	17.1	14.8	1.51
44	42	0.94	16.2	20.1	2.14
45	41	1.19	16.7	26.5	2.23
46	40	0.90	16.4	13.7	1.52
47	39	1.26	16.8	18.8	1.49
48	38	0.98	15.5	17.1	1.75
49	37	0.98	15.6	20.4	2.08
50	36	0.80	16.7	15.1	1.88
51	35	0.71	16.4	14.2	2.00
52	34	0.61	13.1	16.0	2.63
53	33	0.56	14.4	12.0	2.14
54	32	0.52	14.0	10.8	2.07
55	31	0.49	14.8	10.6	2.17
56	30	0.41	16.3	6.8	1.65
57	29	0.55	14.1	10.7	1.94
58	28	0.54	14.2	10.3	1.90

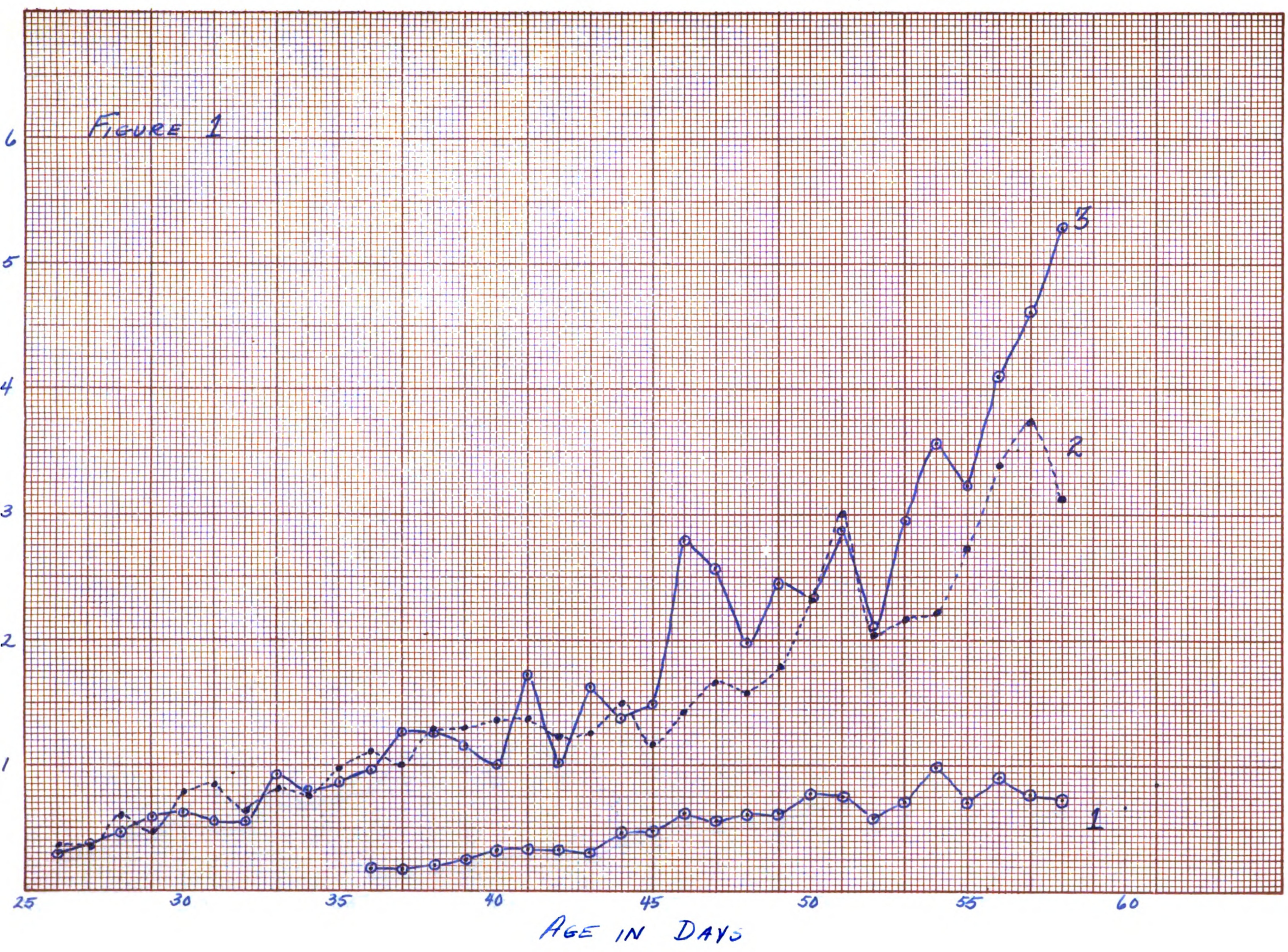


Figure 1
6
5
4
3
2
1
3
2
1
25
30
35
40
45
50
55
60
Age in Days

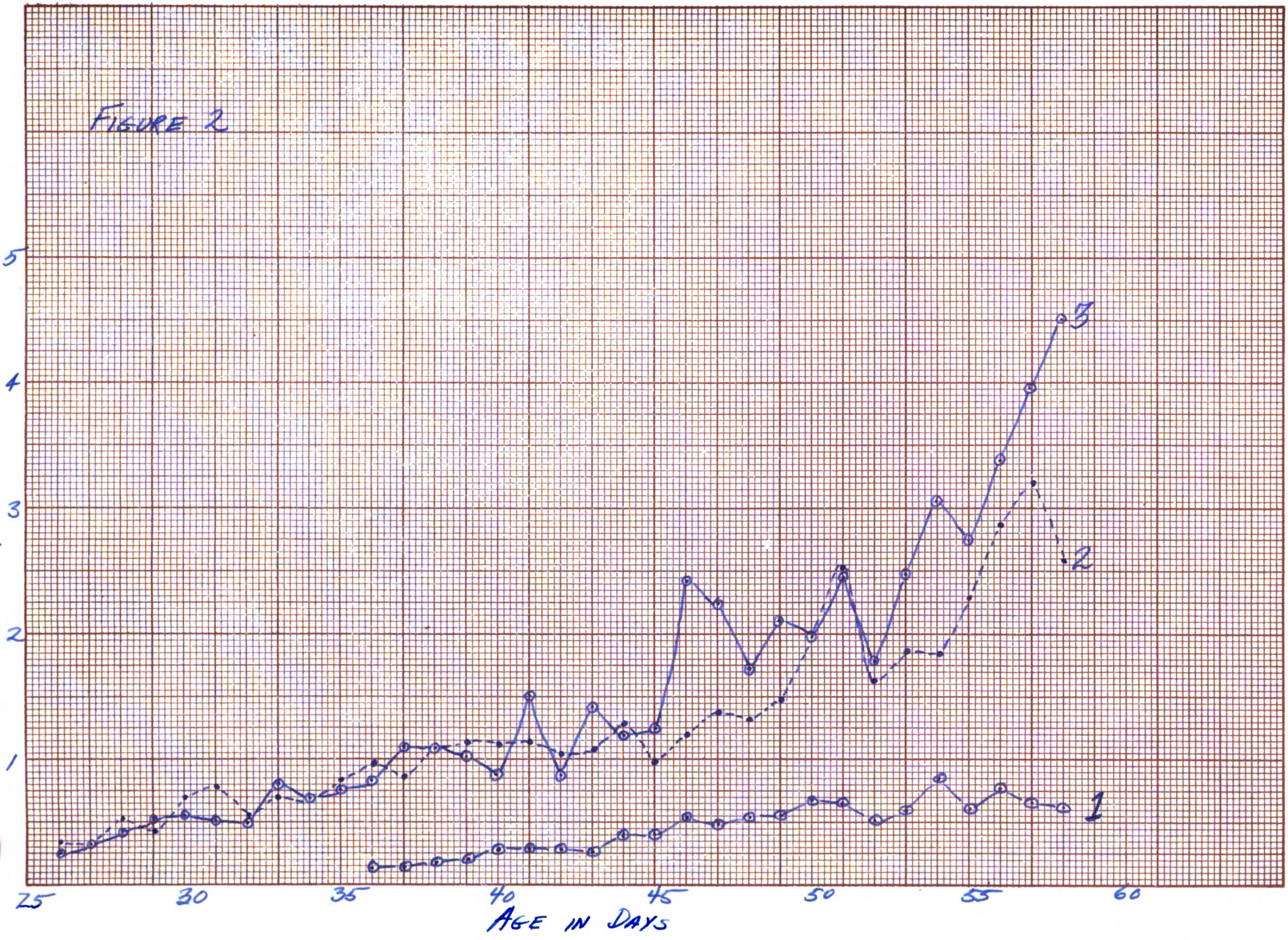


FIGURE 2
5
4
3
2
1
3
2
1
25
30
35
40
45
50
55
60
AGE IN DAYS

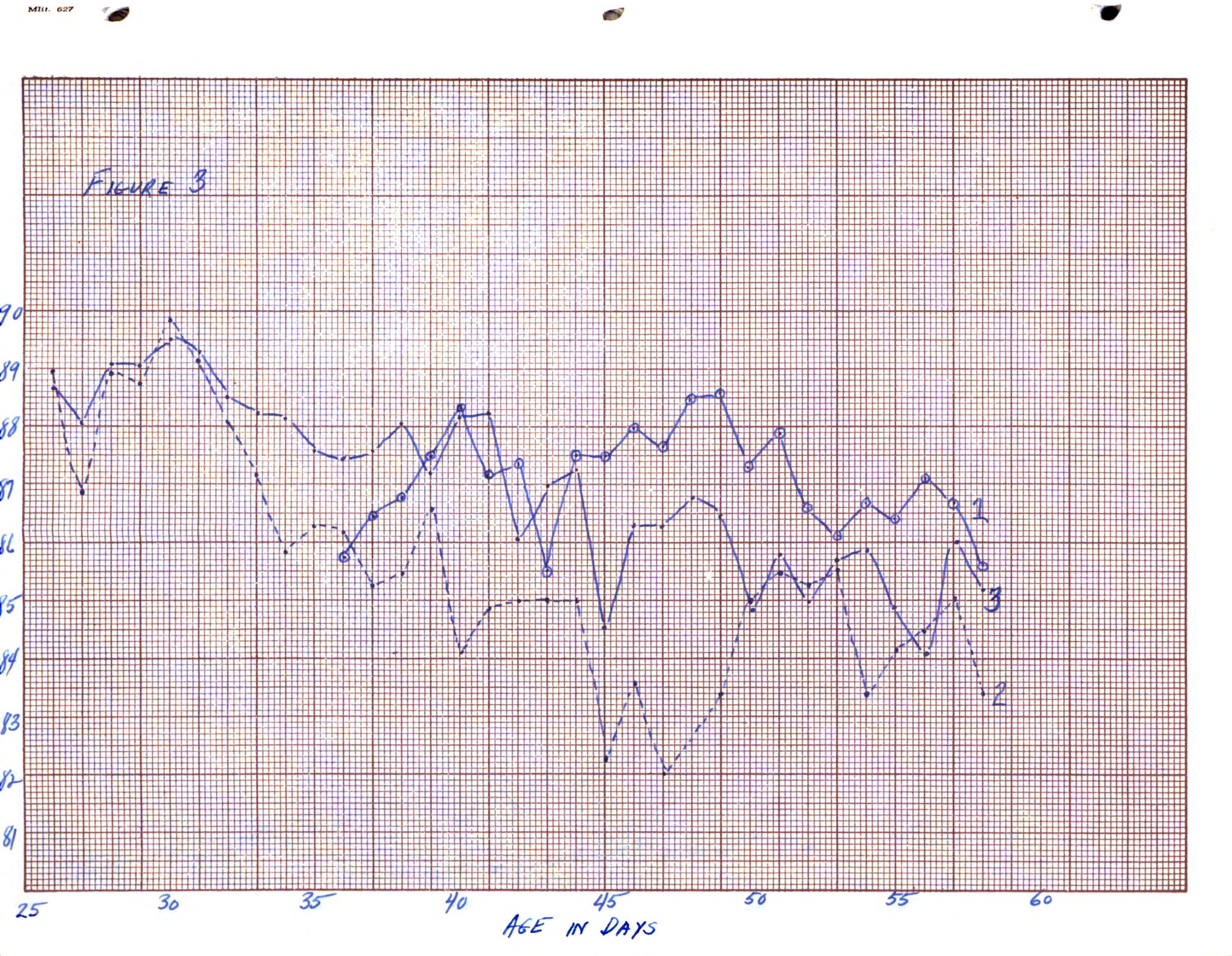


FIGURE 3
90
89
88
87
86
85
84
83
82
81
25
30
35
40
45
50
55
60
AGE IN DAYS
1
2
3
Mill. 627

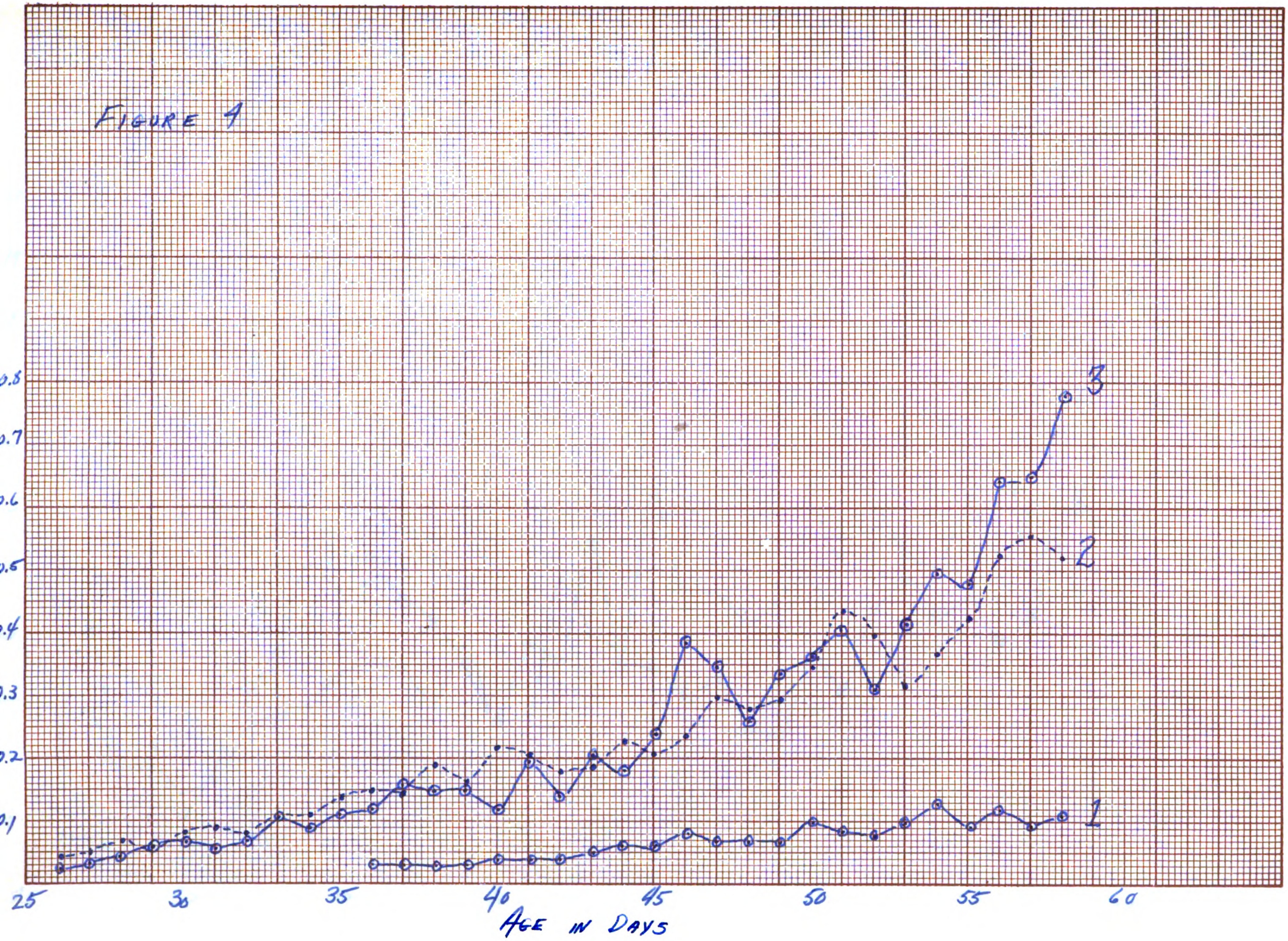


FIGURE 4
3
2
1
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
25
30
35
40
45
50
55
60
AGE IN DAYS

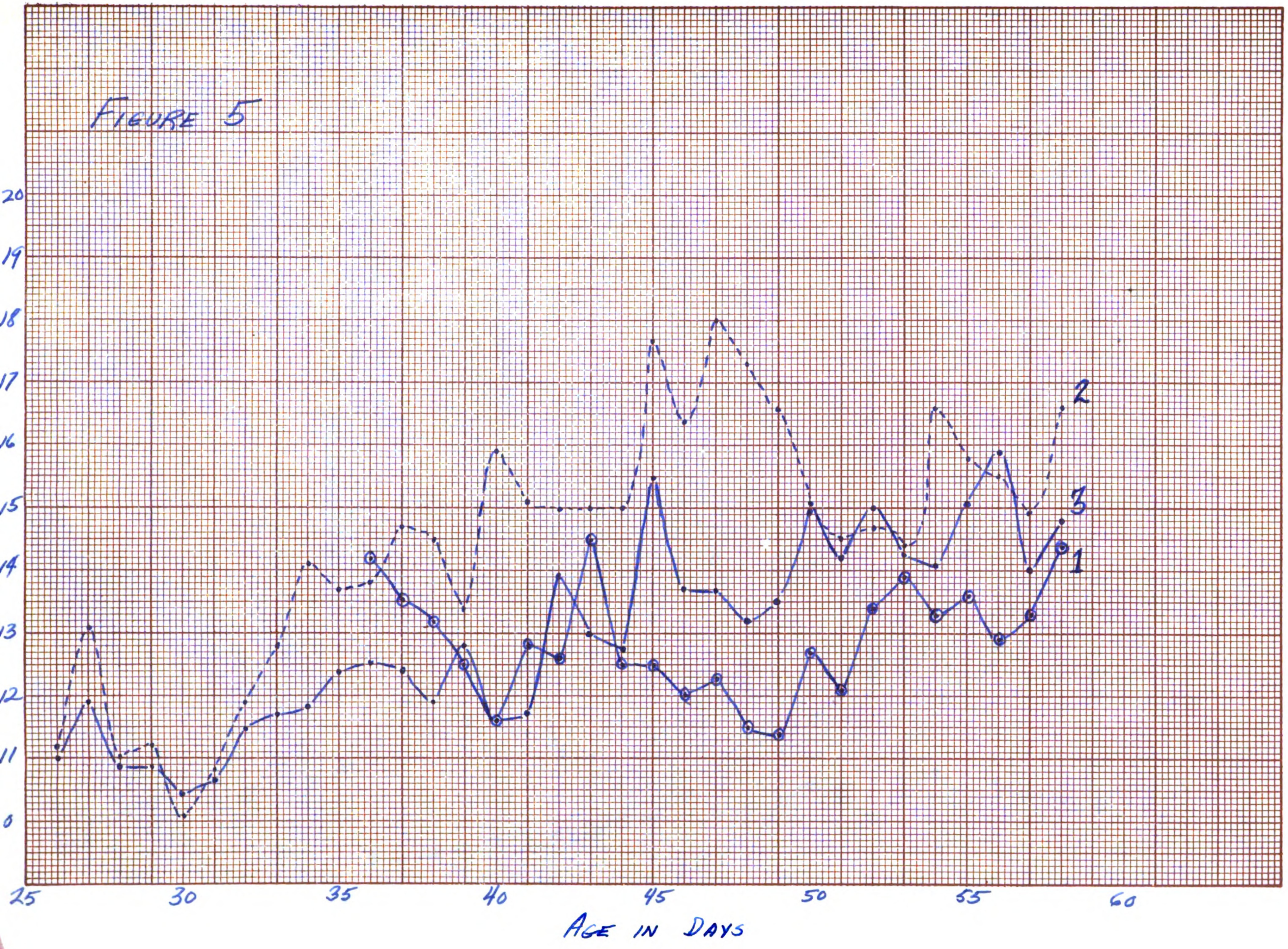


FIGURE 5
20
19
18
17
16
15
14
13
12
11
10
25
30
35
40
45
50
55
60
1
2
3
AGE IN DAYS

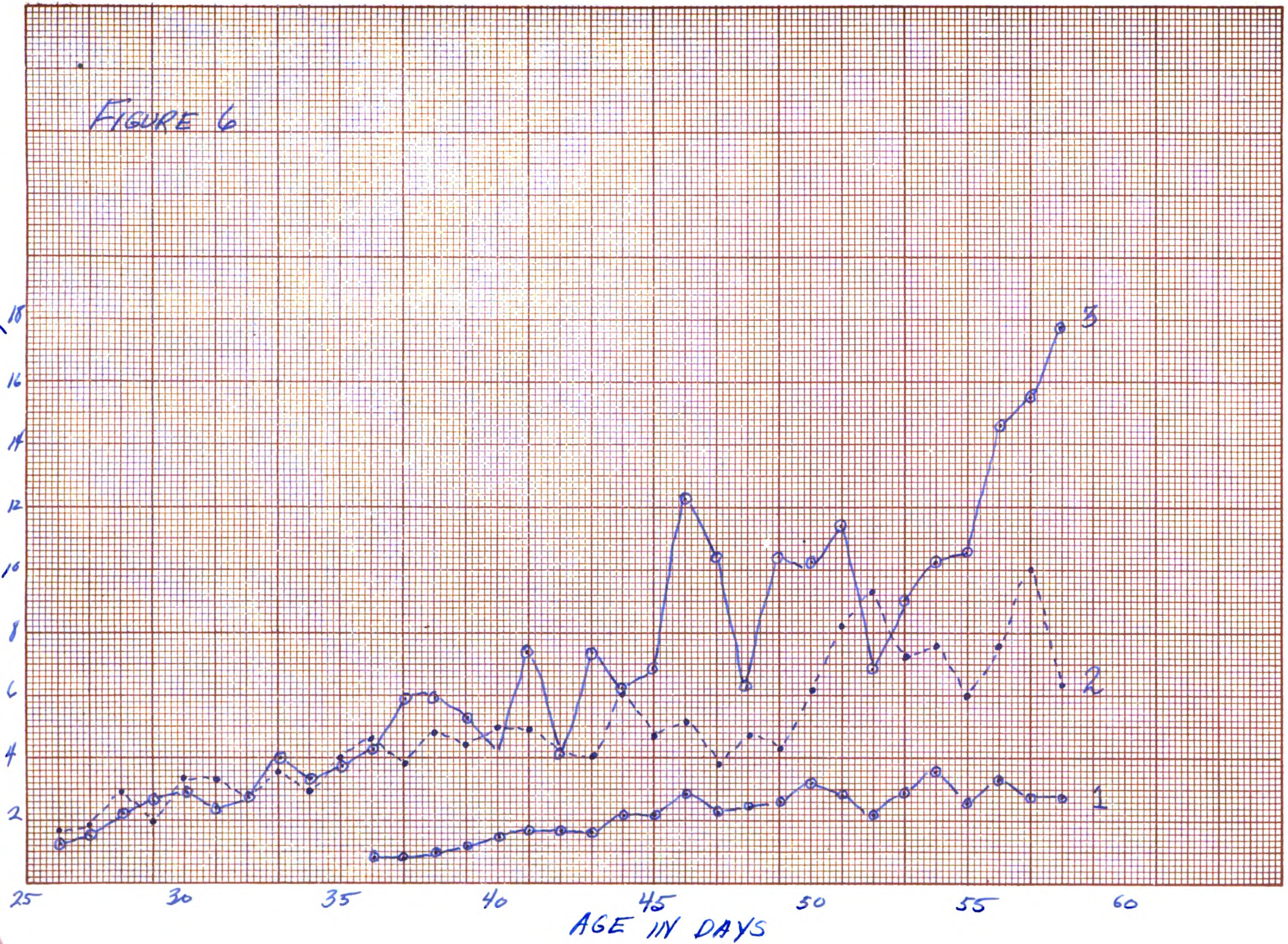
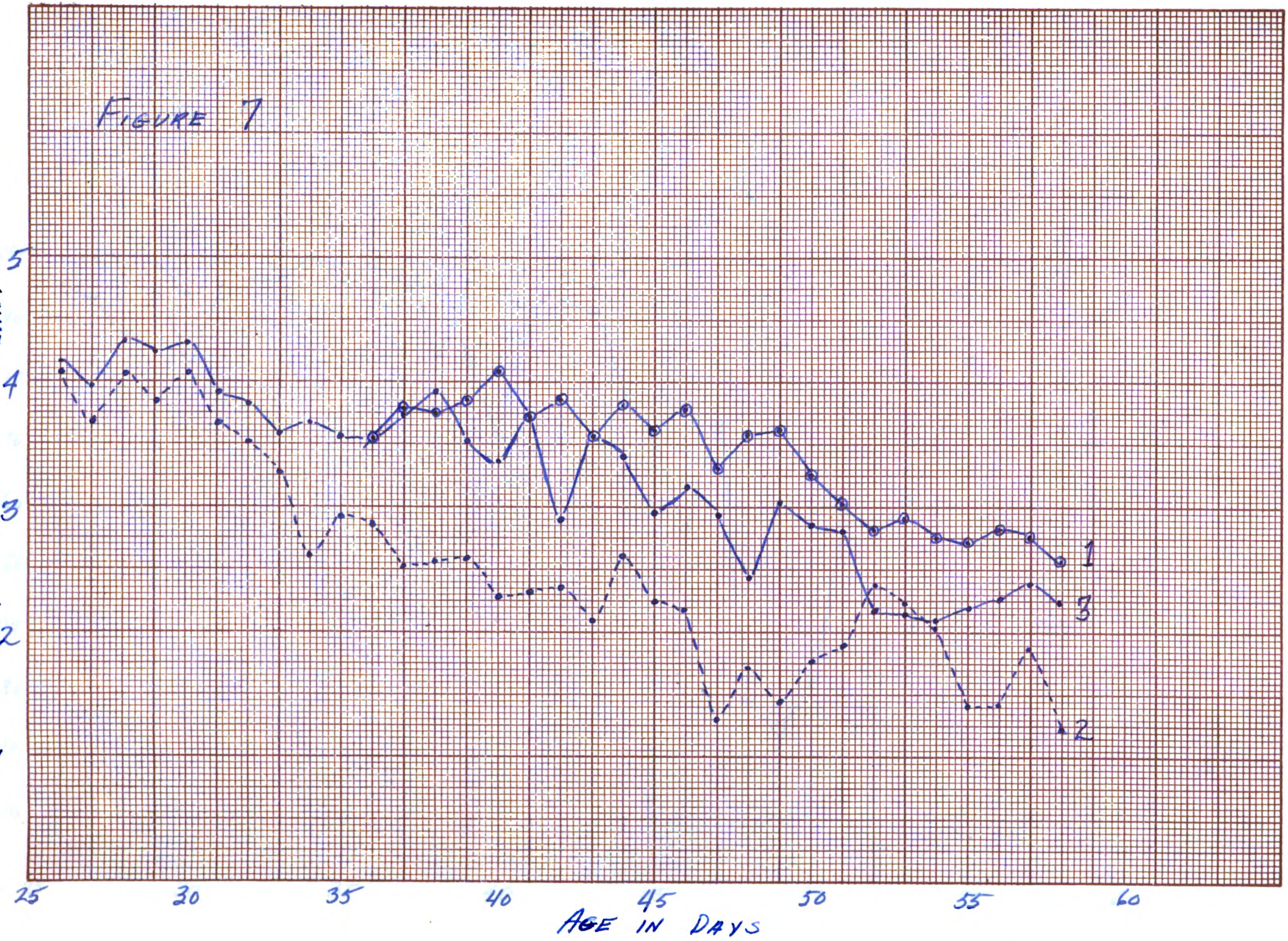


FIGURE 6
18
16
14
12
10
8
6
4
2
25
30
35
40
45
50
55
60
AGE IN DAYS
3
2
1

FIGURE 7



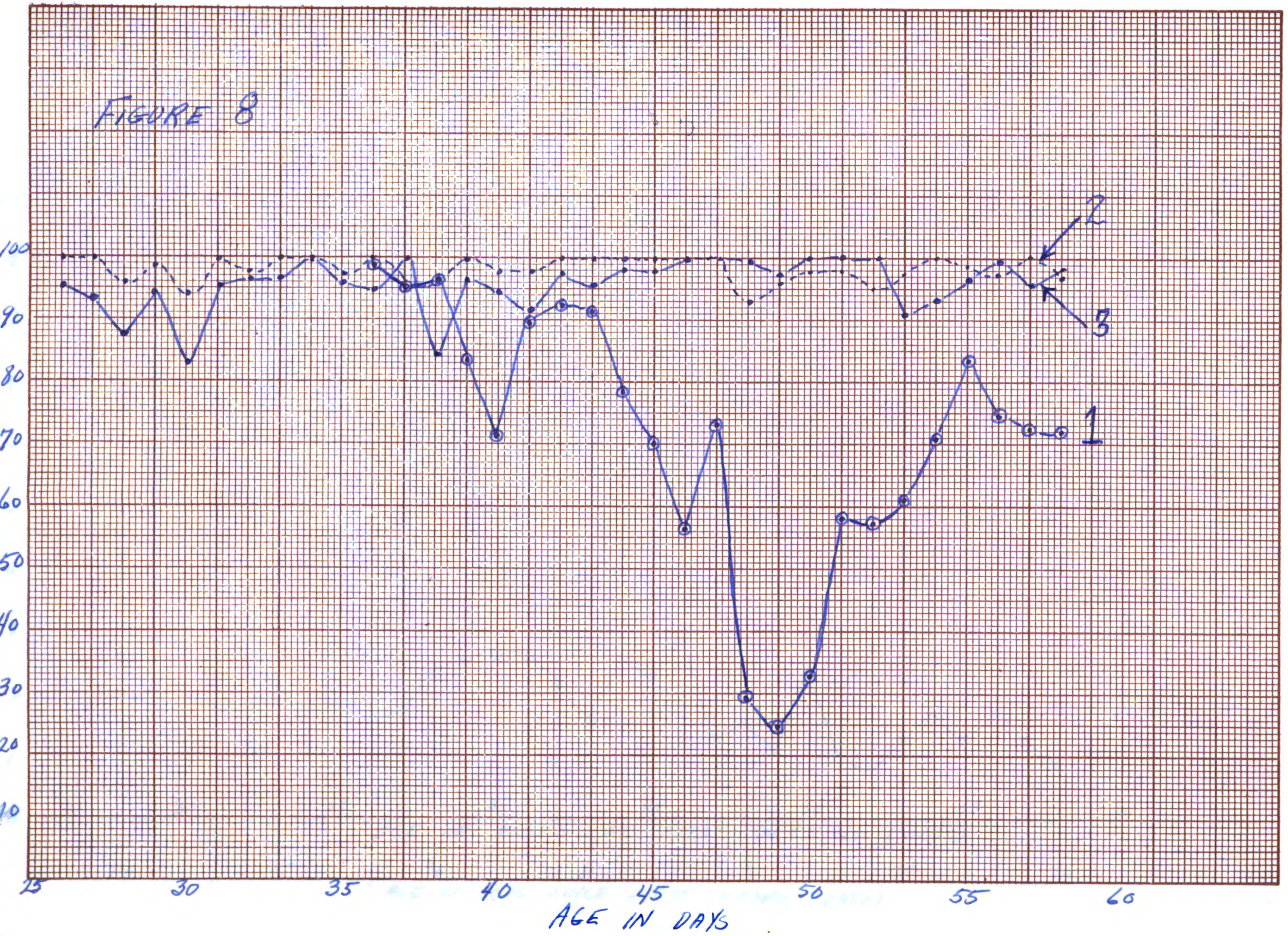
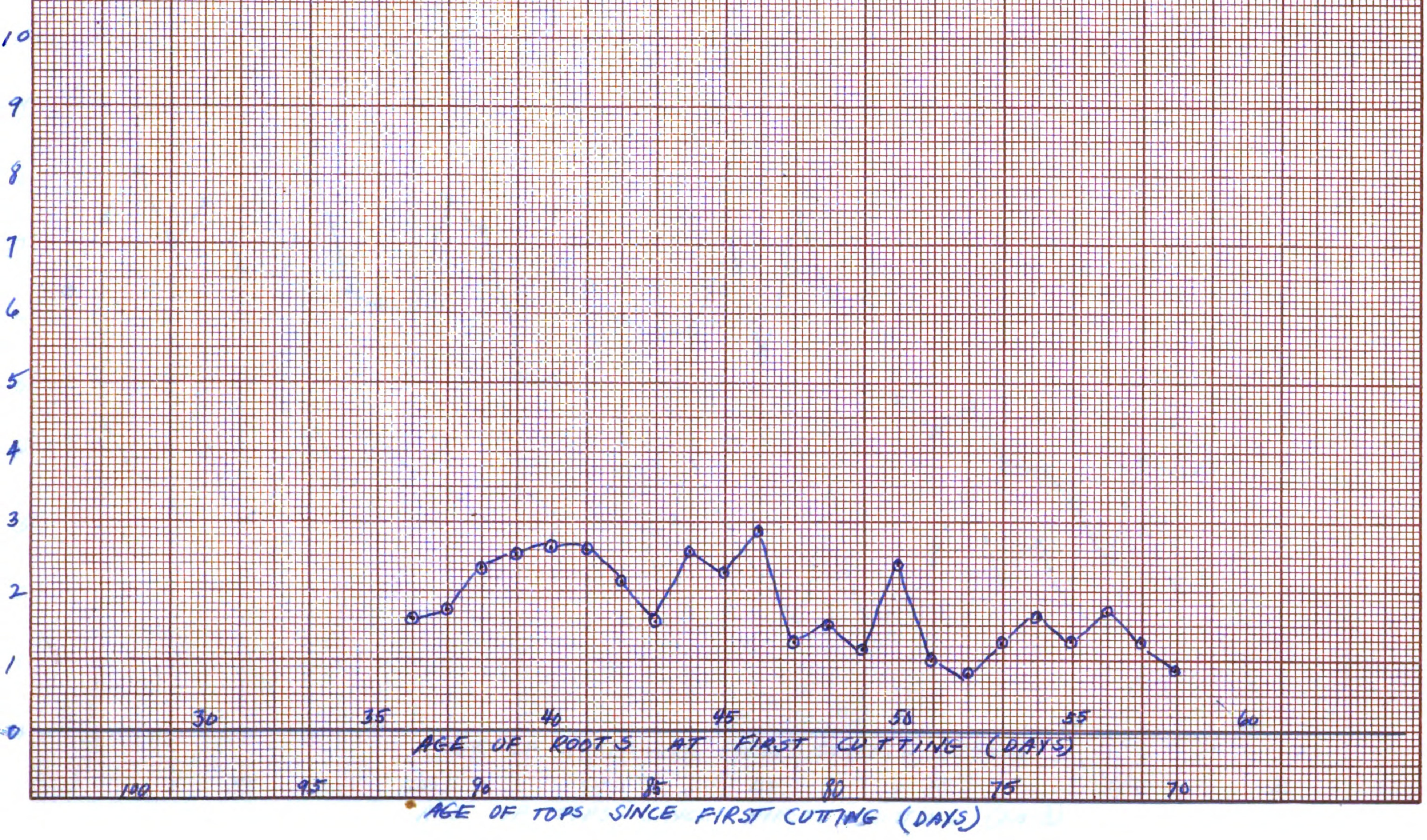


FIGURE 8
1
2
3
100
90
80
70
60
50
40
30
20
10
25
30
35
40
45
50
55
60
AGE IN DAYS

Figure 9



10
9
8
7
6
5
4
3
2
1
0
30
35
40
45
50
55
60
AGE OF ROOTS AT FIRST CUTTING (DAYS)
100
95
90
85
80
75
70
AGE OF TOPS SINCE FIRST CUTTING (DAYS)

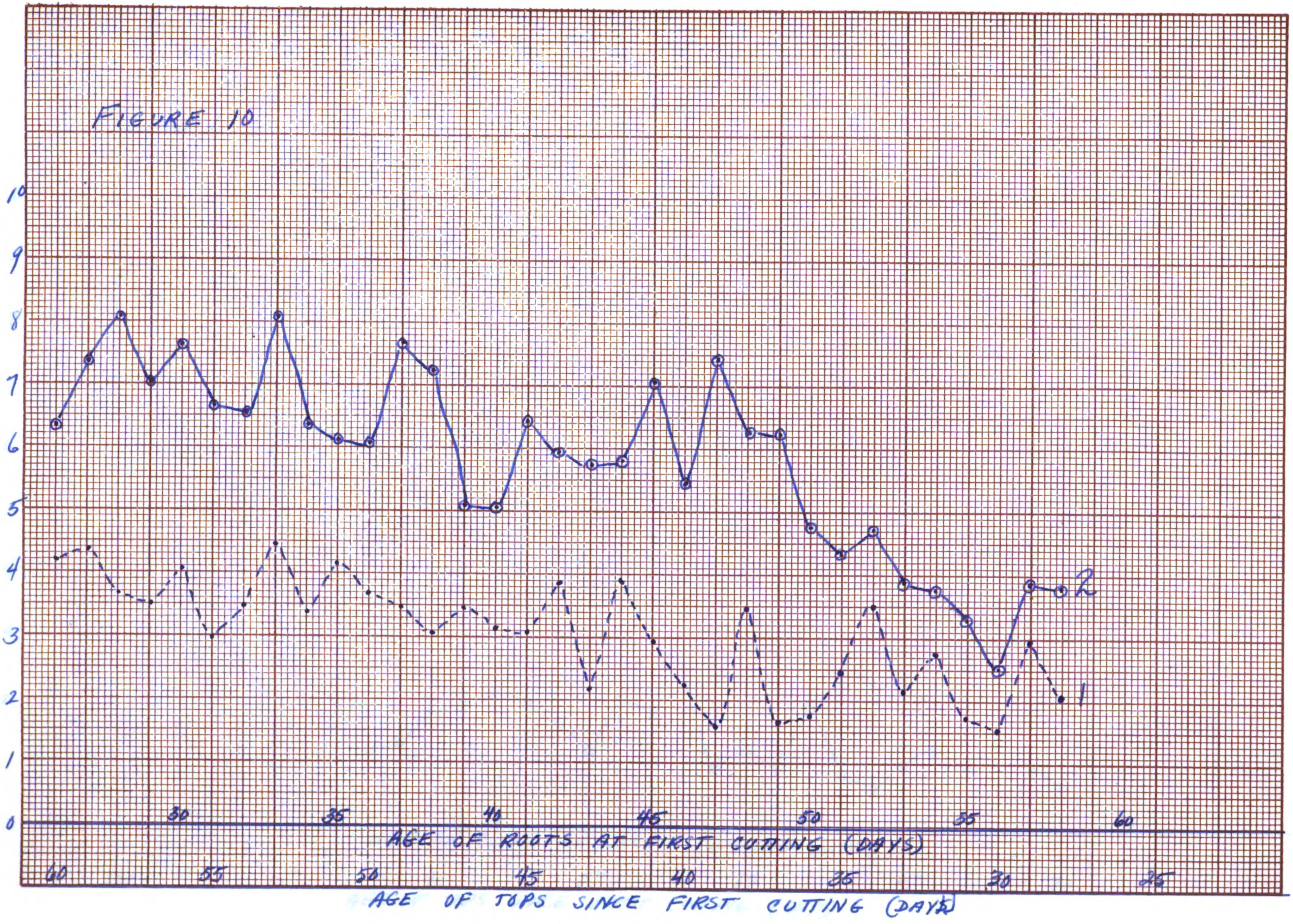


FIGURE 10
10
9
8
7
6
5
4
3
2
1
0
2
1
30
35
40
45
50
55
60
AGE OF ROOTS AT FIRST CUTTING (DAYS)
60
55
50
45
40
35
30
25
AGE OF TOPS SINCE FIRST CUTTING (DAYS)

FIGURE 11

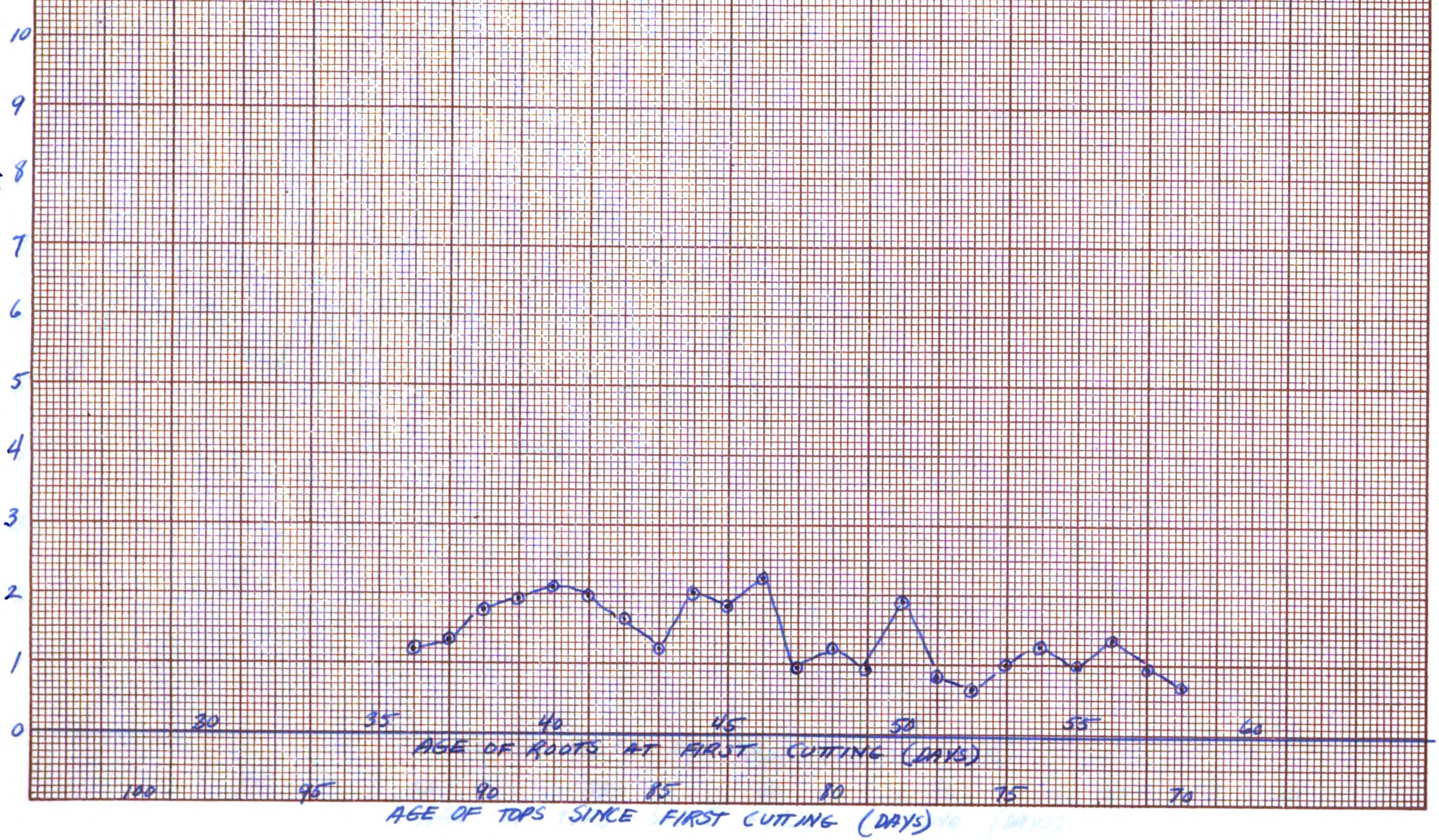
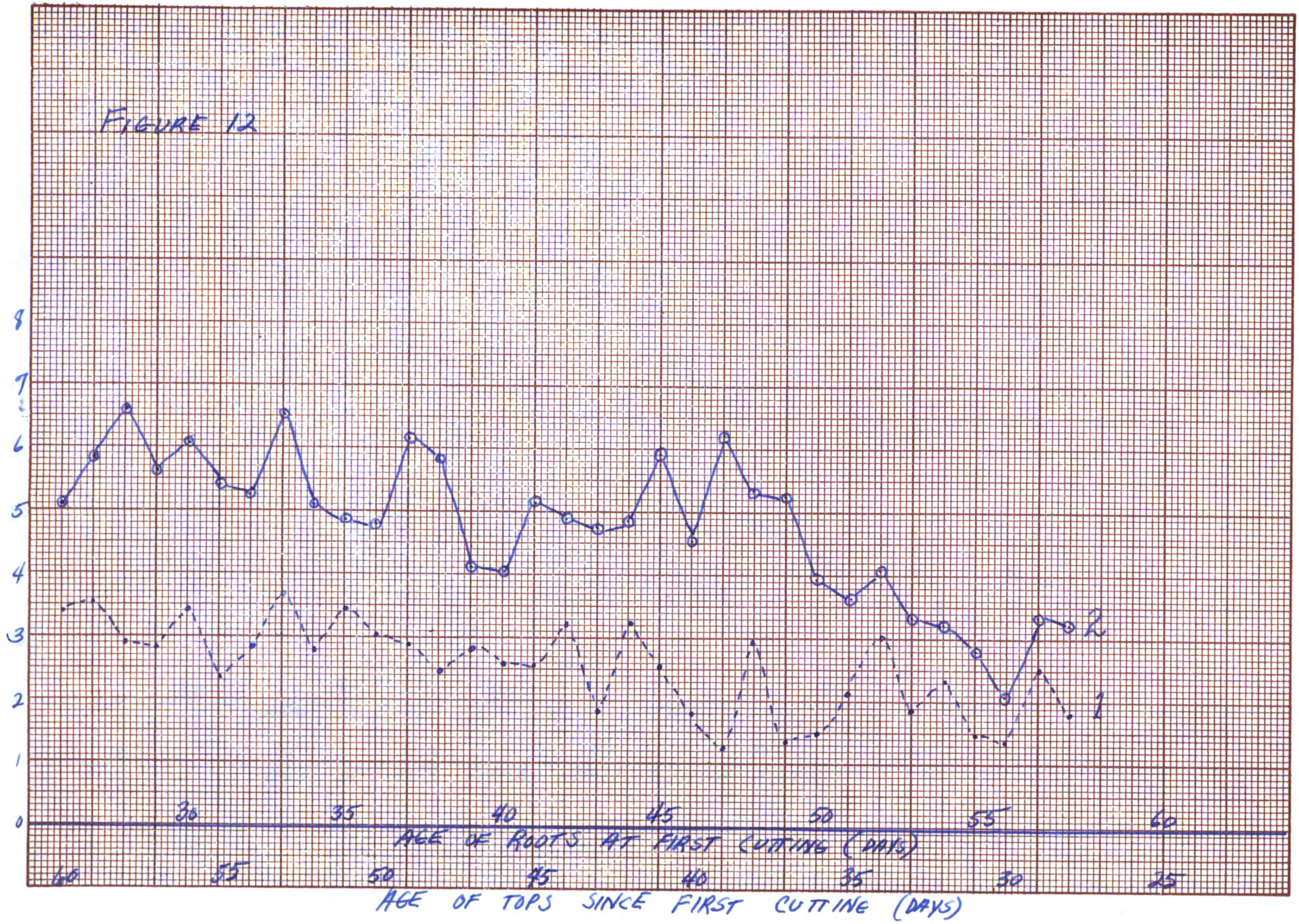
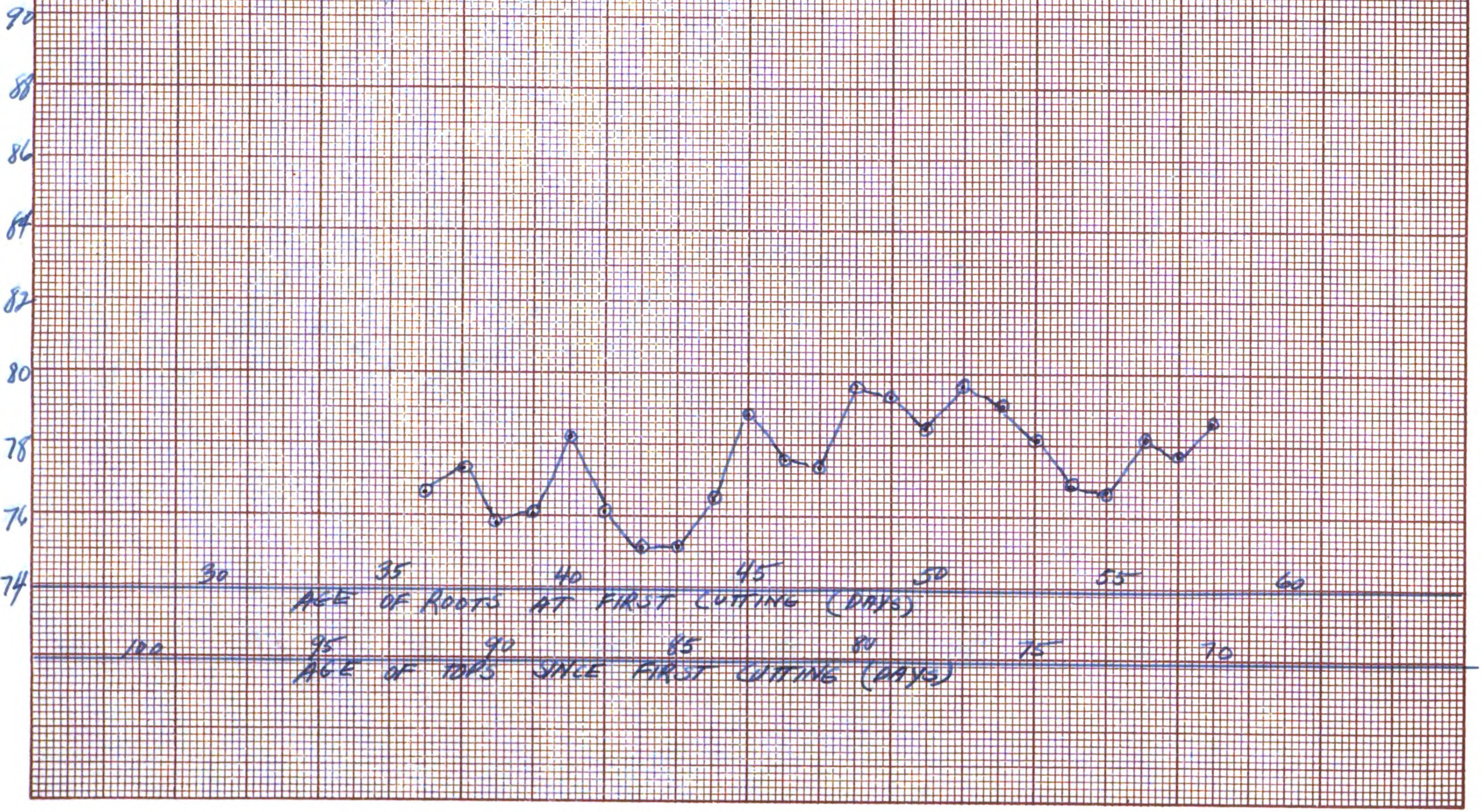

10
9
8
7
6
5
4
3
2
1
0
30
35
40
45
50
55
60
AGE OF ROOTS AT FIRST CUTTING (DAYS)
100
95
90
85
80
75
70
AGE OF TOPS SINCE FIRST CUTTING (DAYS)

FIGURE 12



8
7
6
5
4
3
2
1
0
30
35
40
45
50
55
60
AGE OF ROOTS AT FIRST CUTTING (DAYS)
60
55
50
45
40
35
30
25
AGE OF TOPS SINCE FIRST CUTTING (DAYS)
2
1

FIGURE 13


90
88
86
84
82
80
78
76
74
30
35
40
45
50
55
60
AGE OF ROOTS AT FIRST CUTTING (DAYS)
100
95
90
85
80
75
70
AGE OF TOPS SINCE FIRST CUTTING (DAYS)

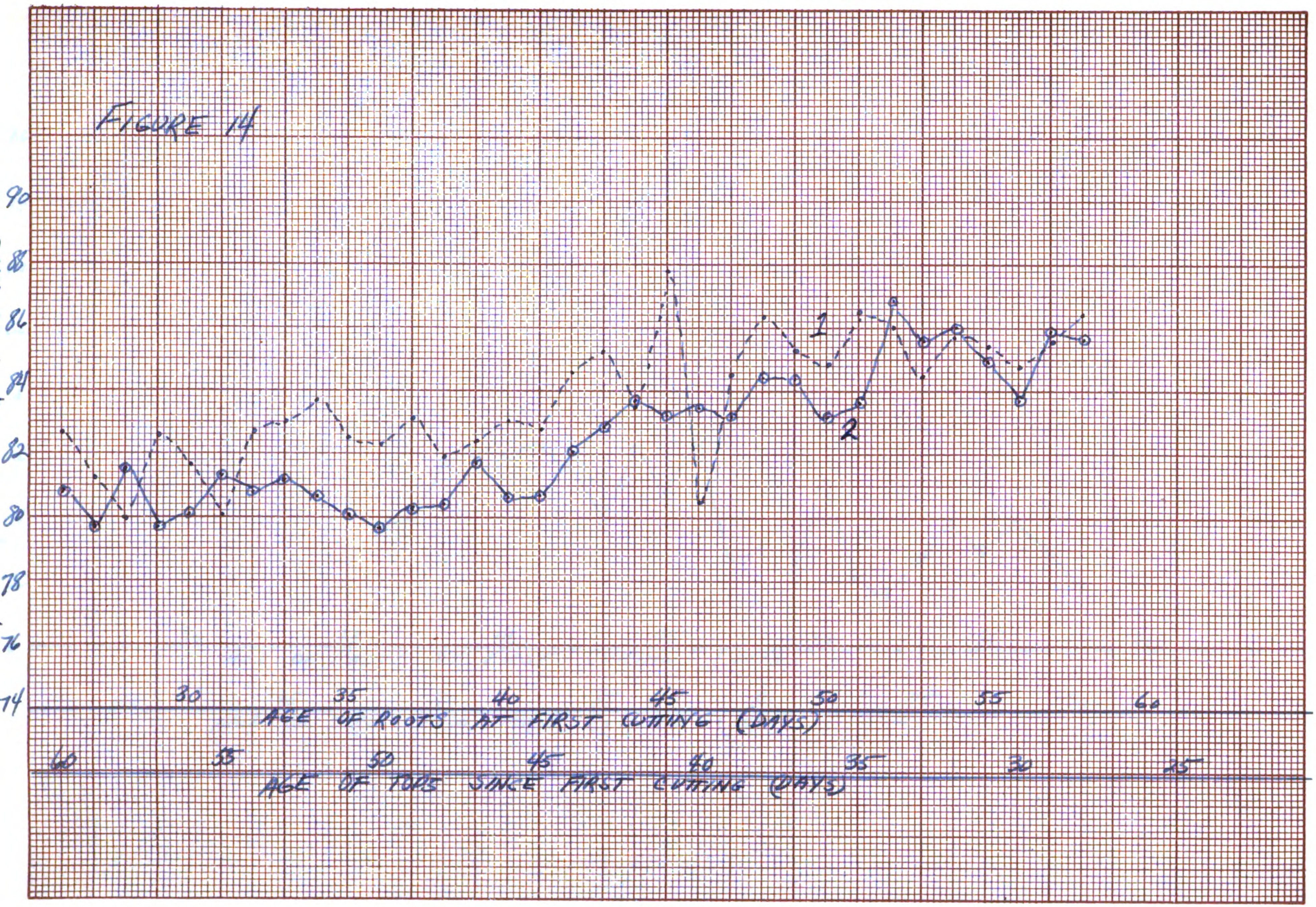
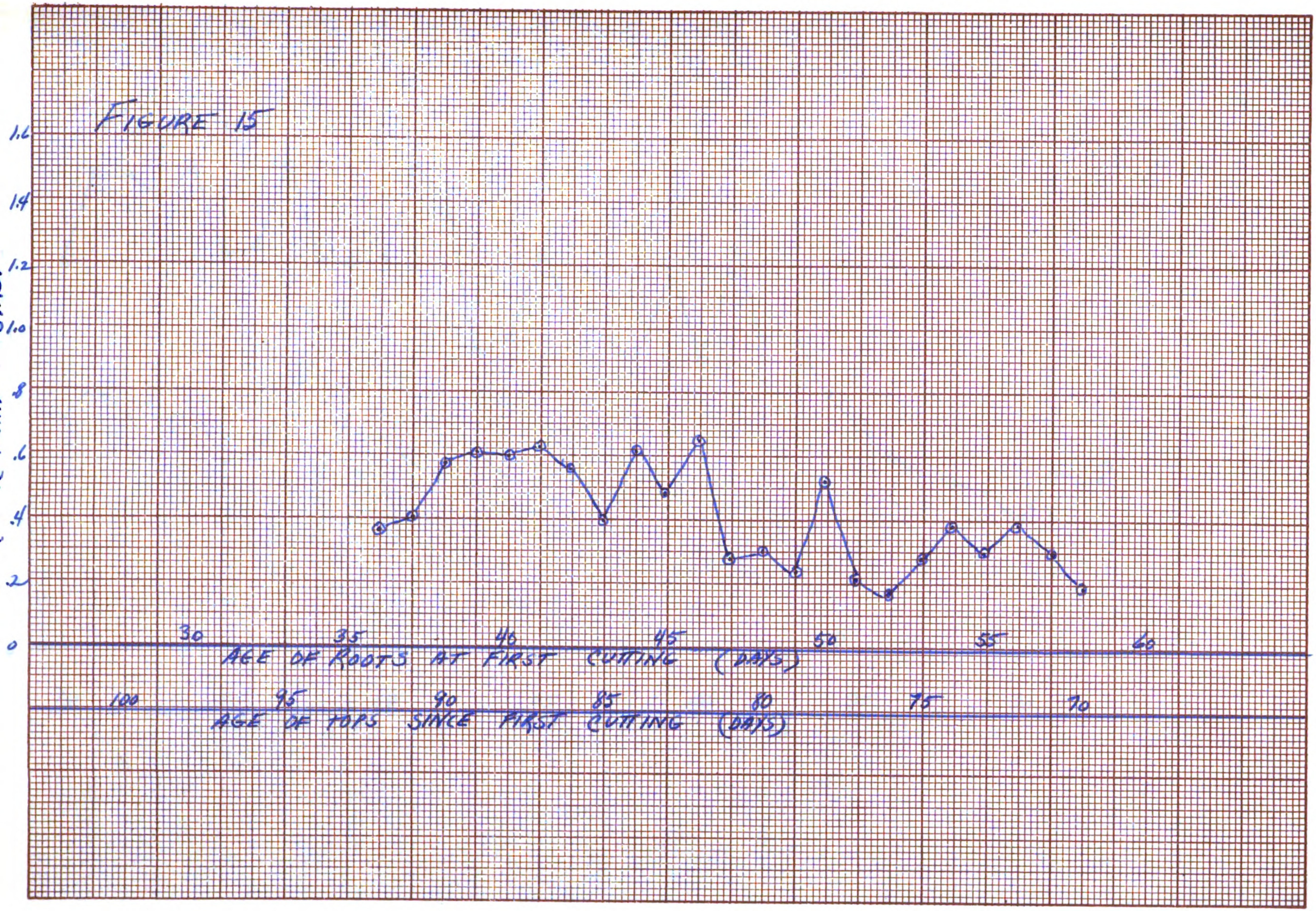
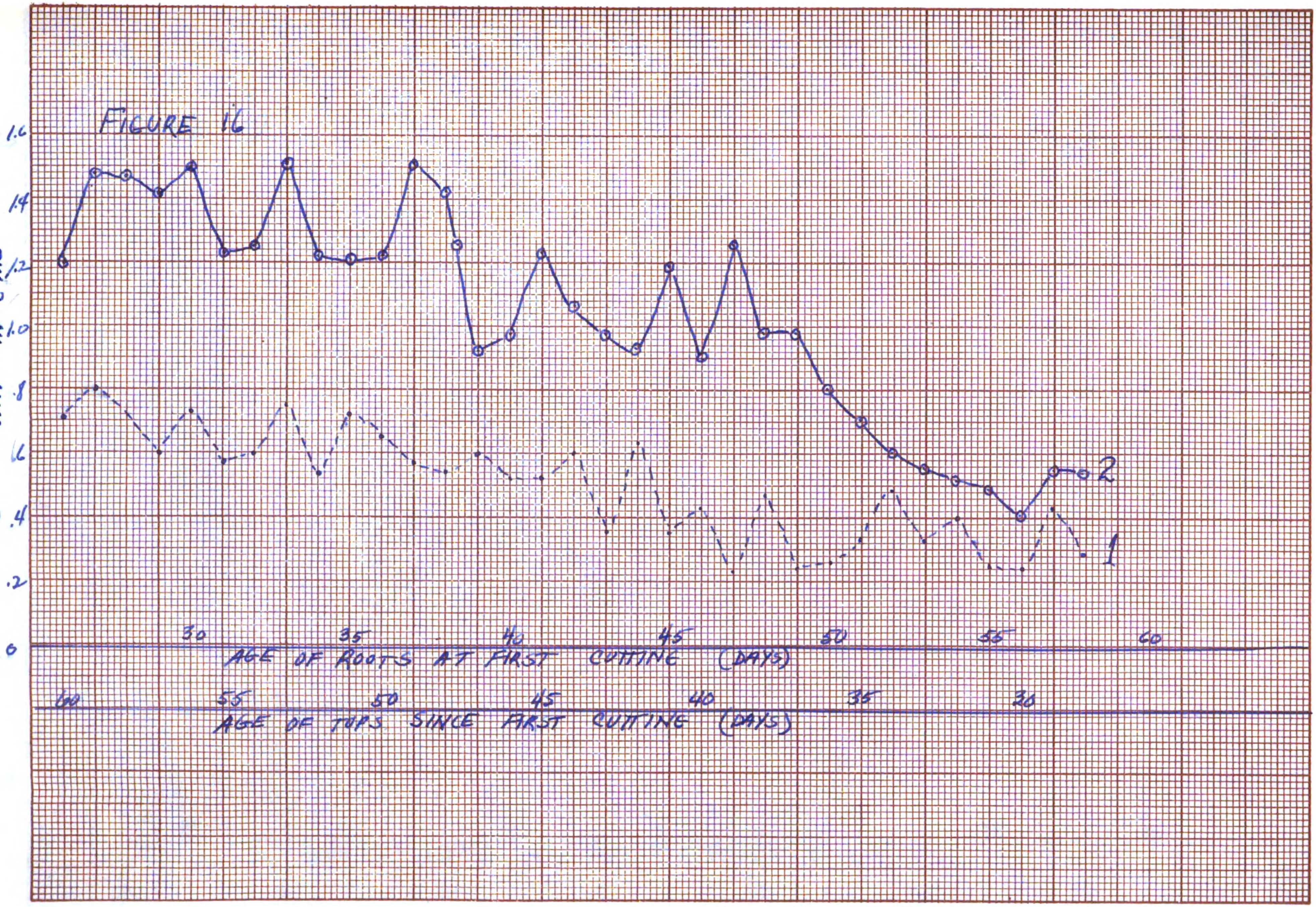


FIGURE 14
90
88
86
84
82
80
78
76
74
1
2
30
35
40
45
50
55
60
AGE OF ROOTS AT FIRST CUTTING (DAYS)
60
55
50
45
40
35
30
25
AGE OF TOPS SINCE FIRST CUTTING (DAYS)

FIGURE 15


1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
30
35
40
45
50
55
60
AGE OF ROOTS AT FIRST CUTTING (DAYS)
100
95
90
85
80
75
70
AGE OF TOPS SINCE FIRST CUTTING (DAYS)


1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
2
1
30
35
40
45
50
55
60
AGE OF ROOTS AT FIRST CUTTING (DAYS)
60
55
50
45
40
35
AGE OF TOPS SINCE FIRST CUTTING (DAYS)
FIGURE 16

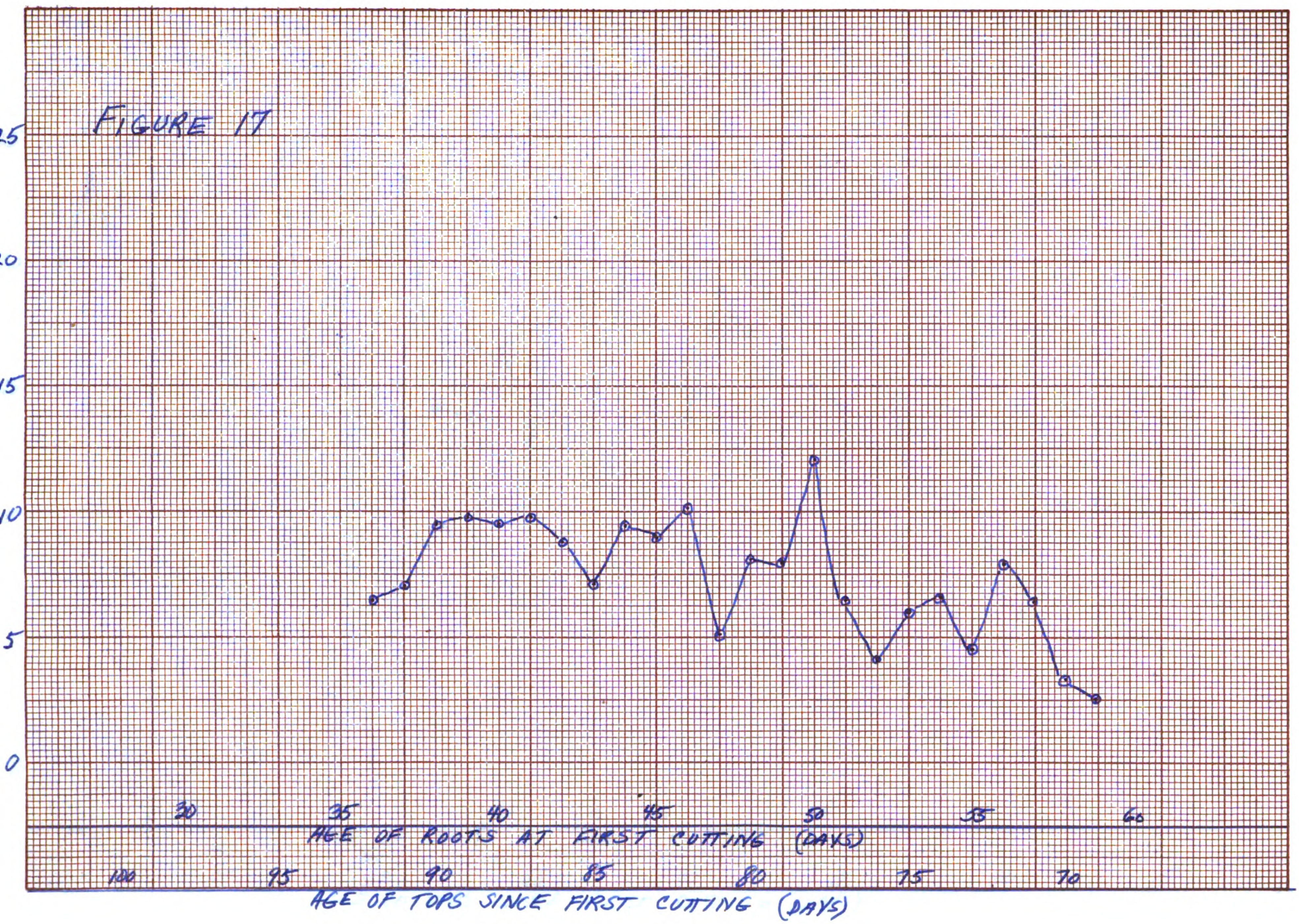


FIGURE 17
25
20
15
10
5
0
30
35
40
45
50
55
60
AGE OF ROOTS AT FIRST CUTTING (DAYS)
100
95
90
85
80
75
70
AGE OF TOPS SINCE FIRST CUTTING (DAYS)

FIGURE 18

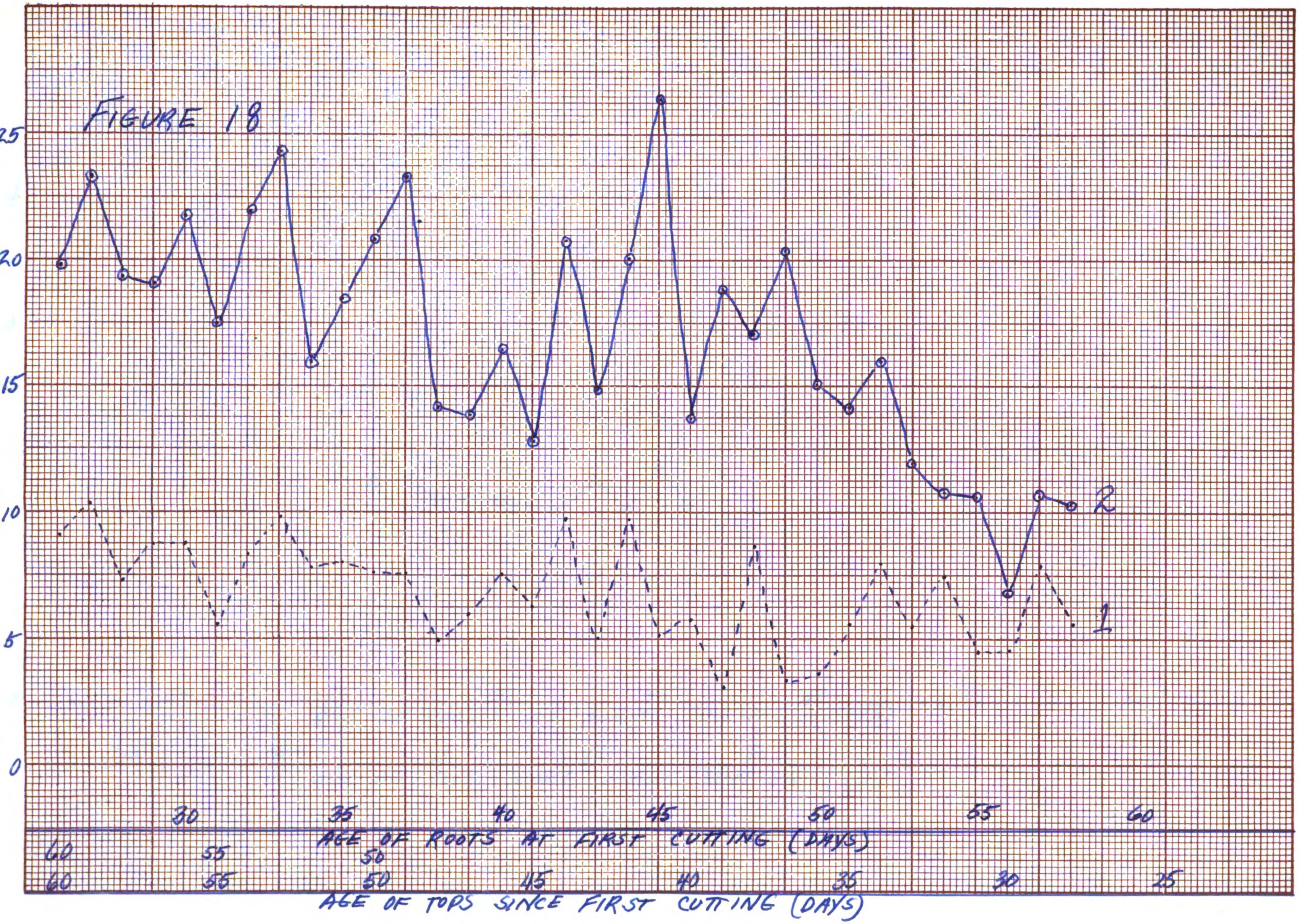
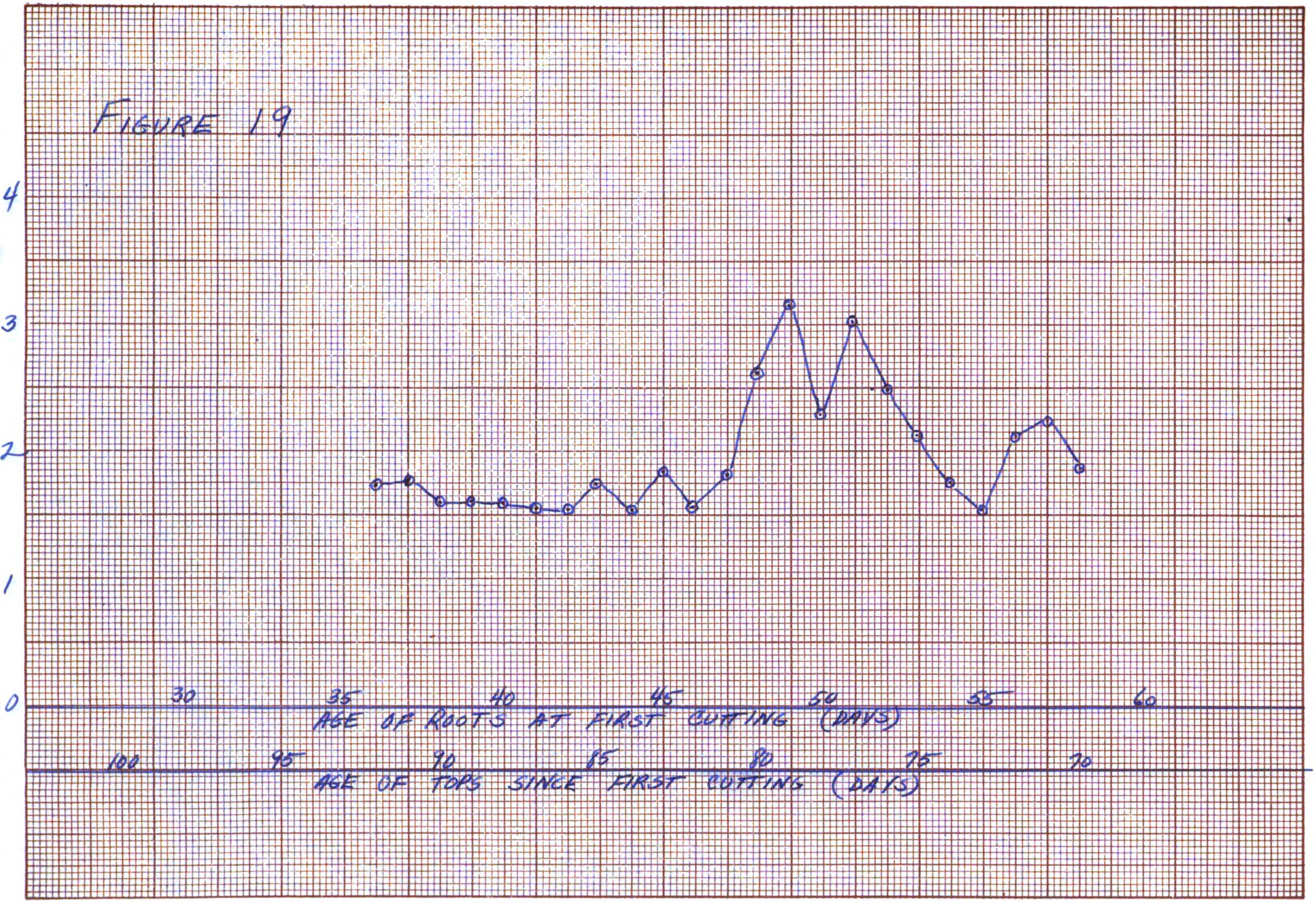

25
20
15
10
5
0
2
1
30 35 40 45 50 55 60
AGE OF ROOTS AT FIRST CUTTING (DAYS)
60 55 50
60 55 50 45 40 35 30 25
AGE OF TOPS SINCE FIRST CUTTING (DAYS)

FIGURE 19



4
3
2
1
0
30
35
40
45
50
55
60
AGE OF ROOTS AT FIRST CUTTING (DAYS)
100
95
90
85
80
75
70
AGE OF TOPS SINCE FIRST CUTTING (DAYS)

FIGURE 20

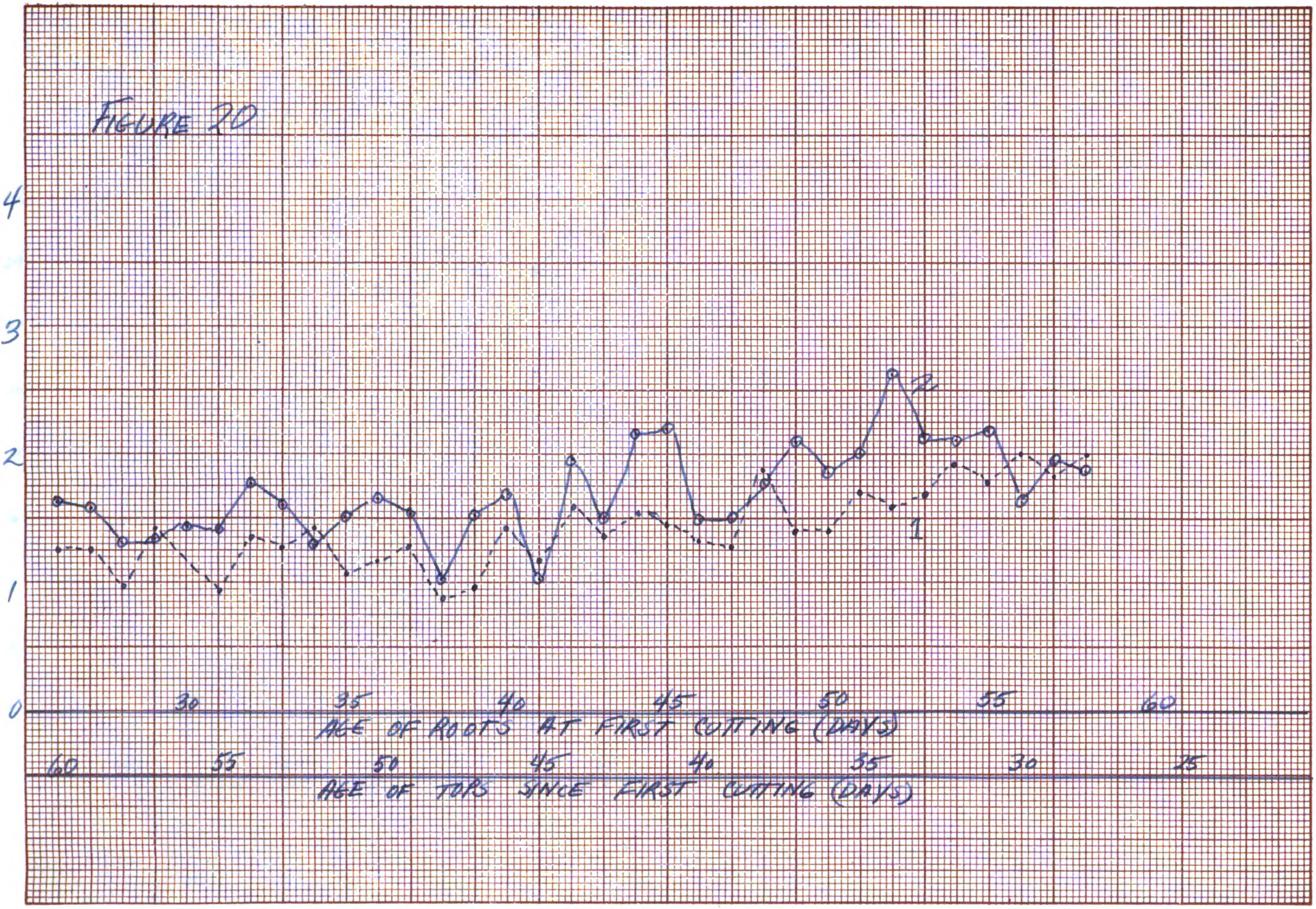
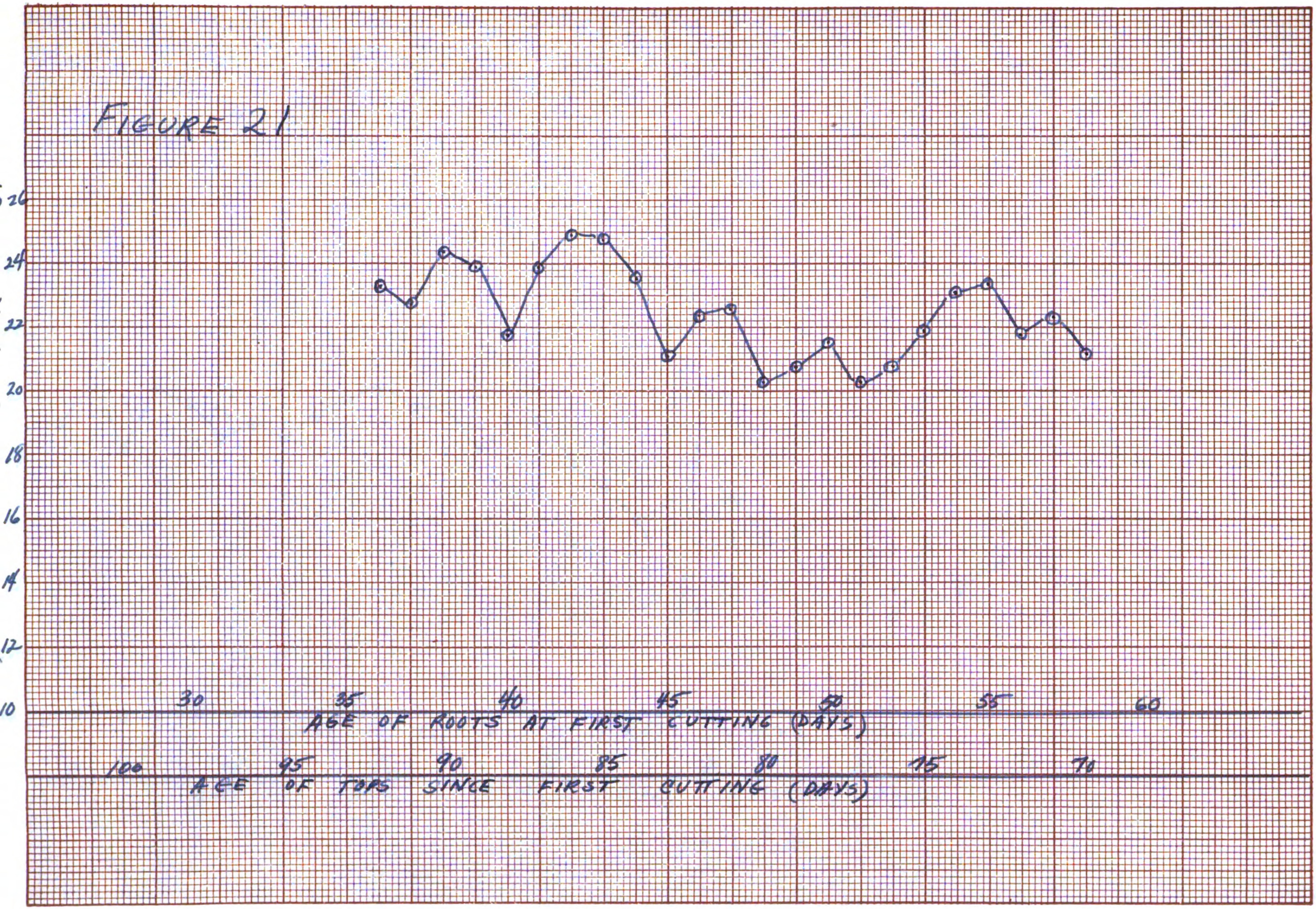

4
3
2
1
0
2
1
30
35
40
45
50
55
60
AGE OF ROOTS AT FIRST CUTTING (DAYS)
60
55
50
45
40
35
30
25
AGE OF TOPS SINCE FIRST CUTTING (DAYS)

FIGURE 21


26
24
22
20
18
16
14
12
10
30
35
40
45
50
55
60
AGE OF ROOTS AT FIRST CUTTING (DAYS)
100
95
90
85
80
75
70
AGE OF TOPS SINCE FIRST CUTTING (DAYS)

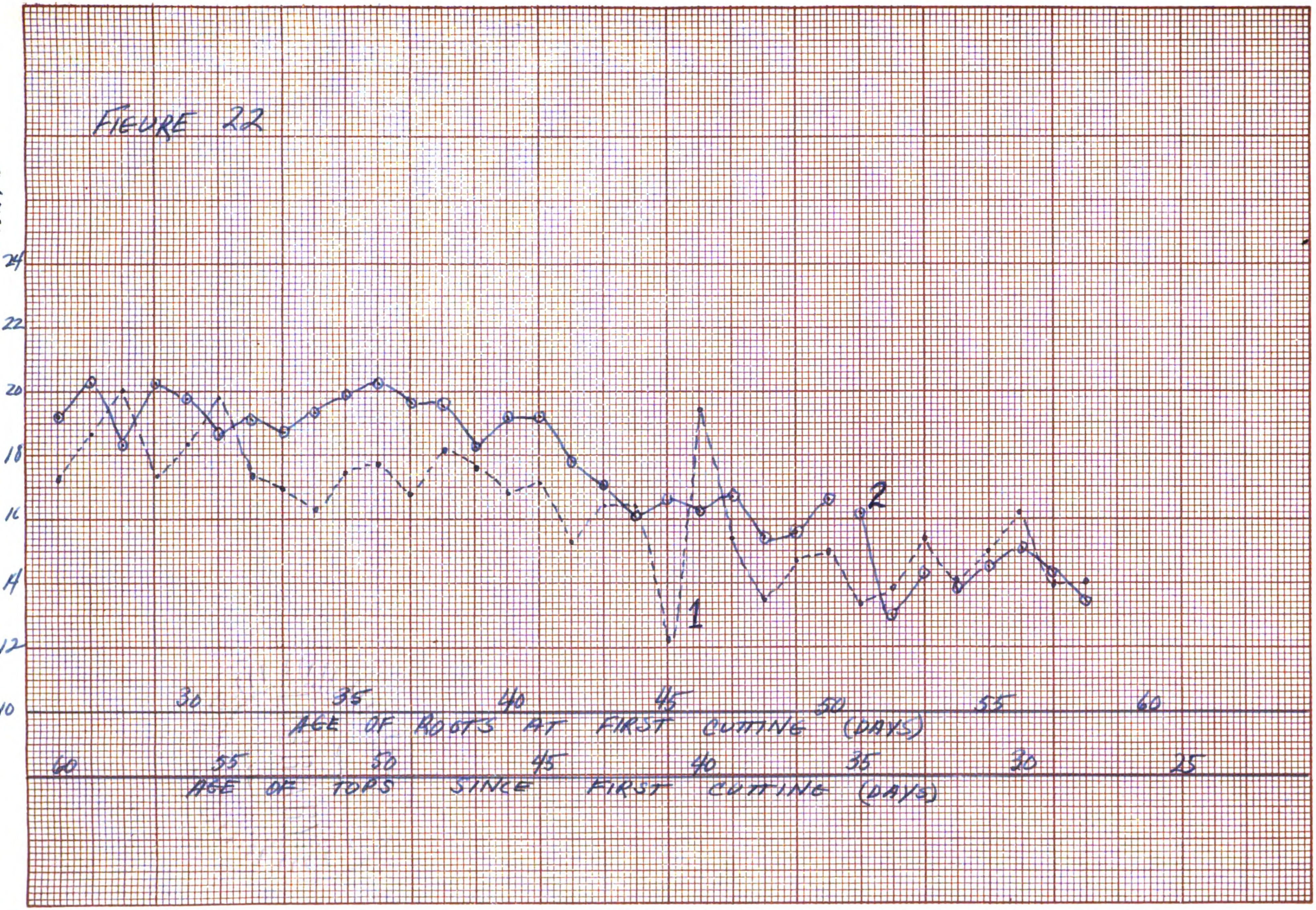


FIGURE 22
24
22
20
18
16
14
12
10
1
2
30 35 40 45 50 55 60
AGE OF ROOTS AT FIRST CUTTING (DAYS)
60 55 50 45 40 35 30 25
AGE OF TOPS SINCE FIRST CUTTING (DAYS)