To the Committee on Graduate Study:

I submit herewith a thesis written by Mr. Lawrence D. Smith, "Artificially Cured Roughages for Dairy Cattle," and recommend that it be accepted for nine quarter hours credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Dairying.

L E Gaylie
Major Professor

At the request of the
Committee on Graduate Study,
we have read this thesis,
and recommend its acceptance.

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Accepted for the Graduate Committee

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ARTIFICIALLY CURED ROUGHAGES FOR DAIRY CATTLE

-o-

A THESIS

Submitted to the Graduate Committee
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

By

LAWRENCE D. SMITH

August 1938

PREFACE

The material contained in this thesis has been collected by the writer during a year of graduate study in Dairying at the University of Tennessee.

A review of the written material on this subject was made and credit in each case has been given to the author of such material used in this review.

Acknowledgment is hereby given to Professor C. E. Wylie, Head, Mr. S. A. Hinton, and Mrs. M. K. Greenway of the Department of Dairying of the University of Tennessee for their valuable suggestions and assistance during the progress of the research and writing of this thesis.

---Lawrence D. Smith

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ARTIFICIALLY CURED ROUGHAGES FOR DAIRY CATTLE

INTRODUCTION

Artificially cured roughages may be divided into two classes, namely, silages and hays. All roughages cured or preserved artificially will fall into this grouping, either as machine dried hays or preserved silages. In the past few years there has been a tremendous increase in crops grown for roughage. The Agricultural Adjustment Administration has estimated that one acre out of every six formerly producing row crops of a depleting nature have been put back into permanent pasture land or sown to legume crops for soil improvement. This increasing interest in soil conservation and improvement has resulted in an increasing volume of leguminous crops available for hay or silage. The problem of preserving these crops without losing their nutritive value is faced by the majority of the farmers of our nation.

The artificial curing and preserving of roughages is not a new discovery, but has been practiced since the changing of man from the pastoral stage to the farming stage of history. However, probably more experimental and improvement work has been done in regard to the curing of such roughages in the last fifty years than in any other period. In fact, the artificial curing of hay on a commercial scale is a rather modern practice of scientific agriculture. The improvement of machinery used in drying and preserving roughages, the need for such feeds, and adverse weather conditions which hinder nature in her method of curing roughages have all entered into the development of the curing of roughages artificially.

As roughages are a primary consideration in dairy cattle feeding, the object of this report is to give information regarding the

curing and preserving of roughages artificially, their feeding value for dairy cattle, and experimental results with such feeds as obtained by the author in research work.

PART I

REVIEW OF LITERATURE

ARTIFICIALLY CURED ROUGHAGES IN DAIRY CATTLE FEEDING

THE DIGESTIVE SYSTEM OF THE COW.

The digestive system of the cow makes her, by nature, a roughage consuming animal. In fact, in the evolution of cattle and for a long time after their domestication, the rations of cattle were made up entirely of roughages. The digestive system of the cow has endowed her with the power to change large quantities of cheap roughages into milk and meat for human consumption. The secret of this power lies in the fact that the cow is a ruminant, or an animal with four stomachs. The first and largest of these stomachs is the paunch or store house where a cow may store large quantities of roughages which she will later digest by a rather unique method. A roughage is defined by Henry and Morrison (1) as "A feed being high in fiber and low in nutritive value."

A ruminant, or cud chewing animal, is unique in its digestion in that such an animal may eat or swallow large quantities of roughages in a short time and belch them back up into the mouth later for the proper chewing and mastication before complete digestion will take place. This accounts for the fact that a dairy cow may eat grass or some other type of roughage in the morning and then lie down in the afternoon and chew her cud. She has stored the food up in the morning and prepares it in the afternoon for the digestive process which really takes place in her second and third stomachs. According to Henry and Morrison (1) the paunch of a good size cow may have a capacity of sixty to seventy-five pounds of silage or grass. This physical characteristic of the cow makes roughages not only the economical part of

her ration but an essential part. The economical part of her ration is or should be made of large quantities of cheap roughages such as silage, hays, fodders, and by-products of other feeds which other animals on the farm may be unable to utilize. The deer, the elk, and the goat are also ruminant animals and are able to utilize large quantities of roughages in the same manner as the cow.

GREEN OR SUCCULENT FEEDS PROVIDED THE YEAR ROUND.

It is a rather commonly known fact that green feeds will stimulate milk production in dairy cattle, especially is this true where the cows do not have access to water at all times. As pasture grass serves as a source of green feeds and roughage, its importance in the dairy ration should not be overlooked. However, in most parts of the temperate zone where cattle are kept for milk production, year round pasture is almost impossible. Much experimental work has been done in regard to pasture improvement such as mowing, growing a variety of grasses, fertilizing, and pasture rotation, but at the best there are generally two seasons of the year when succulent or green feeds should be added to the farmer's dairy ration. These two seasons are in the hottest and driest part of the summer and the extreme cold months in the winter. Such a condition would exist where the dairyman had sufficient improved pasture land, but many dairymen do not have their pastures improved and in many cases where milk is produced near the larger cities no pasture is available for the animals. In this case green feeds and roughages would have to be provided the year round if economical milk production and growth of younger animals was expected. The two short seasons mentioned above would be only a minimum time that the dairyman would need a green or succulent feed, for in reality many dairy farmers feed silage and hays the year round

and cut down on these feeds only when pasture is available. Many dairymen figure the average dairy cow will need about three pounds of succulent feed and one pound of dry roughage per 100 pounds of live weight per day. Such high figures should indicate to the dairyman with the unprofitable herd that some provision should be made to meet these requirements, as nature has clearly demonstrated that she is unable to provide such large amounts of feeds day in and day out in the form of pasture and growing crops. The answer to the problem lies in providing silage and cured roughages at all seasons of the year and especially in those seasons when nature is a poor provider.

COMPLETE CROP UTILIZED.

The secret of dairy cattle feeding is found in the amount and kind of feed she consumes and her utilization of the nutrients within these feeds. Possibly the greatest advantage that silage has as a feed is that the complete growing plant with all its nutrients may be utilized for feed. This may be more clearly illustrated by Table 1, taken from the First Annual Report of the Pennsylvania State College.

Table 1. Yield of Digestible Matter in Corn.

Constituent	Ears	Yield per acre Stover	Total Crop
Protein, lbs.	244	83	327
Carbohydrates, lbs.	2,301	1,473	3,774
Fat, lbs.	125	22	147
Total lbs.	2,670	1,578	4,248

According to the data in this table, 63 per cent of the digestible food materials present in the corn plant are found in the ear and 37 per cent in the stover. If only the corn ears are gathered and the stalks left in the field, as is generally the case, the 37 per

of the possible nutrients of the corn crop is lost.

Large yields may be obtained from crops grown for silage; in fact, a yield of as high as 20 tons may sometimes be obtained from an acre of corn. A fifty-bushel crop of corn yields from 8 to 12 tons of silage, depending on the amount of stalks that accompany the ears and the stage of maturity at which it is siloed. The quantity of silage that may be expected per acre is often roughly estimated at one ton for each five or six bushels of ear corn. Southern varieties of corn as a rule have larger proportion of stalk and leaves than northern grown varieties.(2) Some legume crops and woody forage crops may be fed with less waste when made into silage because stock will leave some of the dry stover uneaten. Furthermore, weather has little, if any, chance to cause deterioration in the quality of forage when harvested for silage or if dried artificially for hay, while great losses in feeding value often results when forage crops are allowed to lie out in the field and cure for hay. The effect of allowing forage plants to lie out in the weather in the curing process is shown by Headden (3) in Table 2 as related to alfalfa.

Table 2. Composition of Alfalfa Hay Before and After Exposed to 1.8 Inches of Rain.

	C. Protein	Fiber	Nitrogen Free Extract	Fat
	%	%	%	%
Hay not rained on	18.7	26.5	38.7	3.9
Hay damaged by rain	11.0	38.8	33.6	3.8

It will be noted that the damaged hay contained much less crude protein, considerable less nitrogen free extract, and much more fiber. Of the original, 41% of the crude protein and 13% of the nitrogen free extract was lost, due to the rain. The actual damage

was even greater for the nutrients lost were those most soluble and hence most easily digested. Woodward (2) on the other hand found that when crops were made into silage the losses of dry matter for various crops were as follows: corn, 4.01%; grass crops, 18.06%; peas and oats, 6.90%, and legume crops, 2.12%. As hay cured artificially is taken from the field immediately after cutting, no such loss from weathering as found by Headden would occur. In a further study Headden (3) also found that when legumes were allowed to field cure, large amounts of food nutrients were lost in the leaves due to shattering while handling. When cured in swaths or windrows, the leaves became dry and brittle long before the stems were dry enough for storage. He found that 40 to 60 per cent of the weight of the alfalfa plant was in the leaves, which carry four-fifths of the crude protein and over half of the nitrogen-free extract. For each ton of alfalfa hay taken off the field, he estimates that as much as 350 lbs. of leaves may be lost, and with unfavorable conditions and careless handling, there may be a greater loss. The economic value of saving these food nutrients through the process of silaging and curing hays artificially is very important to the dairy farmer.

CROPS GROWN UNDER ADVERSE WEATHER CONDITIONS.

The widely varying character of grass and legume crops, the dryness and temperature of the soil of the meadow, the humidity of the atmosphere, and the intensity and continuity of sunshine and heat, are all modifying factors that combine to make the field curing of hay a very difficult problem. In fact, in many localities it is almost an impossibility. In the last few years much work has been done on the drying of hays artificially either by hot or cold air blast. This method is proving its worth in many sections of the country, especially

where weather conditions are unfavorable for field curing. In many sections of the United States where rainfall is excessive, this method of hay making is becoming more important and several agriculture experiment stations, which will be referred to later, are testing the machine cured hay as to economy and feeding value with the sun cured.

AN ECONOMICAL FEED FOR GROWTH AND MILK PRODUCTION.

One of the chief advantages given by those who advocate silage as a feed for dairy animals is its economy. As none of the silage is wasted and very little of the food nutrients lost in the curing process (2) the total cost is charged against the growing of the crop and the ensilaging cost. Such cost per ton may vary from one dollar to several dollars per ton, depending on the type of equipment used in making it, the yield per acre, extra labor, and many other variable factors. The general fact is conceded by Ansen (4) that the use of silage and hay as a feed for milk and meat production can not be exceeded in economy by any other type feed, except pasture.

A PALATABLE FEED.

Silage being a succulent feed is very palatable to most classes of livestock. The cow being a ruminant will consume large quantities of such feed without injury to herself or her appetite. The general practice of most silage feeding for dairy animals is to feed three pounds of silage for each hundred pounds of liveweight. This would be about 30 pounds a day for an average dairy cow, but she will consume much larger quantities if allowed access to good silage. While silage is an excellent feed and dairy animals will consume large amounts, it is not a complete feed. It is too bulky and watery and contains insufficient protein and mineral matter to meet fully the requirements of the dairy cow. It should be fed with some

legume hay such as clover, cowpeas, or alfalfa and also some grain, which will tend to balance the silage in dry matter, protein, and mineral constituents. A ration of silage and hay alone is satisfactory for cows which are dry or those giving only a small amount of milk, and for heifers and bulls. Cows in full milk should have some concentrate feed in addition to hay and silage, as they cannot consume enough of these feeds to keep up a large flow of milk and maintain body weight.

Woodward (2) has the following to say in regard to the palatability and the amount of silage to feed to dairy cattle:

> "The amount of silage to feed a cow will depend upon the capacity of the animal to consume feed. She should be fed as much as she will clean up without waste when consumed along with her hay and grain. Raise or lower the amount until the proper quantity is found. Generally speaking, a good cow should be fed just short of the limit of her appetite. If she should refuse any of her feed it should be reduced at once. The small breeds will eat 25 to 30 pounds per day; the large breeds 40 or more; and the medium ones amount varying between."

The palatability of air dried hay is a much discussed topic. This is probably due to so many factors that enter into the curing and feeding of such a feed. Newland (5) found that artificially cured hay could be substituted for regular sun cured hays and that dairy animals would consume like amounts of both kinds. The palatability of either the sun cured or the machine cured would of course depend upon the kind of hay or green material to start with and the curing process.

STORAGE SPACE.

One of the big problems of any type of livestock farming is the storage of feed. This is indeed a problem for the dairy farmer as a large amount of roughages must be kept on hand at all times to supply the milking herd, bulls, and young growing stock.

Hay lofts and hay sheds are rather common buildings on most dairy farms and silos are becoming standard dairy farm equipment. Silos have the advantage, however, in as far as storage capacity is concerned. Morrison (1) estimates that a cubic foot of hay in a mow will weigh about five pounds and contain approximately 4.3 pounds of dry matter, while an average cubic foot of corn silage in a 30 foot silo will weigh about 39 pounds and contain 10.2 pounds of dry matter. From these figures it can be seen that nearly two and one-half times as much feeding stuff calculated in dry matter can be stored in a given space when stored as silage as when stored as hay. The cost of providing a cubic foot of storage space in a silo and in a hay mow would, of course, enter into the total cost of storage. A cubic foot of storage space could be provided cheaper in a hay mow than in an above ground silo, but whether it could be provided two and one-half times cheaper would depend upon the type of construction and the material used in both cases. However, the increasing use of the trench silo is a marked advantage in favor of such feed, especially in the cost of storage. The practice of chopping hay will decrease the storage cost, but whether such a practice is economical when all factors are considered, is a debated question.

ARTIFICIALLY CURED ROUGHAGES

Hays

PRINCIPLES OF HAY DRYING.

Whether hays are machine dried or sun cured, the objectives sought are the same, that is, the securing of a bright green color, good aroma, retention of leaves and other finer parts, and freedom from dust and molds. Under ordinary hay curing conditions, according to Piper,(6) three distinct processes take place. (1) A reduction in water content to about 15 per cent (ranging from 7 to 25 per cent). (2) Fermentation of the hay produced by enzymes, which usually develop a characteristic aroma. (3) More or less bleaching, due to the destruction of the green chlorophyll by sunlight, the bleaching being increased by the action of the dew. In the artificial curing of hay by machinery or either in ventilated mows the third process as given by Piper is omitted.

By eliminating the bleaching effect of the sun, machine cured hays are at a distinct advantage, other factors being equal. The machine curing of hays is not a wide practice, but its importance is growing rapidly, especially in regions where excessive rainfall interferes with hay making. Probably the artificial curing of hays will never be developed on a small scale but will be limited to large commercial growers who have capital to invest in machinery, however, the increasing interest in barn curing and ventilated mows may change the situation quite a bit. An understanding of the three principal methods of curing roughages artificially as given below may be helpful in analyzing the above problem.

HOT AIR DRIED HAYS.

Gordon and Hurst (7) have the following to say in regard to the principles of drying hays with hot air driers.

> "The principles involved in these machines are not new, but the direct exposure of material to be dried to the furnace gasses is a practice that has been closely associated with the hay driers of various types in the United States. Previously steam was commonly used, the material to be dried being brought into direct contact with or exposed to air heated by steam radiators. Higher efficiency in the utilization of heat and elimination of the expense and trouble commonly associated with steam boilers are factors frequently cited in favor of direct application of furnace gasses."

Many types of hot air driers of one kind or another have been tried, but it seems that only two of them have ever reached any commercial importance. In the apron-conveyor type of drier the green forage is loaded on an endless screen wire apron and conveyed through the drying chamber, where hot air or furnace gasses are circulated through the layers of forage on the apron by means of one or more fans. Driers of this type may have a single endless conveyor or several conveyors, one above the other. The moisture is allowed to escape from the machine into the outside atmosphere. The forage may be fed into the drier whole, crushed, or chopped.

Barr (8) working with the Louisiana Station found that the drying was most effective in single apron machines when the plant was left whole. The apron driers are usually much larger machines than drum driers, which is necessary because of the longer period of exposure in the apron machines.

Drum hay driers are very similar to the ones used in drying granular substances such as salt. One end of the drum is slightly elevated and as the drum revolves the material is picked up by baffles fastened inside of the shell and then allowed to fall. Each time

some of the material is picked up it falls closer to the discharge end due to the sloping position of the drum. In hay drying the drum is placed in a horizontal position, and a current of heated air or furnace gasses relied upon to dry the hay and move the forage through the machine. In some driers of this type the dry material is drawn into a chamber at the discharge end from which it is conveyed mechanically to a storage structure. In most cases, however, the dry hay passes through the exhaust fan and is blown to a dust collector from which it is collected.

The apron-conveyor drier is a relatively low temperature drier in which the material remains for a considerable period of time. The temperature of the air or furnace gasses entering the machine is usually held at from 250 degrees to 350 degrees F., and the period of exposure may vary from 15 to 45 minutes, depending,of course, upon the initial moisture content of the forage. The temperature of the forage remains much lower than the surrounding gasses, due to the cooling effect of evaporation. The drum driers differ from the apron drier in one respect, in that it is classed as a high temperature machine necessitating a short period of exposure to prevent charring and burning of the hay. The temperature of the furnace gasses entering the machine is usually held at from 1000 to 1500 degrees F. by means of air inlets from the furnace and quantity of fuel supplied to the burner. The material remains in a drier of the drum type for one to three minutes, or even less, depending somewhat upon the initial moisture content of the forage, and also upon the size of the stems of the curing forage, the larger stem forages requiring longer. The temperature of the hay in this type of drier is also lower than the drying gasses.

The nutritive value of the hot air dried hay compared with regular field cured hay is fortunately a problem on which much experimental work has been done, and at the same time, not much conflicting data appears. Hodgsen, Knott, and Murer,[9] of the Bureau of Dairy Industry, in six trials, conducted to determine the digestibility of air dried hay, found that a mixture of 40% English rye grass, 40% Italian rye grass, and 20% white clover dried at a temperature as high as 350 degrees F. showed no significant differences. Their work also showed that such a temperature did not affect the calcium and phosphorus balance when the hay was fed to sheep. However, they also found that when the hay was dried at a temperature of 400 degrees F. and above that not only the digestibility was impaired but the calcium balance in such a feed was low and that the percentage of natural color in the herbage was only 76.3% of that dried at a temperature of 250 degrees F. Hart, Kline, and Humphrey[10] in a similar experiment with dairy cows found very similar results. They did find, however, that no detrimental effect was noticed when the hay was dried in a temperature up to 500 degrees F., while Hodgsen, Knott, and Murer found that the nutritive value of the hay was affected when exposed to a heat of 400 degrees F. It is possible that the type of hay drier and length of time that the forage was exposed to the two temperatures may account for the difference. Hodgsen and Knott,[11] in another experiment using dairy heifers, found that when put on a strict air cured hay ration that the protein digestibility coefficient was 74.92%, the nitrogen free extract 74.55%, and the ether extract 21.90%. This would be considered rather good for all except the fat or ether extract. The animals also showed a favorable balance of calcium and phosphorus when fed on the strict air cured hay ration. Camburn,[12] at the

Vermont Agricultural Experiment Station, found that when artificially dried young grass hay was fed to a group of milking cows, together with two-thirds of the usual allowance of hay and silage, in comparison with grain and the usual allowance of hay and silage to another group, that the production of milk, fat, and solids-not-fat from the two groups were essentially the same. It appears from these experiments that the digestibility and feeding value of air dried roughages is not impaired by the drying process with the exception of the slight difference in the fat or ether extract. There is known to be a difference in the vitamin content of the two kinds of hay.

The vitamin content of feeds for animals has been found to be just as important as vitamins in foods for humans. Probably the two most important in animal feeding are A and D, and it appears that it is also these two that are affected most in the curing of hay artificially. Russell, (13) at the New Jersey Agricultural Experiment Station, found that machine cured alfalfa hay processed at a temperature of 127-129 degrees C. for thirty minutes contained seven times as much vitamin A as the same type of hay sun cured. In the experiment white rats were used to determine the vitamin A content of the two feeds. The author of the experiment also reported that the air cured hay was of a dark green color while the sun cured hay was a brownish color, which was probably due to the bleaching effect of the sun during the curing process. Russell also found in another experiment that the air dried hay was low, however, in the antirachitic vitamin D, while the sun dried hay was relatively high. The same results were obtained by Bethke and Kicke (14) as they found that exposing alfalfa hay to sun, rain, and dew over a period of several days resulted in a marked loss of vitamin A, but that sunlight increased the vitamin D content

of the hay. It is an established fact that the direct rays of the sun cause the increase of vitamin D in field cured hay, but no definite proof has been given that the destruction of vitamin A in sun cured hay is due to the effect of sunlight. In fact, Hauge and Aitkenhead, (15) at Purdue University, indicated in an experiment that the loss of the vitamin A in the field cured hay was due to enzymatic action and not to the ultra-violet rays of the sun. Although the two hays may be equal in nutritive value, as the majority of experiments indicate, there is a big difference in their vitamin content. In animal feeding, however, excepting poultry, vitamin A is much more important than vitamin D. As an animal is exposed to the direct rays of the sun a great deal of the time, not much trouble is had in securing a sufficient amount of vitamin D. The fact that air dried hay is lower in vitamin D than sun cured hay would, therefore, not make any material difference, but the fact that air dried hay is high in vitamin A is a distinct advantage to it, because an animal needs large amounts of vitamin A for proper growth and development and can secure it only through feeds. However, one must not overlook the fact that the quality of the forage to begin with, climate conditions for sun curing, and the method of air curing might materially change the nutritional value or vitamin content of either type hay.

BARN CURED HAY.

Commercial hay driers have been on the market for a number of years and vary in price from $3,500 on up into many thousands. As can easily be seen a farmer would have to be in the hay producing business on a commercial scale before such expensive equipment could be afforded. Such a condition has given rise to some experimental work in drying hay by the use of cold or slightly warmed air blast,

or what is known as the barn curing method. Such a method requires a much longer time to bring the moisture content down within a safe keeping range, but the cost is more in line with the average farmer's purchasing power and very satisfactory results have been obtained under certain conditions with this inexpensive drying system.

Weaver,[16] working in conjunction with the Tennessee Valley Authority, has probably done more experimental work on this method of hay curing than any other individual. His first work was with a one h.p. electric motor which was belted to a centrifugal blower. The air was forced through a duct containing an air blast heater and then on up through the hay from a central slatted chamber 9 feet long, 3 feet high, and 4 feet across. The chamber was made of 2 x 4 members standing on end and slatted down the side with wooden lath. In the test partially cured alfalfa hay from the field, with 40 per cent moisture, was placed on the platform. The heater was used only to heat the air at night. After 22 hours of drying, the moisture content was reduced to 19 per cent. Another test was conducted using partially cured hay of 50 per cent moisture in which 48 hours were required to reduce the moisture content to 20 per cent. The resulting hay was reported to be of good uniform quality and green in color.

Another type of test was conducted by Weaver in which a small gasoline engine was used to drive the blower which was connected by a duct to the hollow center of a small hay stack. The stack was made up of hay containing 65 per cent moisture and the air was blown through the stack for 4 to 6 hours. The results obtained were similar to those obtained by Aitkenhead,[17] at Purdue University. The method of curing was very tedious and quite a bit of moldy and poorly cured hay was obtained when the hay stack was not uniformly made. Weaver,

however, considered the method a failure, but Aitkenhead in his work stated that such a method may be used if hay prices are rather high. Weaver, in his work, used hay of a higher moisture content and smaller stacks than Aitkenhead, which may account for his conclusion. It appears, however, that such a method would be far to troublesome for drying hay under ordinary conditions.

Still another experimental method was developed by Weaver when it was thought that partially cured hay from the field could be loaded in the afternoon on wagons with special hay frames, hauled to a blower, and by attaching air ducts and blowing warmed air through the hay, finish the drying process by morning. It was hoped that by the use of such a simple method that a good quality hay could be obtained rather cheaply. In fact, very good results seemed to be obtained, but it was found that the time required to dry the hay was longer than expected, and too many wagons were required for the plan to be practical.

The last work reported by Weaver was the building of a main duct 16 x 16 and eight lateral ducts 10" x 12" on the floor of a regular hay loft. The sides of the air channels which were made of ordinary lumber were open up one inch from the floor to allow the air to escape up through the hay. A 16 inch centrifugal blower was placed at one end of the main duct and belted to a 5 h. p. motor. The main duct enclosed a series of adjustable gates so that the air could be blown intermittently into any combination of laterals desired. Several different tests were run using this set-up in which the moisture content ran as high as 50 per cent when placed in the barn and the depths ranged from 6 to 12 feet. The air was blown through the hay only in the day time and the heater was used only on occasions

when the humidity was high.

A system of hay drying as given above was installed in the University of Tennessee dairy barn at Knoxville in the summer of 1937. Several tons of mixed hay with varying moisture contents were cured and very satisfactory results were obtained. It was found that the hay, while curing, could easily be kept from heating by simply blowing cold air up through it. No heat was applied, but the top of the barn near the metal roof was boarded up and the air for the blower was sucked down along the metal roof which had warmed the air to some extent. It was also found that the intermittent blowing of air up through the hay would dry it out just as fast as the continuous blowing. It was concluded that as outside moisture from the plants evaporated that the inside moisture had to work to the outer cells before being evaporated. By blowing air up through the hay part of the time and then sucking it back down, no moisture was allowed to accumulate in the top of the barn. In general, the curing process might be considered a success although a few minor details still remain to be worked out.

In summing up his findings, Weaver (17) makes the following observations in regard to this method of curing hay:

> 1. The kilowatt-hour consumption of electricity per dry ton varied greatly throughout the entire group of tests, dependent largely upon initial moisture content of hay, variety of hay used, air conditions, and the need for observations requiring power beyond that necessary to complete the normal drying cycle. Further observations are necessary before any definite average figure can be given, and then it will vary with the variety of hay being dried.
>
> 2. Little difficulty was experienced in drying clean hay of the small stem varieties, such as alfalfa and lespedeza. The higher the grass content in the hay, the more difficult it was to dry. The large stem varieties of hay, such as Mammoth Yellow soybeans, proved difficult in that the drying was slow and drawn out over a long time.
>
> 3. Present indications are that drying is just

as rapid with intermittent blowing as with continuous blowing. Further observations are needed to find the extent to which this is true, in order that the most efficient operation of the system can be definitely determined.

4. Indications with this plan of drying are that a barn with a hay mow of 20 to 40 ton capacity can be equipped for drying the season's hay crop with an investment of about $300.00 (1938 improved system $400.00).

5. Most of the tests conducted to date dealt with hay of above the average grass and weed content. Weather conditions were at times adverse; however, a period of three or four days of rain and high humidity is yet to be encountered during the critical drying period of 8 to 10 tons of hay. Further observations are believed necessary before this system can be declared entirely successful.

It appears from the small amount of work done on the subject that the curing of hay by cold or only warmed air is not as yet successful, but a barn curing system may have possibilities. With the increasing use of cheap electrical power to furnish an abundance of air and small heating units, this method may increase in use because of the low initial cost of equipment needed. As far as the author can determine, no experimental work has been done in determining the feeding value of hay cured by this method except that being done as research work for this thesis, which is reported in Part II of this paper.

VENTILATED MOWS.

In addition to curing hay with hot air blast and cold or only warmed air, some work has been done on the curing of forage in ventilated mows. The development of such a method has not, as yet, reached the experimental stage that the previously mentioned methods have, but such a method, if developed, would probably meet the demand of individual farmers much better than the other two methods discussed. The use of ventilated buildings to reduce the moisture content of forage is not only a hay curing process, but also involves storage. Naturally one would not suppose that hay with an extremely high

moisture content could be cured in such a way, but most workers who have experimented with this process of hay curing have depended upon natural curing to a great extent, and being able to store the hay only after the larger part of the moisture has been removed in the field. Witzel,[18] reporting on chopped hay in ventilated mows from the Wisconsin Agricultural Experiment Station, indicated that where hay is chopped and stored in ventilated containers the length of cut or density is the major factor in determining the quality of hay secured and not the ventilation factor as would be expected. In the investigation as reported by Witzel, six wooden bins varying from 3 to 6 feet wide, 8 feet long on the inside, and 10 feet deep, were used. The sides and end walls were double, with 1 x 2 inch slats spaced 10 inches apart making up the inside wall, except that some of the bins were lined with poultry netting, while the outer wall was of floor boards. An additional container which was a wooden stave silo 14 feet in diameter, equipped with a floor about two feet above the barn floor, was covered with water proof building paper so as to make it practically air-tight, and a ventilated flue three feet square was constructed in the center of the silo. This was constructed so as to have a 3' x 3' connection at the bottom to one side of the doors, thus allowing free movement of air through the chute. In the investigation with this arrangement, Witzel makes the following conclusion in regard to ventilated containers of this type for chopped hays:

> "General conclusions which can be drawn at this time indicate that the major factor determining the temperature and keeping qualities of hay in storage is the density or length of cut. Whether the coarse length of cut affects it only through density is a question. In any event the longer cut undoubtedly keeps better and does not heat as much as the shorter cuts.

> "Width of storage unit is not a very important factor. The difference in the keeping qualities and temperature between a 3-ft. box and a 9-ft. box is not extremely marked, although definitely measurable. However, it will probably be a controlling factor, along with density, in the elimination of danger of spontaneous combustion in the storage of hay that is too damp."

Such conclusions would indicate that the chopping of hay and placing in ventilated mows is not a satisfactory method of curing, but investigation by Rothe (19) with unchopped hay in ventilated mows has given more encouraging results. Rothe in his investigation found that hay of fair quality could be obtained if stored in a compartment with one side of the hay exposed. This would apply only to hay that contained not over 30% of moisture when placed in the mow and provided that no hay was over six feet from the exposed side. In further study, Rothe (19) also found that hay stored in such a manner did not go above 190 degrees F. in the curing process, which is far below the temperature that spontaneous combustion will take place. He indicates that the division of large mows into smaller compartments, by means of alleyways or open work partitions that are not over six feet across with one side exposed or 12 feet with two sides exposed, will serve very satisfactorily as ventilated mows.

Such an arrangement as outlined by Rothe would probably fit in rather nicely with the average livestock farmer who already had a large hay loft and was interested in removing his hay from the field before complete curing took place. Such a procedure should at least preserve part of the green color and aid materially in preventing the loss of leaves by shattering. As far as the author can determine, no investigation has ever been made as to the feeding or nutritional value of hay that has been partially cured in ventilated mows. As the general procedure of curing is very similar to the cold or warmed air system,

one might conclude that its feeding value would also be similar, other factors being equal.

COST OF ARTIFICIALLY CURED HAY.

The cost of curing hay artificially will depend to a great extent upon the type of machinery used in the curing process. The initial cost of dehydration equipment and the depreciation of this equipment is very high. This must be spread over a large tonnage of material to keep these costs from being prohibitive. The New Jersey Experiment Station reports (38) that approximately 50 gallons of fuel oil are required to dry one ton of hay, and $15.00 per ton as a total cost of dehydrated hay. This figure included all cost of labor, fuel, power, fertilizer, transportation, repair, rent, interest and depreciation. Other investigators report a range in total cost of from $8.00 to $16.00 per ton for hay dried in either the drum or conveyor type dehydrators. In these large commercial driers the labor and fuel costs are the two most important items of expense. These two factors are notaffected to any great extent by the tonnage, but of course the investment cost per ton will depend upon the volume of hay dried. Greene, (39) at Brook Hills Farms in Wisconsin, reports a cost of from $2.50 to $3.00 per ton for fuel and power in dehydrating hay. Such a cost is very much in line with legume silage cost per ton on a dry basis.

Very little data are available on the cost of barn cured hay. In fact, the results of the Tennessee Valley Authority experiments are the only data obtainable at this time. Weaver (40) reports that a loft capable of curing 20 to 30 tons of hay may be equipped for $450. This includes all labor, blowers, motor, and building material. Such a cost would be the initial investment, but there would be very little depreciation cost on this type of drying equipment.

He also reports that the average electricity cost for drying a ton of hay at the University of Tennessee dairy barn in 1937 was 86 cents. Two cents per kilowatt hour was the rate used in figuring this cost. The investment cost per ton would depend upon the tons of hay dried, but the power cost would remain unchanged. Of course, the extra labor required to get the green material into the loft must be considered in the total cost.

No data is available on the cost of drying partially cured hay in ventilated mows. It seems, however, that the only expense involved would be the construction of the ventilators and alleyways for proper air circulation. Such an expense, however small, might be too much for the benefits derived from such a system.

The curing of hay in large dehydrating plants will probably never be practiced except where hay is produced on a commercial scale and a high grade of hay for sales purpose is desired. The barn curing system and the ventilated mow may however increase in popularity because of their low cost. Additional experimental data and improvements will be needed, however, before the individual farmer should consider installing such systems.

SILAGES

PRINCIPLES OF PRESERVING SILAGE.

When green forage is packed firmly into an air-tight chamber, such as a silo, fermentation takes place. This fermentation is caused by the enzymes contained in the plant cells and by bacteria and yeast carried into the silo on the forage. During these fermentations much of the sugar in the ensilaged forage is broken down into organic acids, chiefly lactic acid, (the acid in sour milk) with some acetic (the acid in vinegar), and also traces of other acids. In these changes oxygen is taken up and carbon dioxide given off. At first the oxygen in the air which has been entrapped in the ensilaged mass is used up, but if the mass has been well compacted, this is soon exhausted. The enzymes and bacteria then obtain the additional oxygen needed for these decompositions from the oxygen containing compounds in the forage--chiefly the sugar. When the sugar in the forage has been changed into acid the fermentation is checked for the other carbohydrates are attacked to only a small extent. It is due to this that well matured corn or sorghum makes less acid silage than immature plants which contain more sugar. Even though an excess of sugar is present, the fermentation comes to an end at length, for sufficient acid is finally produced to prevent both the further growth of bacteria and yeast and the action of the plant enzymes. During the fermentation process, the temperature rises somewhat, but if the mass has been well compacted so that little air is present, the temperature of the interior of the silo should rarely reach 100 degrees F.

The accumulation of acid not only automatically checks the further action of the acid forming enzymes and bacteria, but it also prevents the growth of undesirable bacteria that cause putrefication

and spoiling. After a few days the silage making process ceases, and no appreciable changes will take place so long as the air is kept out. In fact, instances are on record where silage twelve to fourteen years old has been found to be of excellent quality. Some types of forage, especially the legumes, require additional treatment to bring about the proper preservation action, but the principles involved in the ensiling process are the same.

ORDINARY SILAGE.

By ordinary silage is meant silage that has been made from carbonaceous green forages without any special treatment used to preserve it. Such silages as corn and cane are in this group. This is by far the most important type of silage that is used, in fact, the special treatment of legumes and grasses for silage is only in the experimental stage. Such a classification would include a great number of forage plants, but no detailed discussion will be made here of each plant. All crops used for silage must be cut while green or if allowed to dry out to any extent water must be added at the time the forage is placed in the silo. The crop may either be cut by hand or with binders, but hand cutting is rather slow and laborious and is used only to a small extent. A binder, as reported by Woodward, Rommel, Ward, and Shaw, (20) with three horses will cut on the average of six acres a day. The green forage is then loaded on wagons and hauled to the cutter, or in some cases the forage is cut in the field by a combination binder and cutter and then hauled to the silo. There the forage is cut into one-half to one inch lengths by the cutter and is blown directly into the silo. If the forage is rather dry and shows many dead leaves, water is usually added either as the forage is being cut or on the material in the silo. As much air should be excluded

from the cut material as possible in order for the proper chemical and bacterial action to take place. To get the desired or most successful results (according to the United States Department of Agriculture)[20] some packing should be done as the material is added to the silo, or at least when the complete silo is filled in a few hours time and no settling is allowed until filled. Several years ago it was a common practice to cover the silage with some material such as dirt or cut straw in order to prevent the top layer from spoiling. Now, however, the general practice is to omit the dirt and place some of the coarser material of the forage that is being used to fill the silo rather than the chopped straw and dirt. There will always be a layer of spoiled silage no matter which system is followed and the use of dirt and straw is rather troublesome. After covering, the whole mass is wet down and sometimes oats are sown on top of the silage as the fermenting silage will generate enough heat to sprout the oats which, in turn, form a dense sod that serves to shut out all air. This is especially true of trench silos that are covered with dirt. Hunter[21] indicates that any green forage crop of the carbonaceous type may be ensiled successfully if it contains the proper amount of moisture and the air excluded from the fermenting silage. More silage is made from corn than from any other forage. According to the Agricultural Statistics of 1937,[22] the number of acres of corn harvested for silage in the United States was 4,721,000, and about three-fourths of this total was harvested in the North Central States. The grain sorghums and sweet sorghums are other carbonaceous plants that are used for silage.

LEGUME SILAGE.

As stated before most investigations show that a legume crop cannot be ensiled in the ordinary way and good results secured. How-

ever, a few experiments have disproved this rule. One of the principal reasons for the numerous failures in the making of silage from legumes, as observed by Wilson,(23) is that leguminous materials require more organic or mineral acid to reduce their pH one unit than is required by a similar quantity of a non-legume material. He also emphasized the fact that legume forage crops may be deficient in acid producing carbohydrates. If the latter is true, then these two characteristics of the legumes may explain the numerous failures in efforts to produce silage from highly nitrogenous crops. Wilson and Webb,(24) at Cornell University, in experimental work on legume and non-legume silage, found that there was three times as much fermentable sugar in the non-legumes that produced acceptable silage as there was in the legumes that produced inferior silages. Their conclusion is also strengthened by the fact that vetch and possibly red clover, which proved to be the most reliable silage legume in their investigation, had the highest percentage of water soluble carbohydrates of all the legumes analyzed. Conclusions thus far indicate that legumes, when ensiled by themselves, will not usually be satisfactory, therefore, they must be given additional treatment to take care of their low carbohydrate content.

Two different methods have been used to take care of this deficiency. As the main objective is to get enough acid to get proper preservation one method has been the addition of a carbohydrate material from which acid may be formed, and the other the direct addition of acid itself to the material as it is being put in the silo.

MOLASSES SILAGE.

Molasses has been one of the most widely used carbohydrate materials to be used in preserving legume and grass silage. Molasses may serve a twofold purpose in such a capacity by furnishing material

from which acid may be formed and at the same time serve as a feed itself in case all of it is not used up in producing acid. Probably this is the reason that such varying amounts of molasses are added to a ton of green material. In case molasses is a rather cheap feed, then a larger amount may be put on the silage than is actually required to preserve it, and at the same time it is not wasted. Investigators at the New Jersey Experiment Station (25) found that with a varying amount of from 72 to 120 pounds of molasses to a ton of dry matter that the percentage of moisture was the most important factor to be taken care of. They found that 40 pounds of molasses on a ton of grass containing 66 per cent moisture made satisfactory silage, while a like amount on grass containing 44 per cent moisture proved to be unsatisfactory for feeding.

Similar investigations by Nevens and Kuhlman (26) at the University of Illinois showed that alfalfa silage put up with less than 66 per cent moisture did not prove satisfactory even though molasses and several other carbohydrate materials were added. Such results would, therefore, indicate that legume silage might be made rather successful with molasses if the green material contained the correct amount of moisture, however, Swanson and Tague (27) at the Kansas Agricultural Experiment Station found that satisfactory legume silage may be made with either fresh cut alfalfa, wilted alfalfa, or wilted and watered. In all the cases listed, the molasses was diluted with water for ease in handling and for proper distribution. In most instances the mixture was one part molasses to two parts of water, however, some commercial enterprises and unofficial reports indicate that molasses may be added direct to the green feed as it is being run into the silage cutter and that from three to seven gallons per ton of green material

may be used with good results. A rather common method of regulating the flow of molasses onto the green material as it is being put in the silage cutter is:

(1) Time required for a load of hay to go through the cutter.

(2) Time it required to fill a quart jar with molasses.

(3) Multiply the number of minutes it takes to run a ton through the cutter by 180 and divide by the number of seconds it takes to fill the bottle.

(4) The results will give the number of pounds of molasses used per ton.

Other methods, especially the use of acids, have been used for legume, grass, and cereal plant silage, but it appears that molasses is rather easy to put on and also gives satisfactory results. The use of molasses in making silage will probably be greater than the use of acids because the average farmer is not acquainted with the chemistry involved in the acid preparation and application, while the use of molasses is rather a simple procedure. The results obtained will always be the main factor, however, with the cost second in importance.

ACID SILAGE.

Instead of adding material from which organic acid may be formed to preserve legumes and grasses for silage, some investigators have added mineral acid directly to the silage to bring about the correct acidity. Among the first to develop such a method was A. I. Virtanen of Finland. This method is now known as the A.I.V. system of silage making, the initials being taken from his name. It consists of the use of a mixture of hydrochloric and sulphuric acid. A great deal of variation as to the proper mixture and amount of application is en-

countered. The object, of course, is to obtain a pH of between three and four of the ensiling matter, which is considered the best acidity for silage preservation. The amount of soluble carbohydrates in the legume or grass should govern the amount of acid required.

An example of this is shown by Wilson and Webb [24] who found that vetch and red clover were extra high in soluble carbohydrates compared with other legume plants, and required a smaller amount of acid or molasses to preserve properly. The general accepted method is to use four parts of hydrochloric acid to one part of sulphuric. This mixture is made into a 2Normal solution before being added to the silage. A relatively easy but satisfactory method for making a 2N solution of the acids as given by Wilson [28] is to obtain the commercial form of acid in carboys holding 12 gallons and mixing the contents with 60 gallons of water. This would give a 2N solution of acid without involving much chemical calculation.

The idea generally associated with making acid silage is that the chemicals are rather difficult to apply. Several different methods of application have been used but Wilson [28] and associates, who have put up many hundred tons of silage in the United States have the following to say in regard to this problem.

> "The amount of acid required varies with the kind of crop, the stage of maturity, and the type of soil on which it is grown. Therefore, it is necessary to assay the crop to determine how much acid to use. This assay requires a very limited amount of chemical equipment and can be carried out with anyone who is somewhat familiar with chemical methods.
>
> "The silo to be used may be of the pit or tower type. The inside surface should be wood or else painted with asphalt paint. The equipment usually used for mixing and applying the 2N acid should consist of:
>
> (1) A mixing tank of about 300 gallon capacity.
> (2) Measuring barrel for measuring the acid.
> (3) An acid resisting pump.
> (4) A hose to convey the acid into the silo.

"The mixing tank should be of wood or else metal thickly coated with asphalt. It should be set up on a platform so it will drain into the measuring barrel.

"Oil drums holding 55 gallons make satisfactory measuring barrels. They are set on end, the tops knocked out, and the bottoms fitted with connecting drains. The drains should be coated with asphalt paint. A calibrated wooden stick is used to measure the amount of acid in the barrels. It is advisable to have two barrels so that one can be filled while the acid is being used out of the other. The pump should be bronze or some other acid resisting material. A gear type marine pump has been found very satisfactory. All fittings should be of brass or rubber to prevent reactions with the acid. Each load of fodder is weighed and the valves are regulated so that the amount of 2N acid indicated by the assay is applied. It is best to run the fodder through the cutter and spray the acid on in the silo."

As will be noted, Wilson gives no definite amount of acid to be used, but explains that different factors will cause the amount to vary. His investigation is also supported by Peterson, Bohstedt, Bird, and Beeson, (29) at the Wisconsin College of Agriculture, who used amounts of acid varying from 90 liters to 120 liters per ton of green material with satisfactory results.

From the data available it appears that satisfactory silage may be made from legumes and young grasses by the use of hydrochloric and sulphuric acid or the A.I.V. method, although a little knowledge of chemistry and some special equipment is required. It is still doubtful if this method will become popular with the small farmer because of these two factors, but larger stock farms may use this method if it continues to prove successful.

Other kinds of acid have been used besides hydrochloric and sulphuric but none of them have proven quite so effective as these two. Recent investigation with phosphoric acid, however, has proven interesting. The general concession by Rommel (43) is that this acid will bring down the pH enough to prevent undesirable enzymatic and bacterial action and at the same time furnish phosphorus in the ration of the

animal. If such concessions are true it would have one advantage over the A.I.V. method in that no limestone would have to be added to the animal's ration to take care of the excess acid which is usually done when feeding A.I.V. silage. The amount of phosphoric acid to use for a ton of green material will vary, but Babcock, (29) in a popular report, indicates that he has had very good results with one and one-fourth gallons of 68 per cent phosphoric acid which would be about 74 liters of 2N acid. Work at the Cornell (New York) Experiment Station as given by Babcock (29) also indicates that around 17 pounds of 90 per cent phosphoric acid will be sufficient for a ton of green material. Such figures are slightly lower than the amounts used for the A.I.V. method and would, therefore, suggest that phosphoric acid has a slight advantage over the hydrochloric and sulphuric acid in bringing down the pH content of legume silages other factors being equal. Other investigators have used as high as 20 to 25 pounds of 90 per cent phosphoric acid with satisfactory results; however, if 17 pounds should prove satisfactory there would be no need for the extra amount which would involve extra expense.

OTHER TREATMENTS FOR ENSILING LEGUMES AND GRASSES.

No other methods of ensiling legumes and young grasses have met with as much success as the molasses and acid treatments, however, many more have been tried. Nevens and Kuhlman (26) used whey powder to serve in an acid increasing capacity and found that it proved rather satisfactory but was expensive. They also used lactic acid culture and bulgartac culture by incorporating the material with the alfalfa at the time of ensiling. Although they stated that such materials would increase the acid content of the silage, they also indicated that the procedure was not practical for the average farmer.

Swanson and Tague [27] also found that such products as corn meal, dried milk, and sugar would increase the acid content of legume and grass silage but were either too expensive or not practical. The mixing of a legume or grass roughage with a roughage high in carbohydrates has long been in use for ensiling these low carbohydrate plants and in many mixtures very good results have been secured.

From the limited amount of data available on the subject, one might assume that any carbohydrate material that contained a high water soluble starch content might be used to raise the acid content of legume or grass silage, however, such factors as cost and practicability would limit their use.

COST OF SILAGE.

The cost of silage is a much discussed topic. Because the cost of silage is given as so much per ton, most farmers consider silage as their most economical feed. Such a belief may or may not be true. The total amount of digestible matter in a feed should be considered in arriving at its cost. The fact that silage may contain as high as 70 per cent of water is very significant in determining the cost of production. The yield per acre, labor, and the type of machinery used are all factors that will enter into the cost of producing a ton of digestible nutrients in the form of silage.

Fitch [41] reports that cost studies made in Minnesota indicated that 100 pounds of nutrients in the form of alfalfa hay cost about 43 cents as compared with 79 cents for silage. Some of the projects studied showed a still wider variation between the two types of feeds. Other investigators report, however, that silage can be produced with less expense than hay. It seems that local conditions would determine the cheapest feed. Fitch also stated that legume silages put up with molasses or acids will involve an extra expense of

from 65 cents to 85 cents per ton of green material. Such extra expense includes only the cost of the preserving materials, but some extra equipment and labor would also be needed to apply the preservatives.

So many variable factors enter into the cost of producing or ensiling a crop that no definite figure can be given as the cost of a ton of silage. Some of the factors affecting the cost and the relative importance of the different classes of cost are: (1) Quantity of silage made, (2) Yield per acre, (3) Amount of regular labor available on the farm, (4) Cost of hired labor, and (5) Alternative uses for labor, power, and capital.

Myers, (42) in a study of the cost of filling silos in the North Central States, found that the average cost of filling a silo with a stationary cutter was $1.41 per ton when the equipment was owned by the farm operator and $1.49 per ton when a custom machine was hired. It cost $1.30 per ton to fill with a field harvester, either a power take-off or a motor-mounted type. These average costs included all items such as direct cash cost, allowance for depreciation, and interest on investment, the assigned value of the operator's labor and that of his family, cost of housing the equipment, and the cost of horse work.

Such figures appear to be rather low for the cost of a ton of feed stuff, but it must be kept in mind that this does not include the cost of growing the crop, and the fact that the silage is approximately 65 to 75 per cent water. An additional expense of from 65 to 85 cents per ton should be expected for legume silages to cover the cost of the molasses or acid needed. From the data surveyed, it appears that the total cost of producing and placing silage in a silo may range from $2.00 to $5.00 per ton of green material.

SUMMARY OF SURVEY OF LITERATURE

1. The cow is by nature a roughage consuming animal, and requires large amounts of such feeds for economical milk production.

2. Succulent feeds such as silage should form a part of the dairy cow's ration whenever possible because of its economy and palatability.

3. Forages cured in the field frequently lose part of their nutrients due to the action of rain and the bleaching effect of the sun. Shattering of the leaves also accounts for part of the nutrients lost in field cured hay.

4. Hot air drying plants for curing hay are very expensive, but a good quality hay with all the known original nutrients preserved can be made by this artificial drying process.

5. Artificially dried hay cured by hot air or the barn curing system is higher in vitamin A than the ordinary field cured hay. It is lower, however, in vitamin D.

6. The drying of hays by the barn curing method may be the answer to the problem of a low cost hay drier for the average farmer.

7. The curing of partially cured hay in ventilated mows involves some extra trouble and expense and the quality of the hay may not be improved to any great extent.

8. The artificial curing of hay apparently has no detrimental effect on its feeding value, and more of the original nutrients in the plant are preserved.

9. Some expense is involved in the artificial curing of hay. The extent of such an expense will depend upon the type of equipment or the curing method used.

10. The preservation of silage involves a chemical and bacterial action. The results is an acidity of from 3 to 4 pH which really is the preserving agent.

11. Ordinary silages made from carbonaceous plants need no special treatment because they contain sufficient carbohydrates from which the preserving acids may be formed.

12. Legume plants and grasses require a supplement to increase the carbohydrates from which the preserving acids are formed. The direct addition of certain mineral acids will bring about the same results.

13. Molasses is the most widely used supplement for preserving legume silage. It is easy to apply, inexpensive, and is very effective in its preservation action.

14. Many other carbohydrate materials have been used in legume silage experiments, but thus far, none of them have reached any commercial importance. This does not mean, however, that some of them have not proven successful. Among those tested have been sweet potatoes, apples, sugar, carrots, milk powder, corn meal, and sugar beets.

15. The use of mineral acids, such as hydrochloric, sulphuric, and phosphoric has given very good results in preserving legume silage, but some knowledge of chemistry and special equipment is needed in its application.

16. Good legume silage is a more valuable feed than carbonaceous silage because of its high protein content.

17. In feeding value, three pounds of silage has been found to be equal to about one pound of hay.

18. The cost of silage is somewhat variable because of the many factors involved, but it is considered one of the most economical feeds for dairy cattle feeding.

PART II

EXPERIMENTAL INVESTIGATION

PART II

EXPERIMENTAL INVESTIGATION

SECTION A

AIR DRIED HAY VERSUS FIELD CURED HAY FOR DAIRY HEIFERS

PURPOSE.

The purpose of this experiment was to determine the difference in the feeding value of air cured hay (barn cured) and similar hay, field cured, for dairy heifers. Such information was needed in furthering the investigation being conducted here at the University of Tennessee with the barn curing system of hay drying. The air dried hay was cured in a cooperative project by the Tennessee Valley Authority and the University of Tennessee by the barn curing method as outlined on page 17.

PLAN OF EXPERIMENT.

This experiment was conducted at the University of Tennessee Farm, at Knoxville, during the five and one-half month period from October 20, 1937, to April 3, 1938. Two groups of heifers, each consisting of three Holsteins and two Jerseys ranging in age from thirteen to seventeen months, were used in the experiment. The groups were divided as equally as possible in regard to age, weight, height at withers, heart girth measurement, and condition of the animals.

The following rations were fed to the two groups of heifers:

Group I. Artificially dried (barn cured) mixed alfalfa and clover hay ad libitum.

Concentrates, 2 pounds per animal per day--equal parts ground corn and cotton seed meal. (First month, 4 pounds per animal per day).

Corn silage, 10 pounds per animal per day.

Minerals, steamed bone meal and salt equal parts--3% grain mixture.

Group II. Field cured hay ad libitum.

Concentrates, 2 pounds per animal per day--equal parts ground corn and cotton seed meal. (First month, 4 pounds per animal per day).

Corn silage, 10 pounds per animal per day.

Minerals, steamed bone meal and salt equal parts--3% of grain mixture.

The heifers were kept in two large stalls in the dairy barn, there being plenty of room for them to move about as they desired. Water was available at all times at drinking fountains, and the heifers were never allowed out of the barn except for exercise in an adjacent lot. Wood shavings were used for bedding, the stalls being kept as dry and clean as possible.

The heifers were fastened in stanchions when silage and grain was fed. The grain and silage was fed as the first feed in the morning. After they had cleaned up this feed a generous amount of their respective hay was placed before them in open troughs. A second feeding of hay was given in the late afternoon. The hay was weighed when fed and any that was left over was weighed back the next morning. All the hay was ground to prevent waste and for ease of handling.

The heifers were kept under close observation in order to note any change in their condition or correct any irregularity that might have any influence on the experiment. The grain feed was cut from 4 pounds per animal per day to 2 pounds per animal per day after the first month, because the heifers were becoming too fat.

RECORDING DATA.

The heifers were weighed three days in succession at the beginning of the experiment, and also measured for height at withers, and heart girth at the same time. This was repeated at thirty day intervals and at the end of the experiment. Daily feed records of the amount of hay fed, amount refused, and amount consumed were kept of the two groups. None of the silage or grain was refused so monthly records of consumption were adequate for these feeds. A breeding record of each heifer was also kept. Any abnormal condition was recorded in a "Remarks" column on the daily feed record.

RESULTS OBTAINED.

Group I. (Air Cured Hay)

At the beginning of the experiment this group of heifers averaged 44.8 inches in height, 57.8 inches in heart girth, and 567.2 pounds in weight. At the end of the experiment, five and one-half months later, they averaged 47.9 inches in height, 64.6 inches in heart girth, and 815 pounds in weight. This was an average gain of 3.1 inches in height, 6.8 inches in heart girth, and 247.8 pounds in weight during the five and one-half months.

The five heifers in this group consumed a total of 1950 lbs. of grain, 8250 pounds of corn silage, and 10,927 pounds of the air cured hay during the experiment. This was an average, per animal, of 390 pounds of grain, 1650 pounds of corn silage, and 2185 pounds (or slightly over a ton) of hay. The daily feed of grain was reduced from 4 pounds per animal per day to 2 pounds per animal per day after the first month, because the heifers were fattening too rapidly.

Some difficulty was encountered in getting the two Jersey heifers in this group bred. It was thought, however, that the trouble



University of Tennessee Dairy Barn



Experimental Heifers in Barn



Scales Where Heifers Were Weighed

Figure I. - Scenes where experiment was conducted

was due to the bull as some difficulty was also encountered in getting older cows in the herd bred to the same bull.

The following pages show the photographic growth records of the heifers fed the air cured hay. The lower picture on each page appears to be slightly out of proportion, but this is due to the fact that the animals were farther away from the camera as compared with the upper pictures.

The graphs after each picture show the growth of that particular animal compared with the normal growth of heifers the same age and breed. The normal growth standards for heart girth were taken from Ragsdale, A. C., Growth Standards for Dairy Cattle, Missouri Agricultural Experiment Station Bulletin No. 336. The normal height at withers and weight standards were taken from Eckles, Dairy Cattle and Milk Production.

GROUP I



Beginning of Experiment

Age 15 Months and 6 Days



End of Experiment

Age 20 Months and 21 Days

Figure 2 - Photographic Growth Record of Heifer No. T56

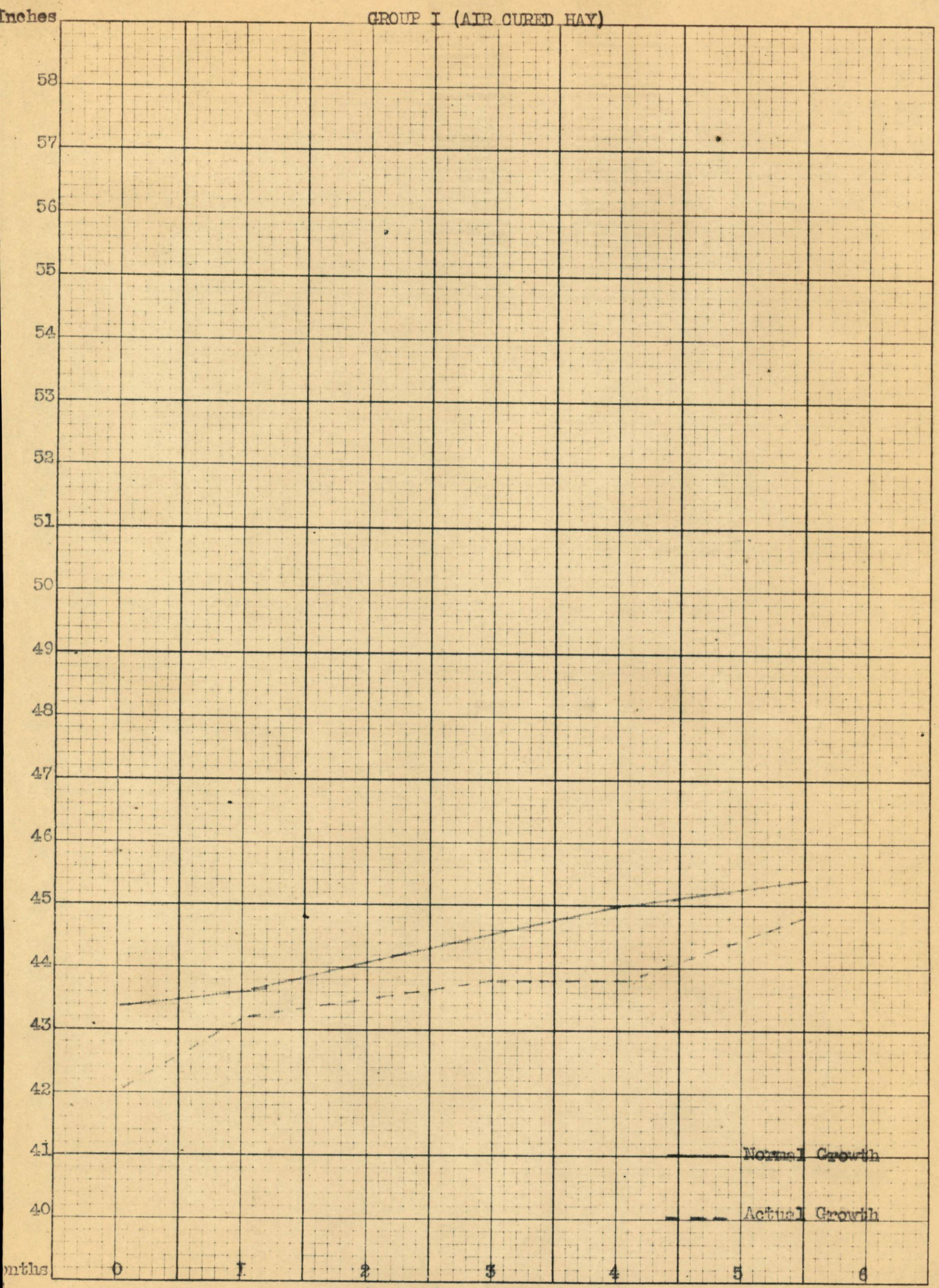


Figure 3. - Growth rate (height) of heifer No. T56

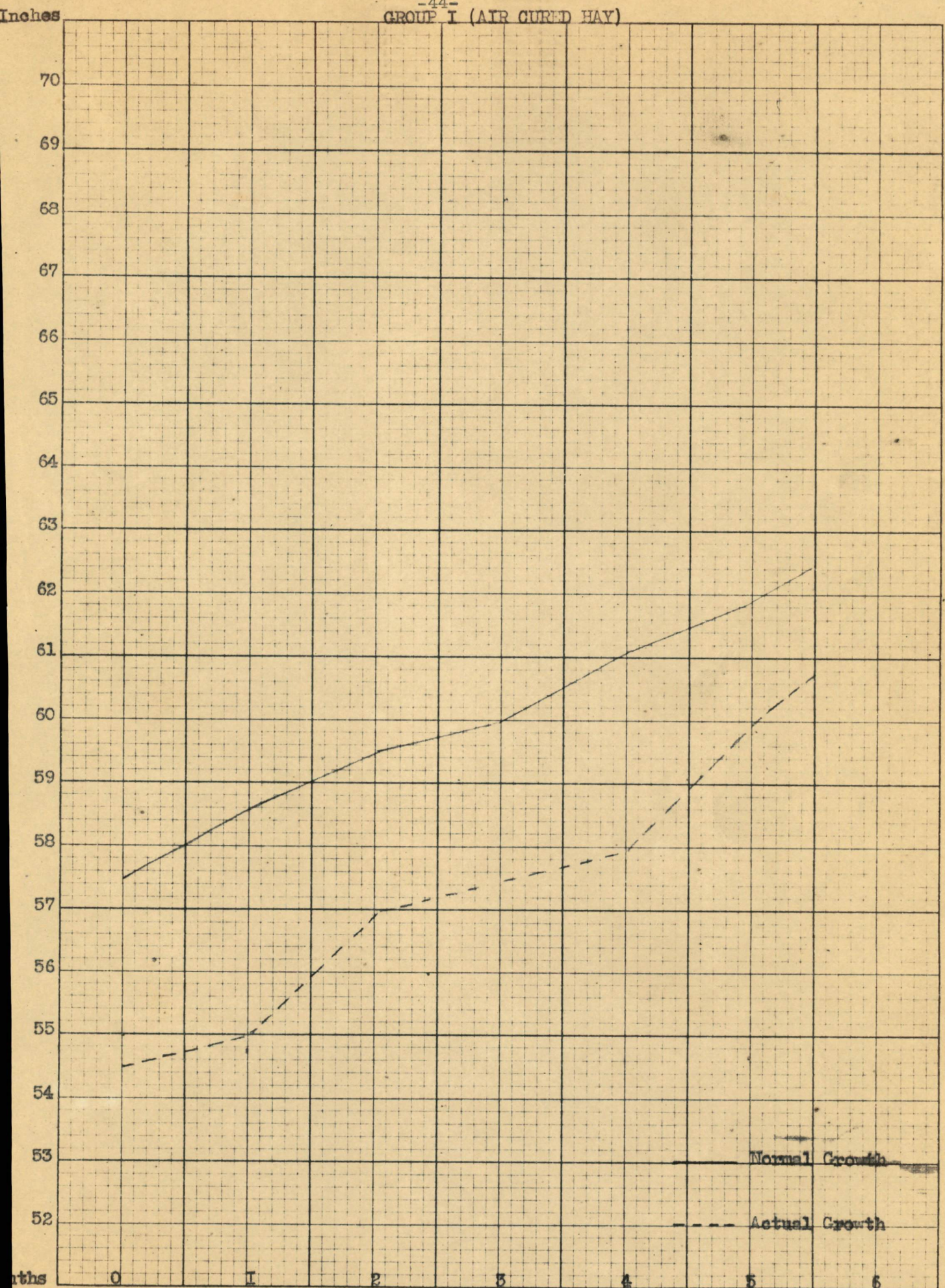


Figure 4. - Growth rate (heart girth) of heifer No. T56

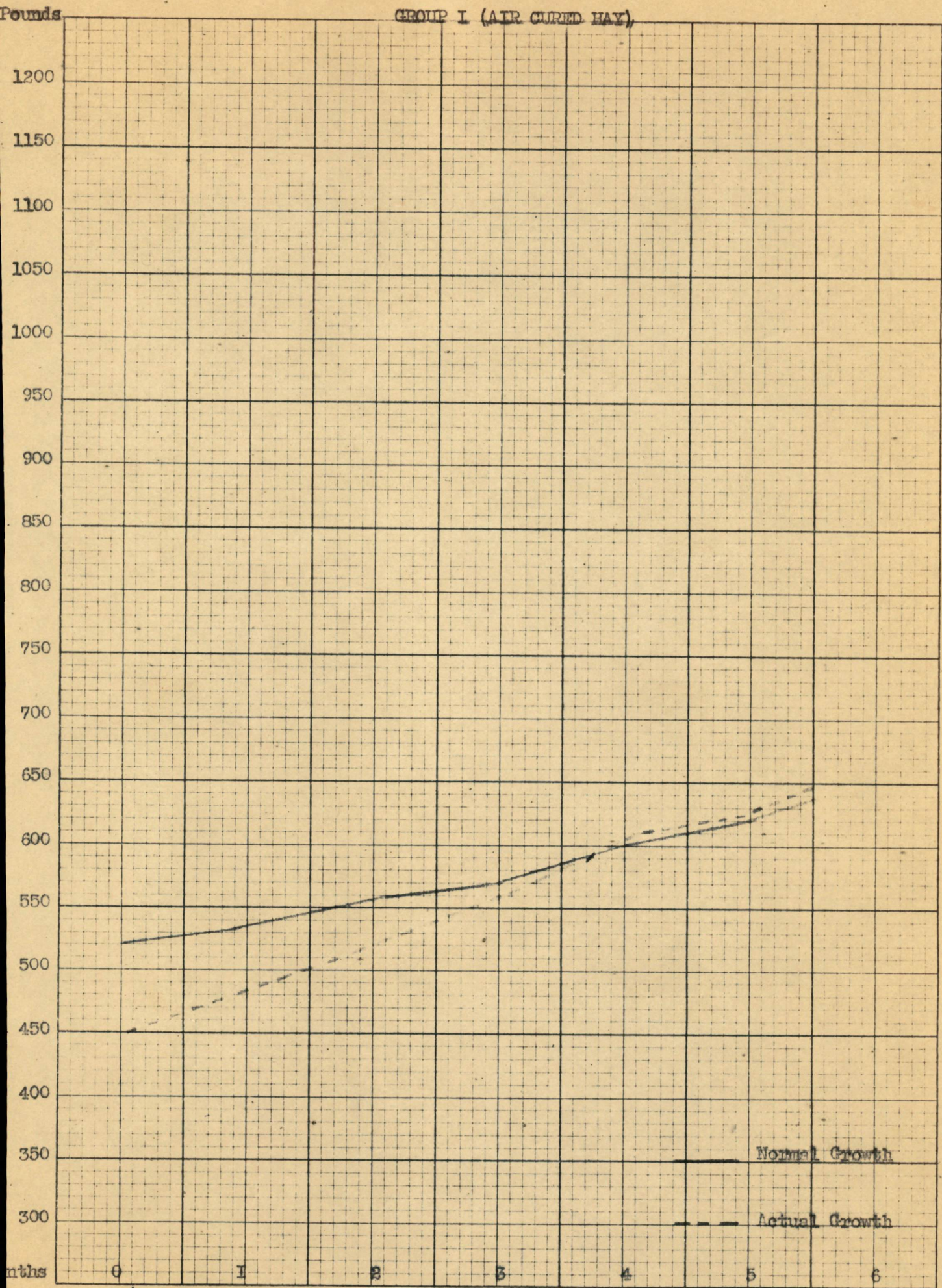


Figure 5. - Growth rate (weight) of heifer No. T56

GROUP I



Beginning of Experiment

Age 15 Months and 10 Days



End of Experiment

Age 20 Months and 25 Days

Figure 6 - Photographic Growth Record of Heifer No. T55

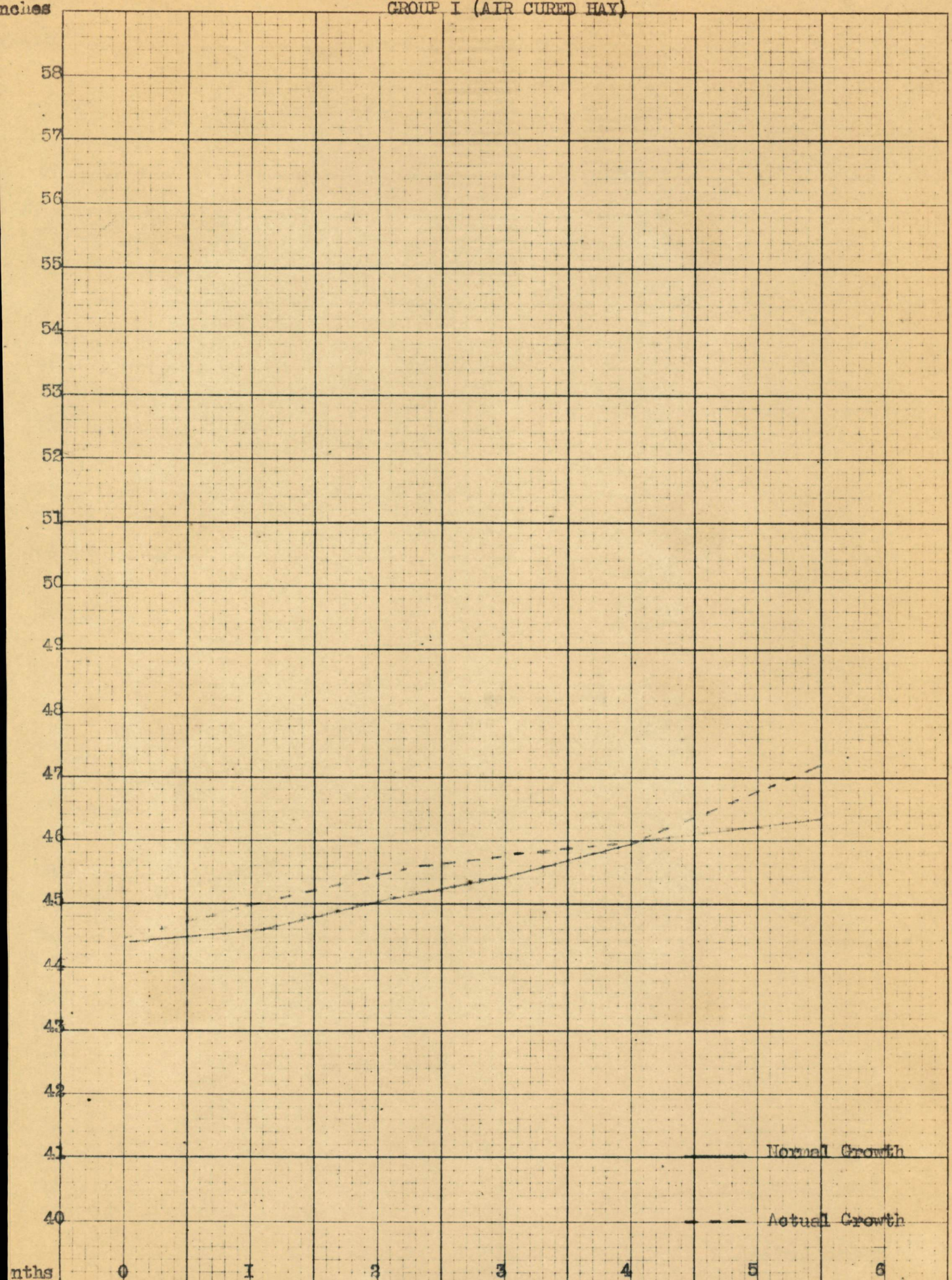


Figure 7. - Growth rate (height) of heifer No.T55

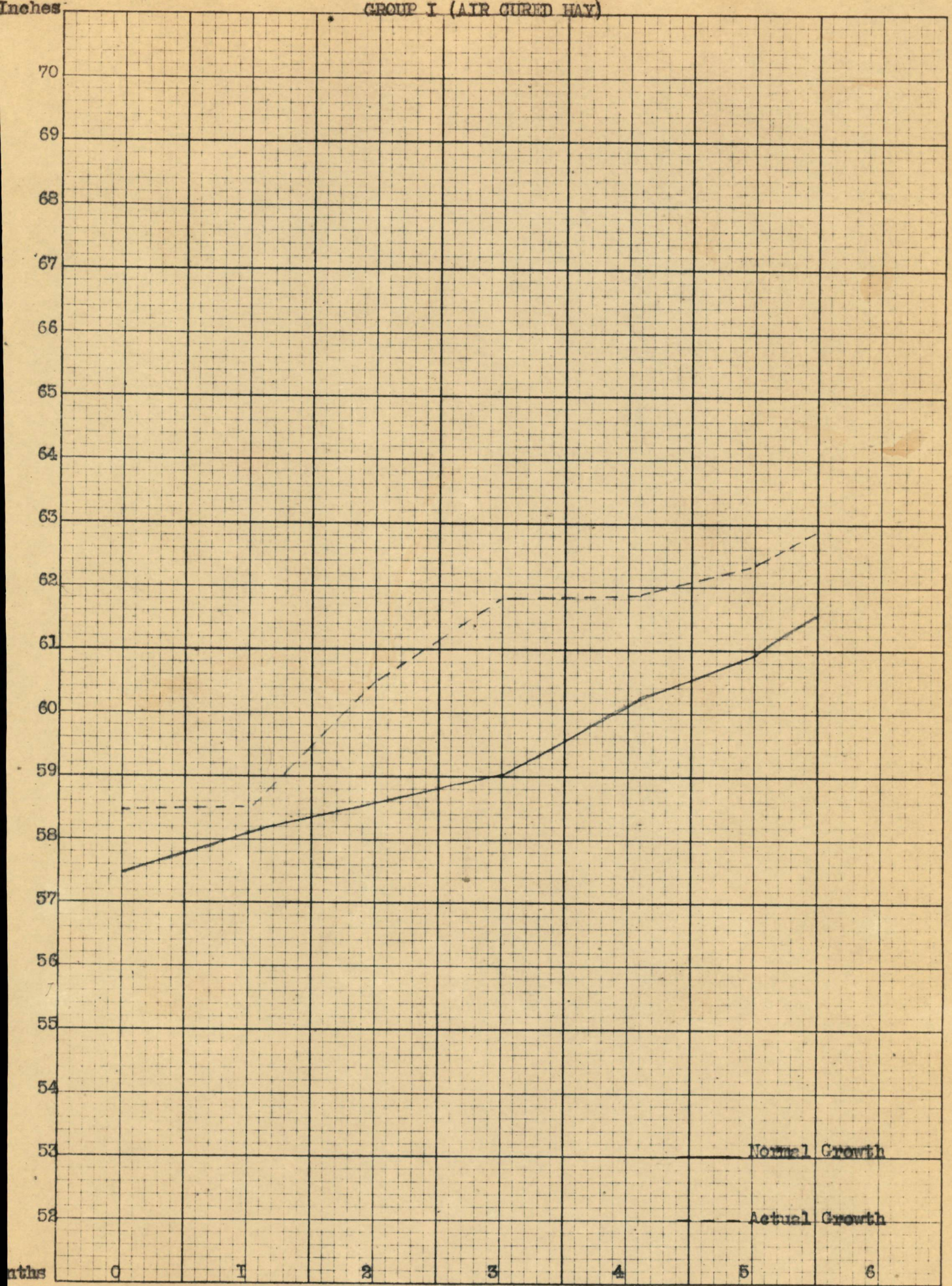


Figure 8. - Growth rate (heart girth) of heifer No. T55

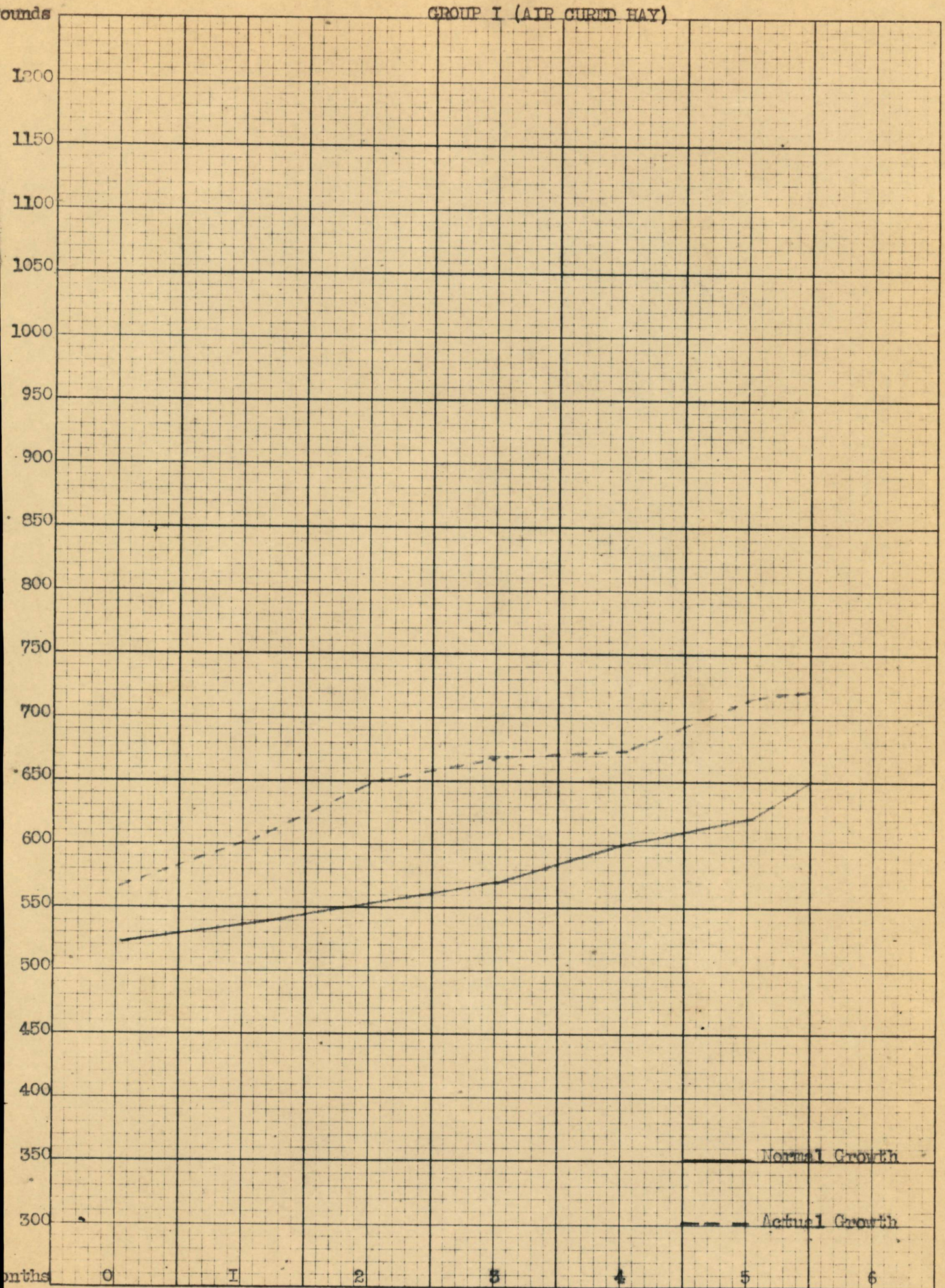


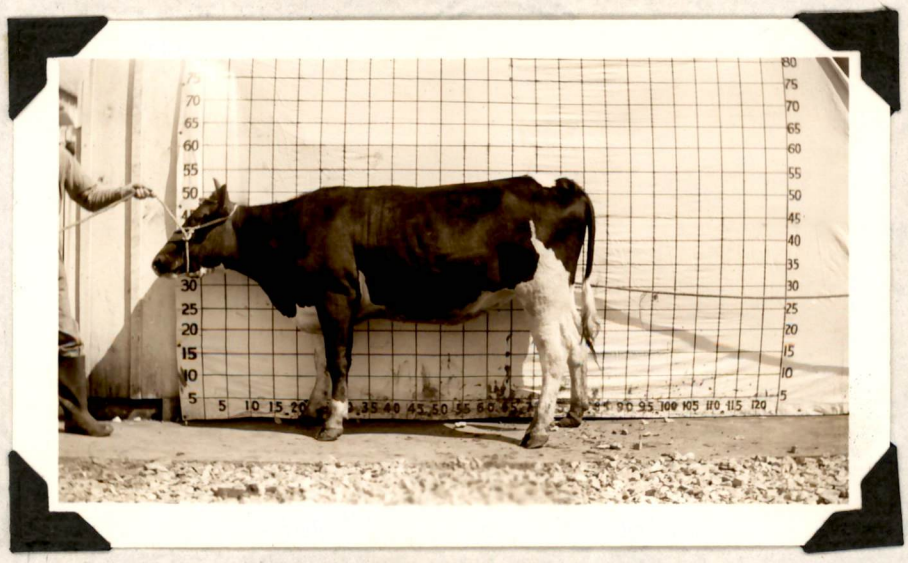
Figure 9. - Growth rate (weight) of heifer No. T55

GROUP I



Beginning of Experiment

Age 15 Months and 8 Days



End of Experiment

Age 20 Months and 23 Days

Figure 10 - Photographic Growth Record of Heifer No. 309

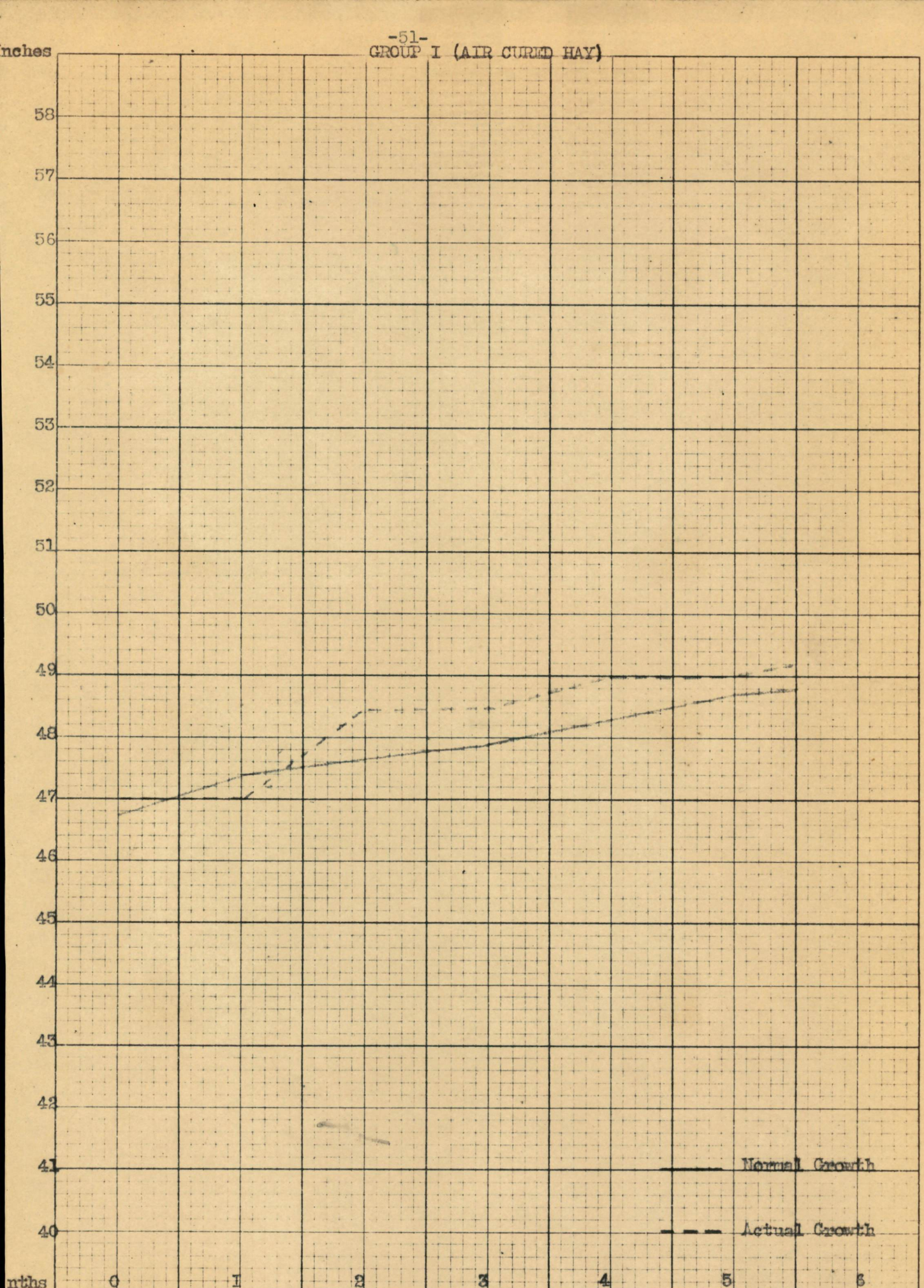


Figure 11. - Growth rate (height) of heifer No. 309

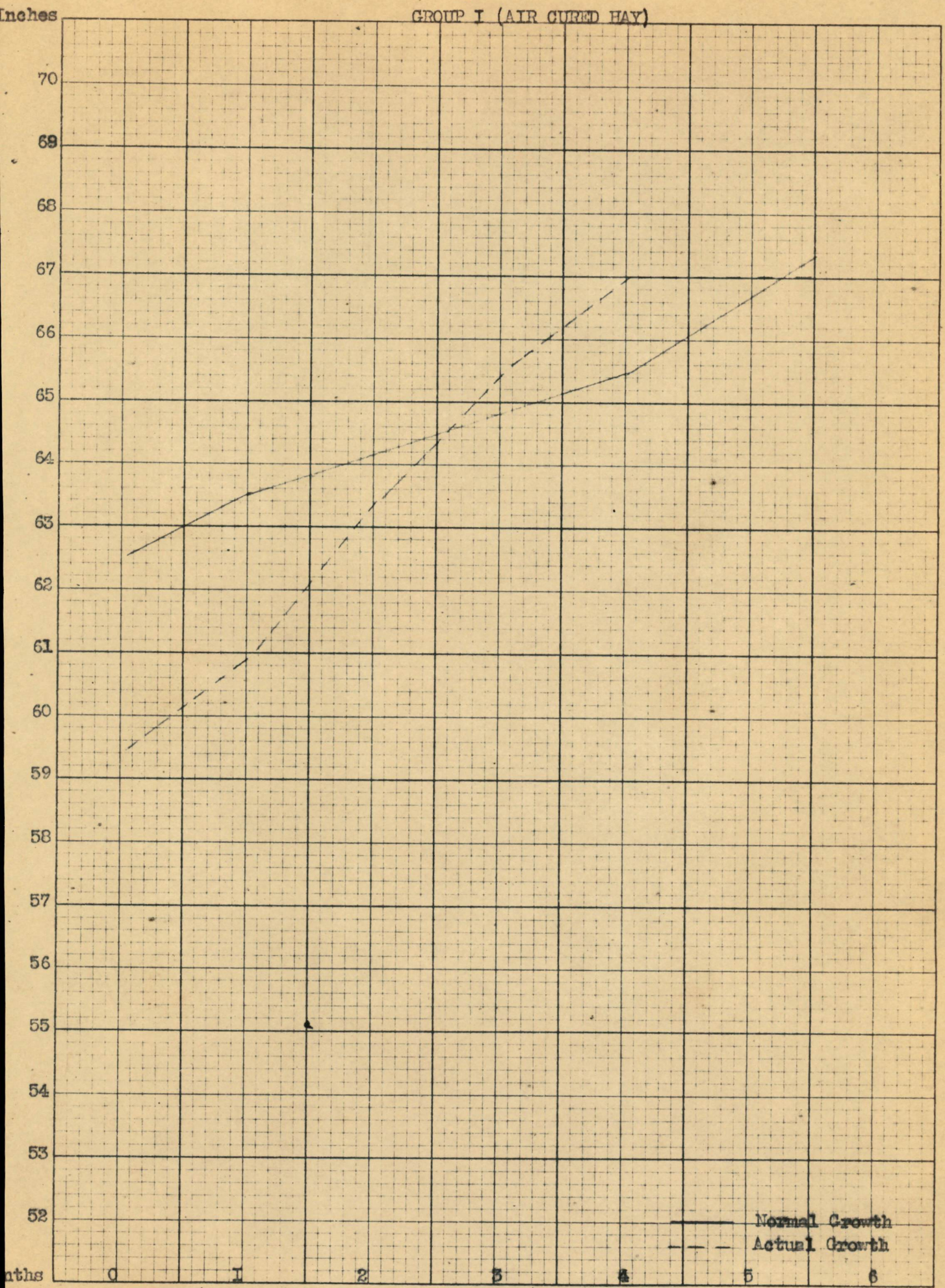


Figure 12. - Growth rate (heart girth) of heifer No. 309

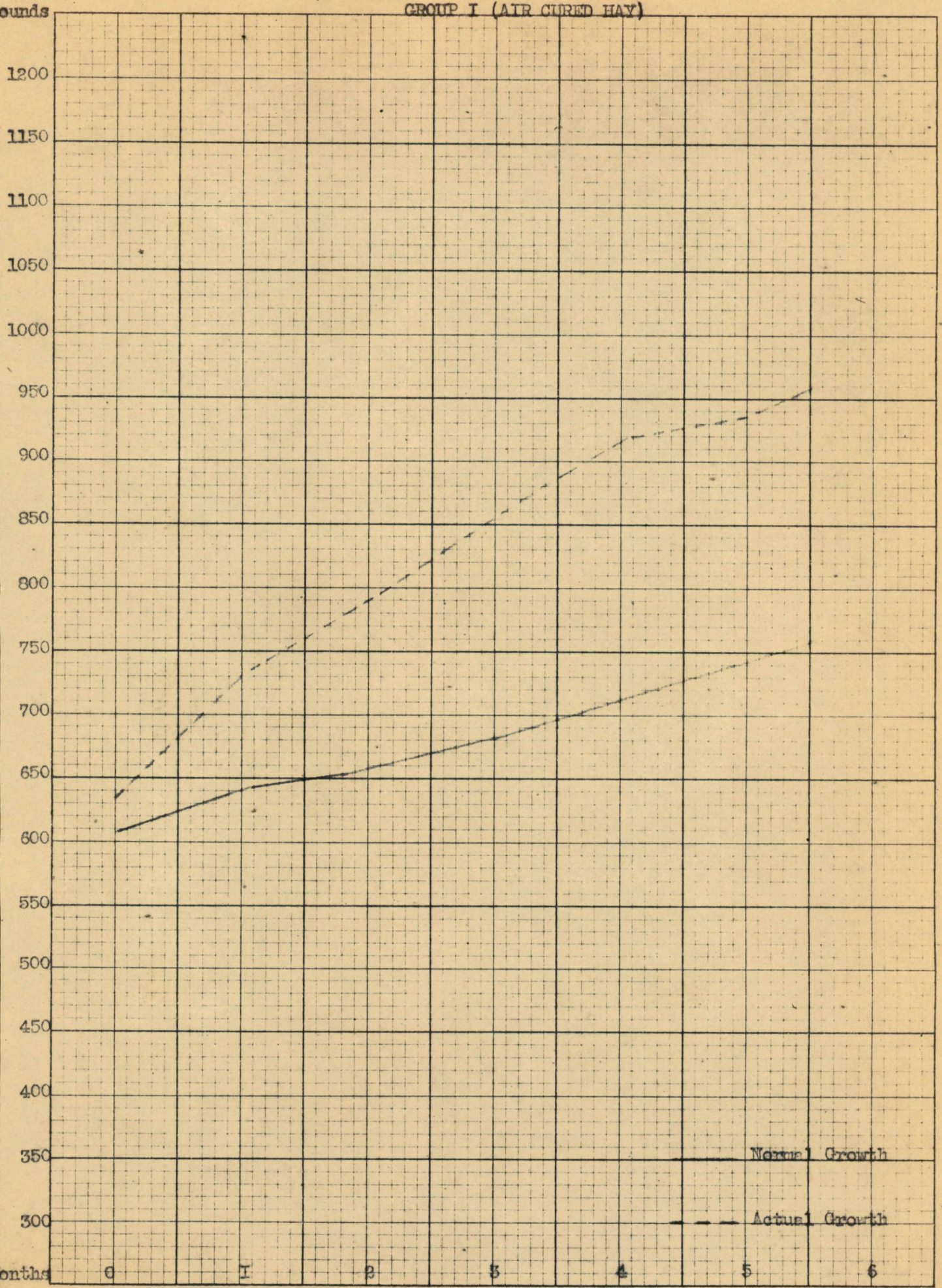
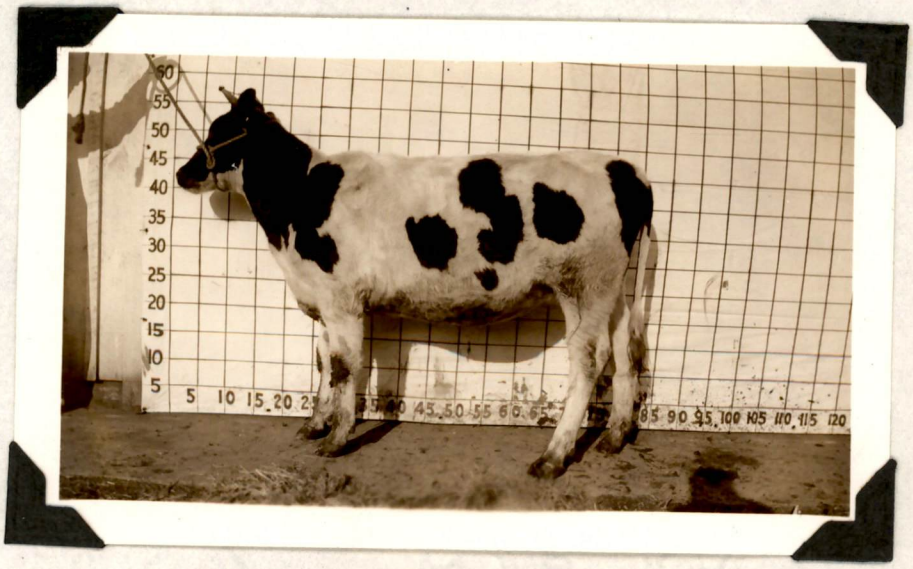


Figure 13. - Growth rate (weight) of heifer No. 309

GROUP I



Beginning of Experiment

Age 13 Months and 16 Days



End of Experiment

Age 18 Months and 31 Days

Figure 14 - Photographic Growth Record of Heifer No. 311

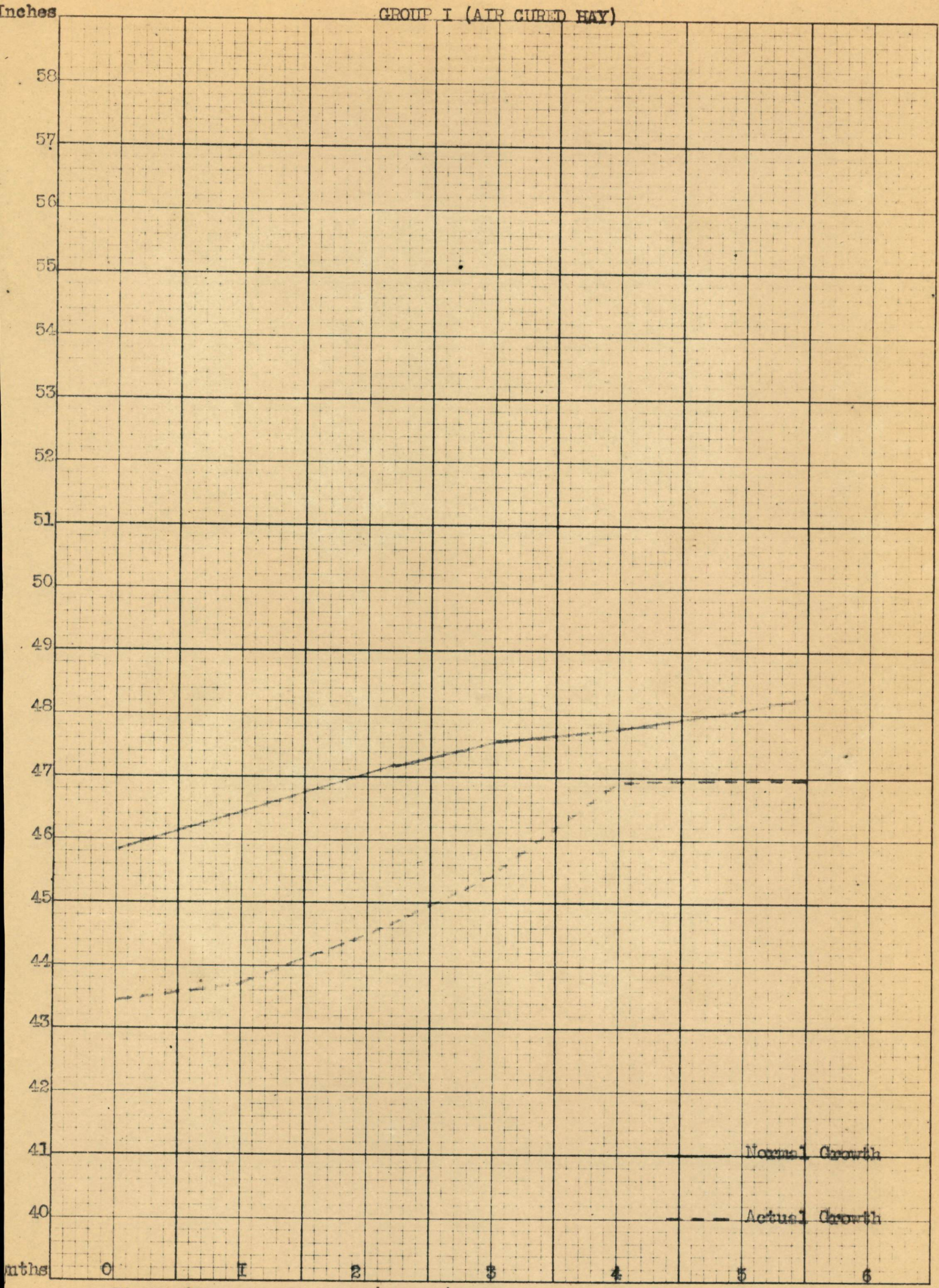


Figure 15. - Growth rate (height) of heifer No. 311

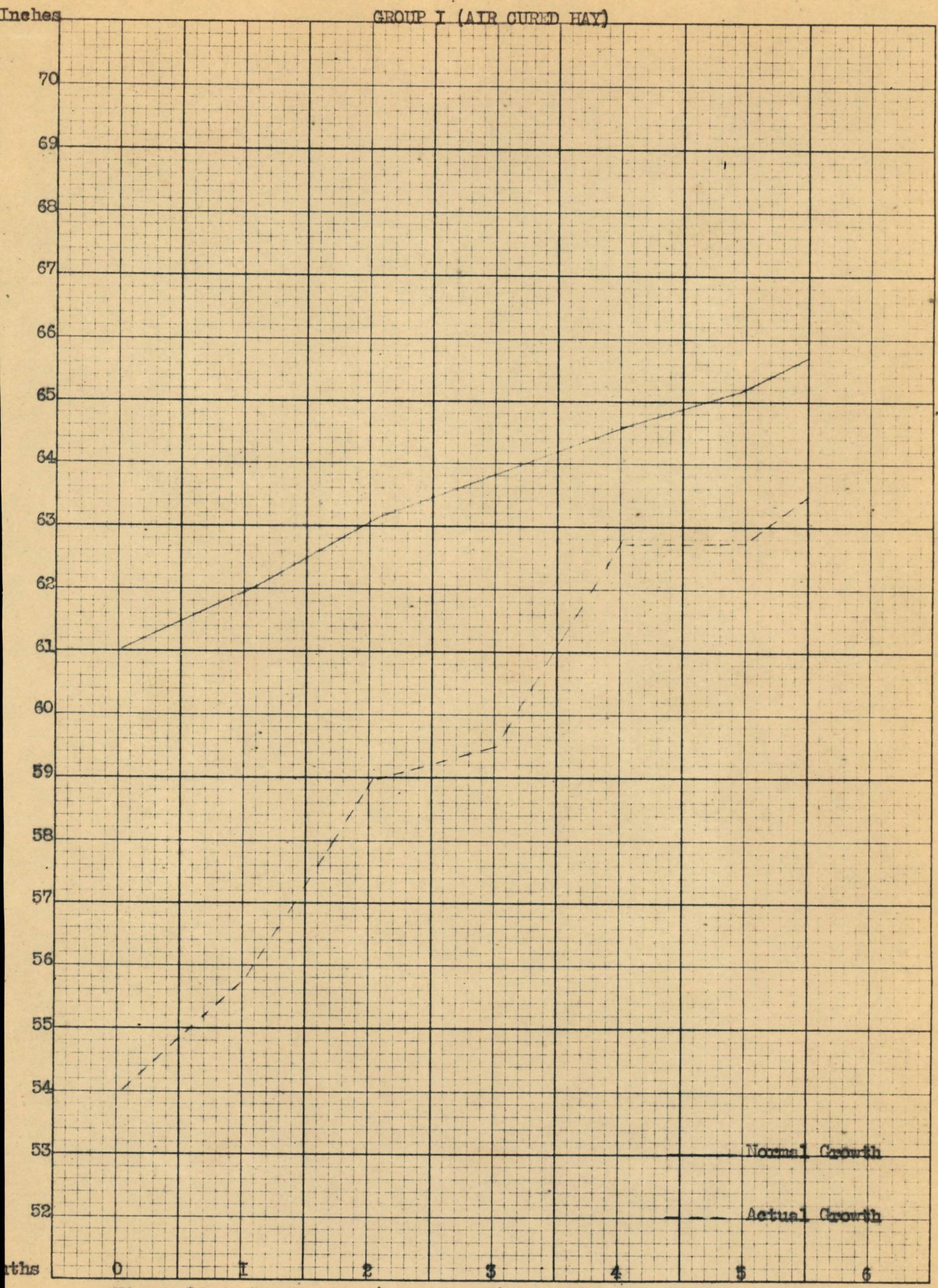


Figure 16. - Growth rate (heart girth) of heifer No. 311

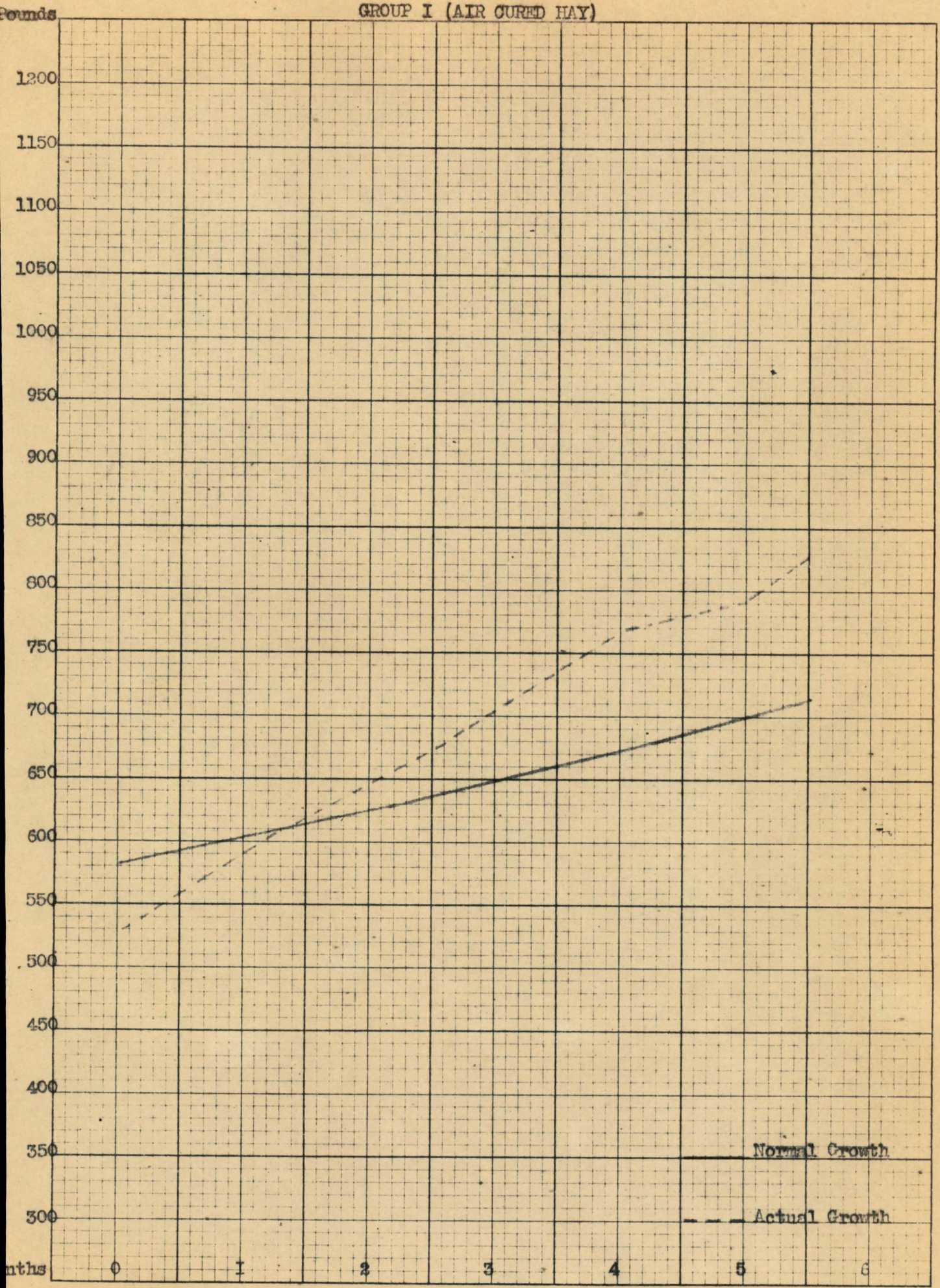


Figure 17. - Growth rate (weight) of heifer No. 311

GROUP I



Beginning of Experiment

Age 13 Months and 10 Days



End of Experiment

Age 18 Months and 25 Days

Figure 18 - Photographic Growth Record of Heifer No. 312

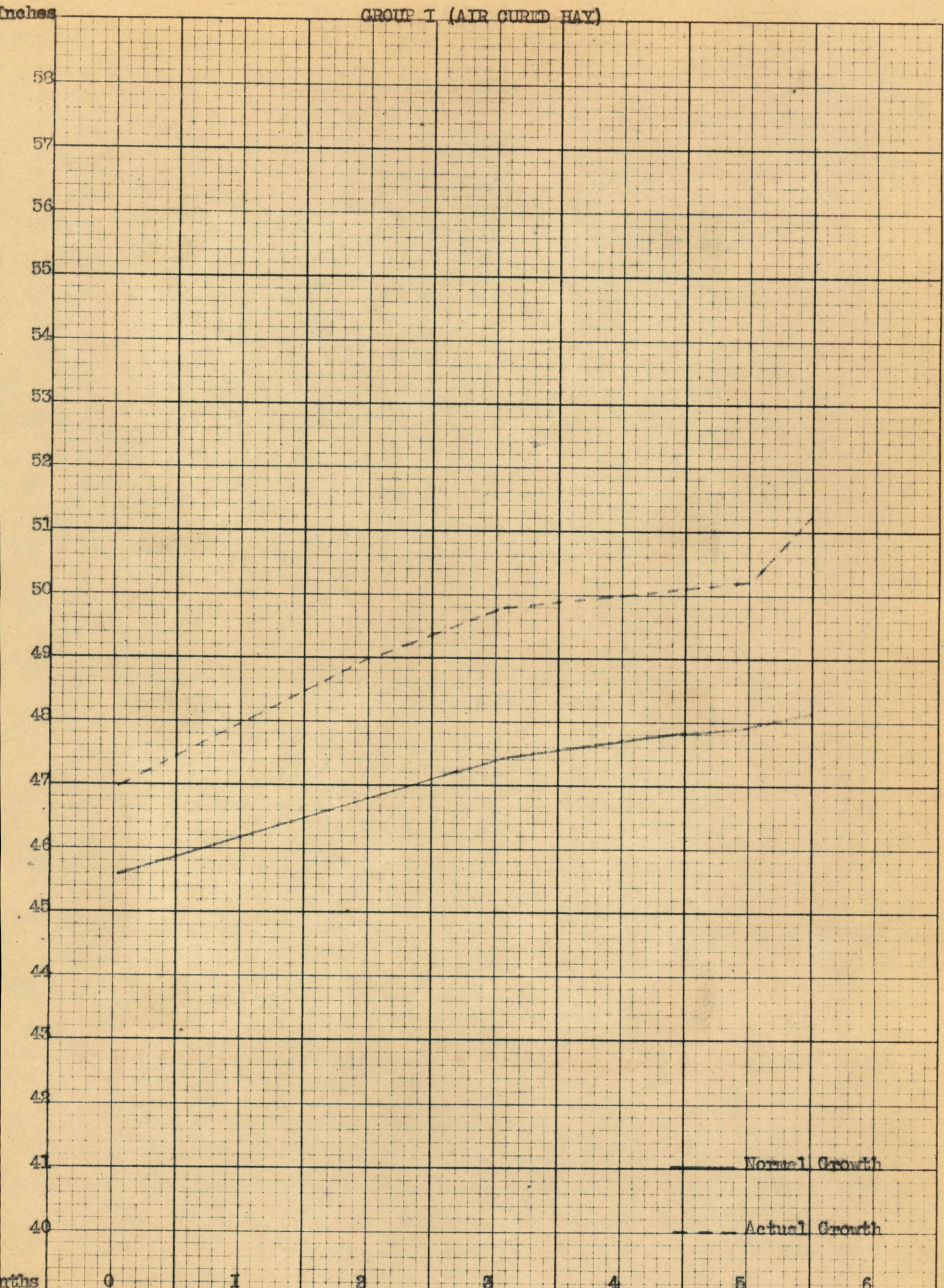


Figure 19. - Growth rate (height) of heifer No. 312

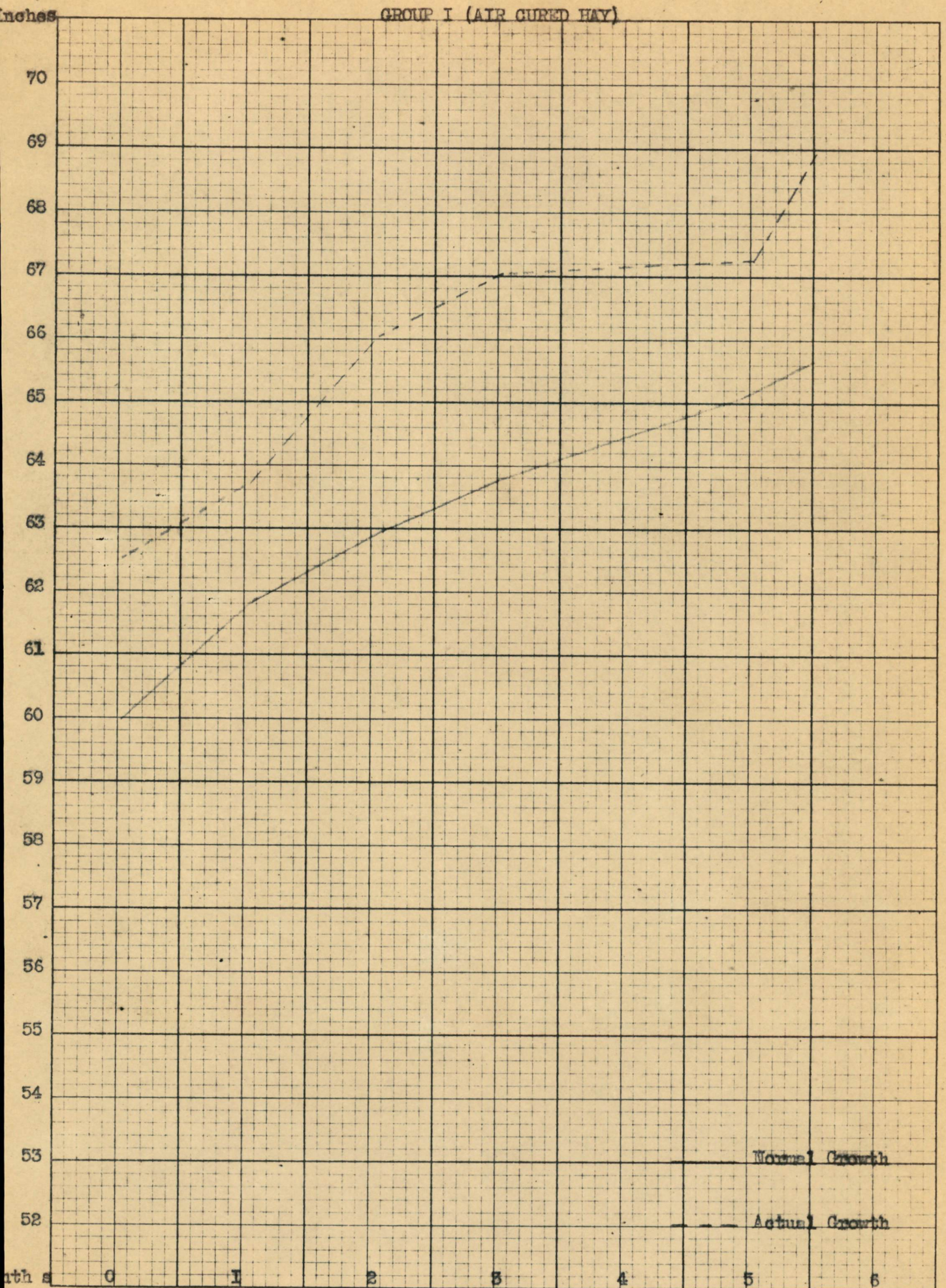


Figure 20. - Growth rate (heart girth) of heifer No. 312

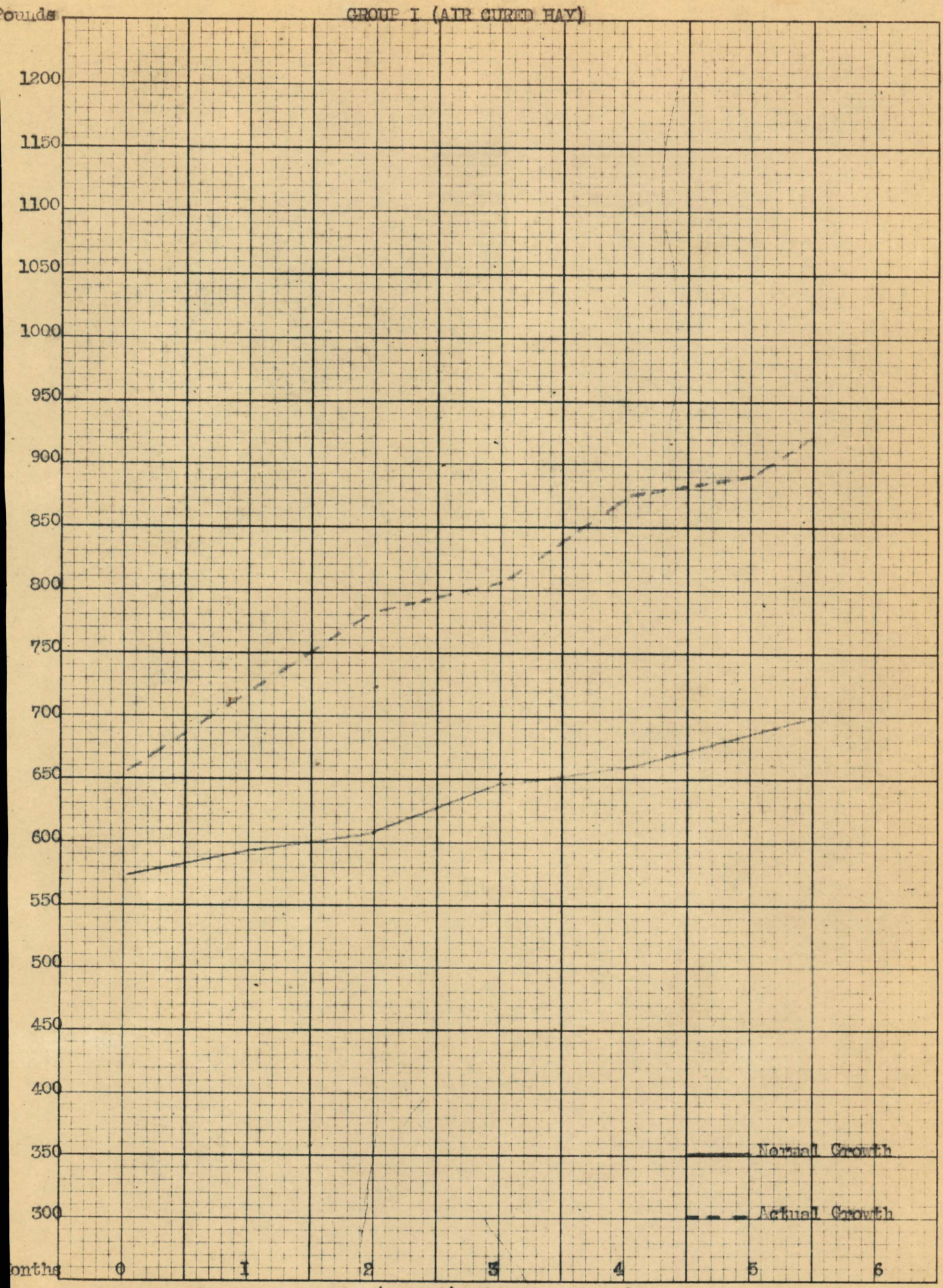


Figure 21. - Growth rate (weight) of heifer No. 312

Group II. (Field Cured Hay)

This group of heifers averaged 44.2 inches in height, 56.7 inches in heart girth, and 562.6 pounds in weight at the beginning of the experiment. At the end of the experiment, five and one-half months later, they averaged 47.75 inches in height, 63.5 inches in heart girth, and 793 pounds in weight. This was an average gain of 3.55 inches in height, 6.8 inches in heart girth, and 230.4 pounds in weight during the five and one-half months.

The five heifers in the group also consumed 1950 pounds of grain, 8250 pounds of corn silage, and 9691 pounds of the field cured hay during the experiment. This was an average per animal of 390 lbs. of grain, 1650 pounds of corn silage, and 1938 pounds, or slightly less than a ton, of hay. The daily feed of grain to this group was also reduced from 4 pounds per animal per day to 2 pounds per animal per day after the first month.

Difficulty was also encountered in breeding one of the Jersey heifers in this group. The other Jersey in the group, No. T56, was unknowingly with calf at the beginning of the experiment. She calved soon after the experiment was over.

The following pages show the photographic growth records of the heifers fed field cured hay. The graphs after each picture show the growth of that particular animal compared with the normal growth of heifers the same breed and age. The normal growth standards were taken from the same sources as those used in Group I.

GROUP II



Beginning of Experiment

Age 14 Months and 19 Days



End of Experiment

Age 20 Months and 4 Days

Figure 22 - Photographic Growth Record of Heifer No. T58

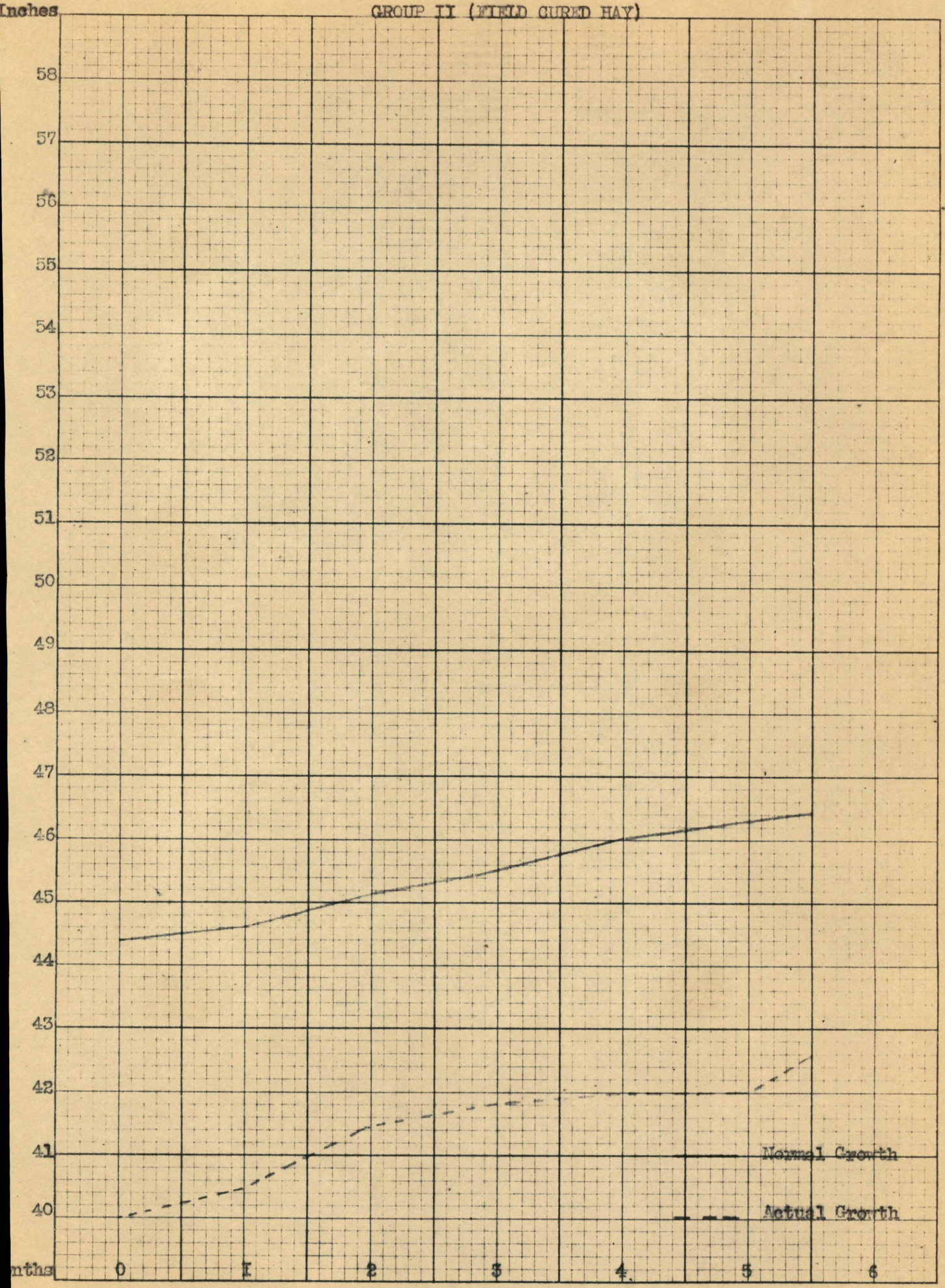


Figure 23. - Growth rate (height) of heifer No. T58

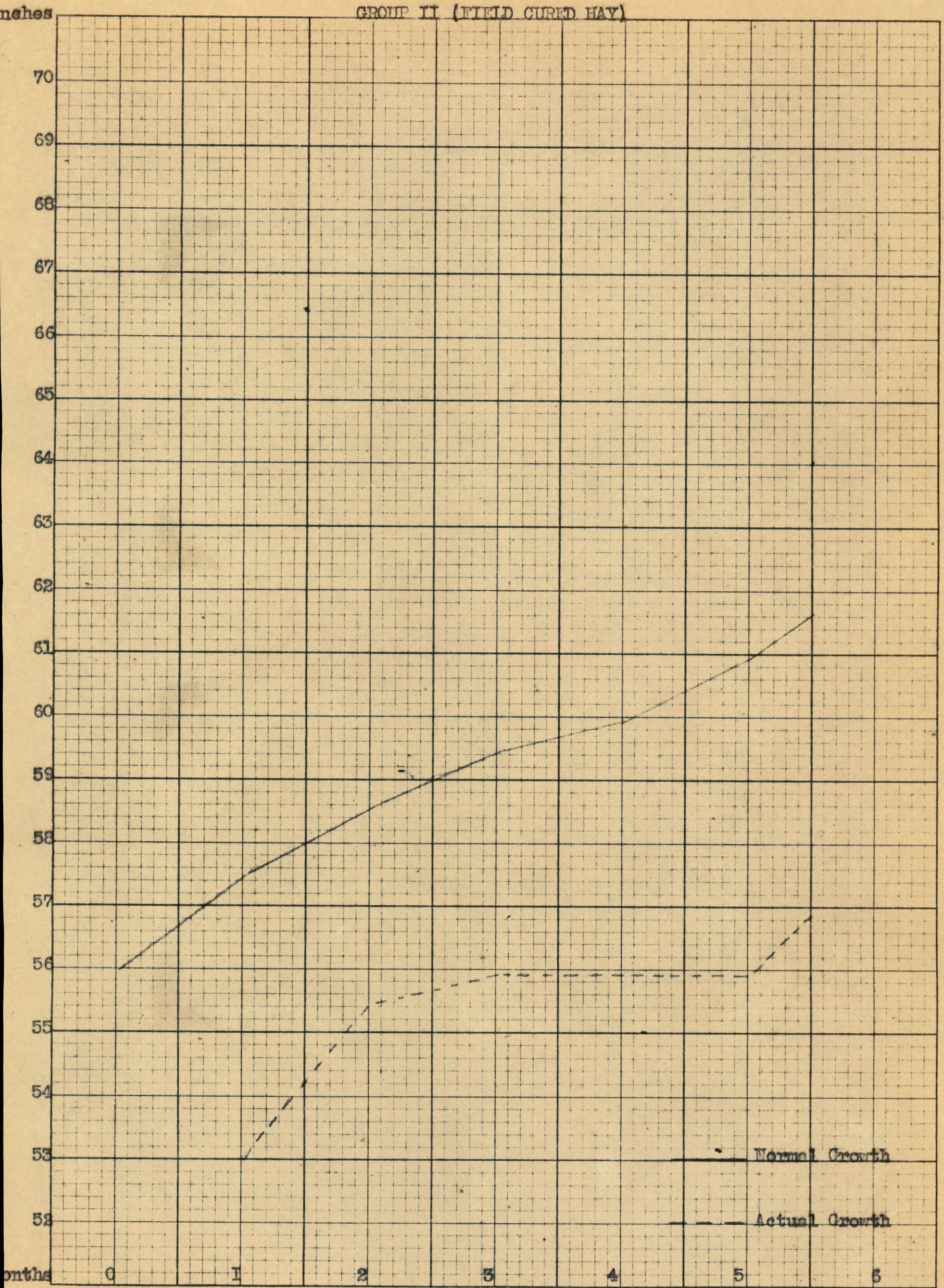


Figure 24. - Growth rate (heart girth) of heifer No. T58

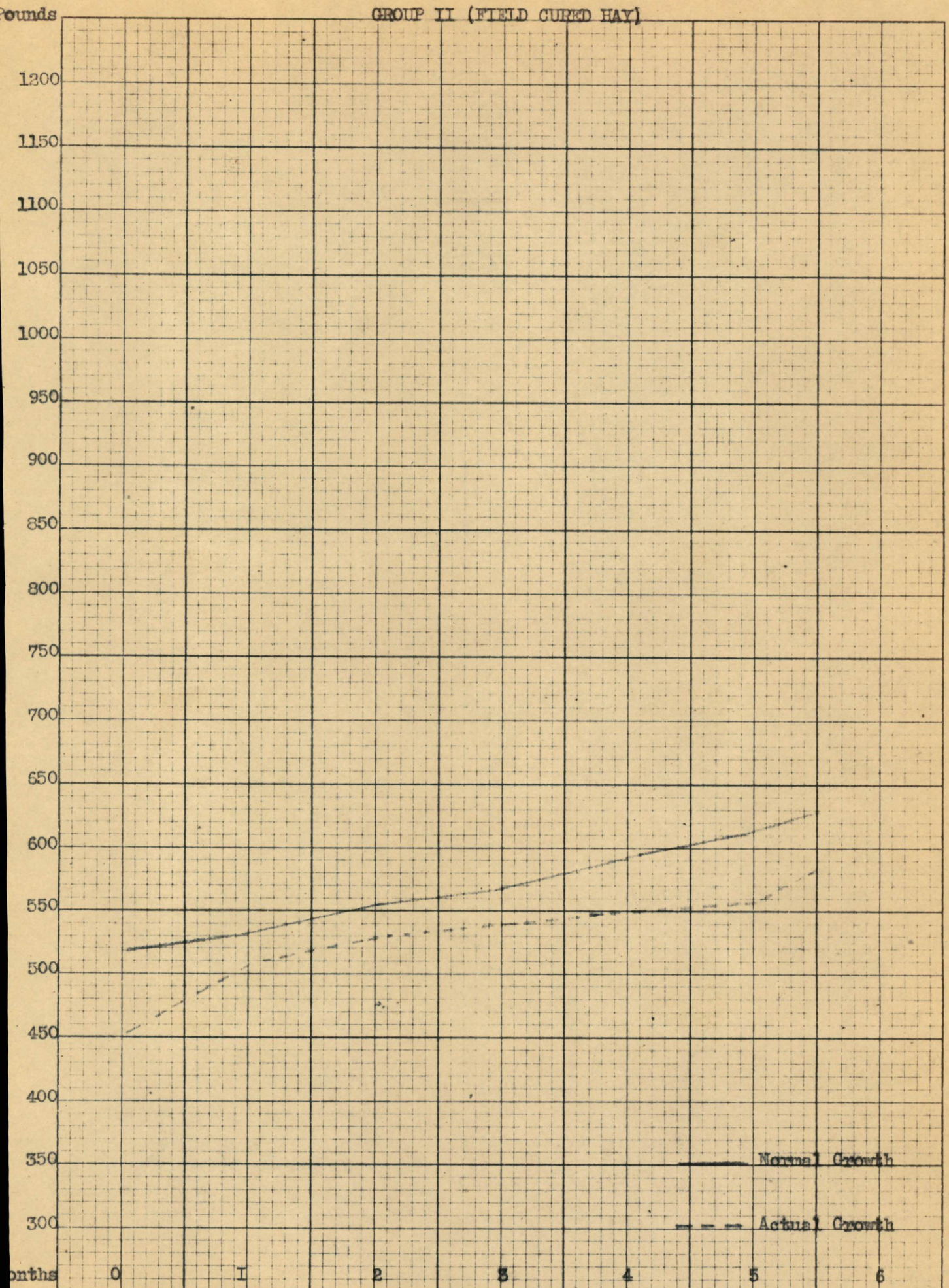
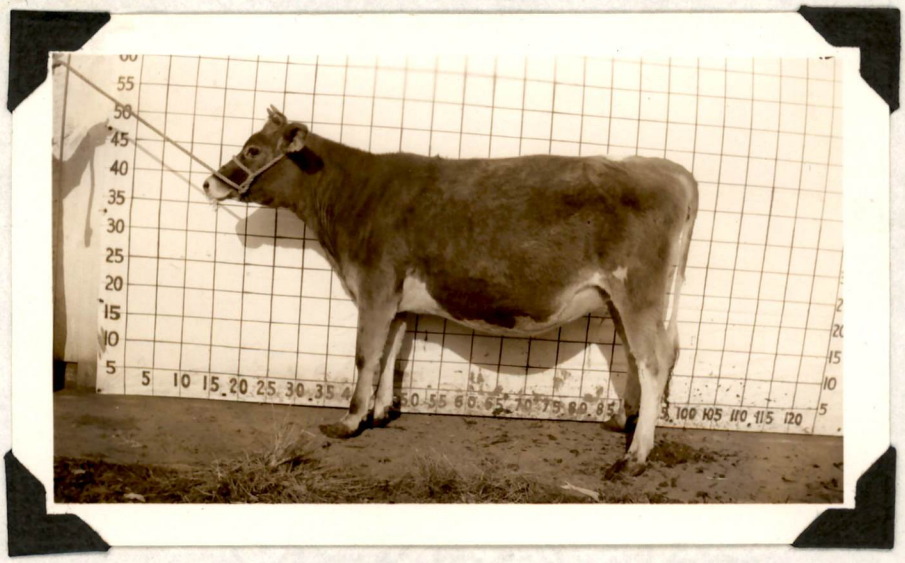


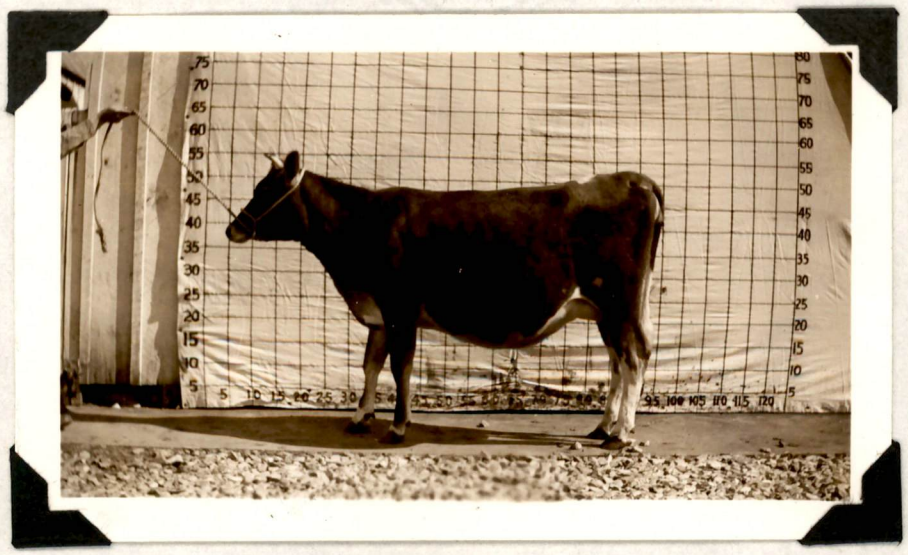
Figure 25. - Growth rate (weight) of heifer No. T58

GROUP II



Beginning of Experiment

Age 15 Months



End of Experiment

Age 20 Months and 15 Days

Figure 26 - Photographic Growth Record of Heifer No. T57

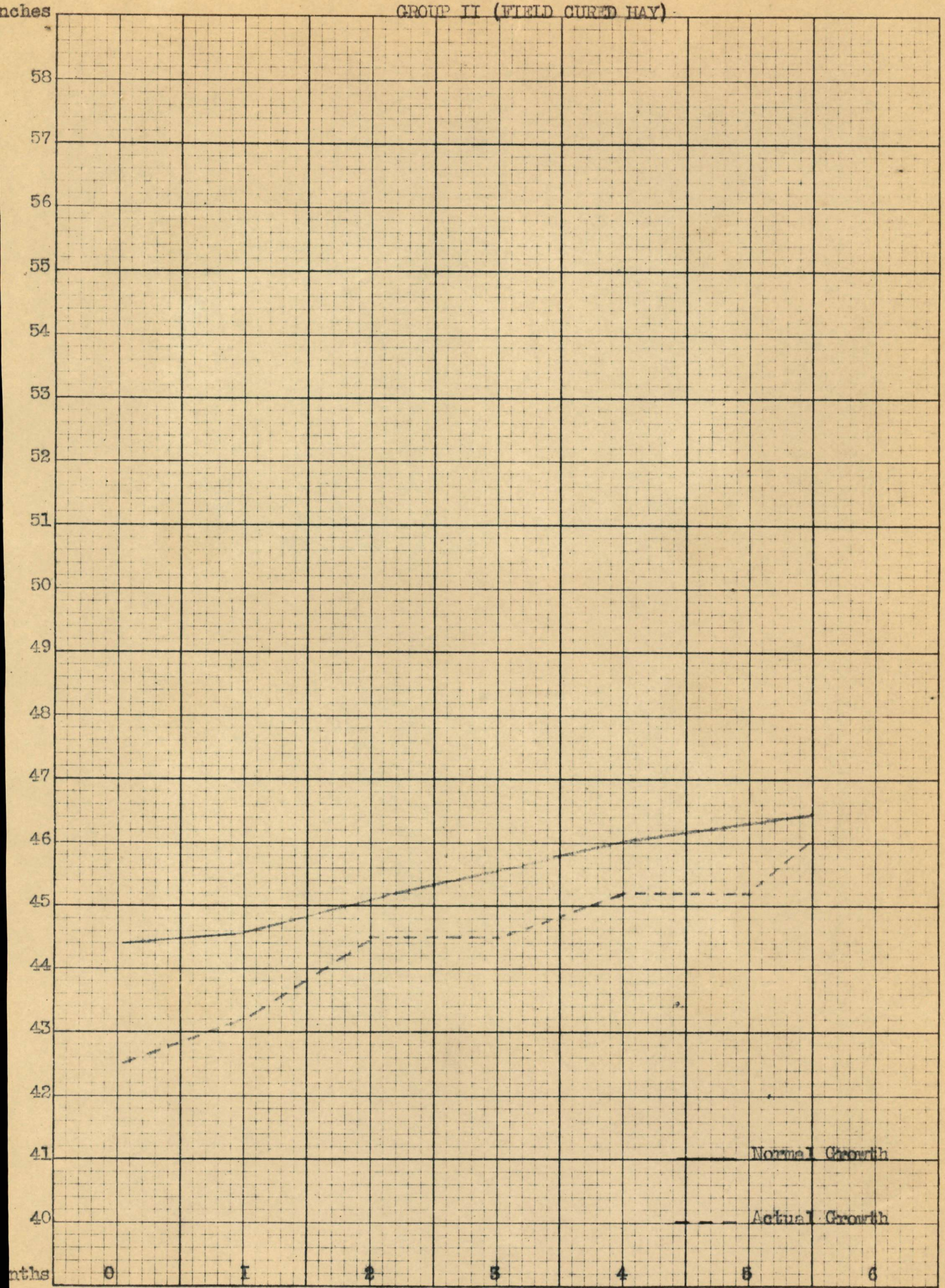


Figure 27. - Growth rate (height) of heifer No. T57

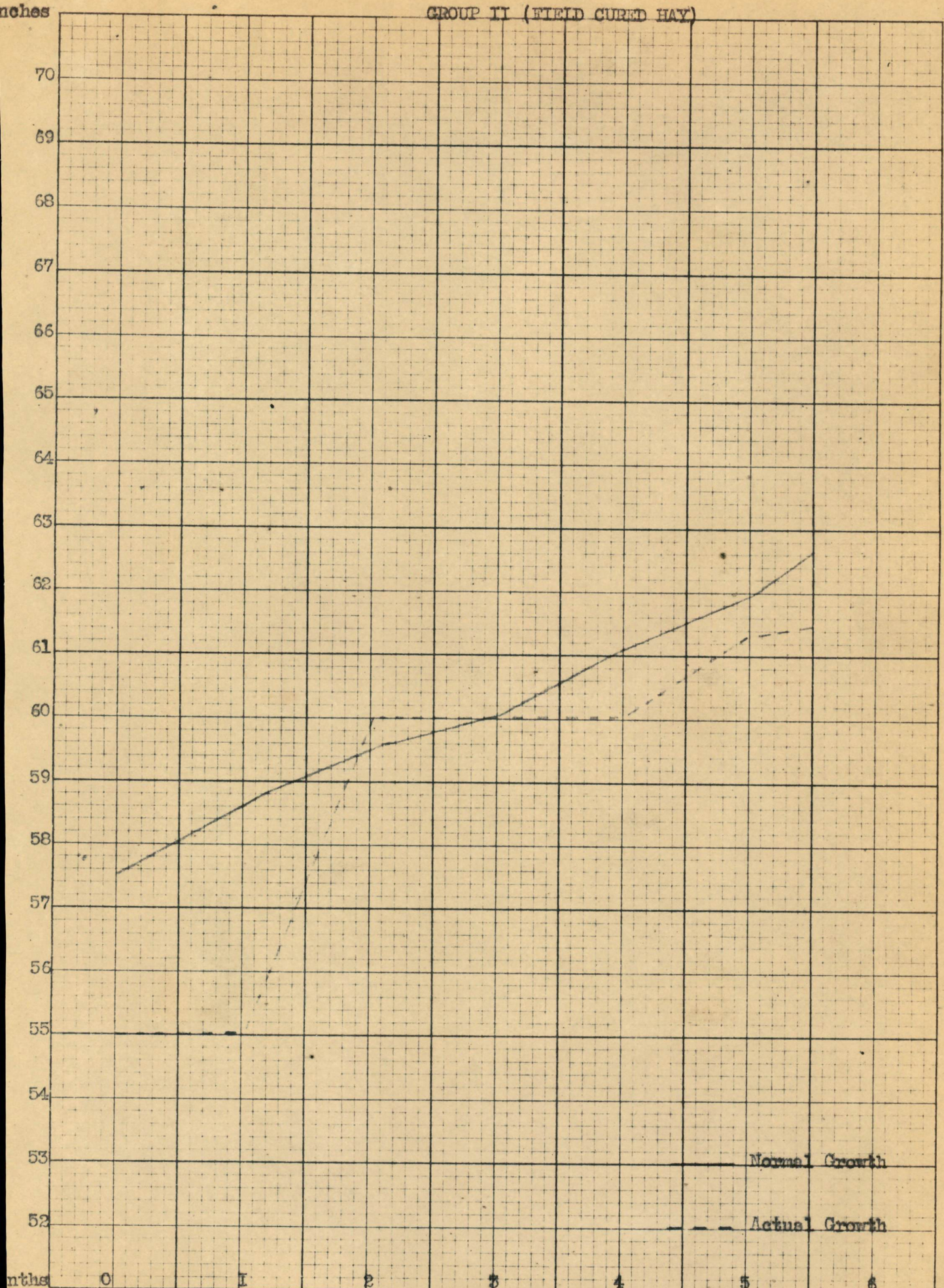


Figure 28. - Growth rate (heart girth) of heifer No. T57

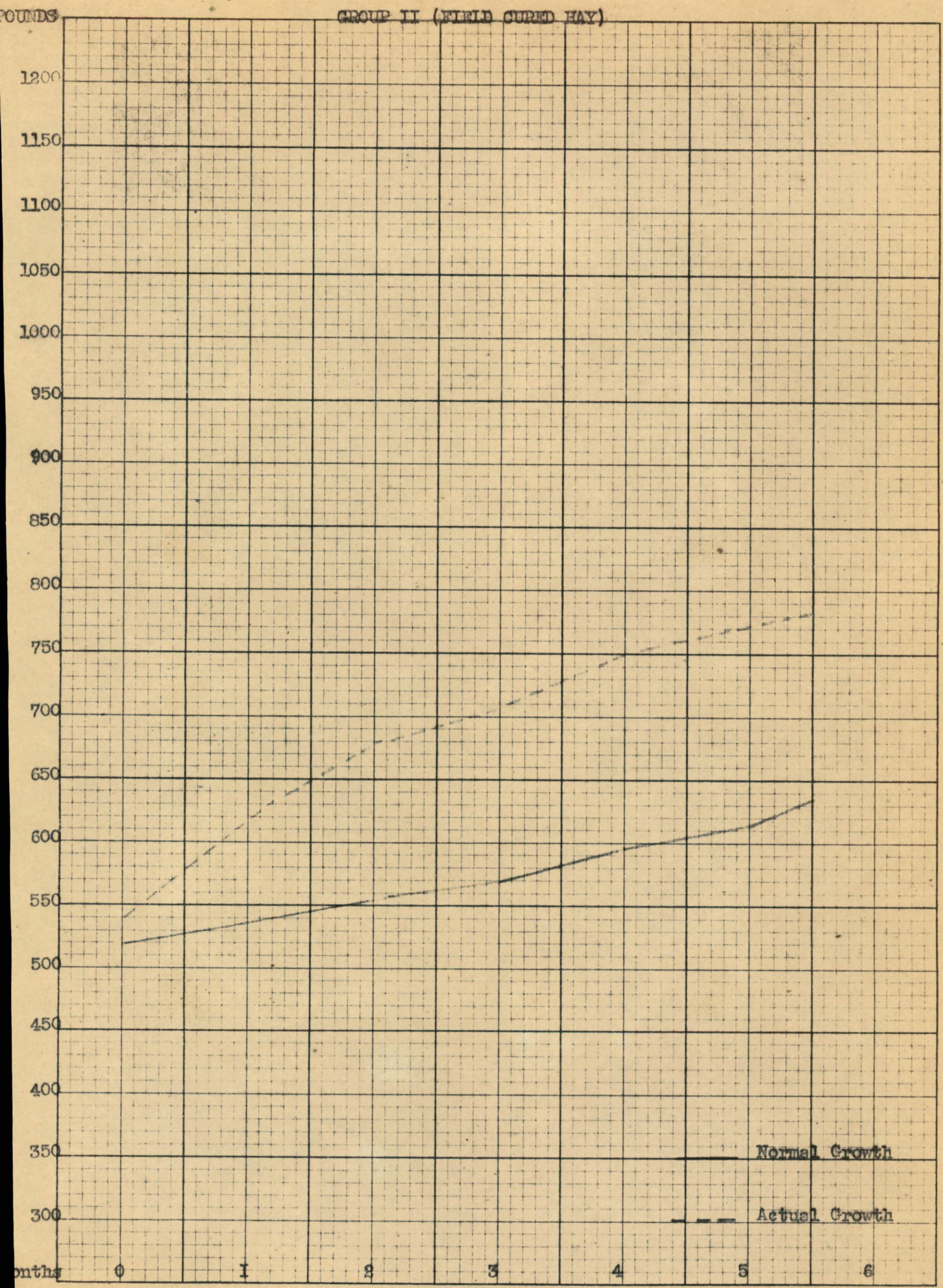


Figure 29. - Growth rate (weight) of heifer No. T57

GROUP II



Beginning of Experiment

Age 14 Months and 5 Days



End of Experiment

Age 19 Months and 20 Days

Figure 30 - Photographic Growth Record of Heifer No. 310

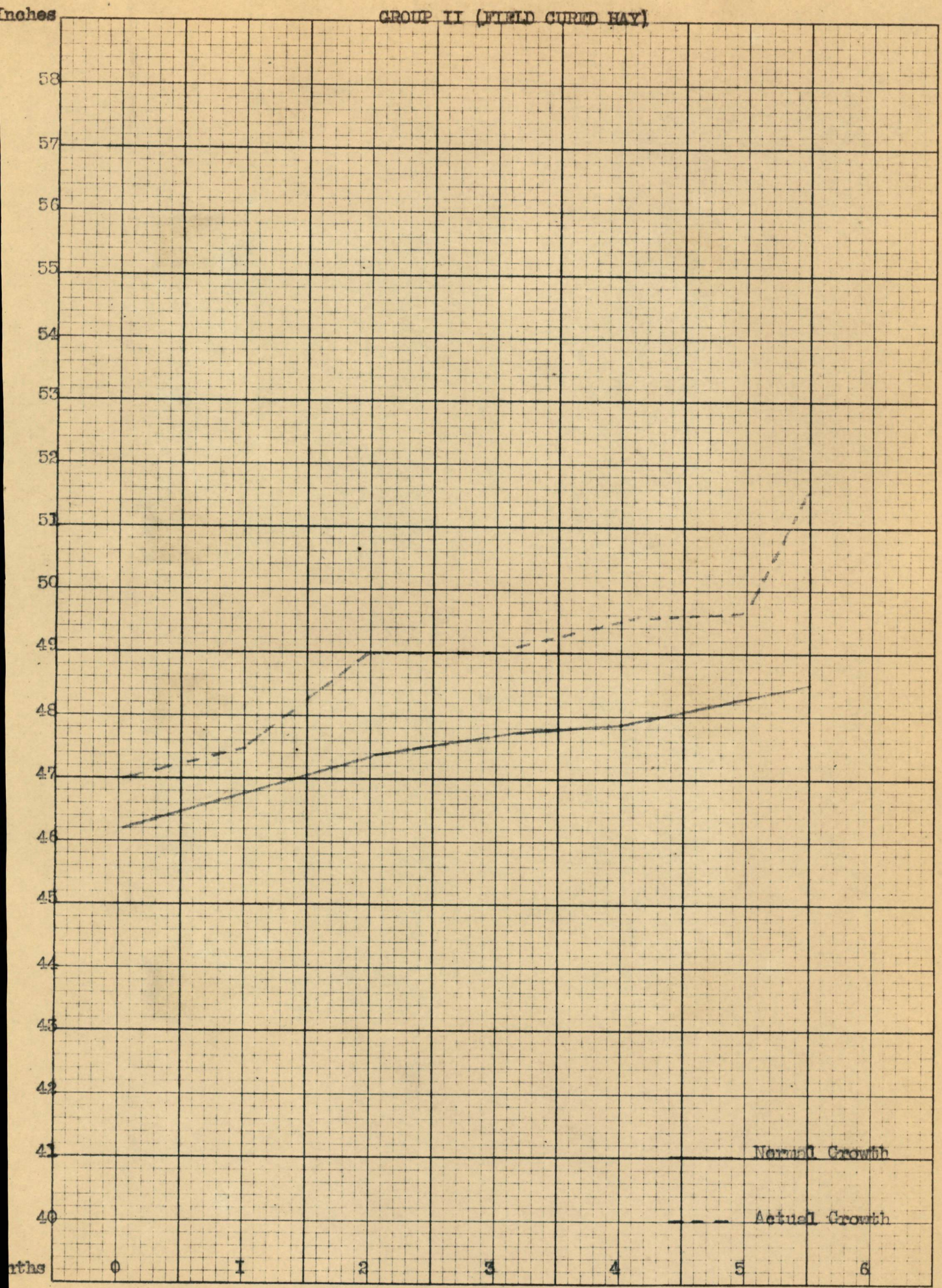


Figure 31. - Growth rate (height) of heifer No. 310

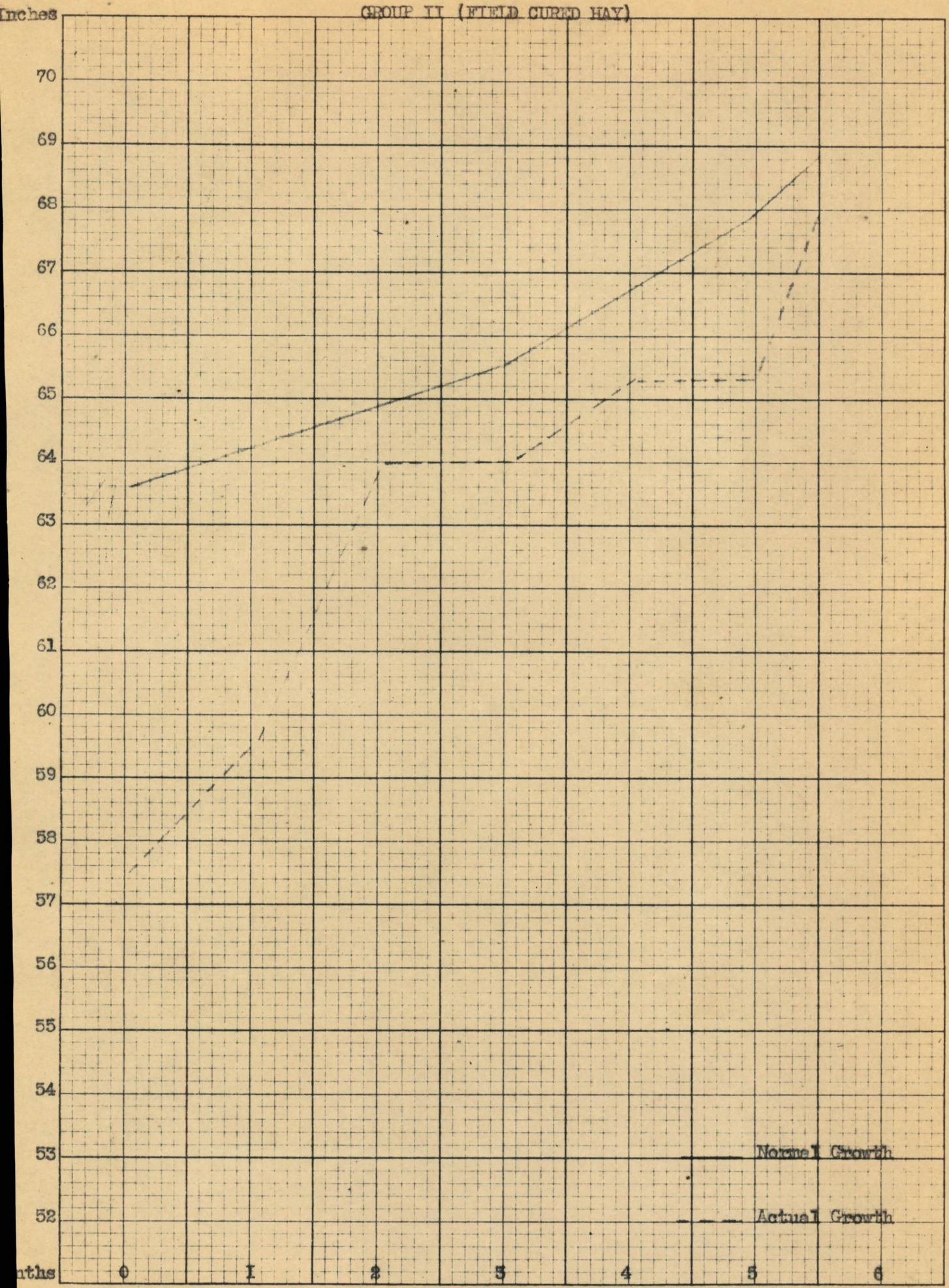


Figure 32. - Growth rate (heart girth) of heifer No. 310

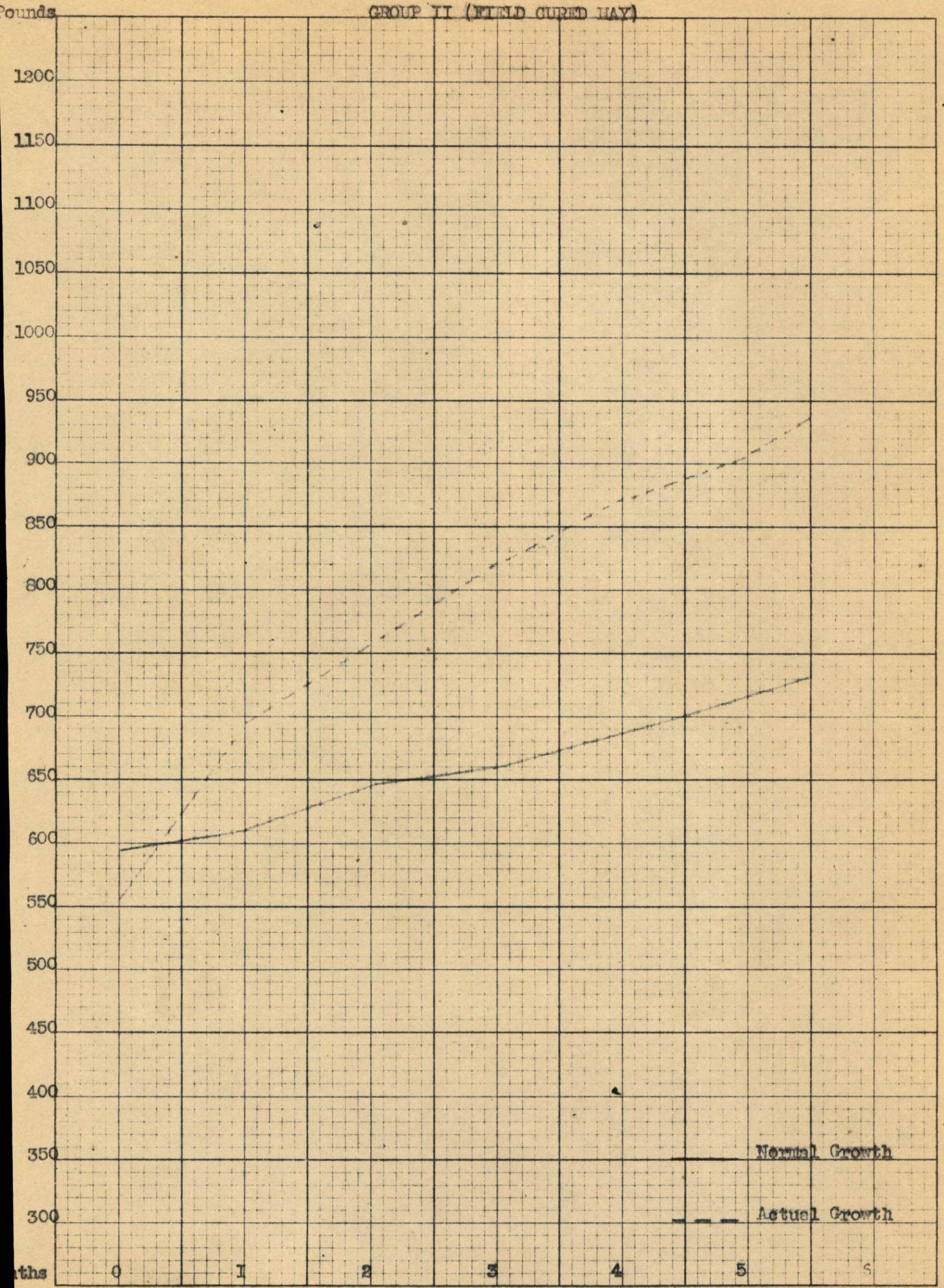


Figure 33. - Growth rate (weight) of heifer No. 310

GROUP II



Beginning of Experiment

Age 11 Months and 5 Days



End of Experiment

Age 16 Months and 20 Days

Figure 34 - Photographic Growth Record of Heifer No. 315

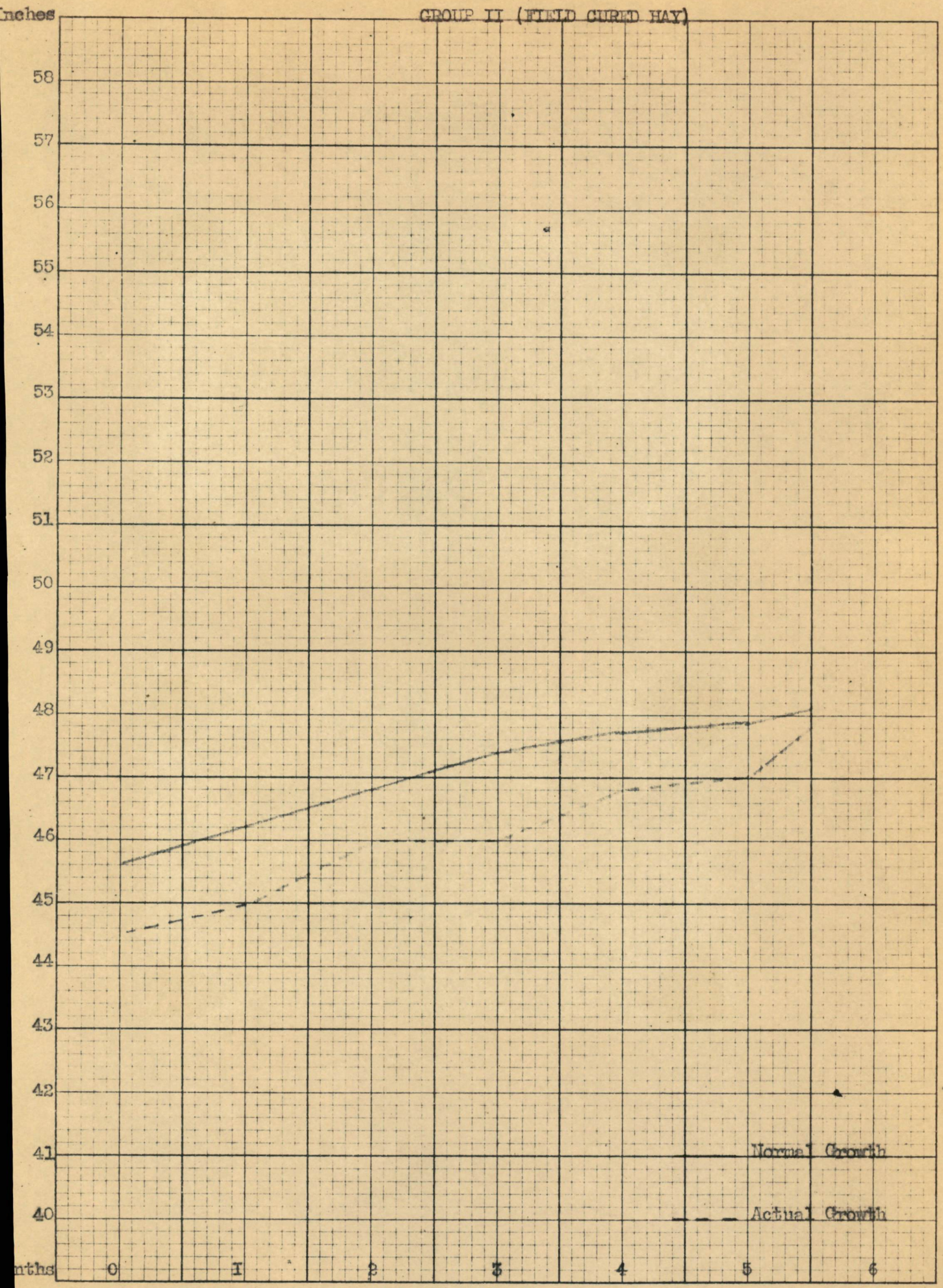


Figure 35. - Growth rate (height) of heifer No. 315

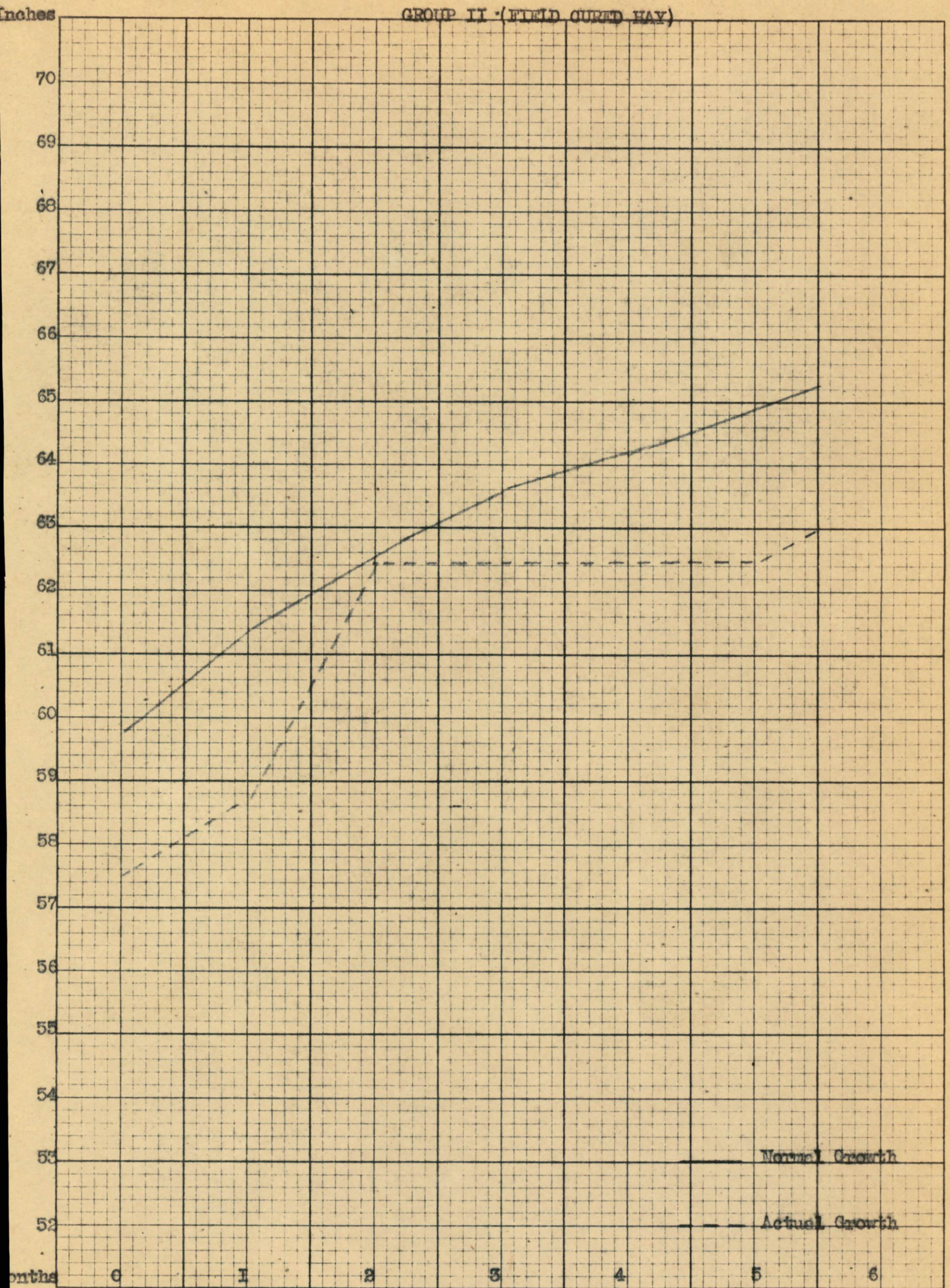


Figure 36. - Growth rate (heart girth) of heifer No. 315

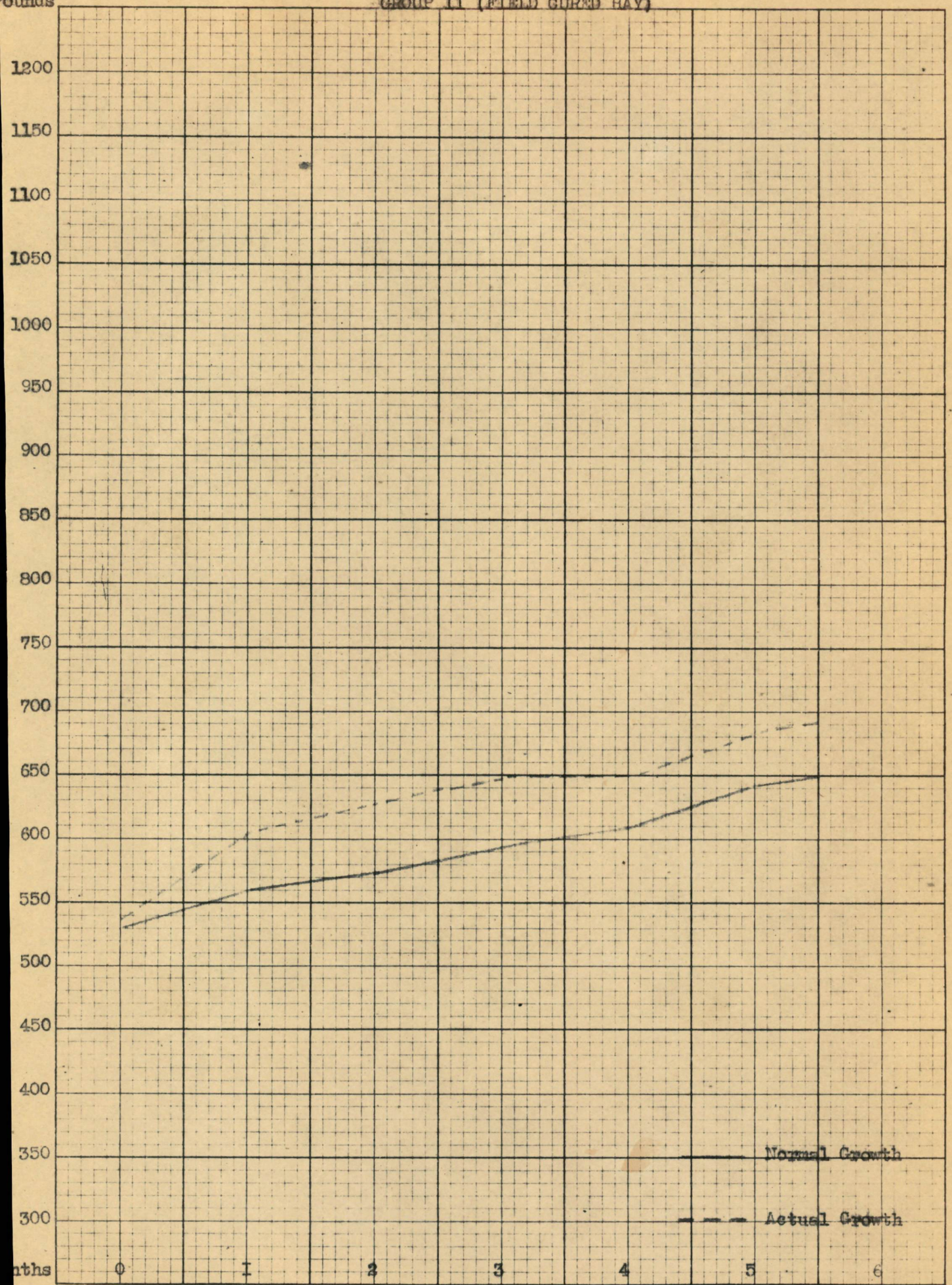


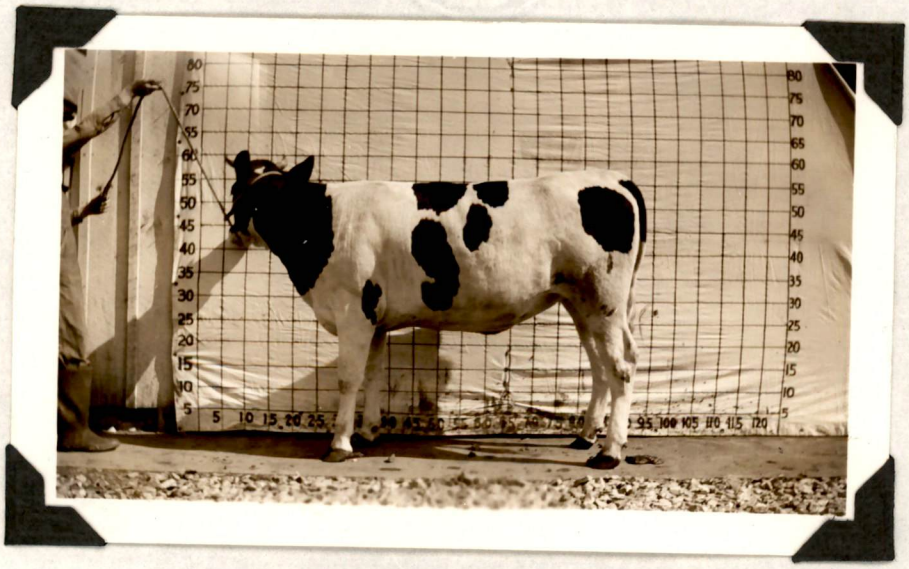
Figure 37. - Growth rate (weight) of heifer No. 315

GROUP II



Beginning of Experiment

Age 17 Months and 23 Days



End of Experiment

Age 23 Months and 8 Days

Figure 38 - Photographic Growth Record Of Heifer No. 308

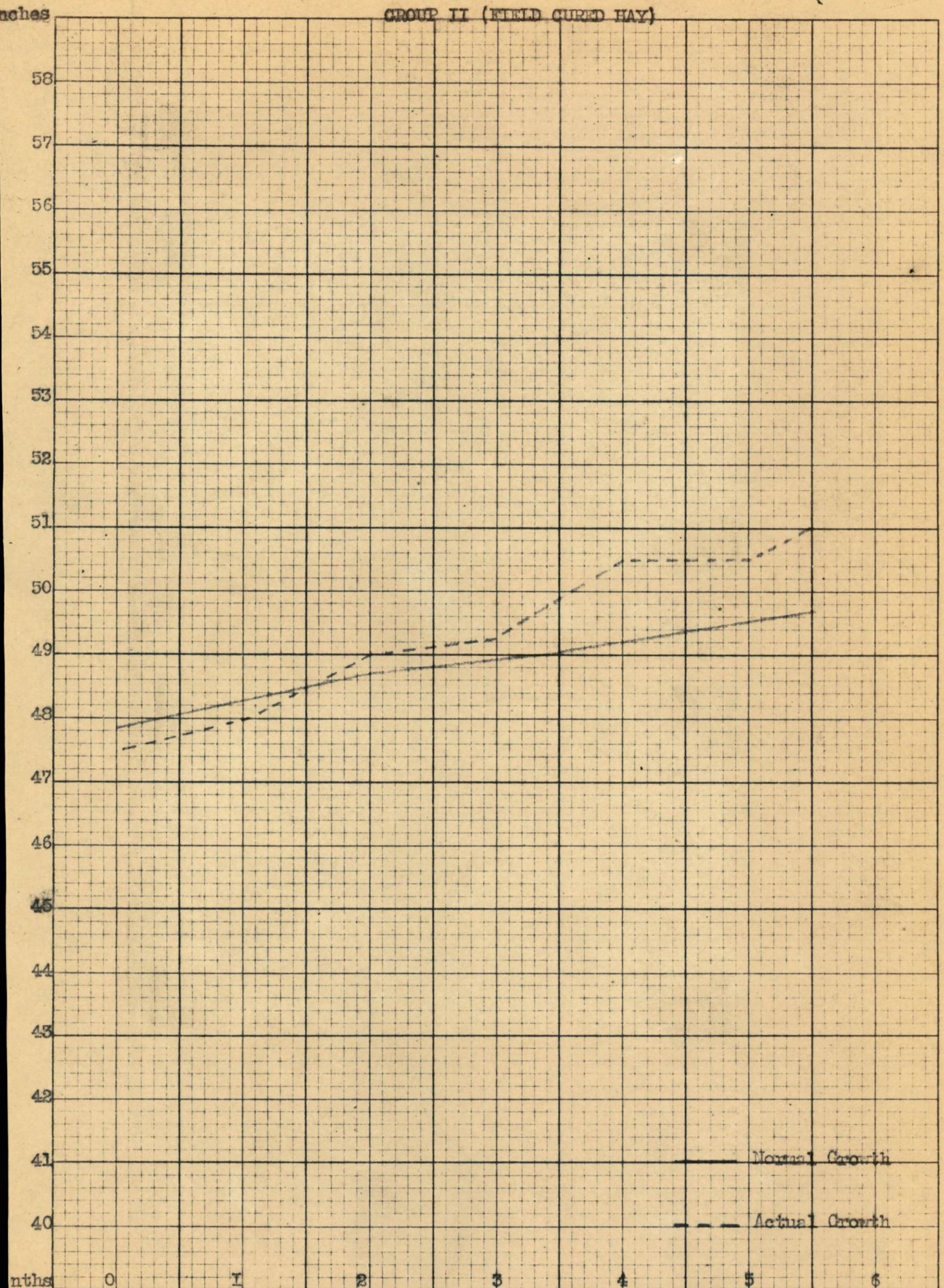


Figure 39. - Growth rate (height) of heifer No. 308

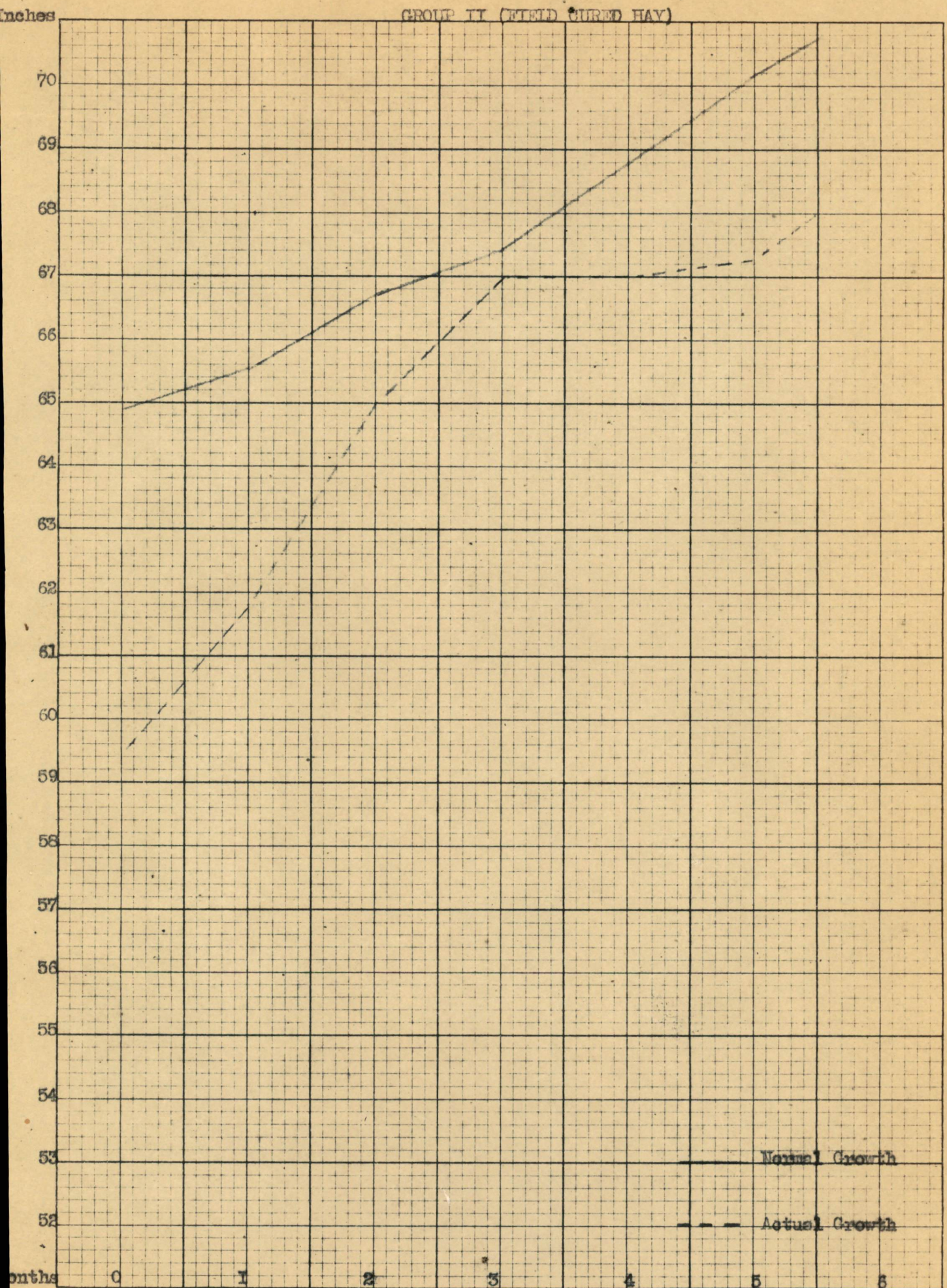


Figure 40. - Growth rate (heart girth) of heifer No. 308

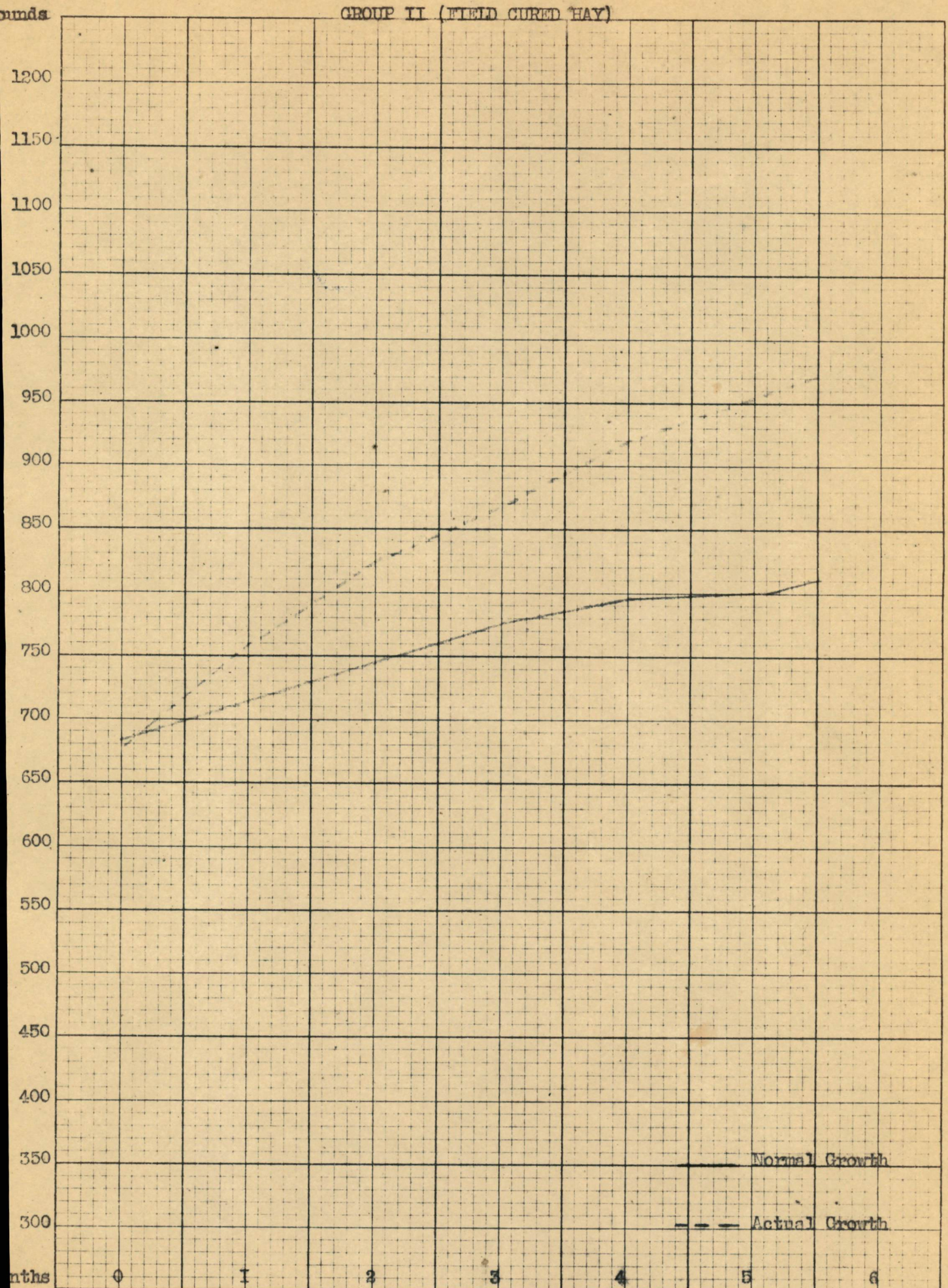


Figure 41. - Growth rate (weight) of heifer No. 308

DISCUSSION OF RESULTS

The data indicates that there was no significant difference in the feeding value of the field cured hay and the air cured hay (barn cured) for dairy heifers. As may be seen in Table 3, there was very little difference in the total feed consumption and growth of the two groups.

Table 3. Feed Consumption and Growth Chart.

5 Heifers in Each Group--165 Days

	Air cured group	Field cured group	Total differ-ence	Av. difference per animal
Total hay consumed, lbs.	10,927	9,691	1,236	247
Total concentrates consumed, lbs.	1,950	1,950	0	0
Total corn silage consumed, lbs.	8,250	8,250	0	0
Gain in height, inches	15.50	17.75	2.25	.45
Gain in weight, lbs.	1,240	1,153	87	17.4
Gain in heart girth, inches	34	34	0	0

Although the heifers fed the air cured hay gained a total of 87 pounds more than the heifers fed field cured hay, this was to be expected because they consumed 1236 pounds more hay. The air cured hay did, however, appear to be more palatable, which accounts for the extra consumption. There was no difference whatsoever in the total gain at heart girth of the two groups, and the 2.25 inches difference in the height at withers growth was easily in the range of experimental error.

It may be noted by the growth graphs for the individuals and for the groups that all of the animals made about normal growth. It was found, however, that four of the heifers in each group or a total

of eight animals were slightly over the weight standards as set up by Eckles in Dairy Cattle and Milk Production.

As the field cured hay used in this feeding trial was cured under ideal hay curing conditions, not so much difference was to be expected between it and the air cured hay. Plans are now being made, however, here at the University of Tennessee to conduct a similar experiment using field cured hay, part of which has been exposed to unfavorable weather conditions which will really be the average kind of hay produced in this section of the country. The air dried hay will again be cured by the barn curing system through the cooperation of the Tennessee Valley Authority. The drying system has been revised and better hay is expected for the next feeding trial.

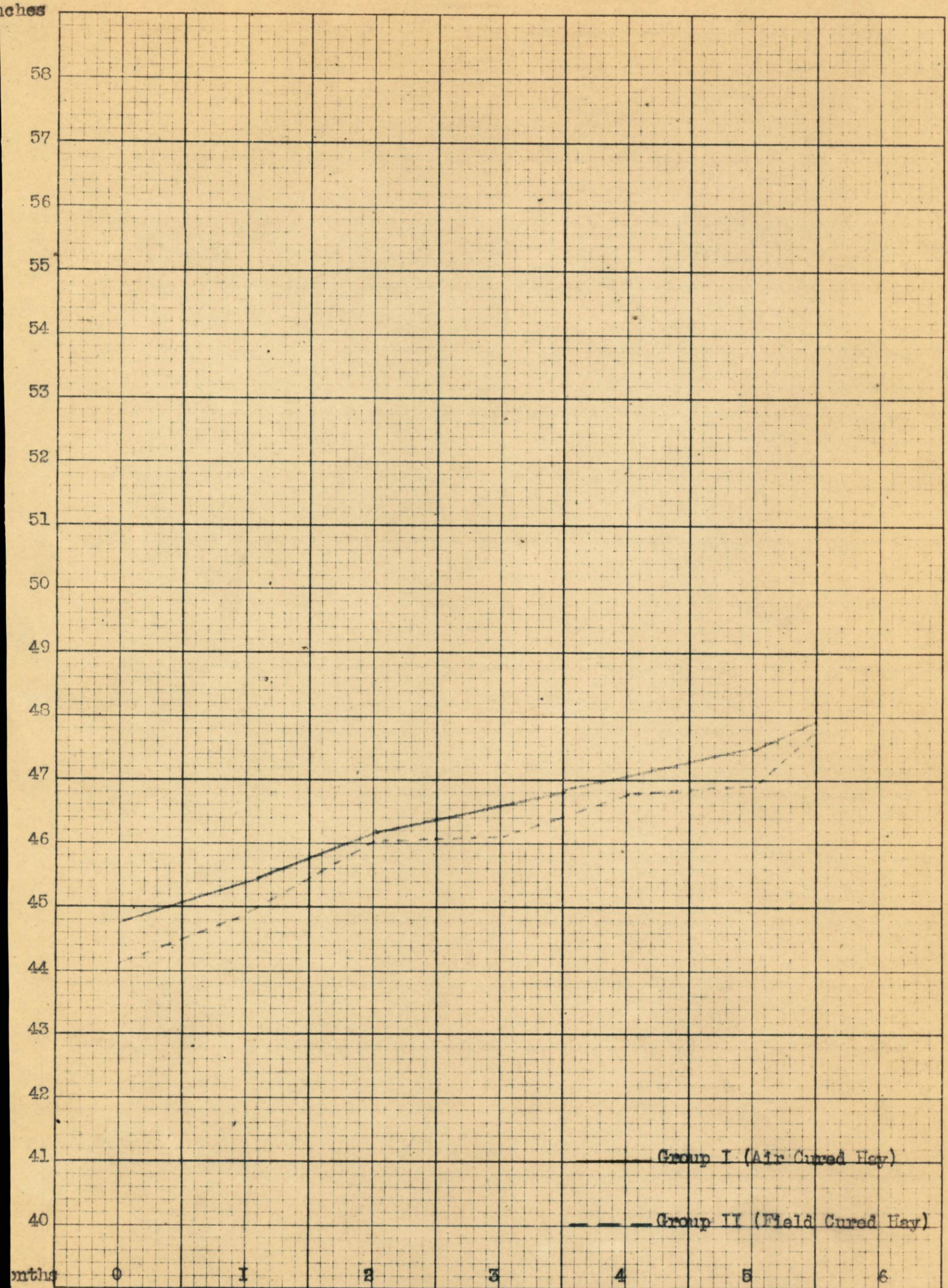


Figure 42. - Average growth rate (height) of heifers on experiment

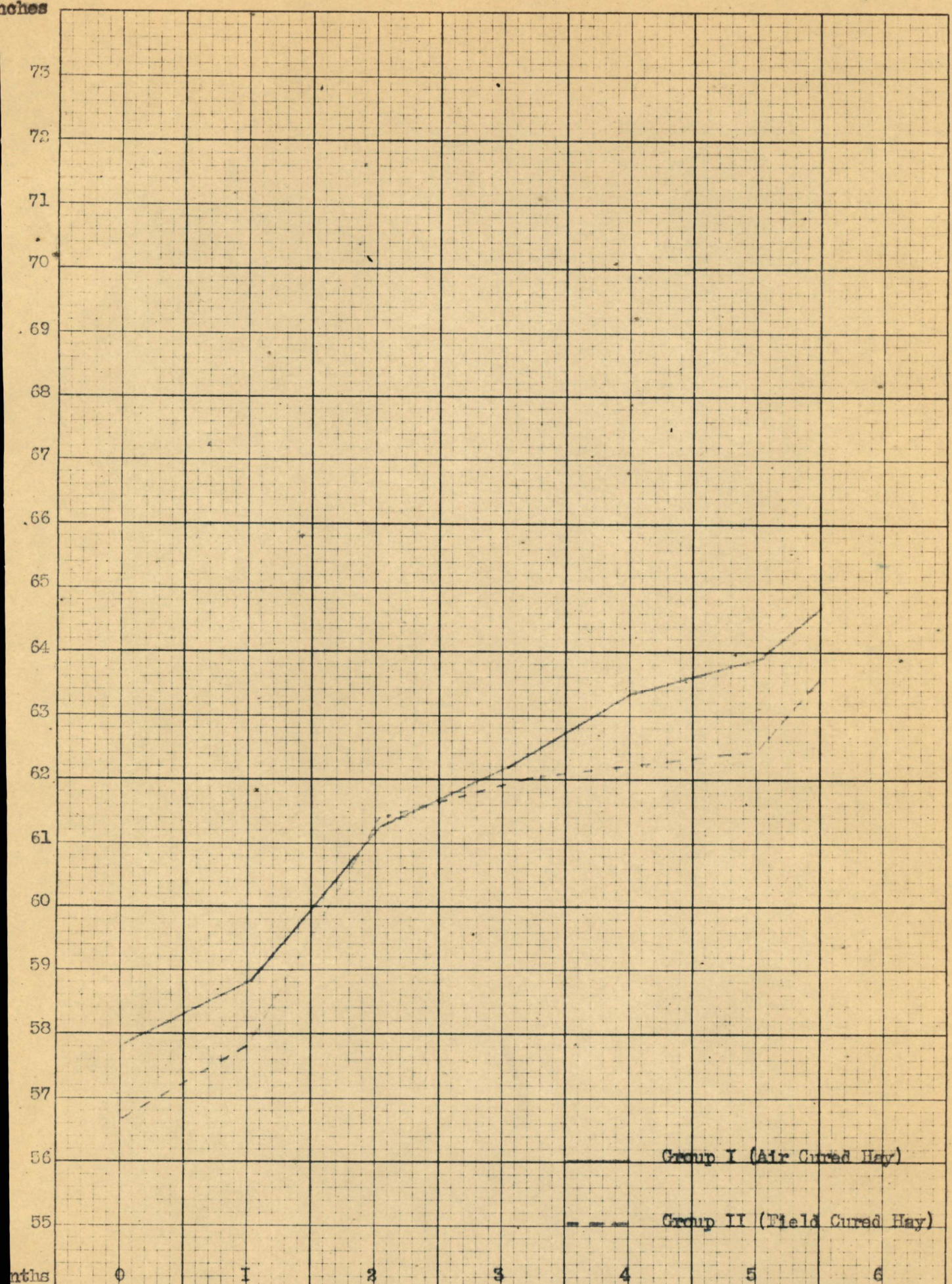


Figure 43. - Average growth rate (heart girth) of heifers on experiment

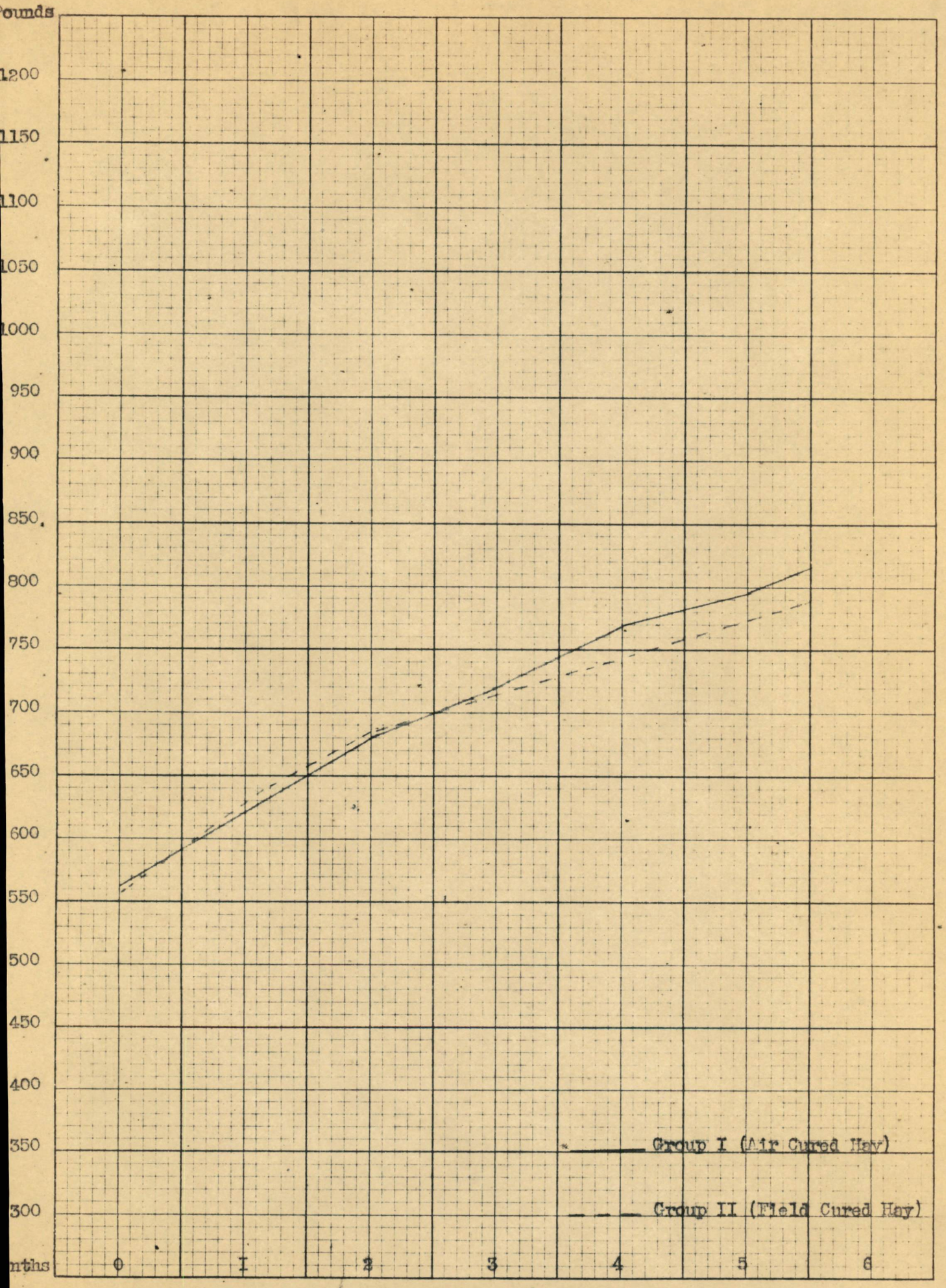


Figure 44. - Average growth rate (weight) of heifers on experiment

Table 4. Summary Growth Chart.

165 Days

Group I (Air cured hay)

No.	Height	Heart Girth	Weight
	Inches	Inches	Pounds
T56	2.75	6.25	197
T55	2.75	4.25	154
309	2.25	7.50	324
311	3.50	9.50	301
312	4.25	6.50	264
TOTAL	15.50	34.00	1240
Average	3.10	6.80	248
Group II (Field cured hay)			
T58	3.00	4.00	131
T57	3.50	5.50	244
310	4.50	10.50	337
315	3.25	5.50	152
308	3.50	8.50	289
TOTAL	17.75	34.00	1153
Average	3.53	6.80	230.6

SECTION B

THE VITAMIN A CONTENT OF FIELD CURED AND AIR CURED HAY

(Rat Feeding Investigation)

PURPOSE.

The purpose of the experiment was to determine the difference in the vitamin A content of mixed alfalfa and clover air cured hay (barn cured) and similar hay field cured. The hay was approximately 75 per cent alfalfa and 25 per cent red clover. The term vitamin A stands for a substance present in certain foods and feeds that is essential to normal growth in the young. Evidence has also been brought forward[44] that supports the belief among some stockmen that a lack of vitamin A will cause breeding difficulties. In the experiment carried on at the University of Tennessee with dairy heifers, as reported in Section A of this paper, no material difference was found in these two hays, but some difficulty was encountered in getting some of the heifers bred. Under average conditions artificially cured hay will contain more vitamin A than field cured, but it was decided to determine the vitamin A content of these two hays in furthering the investigation as to their nutritional value.

With the increasing interest in the air curing of hay it is desirable to know its nutritional value as compared with the more commonly field cured type. Of course the nutritional value of hay will depend upon several factors and will vary from year to year, but it has been found that the curing process plays an important part in its actual feeding value. Since vitamin A is an essential in the ration for optimum growth and reproduction, its importance must not be overlooked.

METHOD OF PROCEDURE.

The feeding experiments in this study were performed upon young albino rats raised in the Nutritional Laboratory of the University of Tennessee. It is essential to use animals of known nutritional history because vitamin A is stored in the body according to the amount of vitamin A furnished in the diet. The breeding animals in this laboratory are given a stock diet consisting of casein 18 per cent; cornstarch 48 per cent; butter 8 per cent; cod liver oil 2 per cent; Osborne and Mendel salt mixture 4 per cent; and dried yeast 20 per cent. Approximately 30 grams per week of lean beef is given to each adult rat in order to promote reproduction, lactation, and to secure healthier, sturdier animals.

A vitamin A-free diet, consisting of A-free casein 18 per cent; cornstarch 67 per cent; Osborne and Meldel salt mixture 4 per cent; dried yeast 10 per cent; salt 1 per cent; and irradiated ergesterol was used for furnishing vitamin D. This basal diet lacks vitamin A but is adequate in all other respects, according to present day information.

The protein in the diet was furnished by the use of purefied casein. The casein was freed of vitamin A by extraction with hot 95 per cent alcohol. The extraction method was as follows: Five hundred grams of fine grained high grade casein was placed in a three-liter Pyrex flask with 1,250 cc. of 95 per cent alcohol. The casein was boiled for one hour on a steam bath under a reflux condenser, and then transferred rapidly without cooling to a heavy canvas bag and the alcohol thoroughly pressed out. The casein was returned to the flask and the process was repeated with the redistilled alcohol. The third time 1,250 cc. of fresh 95 per cent alcohol was used. After the third boiling the casein was dried at room temperature and sifted.

Vitamin D was furnished by washing irradiated ergosterol directly into the mixture with ether. The ether was then allowed to escape by leaving the mixture in an open container.

The pure cornstarch was added to furnish energy.

Vitamins B and G were supplied by a tested yeast especially rich in these vitamins and manufactured by the Northwestern Yeast Co.

The mineral essential to normal growth was furnished in the Osborne and Mendel salt mixture.(45)

Sodium chloride was added in order to make the diet more palatable.

Young rats, weighing 35 to 42 grams, whose mothers had been fed the stock diet and raised in this laboratory, were weaned at about 21 days of age. At the time of weaning, each litter of rats was placed in a large galvanized iron wire cage with raised screen bottom to prevent access to excreta. The vitamin A-free diet described above and fresh distilled water were kept in the cage at all times. One litter of rats was started on this diet at weaning, 21 days of age, but the second litter was started when they were 28 days old. The animals were kept on this A-free diet until they were depleted of their bodily stores of vitamin A. The average depletion period for the rats used in these experiments was 30.5 days. The younger rats started at 21 days required 23 days, while the older rats required 33 days for depletion. The end of the depletion period was determined by the time when the animals ceased to gain in weight. At the end of the depletion period the animals were started on the five weeks experimental test. They were placed in separate round galvanized iron wire cages. One representative rat from each litter was left on the vitamin A-free diet as a "negative control." After death they were

autopsied and the symptoms of vitamin A deficiency were recorded.

The other animals were fed, in addition to the basal vitamin A-free diet, graded portions of air cured and field cured hay in an effort to find their vitamin A content. The supplement was fed three times a week during the test period of five weeks. Animals from each litter were placed on each level of feeding. For comparison of the air cured and field cured hay for their vitamin A content, the rats of each litter and sex were as equally divided as was possible on the graded amounts of each kind of hay.

The air cured hay used in this experiment was grown on the University of Tennessee farm and cured in the U. T. dairy barn according to the method previously described.

The sun or field cured hay used was similar hay, but cured in the field. The hay was a mixture of alfalfa and clover with some Johnson grass.

In these experiments, using the air cured and the field cured hay, a total of ten rats were used on the four levels of feeding. Two rats were placed on each of the levels; .05 gram air cured daily, .05 gram sun cured daily, .1 gram air cured daily, .1 gram sun cured daily, and two rats were left on the A-free diet as the "negative controls." No two rats from the same litter were placed on the same level. The eleventh rat depleted of vitamin A was not used in the experiment because it could not be fitted in very well on any of the levels. These graded amounts of hay were the only source from which the animals could receive vitamin A.

Records of the weights of the animals, of the food eaten, and of their physical condition were kept each week. Newspapers were used in the pens to catch the excreta and were changed daily. The

cages were kept clean. The food cups, drinking fountains, and pans were changed once a week, and clean supplement dishes were used for each feeding. A record of each rat including number, sex, ear punch, the amount of supplement given, and the amount of basal diet consumed during each week was kept on a card attached to the cage. These records were also recorded in the laboratory book.

The rats were carried through an experimental period of five weeks and were then killed and autopsied. When rats died before the experimental period was over they were autopsied and all symptoms of vitamin A deficiency were recorded.

PRESENTATION OF DATA ON VITAMIN A

The two negative control animals that were kept on the vitamin A-free diet, without any supplement, showed a total average loss of -42 grams, and survival average of 16 days after the test period began. The results for these animals are summarized in Table 5.

The results for the different levels of air cured and field cured hay are also summarized in Table 5. All of the animals with the exception of the negative controls and one on .05 gram of air cured hay survived the experimental period of five weeks.

The low level of feeding was .05 gram per rat per day, six days a week. The 2 rats receiving .05 gram of air cured hay showed an average loss of -18.5 grams. The average survival was 28 days as one of the rats died at the end of the third week. The 2 rats receiving .05 gram of field cured hay showed an average loss of -12.0 grams, but both rats survived the experimental period of five weeks.

The two rats receiving the higher level of air cured hay, .1 gram per rat per day, made an average gain of 44.0 grams for the five weeks. The two receiving .1 gram of field cured hay showed an average gain of 12.5 grams for the same period.

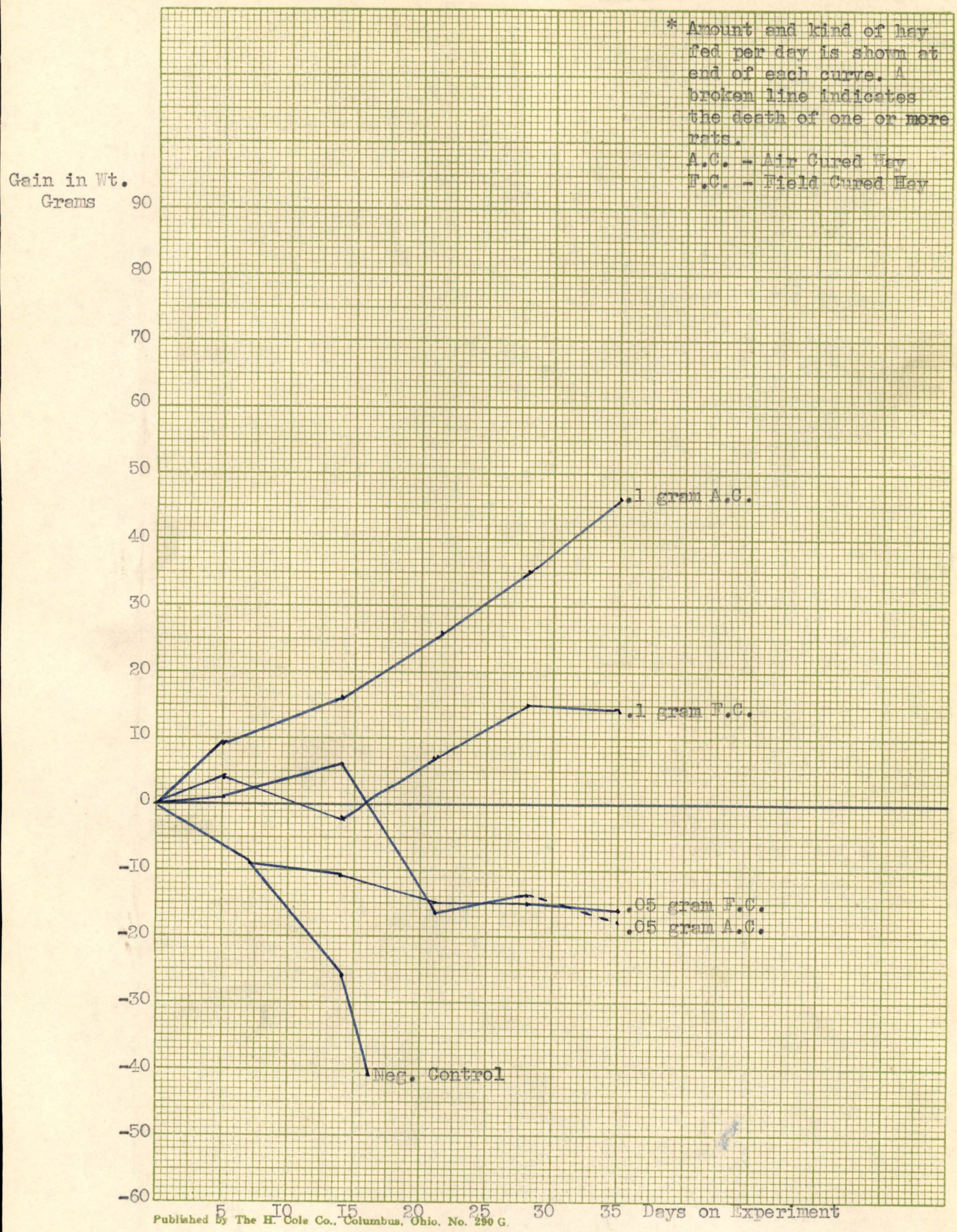
Figure I shows the average gain curves of rats fed different amounts of air cured and field cured hay as the sole source of vitamin A. The kind and amount of hay fed per rat per day is shown at the end of each curve.

Table 5. Record of Rats Receiving Vitamin A-Free Diet and Air Cured and Field Cured Hay.

Amount of supplement given per rat per day Grams	No. of Rats	Average weight at the beginning of the depletion period Grams	Average weight at the end of the depletion period. Grams	Average depletion period. Days	Average survival period. Days	Average Weekly Gain in Grams					Average gain in five weeks. Grams
						1st.	2nd.	3rd.	4th.	5th.	
.00	2	37	126.5	30.5	16	-9.0	-18.0	-15.0	(Two Days)		-42
.05 A.C.*	2	38.5	127.5	30.5	28	.5	4.5	-21.5	2.0	-4.0	-18.5
.05 F.C.**	2	42.5	131.0	30.5	35	-8.5	-2.0	-.5	0.0	-1.0	-12.0
.1 A.C.	2	37.5	127.0	30.5	35	8.5	7.0	9.5	8.5	10.5	44.0
.1 F.C.	2	37.0	122.5	30.5	35	3.0	-5.0	9.5	5.5	-.5	12.5

* A.C. ---- Air cured.

** F.C. ---- Field cured.



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Figure 45. - Growth rate of rats receiving different amounts of air cured and field cured hay

DISCUSSION OF RESULTS WITH RATS

The results obtained cannot be said to be a true biological test for the vitamin A content of the hays tested because not enough animals were used on each level to determine the actual vitamin A units in each kind of hay. However, the results obtained are accurate as far as research procedure is concerned, and do give a good indication of what the results might be with a larger number of animals.

The data indicate that the low level of .05 gram of hay per day does not contain enough vitamin A for the normal growth of rats. In fact, the four rats on this level lost weight and one died before the experiment was ended. No material difference could be seen between the two hays at this low level because it was below normal and no accurate measure could be obtained.

The higher level of hay fed, .1 gram per day, did contain enough vitamin A for growth in the four rats on this level. The data also indicate that the air cured hay is higher in vitamin A as it gave an average gain of 44 grams for the five weeks while a similar amount of sun cured gave only a gain of 12.5 grams.

As the data obtained were from such a small number of rats, no attempt will be made to determine the actual unit value of vitamin A in the two hays. The results might be given in general terms by saying that both hays were rather low in vitamin A or carotene, but that the data indicated that the air cured hay contained more vitamin A than the field cured when fed on a level high enough to support growth.

SUMMARY AND CONCLUSION OF VITAMIN A INVESTIGATION

The results of the experiments reported in this study indicate that there is a difference in the vitamin A content of hays. Whether such differences will affect the reproduction of livestock or whether the average hay will furnish enough vitamin A for reproduction is still a disputed point.

It is an established fact that vitamin A is affected by light and heat, and that hay will decrease in its vitamin A value in storage. Such factors and knowledge lead one to question other possible avenues of research in relation to the vitamin A value of all livestock feeds.

In view of the fact that vitamin A is essential to normal health and nutrition of humans it is reasonable to expect that it is necessary for optimum growth in livestock. Since hays and forages form a large part of an animal's ration, their vitamin A content should not be overlooked. Of course, an animal is able to get plenty of vitamin A if it has access to pasture, and is also able to store the vitamin in its body, but during the long winter months hay is about the only source of vitamin A on most farms.

SECTION C

MIXED ALFALFA AND RED CLOVER SILAGE PILOT EXPERIMENT

PURPOSE.

Corn silage has been extensively used for dairy cattle throughout the United States for many years. There have been many experiments with this kind of silage to determine its value, but very little experimental work has been done with silage made from legume grasses. Since legume crops fit into the National Soil Conservation program it is important to obtain information on their use as silage. The object of this investigation was to determine the keeping qualities, color, aroma, acidity, and palatability of mixed alfalfa and clover silage preserved by various methods.

PROCEDURE.

Six fifty-gallon lard barrels were used as silos for this experiment. They were steamed and washed in order to remove all of the lard. The barrels were very sturdy, being made of hardwood staves. The alfalfa and clover was rather watery and had attained a height of about six inches following a previous cutting. It was mowed on the morning of October 25, 1937, and placed in the barrels immediately. It was cut with a regular silage cutter into one-half inch lengths and packed firmly in the barrels up to about eight inches from the top. This space was left for covering material to seal the barrel.

The following shows the treatment of the silage put in each barrel:

No. I. Phosphoric acid (P_2O_5) 80 per cent was sprinkled over the alfalfa and clover as it was being put in the barrel. It was sprinkled on at a rate of 24 pounds acid to a ton of green material, the acid being diluted with two parts of water by volume in order

to get it equally distributed and for ease of handling. At the above rate 2 pounds of acid was used for the barrel. The weight of the green material was 175 pounds.

No. II. Phosphoric acid (P_2O_5) 80 per cent was added to this barrel in the same proportion as barrel No. I, but it was sprayed on with a sprayer instead of being sprinkled, and was therefore given a more equal distribution. Weight of green material, 175 pounds.

No. III. Blackstrap molasses (regular commercial feeding type) was added to this barrel at the rate of five gallons to a ton of green material. It was diluted one part of molasses to four parts of water by volume and sprinkled on the silage as it was being put in the barrel. One-half gallon of molasses was used for the barrel (175 pounds of green material) at the above ratio.

No. IV. Same treatment as No. III. Weight of green material, 175 pounds.

No. V. The A.I.V. method of silage making was used on this barrel. The acid mixture being one part of commercial sulphuric acid (H_2SO_4) to four parts of hydrochloric (HCl) by weight was made into a 2N solution. The acid was sprayed on the green material as it was added to the barrel at the rate of 100 liters to a ton of green material. At the above ratio, 800 cc. of HCl was added to 200 cc. of H_2SO_4 and the mixture added to 9 liters of water for the barrel. Weight of green material, 175 pounds.

No. VI. This barrel was used as a check and was, therefore, given no treatment, the green material being chopped and packed in it in the regular manner. Weight of green material, 175 pounds.

The barrels were all covered alike. First a wet burlap was placed over the top of the silage, and then about three inches of

of wet straw was added. The remaining seven inches of the barrel was filled with dirt (clay loam) and packed firmly. After being packed firmly the soil was given a thorough soaking with all the water it would take up and the barrels placed in the University barn.

The phosphoric acid was supplied for the experiment by the Tennessee Valley Authority through the cooperation of George W. Rommel.

Each kind of the silage was packed in half gallon glass jars and sealed for observation. The jars were kept in the dark at the same temperature of the barrels.

Each kind of the silage was also placed (not packed) in quart jars and sealed. Some air was left in these jars to study mold and bacterial growth on the different treated silages.

RECORDING DATA.

Changes that occurred in the silage placed in the glass jars were observed and the data recorded. One barrel each of the phosphoric acid, molasses, check, and A.I.V. treated silage was opened after three and one-half months. The other two barrels, phosphoric acid treated and molasses treated, were opened after five and one-half months. Professor C. E. Wylie and Mr. S. A. Hinton of the Dairy Department, Professor O. W. Dynes of the Agronomy Department, and the author examined the silages as to color, keeping quality, odor, and acidity. The palatability of the silages was determined by feeding to dairy cows in the University herd.

RESULTS OBTAINED.

Loosely Packed Jars

Figure 46 shows the loosely packed jars of silage at the beginning of the experiment. After one month's time the silage treated with phosphoric acid showed mold growth. At the end of two

months the A.I.V. treated and check samples also showed mold growth. In fact, at this stage, these three three samples were almost covered with mold growth. No mold growth ever appeared on the molasses treated silage, however, which may be seen in the photograph in fig. 46. This photograph was taken four months after the beginning of the experiment. The molasses treated sample was still mold-free after seven months and had been preserved into a typical legume silage. The phosphoric acid, check, and A.I.V. treated samples were all decayed at this time.

The quick growth of mold on the phosphoric acid treated silage was probably due to the presence of the acid itself. The phosphoric acid being a weak acid, and in the presence of air, was conducive to mold growth. The A.I.V. silage being preserved with a stronger acid and the check being of a more neutral nature, were not so conducive to mold growth, and therefore did not show their development so quickly as did the phosphoric acid silage. Such an explanation was given by Dr. W. H. MacIntire, Chemist, Agricultural Experiment Station, Knoxville, Tennessee, and seems very logical.

The fact that no mold appeared on the molasses silage is rather difficult to explain. There is a possibility that there was not enough air space left in the jar and the lid was tightened so much that it sealed the jar. The absence of sufficient oxygen in the jar would, of course, prevent mold growth. This seems to be the only satisfactory explanation that can be given for the results obtained on this jar.

Tightly Packed Jars

The jars of silage shown in figure 47 were treated in the same manner as the loosely packed jars and the barrels, but the silage

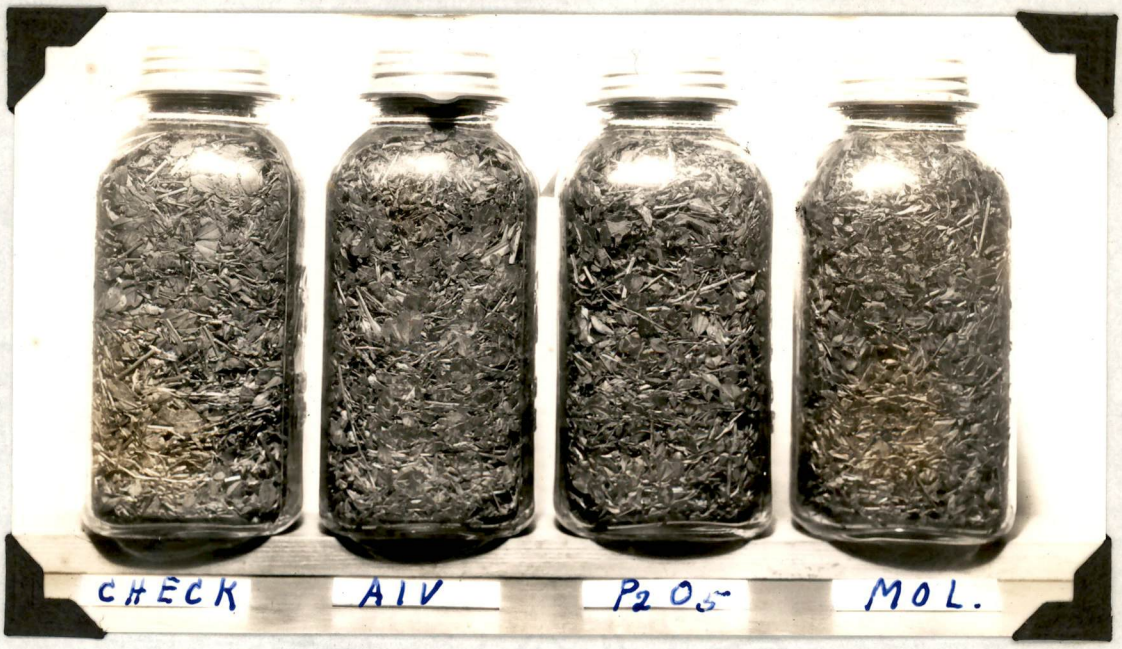


Beginning of Experiment



Same Jars after Four Months

Figure 46. - Loosely packed jars of mixed alfalfa and red clover silage having various treatments for preserving



Beginning of Experiment



Same Jars after Four Months

Figure 47. - Tightly packed jars of mixed alfalfa and red clover silage having various treatments for preserving

was packed very tightly and the jars sealed. Within a very short time (two hours) after sealing the silage treated with phosphoric acid and the A.I.V. solution turned rather dark, while the check jar and molasses jar retained their green color. This sudden darkening of the silage material was probably due to the immediate effect of the acids on the green material. At the end of four months, however, as shown in figure 47 the molasses treated silage was much darker than the other silages. All of the silages, including the check, appeared to be well preserved even after eight months. As these jars were under the same conditions as the barrels it is assumed that similar color and preservation changes took place in the barrels.

Barrels

One barrel each of the phosphoric acid, molasses, check, and the A.I.V. treated silage was opened after three and one-half months. All of the silage was in excellent condition and only two or three inches of spoilage was taken off of the top of each barrel. The phosphoric acid treated appeared to be slightly lighter and greener in color, while the molasses treated was the darkest. All of the barrels had a very good aroma, but the molasses treated seemed to have a sweeter aroma. There was no material difference in the palatability of the silages as the cows ate each kind readily, and appeared to make no choice between the legume silage and the corn silage that they had been accustomed to receiving. The two remaining barrels that were treated with phosphoric acid and molasses respectively, which were opened after five and one-half months had very similar characteristics to the ones opened previously.

DISCUSSION OF RESULTS.

The results obtained from this experiment indicate that

legumes may be satisfactorily ensilaged by the use of either phosphoric acid, the A.I.V. treatment, molasses, or even without any treatment. Such a statement, however, regarding legume silage without any treatment conflicts with most of the data available on this subject. Although the barrel containing the silage material without any treatment was preserved into very satisfactory silage, it is possible that the alfalfa and clover used in this experiment may have been rather low in protein because it was cut late in the season. A low protein content may have been responsible for the absence of putrefaction or spoilage which is usually associated with early cut legume silage. The results obtained with the phosphoric acid, the A.I.V., and the molasses treated supports the data obtained by other investigators in that satisfactory legume silage may be made by either of these three methods. The fact that the molasses silage was darker and had a sweeter aroma was to be expected due to the presence of the molasses. The phosphoric acid treatment seems to be more popular and offers greater possibilities than the A.I.V. treatment, especially in this country.

In furthering this investigation two barrels of phosphoric acid treated sericea and four barrels of molasses treated sericea have been put up for silage. The procedure of ensiling was very similar to the procedure followed in the experiment above. These barrels are now in storage and will be opened sometime in the fall of 1938.

SUMMARY AND CONCLUSIONS

1. No material difference was found in the feeding value of air cured (barn cured) hay and similar hay field cured when fed to dairy heifers. Under average farm conditions, however, a poorer grade of field cured hay is produced than was used in this investigation. Such poor hay is in many cases the direct result of the damage done by rain and the bleaching effect of the sun. Further investigation should be conducted in order to determine the feeding value of hay cured by the two methods, including some hay which has been cured under average farm conditions.
2. A significant difference in the vitamin A content of the air cured hay and field cured hay was found when fed to young albino rats. Although both hays contained vitamin A in measurable quantities, the air cured hay contained approximately three times as many vitamin A units per gram as did the field cured hay.
3. There are several satisfactory methods of making legume grass silage. Either the direct addition of a mineral acid or the addition of a carbohydrate or sugar supplement from which acid may be formed have given satisfactory results. Pilot experiments proved very promising for the direct application of phosphoric acid or the use of molasses as a supplement in making legume silage.
4. Additional investigation as to the best methods of curing roughages artificially and their feeding value should be conducted in order that such feeds may be more efficiently produced and used in livestock feeding.

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