A STUDY

of the

VARIATIONS IN CHEMICAL COMPOSITION

of the

TIMOTHY AND WHEAT PLANTS

DURING

GROWTH AND RIPENING

by

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THE VARIATIONS IN THE CONSTITUENTS OF THE TIMOTHY AND WHEAT PLANTS IN THE VARIOUS STAGES OF GROWTH.

Historical.

Much work has been done and much data published concerning the composition of feed stuffs. Many reports are on record of the composition of timothy hay, wheat, grain, straw, etc. but as this data is not accompanied with information regarding growth of the plant, condition and time of harvesting, it conveys no idea as to how the plant appropriates and utilizes these constituents in the process of its development. It would be interesting to know what was the yield per acre, of the crop as a whole, and of its several constituents. Moreover, if we knew the amount of the constituents which are removed in taking off the crop, we could estimate the loss in fertility of the soil due to growing the crop and what could be done to replenish this loss. It is a fact well known that the time of harvesting will have something to do with the yield of the crop. This would be especially true in the case of hays, as the time admits of being varied considerably as to the exact date. It has been found that the palatability of the timothy hay is closely associated with its stage of growth when cut. (1). In the literature also appears many reports upon hays and upon wheat collected and analyzed for some special condition of growth or use. Besides this, other reports have been made upon a part or all of the wheat or timothy plant collected at different dates, and these furnish valuable information as to the variations which are occasioned by growth.

Kellner (2) was one of the first to report the analyses of a series of cuttings of grass or hay. He does not state the kind of hay upon which the experiment was conducted, but simply states it to be grass cut from meadow land. The cuttings were made May 14, June 9, June 29, and the report gives the per cents of nitrogenous material, fat, fibre, ash and non-nitrogenous extract for each cutting. His results show that the nitrogenous material decreases in per cent as the grass grows older. The per cents of fat and ash also decrease as ripening progresses, while fibre and non-nitrogenous extract increase in per cent. He estimated also the amount of amido nitrogen compounds present in each cutting, which cannot be regarded as a nutritious form of nitrogen. In the first cutting 31.6 per cent of the total nitrogen was found as acid amides. In the second 13.4 per cent and the third 2.5 per cent.

Jordan (3) in 1882 makes a report upon the analyses of timothy in different stages of growth. For the experiment two plots were planted to timothy. One of these was manured and the other was planted without any fertilizer. The hay was cut at three different stages and the hay analyzed. The results show the per cents of fat, nitrogen and ash diminish as the plant developes while the per cents of fibre and extractives increase. Comparing the manured and the unmanured plots, it appears that the per cents of nitrogen, ash and fibre are increased by manuring.

Wilson (4) experimented with timothy and some other meadow grasses. The plot of timothy was divided into two parts, A and B. The hay was harvested from A June 3, 1885, then from B on July 13. The hay which had made a second growth on A was cut August 25, the second growth on B September 25, The third growth on A was cut October 12. The hay analyzed was the first and third cutting of A and the second cutting of B. The three stages of growth represented by these cuttings were timothy in bloom, first A, overripe timothy, second B and young succulent shoots, third A. The timothy in bloom contained the highest per cent of moisture and the lowest per cent of Nitrogen free extract, the other constituents being intermediate in per cent between the other two stages. The overripe timothy contained the least moisture, fat and protein and the highest per cent of fibre and nitrogen free extract. The young succulent shoots showed the highest per cent of ether soluble material, ash and protein, the lowest per cent of fibre and an intermediate value for the per cents of moisture and nitrogen free extract. These cuttings do not represent one single growth but a distinct part of three separate growths, which may introduce some irregularity in the results.

Ladd (5) reports the analysis of the timothy plant cut at four different periods of growth. According to his results the per cent of water decreases rapidly after blossoming. Sugar also decreases, while starch on the other hand, increases substantially in per cent. The albuminoids become less digestible as the plant approaches ripening. He concludes that albuminoids pass on from the stems to the seed during ripening, and it is therefore advisable to mow the plant for fodder at the time of blossoming, to procure a uniform distribution of nutritious material throughout the plant.

President H. J. Waters of Kansas State Agricultural College, while Dean of the College of Agriculture at the University of Missouri, carried on a series of experiments with timothy for the purpose of studying the yield, digestibility and palatability of the hay in the various stages of growth and in different seasons. (1). The five cuttings indicated were made for five successive seasons except that in one or two seasons certain cuttings were not obtained. The results were averaged for those years when a full series were as follows:

1. Cut when plant was in full head, usually about June 12.
2. Cut when plants on average were in full bloom, usually about June 18.
3. Cut when the seed was formed or when the bloom had all been shed, usually about July 1.
4. Cut when the seed was in the dough, about July 8.
5. Cut when the seed was ripe but not shattered, about July 16.

The first factor to be studied was the yield of cured hay per acre. As the hay of one cutting has more water than another and corresponding cuttings of different seasons may also have different amounts of moisture, there was no constituent agreement in the yield thus found. The cuttings which gave the largest yields were as follows; 1st year, second cutting; 2nd year, fifth cutting; 3rd year, fourth cutting; 4th year, fourth cutting; 5th year, third cutting. A more reliable guide to yield is found in the results for yields of dry matter per acre. Taking the average of all the years in which all five cuttings were obtained the yields of dry matter per acre were in their order, the maximum first;-the third cutting, the fourth cutting, the second, the fifth, the first. To ascertain the digestibility of the different cuttings, the hays were fed to one and two year old steers in a digestion trial. The results show that the first cutting was the most digestible and that the digestibility steadily declined with each cutting until the last. Averaging all the digestion trials, the yield of digestible dry material per acre for the different cuttings stood in the following order; second cutting, maximum; third cutting next, first cutting, fourth cutting, fifth cutting. The palatability of the cuttings was tested by placing one hundred pounds of cured hay from each cutting, side by side in a long rack, and allowing two steers, whose feed was exclusively timothy hay, to eat from the racks ab libitum. In all cases the animals ate the youngest cutting of hay first. Moreover, the first three cuttings were cleaned up before the last two were hardly touched, showing plainly that the hay had lost considerably in palatability when the seed had reached the dough stage. Considering the convenience in harvesting and the keeping qualities of the hay, the advantages were in favor of the later cut hays. Young hay takes longer to cure, and is more easily damaged by rainfall, than the later cut timothy. When hay is cut before the seed is produced the field is liable to become less productive, due to the plant drying out. If cut at a time when the heads will partly shatter when the hay is gathered, the stand of the plant is maintained much better.

One of the first reports upon wheat constituents of interest to us in this study was made by Sorby (6). He studied the sulphur and phosphorus content in grasses, vegetables and various grain crops. The amounts are given in per cents of dry substance, for entire wheat plant after flowering, ear of wheat and straw in the milk stage, and ear of wheat and straw when ripe. Concerning his data upon phosphorus, he states that "it may be inferred from these analyses that when grain is growing and ripening the amount of phosphorus increases in greater proportion than the total weights, and diminishes in the straw, the grain abstracting that constituent from it".

Liebscher (7) groups the work of the investigators who had studied the growth of barley, oats, wheat and some other crops in different stages of growth giving the amount of each constituent present at any stage, in per cent of the maximum amount found in the course of the experiment. On wheat the work of Wolff (8) from 1854 to 1857 is grouped with the work of Pierre (9) 1861 to 1864. The substances reported are dry substance, organic substance, nitrogen, ash, potassium oxide, calcium oxide, magnesium oxide and phosphoric anhydride. The analyses were made upon the plant above the ground only, and are given for six periods of growth as follows: 1. The sprout or young blade before spring growth. 2. The beginning of the growth in the spring. 3. The formation of the head. 4. From the formation of the head to the end of blossoming. 5. From the close of the blossoming until the beginning of ripening of the grain. 6. From the beginning of ripening until the grain was fully ripe. The results show that during the first period the plant is collecting much nourishment, especially nitrogen. Potassium oxide and calcium oxide come next in order and lastly phosphoric anhydride. As large a part of the dry substance is not produced as any of these substances above mentioned. In the second period the same changes are going on but rather less rapidly. Rather more dry matter is being formed now than before. In the third stage the plant is still taking in plant food but at a slowly decreasing rate. Considerable organic matter is likewise being formed at this stage and a large amount of ash is stored up due to greater amounts of the minor constituents (silica, chlorine, iron, sulphuric anhydride, etc.) being added. In the fourth stage practically all of the nitrogen, potassium oxide, calcium oxide and phosphoric anhydride has been laid up. There has been at the same time a large production of organic and total dry matter. The plant is apparently working over the nourishment already in store. In the fifth stage the formation of organic and dry matter reaches its maximum and nearly all the food constituents have been received. In the sixth stage the storing of food constituents is complete.

Déhérain and Meyer (10) report water, dry matter, nitrogenous matter, fat and chlorphyll, ash, nitrogen, phosphoric anhydride, cellulose, starch and sugar in kilos per hectare. The materials for analysis were collected May 31, June 13, July 16, July 23 (harvest) and July 30 and the samples used were whole plant, stems, ears and roots. Concerning the entire plant Déhérain and Meyer assert the following: an increase in dry matter was observed up to harvest time; some loss occurred when it stood beyond the harvest. This gain in weight was mostly starch and cellulose, the nitrogen and ash remaining constant in the last two months of growth. Bright days favored the building up of carbohydrates and drought retarded the assimilation of nitrogen and ash by the roots. Concerning the roots, the per cents of nitrogen, ash and phosphoric anhydride are highest in the young plant, after a sharp decline in the per cent of ash in the second stage, it again slowly rises. Nitrogen declines steadily in per cent to the end, while phosphoric anhydride becomes a constant value before the end. The roots of the wheat plant are relatively a larger part of the entire plant when young than in the ripe stage, and it seems probable that the roots store up nourishment at the first, to give it up later to the growing and ripening grain.

Lawes and Gilbert (11) have completed a large amount of work upon the composition of wheat through different seasons as affedted by manuring in comparison with no manuring. In 1882 the analyses of the ashes of the wheat and straw for sixteen consecutive seasons are given. These analyses are of course those of the ripe grain and straw at harvest ~~ing~~ time. These results show that the total amount of nitrogen, ash and ash constituents, depend upon the seasons and the fertilization of the crop. From one-fourth to one-third of the assimilated potassium oxide, and three-fourths of the phosphoric anhydride, are collected in the grain. A series of analyses upon the wheat grain was reported upon by Heinrich (12) in 1871. The grain was collected (1) when the plant was in flower, (2) when the blossoming was completed (fourteen days later), (3) when the wheat began to ripen (fourteen days later), (4) when the wheat was ripe and was cut (seven days later), (5) when the wheat was over ripe (fourteen days later). The potassium oxide remained in fixed ratio to the gummy matters (1 to 10 or 11), the lime to the cellulose (1 to 41 or 43), the phosphoric anhydride to the nitrogen (1 to 1.8 or 2). The starch had no fixed ratio but continued to increase relative to them all. That the composition of the wheat plant will vary according to fertilization of the soil has been shown by Lawes and Gilbert's work (11). The per cents of ash, nitrogen and phosphoric anhydride on the green plant, the straw, and the grain are given by Ritthausen and Potts (13) who experimented with manured and unmanured spring wheat. Their results show an increase of the nitrogen content due to manuring.

Hébert (14) cut wheat in four stages the first two before the plant headed, the third when the plant was blossoming and fourth when the grain was ripening. On account of loss of grain from the heads at ripening time, the ripe heads were not analyzed. Nitrogenous matter accumulated in the straw and later passed on to the grain. Starch is not formed in the early stages of growth, but is formed in the ripening stage, and mostly in the head. Sugar and dextrin are transported to the head, and there changed into starch during ripening.

The variation in the carbohydrates of wheat is reported upon by Jessen - Hansen (15). The samples of wheat were collected in three stages, July 4, July 13, July 31. The starch increased from 26.45 per cent to 65.90 per cent, the pentosans from 5.4 to 6.4 per cent, the dry matter 27.85 to 55.29 per cent.

Some interesting results are furnished by the works of Berthelot and André (16) reported in 1896. Seed wheat was sown April 10, 1893. Plants were gathered for analysis May 3, May 25, June 14, July 1, August 24. The roots, stems, leaves, flowers and seeds were separately analyzed. In the first cutting of plants the potassium oxide had increased but the phosphoric anhydride had diminished from the amount originally present in the grain planted. In the next three weeks the plant increased in weight about four times. The roots were 11.4 per cent by weight of the plant and contained the greater amount of mineral matter. Potassium oxide increased more in the stems than elsewhere. In the next three weeks the plant increased more in organic than in mineral matter, which showed an actual decrease in per cent. The roots decreased in per cent of the total plant, and the ash constituents were most abundant in the leaves. In the next two weeks the plant increased in weight more slowly, most of it being mineral matter. In the last period when the fruit was ripe, the absolute weight of dry matter fell off one-third. Most of this loss was organic although some was mineral matter. The roots contained the least ash, and the leaves the most. The weight of the plant was divided as follows, roots 11.2 per cent, leaves 3.7 per cent, stems 40.7 per cent, fruit 44.4 per cent. The works of Pierre (9), Déhérain and Meyer (10), and Berthelot (16) seem to show that the total nitrogen of a wheat crop does not increase after commencement of maturation, but that nitrogen migrates from the lower to the upper leaves and is then concentrated in the grain.

Déhérain and Dupont (17) in 1901 contribute further work on the starch of the wheat grain. Unlike certain vegetables such as the potato, there is no reserve of starch at any time in the wheat plant. The rapid accumulation of starch in the ripening stage is the result of the working over of other substances, such as the dextrims and non-reducing sugars. The reducing sugars and nitrogen remain, at this time, in the upper part of the stem. The upper portions of the stem, which remain green the longest, have the same function as the leaves in decomposing CO_2. In Schulze's (18) report on the development of wheat, he showed that nitrogen is assimilated from the end of April to the beginning of grain formation. Potassium oxide at the time of the production of carbohydrates, is present in large quantities, while phosphoric anhydride is taken up during the growth period in spring and after blossoming also.

Adorjan (19) has a most interesting report upon the analysis of the wheat plant above the ground. Fifteen cuttings of the wheat plant were made, beginning April 4, and every ten days thereafter until blossoming time, when cuttings were then made five days apart. The development of the plant is not definitely stated but it appears to be shooting between the third and thirteenth of May, and beginning to blossom about the end of May. Analyses are reported upon the stem, leaves, chaff and grain. No separation could be made upon the young plants until the spike was formed, and no separation of this into chaff and kernel was made until after blossoming. The determinations which may be studied in this report are weights of the parts, per cents of water, of dry substance, of nitrogen, ash and phosphoric anhydride. The weight of grain steadily increases until at ripening it equals one-third the weight of the plant. The chaff increases slightly in weight but shows a loss in absolute amount at ripening due to some falling off from the plant. The maximum weight of the leaves occurs at blossoming time, after which it decreases as the leaves dry out. The weight of stem increases up to blossoming time, then remains fairly constant to ripening. The dry matter has its lowest, and the moisture its greatest value, in the youngest plants. Dry matter steadily increases in amount up to June 30, after which a loss in amount occurs due to falling off of parts of the plant.

The nitrogen results are given in per cents of the dry substance and is reported for all parts of the plant. The amount of nitrogen in the grain is greatest at its formation, the explanation being that the cell tissue is first filled with protoplasm rich in nitrogen, and then the necessary reserve food for the germ, - the starch - is afterwards stored up. A little later the per cent of nitrogen becomes almost constant, indicating that the nitrogen and dry matter are being stored up in the same proportion. The regular storing up of nitrogen in the grain, is assisted by other parts of the plant, which give up a part of their nitrogen to the grain in the ripening stage. However, even while the storing up of protein and starch goes forward regularly, the two may vary considerably, for the plant takes little nitrogen from the ground druing the kernel growth, but principally from the stem, leaves and chaff. The grain gathers about one-half of the nitrogen of the plant for itself, the leaves contribute

50 per cent of their nitrogen, the stems and chaff 40 per cent so that the grain takes up scarcely 40 per cent of its nitrogen from the ground directly. If the time of the ripening of the wheat be short due to a scarcity of rain, the amount of protein with respect to starch will be greater. The grain as before stated draws upon the other parts for its protein during ripening; this does not depent upon moisture, but the starch formation depends upon the CO_2 assimilation in the presence of water, and is therefore retarded by dry weather. The per cent of nitrogen falls off in the chaff as the ripening progresses, which shows that the nitrogen passes over to the grain. The loss amounts to 40 per cent of the total amount present. The nitrogen content of the wheat heads has an intermediate value between that of the grain and chaff respectively. The leaves lose nitrogen with much fluctuation between blossoming and ripening and the amount lost corresponds with the loss of nitrogen in the entire plant, which is due to the falling away of the blossom parts. At the same time the stems undergo a loss of nitrogen due to the steady drawing away of the nitrogen and to the loss by falling parts. A rainfall between blossoming and ripening caused a rise in the per cent of nitrogen and from this time until full ripening there is a steady decrease. The stems thus appear to play a transition role in the collection of the nitrogen in the grain. The loss which amounts to 40 per cent fluctuates considerably. In the whole plant the per cent of nitrogen is highest in the young stages, due to the protoplasm in the young cells. At the beginning of the

development of the grain the per cent of nitrogen remains practically within 0.2 per cent of constant. This shows that the nitrogen taken in at this time is about in the same proportion as the dry substance. At the beginning of growth the plant develops slowly, forming about 2 per cent of its dry matter while forming 5 to 7 per cent of its nitrogen.

The ash content is high at the beginning of the grain formation, as the hull which is first developed contains much ash. The per cent of ash remains quite constant during the ripening process. The collection of mineral matter goes forward, somewhat more rapidly than that of dry matter, in the early stages, but this deviation ceases with further growth. In the chaff a large amount of mineral matter is laid up which amount is at its maximum at ripening. A large amount of this ash appears to be silica. The ash content of the head shows quite naturally an average value of that of the chaff and grain. The leaves contain a high per cent of mineral matter which value remains quite constant. A variation in the per cent of ash occurs simultaneously with a variation in the nitrogen, which seems to indicate a connection between the ash of the plant and the assimilation of its organic food. The constancy of the ash per cent, indicates that but a small part of the mineral nutrients pass from the leaves to the grain. The ash content of the stems is also quite constant, and reaches its maximum at blossoming. The fluctuation which occurs while the stem is transferring a noticeable amount of phosphoric anhydride over to the grain, may be caused by the fact that the collection of mineral matter has not ceased, although it is possible that the stem has ceased to take up more for itself but is only passing it along to the grain. On the whole plant we find the per cent of ash greatest in the young stages, falling off to blossoming time, then becoming constant. The taking up of ash is much faster than the formation of dry matter in the young plant, but this rate declines until the blossom withers, when it becomes the same as for dry matter. The plants need for mineral matter in the early stages while quite strong is not as its need for nitrogen. Both reach their maximum at blossoming.

The per cent of phosphoric anhydride of the grain in regard to the later stages is higher at the beginning of the grain formation. This is due to the protoplasm in the berry at this stage. The amount taken in is large, although the per cent remains quite constant during growth. Compared to dry matter formed the amount is irregular. At the last stage an increase in per cent takes place. In the chaff the reduction in per cent of the phosphoric anhydride, is proportional to the reduction in absolute amount, and as the table shows, the chaff gives over to the grain more than one-half of its phosphoric anhydride. Thus the chaff plays the same part with the phosphoric anhydride in reference to the grain, as it does with the nitrogen. The heads show a content of phosphoric anhydride intermediate between that of the chaff and the grain. The leaves reach their maximum amount of phosphoric anhydride at blossoming time, after which the per cent and the amount of phosphoric anhydride, step by step decreases, the difference going to the grain. The last two trials show an increase in the per cent of phosphoric anhydride as was seen in the case of the grain. As was apparent with the nitrogen an abnormality visible in the plant may warn us to look for another in the leaves, which may be called the workshop for the working over of the plant food. While this does not explain the matter we observe that this coincidence exists. The stems show the maximum amount of phosphoric anhydride at blossoming, after which this constituent passes over to the grain. The phosphoric anhydride content of the whole plant reaches its maximum with the beginning of blossoming, and remains almost constant to the end of growth; and only in the last two trials, due to the before mentioned abnormality in the grain and leaves, does it increase again. This variation is proven by the regularity of its absolute amount during the previous period. Omitting these last two abnormal periods, we conclude the following in regard to the taking in of phosphoric anhydride: The plant in the earliest stages collects the phosphoric anhydride along with with other plant food rapidly. This continues at a varying rate and reaches its maximum at blossoming time. As was apparent with the nitrogen and other plant food the phosphoric anhydride is stored up in the early stages of growth in order that the plant may contribute it to the growing grains later.

An experiment upon growing wheat made at Michigan

Agricultural College (20) gives the per cents of protein, fat, crude fibre, ash and nitrogen free extract in wheat grains and straw, made on a series of forty-six daily cuttings of growing wheat of uniform appearance and quality, so as to secure a representative sample of the crop. Each cutting of wheat was hung in a dry, well ventilated room until it had reached the air dry condition. The kernels were then separated by rubbing out by hand, and were finally ground for analysis. The tabulated results of the analysis, which are per cents in dry material, vary as follows:

The protein varies from 36.2 per cent at the beginning, to 11.7 per cent at the end of the dough stage, then rises to about 13 per cent at the close. The ether extract has the highest value at the beginning,--2.42 per cent, falling to 1.87 per cent in the milk stage then increasing with some irregularity to 2.24 per cent. The crude fibre begins with a value of about 5 per cent, falls in value with some fluctuation through thirty-five cuttings to 1.83 per cent then rises back to about 2 per cent. The ash has its highest value at the beginning, 4.72 per cent, and decreases in value to the dough stage, 2.14 per cent, after which it remains quite constant. The nitrogen free extract begins at 51.7 per cent, increases to about 82 per cent in the dough stage, after which it remains fairly constant. In the analysis of the straw, the protein shows its highest value, 2.96 per cent, at the first cutting. It then decreases to 1.77 per cent at the thirty-sixth cutting, and then remains fairly constant to the close of the experiment. The ether extract begins at 1.66 per cent, drops to 1.06 per cent at the fourteenth cutting (milk stage), increases to 1.39 per cent at the twenty-sixth cutting, falls again to 1.06 per cent at the thirty-ninth cutting and closes at 1.12 per cent. The crude fibre begins at 41 per cent, falls to 37.44 per cent at the fifteenth cutting, then rises steadily to 48.21 per cent at the close of the experiment. The nitrogen free extract increases but slightly through the first fifteen cuttings, 48.2 per cent to 53.6 per cent, then decreases to 44.12 per cent at the close.

A study of these results shows that the grain has gathered a large part of its nitrogen and ash before the grain has begun to fill in the ripening process. The ether soluble material which is largely chlorophyll at blossoming, falls off at first but increases due to the storing up of oil in the grain. The variations show that nitrogen, ether soluble material, crude fibre and ash are all formed or stored during ripening but decrease in per cent at first because of the more rapid formation of nitrogen free extract which, however, decreases in its rate toward the last so that the per cents of the other constituents again increase.

In the straw the nitrogen appears to be gradually removed as the ripening goes on. The variations in ether soluble material first up then down, indicate that this material is passed along to the head and replaced by material from below. This takes place in a somewhat irregular manner probably due to weather conditions. The falling value in crude fibre is due to increase in nitrogen free extract while the production of fibre in the straw has practically ceased. The straw becomes more fibrous in the last stages and at the same time sugars and other carbohydrates are being transferred from the straw to the grain.

Among other articles on wheat of more recent date may be mentioned that of Thatcher and Watkins (21). This article is interesting in that it shows variations in composition between parts of the wheat head itself. The analyses were made upon wheat kernels grown from a single seed. It is shown that the outer kernels contain more nitrogen than the inner, and that the per cent of nitrogen increases in value as we pass from the top to the bottom of the spike. Brenchley and Hall (22) in 1910 have reported upon the results of some experiments with wheat at Rothhamsted Experiment Station. The wheat was cut every three days, the grain examined microscopically and then analyzed. They conclude from their analysis that the material delivered to the grain by the plant always shows a certain ratio of nitrogen to non-nitrogenous materials and ash. Variety, the kind of season and soil, will affect the character of these materials. While they say that sugar does change to starch in ripening, they affirm that this is not the principle operation in the process, but that desiccation is more important.

The variation in the phosphorus, potassium and nitrogen content of wheat grain and wheat straw has recently been reported upon by Ames (23). He shows that the composition of the wheat plant will vary in these constituents according to the composition of the soil, whether the crop be fertilized or not, the kind of fertilizer and the availability of the plant food contained therein. In general, an increase of these constituents to the soil will cause an increase in the proportion of these elements in the wheat plant. Also an addition of lime to the soil assists the assimilation of phosphorus, and an addition of phosphorus, the assimilation of nitrogen,

Stoklasa (24) found that potassium was chemically associated with the chlorophyll and shows that a certain amount of starch is produced for every part of potassium present. Ivanovska (25) has shown that phosphoric anhydride is changed over to an organic combination in the process of nutrition of the wheat plant. Phytin and nucleoprotein are formed which collect in the seed.

To sum up the results of past work on timothy; the young plant appears to furnish the most palatable and digestible hay, but the older plant yields the largest amount of dry hay. The young plants show the highest per cent of protein, moisture, ether soluble material and ash and the lowest amounts of fibre and nitrogen free extract. As the plant ripens, nitrogen appears to collect in the head and nitrogen free extract is formed within the plant cells at the same time. The plant collects its nitrogen and ash rapidly in the young stage after which the rate slowly decreases. At the same time the rate of formation of fibre, oil and extractives increases.

The work upon wheat shows that the young plant and all its parts contain more moisture and less dry matter than in the later stages. Desiccation is one of the most evident changes going on during the ripening process. In the young plant, the cells appear to be filled with protoplasm and but little carbohydrate material. This protoplasm which contains a high per cent of nitrogen is not protein, for it has been shown that about 31 per cent of the total nitrogen (2) is present as amido bodies in the young plant; but as the plant ripens, these diminish in per cent and the nitrogen is found combined as true protein.[26] Throughout the different stages, ash and total organic matter appear to vary together, apparently indicating that the mineral matter has something to do with the synthesis of organic matter. The articles by Stoklasa[24] and Ivanovska[25] are interesting in this connection. The absorption of ash, and particularly of phosphoric anhydride from the soil, appears to continue longer at a uniform rate, or to diminish in its rate of assimilation more slowly, than do the other constituents. The wheat plant thus takes up the largest part of its food, - the nitrogen, potassium oxide and phosphoric anhydride - in the young stages, and then in the ripening process, these assimilated constituents distributed about in the plant tend to collect in the grain. Coincident with this transferring of nutrients during ripening, organic material, such as sugar, is synthesized and afterwards converted into fibre, starch and cellulose, under the action of sunlight and moisture in the presence of the mineral constituents of the plant. Crude fibre and starch are probably not transferred from one part of the plant to another, but are formed in the part where they are stored. The results of the large amount of work upon wheat show quite conclusively the same facts that were shown for timothy, namely, that in the young stages the heads and straw show their highest per cent of protein, moisture, ether soluble material, and ash and their lowest per cent in fibre and nitrogen free extract. In general the principal constituents of the ash, - the potassium oxide and phosphoric anhydride, - vary in per cent in the same manner as the ash. The leaves show a rather higher per cent of ash, and the stems a higher per cent of potassium oxide than other parts of the plant in the same stage. It has been pointed out that the leaves, and possibly the green stem also, act as a workshop for the production of organic matter, and any fluctuation in organic matter observed in any part of the plant, is liable to be accompanied by a fluctuation of mineral matter in the leaves. This is in agreement with the similarity of the variations in ash and organic matter observed above. The roots (10) show their high per cent of nitrogen, ash and phosphoric anhydride, in the young plant, and these values decline as ripening progresses.

The young stages of plant life are the times for the plant to obtain its food from the soil, and the investigations show that the plant does this and little else. Apparently growth in size, for a time at least, is merely for the purpose of providing storeroom for the rapidly accumulating nourishment. It has been shown (10) that the absorption of nitrogen and ash by the roots is decidedly hindered by drought, by which we may infer that a lack of rainfall in this critical period, is a strong prediction of a poor crop. Beginning before blossoming and continuing through the season, the function of the plant becomes more and more the production of plant substance and plant fruit. The need of moisture grows steadily less, and the need of warmth and sunlight, greater. The investigations here cited throw much interesting light upon the distribution and function of the constituents in the plant, and serve to give a scientific reason for facts of plant life with which we are familiar, in a general way, through study and observation. Nearly all the investigations, however, have concerned themselves with a part of the plant only. Very little work has been made upon wheat roots, no report has been made upon timothy bulbs and no separation has been made of the timothy stalks and heads. Moreover, all of these reported results will vary according to the season and the character and treatment of the soil

The Plan of this Study.

It seems advisable therefore to undertake the analyses of a series of cuttings of timothy and wheat grown in a single season and make these analyses upon all the parts of the plant. The present work was planned with this idea in view. The timothy and wheat were harvested at certain definite stages of growth, removing the entire plant at each cutting and making separate analyses of the heads, stalks, roots, stubble and bulbs in each case. By making two or three cuttings out of the field at each stage we were able to obtain a more nearly average sample at that stage of growth. It is obviously impossible to ascertain the composition of any one plant, or single group of plants, in each stage of growth. Therefore, the analytical data obtained from each cutting must serve to indicate the composition of the other plants at that particular time, which are to be cut later and analyzed. Since we have a fairly large number of plants in each area, and since we may average the three areas cut in each series, the results ought to represent a fair average for the entire field at that particular stage.

The series of cuttings of timothy were taken from a field which lay upon a gentle slope. The strips of the field furnishing plots 1 and 2, of the various series, lay side by side near the top of the swale, while the strip furnishing the cuttings of plot 3 of the different series, lay about one hundred feet away near the bottom of the swale. The more luxuriant growth from the cuttings of plot 3 are thus explained by the location. At the beginning of the experiment, at the time of cutting series one, the areas of each plot to be harvested in the various series, were seledted and marked off by corner stakes. Each of these areas was 2 x 6 feet and lay side by side in the order to be cut, except that a foot or two of growth might be omitted to avoid a bare spot or an unusual condition of growth. In selecting these areas the aim was, of course, to secure as uniform a stand as possible in each area. The strips or plots for wheat lay a few feet from each other upon the same level, and the cuttings were selected side by side for various series of cutting, with the same view of uniformity in stand. These cuttings were also 2 x 6 feet in area. The wheat and the timothy were dut off two inches above the ground. After removal of the hay the bulbs with the stubble were dug up very carefully to obtain all of these within the given area.

The first cuttings, (Series 1), of timothy were made May 23. The young plant was eight inches to ten inches high and growing vigorously. The heads had not yet appeared, but were inclosed by the leaves of the stem. On June 6, the series 2 of cuttings, was obtained. The plant was now beginning to head, but as seen from the tables, the heads were allowed to remain with the stalks as they were not large enough to be made into a separate sample. Many new sprouts were growing out of the bulbs, and in the plot were found many dead bulbs, which were rejected. June 18 was the date for Series 3. The plant was now in full bloom, and many sprouts were found upon the bulbs. On June 30, when series 4 was harvested, the plant was just out of bloom and the seed had just been formed. Bulbs with side sprouts were still in evidence and somewhat greater in number than in the last series. In series 5, cut July 9, the seed was in the dough stage and a somewhat larger number of bulbs, having small sprouts than in series 4 were found. The last cutting of the season, Series 6, was made July 20. Plot 1 appeared to be scant in seed stalks as compared to the others. About ten per cent of the heads had dried out enough to shell. Scarcely any green heads remained. This cutting ought to have been made about three days earlier to obtain the heads in the proper condition. To correct for this condition these shelled heads were replaced by perfect heads of the same length, diameter, and degree of ripeness, from another part of the field. The stems were yellow for fully six inches below the heads. The stem leaves were practically all dead but there was some green foliage of the second growth about the bottom of the stems, varying from a few inches to eighteen inches high. Many of the large bulbs were dead with a small bulb grown out at the side, carrying a green sprout. The small bulbs were saved, but the dead bulbs were rejected as in the previous case. On March 16, 1909, a 2 x 6 foot area in each of the plots was dug up, to obtain the bulbs for the purpose of analyses, before the growth of the plant had fairly begun. A green growth from the bulbs was formed above the ground, less than two inches high and therefore below the dead stalks of the previous year. This green growth, collected with the bulbs, is tabulated as stalks and hay; the dead stalks were rejected. This data is designated in the tables as Series 0.

The first cutting of wheat was made May 23. This was winter wheat sown about October 1, 1907. At the time of this first cutting, the plants were well headed out and and were about ten to twelve inches high. At the second cutting, June 4, the wheat grains were full size and nearly all in milk, the whole plant being less green than in the first stage. The third cutting, June 11, finds the grains in the dough stage, and the whole plant changing more to the yellow appearance of the ripe plant. The fourth and last cutting finds the grain ripe and firm and whole plant quite yellow and dried out.

Preparing the Material at the Laboratory, and Methods of Analysis.

As soon as the timothy hay or wheat plant above ground was cut, it was placed in a covered tin container and weighed within thirty minutes, accurately, to 0.1 gram. The heads were cut off close, then weighed at once to 0.1 gram. This gives us the green weight of heads and stalks. The stalks include therefore, the leaves and stems, which when added to the heads constitute the hay. The stalks are now cut into short pieces, and after thorough mixing a can with wire cloth sides was filled with the same, and the gross weight recorded at once. The heads were also placed in such a can and the gross weight recorded. These cans were placed where the air could circulate freely about them, and were weighed at frequent intervals until their weight was constant. This gives us the data for the amount of moisture lost in passing from the green to the air dry condition.

The clods of dirt containing the timothy bulbs or wheat roots were soaked in water in tubs, and the bulbs or roots were then washed with two or three changes of water, so that all adhering dirt was removed. The timothy bulbs with the stubble attached, were striped of their fibrous roots and outer dead covering, and they and the wheat roots and stubble, spread out on a paper to dry until all visible water was dried off. The timothy stubble was then clipped from the bulbs; both were again spread out on paper and allowed to lie exposed to the air until the weight was constant. The wheat roots and stubble were transferred from the paper to tared wire cloth cans, and allowed to come to the air dry condition as in the case of the heads and stalks. As one object of this study is to determine what part of the plant constituents remain upon the ground, it does not appear especially necessary to separate the stubble from the roots. However, in the case of the timothy, the bulbs obviously perform a function quite distinct from other parts, so these have been analyzed by themselves.

For the analysis these air dry samples were composited so as to make one sample of each kind in each series. For example, the heads of timothy from plots 1, 2, and 3 in Series 3 were all mixed to make one sample the same mixture being made of the three samples of stalks, of stubble and of bulbs. This was done for each series of cuttings of both the timothy and the wheat so that one sample each of heads, stalks, stubble and bulbs was analyzed for each series.

These composited samples were ground until the material would pass through 1 mm. mesh sieve. To reduce the samples to this condition they were passed first through a drug mill and then through a coffee mill with the burrs set close. If a sample proved to be tough and very difficult to reduce it was dried at 100° or less when it became quite brittle and could then be ground fine. By allowing the ground material to lie exposed to the air for two or three days, it returned to its air dried condition.

Moisture was determined in duplicate samples by drying two grams of the air dry sample, in an open aluminum dish in a partial vacuum (about 60 cm.) at 80°- 90°, until the weight became constant. The material thus dried was transferred to an S. and S. extraction capsule, and after drying this to constant weight, it was extracted in a Soxhlet extractor for three days with water free ether. The loss in weight of the capsule and contents gave the weight of ether soluble material extracted from two grams. The crude fibre was determined upon the extracted residue in the regular official method (27) by boiling first with 1.25 per cent H_2SO_4 and finally with 1.25 per cent solution of NaOH. The washed fibre was collected and weighed in a gooch crucible, the fibre was then burned off and the crucible again weighed to determine the loss.

Nitrogen was determined by the Kjeldahl method (27) slightly modified by this laboratory for general nitrogen work.

One gram of the material is heated in the regular Kjeldahl flask with 25 c.c. concentrated sulphuric acid and 0.7 grams mercury. After incipient frothing is over and the mass has changed from a pasty to a more liquid condition, about seven grams of potassium sulphate are added and the heating continued until the liquid is colorless or nearly so. The flask is cooled and 25 - 30 c.c. of distilled water are used to rince down the neck and inside of the flask. The flask is then reheated for one hour, cooled and the contents diluted to 300 c.c.; 80 c.c. of a solution, containing 40 pounds of Greenbanks caustic soda and 375 grams of potassium sulphide in 30 liters of water, are added and the ammonia is distilled off into tenth normal HCl and the titration made with tenth normal ammonia using cochineal as an indicator. Nitrogen multiplied by 6.25 gives the result as protein. Ash was determined by burning two grams of the air dry material at a low heat in a muffle until thoroughly charred; then raising the heat to produce as nearly a white ash as possible, or until the weight was constant. No direct determinations of carbohydrates were made in this series of analyses. The nitrogen free extract as given in the table is the difference of the sum of the other constituents and 100 per cent.

The amount of the constituents have been given in pounds per acre upon the dry basis in order that other data may readily be compared with it. The figures used in discussing the variations are the average values for the three plots. As the cuttings of plots 1 and 2 were taken quite close to each other, they ought therefore to show about the same values for any constituent in any stage. While the data from these plots shows an approximate uniformity of growth, it will be seen that plot 1, in the young stages, shows slightly greater values than plot 2, for the constituents in all parts of the plant, while in the later stages this condition is reversed for the hay or plant above ground. There are exceptions to these statements, however, for these cuttings which represent the poorest growth have many fluctuations. The growth from plot 3 is much more vigorous than from the first two plots on account of location. In many cases the yield of the constituent under consideration equals the amount in plots 1 and 2 together. This plot gives figures which vary in a more regular manner than does the average value in many cases. This data may serve therefore to illustrate the trend of variation as pointed out in the discussion.

Discussion of the Data.

The results in the last stage in both timothy and wheat plants show losses which are due to parts of the plant, such as chaff from the heads and leaves from the stem, drying up and falling away from the plant. An additional error in the data for the wheat heads is caused by birds eating the ripe grain. Anyone who has seen the great flocks of birds which hover over the fields at harvest, will realize that this error may be considerable. Hébert (14) on account of this same difficulty omitted his analysis of the wheat heads at this stage.

TIMOTHY PLANT.

Observe the variation in the per cent of water in the green plant above ground through the different stages. (Table I.) The data shows clearly the steadily decreasing content of water in the timothy hay as the plant approaches maturity. The cause contributing to this result is found by comparing the average total green weight per acre of the hay, (Table II) with the average weight of dry matter in the hay, (Table III) through the various stages. The green weight increases but slightly after Series 2 and commences to decrease after Series 4. On the other hand, the dry substance of the hay increases steadily in amount, showing that the loss of water by drying out, takes place more rapidly than the addition of dry substance in the last stages of ripening. The moisture in the green weight of Series 0 is slightly less than Series 1. The green growth of Series 0 was somewhat wilted before the green weight could be taken, which accounts for this low result. Wilson (4) reports the young plant as having less moisture than the plant in bloom. But in his experiment the young plant was cut in October while the plant in bloom was cut in early summer. The analyses do not represent the same stand of hay, which may have something to do with the low per cent of moisture in the young plant.

A study of the weights of dry matter in the parts of the plant shows us that the most rapid increase is found in the heads, or seed bearing part. (Table III.) The timothy heads double in weight from blossoming (Series 3) to maturity (Series 6) in a period of 32 days. The bulbs of the timothy show a tendency to increase their dry matter rapidly in the first three stages, and more slowly in the fourth, fifth and sixth stage. The weight of dry matter in the bulbs harvested in March, before growth had fairly started, (Series 0) is also in accordance with this statement. The tendency of the stalks to lose in dry matter at the last stage or two, is probably due to the lower leaves on the stem, withering and falling to the ground as the plant ripens. These may contain 80 to 90 per cent of dry matter. Many such detached leaves were found in harvesting the last two series of timothy. Before preparing the stalks for drying and subsequent analysis, the stalks of hay were picked up by hand from the pile cut from the plot, the heads were removed and the green weights taken. The stalks were then cut up for drying and analysis. This left small pieces of detached dead leaves of which there were rather more in the last stage than in the preceding cuttings. The stubble gains in dry matter as the hay ripens following the changes in the stalks, except that there is less loss due to falling parts. Much of the data on the stubble recorded in this paper varies in an irregular manner, making it impossible to discuss it like the other parts of the plant.

Table IV shows that the plant increases its weight in nitrogen between two and three times from incipient growth to full ripening. Counting from Series 3, the heads and bulbs show the highest rate of gain, the stalks and stubble the least. We see from Table XI that the per cent of protein remains almost constant, so that dry matter and nitrogen are increasing in about the same ratio. The stalks are also storing up nitrogen, but at a slower rate, and with some fluctuation. In the stubble the protein percentage varies irregularly for some reason not easily explained (Table XIV). The fairly regular figures for the protein in the bulbs show that development of root system as well as plant above ground goes on steadily throughout the plant growth. The ether soluble material, which includes oil and chlorophyll, of the timothy plant (Table V) gains with sharp fluctuation between Series 2 & 4 up to ripening, falling off in amount at the last trial in the same manner as dry matter, and probably due to the same cause, i.e. - falling off of the lower dead leaves of the stem. After a slight drop in the heads at the end of blossoming (Series 4), it increases due to storing of oil in the seed. Kellner (2), Jordan (3), and Wilson (4) make no mention of this increase of oil in the hay during ripening. The per cent of ether soluble being higher at the beginning and end of growth than in the intermediate stages probably indicates an excess of chlorophyll in the young heads and the larger amount of oil in the seeds when ripe (Table XI). The stalks on the whole gain in ether soluble material until just before ripening, when the falling value in both amount and per cent (Table XII) indicates that some of this passes on to the seeds.

The bulbs rise rapidly to the maximum amount stored up, which occurs at about blossoming time, (Series 3), after which the amount remains practically constant, and the per cent falls, due to the addition of other dry matter. Table VI shows that the crude fibre increases in amount as long as the plant is increasing in weight; also that it is not passed along to other parts, but remains where it was formed. The falling of some leaves from the stem explains the actual loss in the amount in the hay in the last stage. The fibre increases in amount in the heads, but owing to the rapid storing of other constituents it falls in percentage value after blossoming (Series 4, Table XI). In the stalks the crude fibre is proportional to the growth, while below the ground, the maximum amount is reached before the storing of other constituents is complete, as is evidenced by the decreasing per cent of crude fibre in the bulbs (Table XV). The ash of the total timothy plant (Table VII) gains in amount rapidly at first and more slowly toward the last, causing a drop in the percentage values (Table X), which fact has been noted by the investigators on timothy previously cited. The falling of parts from the stem explains the loss in amount in the stalks and hay in Series 6. The storing up of the ash in the heads is more pronounced than in any other part, although the amount in the stalks increases appreciably also. The data seems to show that the bulbs and stubble pass some of their mineral constituents along to the plant above, and show a partial recovery of these constituents at full ripening

(Series 6). The nitrogen free extract will include the gums, starches, sugars, pentoses and pentosans of the plant. We should expect that these constituents will show a substantial increase as the plant developes and ripens (Table VIII). Both the amount and percentage value increases through the different stages, showing that the increase is in a greater ratio than the sum of the other constituents. All the parts of the plant increase their amount per acre, of these nitrogen free constituents, but the heads show the greatest rate of increase. The bulbs of the timothy continue to grow and store up material throughout the ripening period, for their function is to carry the life of the plant over the winter to another growing season. Just what these carbohydrates are, which are stored up in the plant, cannot be definitely stated from the results of this work. The bulbs, however, were tested with much care for starch. The results were in every case negative, with no test being given for starch in the bulbs obtained in any of the seven stages of growth. The carbohydrate material contained in the bulbs is more like gum, as was proven by the difficulty in grinding these for analysis even after drying. The ground material would pack to a glue like mass upon the burrs, making it impossible to continue the grinding until the machine had been cleaned. Starch is, of course, the principal constituent in the ripe seed, although sugars, fibres, cellulose, etc., are also present. Ladd (5) with timothy; Hebert (14), Deherain and Dupont (17) with wheat have shown that sugar, during the ripening period, is changed into starch, in the plant above the ground. Table IX on the distribution of the dry weight of the timothy plant reveals the following:- The heads and stalks gain quite uniformly in per cent of total dry substance as growth proceeds. The dry substance stored by the hay is about equally divided between the heads and the stalks. The stubble, which has gained but little dry matter, has lost in percentage value one half. The bulbs which have gained substantial amounts of dry matter through the seven stages have fallen off about one-seventh in percentage value. The dry substance of the hay crop is about 57 per cent of the total dry matter of the plant when young (Series 1), and about 69 per cent of dry matter of the mature plant.

To sum up the composition of the timothy plant as a whole, we see that the protein per cent has its highest value in the young plant, which serves well to indicate that much nitrogen should be available for the young plant to grow vigorously. Kellner (2), Jordan (3) and Ladd (5) reports show this same result. The ether soluble material (oil and chlorophyll) reaches a high value in the early stage, when we should expect a preponderance of chlorophyll. The subsequent falling and then rising in per cent as the plant developes may be explained by the progressive change in the nature of the chlorophyll and formation of the vegetable oil as the plant nears maturity. The maximum per cent of the oil is reached about twenty days before full maturity of the plant. The crude fibre varies but little in per cent which means that it is proportional to total dry substance present. If weather conditions such as cloudiness, which retard the change of sugar into starches in the plant, should occur in the last stages, the crude fibre might increase in per cent, although not increase in amount. Reports published heretofore (2) (3) report the percentage as increasing in the last stages. Taking the timothy plant as a whole the ash and the protein decrease steadily in per cent. The rapid ratio of increase in the nitrogen free extradt, is the cause of these decreasing values in the other constituents.

As was stated before, many soft, dead bulbs were found on washing the soil away from the bulbs. These were rejected and only firm bulbs saved for analysis. These firm bulbs were counted in each plot. Beginning at Series 3 many small green sprouts were found, growing from the side of the large bulbs, and in some cases these sprouts had developed far enough to show the formation of a bulb at the base. A count was made of these new sprouts, which were retained with the bulbs to be ground for analysis. In the table the average number in the three plots in each series is given, both for the large bulbs and the small sprouts. Starting with the small number of bulbs (586) in the 2 x 6 area dug up in March, the number found increases up to series 4 at about which time the plant attains its maximum size, after which the number found decreases. At the same time the number of small sprouts some with bulbs, which began to appear in Series 3 is found to increase and with some fluctuation, this number continues to increase. At the same time the number of dead bulbs rejected continues to increase. From this count we conclude that the life development of the bulbs works in the following cycle. The bulbs in the ground over winter send up the stalks in the spring, and after a time small sprouts bud out from the side of these and produce a small bulb, which furnishes the second growth of the plant in late summer, and accounts for the thickening of growth of the timothy meadow and the small immature heads which are sometimes found associated with the ripe heads at harvest. The number of these small bulbs increases steadily, and as they are formed the large parent bulb turns soft and decays. These small bulbs carry the plant through the winter.

A count was also made of the timothy heads of all plots from Series 5 and 6. Although heads were obtained and weighed from Series 4 and 5 the probable value of having the number of these did not occur to the writer until it was too late to make this count. In Table XVa is given the number of bulbs and heads for each plot in Series 5, 6 and 0 and also the average number. The number of sprouts found shooting out from the solid bulb are also enumerated for Series 5 and 6. These serve as an indication of the number of small new bulbs which are produced during the growing season to carry the plant through the winter. At the point where these sprouts grow out from the parent bulb, a new bulb forms, sometimes as many as three or four depending upon the number of sprouts. The sharp variations in the number of sprouts of the different plots, show the difficulty of drawing any exact conclusion from the data. Each series of course represents an entirely different lot of bulbs dug up, and this alone would be reason for some variation. We may also expect that many more new sprouts would be produced between July 20 and the following March, which would explain the increase in bulbs of plot 2 and 3! Or some sprouts might wither away and produce no new bulb, which would account for a decrease in number. It would have been interesting to have obtained some proof for this progressive increase or decrease in the number of bulbs, by removing and counting the bulbs and sprouts two or three times between July 20 and the end of the season. It may be noted, however, that most of the bulbs which start out the season in March apparently produce one head in the first growth of the season, as their number shows some relation to the heads produced. It has been pointed out that plant food, and nitrogen in particular, seem to be stored up quite steadily in the bulbs during the growth and ripening period. It would seem likely that most, if not all, of this addition of plant food goes to the new sprouts and bulbs after these begin to form, and that the old bulbs give up their plant food to the other growing parts as they turn soft and decay. No separation was made of old and new bulbs for analysis and no dead bulbs were analyzed at all. We lack, therefore, analytical proof of this change in the bulbs.

WHEAT PLANT.

The weight of green wheat plant per acre shows a tendency to decrease from Series 1 to Series 4, while the dry matter which it contains increases in amount (Tables XVI, XVII, XVIII.)

Thus the per cent of dry matter rises rapidly due to addition of solid substance and loss of water by drying out. This large content of moisture in the young plants has been pointed out in nearly all the publications heretofore cited, and may be regarded as a normal condition of plant growth. Again the wheat heads show a more rapid gain in dry substance than any of the other parts, gaining five to six times in weight in about 27 days. The stalks, roots and stubble have gained their maximum amount of dry matter by the time the milk stage (Series 2) is reached, after which they lose steadily to the end. A part of this loss at the last stage is due to falling chaff and leaves, as the amount for the total plant is seen to be less. The loss in amount in the stalks, roots and stubble, indicates that the dry matter is being transferred to the head as it ripens. The constituents which are transferred during these stages will be indicated as we follow the data. The young plant above ground contains about 79 per cent of the dry matter, while the ripe plant contains 86 per cent. The total wheat plant gains continuously in amount of nitrogen from the start (Table XIX). The per cent (Table XXV) is highest in the young plant showing it to be taken up the most rapidly at this stage. Liebscher (7) places nitrogen as a constituent, as first in order in amount of all the material absorbed by the plant in its young stage. As we should expect, the great gain in nitrogen occurs in the heads of the wheat plant. The percentage in value falling slightly indicates that addition of other substance is somewhat greater. Again we see from the decreasing amount and per cent in the stalks, roots and stubble (Tables XXVI and XXIX), that at least a part of the nitrogenous substance is being transferred from these parts to the head. The variations in the amount of ether soluble in the wheat plant (Table XX) are much the same in kind as for timothy. Although high at first in the total plant, due to excess of chlorophyll in the young stages, it drops quickly and again rises. The oil is apparently formed rapidly in the head after the head is formed as evidenced by the rapid rise in amount present. The drop in amount at the last stage is due to falling parts and to loss of ripe grain by birds. The falling amount per acre and percentage value of the ether soluble of the roots (Table XXIX), indicates that this material is passing on from the roots to the plant above ground. The crude fibre in the wheat plant (Table XXI) appears to increase in amount while growth is going on. It reaches its maximum in quantity in all parts of the plant about the second or milk stage, after which it remains practically constant. That the amount does not decrease in the stalks, roots and stubble, except when parts fall off, shows that crude fibre is not transferred from one part of the plant to another but remains where it was formed. The dropping off of the chaff from the heads in the last stage, accounts for its loss here at this period. Ash is absorbed by the plant (Table XXII) in considerable quantities during the growth period, but is appears to be constant during the ripening period, except for losses due to falling parts. Plot 1, of Series 2 and 3, shows this more clearly than the average. During ripening (Series 2, 3, and 4) the roots and stubble are contributing mineral constituents to the stalks and heads. The stalks store some ash during ripening, while the heads add mineral matter quite steadily. The starches, pentoses, pentosans and sugar-like bodies are included in the nitrogen free extract of the plant. (Table XXII). These constituents increase more than all the others, especially in the heads, where the increase goes on rapidly throughout the growing and ripening period. The stalks, the roots and the stubble pass on these constituents to the heads during ripening. The roots have practically ceased to contribute of their carbohydrate material by the time the dough stage (Series 3) is reached, for at this time the amount present in the plant above the stubble has become constant.

The rapid storing up of dry matter, nitrogen and ash in the young plant which has been pointed out in this report is in accordance with the work of Pierre (9), Wolff (8), Berthelot (16) and Adorjan (19). That the roots and stalks contribute nitrogen and starch forming materials to the grain while ripening, has been mentioned or proven by Deherain, Meyer (10), Dupont (17), Hebert (14), Adorjan (19) and perhaps others. Schroeder (28) working with plants and young shoots of trees, states that the nitrogen and mineral constituents are most abundant in the young growth or ends of the shoots; that the lower part of the plant or old growth loses about one-half of its phosphoric pentoxide, one-third of its potassium oxide and one-fourth of its nitrogen, to the young shoots. Thus these constituents tend to collect in the newer and upper extremity of the plant growth, (29); the wheat plant shows the analogous property in collecting these constituents in the heads. Hansteen (29) working with a few typical plants of different orders, points out that there is a correlation between different organs of a plant in regard to the distribution of the potassium and phosphorus. He points out a tendency of the plant to store its ash constituents in the leaves and blossoms. This accords with Schroeder's (28) statement that these constituents collect in the extremities of plant growth.

Considering the timothy and wheat plant side by side we find characteristics of growth and composition, which vary similarly in both plants, and others which are unlike. In both the timothy and wheat plant the moisture in the green plant is highest in the young stages and this moisture diminishes by evaporation as the plant ripens. The heads of both plants gain rapidly in dry matter during growth and ripening, the timothy heads doubling in weight and the wheat heads increasing five or six times in their weight of dry matter. The stalks, stubble and bulbs of timothy increase in weight of dry substance, both in the growth and ripening period of the plant. The wheat stalks, roots and stubble increase in weight during the growth period, and then yield up more or less of this substance during the ripening period. Nitrogen and ash are absorbed rapidly in the young stages and more slowly by the older plant. The nitrogen is used by all parts of the timothy plant, but especially by the head and bulbs. The wheat heads absorb most of the nitrogen of the plant, the other parts contributing some of this constituent to the heads. The ash in both plants accumulates, especially in the heads, but also in the stalks. The root systems of both plants yield mineral matter to the plant above ground during ripening. Ether soluble material as chlorophyll, is high in the young plant, and as oil is high in the ripe plant and particularly in the heads. Some of this material is transferred from the roots and stubble of the wheat to the plant above ground. In both plants, crude fibre is formed in all parts of the plant during growth, attaining its maximum about blossoming time. Most of the fibre is found in the stalks. Nitrogen free extract increases rapidly in the heads of both plants, and in the bulbs of the timothy, during growth and ripening. It also increases in the timothy stalks during the life of the plant. With wheat the stalks, roots and stubble pass these constituents to the head during ripening.

The Ash of Plants.

Many investigators have reported analyses of plant ashes giving their content of phosphorus and potassium. Storer (29) shows that the amount of potassium oxide obtained from different plant ashes varies considerably in amount. Some plants show a high per cent of potassium oxide. The waste parts of tobacco leaves and the stalks are used as fertilizer; the dry stalks contain about 5 per cent of "potash" (30) besides much phosphoric acid and nitrogen. These constituents are readily available as food for other crops, as is shown by the ready response in growth of the crop after their addition to the land. Wood ashes or any kind of plant ashes may be used with good results on any soil with many kinds of crops.

The value of potassium oxide for the growth of the timothy plant has been shown by Lyon and Morgan (31). Timothy was grown upon experimental fields and was followed by corn crops. The soil of the plots was a silty clay loam. Some plots received no fertilization, while other plots received potash, phosphoric acid, nitrogen or mixed fertilizer applied to the timothy. All of these fertilizers produced an increase in both the timothy and corn crops but the potash fertilizer increased the yield of ear corn more than any other simple fertilizer. The increase in the yield of hay, in every case, paid for the cost of fertilizer used. Another interesting experiment which has shown the responsiveness of timothy to potash fertilizer, was performed at the Rhode Island Station. (32). Two unmanured rotation plots, in grass for two years, were selected, one was dressed with wood ashes, the other received no treatment. When the grass had headed out, a definite area was cut from each of the plots and the plants sorted and counted. Only a "trace" of timothy plants were found on the plot which had received no treatment, but from the other plot, the number of timothy plants found was 22 - 23 per cent of the total.

Composition of the Ash of the Timothy Plant. and Discussion of the Data.

The composited samples furnishing the analytical data previously discussed, were burned in platinum dishes over a low flame until thoroughly charred, then leached and washed with distilled water on an ashless filter until all soluble material was removed; the insoluble residue containing the carbon was burned ina platinum dish in a muffle, until all carbon was removed. The solution of the soluble ash was added to the platinum dish and evaporated to dryness. The resulting recombined ash furnished the material for the samples for the determinations of potassium oxide and phosphoric anhydride. The potassium oxide was determined by the regular Lindo-Gladding method as carried out for potash in fertilizers (27). The sample used was 0.5 gram instead of 10 grams. This determination gives the water soluble potassium oxide, which is 90 to 99 per cent of the total amount present, as was proven by some preliminary work on the total potash. It is the intention of the writer to make a complete set of determinations of the total potassium oxide for comparison with water soluble potassium oxide. The phosphoric anhydride was determined, by fusing 0.5 grams of the ash with 5 grams of a mixture of potassium and sodium carbonate in molecular proportions, until the mass was uniform and action had ceased. The fused mass was dissolved from the crucible with hot water, made acid with HNO_3 and after gentle boiling for ten or fifteen minutes was cooled to room temperature, made up to 250 c.c. and 50 c.c. samples were drawn. These portions were evaporated to dryness and heated at 110°-120° for two to three hours to dehydrate silica, then taken up with water and HNO_3, and after warming the solution to 60°, Ammonium Molybdate solution was added to precipitate the phosphorus. Following the usual procedure the yellow precipitate was filtered off, washed, dissolved in ammonia, magnesia mixture added to precipitate the ammonium magnesuim phosphate, which after standing is filtered off, washed, dried, ignited and weighed as magnesium pyrophosphate.

The study of the amounts of these two constituents in the ash shows some interesting variations. The amount of potassium oxide and phosphoric anhydride removed per acre, with the crop of hay, is directly proportional to the age when cut. (Tables XXXI and XXXIII). Thus the amount of potassium oxide in the ripe hay has been increased 75 per cent above the amount in the young hay while the amount of phosphoric anhydride has increased about 130 per cent. In the ripe timothy plant, 77 per cent of the potassium oxide and 81 per cent of the phosphoric anhydride in the whole plant are carried off with the hay, the amount being respectively 61 and 41 pounds per acre. The amounts left behind with the bulbs and stubble, (18 and 9 pounds per acre respectively), are probably more available as plant food for the next crop, than they were before the timothy was grown. Nevertheless, the removal of the hay crop entails a large loss to the soil of these mineral constituents. The most remarkable point in the above data is the large increase both in amount and per cent of the phosphoric anhydride at the time of ripening of the plant. The formation of phosphorized proteids in the seed is probably the explanation. This important role, which has been shown to be played by phosphorus in the wheat grain at this time, is doubtless occurring in the timothy seed also (25). Adorjan (19) observed the same phenonenon but ascribes it to wet weather. The stalks show the same variation in potassium oxide and phosphoric anhydride as they do in the hay. The per cent remains about the same, which shows that it is taken up at the same rate as total dry matter, and is due therefore to the increase in size of the plant. In the stubble the amount of potassium oxide and phosphoric anhydride fluctuates considerably, but on the whole the amount does not vary greatly. The per cent, however, tends to increase, by which we conclude that these mineral nutrients are being passed along to the upper growing parts. This loss is replaced, however, from the roots below, and the steady drying and withering of the stubble tend to raise the value in per cent. In the bulbs the amounts of potassium oxide and phosphoric anhydride vary somewhat, but in the main the supply of these mineral substances remains constant throughout the growth period. The bulbs thus maintain their own supply of mineral matter, while contributing large amounts to the growing plant above.

If we reduce the weights of the various constituents to the basis of one ton of dry hay harvested, the later crops do not exhaust the soil, at least to the extent in potassium oxide, as the younger crops would. For one ton of dry hay obtained at the time of cutting Series 2, we would remove 43 pounds of potassium oxide and 17 pounds of phosphoric anhydride, while if cut when in the dough stage (Series 5), we would remove 27 pounds of potassium oxide and 18 pounds of phosphoric anhydride. Perhaps the most surprising result of the analysis of the ash of timothy is the large amount of this mineral food which it requires for growth. These mineral nutrients, especially the potassium oxide, are in a readily soluble form as found in the plant ash, and therefore available for plant food. One ton of air dry timothy hay, cut when nearly ripe, will contain 25 pounds of potassium oxide or 1.25 per cent, and 16 pounds each of phosphoric anhydride and nitrogen, or 0.8 per cent each. The value of these mineral nutrients in terms of the coat of fertilizer may be figured as follows:

1.25 per cent K_2O at $1.20 per unit	$1.50
0.8 per cent P_2O_5 at $1.20 per unit	.96
Fertilizer value of mineral nutrients	$2.46

The yield of this air dry hay was about two and one-half tons to the acre, therefore the fertilizer value in "potash" and "phosphoric acid" abstracted from the land was a little over $6.00 per acre. If to this is added the fertilizer value of the nitrogen the value removed amounts to $8.00 more to the acre or about $14.00. The amount of available potassium oxide in timothy hay is therefore as much or more than the same weight of ordinary mixed fertilizers contain. A whole crop of timothy hay trampled flat and turned under would contribute much available potassium oxide, and probably phosphoric anhydride to succeeding crops. But this could hardly be adopted as a practical procedure. The nitrogen required by the crop could doubtless be all replaced by occasional manuring, and if the farmer could get $5.00 or $6.00 per ton for his hay on the field his yield of two and one-half tons would bring him $12.00 - $13.00 per acre. It thus follows that timothy is not a profit yielding crop, on soil which requires reinforcement of the mineral elements to give a good yield. For a large crop of timothy hay an abundance of potassium oxide must be present in the soil. Some analyses of the ashes of timothy reported by Wolff (33) and meadow grasses by Stutzer (34) show that large amounts of potassium oxide have been stored up. It would thus appear that clay loam soils, which contain 1.5 to 4.0 per cent potassium oxide (29), ought to produce the best crops of timothy. The investigations of Morse and Curry, of New Hampshire Experiment Station (35) upon clay loam soils, show that there are large amounts of potassium oxide available in these soils, which are sufficient for large crops of grass without additional fertilization. They do not find that the crops are materially increased by the addition of potash fertilizer.

This last statement is contrary to the findings of Lyon and Morgan, who obtained substantial increases in both the timothy and in the corn crop following the timothy, by the addition of potash fertilizer to a clay loam soil. If we reduce the weights of the materials to the basis of one ton of dry hay for each cutting, we see that the amount of constituents taken from the land steadily declines in amount. The ash decreases from 261 pounds in the first stage to 131 pounds in the last stage, the potassium oxide from 61.7 pounds in the second stage to 35.2 pounds in the fifth and in the same interval the phosphoric anhydride decreases from 25.6 to 22.2 pounds. The amount of material left in the ground per ton is naturally less in every case. The roots are always a larger per cent of the total plant in its young stage than when ripe. While the amount of total and organic matter increases in amount above ground, the amount left in the ground per ton of dry hay will grow steadily less.

SUMMARY.

1.- The timothy plant takes up its plant food, - nitrogen and ash constituents,- at the most rapid rate in the young stages . It continues at a decreasing rate to absorb plant food during growth and in about the same rate as this growth proceeds. The per cent of moisture in green plant is also the highest in the young stages.

2.- The heads of timothy increase in dry matter throughout the growth and ripening period. This increase includes all the plant constituents, of which nitrogen free extract is added at the greatest rate. As the heads approach full ripening, a large increase of phosphoric anhydride occurs.

3.- The stalks of the timothy increase in dry matter during growth and ripening; this dry matter added consisting chiefly of crude fibre, nitrogen free extract, potassium oxide and phosphoric anhydride. Nitrogen and other soluble material increase during growth, but decrease during ripening.

4.- The bulbs increase in dry matter throughout the growth period, but the amount becomes constant before ripening of the hay. The material stored up is principally nitrogenous matter and nitrogen free extract. No starch is produced in the bulbs during the storing process. Potassium oxide and phosphoric anhydride are maintained at a practically constant value during growth and ripening.

5.- Large amounts of available "potash" and "phosphoric acid" are required for a crop of timothy. Timothy would not prove a profit yielding crop on land where these constituents would have to be supplied in the form of fertilizer to produce a good yield.

6.- The wheat plant also takes up its principal plant food,- nitrogenous and mineral matter,- at the greatest rate in the young stages. Absorption goes on at a decreasing rate during growth. The highest per cent of moisture in the green plant is found in the young stages.

7.- The heads of wheat gain more uniformly and rapidly in their amount of dry matter than any other part. Nitrogen free extract is produced and stored at a greater rate than any other constituent, but nitrogen, ash and other soluble matter are added in some quantity also. Fibre is practically all formed by the time of the falling blossom and remains constant to ripening.

8.- The wheat stalks contain their maximum amount of dry matter at blossoming time, after which they pass some of this material along to the ripening heads. Nitrogenous substance and nitrogen free extract, appear to be the constituents which the stalks yield up to the heads.

9.- The wheat roots and stubble increase in dry matter up to the milk stage, after which it decreases in amount, being passed along to the plant above ground. Fibre present in the roots does not decrease in amount, but nitrogenous and other soluble material, ash and nitrogen free extract, pass out of the roots into the growing plant above ground during the ripening of the heads.

This study was undertaken at the suggestion of President H. J. Waters, Manhattan, Kansas, formerly Dean of the College of Agriculture of the University of Missouri. The details of the work, as presented in this paper, were carried out under the general direction of Professor P. F. Trowbridge of the Department of Agricultural Chemistry. The author desires to acknowledge his indebtednedd to these men and also to his associates in the Department of Agricultural Chemistry.

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Table I. MOISTURE and DRY SUBSTANCE of the TIMOTHY PLANT.
Average of all plots.

No. Cutting.	Total Green Weight per Acre of the Hay. (pounds)	Total Dry Weight per Acre of the Hay. (pounds)	Per Cent Dry Substance in Green Hay.	Per Cent Moisture in Green Hay.
Series 0.	6506.20	1799.61	27.66	72.34
" 1.	17101.70	4416.37	25.82	74.18
" 2.	24688.30	6281.84	25.44	74.56
" 3.	28617.60	9862.64	34.46	65.54
" 4.	29089.80	11927.46	41.02	58.98
" 5.	25752.70	13526.50	52.52	47.48
" 6.	21671.30	12344.50	56.97	43.03

Table II

WEIGHTS OF THE GREEN TIMOTHY PLANT HARVESTED.

Designation of Cuttings.	Green Weight per Plot of Heads. (grams)	Green Weight per Plot. of Stalks. (grams)	Green Weight per Acre of Heads. (pounds)	Green Weight per Acre of Stalks. (pounds)	Total Green Weight per Acre of the Hay. (pounds)
Series 0 Plot 1.		195.00		1 506.5	1 506.5
" 0 " 2.		176.00		1 408.5	1 408.5
" 0 " 3.		442.00		3 537.2	3 537.2
Total.		813.00		6 506.2	6 506.2
Average.		271.00		2 168.7	2 168.7
Series 1 Plot 1.		535.00		4 281.4	4 281.4
" 1 " 2.		526.00		4 209.4	4 209.4
" 1 " 3.		1 076.00		8 610.9	8 610.9
Total.		2 137.00		17 101.7	17 101.7
Average.		712.30		5 700.6	5 700.6
Series 2 Plot 1.		788.00		6 306.1	6 306.1
" 2 " 2.		815.00		6 522.2	6 522.2
" 2 " 3.		1 482.00		11 860.0	11 860.0
Total.		3 085.00		24 688.3	24 688.3
Average.		1 028.30		8 229.4	8 229.4
Series 3 Plot 1.	78.60	821.40	629.0	6 573.4	7 202.4
" 3 " 2.	105.40	913.60	843.5	7 311.3	8 154.8
" 3 " 3.	163.30	1 493.70	1 306.8	11 953.6	13 260.4
Total.	347.30	3 228.70	2 779.3	25 838.3	28 617.6
Average.	115.80	1 076.20	926.4	8 612.8	9 539.2
Series 4 Plot 1.	76.90	842.10	615.4	6 739.1	7 354.5
" 4 " 2.	94.60	901.40	757.1	7 213.6	7 970.7
" 4 " 3.	185.50	1 534.50	1 484.5	12 280.1	13 764.6
Total.	357.00	3 278.00	2 857.0	26 232.8	29 089.8
Average.	119.00	1 092.70	952.3	8 744.3	9 696.6
Series 5 Plot 1.	108.50	754.50	868.3	6 038.0	~~5 169.7~~ 6906.3
" 5 " 2.	133.30	777.70	1 066.8	6 223.7	7 290.5
" 5 " 3.	231.10	1 429.90	1 849.4	11 443.1	13 292.5
Total.	472.90	2 962.10	3 784.5	23 704.8	25 752.7
Average.	157.60	987.40	1 261.5	7 901.6	~~8 584.2~~ 9163.1
Series 6 Plot 1.	95.00	574.00	760.3	4 593.5	5 353.8
" 6 " 2.	117.00	582.00	936.3	4 657.6	5 593.9
" 6 " 3.	179.00	1 161.00	1 432.5	9 291.1	10 723.6
Total.	391.00	2 317.00	3 129.1	18 542.2	21 671.3
Average.	130.30	772.30	1 043.0	6 180.7	7 223.8

Table III.

Dry Weight of the Plant Per Acre

in Pounds (Water Free)

Designation of Cuttings.	HEADS	STALKS	HAY	STUBBLE	BULBS	TOTAL PLANT
Series 0 Plot 1.		431.64	431.64		231.83	663.4
" " 0 " 2.		389.58	389.58		210.29	599.8
" " 0 " 3.		978.39	978.39		485.19	1 463.5
Total		1 799.61	1 799.61		927.31	2 726.9
Average		599.87	599.87		309.10	908.9
Series 1 Plot 1.		1 179.30	1 179.30	665.18	627.37	2 471.9
" 1 " 2.		1 153.54	1 153.54	414.78	490.37	2 058.7
" 1 " 3.		2 083.53	2 083.53	529.46	551.75	3 164.7
Total		4 416.37	4 416.37	1 609.42	1 669.49	7 695.3
Average		1 472.12	1 472.12	536.47	556.50	2 565.1
Series 2 Plot 1.		1 679.04	1 679.04	780.74	888.38	3 348.2
" 2 " 2.		1 640.95	1 640.95	682.23	812.70	3 135.9
" 2 " 3.		2 961.85	2 961.85	629.17	786.50	4 377.5
Total		6 281.84	6 281.84	2 092.14	2 487.58	10 861.6
Average		2 093.95	2 093.95	697.38	829.19	3 620.5
Series 3 Plot 1.	214.14	2 260.56	2 474.70	711.52	1 008.69	4 194.9
" 3 " 2.	281.55	2 464.92	2 746.47	770.18	875.68	4 392.3
" 3 " 3.	453.34	4 188.13	4 641.47	734.09	1 101.07	6 475.[illegible]
Total	949.03	8 913.61	9 862.64	2 215.79	2 985.44	15 063.9
Average	316.34	2 971.20	3 287.54	738.60	995.15	5 021.3
Series 4 Plot 1.	244.92	2 742.17	2 987.09	867.33	1 062.61	4 917.0
" 4 " 2.	300.97	2 931.85	3 232.82	673.19	859.03	4 765.0
" 4 " 3.	603.51	5 104.04	5 707.55	748.09	1 109.59	7 565.2
Total	1 149.40	10 778.06	11 927.46	2 288.61	3 031.23	17 247.3
Average	381.13	3 592.69	3 975.82	762.87	1 010.41	5 749.1
Series 5 Plot 1	420.75	2 983.09	3 403.84	553.95	877.98	4 835.8
" 5 " 2	508.00	3 068.30	3 576.30	766.34	977.35	5 320.0
" 5 " 3	894.07	5 652.29	6 546.36	829.08	1 344.98	8 720.4
Total	1 822.82	11 703.68	13 526.50	2 149.37	3 200.31	18 876.2
Average	607.61	3 901.23	4 508.83	716.46	1 066.77	6 292.1
Series 6 Plot 1.	492.87	2 518.12	3 010.99	875.18	1 112.78	4 999.0
" 6 " 2.	676.32	2 733.87	3 410.19	555.39	670.64	4 636.2
" 6 " 3.	978.38	4 944.94	5 923.32	855.81	1 507.27	8 286.4
Total	2 147.57	10 196.93	12 344.50	2 286.38	3 290.69	17 921.6
Average	715.86	3 398.98	4 114.83	762.13	1 096.90	5 973.9

Table IV.

Weight of the Protein

Per Acre in Pounds.

Designation of Cuttings.	HEADS	STALKS	HAY	STUBBLE	BULBS	TOTAL PLANT
Series 0 Plot 1.		71.83	71.83		10.94	82.7
" 0 " 2.		64.82	64.82		9.93	74.7
" 0 " 3.		162.80	162.80		22.90	185.7
Total		299.45	299.45		43.77	343.2
Average		99.82	99.82		14.59	114.4
Series 1 Plot 1.		119.97	119.97	18.85	12.60	151.4
" 1 " 2.		117.35	117.35	11.76	9.85	139.0
" 1 " 3.		211.95	211.95	15.00	11.09	238.0
Total		449.27	449.27	45.61	33.54	528.4
Average		149.76	149.76	15.20	11.18	176.1
Series 2 Plot 1.		134.66	134.66	15.33	14.52	164.5
" 2 " 2.		131.59	131.59	13.40	13.28	158.3
" 2 " 3.		237.55	237.55	12.36	12.86	262.8
Total		503.80	503.80	41.09	40.66	585.6
Average		167.93	167.93	13.70	13.55	195.2
Series 3 Plot 1.	25.82	120.28	146.10	11.80	19.01	176.9
" 3 " 2.	33.93	131.15	165.08	12.77	16.50	194.4
" 3 " 3.	54.63	222.84	277.47	12.17	20.75	310.4
Total	114.38	474.27	588.65	36.74	56.26	681.7
Average	38.13	158.09	196.22	12.25	18.75	227.2
Series 4 Plot 1.	27.80	129.52	157.32	18.05	25.78	201.2
" 4 " 2.	34.17	138.47	172.64	14.01	20.84	207.5
" 4. " 3.	68.50	241.07	309.57	15.57	26.91	352.1
Total	130.47	509.06	639.53	47.63	73.53	760.7
Average	43.49	169.69	213.18	15.88	24.51	253.6
Series 5 Plot 1.	47.73	124.36	172.09	11.03	25.58	208.7
" 5 " 2.	57.63	127.91	185.54	15.26	28.47	229.3
" 5 " 3.	101.41	235.63	337.04	16.51	39.18	392.7
Total	206.77	487.90	694.67	42.80	93.23	830.7
Average	68.92	162.63	231.56	14.27	31.08	276.9
Series 6 Plot 1.	58.03	96.01	154.04	24.99	51.80	230.8
" 6 " 2.	79.63	104.23	183.86	15.86	31.22	230.9
" 6 " 3.	115.21	188.54	303.75	24.44	70.17	398.4
Total	252.87	388.78	641.65	65.29	153.19	860.1
Average	84.29	129.59	213.88	21.76	51.06	286.7

Table V.

Weight of the Ether Soluble (Fat)

per acre in pounds.

Designation of Cuttings.	HEADS	STALKS	HAY	STUBBLE	BULBS	TOTAL PLANT
Series 0 Plot 1.		12.95	12.95		1.18	14.1
" 0 " 2.		11.69	11.69		1.07	12.7
" 0 " 3.		29.35	29.35		2.47	31.8
Total		53.99	53.99		4.72	58.7
Average		18.00	18.00		1.57	19.5
Series 1 Plot 1.		54.41	54.41	9.95	4.96	69.3
" 1 " 2.		53.22	53.22	6.21	3.88	63.3
" 1 " 3		96.12	96.12	7.92	4.36	108.4
Total		203.75	203.75	24.08	13.20	241.0
Average		67.92	67.92	8.03	4.40	80.3
Series 2 Plot 1.		68.41	68.41	17.56	8.07	94.0
" 2 " 2		66.87	66.87	15.34	7.38	89.6
" 2 " 3.		120.68	120.68	14.15	7.15	142.0
Total		255.96	255.96	47.05	22.60	325.6
Average		85.32	85.32	15.68	7.53	108.5
Series 3 Plot 1.	7.08	51.83	58.91	4.46	11.69	75.1
" 3 " 2	9.30	56.50	65.80	4.83	10.15	80.8
" 3 " 3	14.97	96.01	110.98	4.60	12.76	128.3
Total	31.35	204.34	235.69	13.89	34.60	284.2
Average	10.45	68.11	78.56	4.63	11.53	94.7
Series 4 Plot 1.	5.38	87.96	93.34	6.57	8.44	108.4
" 4 " 2.	6.61	94.07	100.68	5.10	6.82	112.6
" 4 " 3.	13.27	163.76	177.03	5.67	8.81	191.5
Total	25.26	345.79	371.05	17.34	24.07	412.5
Average	8.42	115.26	123.68	5.78	8.02	137.5
Series 5 Plot 1.	10.98	86.68	97.66	6.64	8.93	113.2
" 5 " 2.	13.25	89.15	102.40	9.19	9.95	121.5
" 5 " 3.	23.32	164.22	187.54	9.94	13.68	211.2
Total	47.55	340.05	387.60	25.77	32.56	445.9
Average	15.85	113.35	129.20	8.59	10.85	148.6
Series 6 Plot 1.	23.17	58.73	81.90	8.74	10.77	101.4
" 6 " 2.	31.79	63.76	95.55	5.56	6.49	107.6
" 6 " 3.	45.99	115.32	161.31	8.54	14.59	184.4
Total	100.95	237.81	338.76	22.84	31.85	393.5
Average	33.65	79.27	112.92	7.61	10.62	131.2

Table VI.

Weight of the Crude Fibre

Per Acre in Pounds

Designation of Cuttings.	HEADS	STALKS	HAY	STUBBLE	BULBS	TOTAL PLANT.
Series 0 Plot 1.		94.88	94.88		54.36	149.2
" 0 " 2.		85.63	85.63		49.31	134.9
" 0 " 3.		215.05	215.05		113.78	328.8
Total		395.56	395.56		217.45	613.0
Average		131.85	131.85		72.48	204.3
Series 1 Plot 1.		310.32	310.32	221.56	133.73	665.6
" 1 " 2.		303.55	303.55	138.17	104.52	546.2
" 1 " 3.		548.28	548.28	176.35	117.61	842.2
Total		1 162.15	1 162.15	536.08	355.86	2 054.1
Average		387.38	387.38	178.69	118.62	684.7
Series 2 Plot 1.		523.06	523.06	237.31	170.94	931.3
" 2 " 2.		511.20	511.20	207.36	156.38	874.9
" 2 " 3.		922.69	922.69	191.23	151.34	1 265.3
Total		1 956.95	1 956.95	635.90	478.66	3 071.5
Average		652.32	652.32	211.97	159.55	1 023.8
Series 3 Plot 1.	65.63	768.94	834.57	212.36	185.81	1 232.7
" 3 " 2.	86.31	838.45	924.76	229.89	161.31	1 316.0
" 3 " 3.	138.96	1 424.61	1 563.57	219.10	202.83	1 985.5
Total	290.90	3 032.00	3 322.90	661.35	549.95	4 534.2
Average	96.97	1 010.67	1 107.63	220.45	183.32	1 511.4
Series 4 Plot 1.	69.67	884.66	954.33	243.33	184.40	1 382.1
" 4 " 2.	85.63	945.86	1 031.49	188.85	149.07	1 369.4
" 4 " 3.	171.67	1 646.64	1 818.31	209.89	192.55	2 220.8
Total	326.97	3 477.16	3 804.13	642.07	526.02	4 972.2
Average	108.99	1 159.05	1 268.04	214.02	175.34	1 657.4
Series 5 Plot 1.	83.05	945.27	1 028.32	151.81	137.01	1 317.1
" 5 " 2.	100.29	972.27	1 072.56	209.99	152.52	1 435.1
" 5 " 3.	176.50	1 791.08	1 967.58	227.20	209.88	2 404.7
Total	359.84	3 708.62	4 068.46	589.00	499.41	5 156.9
Average	119.95	1 236.21	1 356.15	196.33	166.47	1 719.0
Series 6 Plot 1.	77.62	857.88	935.50	217.87	180.66	1 334.0
" 6 " 2.	106.53	931.38	1 037.91	138.26	108.88	1 285.1
" 6 " 3.	154.10	1 684.65	1 838.75	213.05	244.71	2 296.5
Total	338.25	3 473.91	3 812.16	569.18	534.25	4 915.6
Average	112.75	1 157.97	1 270.72	189.73	178.08	1 638.5

Table VII.

Weight of the Ash Per Acre
in Pounds.

Designation of Cuttings.	HEADS	STALKS	HAY	STUBBLE	BULBS	TOTAL PLANT.
Series 0 Plot 1.		37.94	37.94		11.15	49.1
" 0 " 2.		34.24	34.24		10.12	44.4
" 0 " 3.		86.00	86.00		23.34	109.3
Total		158.18	158.18		44.61	202.8
Average		52.73	52.73		14.87	67.6
Series I Plot 1.		99.16	99.16	47.93	33.87	181.0
" 1 " 2.		97.00	97.00	29.89	26.47	153.4
" 1 " 3.		175.22	175.22	38.15	29.79	243.2
Total		371.38	371.38	115.97	90.13	577.5
Average		123.79	123.79	38.66	30.04	192.5
Series 2 Plot 1.		127.78	127.78	39.32	36.16	203.3
" 2 " 2.		124.89	124.89	34.36	33.08	192.3
" 2 " 3.		225.40	225.40	31.68	32.02	289.1
Total		478.07	478.07	105.36	101.26	684.7
Average		159.36	159.36	35.12	33.75	228.2
Series 3 Plot 1.	11.60	139.33	150.93	27.00	35.50	213.4
" 3 " 2.	15.26	151.92	167.18	29.23	30.82	227.2
" 3 " 3.	24.56	258.14	282.70	27.86	38.76	349.3
Total	51.42	549.39	600.81	84.09	105.08	790.0
Average	17.14	183.13	200.27	28.03	35.03	263.3
Series 4 Plot 1.	17.24	148.30	165.54	34.91	34.56	235.0
" 4 " 2.	21.19	158.58	179.77	27.09	27.94	234.8
" 4 " 3.	42.48	276.06	318.54	30.11	36.08	384.7
Total	80.91	582.94	663.85	92.11	98.58	854.5
Average	26.97	194.31	221.28	30.70	32.86	284.9
Series 5 Plot 1.	24.63	158.60	183.23	18.14	23.14	224.5
" 5 " 2.	29.74	163.12	192.86	25.10	25.75	243.7
" 5 " 3.	52.34	300.49	352.83	27.16	35.44	415.4
Total	106.71	622.21	728.92	70.40	84.33	883.7
Average	35.57	207.40	242.97	23.47	28.11	294.6
Series 6 Plot 1.	26.50	130.87	157.37	32.23	30.88	220.5
" 6 " 2.	36.35	142.09	178.44	20.45	18.61	217.5
" 6 " 3.	52.60	256.99	309.59	31.51	41.81	382.9
Total	115.45	529.95	645.40	84.19	91.30	820.9
Average.	38.48	176.65	215.13	28.06	30.43	273.6

Table VIII

Weight of the Nitrogen Free

Extract Per Acre in Pounds

Designation of Cuttings	HEADS	STALKS	HAY	STUBBLE	BULBS	TOTAL PLANT
Series 0 Plot 1.		214.01	214.01		154.19	368.2
" 0 " 2.		193.15	193.15		139.87	333.0
" 0 " 3.		485.09	485.09		322.70	807.8
Total		892.25	892.25		616.76	1 509.0
Average		297.42	297.42		205.58	503.0
Series 1 Plot 1.		595.42	595.42	366.92	442.21	1 404.6
" 1 " 2.		582.41	582.41	228.80	345.64	1 156.9
" 1 " 3.		1 051.97	1 051.97	292.02	388.92	1 732.9
Total		2 229.80	2 229.80	887.74	1 176.77	4 294.3
Average		743.27	743.27	295.91	392.26	1 431.4
Series 2 Plot 1.		825.14	825.14	471.28	658.69	1 955.1
" 2 " 2.		806.42	806.42	411.74	602.60	1 820.8
" 2 " 3.		1 455.54	1 455.54	379.73	583.16	2 418.4
Total		3 087.10	3 087.10	1 262.75	1 844.45	6 194.3
Average		1 029.03	1 029.03	420.92	614.82	2 064.8
Series 3 Plot 1.	104.04	1 180.17	1 284.21	455.83	756.69	2 496.7
" 3 " 2.	136.77	1 286.87	1 423.64	493.53	656.90	2 574.1
" 3 " 3.	220.22	2 186.50	2 406.72	470.32	825.97	3 703.0
Total	461.03	4 653.54	5 114.57	1 419.68	2 239.56	8 773.8
Average	153.68	1 551.18	1 704.86	473.23	746.52	2 924.6
Series 4 Plot 1.	124.82	1 491.70	1 616.52	564.43	809.45	2 990.4
" 4 " 2.	153.40	1 594.90	1 748.30	438.07	654.37	2 840.7
" 4 " 3.	307.56	2 776.52	3 084.08	486.88	845.23	4 416.2
Total	585.78	5 863.12	6 448.90	1 489.38	2 309.05	10 247.3
Average	195.26	1 954.37	2 149.63	496.46	769.68	3 415.8
Series 5 Plot 1.	254.37	1 668.18	1 922.55	366.36	683.33	2 972.2
" 5 " 2.	307.10	1 715.84	2 022.94	506.73	760.67	3 290.3
" 5 " 3.	540.50	3 160.87	3 701.37	548.26	1 046.80	5 296.4
Total	1 101.97	6 544.89	7 646.86	1 421.35	2 490.80	11 559.0
Average	367.32	2 181.63	2 548.95	473.78	830.27	3 853.0
Series 6 Plot 1.	307.54	1 374.63	1 682.17	591.32	838.68	3 112.2
" 6 " 2.	422.00	1 492.40	1 914.40	375.25	505.45	2 795.1
" 6 " 3.	610.48	2 699.44	3 309.92	578.28	1 136.01	5 024.2
Total	1 340.02	5 566.47	6 906.49	1 544.85	2 480.14	10 931.5
Average	446.67	1 855.49	2 302.16	514.95	826.71	3 643.8

Table IX.

Distribution of the Dry Weight

of the Timothy Plant.

	% HEADS	% STALKS	% HAY	% STUBBLE	% BULBS
		65.06	65.06		34.94
Series 0 Plot 1.		64.94	64.94		35.06
" 0 " 2.		66.85	66.85		33.15
" 0 " 3.		65.99	65.99		34.01
Average					
Series 1 Plot 1.		47.71	47.71	26.91	25.38
" 1 " 2.		56.03	56.03	20.15	23.82
" 1 " 3.		65.84	65.84	16.73	17.43
Average		57.39	57.39	20.91	21.69
Series 2 Plot 1.		50.15	50.15	23.32	26.53
" 2 " 2.		52.33	52.33	21.76	25.92
" 2 " 3.		67.66	67.66	14.37	17.97
Average		57.83	57.83	19.26	22.90
Series 3 Plot 1.	5.11	53.89	58.99	16.96	24.05
" 3 " 2.	6.41	56.12	62.53	17.54	19.94
" 3 " 3.	7.00	64.67	71.67	11.33	17.00
Average	6.30	59.17	65.47	14.71	19.82
Series 4 Plot 1.	4.98	55.77	60.75	17.64	21.61
" 4 " 2.	6.32	61.53	67.84	14.13	18.03
" 4 " 3.	7.98	67.47	75.45	9.89	14.67
Average	6.66	62.49	69.16	13.27	17.58
Series 5 Plot 1.	8.70	61.69	70.39	11.46	18.16
" 5 " 2.	9.55	57.68	67.22	14.41	18.37
" 5 " 3.	10.25	64.82	75.07	9.51	15.42
Average	9.66	62.00	71.66	11.39	16.95
Series 6 Plot 1.	9.86	50.37	60.23	17.51	22.26
" 6 " 2.	14.59	58.97	73.56	11.98	14.47
" 6 " 3.	11.81	59.68	71.48	10.33	18.19
Average	11.98	56.90	68.88	12.76	18.36

Table X.

Composition of the Dry

Timothy Plant.

Designation of the Cuttings.	% Protein	% Ether Soluble (Fat)	% Crude Fibre	% Ash	% Nitrogen Free Extract
Series 0 Plot 1	12.48	2.13	22.49	7.40	55.50
" 0 " 2	12.46	2.13	22.49	7.39	55.53
" 0 " 3	12.69	2.17	22.47	7.47	55.20
Average	12.59	2.15	22.48	7.44	55.34
Series 1 Plot 1	6.13	2.80	26.93	7.32	56.82
" 1 " 2	6.75	3.08	26.53	7.45	56.19
" 1 " 3	7.52	3.43	26.61	7.68	54.76
Average	6.87	3.13	26.69	7.50	55.80
Series 2 Plot 1	4.91	2.81	27.82	6.07	58.39
" 2 " 2	5.05	2.86	27.90	6.13	58.06
" 2 " 3	6.00	3.25	28.90	6.60	55.25
Average	5.39	3.00	28.28	6.30	57.03
Series 3 Plot 1	4.22	1.79	29.39	5.09	59.52
" 3 " 2	4.43	1.84	29.96	5.17	58.60
" 3 " 3	4.79	1.98	30.66	5.39	57.18
Average	4.53	1.89	30.10	5.24	58.24
Series 4 Plot 1	4.09	2.20	28.11	4.78	60.82
" 4 " 2	4.35	2.36	28.74	4.93	59.62
" 4 " 3	4.65	2.53	29.36	5.09	58.38
Average	4.41	2.39	28.83	4.96	59.41
Series 5 Plot 1	4.32	2.34	27.24	4.64	61.46
" 5 " 2	4.31	2.29	26.98	4.58	62.15
" 5 " 3	4.50	2.42	27.58	4.76	60.74
Average	4.40	2.36	27.32	4.68	61.24
Series 6 Plot 1	4.62	2.03	26.69	4.41	62.26
" 6 " 2	4.98	2.32	27.72	4.69	60.29
" 6 " 3	4.80	2.23	27.71	4.62	60.63
Average	4.80	2.20	27.43	4.58	61.00

Table XI. Composition of the Dry Substance of the Timothy Heads. Average of all plots.

No. Cutting.	% Protein.	% Ether Soluble (Fat)	% Crude Fiber.	% Ash.	% Nitrogen Free Extract.
Series 0.	------	------	------	------	------
" 1.	------	------	------	------	------
" 2.	------	------	------	------	------
" 3.	12.05	3.30	30.65	5.42	48.58
" 4.	11.35	2.20	28.45	7.04	50.97
" 5.	11.34	2.61	19.74	5.86	60.45
" 6.	11.78	4.70	15.75	5.38	62.40

Table XII. Composition of the Dry Substance of the Timothy Stalks Average of all plots.

No. Cutting.	% Protein.	% Ether Soluble (Fat)	% Crude Fiber.	% Ash.	% Nitrogen Free Extract
Series 0.	16.64	3.00	21.98	8.79	49.58
" 1.	10.18	4.61	26.32	8.41	50.49
" 2.	8.02	4.08	31.15	7.61	49.14
" 3.	5.32	2.29	34.02	6.16	52.21
" 4.	4.72	3.21	32.26	5.41	54.40
" 5.	4.16	2.91	31.69	5.32	55.93
" 6.	3.81	2.33	34.07	5.20	54.59

Table XIII. Composition of the Dry Substance of the Timothy Hay. Average of all plots.

No. Cutting.	% Protein.	% Ether Soluble. (Fat)	% Crude Fiber.	% Ash.	% Nitrogen Free Extract.
Series 0.	16.64	3.00	21.98	8.79	49.58
" 1.	10.18	4.61	26.31	8.41	50.49
" 2.	8.02	4.07	31.15	7.61	49.14
" 3.	5.90	2.38	33.74	6.10	51.89
" 4.	5.27	3.13	31.95	5.54	54.12
" 5.	5.06	2.87	30.21	5.38	56.48
" 6.	5.12	2.72	31.07	5.23	55.87

Table XIV. Composition of the Dry Substance of the Timothy Stubble
Average of all plots.

No. Cutting.	% Protein.	% Ether Soluble. (Fat)	% Crude Fiber.	% Ash.	% Nitrogen. Free Extract
Series 0.	-----	-----	-----	-----	-----
" 1.	2.83	1.50	33.31	7.21	55.16
" 2.	1.96	2.25	30.40	5.04	60.36
" 3.	1.66	0.63	29.85	3.80	64.07
" 4.	2.08	0.76	28.06	4.03	65.08
" 5.	1.99	1.20	27.40	3.28	66.13
" 6.	2.86	1.00	24.90	3.68	67.57

Table XV. Composition of the Dry Substance of the Timothy Bulbs.
Average of all plots.

No. Cutting.	% Protein.	% Ether Soluble. (Fat)	% Crude Fiber.	% Ash.	% Nitrogen. Free Extract.
Series 0.	4.72	0.51	23.45	4.81	66.51
" 1.	2.01	0.79	21.32	5.40	70.49
" 2.	1.64	0.91	19.24	4.07	74.14
" 3.	1.88	1.16	18.42	3.52	75.02
" 4.	2.42	0.79	17.35	3.25	76.18
" 5.	2.91	1.02	15.61	2.64	77.83
" 6.	4.65	0.97	16.24	2.77	75.37

Table XVa. TIMOTHY BULBS, SPROUTS, and HEADS.

Cutting & Plot.	No. Bulbs found.	Average.	No. Sprouts found.	Average.	No. Heads found.	Average
Series 0, Plot 1.	407					
" 0, " 2.	301	586				
" 0, " 3.	1051					
Series 1, Plot 1.	999					
" 1, " 2.	1386	1206				
" 1, " 3.	1234					
Series 2, Plot 1.	1444					
" 2, " 2.	1172	1238				
" 2, " 3.	1099					
Series 3, Plot 1.	1467		300			
" 3, " 2.	1097	1297	200	191		
" 3, " 3.	1329		75			
Series 4, Plot 1.	1644		255			
" 4, " 2.	1089	1318	163	229		
" 4, " 3.	1223		271			
Series 5, Plot 1.	975		158		378	
" 5, " 2.	1227	1080	123	177	398	480
" 5, " 3.	1040		250		663	
Series 6, Plot 1.	1401		559		352	
" 6, " 2.	757	1176	175	314	385	439
" 6, " 3.	1370		209		580	

Table XVI. MOISTURE and DRY SUBSTANCE of the WHEAT PLANT.
Average of all plots.

No. Cutting.	Total Green Weight per Acre of the Plant Above Ground. (pounds)	Total Dry Weight per Acre of the Plant Above Ground. (pounds)	% Dry Substance in Plant Above Ground.	% Moisture in Plant Above Ground.
Series 1.	24680.30	6844.61	27.73	72.27
" 2.	23399.90	9500.18	40.60	59.40
" 3.	24408.20	11054.48	45.29	54.71
" 4.	16509.60	10476.67	63.46	36.54

Table XVII.

WEIGHTS OF THE GREEN WHEAT PLANT HARVESTED.

Designation of Cuttings.	Green Weight per Plot of Heads. (grams)	Green Weight per Plot of stalks. (grams)	Green Weight per Acre. of Heads. (pounds)	Green Weight per Acre. of stalks. (pounds)	Total Green Weight per Acre of Wheat Plant above ground (pounds)
Series 1 Plot 1.	200.00	1 290.00	1 600.54	10 323.48	11 924.0
" 1 " 2.	213.00	1 381.00	1 704.57	11 051.73	12 756.3
Total.	413.00	2 671.00	3 305.11	21 375.21	24 680.3
Average.	206.00	1 335.00	1 652.56	10 687.60	12 340.2
Series 2 Plot 1.	393.00	1 033.00	3 145.06	8 266.79	11 411.9
" 2 " 2.	401.50	1 096.50	3 213.08	8 774.96	11 988.0
Total.	794.50	2 129.50	6 358.14	17 041.75	23 399.9
Average.	397.00	1 065.00	3 179.07	8 520.87	11 699.9
Series 3 Plot 1.	548.00	1 072.00	4 385.48	8 578.89	12 964.4
" 3 " 2 .	512.50	917.50	4 101.38	7 342.48	11 443.9
Total.	1 060.50	1 989.50	8 486.86	15 921.37	24 408.2
Average.	530.20	995.00	4 243.43	7 960.68	12 204.1
Series 4 Plot 1.	427.00	616.00	3 417.15	4 929.66	8 346.8
" 4 " 2	432.50	587.50	3 461.17	4 701.58	8 162.8
Total.	859.50	1 203.50	6 878.32	9 631.24	16 509.6
Average.	429.00	601.70	3 439.16	4 815.62	8 254.8

Table XVIII

Dry Weight of the Plant

Per Acre in Pounds, (Water free)

Designation of Cuttings.	HEADS	STALKS	PLANT above ground	ROOTS AND STUBBLE	TOTAL PLANT.
Series 1 Plot 1	436.95	2 869.93	3 306.88	941.78	4 248.7
" 1 " 2	465.35	3 072.38	3 537.73	879.99	4 417.7
Total	902.30	5 942.31	6 844.61	1 821.77	8 666.4
Average	451.15	2 971.16	3 422.31	910.88	4 333.2
Series 2 Plot 1	1 128.44	3 501.81	4 630.25	1 132.99	5 763.2
" 2 " 2	1 152.86	3 717.07	4 869.93	1 057.70	5 927.6
Total	2 281.30	7 218.88	9 500.18	2 190.69	11 690.9
Average	1 140.65	3 609.44	4 750.09	1 095.34	5 845.4
Series 3 Plot 1	1 992.76	3 878.52	5 871.28	892.75	6 764.0
" 3 " 2	1 863.67	3 319.53	5 183.20	919.12	6 102.3
Total	3 856.43	7 198.05	11 054.48	1 811.87	12 866.4
Average	1 928.21	3 599.03	5 527.24	905.93	6 433.2
Series 4 Plot 1.	2 211.92	3 083.50	5 295.42	858.99	6 154.4
" 4 " 2.	2 240.41	2 940.84	5 181.25	782.55	5 963.8
Total	4 452.33	6 024.34	10 476.67	1 641.54	12 118.2
Average	2 226.16	3 012.17	5 238.33	820.77	6 059.1

Table XIX.

Weight of the Protein
Per Acre in Pounds.

Designation of Cuttings	HEADS	STALKS	PLANT ABOVE GROUND.	ROOTS AND STUBBLE	TOTAL PLANT
Series 1 Plot 1	48.81	224.71	273.52	26.46	300.0
" 1 " 2	51.98	240.57	292.55	24.73	317.3
Total	100.79	465.28	566.07	51.19	617.3
Average	50.39	232.64	283.03	25.60	308.6
Series 2 Plot 1	107.77	182.44	290.21	27.87	318.1
" 2 " 2	110.10	193.66	303.76	26.02	329.8
Total	217.87	376.10	593.97	53.89	647.9
Average	108.93	188.05	296.98	26.95	323.9
Series 3 Plot 1	200.47	188.50	388.97	19.10	408.1
" 3 " 2	187.49	161.33	348.82	19.67	368.5
Total	387.96	349.83	737.79	38.77	776.6
Average	193.98	174.91	368.89	19.39	388.3
Series 4 Plot 1.	245.08	99.60	344.68	16.92	361.6
" 4 " 2.	248.24	94.99	343.23	15.42	358.7
Total	493.32	194.59	687.91	32.34	720.3
Average	246.66	97.29	343.95	16.17	360.1

Table XX.

Weight of the Ether Soluble

Per Acre in Pounds.

Designation of Cuttings.	HEADS	STALKS	PLANT ABOVE GROUND.	ROOTS AND STUBBLE	TOTAL PLA
Series 1 Plot 1	7.73	90.69	98.42	20.16	118.6
" 1 " 2	8.24	97.09	105.33	18.83	124.2
Total	15.97	187.78	203.75	38.99	242.7
Average	7.99	93.89	101.88	19.49	121.4
Series 2 Plot 1	13.43	48.67	62.10	23.23	85.3
" 2 " 2	13.72	51.67	65.39	21.68	87.1
Total	27.15	100.34	127.49	44.91	172.4
Average	13.58	50.17	63.75	22.45	86.2
Series 3 Plot 1	88.68	192.76	281.44	10.71	292.2
" 3 " 2	82.93	164.98	247.91	11.03	258.9
Total	171.61	357.74	529.35	21.74	551.1
Average	85.80	178.87	264.67	10.87	275.5
Series 4 Plot 1	77.19	74.93	152.12	6.36	158.5
" 4 " 2	78.19	71.46	149.65	5.79	155.4
Total	155.38	146.39	301.77	12.15	313.9
Average	77.69	73.19	150.88	6.08	156.9

Table XXI.

Weight of the Crude Fibre

Per Acre in Pounds.

Designation of Cuttings.	HEADS	STALKS	PLANT ABOVE GROUND	ROOTS AND STUBBLE	TOTAL PLANT.
Series 1 Plot 1.	136.28	920.10	1 056.38	326.14	1 382.5
" 1 " 2.	145.14	985.00	1 130.14	304.74	1 434.9
Total	281.42	1 905.10	2 186.52	630.88	2 817.4
Average	140.71	952.55	1 093.26	315.44	1 408.7
Series 2 Plot 1	237.88	1 221.78	1 459.66	364.48	1 824.1
" 2 " 2	243.02	1 296.88	1 539.90	340.26	1 880.2
Total	480.90	2 518.66	2 999.56	704.74	3 704.3
Average	240.45	1 259.33	1 499.78	352.37	1 852.2
Series 3 Plot 1.	248.50	1 378.43	1 626.93	324.96	1 951.9
" 3 " 2.	232.39	1 179.76	1 412.15	334.56	1 746.7
Total	480.89	2 558.19	3 039.08	659.52	3 698.6
Average	240.45	1 279.09	1 519.54	329.76	1 849.3
Series 4 Plot 1.	227.38	1 235.25	1 462.63	345.06	1 807.7
" 4 " 2.	230.31	1 178.10	1 408.41	314.35	1 722.8
Total	457.70	2 413.35	2 871.05	659.40	3 530.5
Average	228.85	1 206.68	1 435.53	329.70	1 765.2

Table XXII

Weight of the Ash
Per Acre in Pounds.

Designation of Cuttings.	HEADS	STALKS	PLANT ABOVE GROUND	ROOTS AND STUBBLE	TOTAL PLANT.
Series 1 Plot 1	22.02	256.00	278.02	108.12	386.1
" 1 " 2	23.46	274.05	297.51	101.02	398.5
Total	45.48	530.05	575.53	209.14	784.7
Average	22.74	265.03	287.77	104.57	392.3
Series 2 Plot 1	79.44	285.75	365.19	195.21	560.4
" 2 " 2	81.16	303.31	384.47	182.25	566.7
Total	160.60	589.06	749.66	377.46	1 127.1
Average	80.30	294.53	374.83	188.73	563.6
Series 3 Plot 1	108.20	343.64	451.84	108.56	560.4
" 3 " 2	101.20	294.11	395.31	111.76	507.1
Total	209.40	637.75	847.15	220.32	1 067.5
Average	104.70	318.87	423.57	110.16	533.7
Series 4 Plot 1	109.49	259.32	368.81	81.78	450.6
" 4 " 2	110.90	247.33	358.23	74.49	432.7
Total	220.39	506.65	727.04	156.27	883.3
Average	110.19	253.33	363.52	78.14	441.7

Table XXIII.

Weight of the Nitrogen Free Extract

Per Acre in Pounds.

Designation of Cuttings.	HEADS	STALKS	PLANT ABOVE GROUND	ROOTS AND STUBBLE	TOTAL PLANT.
Series 1 Plot 1	222.10	1 378.43	1 600.53	460.90	2 061.4
" 1 " 2	236.54	1 475.66	1 712.20	430.67	2 142.9
Total	458.64	2 854.09	3 312.73	891.57	4 204.3
Average	229.32	1 427.04	1 656.36	445.79	2 102.2
Series 2 Plot 1	689.93	1 763.16	2 453.09	522.19	2 975.3
" 2 " 2	704.86	1 871.54	2 576.40	487.50	3 063.9
Total	1 394.79	3 634.70	5 029.49	1 009.69	6 039.2
Average	697.39	1 817.35	2 514.74	504.85	3 019.6
Series 3 Plot 1	1 346.91	1 775.20	3 122.11	429.41	3 551.5
" 3 " 2	1 259.65	1 519.35	2 779.00	442.10	3 221.1
Total	2 606.56	3 294.55	5 901.11	871.51	6 772.6
Average	1 303.28	1 647.28	2 950.56	435.75	3 386.3
Series 4 Plot 1	1 552.77	1 414.40	2 967.17	408.88	3 376.1
" 4 " 2	1 572.77	1 348.96	2 921.73	372.49	3 294.2
Total	3 125.54	2 763.36	5 888.90	781.37	6 670.3
Average	1 562.77	1 381.68	2 944.45	390.68	3 335.1

Table XXIV.

Distribution of the Dry Weight of the Wheat Plant

Designation of Cuttings.	% HEADS	% STALKS	% PLANT ABOVE GROUND	% ROOTS & STUBBLE
Series 1 Plot 1	10.28	67.55	77.83	22.17
" 1 " 2	10.53	69.55	80.08	19.92
Average	10.41	68.57	78.98	21.01
Series 2 Plot 1	19.58	60.76	80.34	19.66
" 2 " 2	19.45	62.71	82.16	17.84
Average	19.51	61.75	81.26	18.74
Series 3 Plot 1	29.46	57.34	86.80	13.20
" 3 " 2	30.54	54.40	84.94	15.06
Average	29.97	55.94	85.92	14.08
Series 4 Plot 1	35.94	50.10	86.04	13.96
" 4 " 2	37.57	49.31	86.88	13.12
Average	36.74	49.71	86.45	13.55

Table XXV. Composition of the Dry Wheat Plant.

Designation of Cuttings.		% Protein.	% Ether Soluble. (Fat)	% Crude Fiber.	% Ash.	% Nitrogen Free Extract
Series 1,	Plot 1.	7.06	2.79	32.54	9.09	48.52
" ,	" 2.	7.18	2.81	32.48	9.02	48.51
	Average.	7.12	2.80	32.51	9.05	48.51
Series 2,	Plot 1.	5.52	1.48	31.65	9.72	51.63
" 2,	" 2.	5.56	1.47	31.72	9.56	51.69
	Average.	5.54	1.47	31.69	9.64	51.66
Series 3,	Plot 1.	6.03	4.32	28.86	8.29	52.51
" 3,	" 2.	6.04	4.24	28.62	8.31	52.78
	Average.	6.04	4.28	28.75	8.30	52.64
Series 4,	Plot 1.	5.88	2.58	29.37	7.32	54.86
" 4,	" 2.	6.01	2.61	28.89	7.26	55.24
	Average.	5.94	2.59	29.13	7.29	55.04

Table XXVI. Composition of the Dry Substance of the Wheat Heads
Average of all plots.

No. Cutting.	% Protein.	% Ether Soluble. (Fat)	% Crude Fiber.	% Ash.	% Nitrogen Free Extract
Series 1.	11.17	1.77	31.19	5.04	50.83
" 2.	9.55	1.19	21.08	7.04	61.14
" 3.	10.06	4.45	12.47	5.43	67.59
" 4.	11.08	3.49	10.28	4.95	70.20

Table XXVII. Composition of the Dry Substance of the Wheat Stalks.
Average of all plots.

No. Cutting.	% Protein.	% Ether Soluble. (Fat)	% Crude Fiber.	% Ash.	% Nitrogen Free Extract
Series 1.	7.83	3.16	32.06	8.92	48.03
" 2.	5.21	1.39	34.89	8.16	50.35
" 3.	4.86	4.97	35.54	8.86	45.77
" 4.	3.23	2.43	40.06	8.41	45.87

Table XXVIII. Composition of the Dry Substance of the Wheat Plant.
Above Ground. Average of all plots.

No. Cutting.	% Protein.	% Ether Soluble. (Fat)	% Crude Fiber.	% Ash.	% Nitrogen. Free Extract
Series 1.	8.27	2.98	31.95	8.41	48.40
" 2.	6.25	1.34	31.57	7.89	52.94
" 3.	6.67	4.79	27.49	7.66	53.38
" 4.	6.57	2.88	27.40	6.94	56.21

Table XXIX. Composition of the Dry Substance of the Wheat
Roots and Stubble. Average of all plots.

No. Cutting.	% Protein.	% Ether Soluble. (Fat)	% Crude Fiber.	% Ash.	% Nitrogen Free Extract
Series 1.	2.81	2.14	34.63	11.48	48.94
" 2.	2.46	2.05	32.17	17.23	46.09
" 3.	2.14	1.20	36.40	12.16	48.10
" 4.	1.97	0.74	40.17	9.52	47.60

Table XXX. Per Cents of K_2O in Parts of TIMOTHY PLANT.
Average of all plots.

No. Cutting.	% K_2O in ash of heads.	% K_2O in ash of stalks.	% K_2O in ash of stubble.	% K_2O in ash of bulbs.
Series 1.		29.31	25.03	
" 2.		28.44	15.99	40.65
" 3.		27.30	17.32	39.30
" 4.		27.23	21.23	42.57
" 5.	21.36	25.93	25.40	42.76
" 6.	14.58		22.92	42.33

Table XXXI. Weights of K_2O in Parts of TIMOTHY PLANT.
Average of all plots.

No. Cutting.	Wgt. of K_2O per acre in the heads. (pounds)	Wgt. of K_2O per acre in the stalks. (pounds)	Wgt. of K_2O per acre in the stubble. (pounds)	Wgt. of K_2O per acre in the bulbs. (pounds)	Wgt. of K_2O per acre in total plant. (pounds)
Series 1.		36.28	9.68		
" 2.		45.32	5.62	13.72	64.66
" 3.		49.99	4.85	13.77	68.61#
" 4.		52.91	6.52	13.99	73.42#
" 5.	7.60	53.77	5.96	12.02	79.35
" 6.	5.61		6.43	12.88	

Does not include the weight of K_2O in the heads.

Table XXXII. Per Cents of P_2O_5 in Parts of TIMOTHY PLANT. Average of all plots.

No. Cutting.	% P_2O_5 in ash of heads.	% P_2O_5 in ash of stalks.	% P_2O_5 in ash of stubble.	% P_2O_5 in ash of bulbs.
Series 1.		12.70	6.83	
" 2.		11.20	11.85	14.48
" 3.		10.34	10.15	14.91
" 4.		12.54	13.57	18.68
" 5.	20.42	16.26	12.81	22.00
" 6.	20.75		16.21	18.73

Table XXXIII. Weights of P_2O_5 in Parts of TIMOTHY PLANT. Average of all plots.

No. Cutting.	Wgt. of P_2O_5 per acre in the heads. (pounds)	Wgt. of P_2O_5 per acre in the stalks. (pounds)	Wgt. of P_2O_5 per acre in the stubble. (pounds)	Wgt. of P_2O_5 per acre in the bulbs. (pounds)	Wgt. of P_2O_5 per acre in total plant. (pounds)
Series 1.		15.72	2.64		
" 2.		17.85	4.16	4.89	26.90
" 3.		18.94	2.85	5.22	27.01#
" 4.		24.37	4.17	6.14	34.68#
" 5.	7.26	33.72	3.01	6.18	50.17
" 6.	7.98		4.55	5.70	

\# Does not include the weight of P_2O_5 in the heads.

Table XXXIV. Weights and Percentages of K_2O carried off with the TIMOTHY HAY and left on the field. Average of all plots.

No. Cutting.	Wgt.of K_2O per acre in the hay. (pounds)	Wgt.of K_2O per acre in the bulbs and stubble. (pounds)	Wgt.of K_2O per acre in the total plant. (pounds)	% of K_2O of plant in the hay.	% of K_2O of plant in the bulbs and stubble.
Series 1.	36.28				
" 2.	45.32	19.34	64.66	70.09	29.91
" 3.	49.99#	18.62	68.61#	72.86	27.14
" 4.	52.91#	20.51	73.42#	72.07	27.93
" 5.	61.37	17.98	79.35	77.34	22.66
" 6.		19.31			

Does not include the weight of K_2O in the heads.

Table XXXV. Weights and Percentages of P_2O_5 carried off with the TIMOTHY HAY and left on the field. Average of all plots.

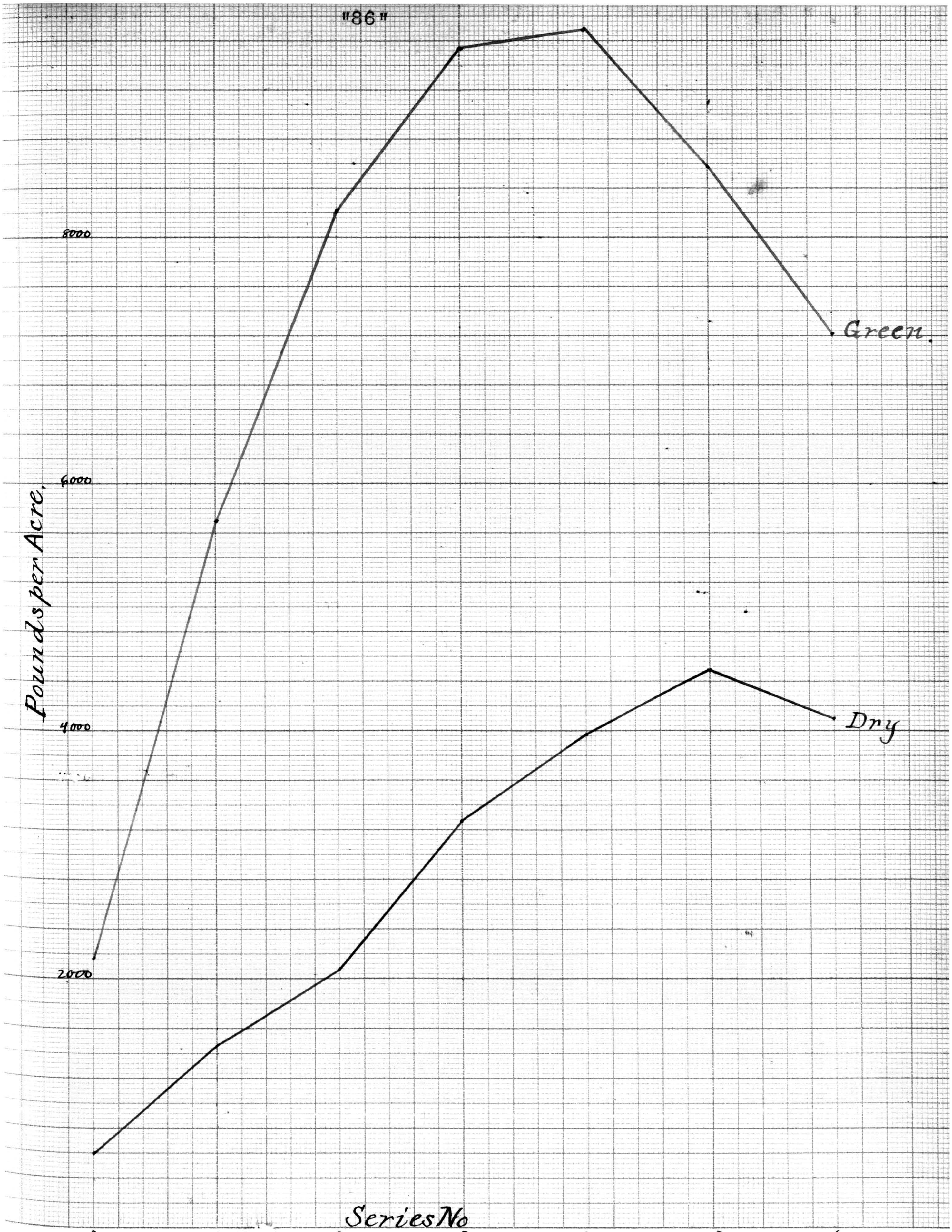
No. Cutting.	Wgt.of P_2O_5 per acre in the hay. (pounds)	Wgt.of P_2O_5 per acre in the bulbs and stubble. (pounds)	Wgt.of P_2O_5 per acre in the total plant. (pounds)	% of P_2O_5 of plant in the hay.	% of P_2O_5 of plant in the bulbs. and stubble.
Series 1.	15.72				
" 2.	17.85	9.05	26.90	66.36	33.64
" 3.	18.94#	8.07	27.01#	70.12	29.88
" 4.	24.37#	10.31	34.68#	70.27	29.73
" 5.	40.98	9.19	50.17	81.68	18.32
" 6.		10.25			

Does not include the weight of P_2O_5 in the heads.

Table XXXVI. Weight of CONSTITUENTS per Ton of Dry TIMOTHY HAY.

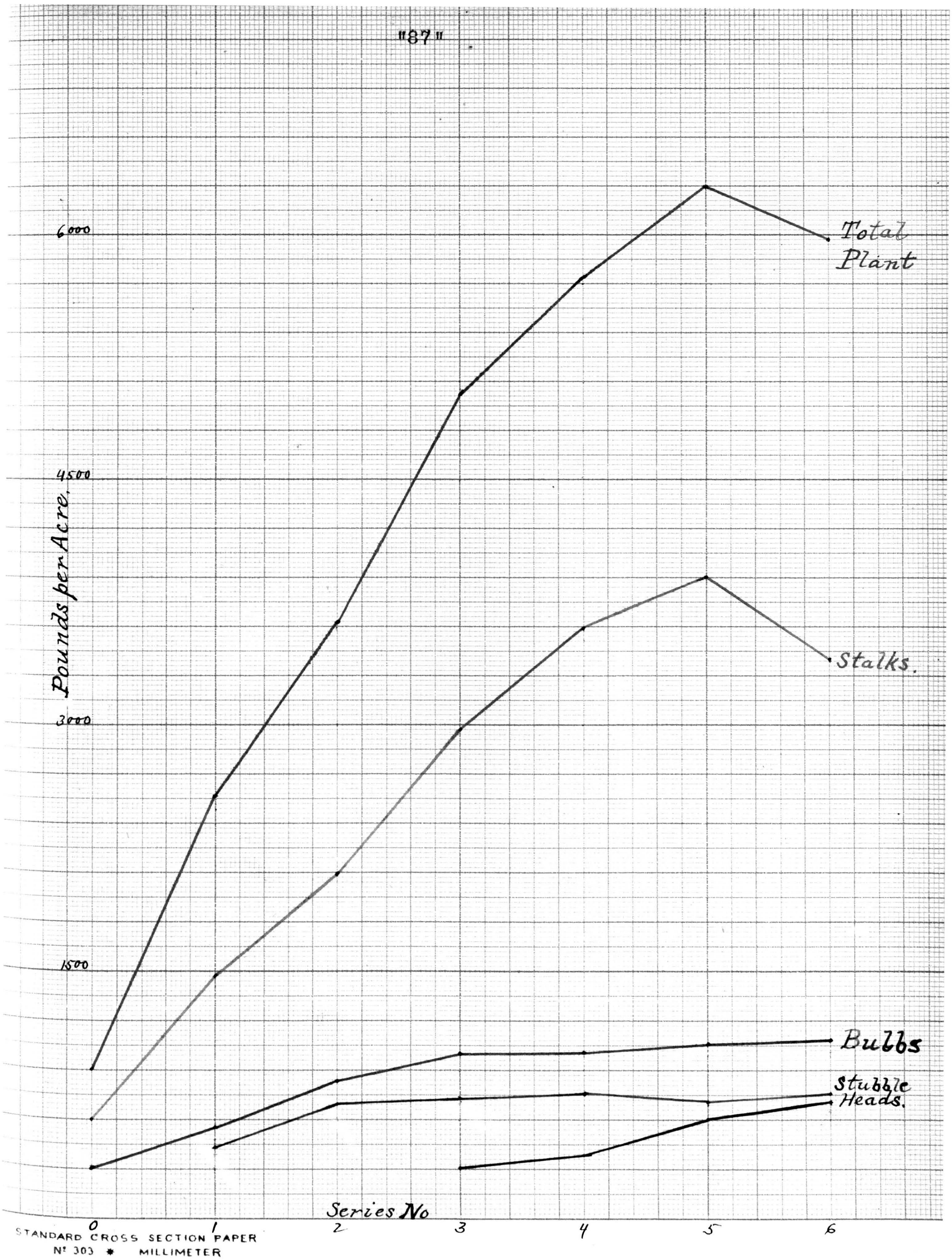
	Series 1	Series 2.	Series 3.	Series 4.	Series 5.	Series 6.
Total weight of dry Timothy Plant yielding one ton of dry hay,	3484.9	3458.1	3167.7#	2987.2#	2791.0	
Subtracting one ton of dry hay,	2000.0	2000.0	2000.0#	2000.0#	2000.0	
Total weight of dry bulbs and stubble found per ton of dry hay,	1484.9	1458.1	1167.7	987.2	791.0	
Weight of Ash of total Timothy Plant which yields one ton of dry hay,	261.51	218.00	165.69#	143.56#	130.66#	
Weight of Ash in one ton of dry hay,	168.17	152.22	123.24#	108.17#	107.78	
Weight of Ash of bulbs and stubble of plant yielding one ton of dry hay,	93.34	65.78	42.45	35.39	22.88	28.43
Weight of K_2O of Timothy Plant yielding one ton of dry hay,		61.76	46.22#	40.88#	35.20	
Weight of K_2O in one ton of dry hay,	49.29	43.29	33.69#	29.46#	27.22	
Weight of K_2O in bulbs and stubble of plant yielding one ton of dry hay,		18.47	12.53	11.42	7.98	9.39
Weight of P_2O_5 of Timothy Plant yielding one ton of dry hay,		25.69	18.18#	19.31#	22.26	
Weight of P_2O_5 in one ton of dry hay,	21.36	17.05	12.75#	13.57#	18.18	
Weight of P_2O_5 in bulbs and stubble of plant yielding one ton of dry hay,		8.64	5.43	5.74	4.08	4.98

Figures do not include the heads of Timothy.



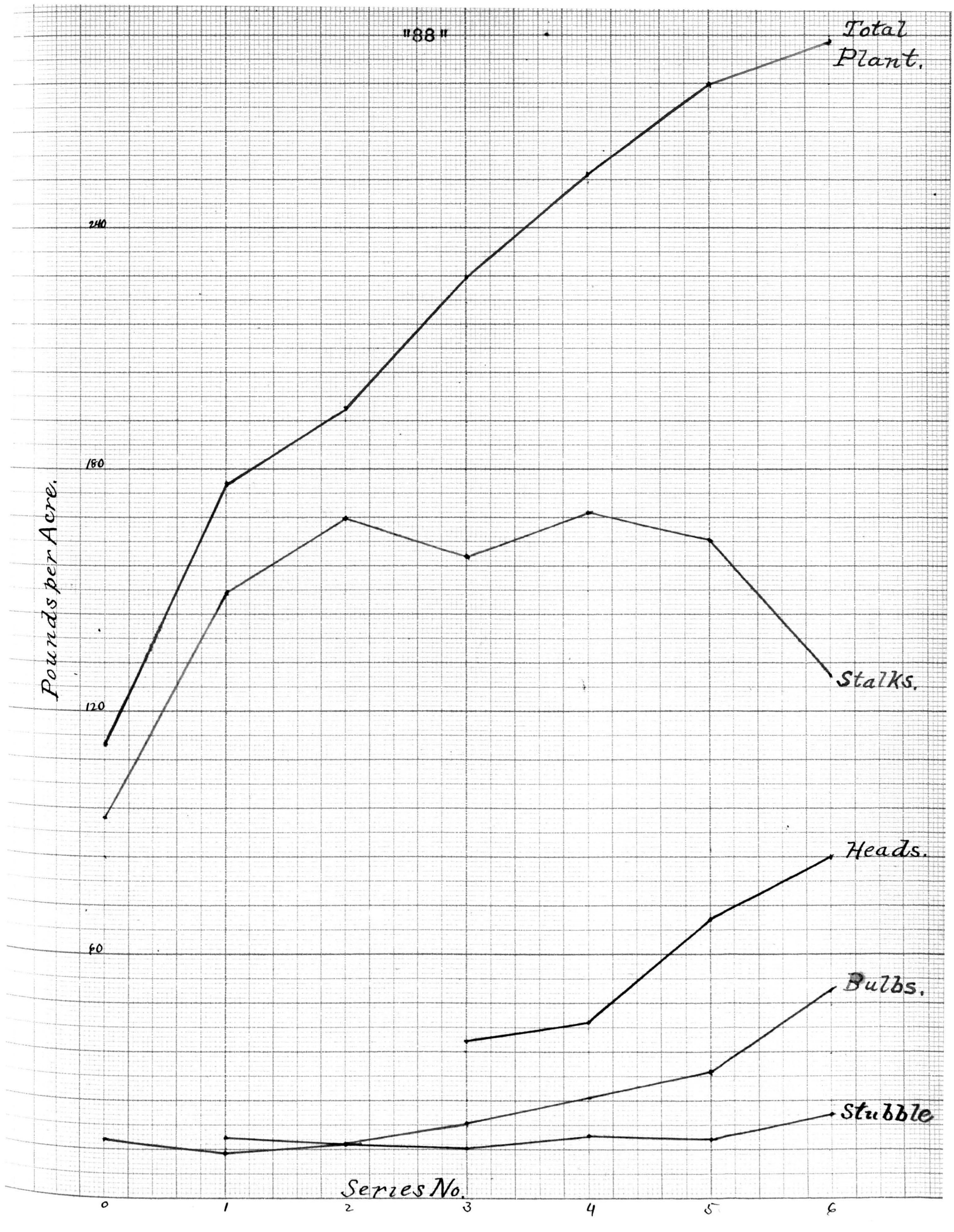
Timothy Plant above ground (Hay.)

Tables II and III.



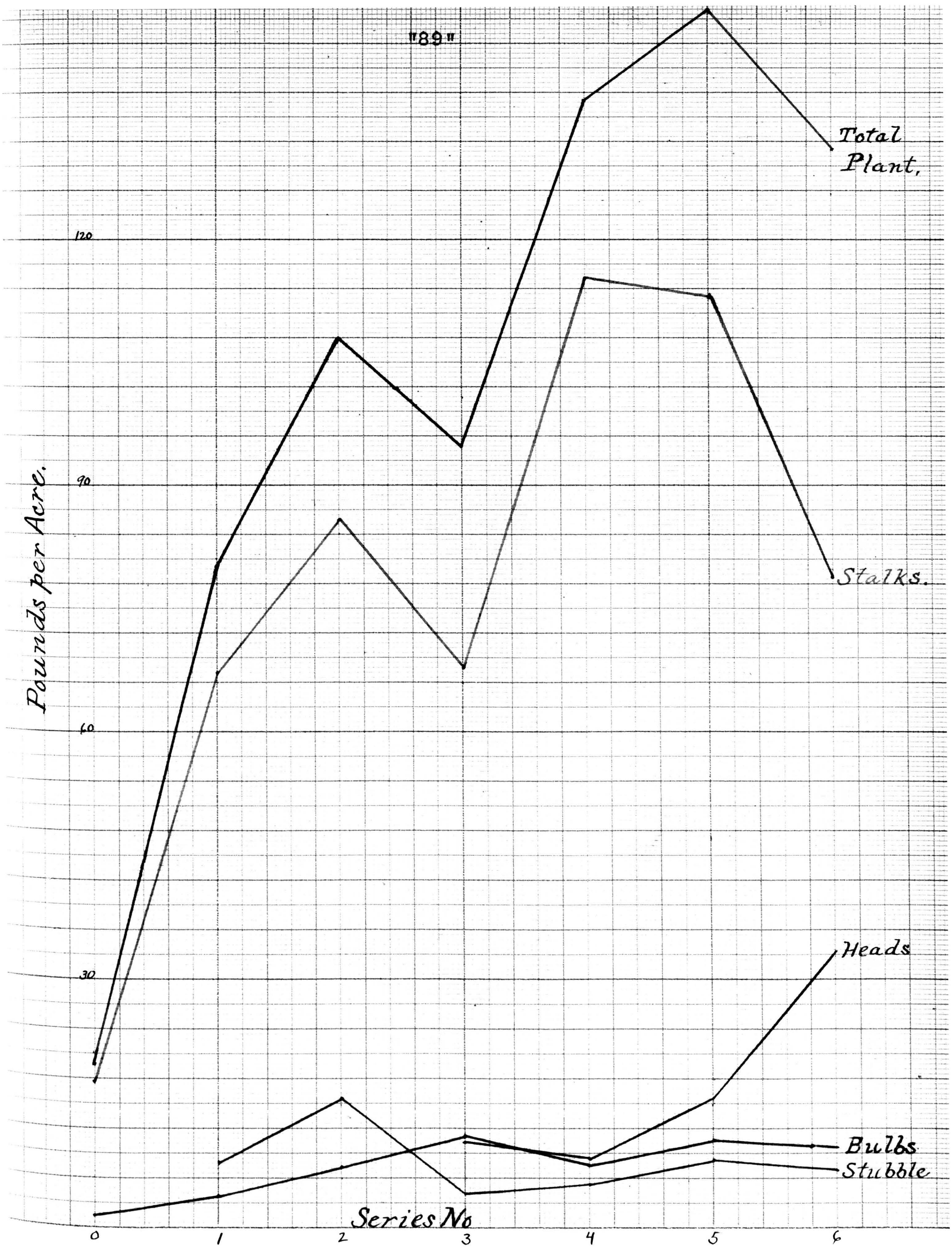
Timothy Plant — Dry Substance.

Table III.



Timothy Plant — Protein.

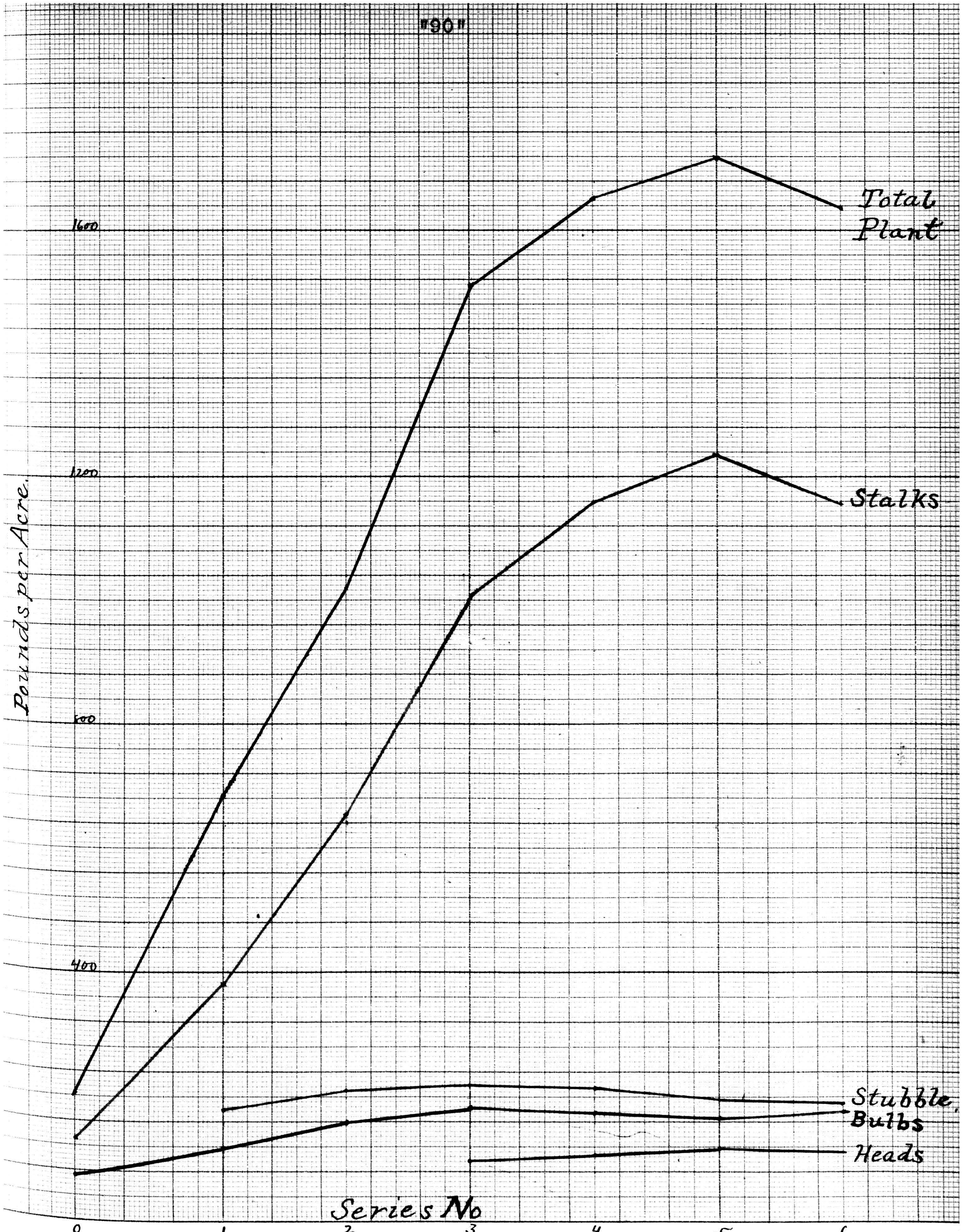
Table IV.



Timothy Plant — Ether Soluble.

Table V.

"90"



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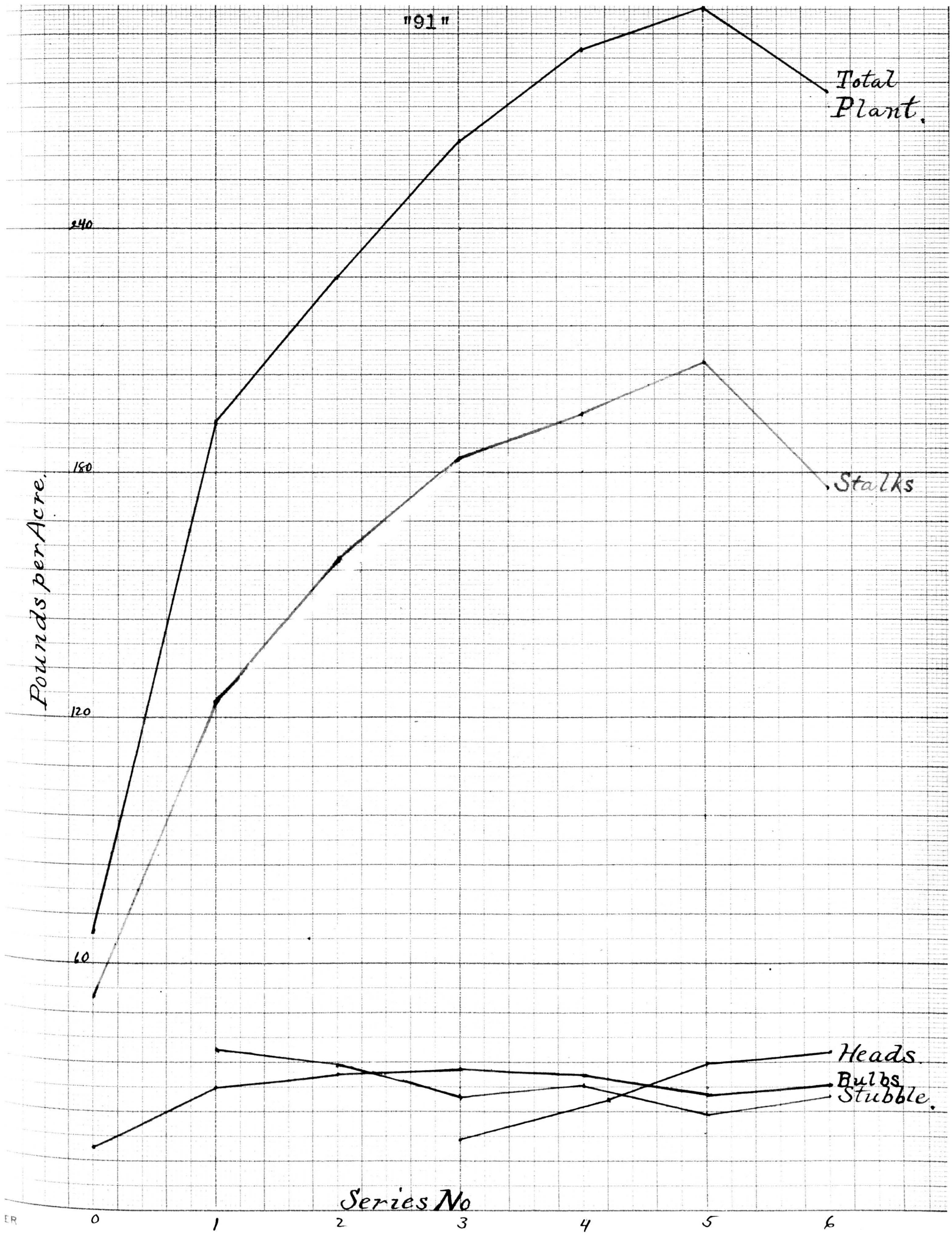
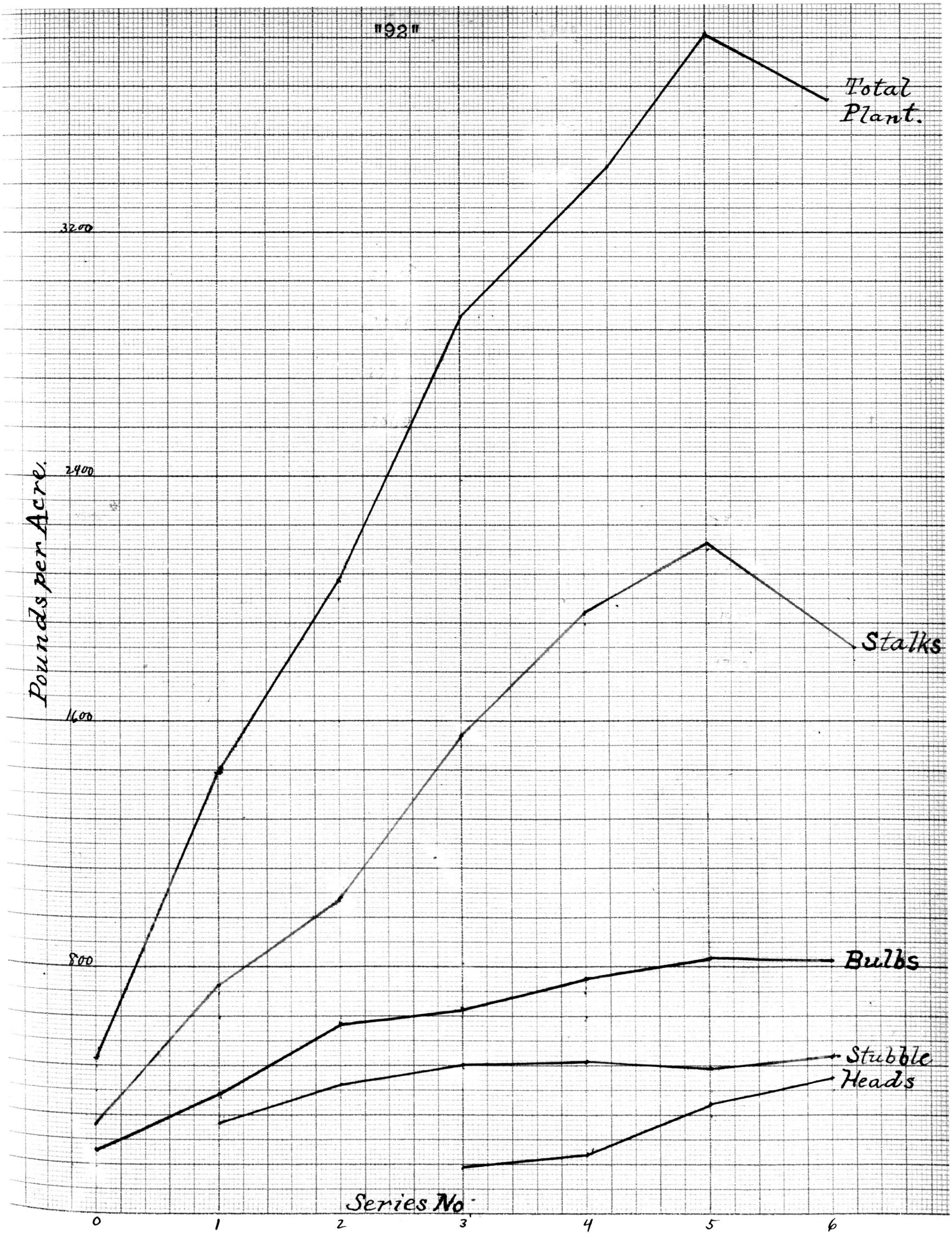
Timothy Plant ~ Crude Fiber.

Table VI.



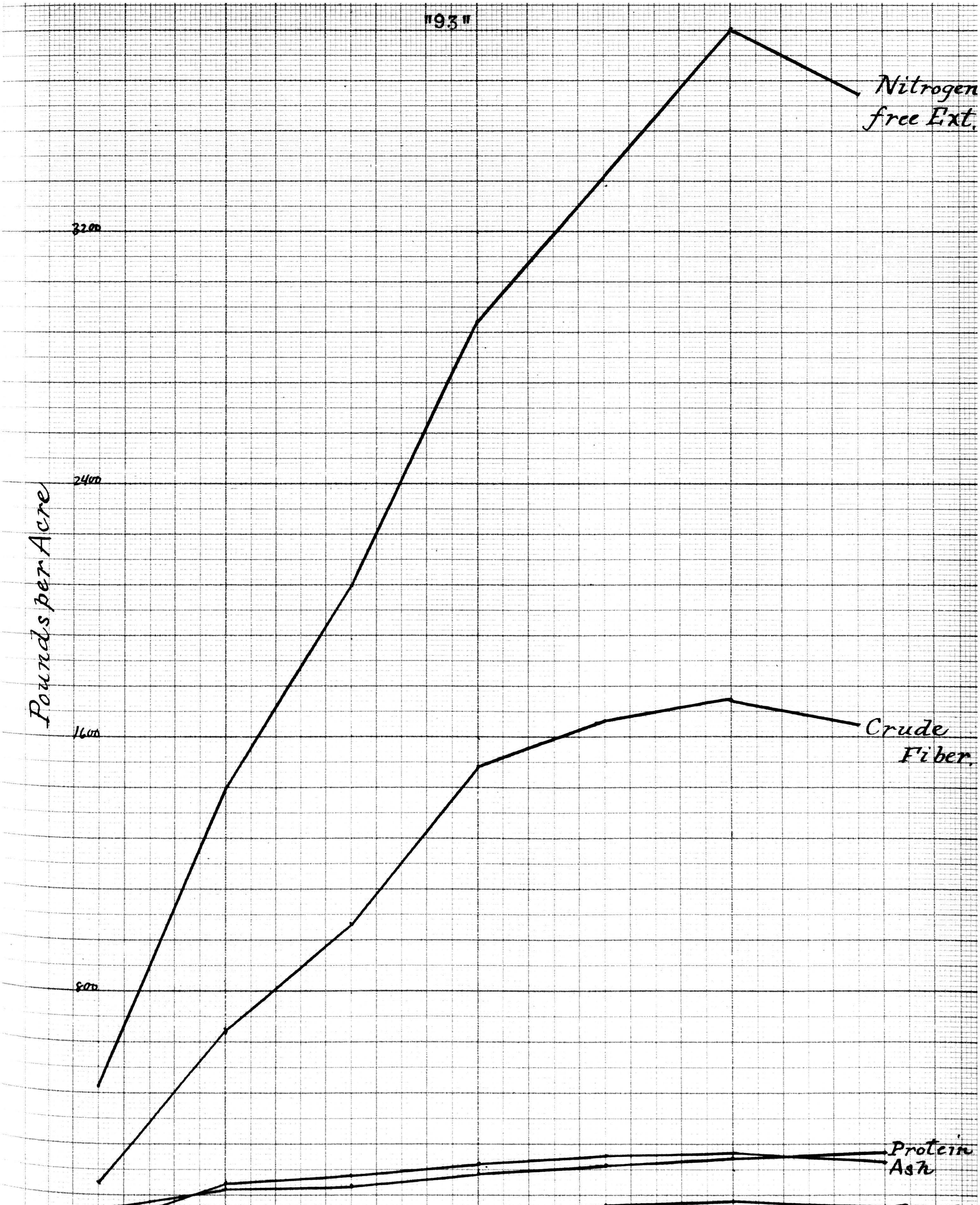
Timothy Plant ~ Ash.

Table VII.



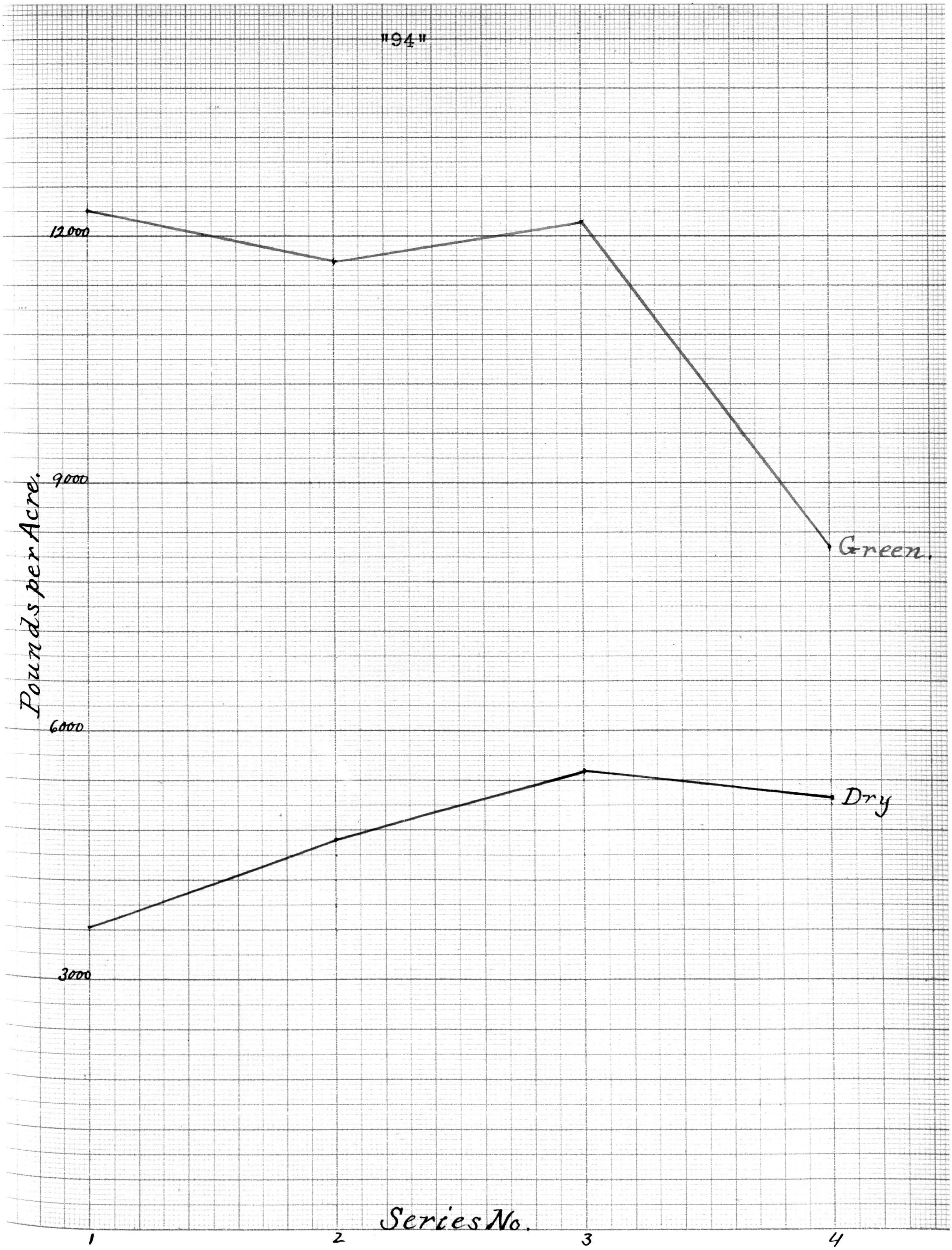
Timothy Plant ~ Nitrogen-free Extract

Table VIII.



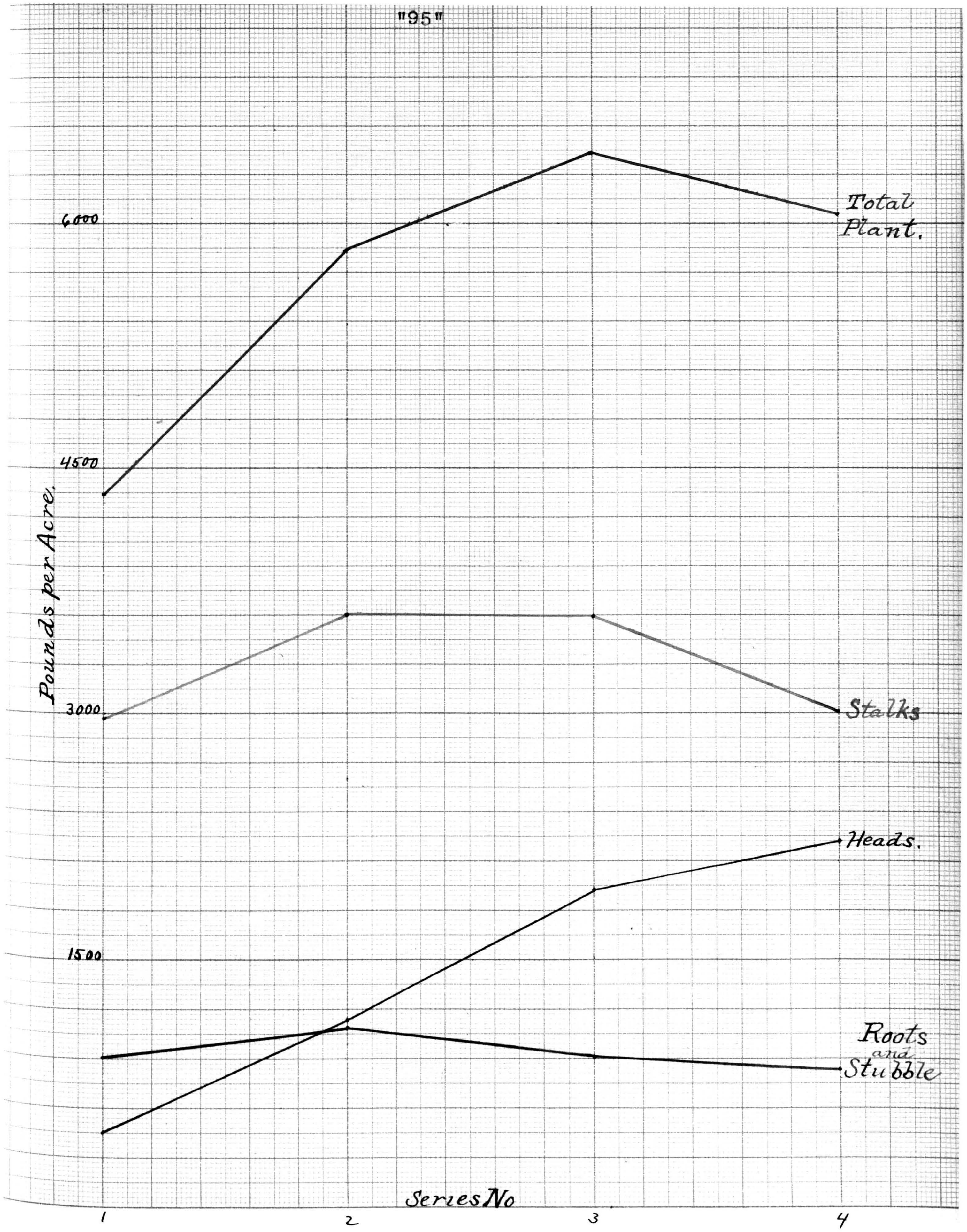
Timothy Plant ~ Constituents of entire plant,

Tables IV to VIII.



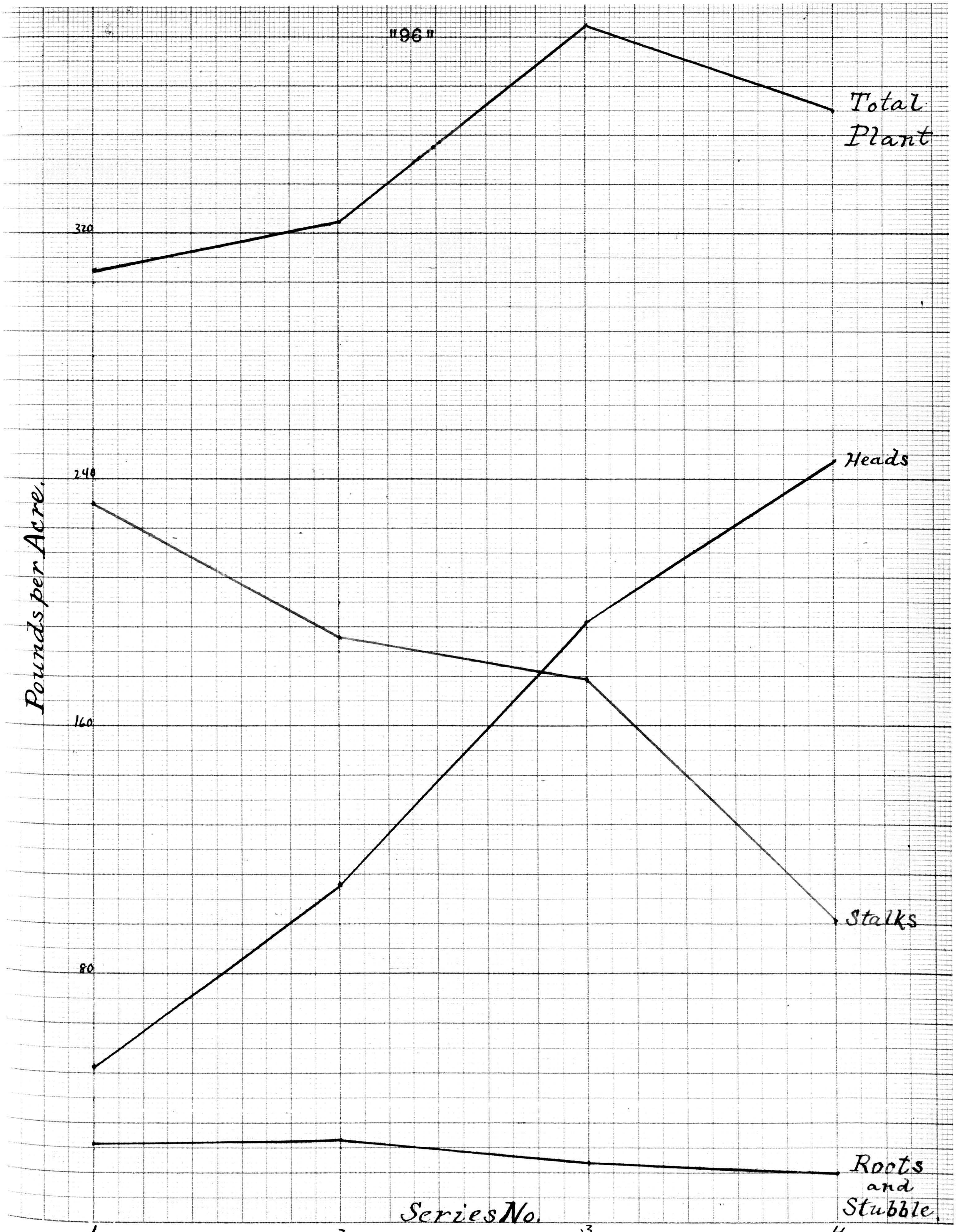
Wheat Plant above ground.

Tables XVII and XVIII.



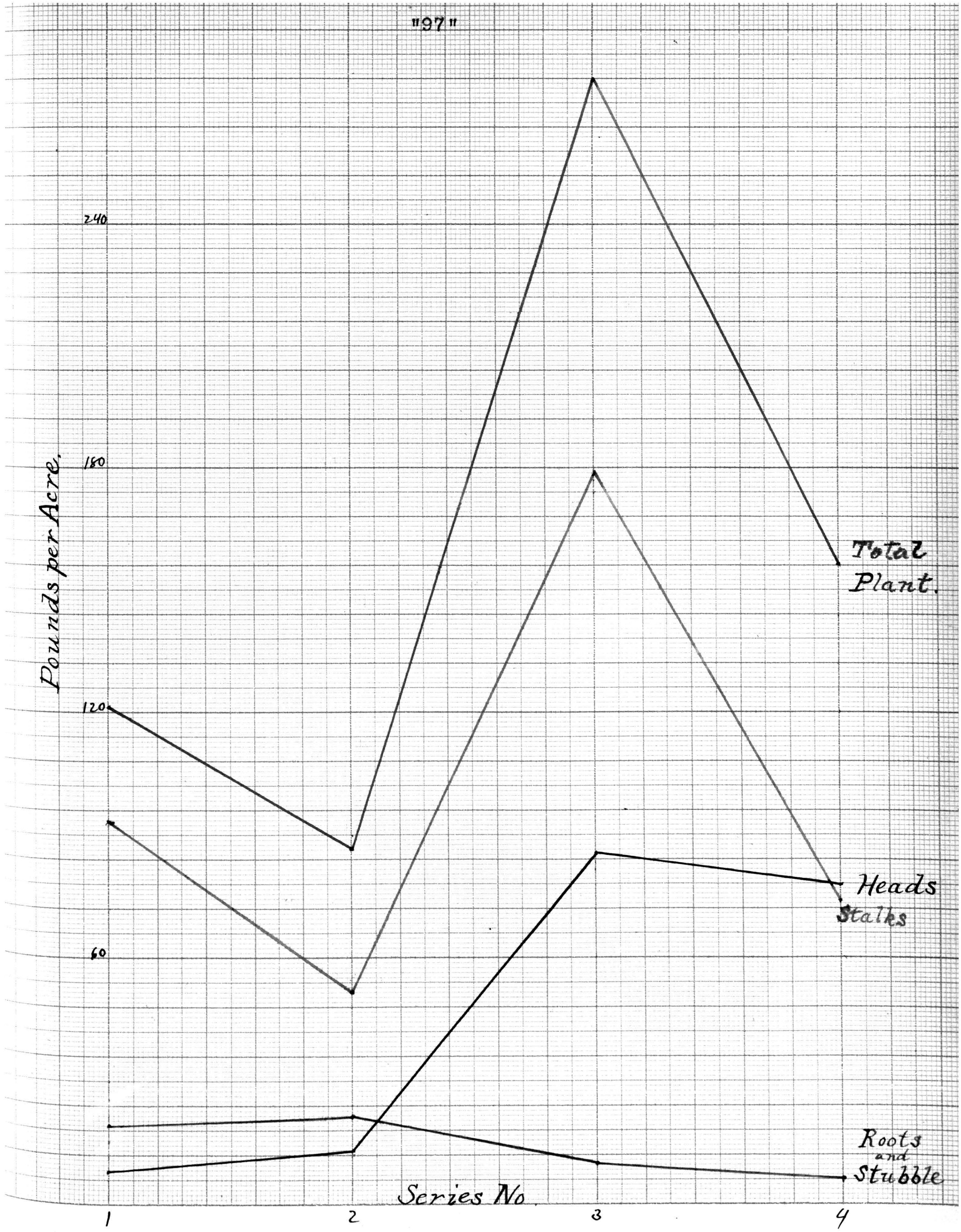
Wheat Plant — Dry Substance.

Table XVIII.



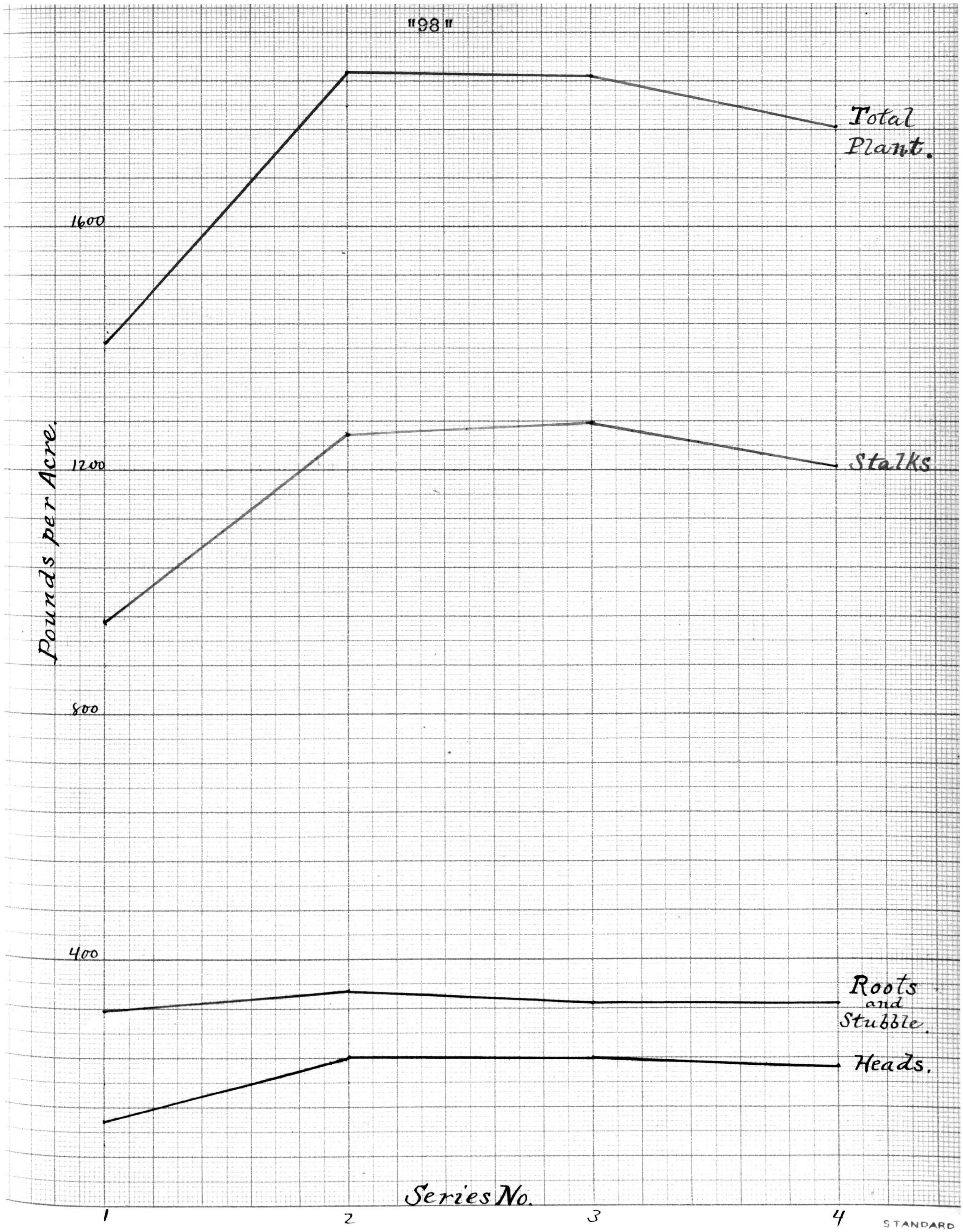
Wheat Plant – Protein.

Table XIX.



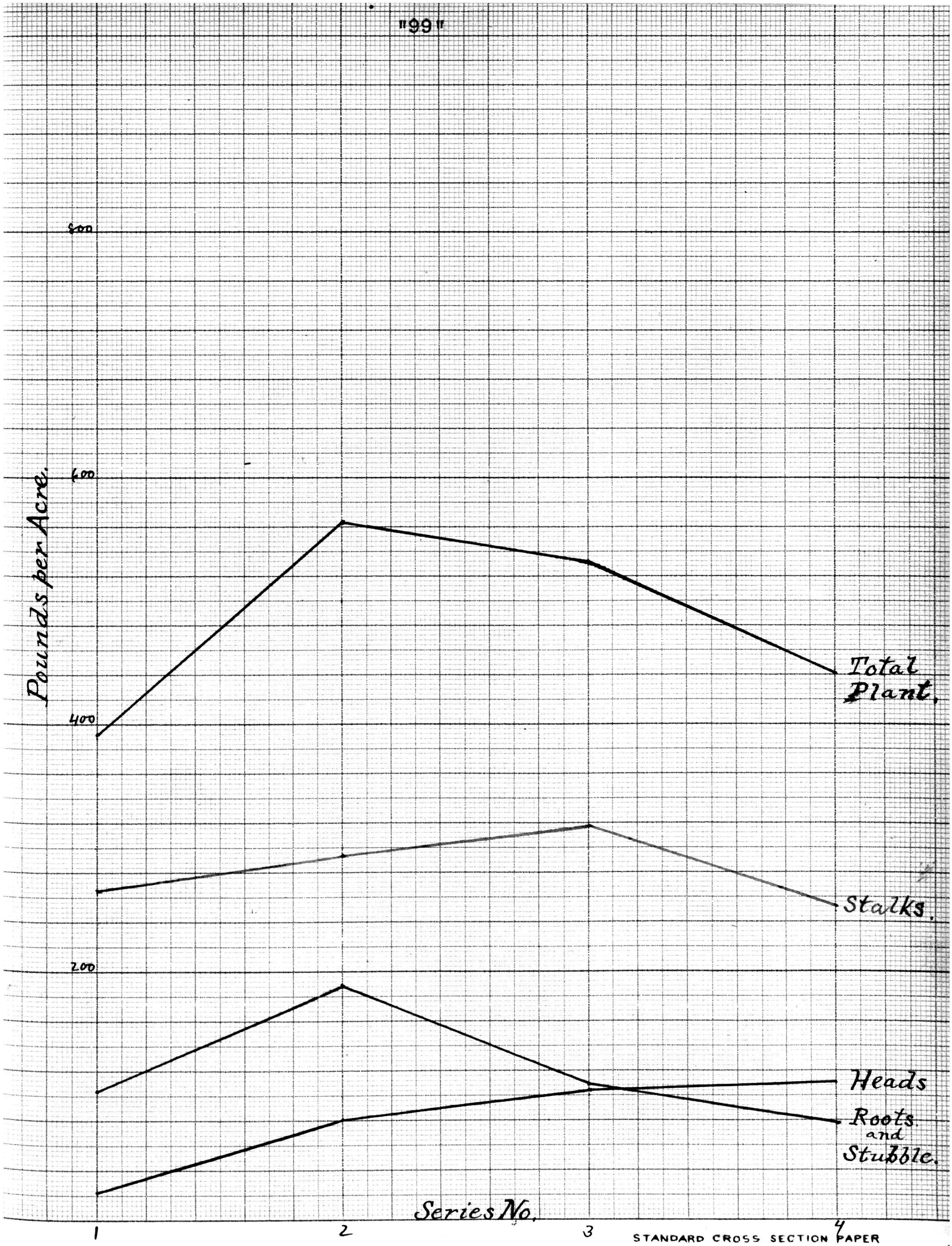
Wheat Plant — Ether Soluble.

Table XX.



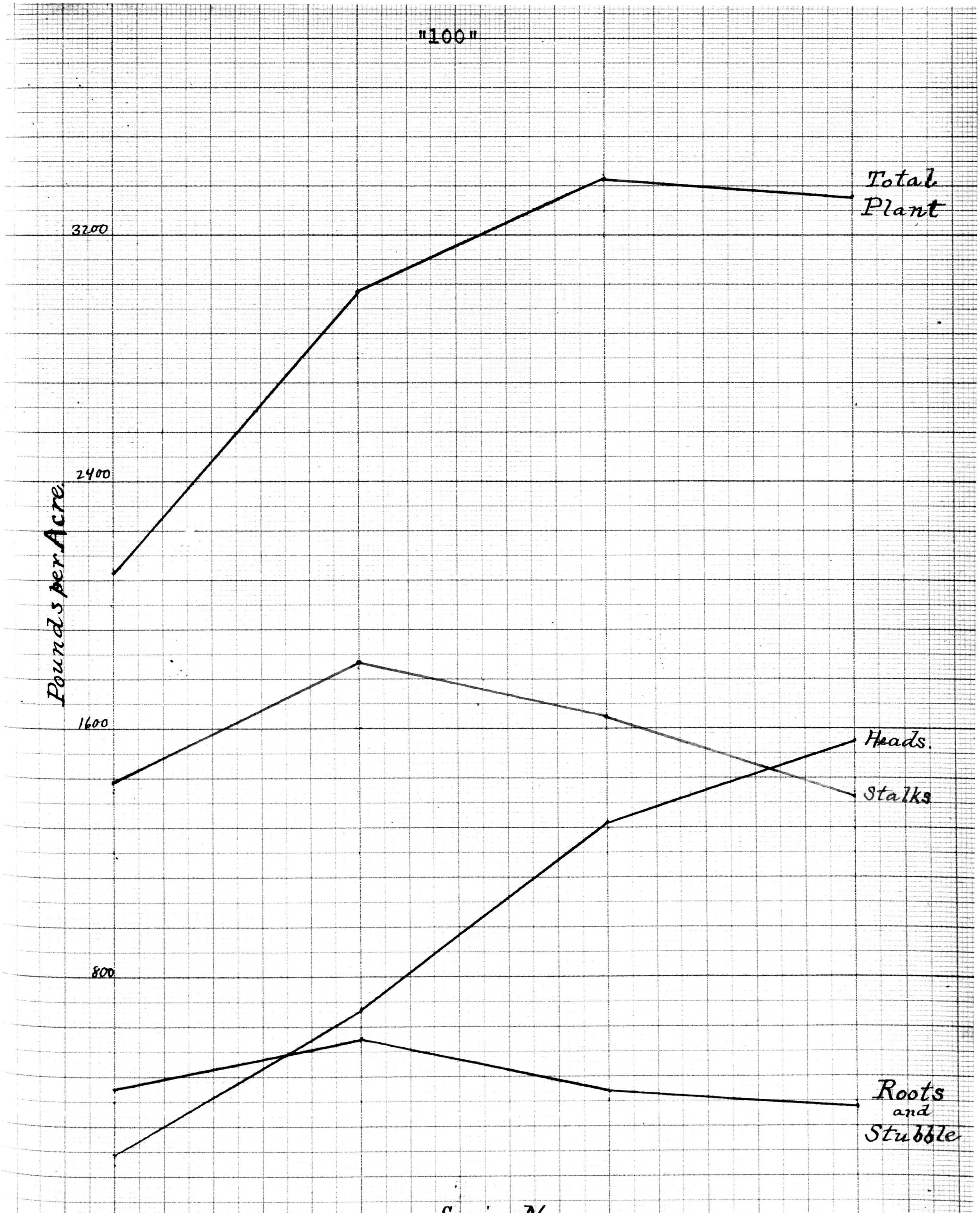
Wheat Plant ~ Crude Fiber.

Table XXI.



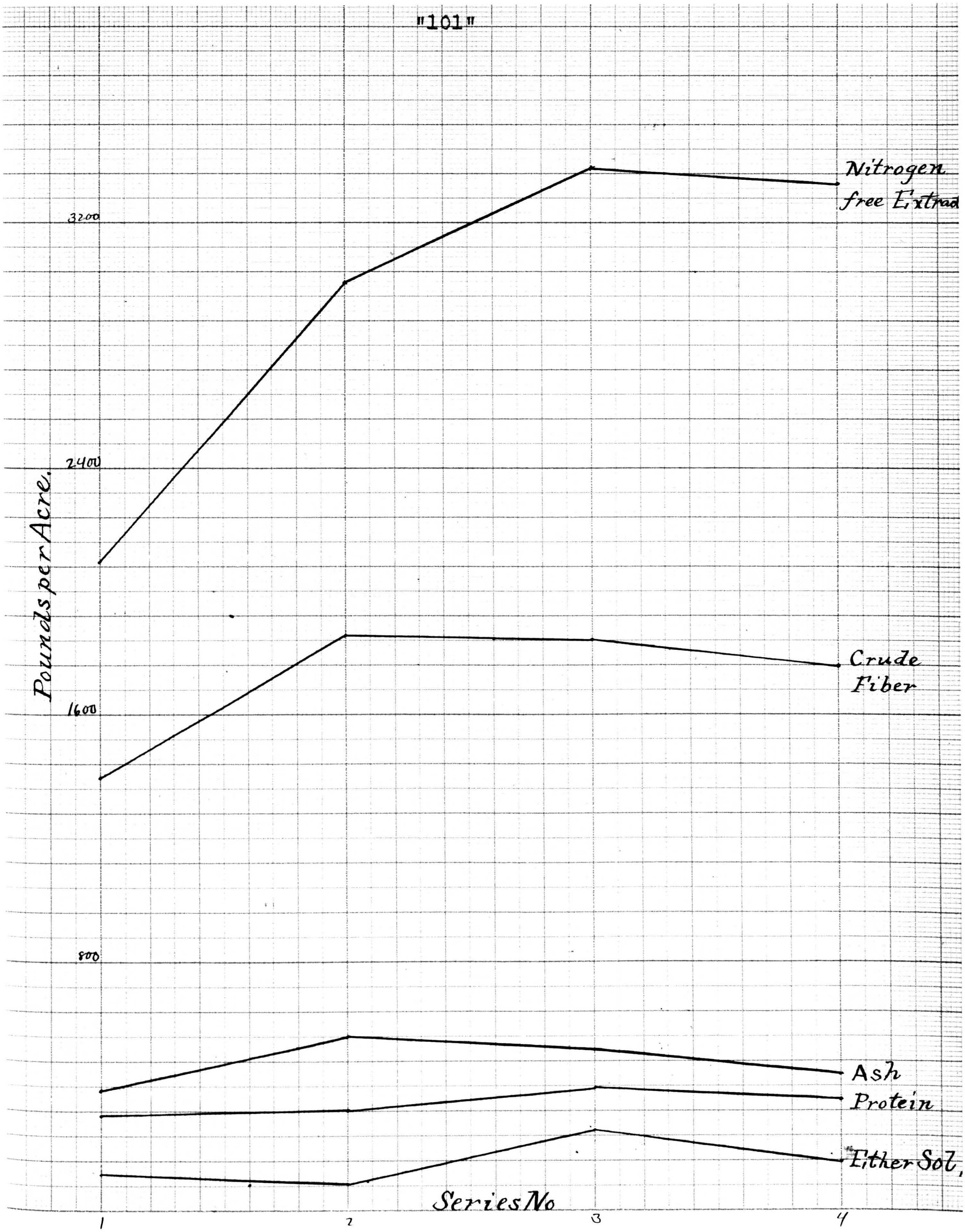
Wheat Plant ~ Ash.

Table XXII.



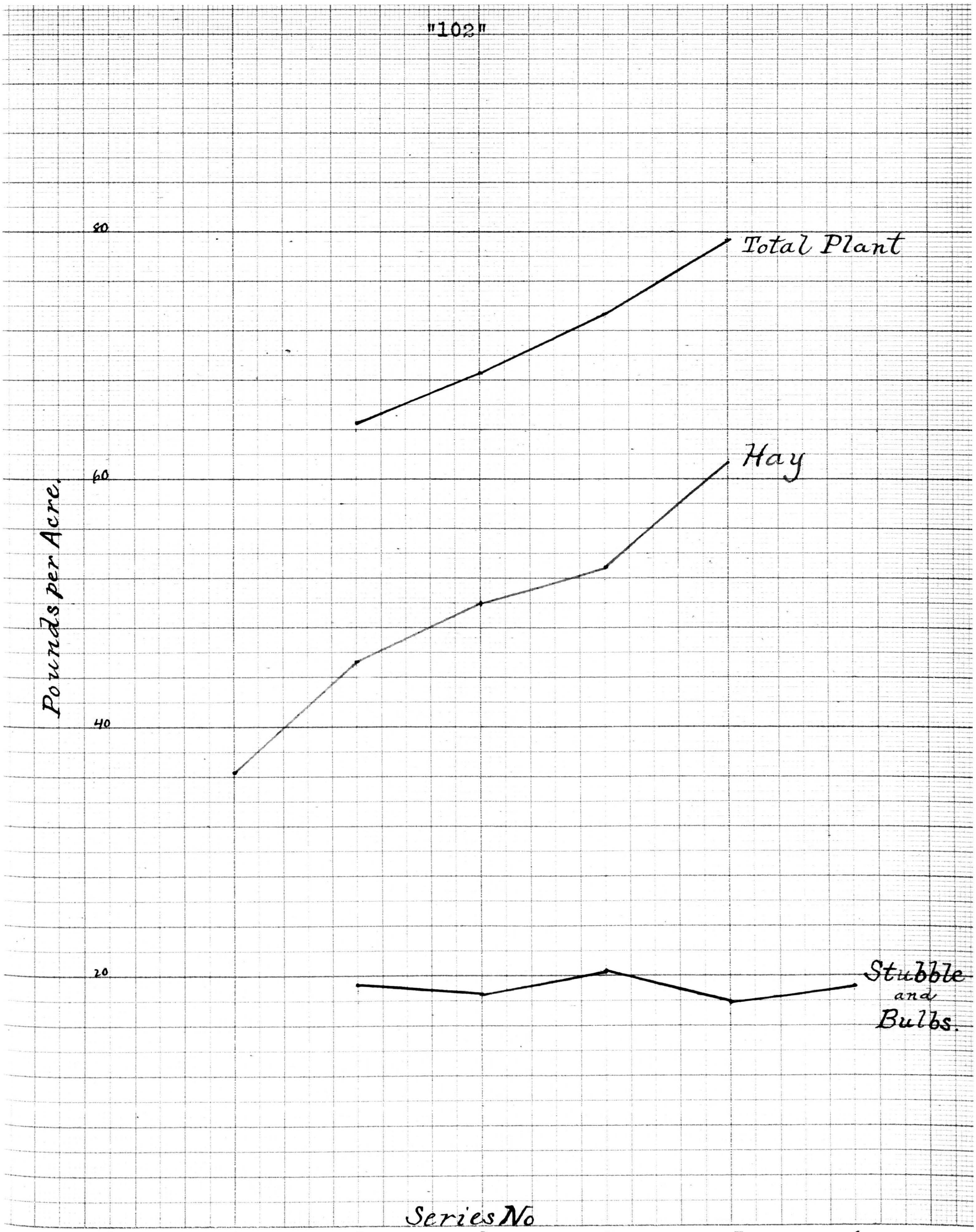
Wheat Plant — Nitrogen-free Extract.

Table XXIII.



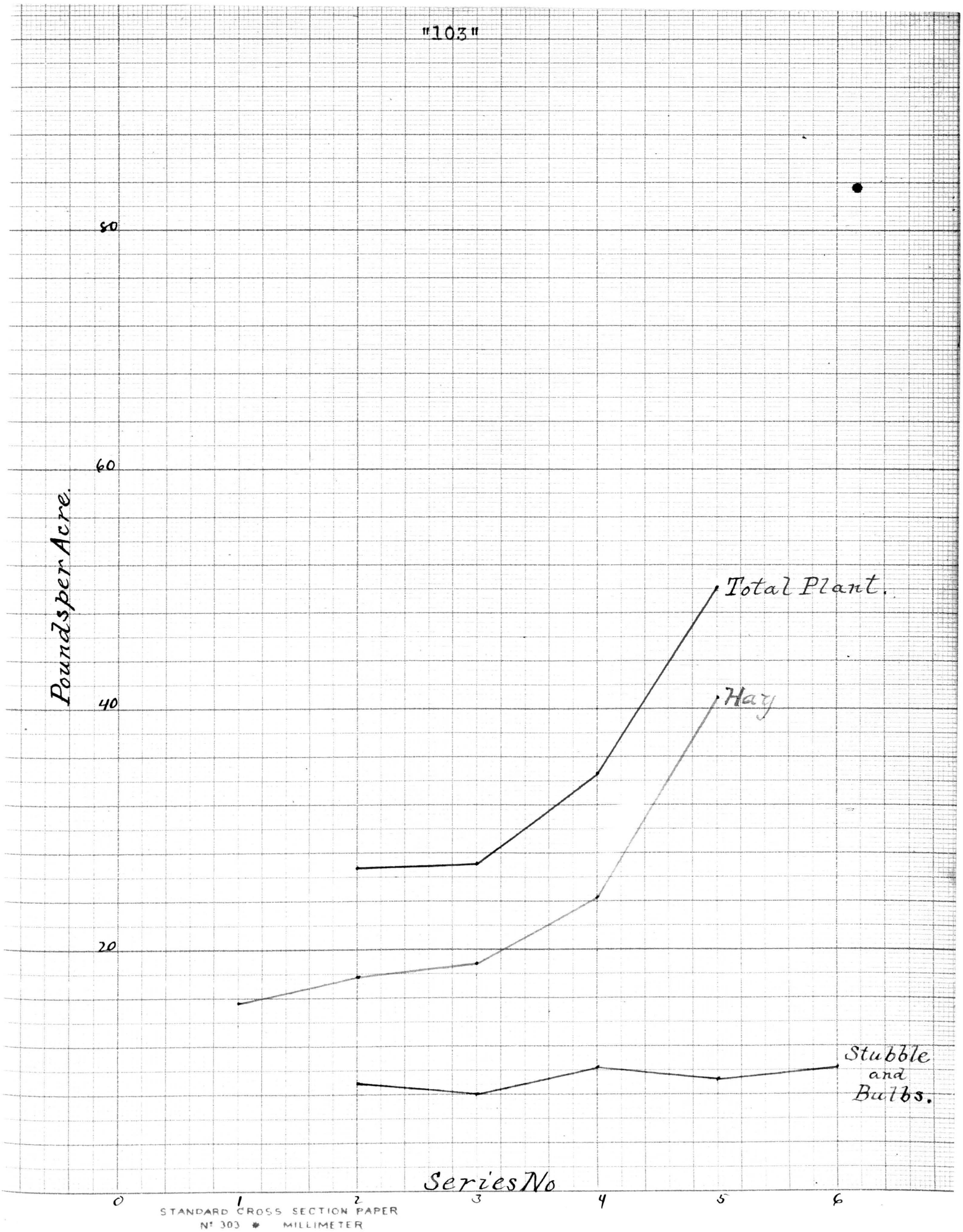
Wheat Plant ~ Constituents of entire plant.

Tables XIX to XXIII.



Timothy Plant — Potassium Oxide.

Tables XXXI and XXXIV.



Timothy Plant — Phosphoric Anhydride.

Tables XXXIII and XXXV.