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Studies of the Timothy Plant

PART II

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SUMMARY

1. The timothy plant takes up nitrogen and ash constitutents at the most rapid rate during the young stages of growth. The absorption of this plant food continues, however, as it approaches maturity but at a decreasing rate, corresponding to the decreasing rate of growth. The per cent and amount of moisture in the green plant is also highest in the young stages.

2. The heads of the timothy plant increase in dry matter thruout the growth and ripening period. This increase includes all the plant constituents except potassium oxide, which has reached its maximum before the plant was collected for analysis in series 3. Nitrogen free extract increases at the greatest rate of all constituents. As the heads approach full ripening, a noticeable increase of phosphorus pentoxide occurs.

3. The stalks and leaves of the timothy increase in dry matter during growth and ripening; this dry matter added consists chiefly of crude fiber and nitrogen free extract. Nitrogen, ether soluble material, potassium oxide and phosphorus pentoxide increase during growth but decrease to some extent during ripening.

4. The bulbs increase in dry matter thruout the growing 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 is found in maximum amount in the first stage; phosphorus pentoxide on the other hand tends to increase in amount as the plant matures. There are approximately as many heads produced at the full height as there are bulbs at the beginning of the season's growth.

5. The timothy plant above ground (hay) loses an absolute amount of dry matter between series 5 and 6 due to washing by rain and dew and to falling off of dead parts.

6. The wheat plant also takes up its nitrogenous and mineral matter at the greatest rate in the young stages and at a decreasing rate as growth proceeds. The highest per cent of moisture in the green plant is found in the first series.

7. The heads of the wheat plant 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 ether soluble matter are added in

some quantity also. Fiber is practically all formed by the time the blossom has fallen and remains constant to ripening.

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

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

10. The wheat plant loses an absolute amount of dry matter per acre at the time of full ripening due to washing by rain and dew and to falling of dead parts.

11. In both plants the percentage of protein, ash, and ether extract tends to show a higher value in the young than in the mature plant while the percentage of crude fiber and nitrogen free extract tends to increase at maturity.

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ACKNOWLEDGEMENT

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Studies of the Timothy Plant

PART II

The Changes in the Chemical Composition of the Timothy Plant During Growth and Ripening, With a Comparative Study of the Wheat Plant

P. F. TROWBRIDGE, L. D. HAIGH, and C. R. MOULTON

INTRODUCTORY

In Part I of this report are presented the results of a comprehensive study of those phases of the growth and development of the timothy plant that are of greatest interest to the grower and user of hay. Studies have shown that there is a progressive change as growth proceeds. Some constituents decrease in amount, others increase. A loss of dry matter appears to occur as the plant approaches maturity. The probability of a double transportation of material is shown, part being stored in the seed and part in the bulb. The study of these data suggested the possibility of explaining these variations in chemical composition by analyzing the entire plant instead of that part which is cut for hay only.

In 1907 at Director Waters' suggestion, plans were therefore laid to make six or seven cutting of the timothy, and about four cuttings of the wheat plant of the same season, and analyze, separately, all the parts of both plants; the purpose being to compare the chemical data of two plants of the same family, one a perennial, the other an annual.*

HISTORICAL

A study of the literature shows that some interesting work has already been reported along this line, especially upon the wheat plant. Upon the timothy plant the work of Kellner,[1] Jordan,[2] and Wilson[3] shows that nitrogenous material and ash are highest in the early

1. Bied. Centr. f. Agr. Chem., 1879, 270. Abstr. J. Chem. Soc. (London) 1879, 819.
2. Bied. Centr. f. Agr. Chem., 1882, 393. Abstr. J. Chem. Soc. (London) 1882, 1127.
3. Trans. Highland and Agr. Soc. Scotland, 1886, 148. Abstr. J. Chem. Soc. (London) 1886, 906.

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*A part of this data was published by L. D. Haigh in abstract by the Eighth International Congress of Applied Chemistry, 1912.

cuttings and decrease in the ripening stages. Also that the reverse condition prevails with respect to the nitrogen free extract. Ladd[4] who reports the analysis of four different stages of growth of timothy hay points out that the per cent of moisture decreases rapidly after blossoming. Sugar also increases in percentage value, while starch, on the other hand, increases substantially in the per cent present. 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 uniform distribution of nutrients thruout the plant.

The wheat plant has received much attention from investigators and many references might be cited. Sorby[5] showed that phosphoric anhydride passed from the straw into the grain as ripening progressed. Lawes and Gilbert[6] studied the composition of the plant thru different seasons as affected by manuring and by lack of manuring. Adorjan[7] reports a very complete study of that part of the wheat plant which is above ground. He cut the plant at intervals of ten days during growth and of five days during grain formation. He divided the plant into stem, leaves, chaff, and grain; the last two samples of course were not obtained until after blossoming. He reports the determination of dry substance, nitrogen, ash, and phosphoric anhydride. The results of this investigation point to the rapid storing up of nitrogen and ash constituents in the young growing plant and the contribution of these constituents to the grain after flowering and during ripening.

A bulletin from the Michigan Agricultural College[8] gives the per cents of protein, fat, crude fiber, 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 separated by rubbing out by hand and then ground for analysis. The straw was cut up and a sample of each cutting was prepared for analysis also. A study of the results shows that a large part of the nitrogen and ash of the grain has accumulated before the ripening process begins. The ether soluble material, which is largely chlorophyll at blossoming, falls off at first but later increases due to storing up of oil in the grain. The variations

4. Bied Centr. f. Agr. Chem., 1888, 574. Abstr. J. Chem. Soc. (London) 1888, 1220.
5. Mem. and Proc. Chem. Soc. (London) 1845-1848, 111, 281.
6. J. Chem. Soc. (London) 10, 1; 16, 100; 41, 373.
7. J. fur Landwirt, 50, 193.
8. Bulletin 101.

show that nitrogen, ether soluble material, crude fiber and ash are all formed or stored during ripening, but less rapidly than nitrogen free extract, which fact is shown by the respective percentages remaining stationary or increasing but slightly.

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 transferred to the head and replaced by material from below. This takes place in a somewhat irregular manner, probably due to weather conditions. The falling off in the relative amount of crude fiber is due to the increase in nitrogen free extract, the production of fiber in the straw having practically ceased. The straw becomes more fibrous in the last stages and at the same time sugars and carbohydrates are being transferred from the straw to the grain.

Among other investigators Liebscher[9] has grouped the work of Wolff[10] and Pierre[11] upon the wheat plant and some other grain crops. Ritthausen and Potts[12] report upon the composition of wheat with and without manure. Jessen-Hansen[13] discusses the composition of the carbohydrates of wheat thru various stages and Nedokutschajew[14] in like manner the nitrogen containing bodies. Brenchley and Hall[15] show the relation of nitrogen to the other nutrients in the grain only, and Stoklasa[16] the relation of potassium in the chlorophyll to starch formation. Schulze[17] shows that nitrogen and potassium are absorbed by the wheat plant mostly before blossoming but that phosphorus is taken up both before and after blossoming. Also the following may be cited: Heinrich,[18] Deherain and Meyer,[19] Hebert,[20] Berthelot and Andre,[21] Deherain and Dupont,[22] Thatcher and Watkins,[23] and Ames.[24]

9. J. fur Landwirt, 35, 330.
10. Text: Die Erschöpfung des Bodens durch die Kultur, ed. 1856.
11. Text: Rescerches exp sur le developpment du ble, Ed. 1866. Comptes rend. 56, 677, 747; 57, 859; 59, 722; 61, 154; 63, 727.
12. Landw. Vers. Stat. 16, 384.
13. Bied. Centr. fur Agr. Chem., 26, 630. Abstr. J. Chem. Soc. (London) 1897, 581.
14. Landwirt. Vers. Stat. 56, 303.
15. J. Agr. Sci., 3, 195.
16. Z. landw. Vers. West Oesterr. 11, 52. Abstr. J. Amer. Chem. Soc., 1908, 1317.
17. Landwirt. Jahrb., 33, 405.
18. Ann. d. Landwirt. 1871, 31. Abstr. J. Chem. Soc. (London) 1872, 516.
19. Ann. Agron. (1882) 23. Abstr. J. Chem. Soc. (London) 1883, 493.
20. Ann. Agron. 16, 358; 17, 97. Abstr. J. Chem. Soc. (London) (1890) 1459; (1891) 1285.
21. Ann. Chem. e. Physik. 1896 (VII) 9, 5. Chem. Veg. Agr. (2) 259. Abstr. J. Chem. Soc. (London) 1899, 319.
22. Compt. rend. 1901 (133) 774.
23. J. Amer. Chem. Soc. (1907) 1342.
24. Ohio Agr. Exp. Station Bul. No. 221.

EXPERIMENTAL PART

Nearly all of the investigators have concerned themselves with a part of the plant only. Very little work has been done upon wheat or timothy roots. Most of the reports on timothy are upon the composition of the hay as such without separation into heads and stalks. None have reported any analyses of the bulbs of the timothy plant. In some cases the different cuttings were in different seasons and in some cases the soil was manured for the experiments.

In planning these investigations these variations were avoided. The timothy was harvested at certain definite stages of growth, removing the entire plant at each cutting and making separate analyses of the heads, stalks, 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 for this experiment were taken from a field which lay upon a gentle slope. The strips of the field furnishing the cuttings of 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 1 the areas of each plot to be harvested in the various series were selected and marked off. Each of these areas was 2x6 feet in size and they lay side by side in the order to be cut except that occasionally a foot or two of space was skipped to avoid a bare spot or an unusual condition of growth. In the selection of these areas the aim was, of course, to secure as uniform a stand as possible in each area.

In making the cuttings of timothy, the stalks were cut off two inches above ground. Immediately after the removal of the hay, the bulbs with the stubble were carefully dug. The following tabulation shows the date of cutting of each series and the condition of the plant at the time of collection. It will be seen that beginning with series 2 the cuttings correspond almost exactly with those made in Director Waters' experiment.

TIMOTHY PLANT

No. of Series	Date of cutting	Stage of development
Series 1	May 23, 1908	About one foot high in rapid growth. No heads showing
Series 2	June 6, 1908	No stalks in bloom but beginning to head.
Series 3	June 18, 1908	In full bloom
Series 4	June 30, 1908	Just out of bloom and seed formed
Series 5	July 9, 1908	Seed all in dough
Series 6	July 20, 1908	Seed fully ripe
Series 0	March 16, 1909	Growth not yet started but considerably green.

In the cutting of series 6, 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, 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.

Series O represents the collection of the bulbs and green growth made from the three plots in the following March for the purpose of studying the composition of the bulbs at the beginning of the growing season. The green growth from the bulbs found at this time was less than two inches high, and therefore below the dead stalks of the previous year, which were rejected in the collection. This green growth, altho only as high as the stubble of other cuttings, really consists of tiny timothy leaves and the analytical results have therefore been compared with those of the hay of the other cuttings as being a more logical classification. There was not sufficient material of this sample with which to carry out an ash analysis.

The amounts 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 value 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 one 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 that of plots 1 and 2, as has been stated before. 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. The data may serve, therefore, to illustrate the trend of variation as pointed out in the discussion.

PREPARING THE SAMPLES

As soon as the timothy was cut it was placed in a covered tin container and within thirty minutes was weighed accurately to 0.1 gram. The heads were cut off close, then weighed at once to 0.1 gram. The stalks with the leaves comprising the remaining part of the hay sample were now cut into small pieces, and after thoro mixing a portion was placed in a tared can with wire cloth sides and the gross weight recorded at once. The heads were also placed in such a can and the gross weight recorded. As may be seen from the table, no separation of the heads from the stalks and leaves was made until series 3 was collected. 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 the data for calculating the amount of moisture lost in passing from the green to the air dry condition. The clods of dirt containing the timothy roots, bulbs, and stubble were soaked in water in tubs, the parts removed from the dirt and washed with two or three changes of water until all adhering dirt was removed. Leaving the stubble attached the bulbs were stripped of their fibrous roots and outer dead covering and then spread out upon a paper until all visible water had dried off. The stubble was then clipped from the bulbs and both were again spread out on paper and allowed to be exposed to the air until the weight was constant. Thus a fresh or green weight of the bulbs and stubble was not obtained as in the case of the timothy hay.

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 plan being followed with the three samples of stalks, stubble, and bulbs, respectively. This was done for each series of cuttings of the timothy so that one sample each of heads, stalks and leaves, stubble, and bulbs was analyzed for each series.

These composited samples were ground until the material would pass thru a sieve with holes one millimeter in diameter. To reduce the samples to this condition they were passed first thru a drug mill, and finally thru a coffee mill with the burrs set close. If a sample proved to be tough and very difficult to reduce to a fine condition it was dried at 80°-100° C. When it became brittle it could then be ground fine quite readily. By allowing the ground material to be exposed to the air for two or three days it would return to its air dry condition.

METHODS OF ANALYSIS

In a general way the official methods of analyses of the A. O. A. C. were followed. 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° C. until the weight was 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 fiber was determined upon the ether extracted residue in the regular official method by boiling first with 1.25 per cent H_2SO_4 and finally with 1.25 per cent NaOH. The washed fiber was collected and weighed in a gooch crucible, the fiber was then burned off and the crucible again weighed to determine the loss.

Nitrogen was determined by the Kjeldahl method slightly modified by this laboratory for general nitrogen work. One gram of the material was digested with 25 c. c. H_2SO_4 and 0.7 gram mercury. After incipient frothing is over and the mass has changed from a pastry to a more liquid condition, about 7 grams of K_2SO_4 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 rinse 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. When cool 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 hydrochloric acid, the titration made with tenth normal ammonia, using cochineal as an indicator. The per cent of nitrogen multiplied by 6.25 gives the per cent of protein.

Ash was determined by burning two grams of the air dry material at a low heat in a muffle until thoroly 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 was 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.

TIMOTHY PLANT

Discussion of the Data. Table I gives the percentage value of moisture and dry substance found in the hay at the exact time of cutting. The corresponding table in Part I gives the same data found for the hay after having been cured in the field. In the fresh cut hay we see that the young hay has the highest percentage of moisture and that this value declines steadily the later the hay is cut. For field-cured hay, if a general average value be taken (Table IIIb, Part I), the percentage is about the same for all hays except the earliest cut, which has a little more moisture. The green weight increases but slightly after series 3 and commences to decrease after series 4 (Table II). On the other hand, the dry substance of the hay increases steadily in amount but not as rapidly as moisture decreases during the ripening process. Between series 4 and 5 there is increase of dry matter coincident with a decrease in the weight of the green hay (Fig. 1). The moisture per cent in the green growth of series O one would expect to be higher than in series 1. So much time was required to pick out this green growth from the dead growth of the preceding year that much moisture was lost before weight could be taken. A study of the weights of dry matter in all parts of the plant shows that the most rapid increase occurs in the heads or seed bearing part (Table III) (Fig. 2). The timothy heads double in weight from blossoming, series 3, to seed bearing time, series 4, in a period of 32 days. The bulbs of the timothy show a tendency to increase their dry matter rapidly in the first three, and more slowly in the last three stages. The tendency of the stalks and leaves to lose in dry matter in the last stage or two may be due to withered leaves which fall off and were not used in preparing the sample for weighing and analysis. Comparing this data with actual yields per acre of the timothy hay (Table II a and b, Part I) we see the same kind of variation shown there.

The stubble gains in dry matter as the hay ripens following the changes in the stalks and leaves except that there is less loss due to falling parts. Considering the average value for the three plots a slight drop in dry matter is noted in series 5. Preceding this cutting a period of several days of sunshine stimulated the flow of nourishment to the top of the plant thus drawing away from the stubble. A period of cloudy weather before series 6 following a shower three days preceding the cutting gives the stubble the opportunity to recover in dry mater because of increased root activity.

Table IX shows how the dry material tends to concentrate in the heads and bulbs in the last stages. In the early stages the distribution of the dry matter remains quite uniform as is shown by the fairly constant value of the percentages for each part. After the heads appear these gather dry matter more rapidly than the other parts and the percentage of heads to total plant rises rapidly. At the time of heading the bulbs begin to fall off in their percentage value and continue to do so until the heads are about ripe. Afterwards storage of dry matter in the bulbs is shown by the increasing percentage value. The stubble represents the lower two inches of the stalk at all stages and therefore as the plant above ground increases in size, the percentage as stubble falls steadily in value. The hay cut from the young plant contains 57 per cent of the dry matter of the entire plant, when cut from the mature plant it contains about 69 per cent of the total dry matter.

The weight of protein increases in the plant between two and three times from incipient growth to full ripening (Table IV) (Fig. 3). The result from series 3 shows that the heads and bulbs make the highest rate of gain: the stalks, leaves, and stubble the least. The per cent of protein in the heads remains almost constant, so that the rest of the dry matter and the protein are increasing in about the same ratio (Table XI). The stalks and leaves are also storing up nitrogen but at a slower rate and with some fluctuation in the yield (Table IV). In the stubble the protein percentage varies irregularly for some reason. Variations in weather conditions at different stages might affect the amount of nitrogen in the stubble at any moment as the nutrients move toward the top of the plant at rates varying with root activity and the extent of the stimulation upon the growth of the upper parts. The fairly regular figures for the protein in the bulbs show that development of the plant under ground as well as plant above ground goes on steadily thruout the plant growth.

The ether soluble material (Table V) (Fig. 4) shows some large variations in yields thru the various stages, reaching a maximum in the total plant at series 5 and falling off at the last stage in the same manner as dry matter and probably due to the same cause—loss of parts.

Fig. 4 shows that the total plant loses an absolute amount of ether soluble material between series 2 and 4. This result is not observed for any other constituent. In ether soluble material one is really dealing with two substances; chlorophyll which is abundant or readily soluble in ether in the younger stages; and oil or true fat which is formed in the late stages of growth. The increase, therefore, in the amount of ether soluble material up to series 2 is probably due to chlorophyll as the deep green color of the young plants indicates. As the plant matures the chlorophyll tends to disappear and the green color becomes less intense. This appears to be accompanied by a falling off in amount of ether extract per acre. This change occurs, however, before the oil which is beginning to form has reached a high enough value to compensate for this loss in chlorophyll. A net loss in amount in the total plant is therefore apparent at series 3. In connection with this fact it is interesting to note the result found for the digestibility of the ether extract in Part I of this report. The digestion coefficient was highest for this constituent in the later cut hays or at the time when the ether extract consists mostly of fat rather than chlorophyll. It seems entirely reasonable to expect this result.

This loss in amount of ether extract is observed to take place in the stalks, leaves, and stubble at the same time, and in the heads a little later. The rapid increase in the heads in both amount and per cent (Tables V, XI) at the last stage of development shows that much oil is being formed in the seed. Kellner,[1] Jordan,[2] and Wilson,[3] make no mention of this increase of oil during ripening. The ether soluble material in the bulbs rises 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 addition of other dry matter.

The crude fiber increases in amount as long as the plant is increasing in weight (Table VI) (Fig. 5). It is also apparent that the crude fiber is not transferred from one part of the plant to another but remains where it is formed. In crude fiber as with protein and ether extract we note the falling off in amount at the last cutting. The crude fiber increases in amount in the heads, but owing to the rapid storing of the other constituents it falls in percentage value after blossoming (Table XI). In the stalks and leaves the crude fiber 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 fiber in the bulbs in the late periods of development. (Table XV.)

The ash of the total timothy plant (Table VII) (Fig. 6) gains in amount rapidly at first and more slowly toward the end of its development, causing a drop in the percentage values (Table X) which fact has been noted by the investigators previously cited. Again the total plant, the stalks and leaves in particular, actually lose in the amount of ash at the last stage. The storing up of ash in the heads is more pronounced than in any other part of the plant altho the increase in the stalks and leaves is also large. 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.

The nitrogen free extract will include the gums, starches, sugars, pentoses and pentosans of the plant. As the plant developes and ripens these constituents may be expected to increase (Table VIII) (Fig. 7). Both the amount and percentage value increase thru 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 show this increase in the 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 to store up material thruout the ripening period. This was to be expected for the function of the bulb is to carry over the life of the plant 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, no test being given for starch in the bulbs obtained from any of the seven stages of growth. The carbohydrate material containted 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 upon the burrs in a glue-like mass making it impossible to continue the grinding until the machine had been cleaned. Starch is, of course, the principal constituent in the ripe seed, altho sugar, fiber, cellulose, etc., are also present. Ladd [4] with timothy, Hebert,[20] Deherain and Dupont [22] with wheat, have shown that sugar in the plant above ground is changed into starch during the ripening period.

It is well to note the trend of the yields per acre of the constituents of the fresh cut hay as compared with the corresponding values in the field-cured hay shown in Part I. of this report. In the fresh-cut hay the yields all tend to increase up to nearly the last while in the field-cured hay the values tend to fall off earlier. This fact proves pretty well that there is an actual loss of nutrients in the process of curing. Rain and dew falling upon the hay after cutting would cause a more marked effect in this respect than they would upon the growing plant.

The variation in percentage value of the constituents in the fresh-cut hay (Fig. 8a and 8b) shows the same trend as in the field-cured hay (Fig. 2a and 2b), namely, a decrease in values for protein, ash, and ether soluble, and an increase for crude fiber and nitrogen free extract as the plant approaches maturity.

To sum up the composition of the timothy plant, it is seen that the protein per cent has its highest value in the young plant, which indicates that much nitrogen is needed for the plant to make a vigorous growth. Kellner,[1] Jordan,[2] and Ladd[4] report this same result. The ether soluble material reaches a high value in the early stage when a preponderance of chlorophyll should be expected. The subsequent decline with later a rise in the percentage and yield of the ether extract is probably coincident with a progressive change in the nature of the chlorophyll and the formation of vegetable oil as the plant nears maturity. The maximum percentage of the oil is reached about twenty days before full maturity of the plant. The crude fiber varies but little in per cent, which means that it is proportional to total dry substance present. Weather conditions such as rain or cloudiness would retard the change of sugar in the plant into starches and wash soluble material from the leaves. If this should occur in the last stages, the crude fiber might increase in per cent altho not in amount. Some works previously cited ([1] and [2]) 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 extract is the cause of these decreasing values in the other constituents.

LOSS OF DRY MATTER AT MATURITY

The loss of dry matter in the stalks and leaves which persistently appears between the fifth and last cutting has been mentioned in the discussion. It has already been mentioned and discussed in Part I of this report where the tables show this same loss to have occurred. Previous investigators have brought out three explanations for this result. First, some of the leaves of the lower end of the stem wither and fall off at maturity[9] or are beaten off by rains. Second, at the time of seed formation and ripening the stems and leaves contribute nutrients not only to the seed but also to the bulbs (Part I). Third, according to LeClerc and Breazeale[25] soluble mineral matter exudes from the stems and leaves and is washed off by the rain and dew into the ground. As regards this last explanation, the authors show that the larger part of this loss by washing occurs at maturity. Some loss occurs earlier but it is small in amount. The more vigorous assimilation of nutrients by the plant at the earlier stages would more than compensate for any loss due to washing by rain at this time. In conformity with this fact, the tables here presented show that the plant as a whole sustains no general loss of nutrients at stages preceding maturity. The loss in absolute amount of ether soluble occurring at series 3 must be explained by a change in the nature of the ether soluble material itself rather than a loss by the three causes above mentioned.

The authors just cited reporting upon wheat, show that with nitrogen and potash the transference is upward and not downward since the lower nodes of the stem contain less than the upper nodes. This is to be expected, since in wheat there can be no tendency to store nutrients anywhere but in the head of the plant. With timothy, on the other hand, a different result might be expected since storage takes place both in the heads and in the bulbs. The percentage of the respective nutrients should be much the same in both upper and lower parts of the stem. We have no analysis of the stems alone, but on comparing the percentage of the nutrients in the stubble with the respective percentage in the stalks and leaves above it, we find that for nutrients other than nitrogen free extract the percentage is uniformly lower in the stubble than in the corresponding stalks and leaves. We can hardly argue, therefore, from this data for any transference of nutrients other than nitrogen free extract from the plant above ground to the bulbs. If this were actually taking place the percentage composition of the dry matter of the stubble should not vary greatly from that of the stalks or perhaps even from the stalks and leaves as we have the data here.

In accounting for the loss of any nutrient one or more of the explanations may apply. Protein, ash, and nitrogen free extract lost from the stalks and leaves presumably may be due to any of the three mentioned causes, all of which may occur in the interval between these last two cuttings. Ether soluble material may be lost thru transference to some other part or to falling of the leaves. Crude fiber is probably lost by the falling of the dead leaves only.

25. Yearbook, 1908. U. S. Dept. of Agr.

Table IV shows that the stalks and leaves lost 33 pounds of protein to the acre between the fifth and last cutting. The heads gained 15 pounds and if we assume that this amount was received from the stalks and leaves we have 18 pounds loss still to be accounted for. Since our data will not permit us to say that any of this material has been transferred to the stubble and bulbs we can only ascribe the loss to washing by rain and to the falling off of a part of the leaves. The stubble at the same time has gained 7 pounds and the bulbs 20 pounds; all of this must have been obtained by absorption thru the roots and synthesis in the plant cells. The 18 pounds of protein lost is the minimum amount for no account has been taken of an upward flow of an unknown quantity of nitrogen-bearing material from the bulbs and stubble into the stalks, leaves, and heads.

In Table V the heads have gained 18 pounds of ether soluble material of which one pound may have come from the stubble. The other 17 pounds would come from the stalks and leaves, leaving 17 pounds of this material lost by falling away of withered leaves. The bulbs have made practically no gain, since the unknown intake due to root activity has balanced the outgo to the parts above which amount must be added to the above loss of 17 pounds.

In Table VI the loss of 7 pounds of crude fiber from the heads, 79 pounds from the stalks and leaves and 7 pounds from the stubble is likely due to falling parts. It is not reasonable to assume that any of the fiber lost by the plant above ground could be accounted for in the 12 pounds of fiber gained by the bulbs during this period. Fiber being almost like an insoluble material doubtless remains where it is built up. On the other hand, assuming it to be built up from the same material as nitrogen free extract it is conceivable that the fiber gained by the bulbs was built up from the soluble materials received from the plant above ground, or contained in the bulbs themselves.

In Table VII it is seen that the heads have gained 3 pounds of ash which, as before, it is assumed, came from the stalks and leaves. This leaves 28 pounds of ash washed from the stalks and leaves by rain and dew and lost by falling of leaves. There have been absorbed by the roots 7 pounds of ash constituents—5 pounds in stubble, 2 pounds in bulbs—plus the unknown quantity which has passed on to the parts above the stubble and lost with the 28 pounds above mentioned.

In Table VIII the total loss of nitrogen free extract from the stalks and leaves, amounts to 326 pounds per acre. Of this, 79 pounds was transferred to the heads, leaving 247 pounds lost by washing, falling of parts, and by transference to the stubble and bulbs, if such has taken place. The bulbs have lost 210 pounds and the stubble has gained 41 pounds, leaving 169 pounds loss in the bulbs, part of which may have passed on to the plant above and part of which may have changed over into crude fiber which it was observed from Table VI made a gain in this period. The 247 pounds of loss from the stalks and leaves at this period has probably all been due to washing and to falling of parts. The actual loss is probably more than this. As regards nitrogen free extract, the data would seem to indicate great activity in the plant cells above ground and comparatively low activity in the roots.

TIMOTHY BULBS AND SPROUTS

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 formed 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 and ground for analysis. In Table XVI the average number in the three plots in each series is given for both the large bulbs and the small sprouts. Starting with the small number of bulbs, 586, found in the area two by six feet dug up in March, we find that the number 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 also to increase.

From these observations it appears that the life development of the bulbs works in the following cycle. The bulbs which have lived thru the winter send up the stalks in the spring, and after growth has proceeded for a few weeks small sprouts start from the side of the bulb, and at the base of these sprouts a small bulb develops. These sprouts continuing to grow upward form the second growth of the plant seen in late summer, and account for the thickening of growth of the timothy meadow and the small immature heads which are found associated with the ripe heads at harvest. The number of these small bulbs formed increases steadily, and as this continues the large parent bulb becomes soft and decays. These small bulbs continue to develop until the end of the growing season and then remain dormant thru the winter ready to repeat the above process of growth the next spring. In Part I of this report a more detailed description of the life history of the bulb may be found.

A count was also made of the timothy heads of all plots from series 5 and 6. Altho heads were obtained and weighed from series 3 and 4 the probable value of having the number of these did not occur to the writer until too late to make the count. In Table XVI 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 bulbs is also enumerated for series 5 and 6. These serve as an indication of the number of new small bulbs which are produced during the growing season to carry the plant thru the winter. The sharp variations in the number of the sprouts of the different plots show the difficulty of drawing an 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 some more new sprouts would be produced between July 20th and the following March which would explain the increase in bulbs of plots 2 and 3. Or some sprouts might wither away and produce no new bulbs 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 20th 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 seems 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 become soft and decay. No separation was made of old and new bulbs for analysis, and no dead bulbs were analyzed at all. Therefore analytical proof of this change in the bulbs is lacking.

Study of the Ash. Many investigators have reported analyses of plant ashes giving their contents of phosphorus and potassium. Storer[26] shows that the amount of potassium oxide obtained from different plant ashes varies considerably in amount. The waste parts of tobacco leaves and the stalks are used as fertilizer; the dry stalks contain about five per cent of potash[26] besides much phosphoric acid

26. Text: Agriculture, Vol. II, p. 462, ed. 1899.

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 beneficial results thus obtained are due not only to the potassium oxide and phosphoric acid which they contain but also to the alkaline nature of the ash which corrects the soil acidity and assists favorable bacterial action. A report from the Rhode Island Experiment Station [27] on the use of ashes for fertilizer shows this result upon the growth of timothy.

Preparation and Analysis of the Timothy Ash. The ground and composited samples which furnished the material for the determination of the food stuff constituents were burned in platinum dishes over a low flame until thoroly charred, then leached and washed with distilled water on an ashless filter until all soluble matter was removed. The solution of the soluble ash was made up to 500 c. c. Aliquots of 10 c. c. were taken for the determination of the total water soluble ash and of water soluble potassium oxide and phosphorus pentoxide. These constituents were then determined by the official gravimetric methods of the A. O. A. C.

The insoluble residue left after leaching was burned in a muffle to remove all carbon and the insoluble ash then weighed. Insoluble potassium oxide and phosphorus pentoxide were determined by treating a weighed amount of the insoluble ash by the J. Lawrence Smith method. The potassium oxide is soluble as potassium chloride and the phosphorus pentoxide insoluble as calcium phosphate after the ignition. The potassium oxide in the soluble portion was determined in the usual manner. The insoluble residue from leaching after the ignition was dissolved in nitric acid, the silica first removed by dehydration and the phosphorus pentoxide determined in the usual manner.

Composition of the Timothy Ash. It will be noticed (Table XIX) that the weight of the potassium oxide and phosphorus pentoxide in the total plant rises to its highest value in series 4. After this the amount decreases, the falling off in value occurring principally in the stalks and bulbs. The washing by rain and the dropping away of leaves account for the loss of the stalks and leaves, while the rejection for analysis of the soft dead bulbs in the late series may be the explanation of the loss from the bulbs. According to other investiga-

27. Bulletin 99.

tors who have analyzed the leaves separately, the amount of potassium oxide is high and the loss of dry leaves of the ripe and nearly ripe plant would mean a considerable loss of potassium oxide which, as the data shows, has occurred in this case. The data seems to show that all the potassium oxide required by the timothy heads has been stored up by the time the heads are formed. Starting with a high per cent at first (Table XVII) the percentage value drops rapidly as the other constituents of the ash are added during seed formation and ripening. A sudden rise (Tables XVIII, XIX) in the per cent and amount of phosphorus pentoxide in the heads occurs at full ripening, probably due to the formation of phospho-proteins. This reaction of phosphorus has been shown [28] to occur in the wheat grain at this time; it is not too much to assume that this may be true with the timothy seed also. Adorjan [7] observed the same phenomenon, but ascribes the occurrence to wet weather. The weather record shows that showers occurred on July 20, the day of making this last cutting, and also on July 17. From July 17 to July 20 the skies were cloudy to partly cloudy.

The timothy stalks and leaves show about the same variations in potassium oxide and phosphorus pentoxide as the plant taken as a whole (Figs. 9 and 10). The dropping off of the amounts per acre at the last stage has already been discussed.

The stubble or lower two inches of the timothy stalk varies somewhat irregularly. The rapid increase in the amount of potassium oxide and phosphorus pentoxide in the stalks and leaves between series 1 and series 3 may account for the corresponding drop of these constituents in the stubble which may yield some of these constituents to the parts above. A period of days of sunshine preceding the cutting of series 5 still further stimulated this process and a drop in the amount and percentage value in the stubble then occurs. The weather conditions mentioned above preceding the cutting of series 6 from July 17 to July 20 would be favorable for root activity while the heads, having reached maturity, would not be drawing upon the lower parts for nourishment, hence we observe a recovery of the stubble in the amount of these constituents.

In the bulbs the maximum quantity of potassium oxide is found in series 1, declining steadily to the end of the experiment, due to transference to the stalks above and to rejection of the soft dead bulbs of the later series. On the other hand, the phosphorus pentoxide shows a tendency to maintain or even increase in percentage value and absolute amount in spite of these conditions. It thus appears

28. Ivanovska: Bot. Centr. 107 (11) 265.

that most of the potassium required by the plant is absorbed in the early stages while the phosphorus is assimilated thruout the entire period of growth and ripening.

The potassium oxide and phosphorus pentoxide were each determined as water soluble and insoluble portions (Tables XVII, XVIII). The results show that, considering the amounts of these constituents in the plant as a whole, the insoluble potassium oxide is about 13.6 per cent of the total and the insoluble phosphorus pentoxide about 30.5 per cent of the total, thruout the entire experiment (Table XX). If the parts of the plant are considered separately, the ratio of the insoluble portion to the total does not seem to vary so uniformly. The ratio of insolubility of the potassium oxide in the stalks and leaves is about the same as in the total plant. In the very young heads, the insoluble potassium oxide is only 10 per cent of the total but in the later series it increases to about 30 per cent of the total. The greater solubility of the potassium and phosphorus oxides in the bulbs as compared with other parts is worthy of attention (Table XX). The insoluble potassium oxide of the bulbs does not exceed 4.5 per cent and the insoluble phosphorus pentoxide, 20 per cent of the total constituent, respectively. Perhaps this may be partly explained by the fact that before being ground for analysis the bulbs were washed with water, thus removing all adhering mineral matter. On burning the bulbs to obtain the ash, the potassium oxide and phosphorus pentoxide would not be rendered insoluble in additional quantities by ignition with extraneous lime and silica. This can hardly be the explanation, however, of the low proportion of insoluble ash constituents, for we recall that the stubble was also washed with water along with the bulbs, yet this part shows about the same proportion of insoluble constituents as do the stalks and leaves which were not washed. It cannot be denied, however, that the removal of dirt from the smooth surface of the bulbs is more certain than from the pockets in the stubble. The insoluble potassium oxide and the insoluble phosphorus pentoxide are measures respectively of the amounts of silica and lime present, which are probably not all extraneous.

The amounts of the potassium and phosphorus oxides found in the ash of the hay (Tables XXI, XXII), which are therefore removed from the land in taking off the crop, are proportional to the age of the hay when cut. Approximately 61 per cent of the potassium oxide and 58 per cent of the phosphorus pentoxide of the plant are removed with the young hay, while with the ripe hay 78 per cent and 68 per cent, respectively, of these constituents are carried off in the harvest. Thirty-seven pounds of potassium oxide and 8 pounds of phosphorus pentoxide are removed per acre in cutting off the young hay, while 53 and 14 pounds per acre, respectively, are removed when the hay is mature. After cutting off the ripe hay, there remain 14 pounds of potassium oxide and 6 pounds of phosphorus pentoxide per acre, present in the bulbs and stubble which are thus ready as plant food in a more or less available form, for succeeding crops. Thus timothy, while making a certain amount of potassium and phosphorus available, is also removing appreciable quantities from the soil.

Some analyses of the ashes of timothy by Wolff[29] and of meadow grasses by Stutzer[30] show that large amounts of potassium oxide have been stored up. It would thus appear that clay soils which contain 1.5 to 4 per cent of potassium oxide[26] ought to produce the best crops of timothy, other conditions being the same. The investigations of Morse and Curry[31] 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 supplying any additional amount. They do not find that the crops are materially increased by the addition of potash fertilizer. This last statement is contrary to the finding of Lyon and Morgan[32] 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 constituents in each series of cuttings to the basis of one ton of dry hay harvested (Table XXIII) the weight of the constituents removed per ton declines rapidly in amount. The organic constituents assume a larger proportion of the composition of the entire plant as growth proceeds. Assuming the price of a ton of timothy hay to be the same whether cut early or late, it is evident that the young hay from the standpoint of the mineral nutrients is the most expensive crop.

It would be expected naturally that as the plant reached its maximum size the weight of the part above ground would attain a larger proportion with respect to the total weight of plant. The figures in this table accord with this expectation. This fact is not so marked with the timothy as with the wheat plant for the root system of the former acting as a storehouse of nourishment, tends to maintain or even to increase its weight (Table III). The root system of an annual however may decrease in weight at maturity (Table XXVI).

29. Text: Aschen Analysen, edit. 1871, Berlin.
30. Landwirt. Vers. Stat. 65, 264. Abstr. J. Amer. Chem. Soc. (1907) 617.
31. New Hampshire Expt. Station Bulletin 142.
32. Cornell Agr. Expt. Station Bulletin 273.

THE WHEAT PLANT

For purposes of comparative study a series of samples of the wheat plant in four growth stages were collected in the same season as the timothy plant. For this purpose two plots were selected thru a level field of winter wheat sown about October 1, 1907. Areas to be harvested—six feet in length and including three rows which were eight inches apart—were first marked off as in the case of the timothy. The date of cutting and stage of development of the four series of cuttings are indicated as follows:

No. of series	Date of cutting	Stage of development
Series 1	May 23, 1908	Plant green and in bloom
Series 2	June 4, 1908	Seed formed and in milk
Series 3	June 11, 1908	Seed in dough
Series 4	June 19, 1908	Seed fully ripe

As in the case of timothy, the plant was cut off two inches above the ground and weighed at once in tight container. The heads were separated from the stalks and leaves and weighed separately. Heads, stalks and leaves were treated in the same manner as the timothy to obtain the air dry sample. The roots and stubble from the area cut were dug up, washed with water, and also allowed to come to the air dry condition. The air dry material, after compositing the like samples from the two plots in each series, was prepared for the analysis by grinding to a fine sample as has been stated before for the timothy. No analyses of the ash of the wheat plant were attempted in this series, due to lack of sufficient material. The determinations made and the methods followed are the same as for timothy and have already been explained in detail.

Discussion of Data. The data of the wheat plant here shown exhibits much the same kind of variation in composition as was seen in the timothy plant. The weight of the green wheat plant per acre shows a tendency to decrease from series I to series 4 while the dry matter which it contains increases in amount (Tables XXIV, XXV, XXVI) (Fig. 11). 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 (Table XXVI) (Fig. 12) than any of the other parts, gaining five or six times in weight in about twenty-seven days. The stalks, leaves, 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 is probably 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 and leaves, 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 of the entire plant while at the ripe stage 86 per cent of the dry matter is above ground.

The root system of the wheat plant appears to empty itself of nutrients as the wheat ripens and the weight of roots and stubble per acre falls. Schulze[33] has published some ratios of the weights of plant tops to weights of their roots at different stages. For wheat at the shooting stage he gives the weight of the roots as 27.8 per cent of the weight of the tops, at the milk stage 10.5 per cent, and at maturity 9.2 per cent. These figures are not exactly comparable with those here presented (Table XXXII) as the roots and stubble are weighed togther and their percentage of the total plant given.

The total wheat plant gains continuously in amount of protein from the start (Table XXVII) (Fig. 13). The per cent is highest in the young plant (Table XXXIII) showing it to be taken up most rapidly at this stage. Liebscher[9] places nitrogen as first in the order of amount of all material absorbed by the plant in its young stage. As we should expect, the greatest gain in nitrogen occurs in the heads of the wheat plant. The percentage value falling slightly indicates that addition of other substances is occurring at a greater rate. Again we see from the decreasing amount and per cent in the stalks and leaves, roots, and stubble (Tables XXVII, XXXV, XXXVII) 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 material in the wheat plant (Table XXVIII) (Fig. 14) are much the same in kind as for timothy. Again we note a loss in amount of the total plant between blossoming time and milk stage of the seed. After this the

33. Festschift 50 Jubilaum Agr. Chem.: Versuchs in Kontrol Stat. Breslau. 67. Abstr. U. S. Dept. Agr. Expt. Station Record 31, 733.

yield again rises as the oil begins to form in the plant above ground. The oil is rapidly produced in the head after the head forms, as is shown by the rapid rise in the amount present. A period of wet weather preceding this cutting may also be a contributing cause, in part at least, to this variation. The drop in amount at the last stage may be 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 (Tables XXVIII, XXXVII) indicates that this material is passing on from the roots to the plant above ground.

Considering the percentage values of the ether soluble in the plant above ground and in the heads we see a drop in value also at series 3. This same variation in percentage value occurred in the wheat grains as reported in Bulletin 101, Michigan Agricultural Experiment Station, to which reference has already been made. As in the case of the data here presented, this drop in value of ether soluble occurred in the milk stage.

The crude fiber in the wheat plant (Table XXIX) (Fig. 15) appears to increase in amount so long as growth takes place. It reaches its maximum in quantity in all parts of the plant about the milk stage, after which it remains practically constant. That the amount does not decrease in the stalks and leaves, roots and stubble except when parts fall off shows that crude fiber 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 the loss here at this period.

Ash is absorbed by the plant in considerable quantities during the growth period (Table XXX) (Fig. 16) but appears to be constant during the ripening period except for losses due to washing by rain or 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, leaves, and heads. The stalks and leaves 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 XXXI) (Fig. 17). These constituents are added more rapidly than all the others, especially in the heads where the increase goes on rapidly thruout the growing and ripening period. The stalks and leaves, 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 is reached, for at this time the amount present in the plant above the stubble has become constant.

As with the timothy, the percentage composition of the roots and stubble of the wheat as compared with the stalks and leaves gives no proof that there is any transference downward of any nutrients, with the possible exception of nitrogen free extract.

The rapid storing up of dry matter, nitrogen, and ash in the young plant which has been pointed out in this report is in accord with the work of Pierre,[11] Wolff,[10] Berthelot,[21] and Adorjan.[7] That the roots and stalks contribute nitrogen and starch forming materials to the grain while ripening has been mentioned or proven by Deherain and Meyer,[19] Dupont,[22] Hebert,[20] Adorjan,[7] and perhaps others. Shroeder[34] 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 and that the lower part of the plant or old growth loses about one-half of its phosphorus 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 parts and upper extremities of the plant growth;[34] the wheat plant shows the analogous property in collecting these constituents in the heads. Hansteen,[35] 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 the phosphorus. He points out a tendency of the plant to store its ash constituents in the leaves and blossoms. This accords with Schroeder's statement that these constituents collect in the extremities of plant growth.

A study of changes in the composition of the oat plant has been reported from the South Carolina Agricultural Experiment Station.[36] The oat plant was cut every day for sixteen days except Sundays and days of rainfall. The constituents determined were moisture, protein, and ash in seed, glume, leaf, and straw and in addition carbohydrates were determined in the seed. This data shows that the protein and ash show a tendency to decrease in per cent as the oat plant ripens. The dry matter of the oat plant, the carbohydrates in particular, increase rapidly in percentage value as the plant approaches maturity.

COMPARISON OF TIMOTHY WITH WHEAT

Considering the timothy and the wheat plant side by side we find characteristics of growth and composition which vary similarly

34. Shroeder: Bied. Centr. fur. Agr. Chem. 1879, 270. Abstr. J. Chem. Soc. (London) 1880, 335.
35. Landwirt. Jahrb. 36, 267. Abstr. J. Amer. Chem. Soc., 1908, 566.
36. Bulletin 163.

in both plants. In both the timothy and the wheat plant the moisture in the green plant is highest in the young stages and this moisture diminishes 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 and leaves, stubble and bulbs of the timothy increase in weight of dry substance both in the growth and ripening period of the plant. The wheat stalks and leaves, 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 by the wheat plant 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 heads and bulbs. The wheat heads absorb most of the nitrogen of the plant, the other parts contributing some of this constituent to the heads. In both plants the ash shows a tendency to accumulate in the heads, also to a less degree in the stalks and leaves. The root systems of both plants yield mineral matter to the plant above ground during ripening. Ether soluble material, probably as chlorophyll, is high in the young plant and, as oil, is high in the ripe plant, particularly in the heads. Some of the ether soluble material is transferred from the roots and stubble of the wheat to the plant above ground. In both plants the absolute amount of ether soluble material in the total plant decreases at about the time of blossoming, probably due to a rapid decrease in the amount or to some change in the nature of the chlorophyll. In both plants crude fiber is formed in all parts of the plant during growth, attaining its maximum about blossoming time. Most of the fiber is found in the stalks and leaves. 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 and leaves during the life of the plant. With wheat, the stalks and leaves, roots and stubble pass these constituents to the head during ripening.

With both plants, all constituents reach their maximum in the plant above ground just before ripening. In most cases the losses previously discussed cause these value to fall at maturity.

The percentage values of the ether extract, ash, and nitrogen free extract in the wheat plant above ground vary in the same way as for timothy hay. The large proportionate increase of protein and nitrogen free extract in the heads of the wheat at maturity causes respectively a rise in percentage of protein at this time instead of a decrease, and a fall in percentage of crude fiber instead of an increase as with timothy.

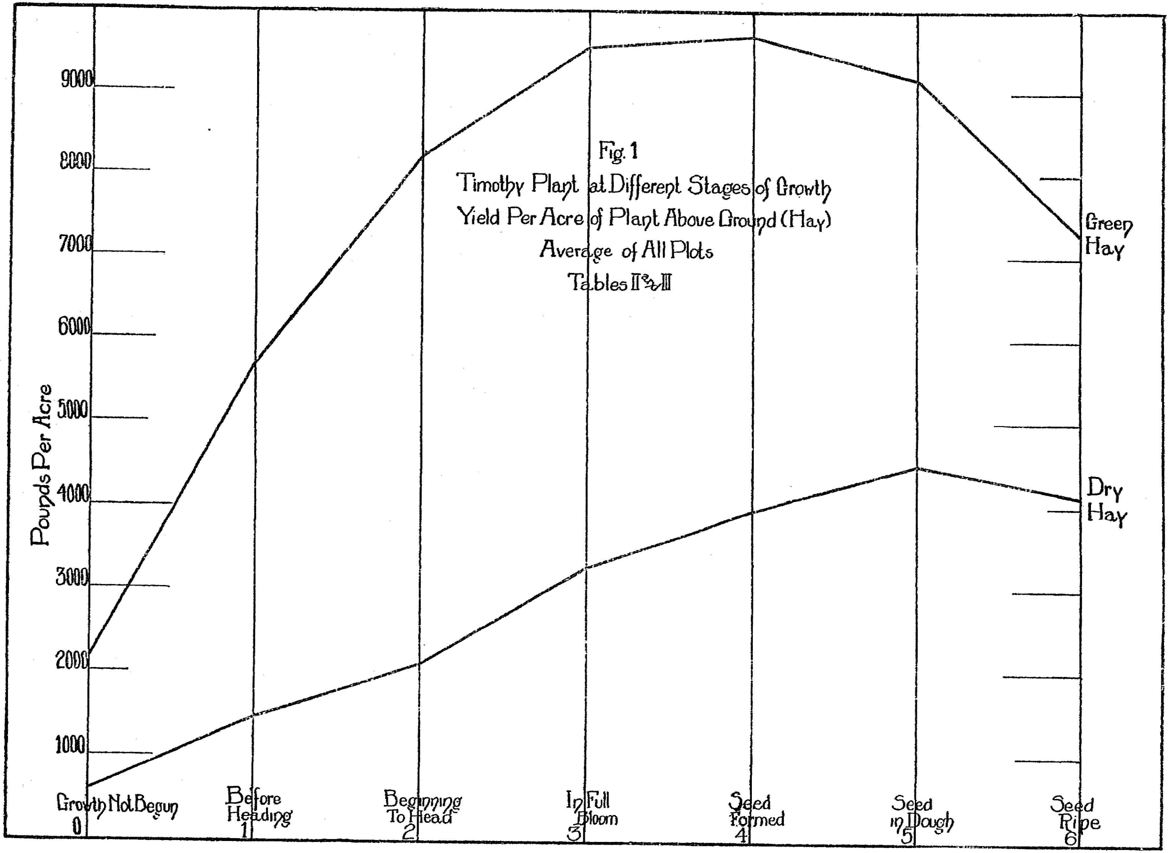

Fig. 1
Timothy Plant at Different Stages of Growth
Yield Per Acre of Plant Above Ground (Hay)
Average of All Plots
Tables II & III

TABLES

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 1......	5700.6	1472.1	25.82	74.18
Series 2......	8229.4	2093.9	25.44	74.56
Series 3......	9539.2	3287.5	34.46	65.54
Series 4......	9696.6	3975.8	41.02	58.98
Series 5......	8584.2	4508.8	52.52	47.48
Series 6......	7223.8	4114.8	56.97	43.03
Series 0......	2168.7	599.9	27.66	72.34

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 and leaves (grams)	Green weight per acre of heads (pounds)	Green weight per acre of stalks and leaves (pounds)	Total green weight per acre of the hay (pounds)
Series 1, Plot 1..........	....	535.0	....	4,281.4	4,281.4
Series 1, Plot 2..........	....	526.0	....	4,209.4	4,209.4
Series 1, Plot 3..........	....	1,076.0	....	8,610.9	8,610.9
Average.............	....	712.3	....	5,700.6	5,700.6
Series 2, Plot 1..........	....	788.0	....	6,306.1	6,306.1
Series 2, Plot 2..........	....	815.0	....	6,522.2	6,522.2
Series 2, Plot 3..........	....	1,482.0	....	11,860.0	11,860.0
Average.............	....	1,028.3	....	8,229.4	8,229.4
Series 3, Plot 1..........	78.6	821.4	629.0	6,573.4	7,202.4
Series 3, Plot 2..........	105.4	913.6	843.5	7,311.3	8,154.8
Series 3, Plot 3..........	163.3	1,493.7	1,306.8	11,953.6	13,260.4
Average.............	115.8	1,076.2	926.4	8,612.8	9,539.2
Series 4, Plot 1..........	76.9	842.1	615.4	6,739.1	7,354.5
Series 4, Plot 2..........	94.6	901.4	757.1	7,213.6	7,970.7
Series 4, Plot 3..........	185.5	1,534.5	1,484.5	12,280.1	13,764.6
Average.............	119.0	1,092.7	952.3	8,744.3	9,696.6
Series 5, Plot 1..........	108.5	754.5	868.3	6,038.0	6,906.3
Series 5, Plot 2..........	133.3	777.7	1,066.8	6,223.7	7,290.5
Series 5, Plot 3..........	231.1	1,429.9	1,849.4	11,443.1	13,292.5
Average.............	157.6	987.4	1,261.5	7,901.6	9,163.1
Series 6, Plot 1..........	95.0	574.0	760.3	4,593.5	5,353.8
Series 6, Plot 2..........	117.0	582.0	936.3	4,657.6	5,593.9
Series 6, Plot 3..........	179.0	1,161.0	1,432.5	9,291.1	10,723.6
Average.............	130.3	772.3	1,043.0	6,180.7	7,223.7
Series 0, Plot 1..........	....	195.0	....	1,506.5	1,506.5
Series 0, Plot 2..........	....	176.0	....	1,408.5	1,408.5
Series 0, Plot 3..........	....	442.0	....	3,537.2	3,537.2
Average.............	....	271.0	....	2,168.7	2,168.7

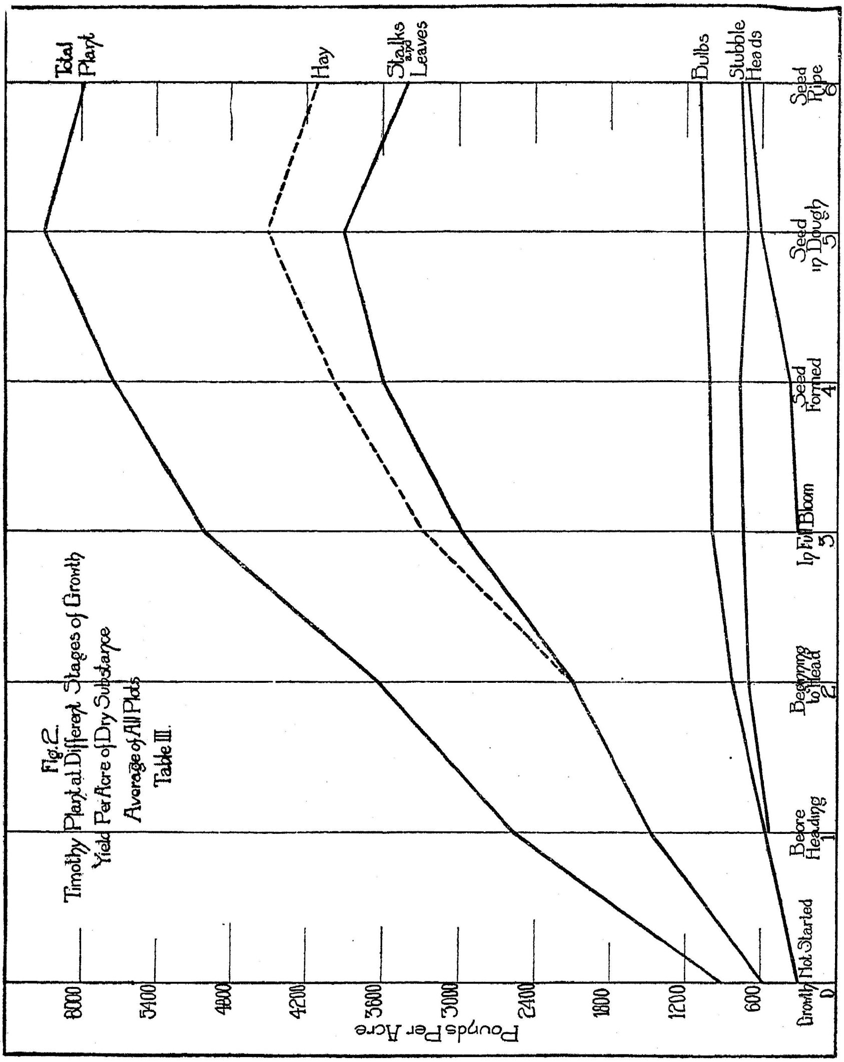
Fig. 2.
Timothy Plant at Different Stages of Growth
Yield Per Acre of Dry Substance
Average of All Plots
Table III.
Pounds Per Acre
6000
5400
4800
4200
3600
3000
2400
1800
1200
600
Growth Not Started 0
Before Heading 1
Beginning to Head 2
In Full Bloom 3
Seed Formed 4
Seed in Dough 5
Seed Ripe 6
Total Plant
Hay
Stalks and Leaves
Bulbs
Stubble
Heads

TABLE III—DRY WEIGHT OF THE PLANT PER ACRE IN POUNDS (WATER FREE)

Designation of cuttings	Heads	Stalks and leaves	Hay	Stubble	Bulbs	Total Plant
Series 1, Plot 1	....	1,179.3	1,179.3	665.2	627.4	2,471.9
Series 1, Plot 2	....	1,153.5	1,153.5	414.8	490.4	2,058.7
Series 1, Plot 3	....	2,083.5	2,083.5	529.5	551.7	3,164.7
Average	....	1,472.1	1,472.1	536.5	556.5	2,565.1
Series 2, Plot 1	....	1,679.0	1,679.0	780.8	888.4	3,348.2
Series 2, Plot 2	....	1,641.0	1,641.0	682.2	812.7	3,135.9
Series 2, Plot 3	....	2,961.8	2,961.8	629.2	786.5	4,377.5
Average	....	2,093.9	2,093.9	697.4	829.2	3,620.5
Series 3, Plot 1	214.1	2,260.6	2,474.7	711.5	1,008.7	4,194.9
Series 3, Plot 2	281.6	2,464.9	2,746.5	770.2	875.7	4,392.3
Series 3, Plot 3	453.3	4,188.1	4,641.4	734.1	1,101.1	6,476.6
Average	316.3	2,971.2	3,287.5	738.6	995.2	5,021.3
Series 4, Plot 1	244.9	2,742.2	2,987.1	867.3	1,062.6	4,917.0
Series 4, Plot 2	301.0	2,931.8	3,232.8	673.2	859.0	4,765.0
Series 4, Plot 3	603.5	5,104.0	5,707.5	748.1	1,109.6	7,565.2
Average	381.1	3,592.7	3,975.8	762.9	1,010.4	5,749.1
Series 5, Plot 1	420.7	2,983.1	3,403.8	554.0	878.0	4,835.8
Series 5, Plot 2	508.0	3,068.3	3,576.3	766.3	977.4	5,320.0
Series 5, Plot 3	894.1	5,652.3	6,546.4	829.1	1,344.9	8,720.4
Average	607.6	3,901.2	4,508.8	716.5	1,066.8	6,292.1
Series 6, Plot 1	492.9	2,518.1	3,011.0	875.2	1,112.8	4,999.0
Series 6, Plot 2	676.3	2,733.9	3,410.2	555.4	670.6	4,636.2
Series 6, Plot 3	978.4	4,944.9	5,923.3	855.8	1,507.3	8,286.4
Average	715.9	3,399.0	4,114.9	762.1	1,096.9	5,973.9
Series 0, Plot 1	....	431.6	431.6	....	231.8	663.4
Series 0, Plot 2	....	389.5	389.5	....	210.3	599.8
Series 0, Plot 3	....	978.4	978.4	....	485.2	1463.6
Average	....	599.8	599.8	....	309.1	908.9

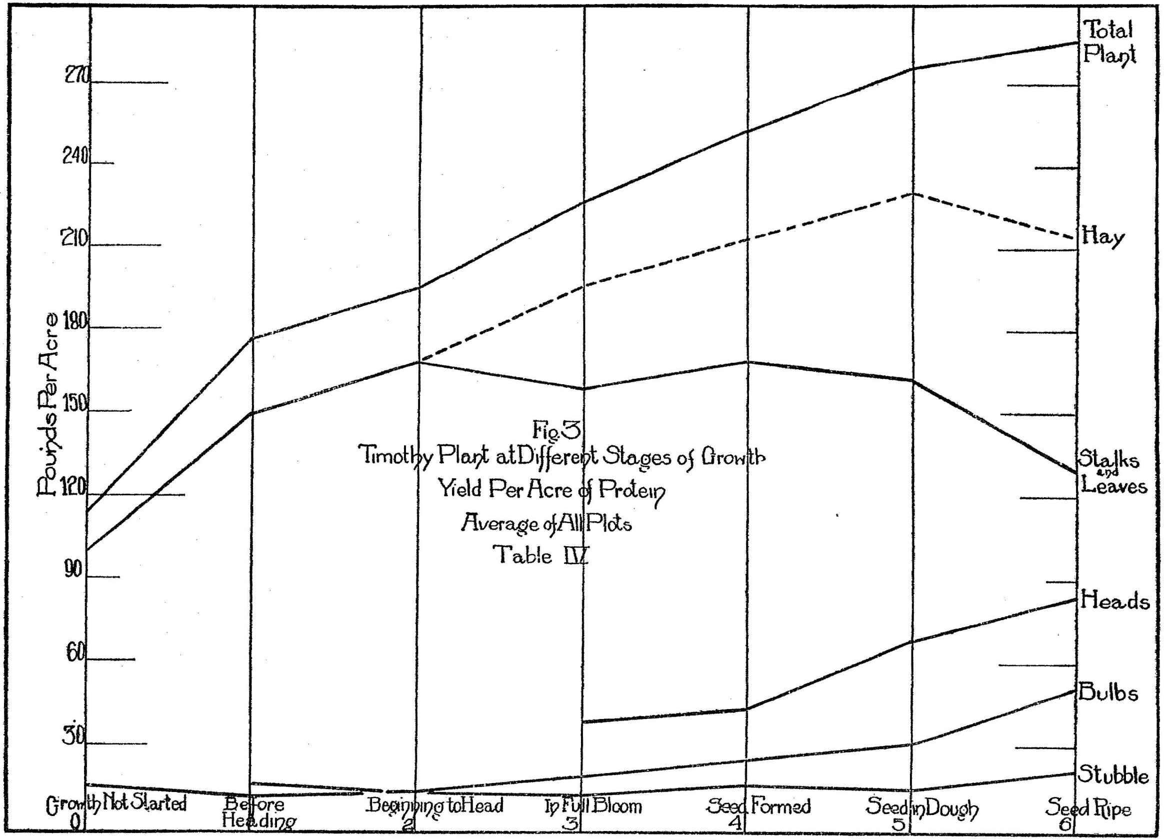

Fig 3
Timothy Plant at Different Stages of Growth
Yield Per Acre of Protein
Average of All Plots
Table IV

TABLE IV—WEIGHT OF THE PROTEIN PER ACRE IN POUNDS

Designation of cuttings	Heads	Stalks and leaves	Hay	Stubble	Bulbs	Total plant
Series 1, Plot 1	....	120.0	120.0	18.8	12.6	151.4
Series 1, Plot 2	....	117.4	117.4	11.8	9.8	139.0
Series 1, Plot 3	....	211.9	211.9	15.0	11.1	238.0
Average	....	149.7	149.7	15.2	11.2	176.1
Series 2, Plot 1	....	134.7	134.7	15.3	14.5	164.5
Series 2, Plot 2	....	131.6	131.6	13.4	13.3	158.3
Series 2, Plot 3	....	237.5	237.5	12.4	12.9	262.8
Average	....	167.9	167.9	13.7	13.6	195.2
Series 3, Plot 1	25.8	120.3	146.1	11.8	19.0	176.9
Series 3, Plot 2	33.9	131.2	165.1	12.8	16.5	194.4
Series 3, Plot 3	54.6	222.8	277.4	12.2	20.8	310.4
Average	38.1	158.1	196.2	12.2	18.8	227.2
Series 4, Plot 1	27.8	129.5	157.3	18.1	25.8	201.2
Series 4, Plot 2	34.2	138.5	172.7	14.0	20.8	207.5
Series 4, Plot 3	68.5	241.1	309.6	15.6	26.9	352.1
Average	43.5	169.7	213.2	15.9	24.5	253.6
Series 5, Plot 1	47.7	124.4	172.1	11.0	25.6	208.7
Series 5, Plot 2	57.6	127.9	185.5	15.3	28.5	229.3
Series 5, Plot 3	101.4	235.6	337.0	16.5	39.2	392.7
Average	68.9	162.6	231.5	14.3	31.1	276.9
Series 6, Plot 1	58.0	96.0	154.0	25.0	51.8	230.8
Series 6, Plot 2	79.6	104.2	183.8	15.9	31.2	230.9
Series 6, Plot 3	115.2	188.6	303.8	24.4	70.2	398.4
Average	84.3	129.6	213.9	21.7	51.1	286.7
Series 0, Plot 1	....	71.8	71.8	....	10.9	82.7
Series 0, Plot 2	....	64.8	64.8	....	9.9	74.7
Series 0, Plot 3	....	162.8	162.8	....	22.9	185.7
Average	....	99.8	99.8	....	14.6	114.4

Fig. 4.
Timothy Plant at Different Stages of Growth.
Yield Per Acre of Ether Soluble (Fat)
Average of All Plots
Table V.

TABLE V—WEIGHT OF THE ETHER SOLUBLE (FAT) PER ACRE IN POUNDS

Designation of cuttings	Heads	Stalks and leaves	Hay	Stubble	Bulbs	Total Plant
Series 1, Plot 1	....	54.4	54.4	9.9	5.0	69.3
Series 1, Plot 2	....	53.2	53.2	6.2	3.9	63.3
Series 1, Plot 3	....	96.1	96.1	7.9	4.4	108.4
Average	....	67.9	67.9	8.0	4.4	80.3
Series 2, Plot 1	....	68.4	68.4	17.5	8.1	94.0
Series 2, Plot 2	....	66.9	66.9	15.3	7.4	89.6
Series 2, Plot 3	....	120.7	120.7	14.2	7.1	142.0
Average	....	85.3	85.3	15.7	7.5	108.5
Series 3, Plot 1	7.1	51.8	58.9	4.5	11.7	75.1
Series 3, Plot 2	9.3	56.5	65.8	4.8	10.2	80.8
Series 3, Plot 3	15.0	96.0	111.0	4.6	12.7	128.3
Average	10.5	68.1	78.6	4.6	11.5	94.7
Series 4, Plot 1	5.4	88.0	93.4	6.6	8.4	108.4
Series 4, Plot 2	6.6	94.1	100.7	5.1	6.8	112.6
Series 4, Plot 3	13.3	163.7	177.0	5.7	8.8	191.5
Average	8.4	115.3	123.7	5.8	8.0	137.5
Series 5, Plot 1	11.0	86.7	97.7	6.6	8.9	113.2
Series 5, Plot 2	13.2	89.2	102.4	9.2	9.9	121.5
Series 5, Plot 3	23.3	164.2	187.5	9.9	13.7	211.1
Average	15.9	113.3	129.2	8.6	10.8	148.6
Series 6, Plot 1	23.2	58.7	81.9	8.7	10.8	101.4
Series 6, Plot 2	31.8	63.7	95.5	5.6	6.5	107.6
Series 6, Plot 3	46.0	115.3	161.3	8.5	14.6	184.4
Average	33.6	79.3	112.9	7.6	10.6	131.1
Series 0, Plot 1	....	12.9	12.9	....	1.2	14.1
Series 0, Plot 2	....	11.7	11.7	....	1.1	12.8
Series 0, Plot 3	....	29.3	29.3	....	2.5	31.8
Average	....	18.0	18.0	....	1.5	19.5

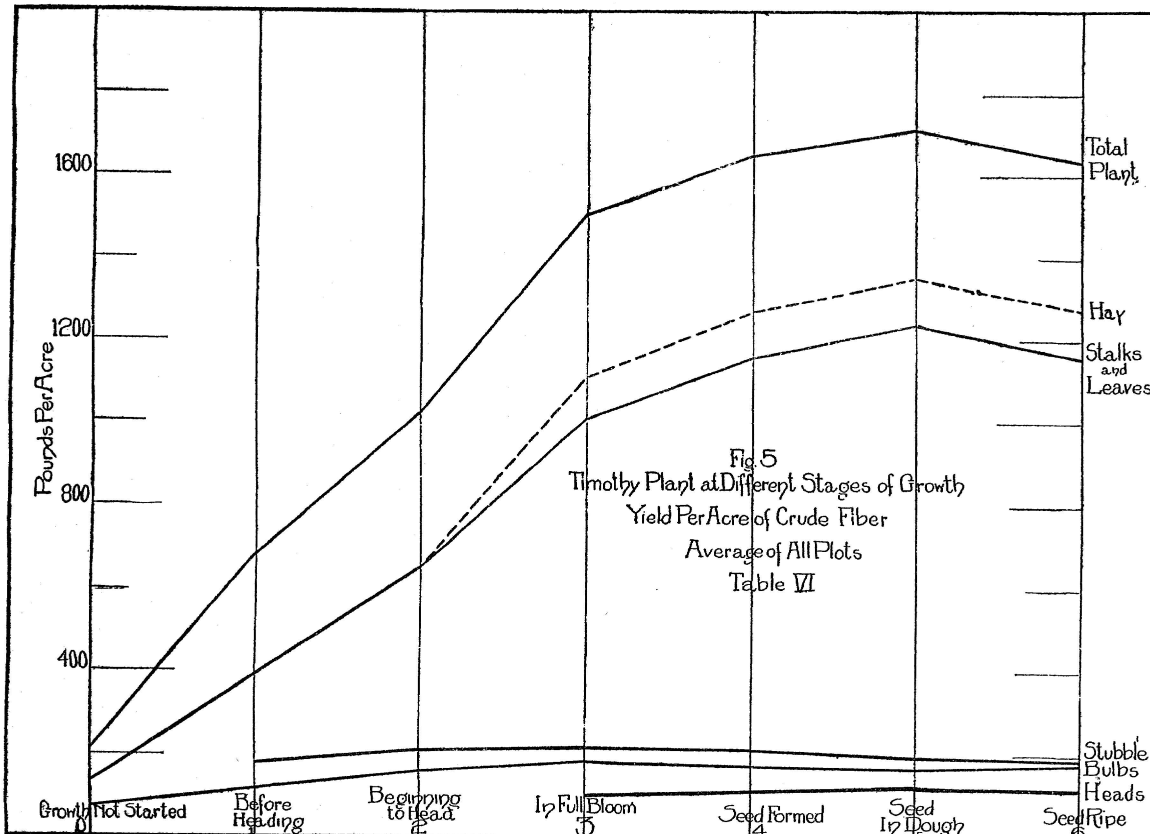

Fig. 5
Timothy Plant at Different Stages of Growth
Yield Per Acre of Crude Fiber
Average of All Plots
Table VI

TABLE VI—WEIGHT OF THE CRUDE FIBRE PER ACRE IN POUNDS

Designation of cuttings	Heads	Stalks and leaves	Hay	Stubble	Bulbs	Total plant
Series 1, Plot 1.....	....	310.3	310.3	221.6	133.7	665.6
Series 1, Plot 2.....	....	303.5	303.5	138.2	104.5	546.2
Series 1, Plot 3.....	....	548.3	548.3	176.3	117.6	842.2
Average.........	....	387.4	387.4	178.7	118.6	684.7
Series 2, Plot 1.....	....	523.1	523.1	237.3	170.9	931.3
Series 2, Plot 2.....	....	511.2	511.2	207.3	156.4	874.9
Series 2, Plot 3.....	....	922.7	922.7	191.2	151.4	1,265.3
Average.........	....	652.3	652.3	212.0	159.5	1,023.8
Series 3, Plot 1.....	65.6	768.9	834.5	212.4	185.8	1,232.7
Series 3, Plot 2.....	86.3	838.5	924.8	229.9	161.3	1,316.0
Series 3, Plot 3.....	139.0	1,424.6	1,563.6	219.1	202.8	1,985.5
Average.........	96.9	1,010.7	1,107.6	220.5	183.3	1,511.4
Series 4, Plot 1.....	69.7	884.7	954.4	243.3	184.4	1,382.1
Series 4, Plot 2.....	85.6	945.9	1,031.5	188.8	149.1	1,369.4
Series 4, Plot 3.....	171.7	1,646.6	1,818.3	209.9	192.6	2,220.8
Average.........	109.0	1,159.1	1,268.1	214.0	175.3	1,657.4
Series 5, Plot 1.....	83.0	945.3	1,028.3	151.8	137.0	1,317.1
Series 5, Plot 2.....	100.3	972.3	1,072.6	210.0	152.5	1,435.1
Series 5, Plot 3.....	176.5	1,791.1	1,967.6	227.2	209.9	2,404.7
Average.........	120.0	1,236.2	1,356.2	196.3	166.5	1,719.0
Series 6, Plot 1.....	77.6	857.9	935.5	217.9	180.6	1,334.0
Series 6, Plot 2.....	106.5	931.4	1,037.9	138.3	108.9	1,285.1
Series 6, Plot 3.....	154.1	1,684.6	1,838.7	213.1	244.7	2,296.5
Average.........	112.7	1,158.0	1,270.7	189.7	178.1	1,638.5
Series 0, Plot 1.....	....	94.9	94.9	....	54.3	149.2
Series 0, Plot 2.....	....	85.6	85.6	....	49.3	134.9
Series 0, Plot 3.....	....	215.0	215.0	....	113.8	328.8
Average.........	....	131.8	131.8	....	72.5	204.3

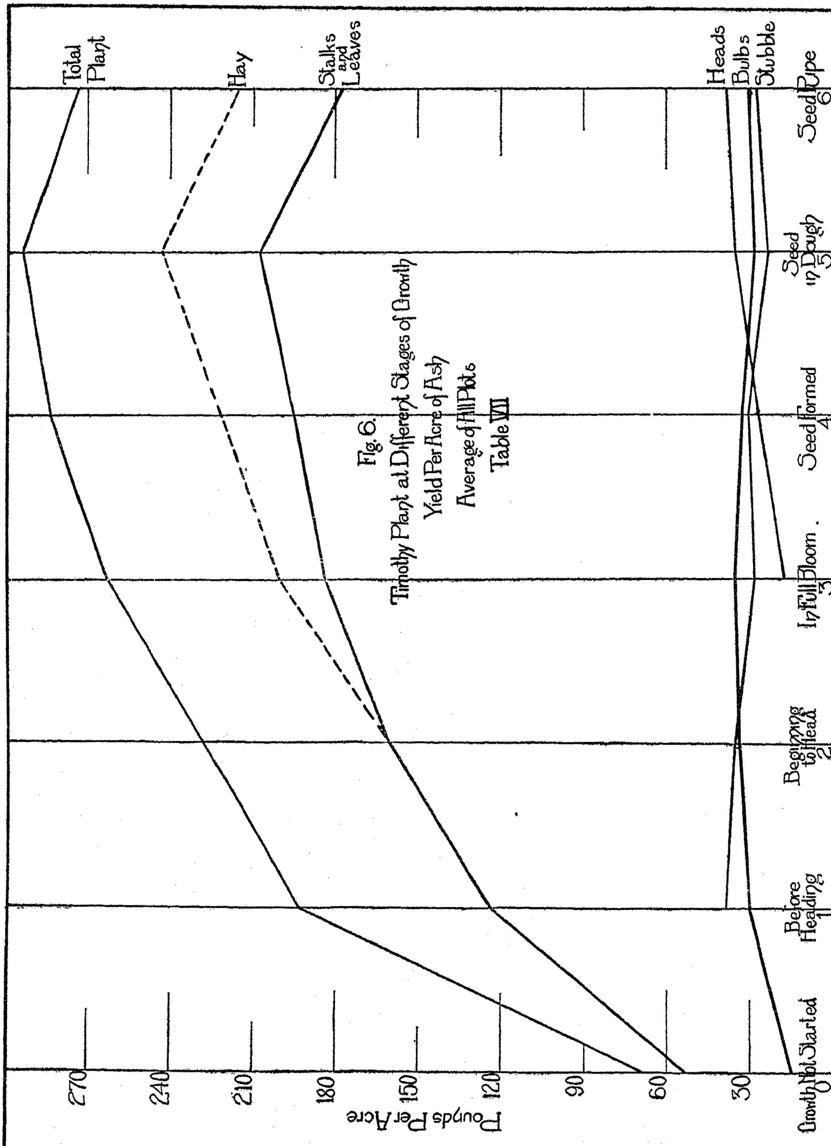

Fig. 6.
Timothy Plant at Different Stages of Growth
Yield Per Acre of Ash
Average of All Plots
Table VII

TABLE VII—WEIGHT OF THE ASH PER ACRE IN POUNDS

Designation of cutting	Heads	Stalks and leaves	Hay	Stubble	Bulbs	Total plant
Series 1, Plot 1	....	99.2	99.2	47.9	33.9	181.0
Series 1, Plot 2	....	97.0	97.0	29.9	26.5	153.4
Series 1, Plot 3	....	175.2	175.2	38.2	29.8	243.2
Average	....	123.8	123.8	38.7	30.0	192.5
Series 2, Plot 1	....	127.8	127.8	39.3	36.2	203.3
Series 2, Plot 2	....	124.9	124.9	34.3	33.1	192.3
Series 2, Plot 3	....	225.4	225.4	31.7	32.0	289.1
Average	....	159.4	159.4	35.1	33.7	228.2
Series 3, Plot 1	11.6	139.3	150.9	27.0	35.5	213.4
Series 3, Plot 2	15.3	151.9	167.2	29.2	30.8	227.2
Series 3, Plot 3	24.6	258.1	282.7	27.8	38.8	349.3
Average	17.2	183.1	200.3	28.0	35.0	263.3
Series 4, Plot 1	17.2	148.3	165.5	34.9	34.6	235.0
Series 4, Plot 2	21.2	158.6	179.8	27.1	27.9	234.8
Series 4, Plot 3	42.5	276.0	318.5	30.1	36.1	384.7
Average	27.0	194.3	221.3	30.7	32.9	284.9
Series 5, Plot 1	24.6	158.6	183.2	18.1	23.2	224.5
Series 5, Plot 2	29.7	163.1	192.8	25.1	25.8	243.7
Series 5, Plot 3	52.3	300.5	352.8	27.2	35.4	415.4
Average	35.6	207.4	243.0	23.5	28.1	294.6
Series 6, Plot 1	26.5	130.9	157.4	32.2	30.9	220.5
Series 6, Plot 2	36.3	142.1	178.4	20.5	18.6	217.5
Series 6, Plot 3	52.6	257.0	309.6	31.5	41.8	382.9
Average	38.5	176.6	215.1	28.1	30.4	273.6
Series 0, Plot 1	....	37.9	37.9	....	11.2	49.1
Series 0, Plot 2	....	34.3	34.3	....	10.1	44.4
Series 0, Plot 3	....	86.0	86.0	....	23.3	109.3
Average	....	52.7	52.7	....	14.9	67.6

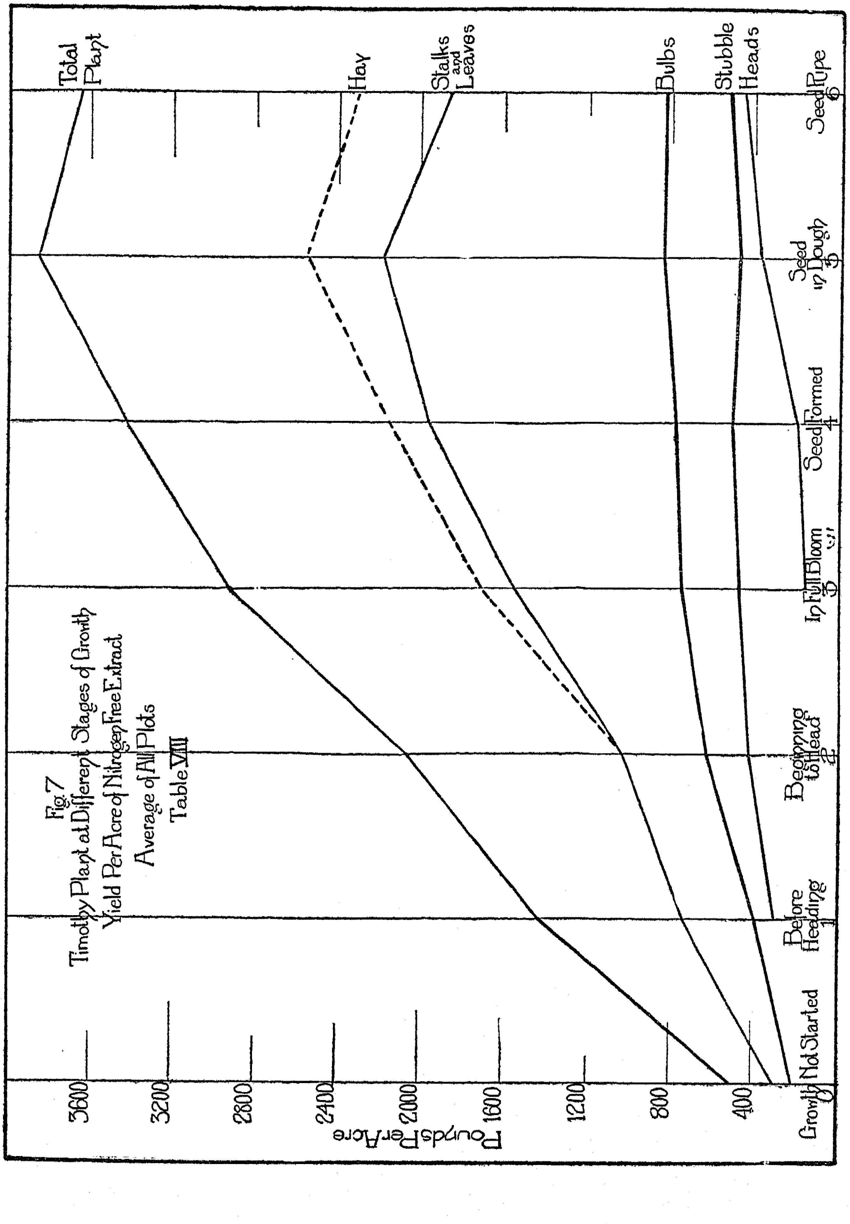

Fig. 7
Timothy Plant at Different Stages of Growth
Yield Per Acre of Nitrogen Free Extract
Average of All Plots
Table VIII

TABLE VIII—WEIGHT OF THE NITROGEN-FREE EXTRACT PER ACRE IN POUNDS

Designation of cuttings	Heads	Stalks and leaves	Hay	Stubble	Bulbs	Total plant
Series 1, Plot 1.....	....	595.4	595.4	366.9	442.2	1,404.5
Series 1, Plot 2.....	....	582.4	582.4	228.8	345.7	1,156.9
Series 1, Plot 3.....	....	1,052.0	1,052.0	292.0	388.9	1,732.9
Average.........	....	743.2	743.2	295.9	392.3	1,431.4
Series 2, Plot 1.....	....	825.1	825.1	471.3	658.7	1,955.1
Series 2, Plot 2.....	....	806.4	806.4	411.8	602.6	1,820.8
Series 2, Plot 3.....	....	1,455.5	1,455.5	379.7	583.2	2,418.4
Average.........	....	1,029.0	1,029.0	420.9	614.8	2,064.7
Series 3, Plot 1.....	104.0	1,180.2	1,284.2	455.8	756.7	2,496.7
Series 3, Plot 2.....	136.8	1,286.9	1,423.7	493.5	656.9	2,574.1
Series 3, Plot 3.....	220.2	2,186.5	2,406.7	470.3	826.0	3,703.0
Average.........	153.7	1,551.2	1,704.9	473.2	746.5	2,924.6
Series 4, Plot 1.....	124.8	1,491.7	1,616.5	564.4	809.5	2,990.4
Series 4, Plot 2.....	153.4	1,594.9	1,748.3	438.0	654.4	2,840.7
Series 4, Plot 3.....	307.6	2,776.5	3,084.1	486.9	845.2	4,416.2
Average.........	195.2	1,954.4	2,149.6	496.5	769.7	3,415.8
Series 5, Plot 1.....	254.4	1,668.2	1,922.6	366.3	683.3	2,972.2
Series 5, Plot 2.....	307.1	1,715.8	2,022.9	506.7	760.7	3,290.3
Series 5, Plot 3.....	540.5	3,160.9	3,701.4	548.2	1,046.8	5,296.4
Average.........	367.3	2,181.6	2,548.9	473.8	830.3	3,853.0
Series 6, Plot 1.....	307.6	1,374.6	1,682.2	591.3	838.7	3,112.2
Series 6, Plot 2.....	422.0	1,492.4	1,914.4	375.2	505.5	2,795.1
Series 6, Plot 3.....	610.5	2,699.4	3,309.9	578.3	1,136.0	5,024.2
Average.........	446.7	1,855.5	2,302.2	514.9	826.7	3,643.8
Series 0, Plot 1.....	....	214.0	214.0	....	154.2	368.2
Series 0, Plot 2.....	....	193.1	193.1	....	139.9	333.0
Series 0, Plot 3.....	....	485.1	485.1	....	322.7	807.8
Average.........	....	297.4	297.4	....	205.6	503.5

TABLE IX—DISTRIBUTION OF THE DRY WEIGHT OF THE TIMTOHY PLANT

Designation of cutting	Per cent Heads	Per cent Stalks and leaves	Per cent Hay	Per cent Stubble	Per cent Bulbs
Series 1, Plot 1	....	47.71	47.71	26.91	25.38
Series 1, Plot 2	....	56.03	56.03	20.15	23.82
Series 1, Plot 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
Series 2, Plot 2	....	52.33	52.33	21.76	25.92
Series 2, Plot 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
Series 3, Plot 2	6.41	56.12	62.53	17.54	19.94
Series 3, Plot 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
Series 4, Plot 2	6.32	61.53	67.84	14.13	18.03
Series 4, Plot 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
Series 5, Plot 2	9.55	57.68	67.22	14.41	18.37
Series 5, Plot 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
Series 6, Plot 2	14.59	58.97	73.56	11.98	14.47
Series 6, Plot 3	11.81	59.68	71.48	10.33	18.19
Average	11.98	56.90	68.88	12.76	18.36
Series 0, Plot 1	....	65.06	65.06	....	34.94
Series 0, Plot 2	....	64.94	64.94	....	35.06
Series 0, Plot 3	....	66.85	66.85	....	33.15
Average	....	65.99	65.99	....	34.01

TABLE X—COMPOSITION OF THE DRY TIMOTHY PLANT

Designation of the cuttings	Per cent protein	Per cent ether soluble (fat)	Per cent crude fibre	Per cent ash	Per cent nitrogen free extract
Series 1, Plot 1.....	6.13	2.80	26.93	7.32	56.82
Series 1, Plot 2.....	6.75	3.08	26.53	7.45	56.19
Series 1, Plot 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
Series 2, Plot 2.....	5.05	2.86	27.90	6.13	58.06
Series 2, Plot 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
Series 3, Plot 2.....	4.43	1.84	29.96	5.17	58.60
Series 3, Plot 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
Series 4, Plot 2.....	4.35	2.36	28.74	4.93	59.62
Series 4, Plot 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
Series 5, Plot 2.....	4.31	2.29	26.98	4.58	62.15
Series 5, Plot 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
Series 6, Plot 2.....	4.98	2.32	27.72	4.69	60.29
Series 6, Plot 3.....	4.80	2.23	27.71	4.62	60.63
Average.........	4.80	2.20	27.43	4.58	61.00
Series 0, Plot 1.....	12.48	2.13	22.49	7.40	55.50
Series 0, Plot 2.....	12.46	2.13	22.49	7.39	55.53
Series 0, Plot 3.....	12.69	2.17	22.47	7.47	55.20
Average.........	12.59	2.15	22.48	7.44	55.34

TABLE XI—COMPOSITION OF THE DRY SUBSTANCE OF THE TIMOTHY HEADS
AVERAGE OF ALL PLOTS

No. cuttings	Per cent protein	Per cent ether soluble (fat)	Per cent crude fibre	Per cent ash	Per cent nitrogen free extract
Series 3...........	12.05	3.30	30.65	5.42	48.58
Series 4...........	11.35	2.20	28.45	7.04	50.97
Series 5...........	11.34	2.61	19.74	5.86	60.45
Series 6...........	11.78	4.70	15.75	5.38	62.40

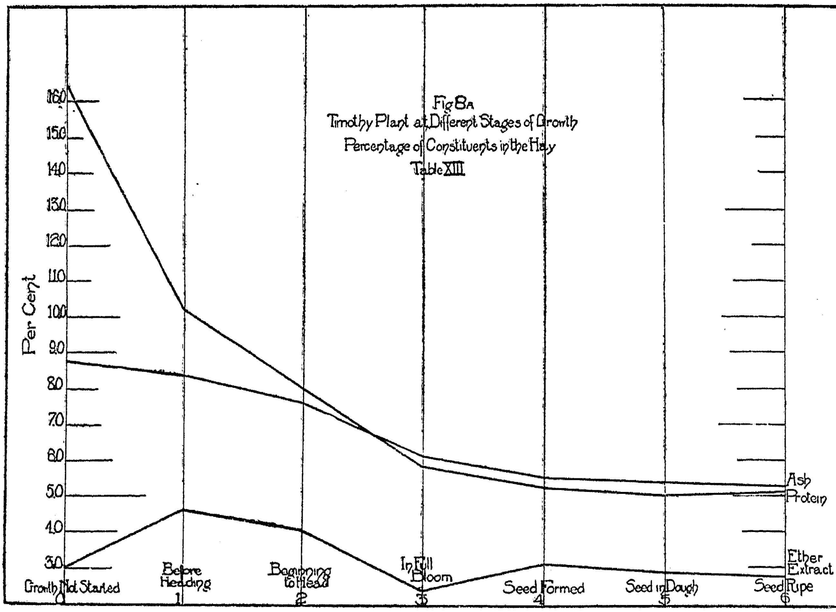
Fig 8A
Timothy Plant at Different Stages of Growth
Percentage of Constituents in the Hay
Table XIII
Per Cent
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
Ash
Protein
Ether Extract
Growth Not Started 0
Before Heading 1
Beginning to Head 2
In Full Bloom 3
Seed Formed 4
Seed in Dough 5
Seed Ripe 6

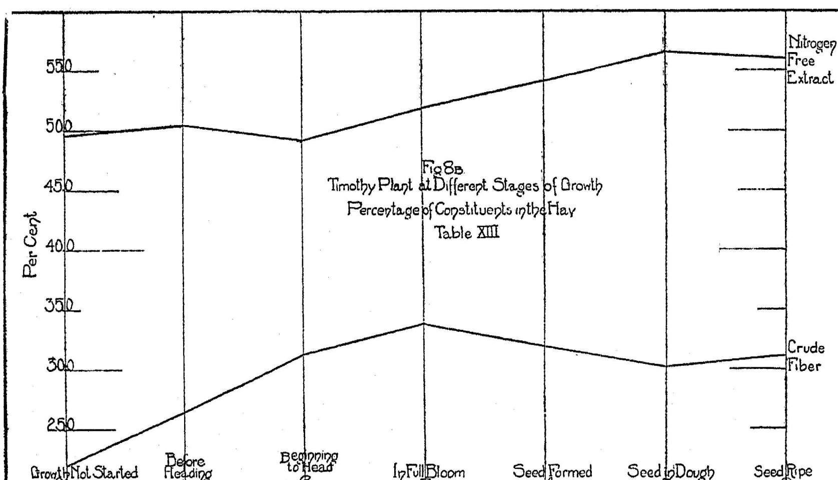
Fig 8B
Timothy Plant at Different Stages of Growth
Percentage of Constituents in the Hay
Table XIII
Per Cent
55.0
50.0
45.0
40.0
35.0
30.0
25.0
Nitrogen Free Extract
Crude Fiber
Growth Not Started 0
Before Heading 1
Beginning to Head 2
In Full Bloom 3
Seed Formed 4
Seed in Dough 5
Seed Ripe 6

TABLE XII—COMPOSITION OF THE DRY SUBSTANCE OF THE TIMOTHY STALKS AND LEAVES. AVERAGE OF ALL PLOTS

No. cuttings	Per cent protein	Per cent ether soluble (fat)	Per cent crude fibre	Per cent Ash	Per cent nitrogen free extract
Series 1...........	10.18	4.61	26.32	8.41	50.49
Series 2...........	8.02	4.08	31.15	7.61	49.14
Series 3...........	5.32	2.29	34.02	6.16	52.21
Series 4...........	4.72	3.21	32.26	5.41	54.40
Series 5...........	4.16	2.91	31.69	5.32	55.93
Series 6...........	3.81	2.33	34.07	5.20	54.59
Series 0...........	16.64	3.00	21.98	8.79	49.58

TABLE XIII—COMPOSITION OF THE DRY SUBSTANCE OF THE TIMOTHY HAY AVERAGE OF ALL PLOTS

No. cuttings	Per cent protein	Per cent ether soluble (fat)	Per cent crude fibre	Per cent ash	Per cent nitrogen free extract
Series 1...........	10.18	4.61	26.31	8.41	50.49
Series 2...........	8.02	4.07	31.15	7.61	49.14
Series 3...........	5.90	2.38	33.74	6.10	51.89
Series 4...........	5.27	3.13	31.95	5.54	54.12
Series 5...........	5.06	2.87	30.21	5.38	56.48
Series 6...........	5.12	2.72	31.07	5.23	55.87
Series 0...........	16.64	3.00	21.98	8.79	49.58

TABLE XIV—COMPOSITION OF THE DRY SUBSTANCE OF THE TIMOTHY STUBBLE. AVERAGE OF ALL PLOTS

No. cuttings	Per cent protein	Per cent ether soluble (fat)	Per cent crude fibre	Per cent ash	Per cent nitrogen free extract
Series 1...........	2.83	1.50	33.31	7.21	55.16
Series 2...........	1.96	2.25	30.40	5.04	60.36
Series 3...........	1.66	0.63	29.85	3.80	64.07
Series 4...........	2.08	0.76	28.06	4.03	65.08
Series 5...........	1.99	1.20	27.40	3.28	66.13
Series 6...........	2.86	1.00	24.90	3.68	67.57
Series 0...........	....	....	....	....	....

TABLE XV—COMPOSITION OF THE DRY SUBSTANCE OF THE TIMOTHY BULBS
AVERAGE OF ALL PLOTS

No. cuttings	Per cent protein	Per cent ether soluble (fat)	Per cent crude fibre	Per cent ash	Per cent nitrogen free extract
Series 1	2.01	0.79	21.32	5.40	70.49
Series 2	1.64	0.91	19.24	4.07	74.14
Series 3	1.88	1.16	18.42	3.52	75.02
Series 4	2.42	0.79	17.35	3.25	76.18
Series 5	2.91	1.02	15.61	2.64	77.83
Series 6	4.65	0.97	16.24	2.77	75.37
Series 0	4.72	0.51	23.45	4.81	66.51

TABLE XVI—TIMOTHY BULBS, SPROUTS AND HEADS

Cuttings and plot	No. bulbs found	Average	No. sprouts found	Average	No. heads found	Average
Series 1, Plot 1	999	....	None	....	Not formed	....
Series 1, Plot 2	1386	1205	None	....	Not formed	....
Series 1, Plot 3	1234	....	None	....	Not formed	....
Series 2, Plot 1	1444	....	None	....	Not formed	....
Series 2, Plot 2	1172	1238	None	....	Not formed	....
Series 2, Plot 3	1099	....	None	....	Not formed	....
Series 3, Plot 1	1467	....	300	....	Not counted	....
Series 3, Plot 2	1097	1297	200	191	Not counted	....
Series 3, Plot 3	1329	....	75	....	Not counted	....
Series 4, Plot 1	1644	....	255	....	Not counted	....
Series 4, Plot 2	1089	1318	163	229	Not counted	....
Series 4, Plot 3	1223	....	271	....	Not counted	....
Series 5, Plot 1	975	....	158	....	378	....
Series 5, Plot 2	1227	1080	123	177	398	480
Series 5, Plot 3	1040	....	250	....	663	....
Series 6, Plot 1	1401	....	559	....	352	....
Series 6, Plot 2	757	1176	175	314	385	439
Series 6, Plot 3	1370	....	209	....	580	....
Series 0, Plot 1	407	....	None	....	Not formed	....
Series 0, Plot 2	301	586	None	....	Not formed	....
Series 0, Plot 3	1051	....	None	....	Not formed	....

TABLE XVII—PERCENTAGE OF POTASSIUM OXIDE IN THE ASH AND DRY MATTER OF EACH PART

	Per cent insoluble K_2O in ash	Per cent water soluble K_2O in ash	Per cent total K_2O in ash	Per cent total K_2O in dry matter
Timothy heads				
Series 1	....	....	....	....
Series 2	....	....	....	....
Series 3	3.65	32.48	36.13	1.96
Series 4	6.56	14.97	21.53	1.52
Series 5	4.16	13.19	17.35	1.02
Series 6	5.12	10.64	15.76	0.85
Timothy stalks and leaves				
Series 1	5.15	25.11	30.26	2.54
Series 2	3.45	25.29	28.74	2.19
Series 3	5.03	23.26	28.29	1.74
Series 4	4.47	23.68	28.15	1.52
Series 5	2.98	19.63	22.61	1.20
Series 6	2.60	19.25	21.85	1.14
Timothy stubble				
Series 1	4.37	20.63	25.00	1.80
Series 2	4.17	13.63	17.80	0.90
Series 3	3.90	14.73	18.63	0.71
Series 4	1.97	15.51	17.48	0.70
Series 5	3.64	14.67	18.31	0.60
Series 6	2.92	20.73	23.65	0.87
Timothy bulbs				
Series 1	1.44	44.85	46.29	2.50
Series 2	1.73	36.28	38.01	1.55
Series 3	1.24	35.38	36.62	1.29
Series 4	0.96	35.20	36.16	1.18
Series 5	1.07	34.64	35.71	0.94
Series 6	0.85	Lost	....	....
Total timothy plant				
Series 1	4.41	27.29	31.70	2.38
Series 2	3.31	25.12	28.43	1.79
Series 3	4.32	24.57	28.89	1.51
Series 4	3.99	23.30	27.29	1.35
Series 5	2.99	19.89	22.88	1.07
Series 6	2.79	Incomplete	due to loss a	bove.

TABLE XVIII—PERCENTAGE OF PHOSPHORUS PENTOXIDE IN THE ASH AND DRY MATTER OF EACH PART

	Per cent insoluble P^2O^5 in ash	Per cent water soluble P^2O^5 in ash	Per cent total P^2O^5 in ash	Per cent total P^2O^5 in dry matter
Timothy heads				
Series 1	....	....	....	....
Series 2	....	....	....	....
Series 3	5.24	11.05	16.29	0.88
Series 4	3.78	6.47	10.25	0.72
Series 5	4.19	4.32	8.51	0.50
Series 6	4.40	5.70	10.10	0.54
Timothy stalks and leaves				
Series 1	2.52	3.95	6.47	0.54
Series 2	2.49	3.85	6.34	0.48
Series 3	2.12	4.19	6.31	0.39
Series 4	2.39	4.11	6.50	0.35
Series 5	1.57	3.73	5.30	0.28
Series 6	2.43	2.77	5.20	0.27
Timothy stubble				
Series 1	0.72	4.60	5.32	0.38
Series 2	1.53	5.13	6.66	0.34
Series 3	1.89	4.84	6.73	0.26
Series 4	1.66	5.81	7.47	0.30
Series 5	1.61	3.54	5.15	0.17
Series 6	1.76	7.33	9.09	0.33
Timothy bulbs				
Series 1	1.17	11.19	12.36	0.67
Series 2	2.13	10.07	12.20	0.50
Series 3	2.47	9.91	12.38	0.44
Series 4	2.27	12.45	14.72	0.48
Series 5	2.43	15.69	18.12	0.48
Series 6	2.42	14.32	16.74	0.46
Total timothy plant				
Series 1	1.95	5.21	7.16	0.54
Series 2	2.29	4.97	7.26	0.46
Series 3	2.35	5.47	7.82	0.41
Series 4	2.43	5.48	7.91	0.39
Series 5	1.97	4.93	6.90	0.32
Series 6	2.64	4.93	7.57	0.35

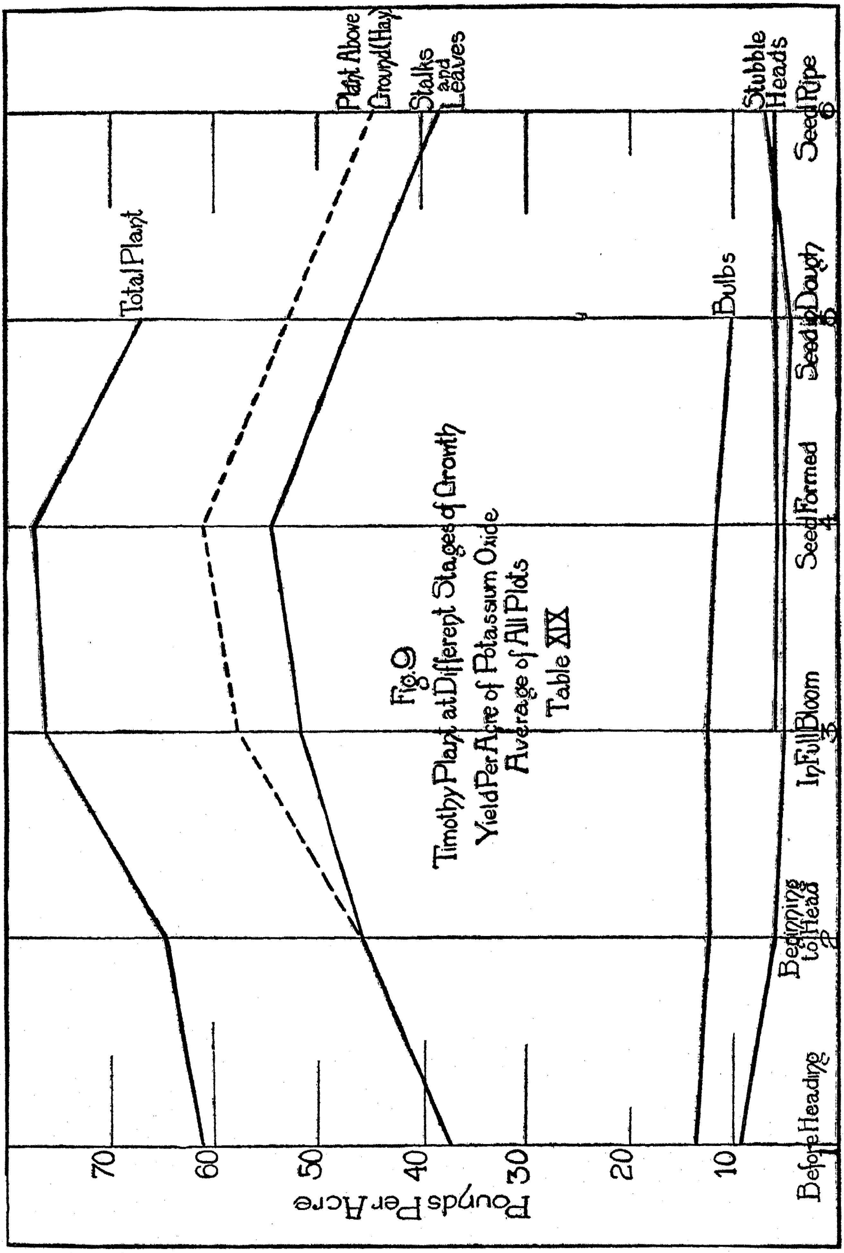

Fig. 9
Timothy Plant at Different Stages of Growth
Yield Per Acre of Potassium Oxide
Average of All Plots
Table XIX

TABLE XIX—WEIGHT OF POTASSIUM OXIDE AND PHOSPHORUS PENTOXIDE PER ACRE IN POUNDS. AVERAGE OF ALL PLOTS

	Insoluble K^2O	Water soluble K^2O	Total K^2O	Insoluble P^2O^5	Water soluble P^2O^5	Total P^2O^5
Timothy heads						
Series 1	....	....	....	....	....	....
Series 2	....	....	....	....	....	....
Series 3	0.62	5.57	6.19	0.90	1.89	2.79
Series 4	1.77	4.03	5.80	1.02	1.74	2.76
Series 5	1.48	4.69	6.17	1.49	1.53	3.02
Series 6	1.97	4.09	6.06	1.69	2.19	3.88
Timothy stalks and leaves						
Series 1	6.37	31.08	37.45	3.12	4.89	8.01
Series 2	5.50	40.30	45.80	3.97	6.13	10.10
Series 3	9.21	42.59	51.80	3.88	7.67	11.55
Series 4	8.68	46.01	54.69	4.64	7.99	12.63
Series 5	6.18	40.71	46.89	3.26	7.73	10.99
Series 6	4.59	34.00	38.59	4.29	4.89	9.18
Timothy stubble						
Series 1	1.69	7.97	9.66	0.27	1.78	2.05
Series 2	1.46	4.79	6.25	0.54	1.80	2.34
Series 3	1.09	4.13	5.22	0.53	1.35	1.88
Series 4	0.60	4.76	5.36	0.51	1.78	2.29
Series 5	0.85	3.44	4.29	0.38	0.83	1.21
Series 6	0.82	5.81	6.63	0.49	2.06	2.55
Timothy bulbs						
Series 1	0.43	13.47	13.90	0.35	3.36	3.71
Series 2	0.58	12.24	12.82	0.72	3.40	4.12
Series 3	0.43	12.39	12.82	0.86	3.47	4.33
Series 4	0.31	11.57	11.88	0.74	4.09	4.83
Series 5	0.30	9.74	10.04	0.68	4.41	5.09
Series 6	0.26	Lost	......	0.73	4.36	5.09
Total timothy plant						
Series 1	8.49	52.52	61.01	3.74	10.03	13.77
Series 2	7.54	57.33	64.87	5.23	11.33	16.56
Series 3	11.35	64.68	76.03	6.17	14.38	20.55
Series 4	11.36	66.37	77.73	6.91	15.60	22.51
Series 5	8.81	58.58	67.39	5.81	14.50	20.31
Series 6	7.64	Incomplete due to loss above		7.20	13.50	20.70

TABLE XX—K^2O AND P^2O^5 RATIO OF INSOLUBLE TO TOTAL EXPRESSED IN PER CENT

	Series 1	Series 2	Series 3	Series 4	Series 5	Series 6
Timothy heads						
K^2O	....	....	10.1	30.4	23.9	32.5
P^2O^5	....	....	32.1	36.8	49.2	43.5
Timothy stalks and leaves						
K^2O	17.0	12.0	17.7	15.8	13.1	11.9
P^2O^5	38.9	39.2	33.5	36.7	29.6	46.7
Timothy stubble						
K^2O	17.4	23.4	20.9	11.2	19.8	12.3
P^2O^5	13.5	22.9	28.0	22.2	31.2	19.3
Timothy bulbs						
K^2O	3.1	4.5	3.3	2.6	2.9	....
P^2O^5	9.4	17.4	19.9	15.4	13.4	14.4
Total timothy plant						
K^2O	13.9	11.6	14.9	14.6	13.1	....
P^2O^5	27.2	31.5	30.0	30.7	28.5	34.8

TABLE XXI—SHOWING POTASSIUM OXIDE REMOVED BY TIMOTHY HAY. AVERAGE OF ALL PLOTS

	Weight of K^2O per acre in hay (pounds)	Weight of K^2O per acre in stubble and bulbs (pounds)	Weight of K^2O per acre in total plant (pounds)	Per cent K^2O of plant in the hay	Per cent K^2O of plant in stubble and bulbs
Series 1	37.46	23.57	61.03	61.38	38.62
Series 2	45.80	19.08	64.88	70.59	29.41
Series 3	58.00	18.05	76.05	76.27	23.73
Series 4	60.50	17.25	77.75	77.82	22.18
Series 5	53.07	14.33	67.40	78.73	21.27
Series 6	44.66	Incomplete due to a lost sample.			

TABLE XXII—SHOWING PHOSPHORUS PENTOXIDE REMOVED BY TIMOTHY HAY. AVERAGE OF ALL PLOTS

	Weight of P^2O^5 per acre in hay (pounds)	Weight of P^2O^5 per acre in stubble and bulbs (pounds)	Weight of P^2O^5 per acre in total plant (pounds)	Per cent P^2O^5 of plant in the hay	Per cent P^2O^5 of plant in stubble and bulbs
Series 1	8.01	5.77	13.78	58.14	41.86
Series 2	10.10	6.46	16.56	61.01	38.99
Series 3	14.35	6.22	20.57	69.75	30.25
Series 4	15.39	7.13	22.52	68.34	31.66
Series 5	14.02	6.30	20.32	68.99	31.01
Series 6	13.07	7.65	20.72	63.10	36.90

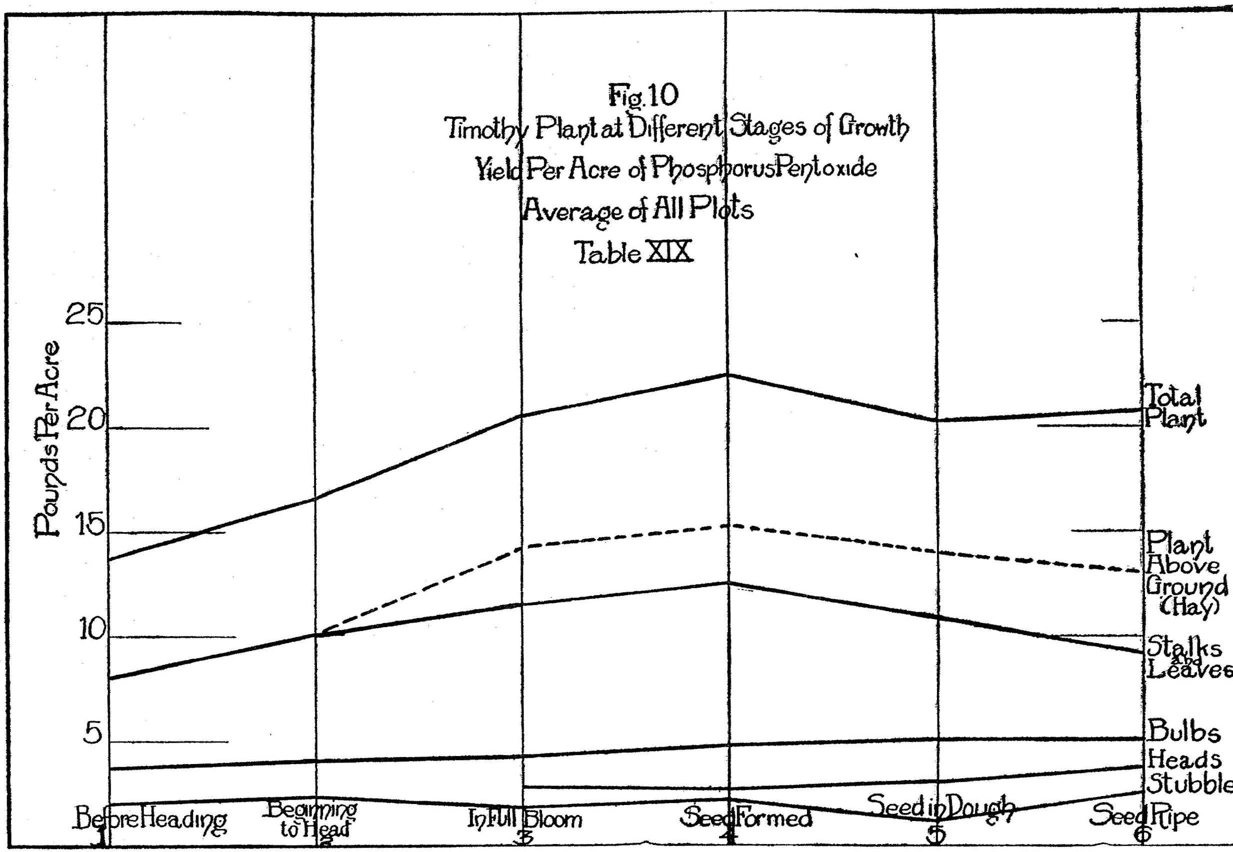

Fig. 10
Timothy Plant at Different Stages of Growth
Yield Per Acre of Phosphorus Pentoxide
Average of All Plots
Table XIX

TABLE XXIII—WEIGHT OF CONSTITUTENTS PER TON OF DRY TIMOTHY HAY (POUNDS)

	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	3054.7	2892.0	2791.0	2903.5
Subtracting one ton of dry hay	2000.0	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	1054.7	892.0	791.0	903.5
Weight of ash of total timothy plant which yields one ton of dry hay	261.51	217.96	160.17	143.33	130.67	132.97
Weight of ash in one ton of dry hay	168.20	152.20	122.00	110.80	107.60	104.60
Weight of ash of bulbs and stubble of plants yielding one ton of dry hay	93.31	65.76	38.17	33.53	23.07	28.37
Weight of K_2O of timothy plant yielding one ton of dry hay	82.91	61.97	46.26	39.11	29.90	
Weight of K_2O in one ton of dry hay	50.88	43.74	35.28	30.44	23.54	21.71
Weight of K_2O in bulbs and stubble of plant yielding one ton of dry hay	32.03	18.23	10.98	8.67	6.36	
Weight of P_2O_5 of timothy plant yielding one ton of dry hay	18.72	15.82	12.51	11.33	9.01	10.06
Weight of P_2O_5 in one ton of dry hay	10.88	9.65	8.73	7.74	6.22	6.35
Weight of P_2O_5 in bulbs and stubble of plant yielding one ton of dry hay	7.84	6.17	3.78	3.59	2.79	3.71

TABLE XXIV—MOISTURE AND DRY SUBSTANCE OF THE WHEAT PLANT. AVERAGE OF ALL PLOTS

	Total green weight per acre of the plant above ground (pounds)	Total dry weight per acre of the plant above ground (pounds)	Per cent dry substance in plant above ground	Per cent moisture in plant above ground
Series 1	12,340.2	5,422.3	27.73	72.27
Series 2	11,699.9	4,750.1	40.60	59.40
Series 3	12,204.1	5,527.2	45.29	54.71
Series 4	8,254.8	5,238.3	63.46	36.54

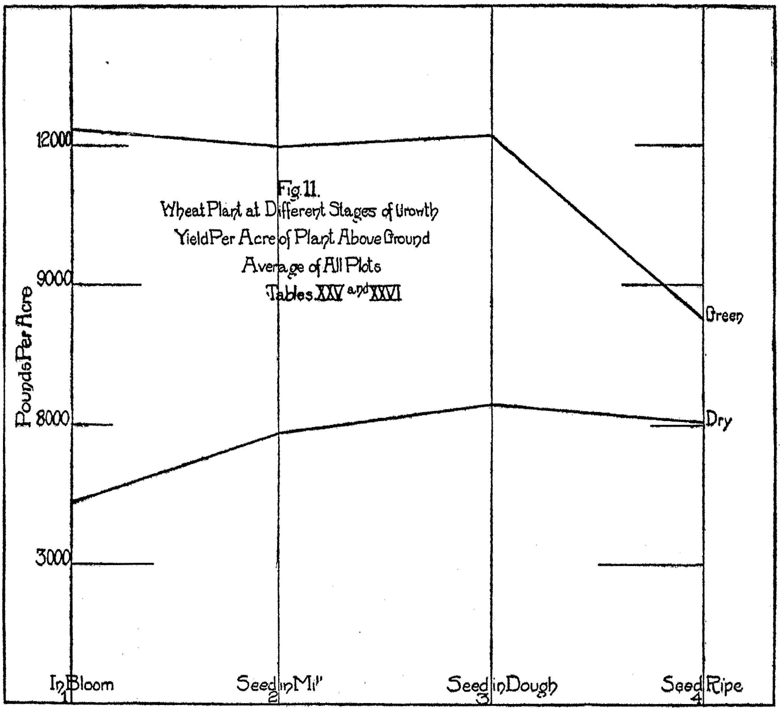
Fig. 11.
Wheat Plant at Different Stages of Growth
Yield Per Acre of Plant Above Ground
Average of All Plots
Tables XXV and XXVI
Pounds Per Acre
12000
9000
8000
3000
Green
Dry
In Bloom
Seed in Mil'
Seed in Dough
Seed Ripe
1
2
3
4

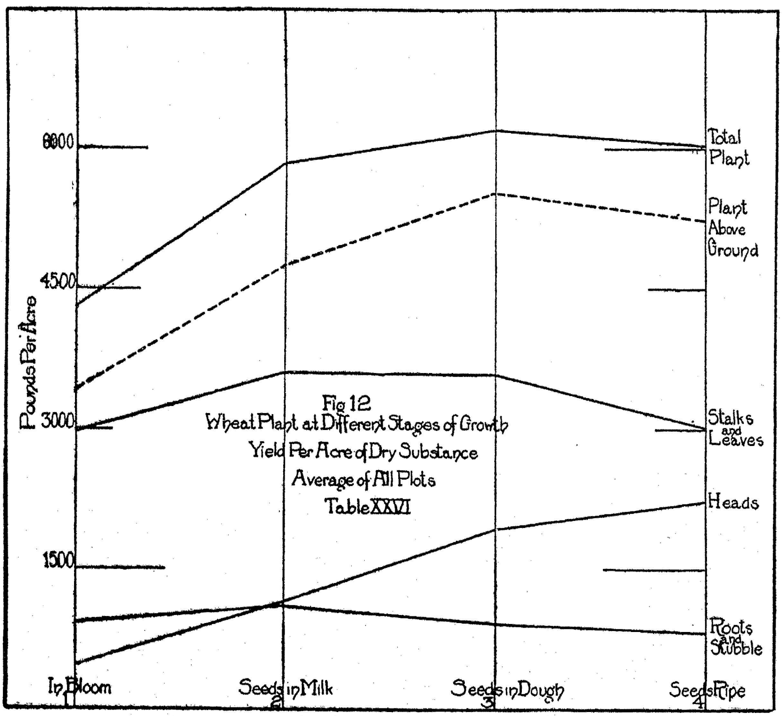
Fig 12
Wheat Plant at Different Stages of Growth
Yield Per Acre of Dry Substance
Average of All Plots
Table XXVI
Pounds Per Acre
6000
4500
3000
1500
Total Plant
Plant Above Ground
Stalks and Leaves
Heads
Roots and Stubble
In Bloom
Seeds in Milk
Seeds in Dough
Seeds Ripe
1
2
3
4

TABLE XXV—WEIGHTS OF THE GREEN WHEAT PLANT HARVESTED

Designation of cuttings	Green weight per plot of heads (grams)	Green weight per plot of stalks and leaves (grams)	Green weight per acre of heads (pounds)	Green weight per acre of stalks and leaves (pounds)	Total green weight per acre of wheat plant above ground (pounds)
Series 1, Plot 1.....	200.0	1,290.0	1,600.5	10,323.5	11,924.0
Series 1, Plot 2.....	213.0	1,381.0	1,704.6	11,051.7	12,756.3
Average.......	206.0	1,335.0	1,652.6	10,687.6	12,340.2
Series 2, Plot 1.....	393.0	1,033.0	3,145.1	8,266.8	11,411.9
Series 2, Plot 2.....	401.5	1,096.5	3,213.1	8,774.9	11,988.0
Average.......	397.0	1,065.0	3,179.1	8,520.8	11,699.9
Series 3, Plot 1.....	548.0	1,072.0	4,385.5	8,578.9	12,964.4
Series 3, Plot 2.....	512.5	917.5	4,101.4	7,342.5	11,443.9
Average.......	530.2	995.0	4,243.4	7,960.7	12,204.1
Series 4, Plot 1.....	427.0	616.0	3,417.1	4,929.7	8,346.8
Series 4, Plot 2.....	432.5	587.5	3,461.2	4,701.6	8,162.8
Average.......	429.0	601.7	3,439.2	4,815.6	8,254.8

TABLE XXVI—DRY WEIGHT OF THE PLANT PER ACRE IN POUNDS (WATER FREE)

Designation of cuttings	Heads	Stalks and leaves	Plant above ground	Roots and stubble	Total plant
Series 1, Plot 1.....	437.0	2,869.9	3,306.9	941.8	4,248.7
Series 1, Plot 2.....	465.3	3,072.4	3,537.7	880.0	4,417.7
Average.......	451.1	2,971.2	3,422.3	910.9	4,333.2
Series 2, Plot 1.....	1,128.4	3,501.8	4,630.2	1,133.0	5,763.2
Series 2, Plot 2.....	1,152.8	3,717.1	4,869.9	1,057.7	5,927.6
Average.......	1,140.7	3,609.4	4,750.1	1,095.3	5,845.4
Series 3, Plot 1.....	1,992.8	3,878.5	5,871.3	892.7	6,764.0
Series 3, Plot 2.....	1,863.7	3,319.5	5,183.2	919.1	6,102.3
Average.......	1,928.2	3,599.0	5,527.2	905.9	6,433.1
Series 4, Plot 1.....	2,211.9	3,083.5	5,295.4	859.0	6,154.4
Series 4, Plot 2.....	2,240.4	2,940.8	5,181.2	782.6	5,963.8
Average.......	2,226.1	3,012.2	5,238.3	820.8	6,059.1

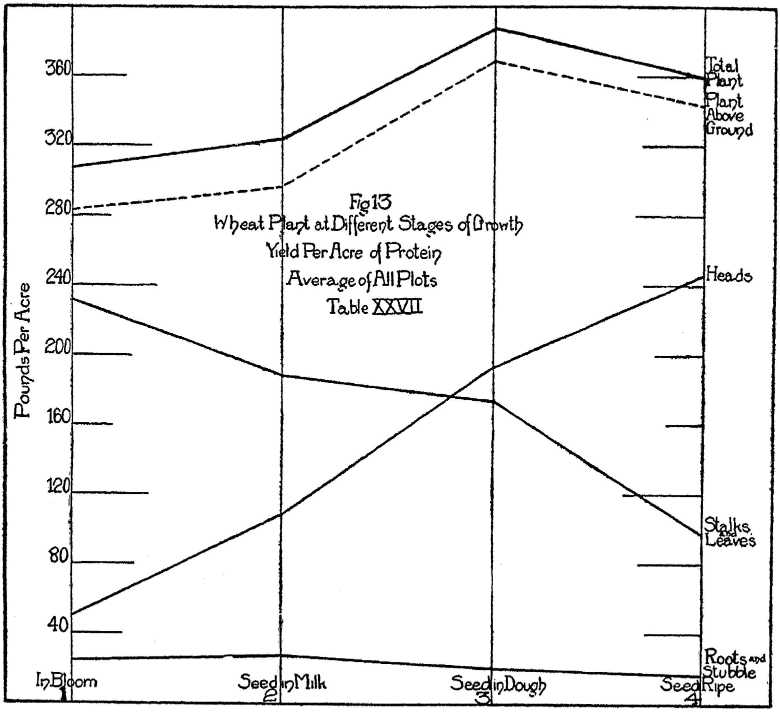
Fig 13
Wheat Plant at Different Stages of Growth
Yield Per Acre of Protein
Average of All Plots
Table XXVII
Pounds Per Acre
360
320
280
240
200
160
120
80
40
Total Plant
Plant Above Ground
Heads
Stalks and Leaves
Roots and Stubble
In Bloom
1
Seed in Milk
2
Seed in Dough
3
Seed Ripe
4

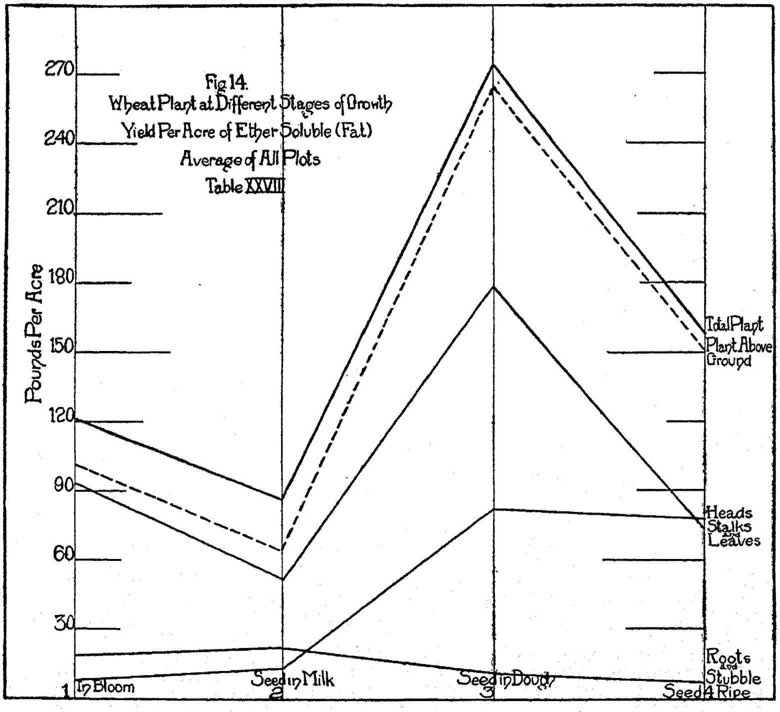
Fig 14.
Wheat Plant at Different Stages of Growth
Yield Per Acre of Ether Soluble (Fat)
Average of All Plots
Table XXVIII
Pounds Per Acre
270
240
210
180
150
120
90
60
30
Total Plant
Plant Above Ground
Heads
Stalks and Leaves
Roots and Stubble
In Bloom
1
Seed in Milk
2
Seed in Dough
3
Seed Ripe
4

TABLE XXVII—WEIGHT OF THE PROTEIN PER ACRE IN POUNDS

Designation of cuttings	Heads	Stalks and leaves	Plant above ground	Roots and stubble	Total plant
Series 1, Plot 1.....	48.8	224.7	273.5	26.5	300.0
Series 1, Plot 2.....	52.0	240.6	292.6	24.7	317.3
Average.......	50.4	232.6	283.0	25.6	308.6
Series 2, Plot 1.....	107.8	182.4	290.2	27.9	318.1
Series 2, Plot 2.....	110.1	193.7	303.8	26.0	329.8
Average.......	108.9	188.1	297.0	26.9	323.9
Series 3, Plot 1.....	200.5	188.5	389.0	19.1	408.1
Series 3, Plot 2.....	187.5	161.3	348.8	19.7	368.5
Average.......	194.0	174.9	368.9	19.4	388.3
Series 4, Plot 1.....	245.1	99.6	344.7	16.9	361.6
Series 4, Plot 2.....	248.2	95.0	343.2	15.4	358.6
Average.......	246.6	97.3	343.9	16.2	360.1

TABLE XXVIII—WEIGHT OF THE ETHER SOLUBLE PER ACRE IN POUNDS

Designation of cuttings	Heads	Stalks and leaves	Plant above ground	Roots and stubble	Total plant
Series 1, Plot 1.....	7.7	90.7	98.4	20.2	118.6
Series 1, Plot 2.....	8.2	97.1	105.3	18.8	124.1
Average.......	8.0	93.9	101.9	19.5	121.4
Series 2, Plot 1.....	13.4	48.7	62.1	23.2	85.3
Series 2, Plot 2.....	13.7	51.7	65.4	21.7	87.1
Average.......	13.6	50.2	63.8	22.4	86.2
Series 3, Plot 1.....	88.7	192.8	281.5	10.7	292.2
Series 3, Plot 2.....	82.9	165.0	247.9	11.0	258.9
Average.......	85.8	178.9	264.7	10.8	275.5
Series 4, Plot 1.....	77.2	74.9	152.1	6.4	158.5
Series 4, Plot 2.....	78.2	71.4	149.6	5.8	155.4
Average.......	77.7	73.2	150.9	6.1	157.0

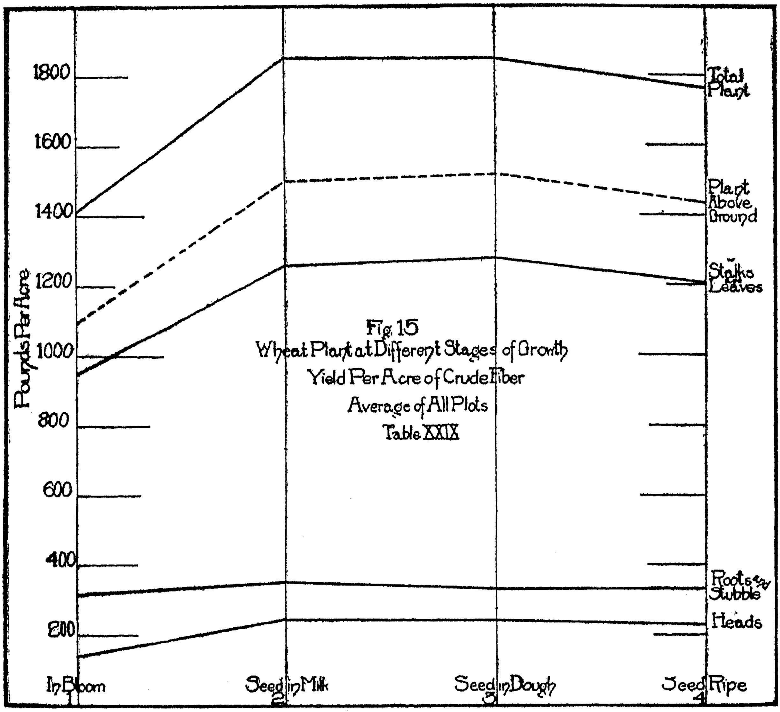
Fig. 15
Wheat Plant at Different Stages of Growth
Yield Per Acre of Crude Fiber
Average of All Plots
Table XXIX
Pounds Per Acre
1800
1600
1400
1200
1000
800
600
400
200
Total Plant
Plant Above Ground
Stalks and Leaves
Roots and Stubble
Heads
In Bloom 1
Seed in Milk 2
Seed in Dough 3
Seed Ripe 4

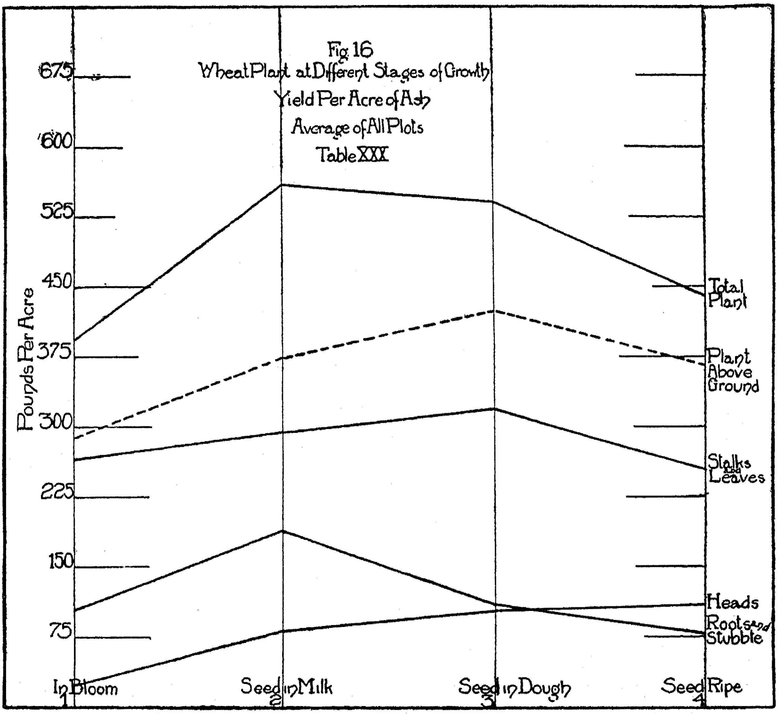
Fig. 16
Wheat Plant at Different Stages of Growth
Yield Per Acre of Ash
Average of All Plots
Table XXX
Pounds Per Acre
675
600
525
450
375
300
225
150
75
Total Plant
Plant Above Ground
Stalks and Leaves
Heads
Roots and Stubble
In Bloom 1
Seed in Milk 2
Seed in Dough 3
Seed Ripe 4

TABLE XXIX—WEIGHT OF THE CRUDE FIBER PER ACRE IN POUNDS

Designation of cuttings	Heads	Stalks and leaves	Plant above ground	Roots and stubble	Total plant
Series 1, Plot 1.....	136.3	920.1	1,056.4	326.1	1,382.5
Series 1, Plot 2.....	145.1	985.0	1,130.1	304.8	1,434.9
Average.......	140.7	952.6	1,093.3	315.4	1,408.7
Series 2, Plot 1.....	237.9	1,221.8	1,459.7	364.5	1,824.2
Series 2, Plot 2.....	243.0	1,296.9	1,539.9	340.3	1,880.2
Average.......	240.5	1,259.3	1,499.8	352.4	1,852.2
Series 3, Plot 1.....	248.5	1,378.4	1,626.9	325.0	1,951.9
Series 3, Plot 2.....	232.4	1,179.7	1,412.1	334.6	1,746.7
Average.......	240.4	1,279.1	1,519.5	329.8	1,849.3
Series 4, Plot 1.....	227.4	1,235.2	1,462.6	345.1	1,807.7
Series 4, Plot 2.....	230.3	1,178.1	1,408.4	314.4	1,722.8
Average.......	228.8	1,206.7	1,435.5	329.7	1,765.2

TABLE XXX—WEIGHT OF THE ASH PER ACRE IN POUNDS

Designation of cuttings	Heads	Stalks and leaves	Plant above ground	Roots and stubble	Total plant
Series 1, Plot 1.....	22.0	256.0	278.0	108.1	386.1
Series 1, Plot 2.....	23.5	274.0	297.5	101.0	398.5
Average.......	22.7	265.0	287.7	104.6	392.3
Series 2, Plot 1.....	79.4	285.8	365.2	195.2	560.4
Series 2, Plot 2.....	81.2	303.3	384.5	182.2	566.7
Average.......	80.3	294.5	374.8	188.7	563.5
Series 3, Plot 1.....	108.2	343.6	451.8	108.6	560.4
Series 3, Plot 2.....	101.2	294.1	395.3	111.8	507.1
Average.......	104.7	318.8	423.5	110.2	533.7
Series 4, Plot 1.....	109.5	259.3	368.8	81.8	450.6
Series 4, Plot 2.....	110.9	247.3	358.2	74.5	432.7
Average.......	110.2	253.3	363.5	78.2	441.7

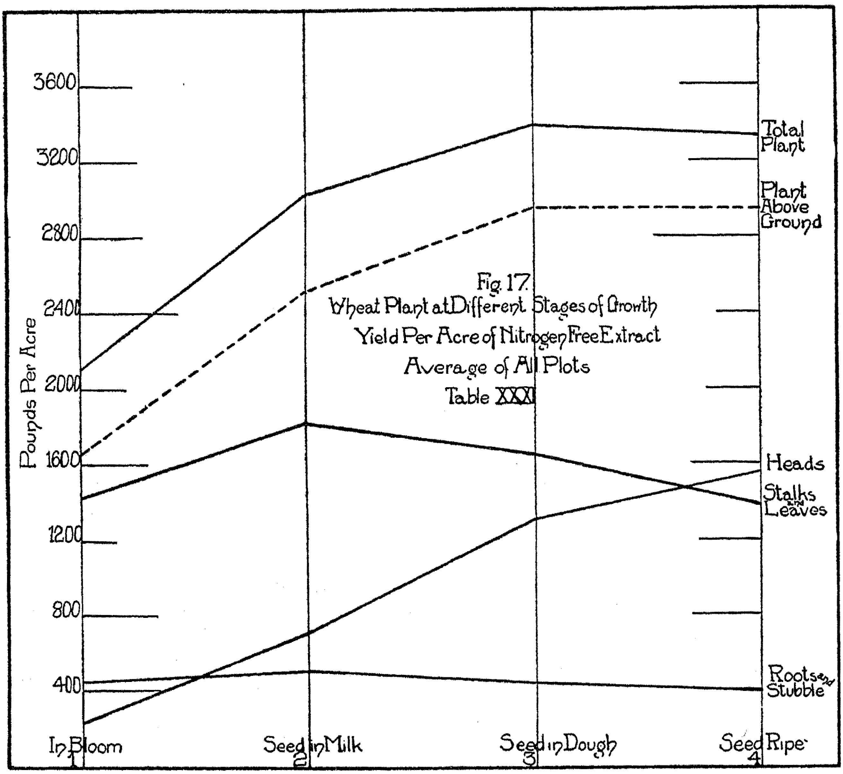
Fig. 17
Wheat Plant at Different Stages of Growth
Yield Per Acre of Nitrogen Free Extract
Average of All Plots
Table XXXI
Pounds Per Acre
3600
3200
2800
2400
2000
1600
1200
800
400
Total Plant
Plant Above Ground
Heads
Stalks and Leaves
Roots and Stubble
In Bloom
1
Seed in Milk
2
Seed in Dough
3
Seed Ripe
4

TABLE XXXI—WEIGHT OF THE NITROGEN FREE EXTRACT PER ACRE IN POUNDS

Designation of cuttings	Heads	Stalks and leaves	Plant above ground	Roots and stubble	Total plant
Series 1, Plot 1.....	222.1	1,378.4	1,600.5	460.9	2,061.4
Series 1, Plot 2.....	236.5	1,475.7	1,712.2	430.7	2,142.9
Average.......	229.3	1,427.1	1,656.4	445.8	2,102.2
Series 2, Plot 1.....	689.9	1,763.2	2,453.1	522.2	2,975.3
Series 2, Plot 2.....	704.9	1,871.5	2,576.4	487.5	3,063.9
Average.......	697.4	1,817.3	2,514.7	504.9	3,019.6
Series 3, Plot 1.....	1,346.9	1,775.2	3,122.1	429.4	3,551.5
Series 3, Plot 2.....	1,259.7	1,519.3	2,779.0	442.1	3,221.1
Average.......	1,303.3	1,647.3	2,950.6	435.7	3,386.3
Series 4, Plot 1.....	1,552.8	1,414.4	2,967.2	408.9	3,376.1
Series 4, Plot 2.....	1,572.8	1,348.9	2,921.7	372.5	3,294.2
Average.......	1,562.8	1,381.7	2,944.5	390.7	3,335.2

TABLE XXXII—DISTRIBUTION OF THE DRY WEIGHT OF THE WHEAT PLANT

Designation of cuttings	Per cent heads	Per cent Stalks and leaves	Per cent plant above ground	Per cent Roots and stubble
Series 1, Plot 1.......	10.28	67.55	77.83	22.17
Series 1, Plot 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
Series 2, Plot 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
Series 3, Plot 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
Series 4, Plot 2.......	37.57	49.31	86.88	13.12
Average.........	36.74	49.71	86.45	13.55

TABLE XXXIII—COMPOSITION OF THE DRY WHEAT PLANT

Designation of cuttings	Per cent protein	Per cent ether soluble (fat)	Per cent crude fibre	Per cent ash	Per cent nitrogen free extract
Series 1, Plot 1.....	7.06	2.79	32.54	9.09	48.52
Series 1, Plot 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
Series 2, Plot 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
Series 3, Plot 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
Series 4, Plot 2.....	6.01	2.61	28.89	7.26	55.24
Average.......	5.94	2.59	29.13	7.29	55.04

TABLE XXXIV—COMPOSITION OF THE DRY SUBSTANCE OF THE WHEAT HEADS. AVERAGE OF ALL PLOTS

No. cutting	Per cent protein	Per cent ether soluble (fat)	Per cent crude fibre	Per cent ash	Per cent nitrogen free extract
Series 1...........	11.17	1.77	31.19	5.04	50.83
Series 2...........	9.55	1.19	21.08	7.04	61.14
Series 3...........	10.06	4.45	12.47	5.43	67.59
Series 4...........	11.08	3.49	10.28	4.95	70.20

TABLE XXXV—COMPOSITION OF THE DRY SUBSTANCE OF THE WHEAT STALKS AND LEAVES. AVERAGE OF ALL PLOTS

No. cuttings	Per cent protein	Per cent ether soluble (fat)	Per cent crude fibre	Per cent ash	Per cent nitrogen free extract
Series 1...........	7.83	3.16	32.06	8.92	48.03
Series 2...........	5.21	1.39	34.89	8.16	50.35
Series 3...........	4.86	4.97	35.54	8.86	45.77
Series 4...........	3.23	2.43	40.06	8.41	45.87

TABLE XXXVI—COMPOSITION OF THE DRY SUBSTANCE OF THE WHEAT PLANT ABOVE GROUND. AVERAGE OF ALL PLOTS

No. cutting	Per cent protein	Per cent ether soluble (fat)	Per cent crude fibre	Per cent ash	Per cent nitrogen free extract
Series 1	8.27	2.98	31.95	8.41	48.40
Series 2	6.25	1.34	31.57	7.89	52.94
Series 3	6.67	4.79	27.49	7.66	53.38
Series 4	6.57	2.88	27.40	6.94	56.21

TABLE XXXVII—COMPOSITION OF THE DRY SUBSTANCE OF THE WHEAT ROOTS AND STUBBLE. AVERAGE OF ALL PLOTS

No. cutting	Per cent protein	Per cent ether soluble (fat)	Per cent crude fibre	Per cent ash	Per cent nitrogen free extract
Series 1	2.81	2.14	34.63	11.48	48.94
Series 2	2.46	2.05	32.17	17.23	46.09
Series 3	2.14	1.20	36.40	12.16	48.10
Series 4	1.97	0.74	40.17	9.52	47.60