SOME DISTINCTIONS IN OUR CULTIVATED BARLEYS WITH REFERENCE TO THEIR USE IN PLANT BREEDING.

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SOME DISTINCTIONS IN OUR CULTIVATED BARLEYS WITH REFERENCE TO THEIR USE IN PLANT BREEDING.

INTRODUCTION.

When the writer began active operations in barley breeding, in 1909 the intelligent selection of mother plants was found to be very difficult because of the lack of sufficient information to enable him to recognize and interpret minor variations. European breeders had subjected the taxonomic details to a most exacting scrutiny, but their results were not immediately useful. It was necessary to confirm the European findings, for a character found stable there could not be considered stable under the widely varying climatic conditions of America until it had been so proven. Again, the European authorities were far from united. There was not even a broad taxonomic character whose stability had not been questioned at some time or other, and often by the highest authorities in barley classification. Moreover, even if the groundwork could have been adopted entire, the more or less established taxonomic characters are only the beginning of the problem. Breeding must take note of characters that are trivial in taxonomy. The intangible must be analyzed and made to serve as well as the tangible.

Even the very plausible idea of adopting European methods and importing improved European stocks, was only partially successful. Conditions in America differ in one vital essential from conditions in Europe. On the Continent and in Great Britain barley has been cultivated for centuries, and is therefore practically indigenous. Each geographical locality has, through long periods of time, been provided by natural selection and acclimatization with superior native races. Breeding, under such conditions is largely concerned with the improvement of these existing stocks, with small likelihood of any importation proving to be a serious competitor.

In America there are no native stocks. The grain producing areas are relatively new. The varieties peculiar to a section are usually the result of chance importations. Breeding material from foreign sources is as likely to contain desirable types as is that already at hand. In this investigation, in order to secure the proper basis upon which to conduct breeding work, stocks were assembled, not only from local sources, but from all over the world. Many distinct strains were isolated from each stock, for both the local varieties and the foreign importations were usually either races that had not been purified, or that had become mixed after purification. The isolation was accomplished by head and plant selections which, when grown in pedigree rows, formed a surprisingly large collection. When to these were added a still greater number from the progeny of hybrids, the problem became one of elimination. The plant selections, from their very nature, were made more or less arbitrarily and hundreds of these forms were necessarily duplicates. These duplicates, especially as long as they were not so recognized, were a drain upon the breeder, and it was soon realized that the efficiency of a nursery was measured, not by the number of stocks it carried, but by the number it eliminated.

It was to better accomplish this reduction that the character studies were made. The distinctions found were of two classes; morphological and physiological. The morphological variations were in the broader divisions of taxonomic value, and many of them were practically invariable. The physiological characters were, from their nature, more difficult to appraise. They were found to possess not only more widely fluctuating limits, but the limits often overlapped and at times the characters became inseparable. In physiological characters a farther distinction was made between permanent and place variations. Some separations were so wide that they never became confusing, while others became evident only when grown under certain conditions of soil and climate. Such distinctions are worthless as systematic features, but have proven very valuable as indications of individual qualities in breeding. Even the lack of stability in a character does not destroy its usefulness, as the tendency of a strain to behave in a certain manner under certain conditions may mark an inherent difference.

It is realized that distinctions of this kind are only a part of plant breeding, and it is not thought that that part is in any great measure solved, but in this paper are given a few of the observations that have been found useful in barley breeding, and with them many that have been found useless. The data upon which the conclusions are based consist of some 200,000 recorded observations, extending over a period of five seasons and embracing experiments in St. Paul, Minnesota; Williston and Dickinson, North Dakota; Highmore, South Dakota; Moccasin, Montana; Abèrdeen and Gooding, Idaho; and Chico, California. Of the work done at these points, that at St. Paul, Minnesota, was the more extensive and was carried on in co-operation with the State Experiment Station.

REVIEW OF LITERATURE.

Although the literature on barley is perhaps more extensive than on any other cereal crop, the publications bearing directly upon this paper are comparatively few. The great mass of the European publications, especially the German, have to do with the malting quality of barley. They are concerned mostly with its chemical constituents, the effect of soil, climate and culture upon the nature and composition of the grain, and the behavior of the converting enzymes in grains of different character. The same is true of the morphology of the grain, and even many of the publications treating directly with barley breeding have little bearing upon the present discussion, as they are often concerned only with the correlation of characters, or with the behavior of hybrids.

It is only the papers dealing with the systematic features of barley, and experiments such as those of the

Svalof Station, which have had for their end the isolation of plant variants that are of particular pertinence.

The first comprehensive systematic work was that of Koernicke[13], in his "Arten und Varietaten des Getreides". He describes forty-four botanical forms of barley, using spikelet fertility, color, nature of the awn and glume, and the adherence or non-adherence of the palea. His groups will undoubtedly form the bases of all future classifications. The classification of Voss[20] is important largely because he based a part of it upon the extent of overlapping of the grains, thus forecasting in an indefinite way the use of density. Atterberg[1] made use of the bristle and nerve characters discovered by Neergaard, mentioned below, and subdivided the previous groups until he had 188 named botanical varieties. Beaven[2], by a rearrangement and compilation of previous classifications, and by growing and describing a large number of hybrids of Karl Hansen, Koernicke, and others, gave a very clear conception of the entire species. His work is perhaps most valuable in the placing of the Abyssinian forms with abortive lateral florets in a group by themselves. He does not make use of the finer sub-divisions employed by Atterberg. Regel[17], on the contrary, carries the sub-division still farther and uses twisting of the spike, earliness, and lateness of the variety, in his separations. The last, a purely physiological phase, he employes in named botanical forms.

A review of the work of the Svalof Station is especially valuable in this connection, both because of the fact that a large part of their effort has been along the same line, and because in many instances this investigation has merely attempted to discover whether results obtained by them were sustained under the great variation of

American climate. In barley their greatest achievement was the discovery of two grains characters which, by various combinations, gave four separations under each previous group.

They found that the rachilla in some barleys was covered with long straight hairs, and in others with short curly ones: that the inner pair of dorsal nerves sometimes bore teeth, and were sometimes smooth. The stability of these characters was questioned by Broili[9], who claimed to have frequently observed one form in the progeny of another. Tschermak[21], Blaringhem[7] and others, have supported the Svalof Station at least as far as the basal bristle is concerned. Although not to be compared w ith this discovery in importance, the Svalof Station has made many other studies. At one time they had developed a very elaborate system of measurements with many ingenious mechanical devices. They have, unfortunately, made no specific, comprehensive, publication of their negative results, but according to Newmann[16] and others, they have abandoned many of the measurements that were formerly made. Of those retained, the most important from the standpoint of this paper is that of density. In the early history of the Station two or three varieties were obtained by the "elete" method. They chose an arbitrary density and made mass selections of spikes conforming to that measurement. Later they used density as a means of valuing head measurements; as a long head, if loose, might contain no more grains than a short one if compact. They finally employed it in varietal description. Blaringhem,[7] who has followed the Svalof Station quite closely, used density as an indication of purity, and to reveal the effect of climate.

The morphological characters of the seed-coat and the grain have been treated by Kudelka[14] and Johannsen,[12] but there is no suggestion of usable varietal differences.

The composition of the grain has been studied by a few American, and a large number of European, scientists. Le Clerc[15] and Wahl, who have made the most comprehensive of the American studies, have clearly demonstrated that composition is of slight use as a varietal character, for while there are differences, the effect of location and season is many times greater than that of sort.

Color in barley has been employed by all systematists, but has received very little analytical attention. Brown[10] has a note in the color in _coerulescens_, and numerous authors have discussed the occurrence of pigments in other plants. A recent article by Wheldale[22] treats of the chemical nature of anthocyanin and traces its origin from a glucoside.

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THE RATE OF DEVELOPMENT.

The rate of development, as with all physiological characters, is subject to considerable fluctuation within the strain. The distinctions are naturally much less absolute than those founded upon morphological characters. They have, however, this advantage, they permit a greater number of separations. A plant structure usually has but two phases. It exists, or it does not exist. With physiological characters this is not the case. The length of time required for one variety to mature may differ three days from a second, or it may differ three weeks.

From the standpoint of observation, the development of the plant is divided into three periods: the early development from germination to the time of jointing, the period of heading, and the epoch of maturity.

Early Development.

For sometime the writer has maintained that the stage of development at which selections of barley are most easily told apart, is during the early growth. This period seems to have been neglected by plant breeders. There are few records of notes taken during this time and even those who have known the cereal crops the best, have based their selections at this period on an intangible something that enabled them to single out any new variatio n.

During the summer of 1913, an attempt was made to analyze the "intangible" with most encouraging results. Besides careful observations on several hundred selections, 1400 plants were chosen in the nursery, and 1700 in drill rows, upon which exact record was kept. One hundred plants were used in each variety. The data included the day upon which each of the 3100 plants produced its second, third, and fourth leaves, and its first tiller. The optically plausible became mathematically evident, and it was soon seen that, aside from the leaf character, there was ample justification for the separations made on appearance during the early stages of growth. As will be seen in Fig. 1, the selections rush through the early stages at an astonishing rate. A centgener only two, or even one, day behind a second may be in an entirely different stage of development and therefore present an appearance which in no way resembles the first. Yet the two barleys may be closely related strains and inseparable, or separated with difficulty, at maturity. The typical curves of the production of the second, third, and fourth leaves are always very sharp. In Fig. 1 the curve of tillering is more flat than is usually the case. The first few of the third leaves emerge about the time of the appearance of the last of the second. The fourth leaf is produced in about the same relation to the third, but perhaps a little earlier. The first tillers are usually simultaneous with the fourth leaves, though in some varieties they appear earlier. The tillering in most varieties is not completed as rapidly as is the production of the fourth leaf, and it is deterred by disease much more than is the leaf.

Besides the difference in dates, there is a difference in method of production. In some varieties the curve of all stages is very acute and the stage is completed in a few days. In others it is more obtuse and the time for completion extended. Fig. 2 shows the relative rapidity of stooling in two selections, the one of the first type and the other of the second.

Differences are revealed in two ways by a comparison of the behavior of strains. There is an actual difference of date in any stage, and still more important, a relative difference between various stages. This is shown to some degree in Fig. 3, and to a still greater degree in Fig. 7, which will be discussed later. Fig. 3 shows the date upon which the greatest number of plants in seventeen selections, sown in drill rows, reached the three stages of development. It will be noticed that the average date of the occurrence of the second leaf varied over scarcely more than two days, while the third extends over five days, and the production of tillers over ten days. No. 550, for instance, produces the third leaf four days after the second, while No. 556 requires another day. Yet No. 556 requires but six additional days to throw off tillers, while No. 550 requires eleven.

Emergence of the ~~Beard~~ awns.

The time of heading is a general agronomic note, and there is no doubt but that an observation of this period is of great value in plant breeding. Distinctions at this time should be easily made, and should be more reliable than those at any later date. The interval between selections is greater than in the earlier stages, and the effect of season is not apparent in any abnormal hastening of development, as it is later in ripening. In any climate most barleys develop in a fairly normal manner until flowering time. The time of heading, for these reasons, should be of great use. It has, however, one disadvantage. It is an extremely difficult note to secure, and hence inaccurate. Barleys differ very much in their manner of heading. Some are exserted rapidly and completely, others slowly and only partially. The observer has not only the difficulty of maintaining an arbitrary mental standard, but is confronted by numerous exceptions that never conform to any standard.

In a study of this difficulty, it was noticed that just previous to heading, the tips of the awns, in all awned varieties, projected from the boot of all plants in the selection with suggestive uniformity. The date of the emergence of the awns was substituted for the date of heading with excellent results. The personal error was immediately removed, and as the facts could be gathered at a glance, the note taking was greatly accelerated. The change made a valuable plant breeding observation out of a dubious agronomic note.

Analyzed, the date of emergence makes almost as sharp a curve as the earlier observations. Fig. 4 shows the curve of 13,108 plants, a summary of the observations upon a large number of selections. It will be noticed that nearly two-thirds of the plants pass through this stage in two days. A difference of a single day serves to change the appearance of a whole centgener, and strains that are three days apart are unbelievably dissimilar when viewed at this time.

This note was used upon a large number of selections for three years to test the transmissions of slight variations in earliness and lateness. The evidence seemed all in favor of accrediting this character a heritable quality equal to that of most plant characters. The data are too cumbersome to include entire, but a random selection of strains of one general type is given in Fig. 5. The variations are, on the whole, parallel, especially when it is remembered that the contgeners were often separated by considerable intervals, allowing variations in soil and moisture. The exceptions are fully as likely to represent differences in the character of the strains, causing them to respond differently to different seasons, as they are to question the value of the note.

Date of Ripening.

The date of ripening is a note universally taken. While less dependable than the emergence of the beards, it is a very useful observation. Within a strain the plants mature quite uniformly. In order to determine the amount of such variation, the exact date of maturity of each spike upon a plot of Manchuria barley, was recorded. The spikes were considered ripe when the last traces of green disappeared from the glumes. In order to avoid confusion, they were harvested as fast as they ripened. The result is shown in Fig. 6. The curve is very sharp, almost half the product of the plot maturing upon the same day.

The weakness of the note is in the abnormal ripening of varieties. At Minnesota the observation is quite dependable in Manchuria forms, but is likely to be much less so in the two-row varieties. Some of the latter mature in a normal manner, while others, especially the later ones, half ripen and half die. Also a rain at this period has much more influence in the development than at other times in the life of the plant.

Comparative Rates of Development.

Although separations can be made by a study of any one of these stages, it is only when the entire seasonal histories of the selections are compared, that the full variation is apparent. Fig. 7 shows the development of fourteen strains from the production of the second leaf until maturity. Each stage was obtained by actual count of all the normal plants in each centgener, usually between ninety and one hundred.

The relation of the earlier stages has already been commented upon. It will be noticed that usually the tillers are produced after the fourth leaves. In Nos. 34, 13, and 24 this is not the case, and these three selections are definitely distinct from the other eleven by this different habit of tillering. Nos. 21 and 57 are parallel in the earlier stages, but are widely separated in the emergence of the beard. No. 29 is one of the earliest of all the selections to throw off the second leaf, and yet is among the very latest in maturity. Indeed, there is some peculiarity about each and every one of the fourteen, when all stages are considered.

VARIATIONS IN THE CULM.

The culm varies in length, diameter, thickness of walls, exsertion of spike, number of nodes, and number of culms per plant.

Length of Culms.

The height of the plant is a note universally taken on all experimental farms, and at any chosen station some varieties are always tall and others always short. This distinction is sufficient to prove a difference between ~~the two~~ such varieties, and as such it is a useful observation in breeding. It is, however, merely a proof that a difference exists and is not necessarily a difference in itself. There is a physiological adaptation of varieties to certain places and it may express itself in height.

In 1911 thirteen pedigree selections, representing nine minor groups of barley, were chosen from the nursery stock and planted at four widely separated points. At maturity the length of culm was carefully noted. The influence of climate and soil was surprisingly great. As will be seen in Table I, there is a marked regional response. The selection of Odessa is a H. s. hexastichum form occurring in the commercial variety Odessa. In Minnesota it is short and unpromising. In California it is ~~a~~ little better. In the north Rocky Mountain and plains area, however, it displays an unexpected vigor and is very tall. The Abyssinian varieties grow well in California, but are short elsewhere.

The great variation evidenced by these few selections is sufficient to show that the length of culm can not be of much taxonomic value. There are varieties that are persistently below average height, and others that are as persistently above average; but beyond that it is difficult to make an unqualified statement. Locally this measurement is of more significance and can often be used to advantage in the study of nursery selections. The differences it reveals are important in breeding, no matter to what cause they may be due.

Diameter of the Culm.

Measurements have not been found very useful in revealing small differences in the diameter of the culm. The experimental error is large, due to the fact that the diameter varies on the same plant with the culm selected, on the same culm with the internode chosen, and on the same internode with the distance from the node. A part of this variation was avoided by measuring the greatest diameter of the first elongated internode, but even then the results were unsatisfactory. There are varietal differences, but they must be great enough to be seen optically before the error of measurement is reduced to the point where it becomes negligible. As a group, the nutans has smaller culms than has the Manchuria, but among the Manchuria strains there is little difference. Only once has this character been used in these investigations to isolate a type. This type has proven to be stable and perhaps the effort of measuring hundreds of selections is rewarded by the one strain obtained, as it is very promising.

Thickness of Walls of Culm.

A large number of determinations were made of the thickness of the walls of the culm with even less satisfaction than upon the diameter. Measurements finer than one-tenth of a millimeter are impractical owing to the variation within the plant and culm. This does not give range enough to disperse the varieties. For instance, of 242 selections of six-row barley, the culms of 153 measured five-tenths millimeters in thickness and only thirty-three fell more than one-tenth millimeter from this figure.

The Exsertion of the Spike.

The exsertion of the spike is closely related to the length of culm because it depends upon the elongation of the peduncle. Some barleys clear the boot much more completely than do others. That this is a true varietal characteristic is shown by the number of varieties in which it has been described. The Prinsess in Sweden is often included at the base. The same is true of this variety in Minnesota or California. The Smyrna seldom clears the boot completely in more than one or two culms on each plant. An interesting fact was noted in this variety with reference to location. In Minnesota half the head often remains in the boot. The same is true over the whole of the plains area. In California, however, the heads are completely exserted. The necks are still short as compared with most varieties, but the exsertion is perfect. Like other physiological characters, the exsertion of the spike is variable, but its range of variation is sufficiently limited to occasionally determine a variety. That it is not more often useful is due to the fact that almost all barleys are of the type in which the spike is completely exserted.

Number of Nodes per Culm.

The number of nodes to the culm is naturally identical with the number of leaves to the culm and is discussed under that heading.

Culms per Plant.

The number of culms per plant seems to be a varietal character, but one which is so dominated by environment as to make it impossible to determine when it is given true expression. It is probable that all students of the cereals have gone through the same process of diminishing confidence to final doubt, as to the utility of this factor. In this investigation the number of tillers was recorded on over twenty thousand plants without being able to discover a method of using such information for minor distinctions, as was found, for instance, with the time and method of tillering. The broad groups vary as groups in this character and occasionally a variety deviates sufficiently from its group to become distinct, but the mass is, for the most part, inseparable.

Two causes of variation were studied in detail; viz., interval and geographical location. At Minnesota a selection of Smyrna, a heavy tillering variety of a two-rowed group, and a light tillering selection of Manchuria of the six-rowed group, were planted at three different intervals. As will be seen in Table II the varieties remained distinct, but as the interval decreased, the difference of over three culms per plant in favor of Smyrna, rapidly dwindled to one. Types falling between these extremes were inseparable at the lesser interval. It will also be noticed that the varieties differ in the interval at which they seem to make complete use of the soil. An increase in number of plants in the Manchuria, beyond the four by four planting, does not increase the number of tillers on the unit area, while for Smyrna the limit is not yet reached.

The response to geographical location is a disturbance sufficient to vitiate all close distinction. Even the groups are often reversed. For instance, when summarized, a large number of selections of six-rowed barley at St. Paul, Minnesota, averaged 2.6 culms per plant, while at Chico, California, the same selections averaged but 1.5. The two-row group, on the contrary, averaged but 4.2 at St. Paul, while at Chico they averaged 5.8. Smyrna, however, stood near the top in both places, showing that in extreme cases the effect of environment does not conceal the character.

LEAF CHARACTERS.

The leaves of mature barley plants present quite a variety of aspects, but these are, as a whole, hard to record. Most of them are mass effects and hence treacherous because of the optical differences due to the angle of observation with reference to the light. This investigation is concerned with four points of variance: color, width, length, and number of leaves.

Color of Leaves.

A very casual observation shows a considerable difference in the color of leaves, but there are so many difficulties in their valuation that the writer is unprepared to discuss their separation at this time.

Width and Length of Leaves.

Any study of leaf dimensions must be statistical and therefore difficult to report briefly. The obstacles to the use of such measurements are two. The leaf varies with its nourishment and with its exposure, and is often damaged by the wind. In a study of mature plants, the second leaf from the top being used in all cases, the normal variation was found to be considerable. For instance, at the same place in the same season the leaves of border plants were from one to two millimeters greater in width than those from the interior of the plot, and the length of the leaves of such plants was from one to three centimeters greater . In Prinsess, one of the least variable varieties, the average size of the leaves of the border plants was 13.7 mm. by 24 cm., and of the interior plants 12.7 mm. by 23 cm.

To be feasible in breeding, a note must be reasonably easy to secure. To test the usefulness of this character, the first twenty-five of the hundred measurements were listed, as in Table III. With width of leaf the experimental error is small, as width can be determined quite accurately, and the broadest part of the leaf is seldom damaged. If the figures then are conclusive mathematically, the method is practical. The probable error in the twenty-five measurements of Prinsess is ± 1.2. It thus fails to separate this variety dependably from Kitzing and Proskowetz, its nearest relatives, or from the selection of deficiens, or Odessa. For the rest, however, the separation is clear enough to be significant. With the two selections of Oderbrucker, the separation is sufficient to establish a difference. In this case the two are closely related and the note becomes serviceable. As a rule the width of leaf is seldom sufficient basis for separation in closely related strains. Fortunately such differences are seldom unaccompanied by other points of variance, and it is often the sum of several differences that mark individual sorts.

In length of leaf the method is much less promising. Not only is the probable error greater, but the measurement is unsatisfactory. The leaves become so broken by whipping in the wind that specimens which are entire at the tip are seldom found. An effort was made to overcome this difficulty by choosing an earlier stage of development and thus utilizing the better protected leaves nearer the ground. Although the extreme tendencies were not yet developed, the second leaf from the seedling was found to offer fewer experimental difficulties. Such leaves were entire and the length measurements were accurate, but even then the width was much less variable than the length. All measurements of one hundred leaves of a strain showed a sharp curve in width, but a flat one in length, the latter sometimes having two summits. Composite curves are shown in Fig. 8.

The summary of 316 pedigree selections in Table IV shows that the common systematic groups based upon spike characters, are correlated in the nature of their leaf growth.

Number of Leaves.

The number of leaves, excluding of course those formed before the appearance of the shoots, is the same note as the number of elongated internodes in the culm. The number of leaves above the basal rosette is a variable, but at the same time a rarely useful, distinction in breeding. Strains may be found which are very different, but usually they are not closely related. Thus in Hannchen the number often drops to three and seldom goes above five. In a selection of _H. s._ _hexastichum_ the number rarely falls as low as five and is usually six or seven. But this distinction is not necessary to separate these forms. In all of several hundred Manchuria selections, the number of leaves per culm fell upon either four or five, giving no opportunity for separation.

THE DENSITY OF THE SPIKE.

The writer is inclined to place even more importance upon the density of the spike than has been the tendency of many barley breeders. Aside from its finer distinctions, to the writer's mind, some of the effects attributed to other characters are in reality due to the length of the internode of the rachis. Most investigators have attributed the difference between H. s. vulgare (tetrastichum) and H. s. hexastichum to a difference in fertility. They have considered that in H. s. vulgare the side florets are more reduced than in H. s. hexastichum. This supposition is not borne out in fact. In the H. s. hexastichum the central row is as favored in nutrition as it is in the H. s. vulgare. This is easily demonstrated by weighing grains from side and central spikelets. In the H. s. vulgare, the lateral grains compared with the central ones are actually greater in relative weight than is the case in the <u>H. s. hexastichum</u>.

Differences, other than density, are likely to be due to the nature of the attachment of the lateral spikelets. Systematists describe the barley spikelets as sessile. This is true in most cases, but approaches an exception in the <u>H. s. hexastichum</u>. In this group the central spikelets are sessile as usual, but the lateral ones either possess an elongation of the base of the flowering glumes, or else are pedicellate. Among barleys collected by the writer, is a Greek form in which the lateral spikelets are elevated upon a pedicel that is over one-half as long as the length of the rachis node itself. This pedicel is jointed both at its attachment to the rachis and at its attachment to the floret. It is the longer attachment of the lateral spikelets that allows the characteristic star-shaped arrangement of H. s. pyramidatum. Density is, however, a parallel factor. The compactness of the spike forces the grains to assume certain relations. Both in H. s. hexastichum and H. s. erectum the angle at which the grains are placed with reference to the rachis, is much wider than in H. s. vulgare and H. s. nutans. The Svalof Station has considered the angle of the inclination of the berries as one of the more important of their notes. It is the opinion of the writer, however, that with rare exceptions it will vary directly with the density and is therefore superfluous if the latter measurement be taken.

In breeding density has not been utilized as fully as its value seems to warrant. Voss[1], Koernicke[2], and Atterberg[3], have all used it in group classification, and

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1 Voss: Journal fur Landwirthschaft, 1885.

2 Koernicke, Friedr.: Die Arten und Varietaten des Getreides, Berlin, 1885, p. 148

3 Atterberg, Albert: Die Varietaten und Formen der Gerste. Journal fur Landwirtschaft, 1889, 47 pp. 1-44.

4 Blaringhem, L.: L'Amelioration des Crus d' Orges, Paris, 1910.

Atterberg and Blaringhem[4] and the breeders of the Svalof Station, have used it in studies of variation and purity, but in the opinion of the writer, its possibilities in the isolation of types and in the identification of strains, have been far from exhausted.

In the years from 1909 to 1913 a close study of density was made, both upon general farms and in experiment station nurseries. In this study 100 spikes of each variety were taken without other choice than that they were not diseased or dwarfed. On each of these spikes ten internodes of the rachis were measured; that is, the distance between six spikelets on one side of the rachis. From these measurements the number of internodes per decimeter was computed and this number taken as a statement of density, the formula was then $D = \frac{100}{L}$ where L was the measurement in millimeters of ten internodes of the rachis.

The use of this formula, while it makes the statement of density more definite, disturbs the natural curve of the measurements to some extent. In all densities below thirty-one the tendency is to condense the groups, above that figure the opposite is true. The worst effect, that of bunching the figures when two length measurements fall upon the same density, was avoided by the use of fractions. None of the curves have been smoothed, however, and it will be noticed that those of the greater densities especially, are slightly rough. This roughness is more mathematical than real, but it seemed more desirable to present the figures as they were than to make them still more artificial by smoothing them.

In a pedigree strain the curve of density is normally sharp with a single summit. If the seeding is not pure, or if the heads from two plots become mixed, the curve is flattened and is characterized by more than one summit. Although included for another reason, the normal curve of a pedigree barley is well illustrated in Fig. 11. When this is compared with the curve of the field sample of Manchuria shown in Fig. 9, the significance of density is readily appreciated, especially when it is remembered that the Manchuria is what is known as a variety and contains no types that merge into such other six-rowed varieties as Bay Brewing or Odessa.

That density of selections is an accurate and comparable note in a nursery where the object is to secure like conditions for all selections, is shown in Fig. 10. Sandrel was included twice in the 1913 planting. The beds were separated by such an interval as to represent the extremes of soil variation in the nursery. The difference in density is very slight. The summits of the curves are separated by only one unit space, but even this is seen to be too great when the entire curves are considered. Although the second summit is on 27 there are 46 spikes whose density is less than that number and only twelve whose density is greater. The actual separation is nearer five-tenths of a space. The degree of separation afforded by a difference of only two internodes to the decimeter is shown in Fig. 11. These are two selections of Manchuria barley taken at random from Table V. By chance they are somewhat more ideal than the average strain in the same table. A difference of only two spaces in density, when taken alone, is perhaps too slight a basis upon which to separate strains, yet as is shown in the figure, the field of actual merging is very little.

The value of this character in the nursery is shown in Fig. 12. These barleys are all closely related pedigree strains of Manchuria. Most of them were from head selections made upon farms in south-eastern Minnesota.

The curve represents the summits of the curves of densities of the individual selections. The variation is considerable and is sufficient to establish some differences of itself. It is, however, only when several characters are compared that the full value of any note is apparent. For this purpose, the date of the emergence of the beard is placed in the same figure. As they are in no way parallel, the combination of the two curves more than doubles the value of each. It will be noticed that Nos. 3, 6, and 55 are suspiciously similar, as their density and the date of emergence of the awns of each are identical. The records show that the emergence was also on the same date the previous year. No. 55 is proven to be distinct by the nature of the rachilla, but the date of heading, time of stooling, etc., are parallel in Nos. 3 and 6 and there is little doubt but that they are identical.

While not pertinent to this phase of the discussion, the curve of density and the curve of emergence of beards is almost opposite in the Manchuria barley. In other words, there seems to be a direct correlation between density and earliness. In Fig. 13, which assembles a number of other types of six-rowed barleys, that are for the most part not closely related, this is not true.

The first five selections in Fig. 13 are from a commercial variety known as Odessa. This so called variety seems to be a loose assemblage of widely varying types which are, however, ones not common in other six-rowed barleys. The component strains are not nearly as closely related as are those of the Manchuria. That this variety itself is of hybrid origin, or that there has been crossing between its members, is indicated in Fig. 14. This selection, the most dense of those made from the Odessa variety, proved unstable. The number of plants bearing dense heads was 71 as opposed to 16 for the looser ones.

While a character need not be invariable under all conditions to be useful, a test was made to discover the affect of soil and climate. Six selections were planted at St. Paul, Minnesota; Chico, California; and at Aberdeen, Idaho. At the latter place they were grown both under irrigation and upon dry land. The measurements at St. Paul and Aberdeen were made by the writer, while those at California were made by Mr. E. L. Adams. The result is shown in Fig. 15. As a whole the variations were parallel. Nos. 6 and 35 were strikingly so. The four less dense selections showed an extreme variation of only three spaces. The two dense selections varied much more. In No. 32 this was in part due to poorly developed heads. At Minnesota particularly, ~~the~~ its spikes were so short that it was impossible to find many in which five successive nodes bore fertile florets. The effect of sterility is to lengthen the internode. All types were most dense at Chico, and least dense at St. Paul. The effect of water, as shown at Aberdeen, was very slight, especially when compared with the effect of the combined factors of geographical location.

The character of the curves was influenced even less than their relative density. By referring to Table 5 it will be seen that some selections always present a much sharper curve than others, and thus afford opportunity for varietal distinctions in the distribution of the measurements. Avoiding the extreme examples, No. 30, for instance, which has already been condensed three or four spaces by the use of the formula of density, is still less compact than No. 35, which has been made slightly less compact by the same operation. At St. Paul No. 35 has a total of 85% of its spikes in three spaces in one instance, and 91% in the other, while No. 30 has but 82%. At Aberdeen, Idaho, under irrigation, No. 35 has a total of 91% of its spikes in three spaces, while No. 30 has but 78%. Upon the dry farm at the same place, No. 35 has a total of 81% of its spikes in three spaces, while No. 30 has but 77%. At Chico No. 35 has 94% of its spikes in three spaces, while No. 30 has 91%.

FERTILITY.

The variation in fertility is the most evident and the most vital of all the modifications that occur in barley. At each node of the rachis is produced a group of three single flowered spikelets. In the six-rowed, each of these develops a separate grain. As the groups of spikelets are placed alternately on opposite sides of the rachis, the result is six columns of grains from the base to the tip of the spike. In the two-rowed, only the central spikelet at each node is fertile, and therefore there are but two columns of grains. This reduction does not take place by the elimination of the outer spikelets, but by their sterility. The median floret of each set of three accomplishes its normal development. On either side are the small, undeveloped, infertile, florets. However, the sexual organs have not disappeared. The three stamens reach an appreciable size and the ovary, though rudimentary in some ways, persists even to the plumose stigma.

There is, in one group of the two-rowed barleys, a still farther modification of the lateral florets. In Abyssinia there is a considerable number of forms in which the side spikelets are rudimentary; that is, they no longer contain even infertile flowers, the whole spikelet being reduced to structures that are little more than hair-like.

In the experience of the writer, these well known taxonomic divisions have proved entirely stable. The observations have included hundreds of varieties, and these varieties have been grown under such varying conditions as to stimulate monstrous developments in many structures, but in no case has there been indication of bridging over these separations. It is the opinion of the writer that the numerous instances recorded have been misinterpreted.

The one cited by Koernicke was most probably a cross, as the variation of the progeny was such as is always secured by hybridization. The more common exceptions usually described are the occurrence of three and eight rowed freaks, and two-rowed barleys in which some of the lateral florets are fertile. All three are probably due to the formation of adventitious spikelets. Such spikelets are common, and if several occur along one side of the rachis of a two-rowed barley, the result is a three-rowed spike. If a duplication of the groups of spikelets at the nodes of one side of the rachis occurs in a six-rowed barley, the result is nine rows, which, if imperfect in any way, are easily mistaken for eight. It is entirely possible that florets of lateral spikelets of two-rowed varieties are sometimes fertile, but in practically all of the numerous cases that have been noted by the writer, a close inspection of such grains has shown them to be adventitious, and that the sterile floret was also present.

Aside from the observations upon established forms, it has been the fortune of the investigation to isolate a number of which there seems to be no published descriptions. These all came from Abyssinian barleys, and as the work is not yet completed, only a general indication of the results need be given here. The group of two-rowed barleys with rudimentary florets seems much larger than has been previously thought. They vary from the wide zeocrithon-like types to narrow nutans-like forms, and through a series of colors and combinations of colors.

In barleys received from the same region, there is a group with a curious irregular, yet heritable, habit of floret abortion. In the ripened spike the spikelets are normal at the base and for a varying distance towards the tip. The upper ~~position~~ portion usually reduces suddenly to a two-rowed form. In this case the side spikelets are not merely sterile, but are represented by only the outer glumes and the rachilla. The floret having disappeared entirely. The spikes are found to present these modifications even when the head first emerges from the boot. The actual time of the reduction has not been determined, but it is early enough so that no scar is present, indicating that the floret never started to develop.

THE EMPTY, OR OUTER GLUMES.

The outer glumes present but two phases. They are usually narrowly lanceolate, but in rare forms are ovate lanceolate. In the latter case they usually bear moderately long awns. A few intermediates are formed by combinations in which certain ones instead of all the normal outer glumes are replaced by ovate lanceolate ones. In this investigation, while numerous ovate lanceolate selections have been made, there has been nothing added to the information already at hand.

THE FLOWERING GLUMES.

Two of the variable features of the flowering glume are treated elsewhere. The toothing of the nerves is considered with the rest of the Svalof system under a heading of that name. The color of the glumes is taken up with color of the other plant organs in the general discussion of pigmentation. Most of the remaining variable points of structure in the flowering glume are to be found in its terminal appendages, which are usually awns, but may be trifurcate hoods; the nature of its base; and its adherence, or non-adherence, to the pericarp.

Awns.

The dimensions of the awns are naturally their most apparent variable features. There are marked varietal differences in both length and breadth of awns, but unfortunately they are so correlated with the systematic groups as to make them of slight use in separating nearly related strains. All the Hanna barleys have long narrow awns, the Zeocrithon and Hexastichum forms have short, rather broad, awns; and the hull-less barleys excessively broad ones. In the Manchuria group there is some suggestive variation, but it needs the support of other variants to become convincing.

There is, in addition to these rather narrow variations, a still greater difference in length of awn. In these cases an abrupt and conspicuous reduction takes place. There are botanical varieties characterized by very short awns, and others in which the glume is merely pointed. ~~Koernicke records varieties of the latter, and~~ Mr. H. B. Derr, of the United States Department of Agriculture, secured such a form through crossing. Such variations make a very decided separation from their long-awned relatives.

The toothing of the awn is subject to many variations, some of which are constant. The distinctions are often merely ones of degree. There are forms, especially in the <u>hexastichum</u> and <u>zeocrithon</u> groups in which the toothing is very profuse and the individual teeth very large. These types are constant and are inherited with no more tendency to variation than are other vegetative characters. In the Manchuria-Oderbrucker barley the teeth are numerous, but only average in size, being much smaller than the ones referred to above. The two-rowed barleys of the Hanna type have fewer teeth, and those very much smaller.

There are other barleys in which the awns are smooth. In 1910 the writer isolated, from a mixed Hanna barley, a form in which the awn was smooth except for a few small teeth at the tip. In 1911 two plants were secured from an English importation, belonging to a seldom cultivated botanical variety, in which the awns are absolutely smooth. Hybrids of this selection upon Manchuria and Bay Brewing sorts show the toothing to be dominant over the absence of teeth. In the second generation smooth awns again appeared. Regel[5] and others have reported a considerable number of such barleys.

Regel, Robert: - Glattgrannige Gersten.

Although it seems not to have been used by systematists, the tenacity of the awn has been found to be serviceable in varietal descriptions. Most barleys thresh rather easily, but there are some which will not thresh clean, no matter how much effort be expended. This character is commonly recognized in the California barley, but exists in Mariout, some of the selections from Odessa, and numerous others as well. These varieties have been grown at a large number of points and show no inconstancy in this character.

There is also a difference in the persistence of the awns. There are a few varieties that are almost deciduous. Primus, for instance, has been observed in a great variety of locations, and it always drops a large percentage of its awns as it ripens. The loss of the awn in such varieties does not come about through the breaking of that organ, but by its being loosened from the glume. It is the tissues of the glume that give way, and is thus in reality a character of that organ.

In the hooded barleys the awn of the flowering glume is replaced by a trifurcate appendage. This is of evident monstrous origin and is connected with the awned class by no true intermediates. The exact nature of the appendage is not clear. In structure the parts appear to be the result of vegetative stimulation and are leaf-like in appearance. The fact that they are three in number, and that they bear rudimentary florets, indicates that they are a partial repetition of the spikelets of an internode, the leafy segments being the flowering glumes. The character is absolutely constant.

The Base of the Flowering Glume.

The method of the attachment of the lemma, or flowering glume, to the rachis has been shown by Atterberg[6]

Atterberg, Albert: - Tidskrift fur Landtmand, 1888.
Versuchs - Stationen, 1899, Bd. 36, S 23.

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to be a distinguishing mark between the _erectum_ and _nutans_ groups. In the _nutans_ group the grain is attached by a very constricted band of tissue which, when separated, leaves the proximal extremity smooth. The surface is oblique to the long axis of the grain and presents a small horseshoe-shaped depression just above the line of attachment. In the <u>erectum</u> group there is more than one variation of form, but all are centered around an attachment to the rachis that is much broader than in <u>nutans</u> and the depression is absent. When the central nerve of the dorsal glume is not too large and continued too far through the base, a transverse crease is found just above the attachment. The six-rowed barleys are separated by the same means.

The Adherence of the Flowering Glume to the Pericarp.

The normal form of barley is one in which the palea are grown fast to the pericarp. There are numerous varieties in which this union does not occur. These constitute our hull-less barleys. Both forms are absolutely stable. The character offers no opportunity for minor distinctions, unless it be in such cases as Prinsess, which the Svalof Station maintains has a low bushel weight due to an abnormally loose attachment of the glumes.

THE SVALOF CHARACTERS.

In 1888, Neergaard, of Svalof, Sweden, announced the most important discovery in the classification of the lesser groups of barley that has ever been brought to the attention of the world. Not only was it of exceptional intrinsic value, but it acted as a great stimulus in the study of elementary forms, and has been the cause of much of the progress that has been made in the isolation of biotypes.

Neergaard's work was based upon the careful study of the spike. He discovered that two previously unobserved variants were dependable morphological distinctions. These were the nature of the covering of the basal bristle, and the toothing of the inner pair of dorsal nerves. The basal bristle, which is the continuation of the rachilla of the spikelet, is clasped within the folds of the glumes and is carried with the grain when it is removed from the spike in the process of threshing. The bristle is covered in some cases with long stiff hairs; in others, with short curly ones. The inner pair of nerves upon the dorsal surface of the grain are in some cases provided with numerous small translucent teeth, in others they are smooth.

The use of these two new characters gave four separations in any group; i. e., long haired bristle, nerves without teeth; long haired bristle, nerves with teeth; short haired bristle, nerves without teeth; and short haired bristle, nerves with teeth. When these separations were applied to the larger groups, *H. s. erectum*, *H. s. nutans* and *H. s. vulgare* (tetrastichum), twelve smaller groups resulted.

Although this new grouping was only a small part of the Svalof obxervations on barley, it soon became known as the Svalof system, due no doubt to its novelty. As a new departure, it has been subject to much more controversy than have most of the older and universally accepted taxonomic features.

Several breeders, among whom Broili[7] is the most notable, have attacked the system, and declared that the characters might be trustworthy on the Svalof Station,

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7 Broili, Josef: - Das Gerstenkorn im Bilde. Stuttgart, 1908

8 v. Tschermak, Eric: - Die Züchtung der Landwirtschaftlichen Kulturpflazen, Berlin, 1910, Vol.IV, p. 286.

9 Blaringhem, M. L.: - La Variation des formes Vegetales, Revue Generale de Botanique, 49-66.

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but when the plants were grown under other conditions they did not remain constant. Tschermak[8], Blaringhem[9], and others, have supported the Svalof Station in the matter of the basal bristle, but have not committed themselves so completely with reference to the toothing of the nerves.

Since the point of contention is the effect of soil and climate, observations in this country are of many times the natural value of those in Europe. The variation between California and Minnesota, or Idaho and Virginia, represents a range that is impossible to a European breeder.

Observations have been made upon some hundreds of selections representing all botanical groups. Very little variation was found in the nature of the rachilla. All observations tend to credit this character with as much stability as is usually found in taxonomic work. As would naturally be expected, the toothing of the dorsal nerves has been found to be a more variable and more influenced by climate. The rachilla is the axis of the spikelet, a definite and vital portion of the fruiting body. The teeth on the dorsal nerves are of no vital significance, being mere manifestations of the epidermis. The writer feels that the Svalof position has here been injured by too enthusiastic defense. The fact that variations may, or may not, occur in a strain is of little importance if the limits are definable. No doubt there is variation and it is especially noticeable in the sparsely toothed varieties. A cactus under proper conditions will display leaves, yet no one will question the propriety of describing the cacti as leafless plants. They never become foliage plants, and no more do we expect a smooth nerved Hanna selection to show the strong toothing of the Manchuria. It may at times present a few scattering teeth, but it would never become even moderately strongly toothed, and certainly there are strongly toothed sorts that are never anything else.

VARIATIONS IN THE GRAIN.

The grain itself varies in many ways. The more definite variations not treated elsewhere are shape, dimensions, weight, and composition.

Shape of Grain.

The shape of the grain is well established as a group distinction and is often a varietal characteristic. The six-rowed varieties are sharply set off from the two-rowed by the twisting of the lateral berries. Even the central grain of the six-rowed varieties, although it is not twisted as are the side ones, is still of a different shape than the two-rowed. In the six-rowed the greatest diameter is nearer the distal end of the grain, while in the two-rowed it is nearer the proximal end.

Within the groups the separations are, of course, less marked. Certain Finnish and Russian barleys may readily be distinguished from the Manchuria because of their less oval shape. The extremities of the grain are more pointed, giving a fusiform, or spindle-shaped, seed. The Goldthorpe barleys, especially such extreme types as Standwell, are readily separated from the other two-rowed forms. The Svalof Station reports that Hannchen and Prinsess can be readily distinguished in bulk samples by the shape of the grain. Most of the distinctions, however, are so dependent upon the relative proportions of the grain that it is impossible to consider shape independent of dimensions.

The Dimensions of the Grain.

The barley grain varies in length, width, and thickness. At times one, or all, of these may constitute a varietal character. No other barley could be confused with the Smyrna. Its long grain is unique. It is also very doubtful if a second strain could be found that possesses the unusual breadth of the Standwell. In all but these very extreme types, the use of these variants must rest upon statistical methods.

At any place the product of a variety in the same season is sufficiently uniform to give a decided indication of the average size of the grain with one hundred measurements. The size of the grain is, however, but partially dependent on variety. In Table VI is given a summary of measurements made upon samples of three varieties grown at various points in the United States. The columns marked "highest" and "lowest" have very little significance, but the averages are quite instructive. The variation is strangely uniform. The length; the lateral, and the dorso-ventral, diameters; of Prinsess differ each five-tenths of one millimeter in the averages. The dimensions of Primus vary each four-tenths, and of Chevalier II two-tenths. It does not necessarily follow that Prinsess is the most variable of the three. This variety was subjected to more extreme conditions than the other two, and in two locations the development was hardly normal.

Of the three measurements, that of length is obviously the most dependable. The actual variation is no greater and since it is based upon a much larger figure it is relatively less. Also the two diameters are more affected by ripening conditions and therefore less serviceable for local distinctions. The length seems to be determined by varietal and climatic influences early in the life of the plant, while the diameters are dependent upon the amount of starch infiltration at ripening time. This is well illustrated in the two samples of Prinsess from Huntley, Montana. The first was irrigated, the second was not. The length of the grains in the two were practically identical, while the diameters evidenced the greatest variation found within a variety.

The weakness of all grain measurements is not in the variation, but in the fact that the interval between varieties is not great. The total range of averages is not large and while many selections may be told apart, a great many more must remain inseparable because of identical, or nearly identical dimensions.

Weight of Grain.

The thousand-berry-weight is a determination that has been considered indispensable in the appraisement of exhibition samples, and it is also a very useful record in plant breeding. From the nature of this factor, it is to be expected that it will vary with conditions and culture, but usually the variations are more or less parallel. In this investigation certain varieties have always been found relatively high, and others relatively low, in berry weight, regardless of location or season. The character is, however, a varietal character, and not often useful in separating related strains.

Composition.

The varietal character of any barley, as far as composition is concerned, is subservient to climatic conditions. If it is grown in California it will be much lower in nitrogen than if it be grown in Minnesota. The average difference of all varieties is often greater than that between the two most extreme at either point.

Despite this fact, there is an actual varietal tendency. Svanhals is reported in Sweden to be relatively high in nitrogen for a two-rowed barley. It is also high in this country. Samples of California Feed from many states in the west and in the plains region were analyzed. This variety was always lower in nitrogen than were other six-rowed forms. LeClerc[10] and Wahl found that the average

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10 Le Clerc, J. A., and Wahl, Robert. Chemical studies of American Barleys and Malts. United States Department of Agriculture, Bureau of Chemistry, Bulletin 124.

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protein content for Bay Brewing from all points was 10.73 per cent, while for the ordinary six-row it was 11.86 per cent.

It is doubtful if a factor with such wide and easily influenced limits can be made to be of assistance in the separation of strains, save in exceptional cases. It can, however, be used in the description of varieties and may be of much importance in the selection of sorts adapted to satisfactory market demands.

PIGMENTATION.

Color is one of the most easily determined characters of barley. Unfortunately it is also one of the most treacherous distinctions. The occurrence of pigments in certain cases, and in certain tissues, is undoubtedly hereditary and is transmitted unfailingly from generation to generation. In other cases the color appears intermittently, and in still others sporadically occurring in strains and tissues ordinarily free from pigments. This erratic behavior, coupled with the fact that white, brown, black, violet, purple, amber, and blue-gray have been used in various classifications, led the writer to make a study of the pigmentation of barley. Since the colors in the seed seemed to be more numerous and less variable than in the other parts of the plant, the grain was used as the basis for the investigation.

The technique was adapted from that used by Mann[11] in his identification and location of the pigments in the cowpea. The grains were first examined by sectioning them dry. This avoided any modification such as might easily come from the action of solvents in an embedding process, or even from water if a freezing method were used. The hand sections were equally as satisfactory as those made with a microtome, as the areas in question were readily defined and the colors more easily seen in moderately thick sections than in very thin ones. The reagents most extensively employed were caustic potash, hydrochloric acid and chloral hydrate. The sections were placed dry upon a microscope slide underneath a seven-eights inch cover glass

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11 Mann, Albert: - Coloration of the Seedcoat of Cowpeas, Journal of Research, United States Department of Agriculture.

held in place by a drop of paraffine on either side. The reagents were drawn beneath the cover glass by means of blotting paper and their action watched through the microscope. Two per cent solutions of the acid and the alkali, and a saturate aqueous solution of chloral hydrate, were used in these tests. If the pigment showed no change within a few minutes, the reagents were allowed to remain upon the section for some hours. In such cases larger pieces were also placed in small vials containing fifteen per cent solutions and examined at the end of twenty-four hours.

It soon became apparent that there were two pigments in barley. One was readily affected by the weak solutions, and from the nature of its reaction was undoubtedly anthocyanin, which occurs widely in the plant kingdom in both its red, or acid, and its blue, or alkaline, form. The other resisted even prolonged soaking in the more concentrated solutions and was probably a melanin-like substance.

The first varieties studied were ones in which the adhering glumes were black. No change was effected by either the weak reagents, or the prolonged soaking in concentrated solutions. The black did indeed become a brown, but this was most probably due to the distention of the pigment containing tissues, attendant upon the absorbtion of water. As a considerable number of varieties with black glumes were tested, and as the results were uniformly the same, it would seem that a black or brown pigment in the glumes may be attributed to a melanin-like compound.

A number of Abyssinian varieties with purple glumes were sectioned and treated with the reagents. The purple color responded at once to weak solutions. It immediately became blue when treated with the alkali, and became red again when the acid was applied. The chloral hydrate test here, and in all other instances, was less definite than is the case with most anthocyanin deposits. Upon its application the red color faded very slowly until the natural yellow of the glumes became apparent. The red immediately returned when acid was added. There is no reasonable doubt but that the color in these barleys is due to anthocyanin.

A hull-less barley with a violet or purple pericarp was examined. The color was also readily demonstrated to be anthocyanin. In this instance, as in some others, the pigment was found both in the pericarp and in the aleuron layer. In the former tissue it was red, and in the latter blue. When treated with acid the red of course was unchanged, while the blue also became red, intensifying the effect very much.

In all barleys studied, the anthocyanin was always red in the pericarp and glumes, and always blue in the aleuron layer. In other words, the resting condition of the protoplasm was alkaline, while the inert tissue seemed to be in an acid condition.

A new form of hull-less barley isolated from an Abyssinian importation gave striking testimony of the systematic value of the distinction between the two pigments. This selection has a dense black pericarp. It was absolutely resistent to all concentrations of reagents, showing the pigment to be melanin-like. As far as the writer can learn, there is no other naked barley of the nutans group in which this pigment occurs, and this botanical form has no published description.

The last variety studied was H. v. pallidum coerulescens. This variety has the peculiar blue color well known upon the market in Californian, Chilian, and like barleys. The color has been held to be variable by both grain dealers and scientists. Regel explains its lack of stability by calling it a hybrid form. Examination showed the color to be due to a deposit of anthocyanin in the aleuron layer. This layer was readily changed to red by the application of acid, and as readily made blue again by the use of alkali.

The stability of this and other forms was studied in the fields. Anthocyanin seems likely to be found in any plant and in any part of the plant. It seems to appear abnormally in cases of malnutrition, and is very likely to occur in conductive tissues that are ceasing to be functional. It has, however, a normal phase in the grain. In certain hull-less forms its stability is unquestioned and, to the writer's mind, its variability in coerulencens has been over estimated. The hybrid theory of Regel in coerulescens becomes untenable when two pigments are admitted. If an intermediate, it could be so only between a white variety and a black one. This is evidently impossible because a cross between a form with a melanin-like pigment and one with no pigment could not result in one characterized by the production of anthocyanin. The wide spread opinion of variability is possibly due to faulty observation. The deposit is in the aleuron layer and the color is sometimes obscured by the glume. The weathering of this organ, especially in humid areas, greatly lessens its transparency. The aleuron layer is covered by both pericarp and hulls. The color must not only be a pronounced one to enable one to detect it from without, but the coverings must also be passibly transparent. When ripening occurs in rainy weather, this is not the case, and the hulls must be removed in order to make a trustworthy determination. Malsters often speak of the blue grains that appear after steeping; that is, when the coverings have become transparent.

There is undoubtedly a difference in the amount of the pigment deposited from year to year. Part of this may be due to the conditions of growth, and part to the conditions of ripening. This pigment, like melanin, is formed during the later stages of growth. It may be that an abbreviation of the ripening period, due to heat or drought, would result in a reduction of pigment.

The inheritance of the character has been tested by observations upon several strains isolated from various barleys. These have been grown for several years and at a number of places, and in every instance the aleuron layer has retained a decided amount of blue color.

The black colors have become more nearly brown in some places, but have never disappeared. Blue-gray and violet-purple colors in hull-less barleys are due to blue anthocyanin in the aleuron layer, combined with a pigment free pericarp in the blue-gray and with a red anthocyanin deposit in the violet. Both are unquestionably inherited.

Minor phases of anthocyanin formation are found in the foliage of the plant, the nerves of the grain, and in the awn. A red foliage, although found more commonly in some forms than others, may ordinarily be disregarded. In most cases it indicates a malnutrition of some sort of other. In the nerves of the dorsal flowering glume it may be more valuable as a distinction. A great many barleys show this character to some extent. Even the Hanna races possess violet or purple nerves just before ripening. None, however, develop the color to the degree that is attained by some of the Russian and Asiatic forms. In the barley nursery are several Russian selections in which the stripes along the nerves are so broad that the grains are almost red. The same is true of the strain known as Kashgar, which was imported from the region of that name in India.

In the awn an apparent anomaly was noted in 1911. In the same selection some spikes were observed in which each awn was marked with two parallel stripes of red extending from its base to its tip, and other spikes in which the same bars were deep purple. When examined in the laboratory, the color proved to be two bright red stripes in the epidermis, below which were two chlorophyll-bearing parenchym areas running the full length of the awn. As long as the chlorophyll was present the color effect was deep purple, as soon as this disappeared it was light red.

SUMMARY.

While all lesser distinctions must be based upon the broader groups, and no study of a cereal could omit its classification; the plant characters useful in taxonomic work, and the ones most useful in plant breeding, are far from being the same. Plant breeding is concerned with minute differences. The broad systematic divisions are serviceable only as groups. The problem of the nursery is not to separate a six-rowed Manchuria from a two-rowed Hanna barley, but to detect a variant in a plot of Manchuria.

Strains are often shown to be distinct in early growth by their rate of development. All barleys rush through the early stages very rapidly and a selection that is one or two days earlier than a second is very dissimilar in appearance.

Leaf production is, in some ways, a varietal character. In some varieties the third leaf appears in three days after the second, in others it occurs six days later. In the fourth leaf even a greater range exists.

In some strains the first tiller occurs decidedly later than the fourth leaf. In others it appears earlier. In some the tillers are all produced within a short time; in others the process is extended over several days.

The emergence of the awn is an extremely important note, as it occurs at a time in the life of the plant when such an observation is of great value. The development is usually normal at this time, as hot weather and drought have ordinarily not yet had any effect. The emergence of the awn has been found to be far more accurate and more easily obtained than the date of heading.

The precocity of strain at the time of the emergence of the awn is a heritable character.

The date of ripening is, unfortunately, often influenced by season, and while a valuable character, is less dependable than the emergence of the awns.

A comparison of the development during all stages serves to reveal many differences not apparent when taken separately.

The length of culm is of use as a local breeding note, but the variations are not parallel when strains are planted in totally different areas.

The diameter of the culm is not serviceable because nearly related barleys have culms of approximately the same size.

The thickness of the walls of the culm is a note with a large experimental error, and therefore of questionable utility.

The degree of exsertion of the spike is sometimes a varietal character, but is not often useful.

The number of culms per plant is to some extent a varietal character, but selections are so affected by season and location that it is very difficult to use.

The width of leaves is useful in group distinctions, and sometimes in varietal separations.

The length is much less dependable and is serviceable only in rather extreme types.

The number of leaves varies with the groups, but usually closely related strains possess approximately the same number of leaves.

The density of the spike may easily be made the basis of many separations. Often varieties that show no other differences are widely dissimilar in density.

The density of a selection varies somewhat with season and location, but the mean is always sharply defined, and the fluctuations more or less parallel.

In some strains all spikes conform closely to the mean. In others the range is greater. This seems to be a varietal character and is true whether the plantings are made in California or Minnesota.

The established systematic groups based upon the relative fertility were found to be invariable under all extremes of American climate.

The natural varieties in the deficiens group of Abyssinian barleys seem more extensive than most classifications have indicated.

From barleys of this same region a group with a peculiar habit of floret abortion has been isolated.

The length and width of awns vary, but are so correlated with other systematic characters that they are seldom useful in close separations.

The tenacity of the awn is frequently a varietal character unaffected by location or season.

The character of the basal bristle has been found to be stable under American conditions.

The toothing of the inner pair of dorsal nerves is much more variable, but the variation is usually within definable limits.

The length of the grain, while influenced by climate, is a varietal character.

The lateral and dorso-ventral diameters are so to some degree, but are so influenced by conditions of growth as to become confusing in most instances.

The composition of the grain is a varietal character, but one dominated by climate.

There are two coloring materials in barley: one, anthocyanin, is red in its acid, and blue in its alkaline, condition. The other, a melanin-like compound, is black. The pigments may occur in the hulls, the pericarp, the aleuron layer, and occasionally in the starch endosperm. The resulting colors of the grain are quite complicated. The absence of all pigment is white. A heavy deposit of the melanin-like compound in the hulls is black; a light deposit, brown. Anthocyanin in the hulls is a light violet-red. In hull-less forms the melanin-like compound in the pericarp results in a black grain. Anthocyanin produces a violet one. The acid condition of anthocyanin in the pericarp superimposed upon the alkaline condition in the aleuron layer gives the effect of a purple color, while a blue aleuron beneath a colorless pericarp is blue-gray. White hulls over a blue aleuron causes the grain to appear bluish, or bluish-gray. Black hulls over a blue aleuron give, of course, a black appearance. The anthocyanin is always violet in the hulls and pericarp and always blue in the aleuron layer, showing the former tissues to be in an acid, and the latter in an alkaline, condition. The occurrence of anthocyanin in the pericarp of hull-less barleys is more significant than its production in the aleuron layer.

TABLE I. - The relation of geographical location to length of culm in thirteen representative selections. The selections are arranged in order of their height at each point.

St. Paul, Minn.	Williston, N. D.	Moccasin, Mont.	Chico, Calif.
Hordeum vulgare	Servian	Odessa	S.P.I.No.20375
Oderbrucker	Odessa	H. vulgare	Oderbrucker
Manchuria	H. vulgare	Surprise	Abyssinian
Summit	Smyrna	Summit	Servian
Prinsess	Oderbrucker	Servian	Smyrna
Surprise	Manchuria	S.P.I.No.20375	Manchuria
Servian	Summit	Kitzing six-row	Summit
S.P.I.No.20375	Surprise	Manchuria	Odessa
Kitzing two-row	Kitzing six-row	Oderbrucker	Kitzing six-row
Kitzing six-row	S.P.I.No.20375	Smyrna	Prinsess
Abyssinian	Prinsess	Abyssinian	Kitzing two-row
Smyrna	Abyssinian	Kitzing two-row	Surprise
Odessa	Kitzing two-row	Prinsess	H. vulgare

Table II. - The effect of interval on the production of culms in selections of Smyrna and Manchuria barley.

	4 in. by 8 in.		4 in. by 4 in.		4 in. by 2 in.	
	Man-churia	Smyrna	Man-churia	Smyrna	Man-churia	Smyrna
Total plants	42	46	87	80	179	190
Total Culms	122	282	234	361	236	446
Culms per plant	2.9	6.1	2.7	4.5	1.3	2.3

The selection of Manchuria was chosen for its low tillering habit, and is not typical of the Manchuria variety of commerce.

TABLE III.- Average measurements of twenty-five leaves in selections from prominent types of barley grown at St. Paul, Minnesota, in 1911. The width is given in millimeters and the length in centimeters.

Pedigreed selection	Width			Length		
	Highest	Lowest	Average	Highest	Lowest	Average
Prinsess	15.0	12.5	13.2	28	20	23.5
Kitzing two-row	15.5	11.0	12.7	28	20	23.7
H. s. deficiens	16.0	12.5	13.7	32	26	28.7
Oderbrucker	17.5	14.0	15.5	23	17	19.2
Manchuria	20.0	14.0	16.7	27	18	22.8
Oderbrucker	22.0	15.0	18.7	28	20	24.3
Summit	15.5	12.5	14.3	26	18	22.5
Kitzing six-row	20.0	16.5	18.5	26	18	22.6
Surprise	20.0	16.5	18.3	26	19.5	22.9
Servian	20.0	15.5	17.8	25	20	22.8
Odessa	15.0	11.0	13.7	22	14	17.9
Abyssinian	22.0	17.0	18.7	25	20	22.0
Proskowetz	16.0	11.0	13.0	28	23	25.5

TABLE IV. - The width and length of leaves in the common groups of barley grown at St. Paul, Minnesota, 1911.

Group.	No. Strains	Width Highest	Width Lowest	Width Avg.	Length Highest	Length Lowest	Length Avg.
H. s. erectum	11	17	13	14.0	26	22	23.9
H. s. nutans							
long haired	67	14	9	11.4	27	20	23.0
short haired	18	18	10	13.6	28	20	24.2
H. s. vulgare							
Manchuria types long haired	49	18	13	16.1	25	20	22.6
short haired, white	85	20	15	17.7	26	22	23.7
blue aleuron	34	19	14	16.8	25	21	23.3
Russian types	23	19	13	17.0	27	22	23.7
H. s. hexastichum	29	19	10	15.4	26	19	22.2

TABLE V. - Distribution into their various densities of one hundred spikes from each of fifty-nine plots.

Name	Place	Stock No.	Row No.	Number of internodes in one decimeter.																									
				21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
Manchuria	St. Paul, Minn.	11	17			6	33	54	6	1																			
Servian	" "	34	29					15	24	39	9	2																	
Eagle	" "	13	31								3	22	39	27	9														
Sandrel	" "	35	33				3	27	35	29	6																		
Malting	" "	73	67					1	4	30	33	20	9	3															
Odessa	" "	9	23					6	10	15	1	1				2	7	21	30	36	2	2			1				
Mariout	" "	32	25							1	3	7	16	31	24	11	5	1	1										
Steigum	" "	24	32				3	15	23	39	8	2																	
Oderbrucker	" "	75	69						4	19	32	33	10	2															
Meyer	" "	77	71							3	14	36	32	13	2														
Lake City	" "	99	96			1	10	35	34	19	1																		
Triangular	" "	96	93							1	18	47	26	5	3														
Silver King	" "	89	83								4	20	41	26	9														
Sandrel	" "	35	87					12	34	42	9	2	1																
Odessa	" "	94	89					8	28	49	11	4																	
Mahrische	" "	72	66				2	12	34	32	14	6																	
Luth	" "	103	100				1	13	32	47	5	2																	
Lake City	" "	100	97			1	11	35	36	15	1	1																	
Summit	" "	8	41									1	2	11	27	22	20	13	4										
Odessa	" "	97	94		1	10	37	39	11	2																			
Hanna	" "	60	54	14	16	35	28	6	1																				
Hanna	" "	23	30					17	27	31	14	9	2																
Featherston	" "	101	98					2	2	34	40	18	4																
Meyer	" "	51	45						2	19	34	34	10	1															
Triangular	" "	102	99					1	3	31	37	21	7																
Luth	" "	5	39							2	17	40	28	10	3														
Meyer	" "	3	91		3	8	23	54	10	2																			
Odessa	" "	31	21					8	25	44	12	8	2	1															
Svanhals	" "	19	22												1	1	9	23	35	24	4	3							
Featherston	" "	6	14			1	15	45	25	13	1																		
Odessa	" "	93	88								2	6	19	28	31	10	3	1											
Featherston	" "	55	49		2	5	16	37	24	13	2	1																	
Italian	" "	30	42		6	15	26	41	10	1		1																	
Minnesota #105	" "	67	61					3	11	30	26	21	6	1		1	1												
Chevalier	" "	56	50		1	6	15	41	23	12	2																		
Luth	" "	57	51		1	4	13	44	20	17	1																		
Hannchen	" "	54	52						1	12	27	42	13	3	2														
Manchuria	Excelsior, "	Field	A			1	3	15	19	17	12	10	7	10	6														
"	" "	"	B			1	3	26	30	25	9	5	1																
"	" "	"	C				1	33	32	29	4	1																	
"	" "	"	D				2	12	21	30	13	13	3	2	2	1	1												
Italian	Chico, California	30	25						3	24	37	30	6																
Mariout	" "	32	28										1	10	39	24	16	9	1										
Eagle	" "	13	31																1	3	7	10	24	13	13	10	10	5	4
Svanhals	" "	19	15																				18	22	34	12	13	1	
Sandrel	" "	35	32									9	51	34	6														
Featherston	" "	6	14						7	35	39	18	1																
Featherston	Aberdeen, Idaho	6	79					3	11	37	31	11	6	1															
Mariout	" "	32	100											1	8	6	11	14	9	20	8	12	9	1	1				
Eagle	" "	13	103						1	1	8	26	30	21	10	2													
Svanhals	" "	19	26													1		2	4	23	12	18	24	6	9		1		
Italian	" "	30	37		3	8	20	34	24	10	1																		
Sandrel	" "	35	74						1	5	24	47	20	3															
Featherston	" "	6	379					2	9	31	30	18	5	1															
Sandrel	" "	35	374						1	11	20	34	24	6	1														
Italian	" "	30	337		3	3	2	12	30	34	13	3																	
Svanhals	" "	19	326													1	1	5	6	18	14	21	28	2	4				
Mariout	" "	32	400														1	2	4	19	9	14	21	9	13	4	4		
Eagle	" "	13	403								1	5	12	24	45	10	3												

Featherston, Luth and Meyer are all Manchuria or Oderbrucker barleys named from the farms upon which the selectionswere made. Measurements of 134 instead of 100 spikes are given in Odessa No. 9, which broke up into two types. The Excelsior barleys were from general fields, three of which wereunpedigreed. At Aberdeen rows 26 to 103 were unirrigated, while rows 326 to 403 were grown upon dry land. The irregularity of Mariout is largely due to imperfect spikes.

Variety	Where Grown	No. Meas.	Length in mm. Highest	Lowest	Avg.	Lateral Diameter Highest	Lowest	Avg.	Dorso-ventral Diameter Highest	Lowest	Avg.
Prinsess (a)	Huntley, Mont.	100	10.0	9.0	9.3	3.8	3.3	3.6	3.0	3.2	2.7
Prinsess (b)	" "	100	9.9	8.7	9.2	3.4	3.0	3.2	2.5	2.0	2.2
Prinsess	McPherson, Kans.	100	9.6	8.8	9.2	3.7	3.1	3.3	2.9	2.2	2.5
Prinsess	Plainfield, Calif.	100	10.2	9.0	9.5	4.0	3.3	3.7	2.9	2.3	2.6
Prinsess	Morris, Minn.	100	9.6	8.7	9.1	3.7	3.0	3.4	2.5	2.0	2.3
Primus	Svalof, Sweden	100	10.1	9.1	9.6	4.2	3.4	3.8	3.3	2.5	2.9
Primus	St. Paul, Minn.	100	10.4	8.7	9.6	3.9	3.4	3.7	3.0	2.5	2.8
Primus	Bonsall, Calif.	100	9.8	9.0	9.5	3.8	3.2	3.6	3.2	2.6	2.8
Primus	Amarillo, Texas.	100	10.0	8.9	9.6	3.7	2.9	3.4	2.6	2.2	2.5
Primus	Milwaukee, Wis.	100	10.5	9.6	9.9	4.0	3.4	3.8	2.8	2.4	2.6
Primus	Fort Atkinson, Wis.	100	10.4	9.0	9.8	3.9	3.4	3.7	3.0	2.4	2.8
Chevalier II	Warren, Minn.	100	10.0	8.3	9.4	3.8	3.1	3.6	2.9	2.2	2.6
Chevalier II	Flandreau, N. D.	100	10.0	9.0	9.6	3.7	3.1	3.5	2.8	2.2	2.6
Chevalier II	Erie, Pa.	100	9.8	8.8	9.4	4.0	3.2	3.6	3.2	2.5	2.8
Chevalier II	Plainfield, Calif.	100	10.0	8.2	9.4	4.0	3.3	3.7	3.1	2.5	2.8
Chevalier II	St. Paul, Minn.	100	10.2	8.3	9.5	3.8	3.0	3.5	3.0	2.1	2.6
Chevalier II	Milwaukee, Wis.	100	10.4	8.4	9.6	4.0	3.2	3.6	3.0	2.3	2.7

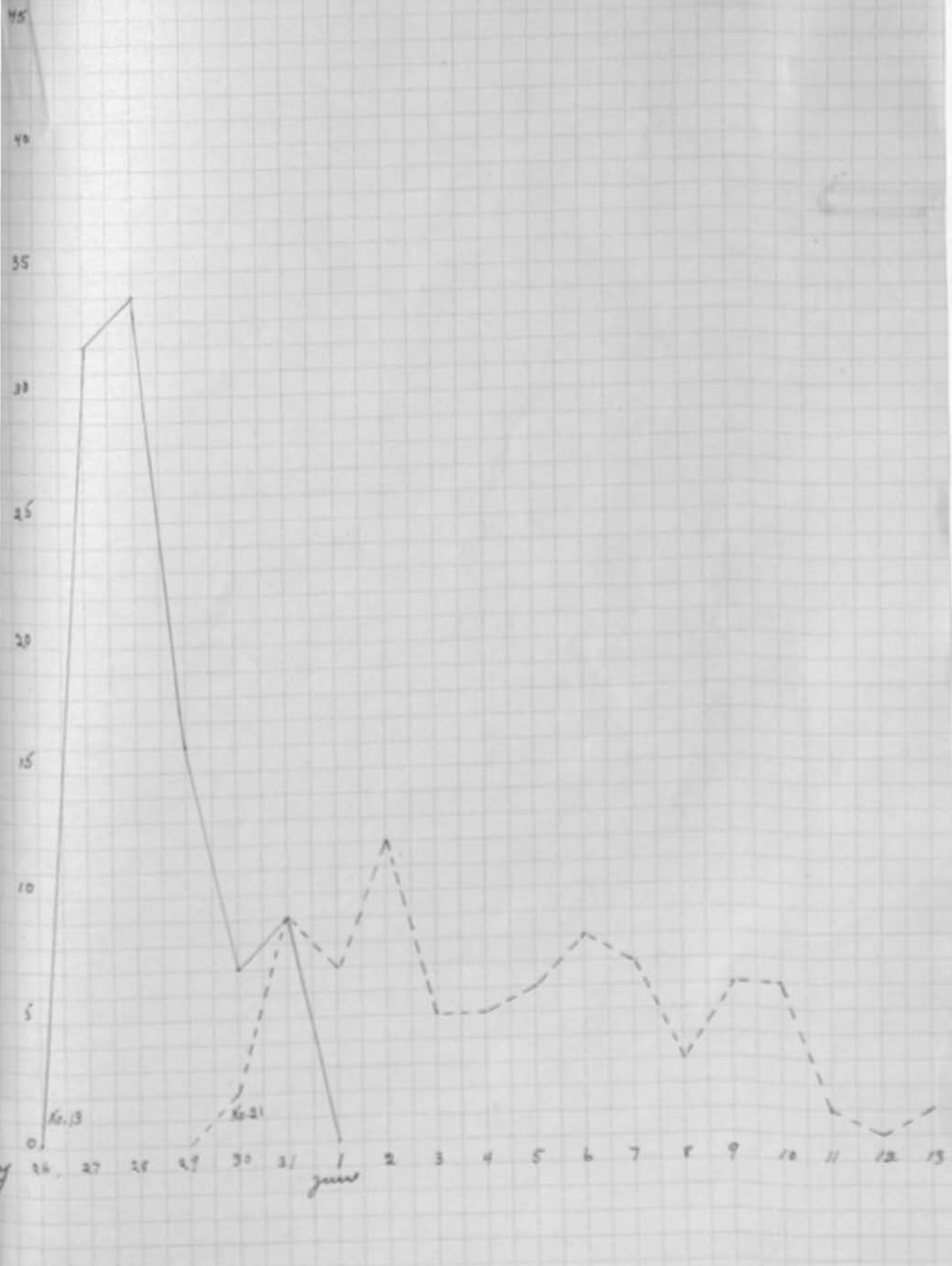
Sample (a) of the Prinsess barley from Huntley, Mont., was grown upon irrigated land, while sample (b) was grown upon the dry farm.

Fig. 1. - The Occurrence of the Second, Third and Fourth Leaves, and of the First Tiller in Ninety-six Plants of Oderbrucker, Selection Number 50. The horizontal numerals represent the date of occurrence; the vertical column the number of plants that have reached the stage on the various dates.

100
96
92
88
84
80
76
72
68
64
60
56
52
48
44
40
36
32
28
24
20
16
12
8
4
0
23
24
25
26
27
28
29
30
31
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Second Leaf
Third Leaf
Fourth Leaf
First Tiller

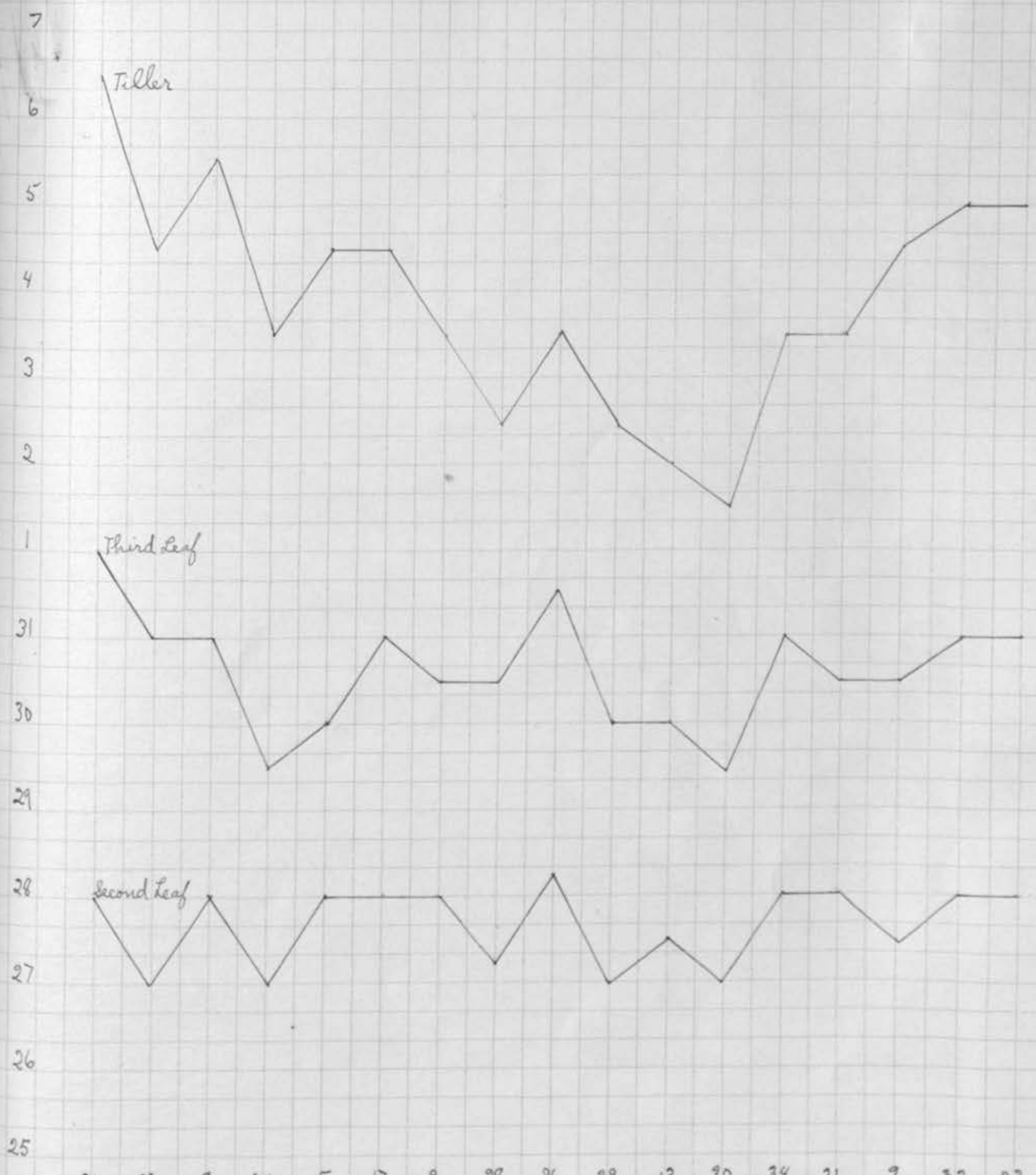
The horizontal numerals represent the dates; and the vertical column the number of plants producing tillers on the various dates

Fig. 2. - Varietal Differences in the Rapidity of Tillering. In Eagle, No. 13, All Plants Produce Tillers Almost Simultaneously, While in Russian, No. 21, the Process Is Extended Over Many Days.



45
40
35
30
25
20
15
10
5
0
26
27
28
29
30
31
1
2
3
4
5
6
7
8
9
10
11
12
13
juin

Fig. 3. - The Average Date of the Production of the Second and Third Leaves, and the First Tiller in One Hundred Plants of Each of Seventeen Selections Grown in Drill Rows. The horizontal numerals are selection numbers: the vertical ones the average date of occurrence



Tiller
Third Leaf
Second Leaf
7
6
5
4
3
2
1
31
30
29
28
27
26
25
21 23 8 24 5 17 2 28 26 29 13 30 34 31 9 32 33

Fig. 4. - Summary of the Emergence of the Awns in 13,108 Plants from various Selections. The vertical numerals represent the number of plants, the horizontal ones the days.

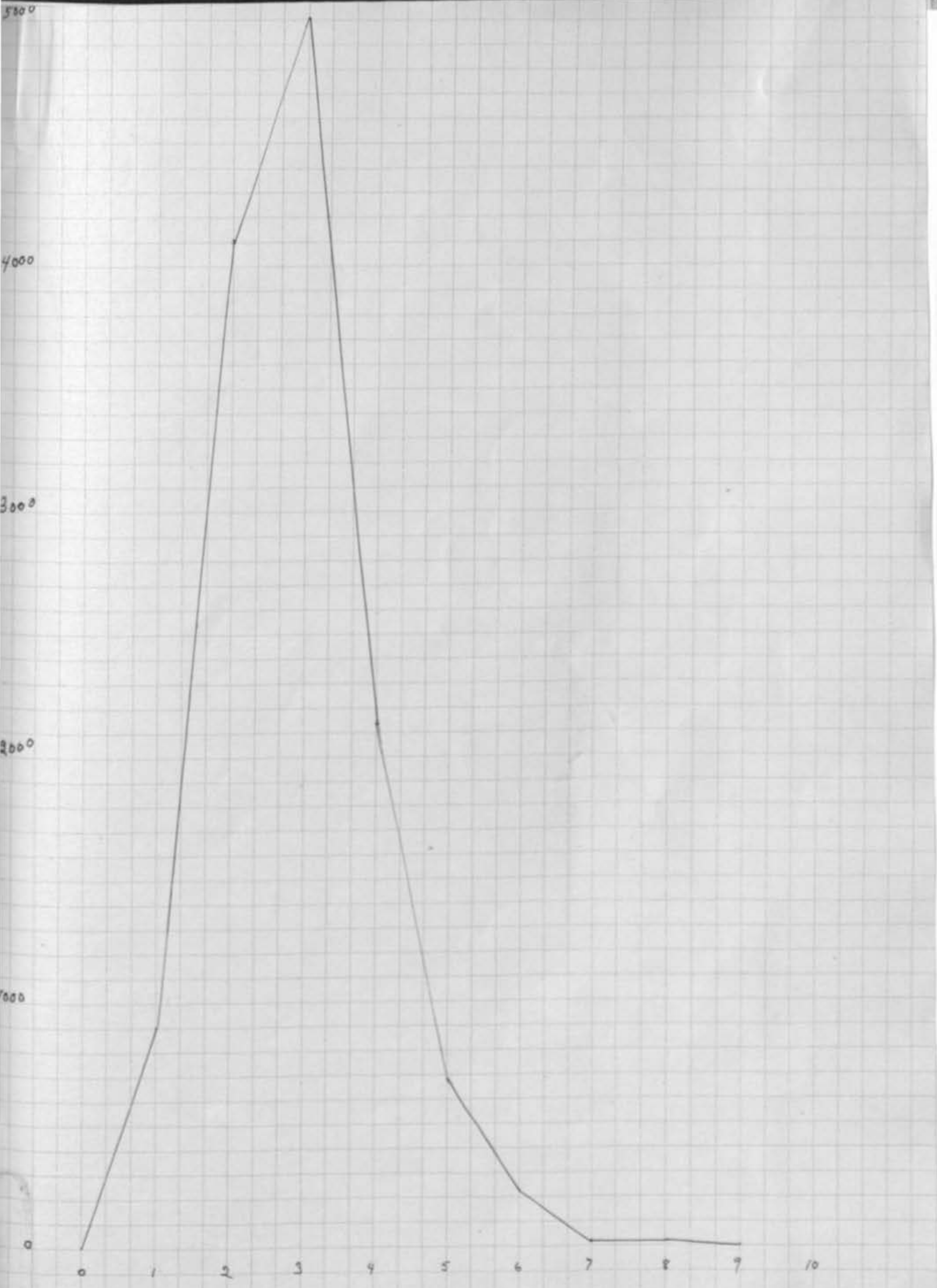

5000
4000
3000
2000
1000
0
0
1
2
3
4
5
6
7
8
9
10

Fig. 5. - The Effect of Season upon the Relative Date of the Emergence of the Awns in Thirty-seven Selections of Six-rowed Barley Grown at St. Paul, Minn., in 1911, 1912 and 1913. The vertical column of numerals represent the dates; the horizontal numerals are the selection numbers.

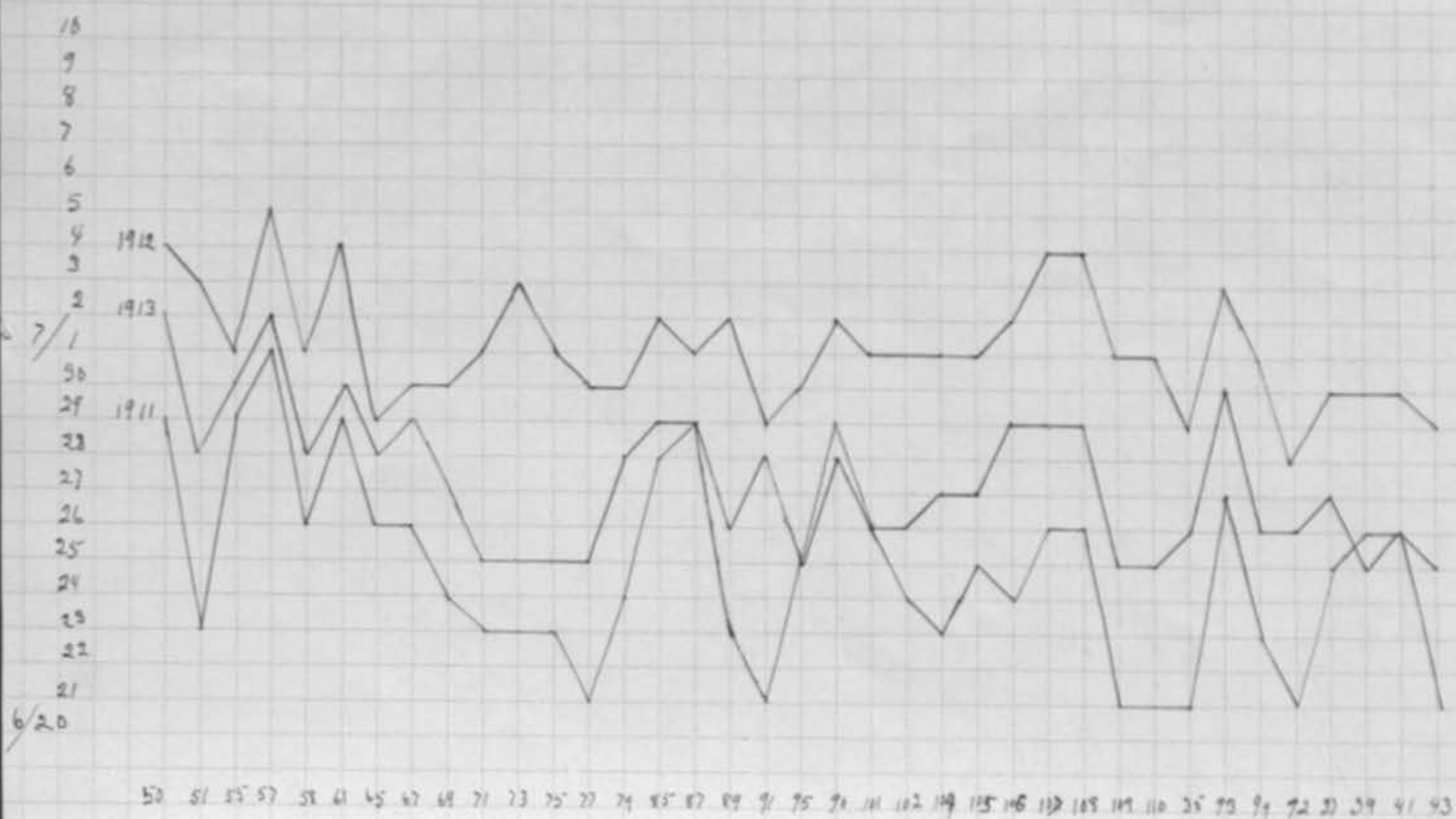

1912
1913
1911
10 9 8 7 6 5 4 3 2
7/1
30 29 28 27 26 25 24 23 22 21
6/20
50 51 55 57 58 61 65 67 69 71 73 75 77 79 85 87 89 91 95 90 101 102 104 105 106 107 108 109 110 35 99 94 92 20 39 41 43

Fig. 6. - The Ripening of Each of 1541 Spikes on a Plot of Manchuria Barley, Stated in Days From Date of Planting. The vertical numerals are numbers of ~~plants~~ spikes ripening on the day from maturity given in the horizontal numerals.

70

60

50

40

30

20

10

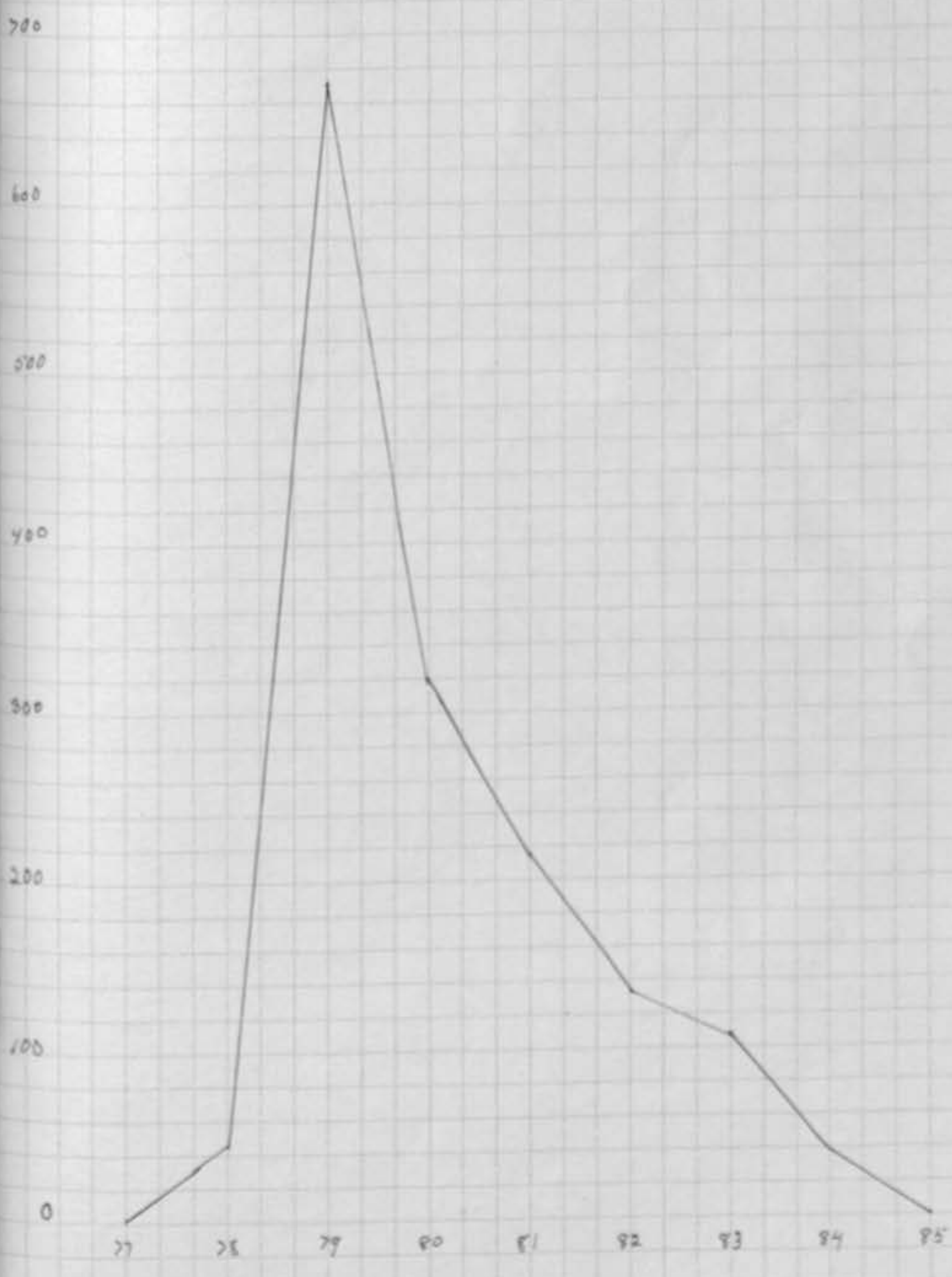

700
600
500
400
300
200
100
0
77
78
79
80
81
82
83
84
85

Fig. 7. - The Date of the Production of the Second, Third and Fourth Leaves, and the First Tiller, the Emergence of the Awns, and the Day of Ripening, in Fourteen Selections of Barley Grown at St. Paul, Minn., in 1913. Each Determination Based on One Centgener of Approximately One Hundred Plants. The horizontal numerals are the numbers of the selections.

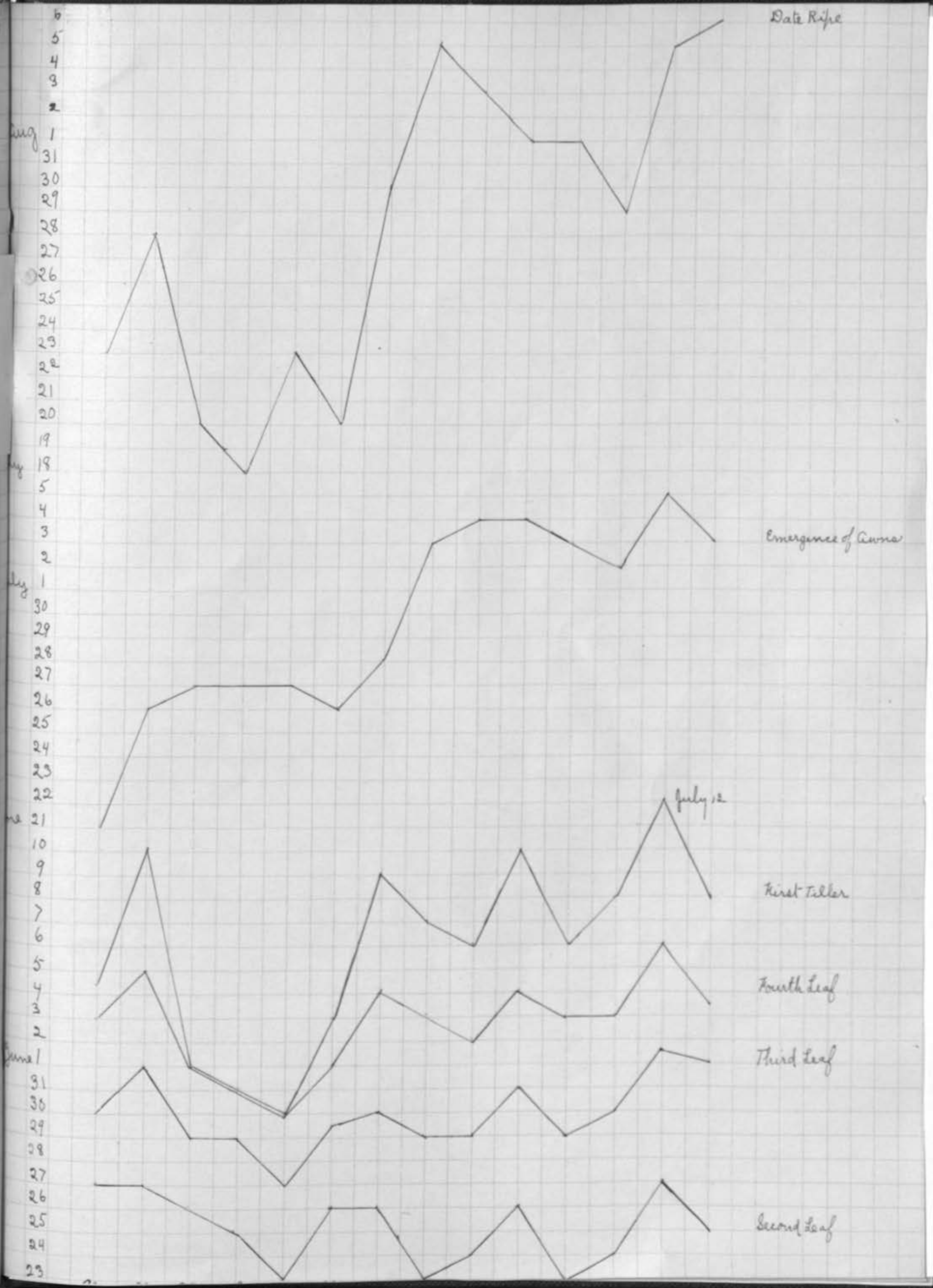
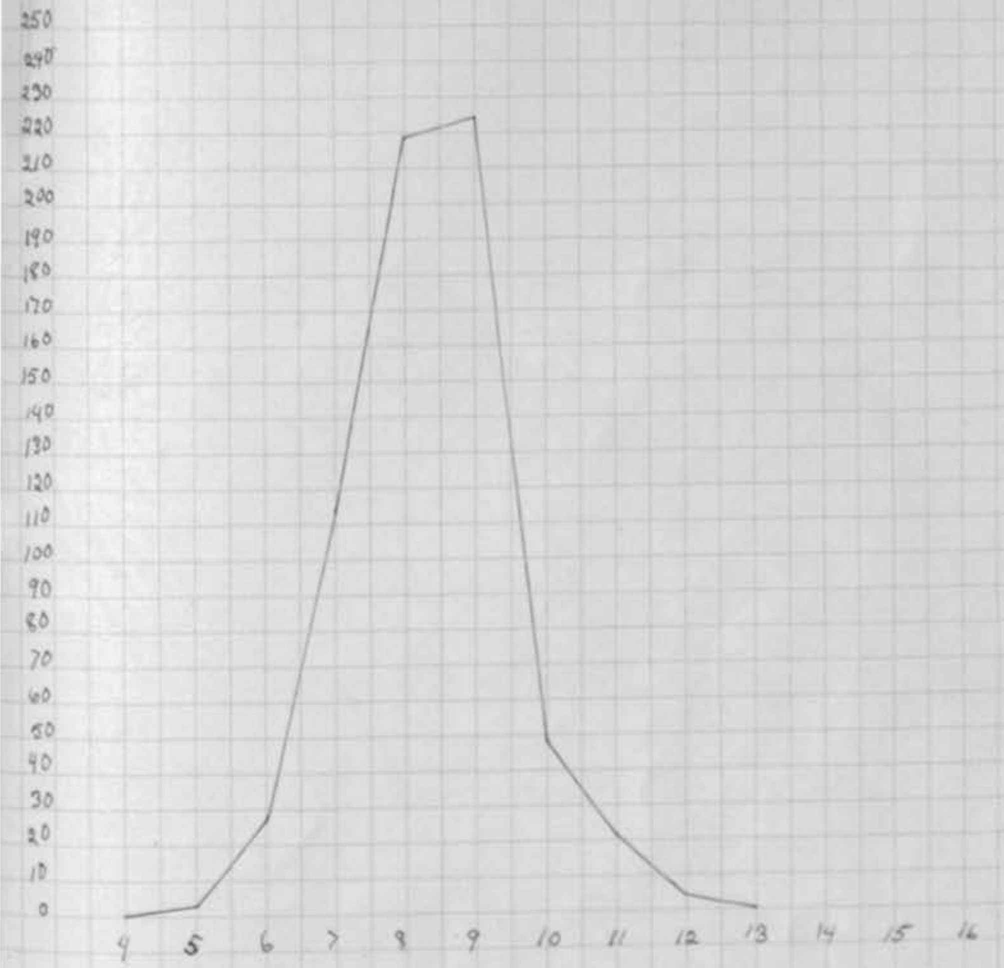

Date Ripe
Emergence of Awns
July 12
First Tiller
Fourth Leaf
Third Leaf
Second Leaf
Aug 1
June 1

Fig. 8. - Composite Curves of the Width and Length of Leaves, the Upper (Width) in Millimeters, the Lower (Length) in Centimeters. The horizontal numerals are measurements; the vertical ones number of leaves.


250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
4 5 6 7 8 9 10 11 12 13 14 15 16

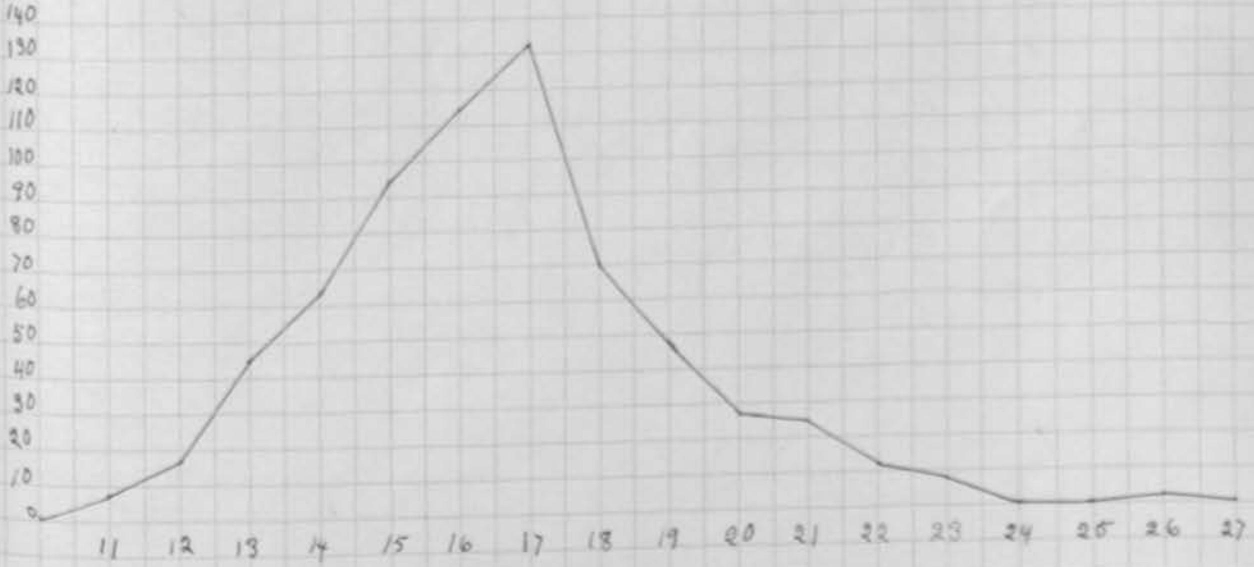
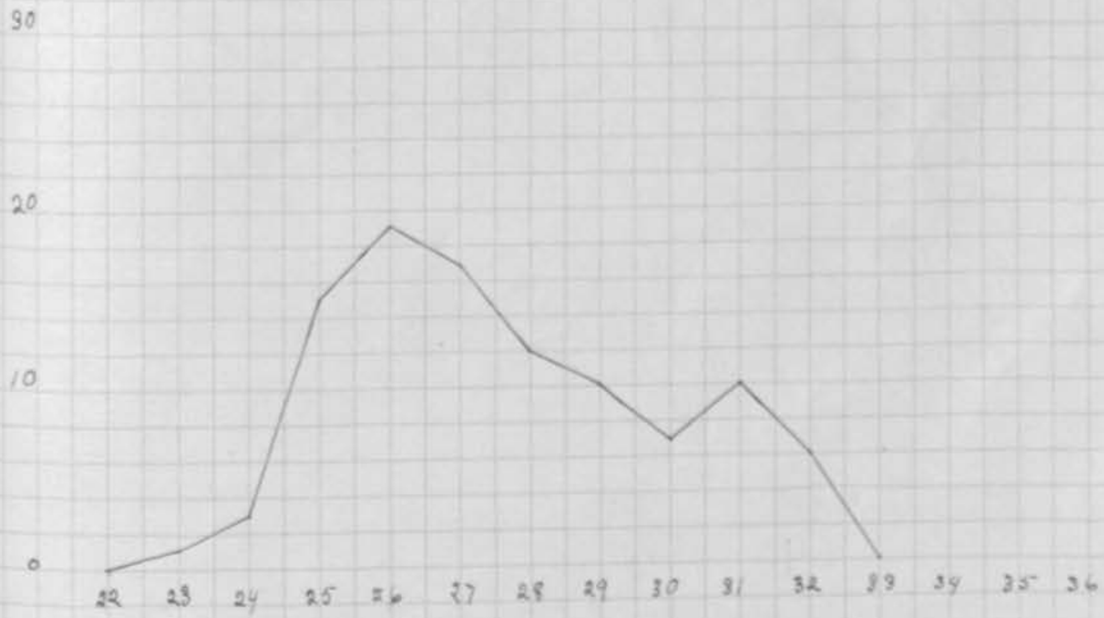

140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27

Fig. 9. - The Density of One Hundred Spikes of Manchuria Barley From a Field Near Excelsior, Minnesota. The horizontal numerals represent density; the vertical ones number of spikes



30
20
10
0
22 23 24 25 26 27 28 29 30 31 32 33 34 35 36

Fig. 10.- The Density of One Hundred Spikes From Each of Two Plots of Sandrel, No. 35, Planted in Different Parts of the 1913 Nursery at St. Paul, Minn. The horizontal numerals are densities; the vertical ones number ~~spikes~~ spikes

Fig. 10.-
Two
Part

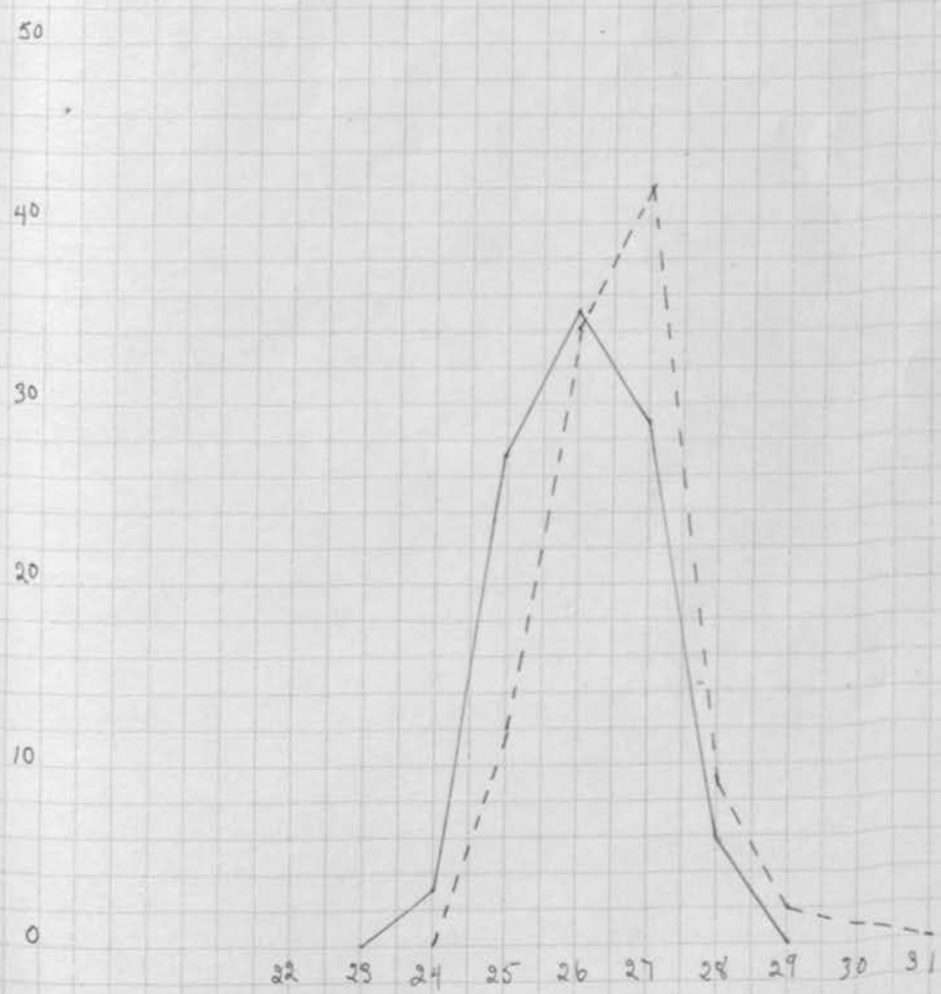
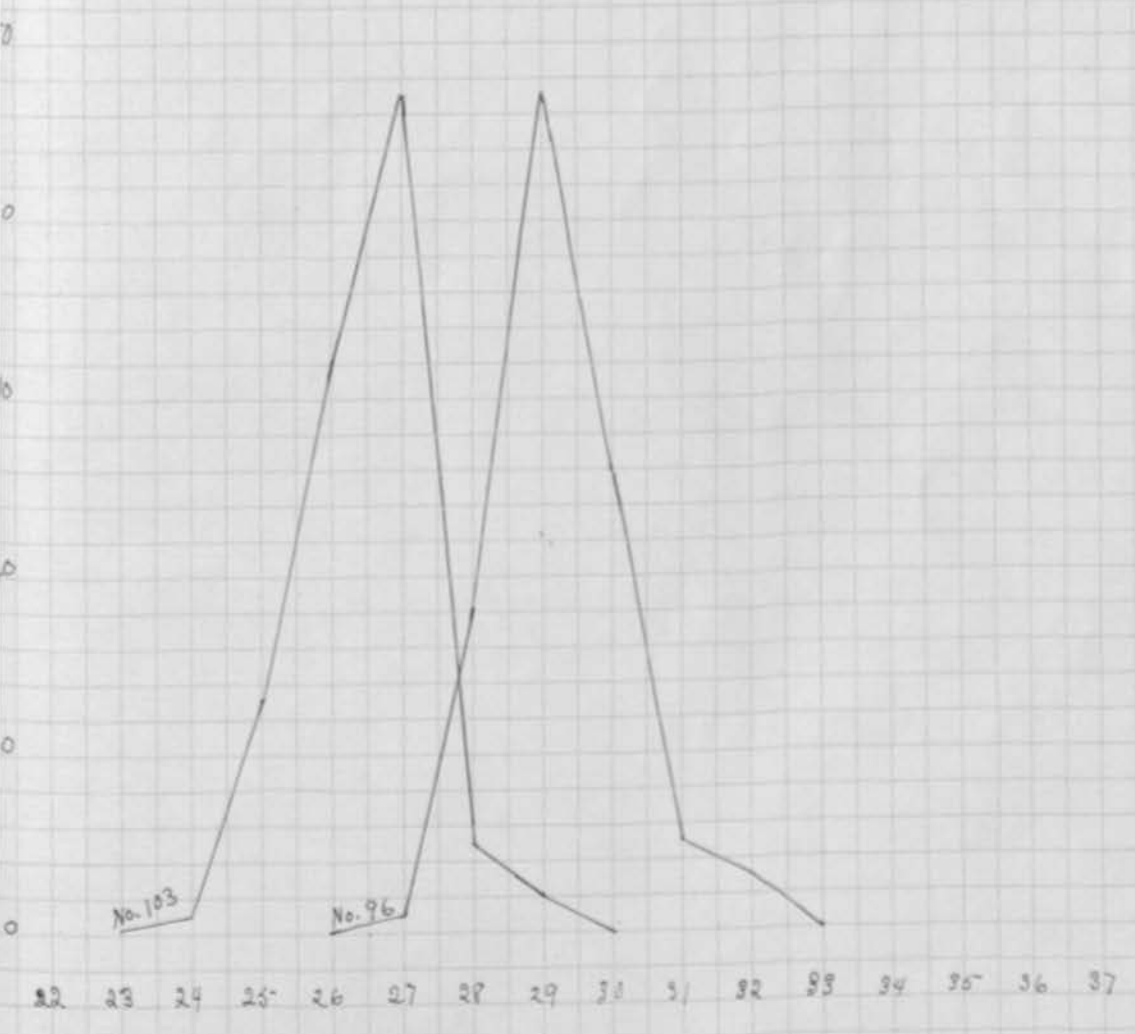


Fig. 11.- The Density of One Hundred Spikes in Each of Two Selections of Manchuria Grown at St. Paul, in 1913. The horizontal numerals represent density; the vertical ones number of spikes


No. 103
No. 96
22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37

The vertical ones, below, density; above, dates.

Fig. 12.- The Average Density, and the Date of Emergence of the Awns, in Sixteen Selections of Manchuria Barley Grown at St. Paul, Minn., in 1913. The horizontal numerals are the numbers of the selections.


9
8
7
6
5
4
3
2
1
30
29
28
27
26
25
24
23
31
30
29
28
27
26
25
24
23
22
0
0 75 77 99 96 89 103 100 101 51 5 3 6 55 67 57 102

Fig. 13.- The Average Density, and the Date of the Emergence of the Awns, in Twelve Miscellaneous Selections Grown at St. Paul, Minn., in 1913. The horizontal numerals are the selection numbers; the vertical ones density, below, date of emergence above.

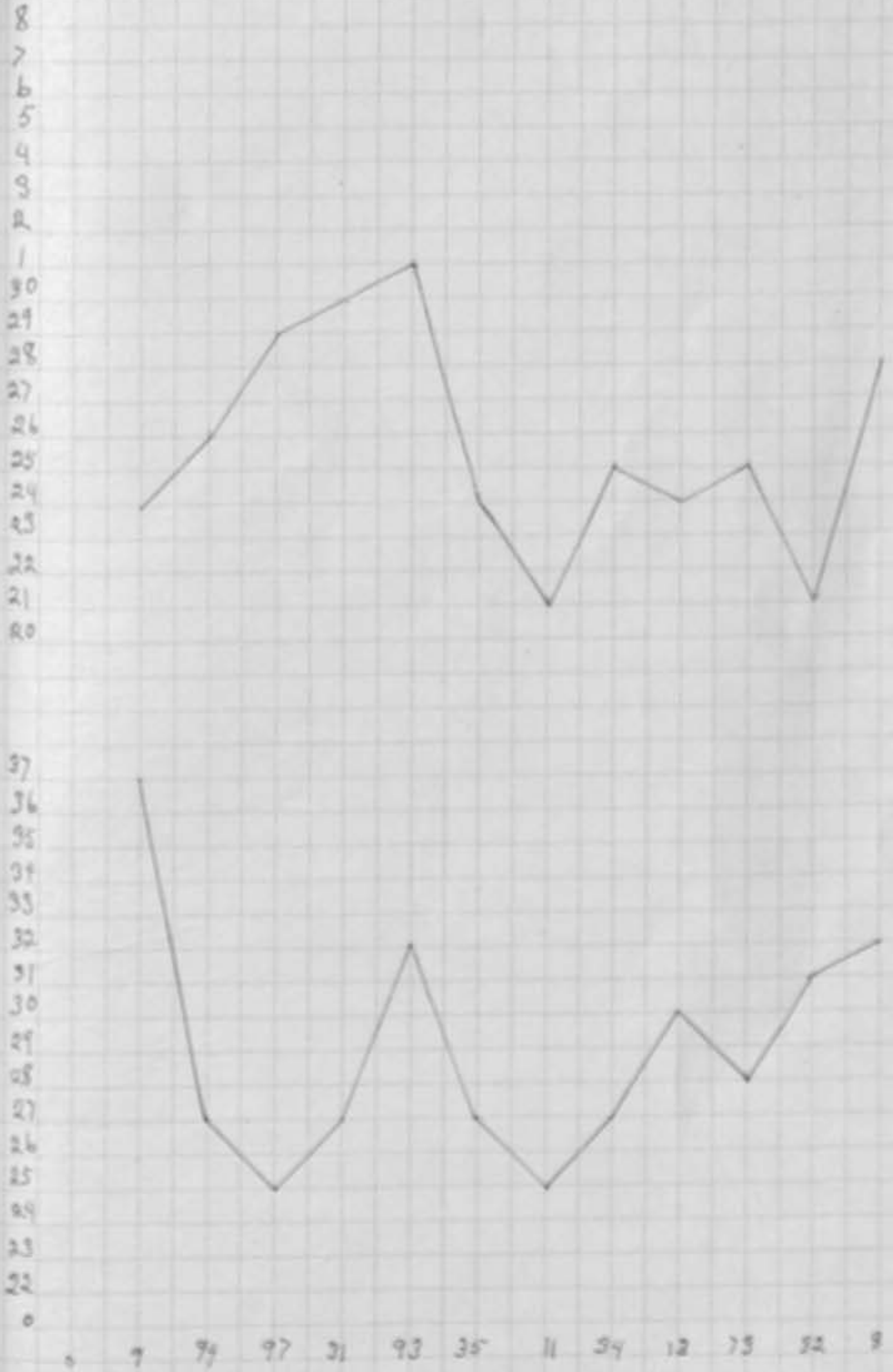

8
7
6
5
4
3
2
1
30
29
28
27
26
25
24
23
22
21
20
37
36
35
34
33
32
31
30
29
28
27
26
25
24
23
22
0
0
7
94
97
31
93
35
11
34
12
73
52
8

Fig. 14.- The Density of 134 Spikes of Odessa, No. 9, Grown at St. paul, Minn., in 1913. the horizontal numerals are densities the verticals are number of ~~plants~~ spikes

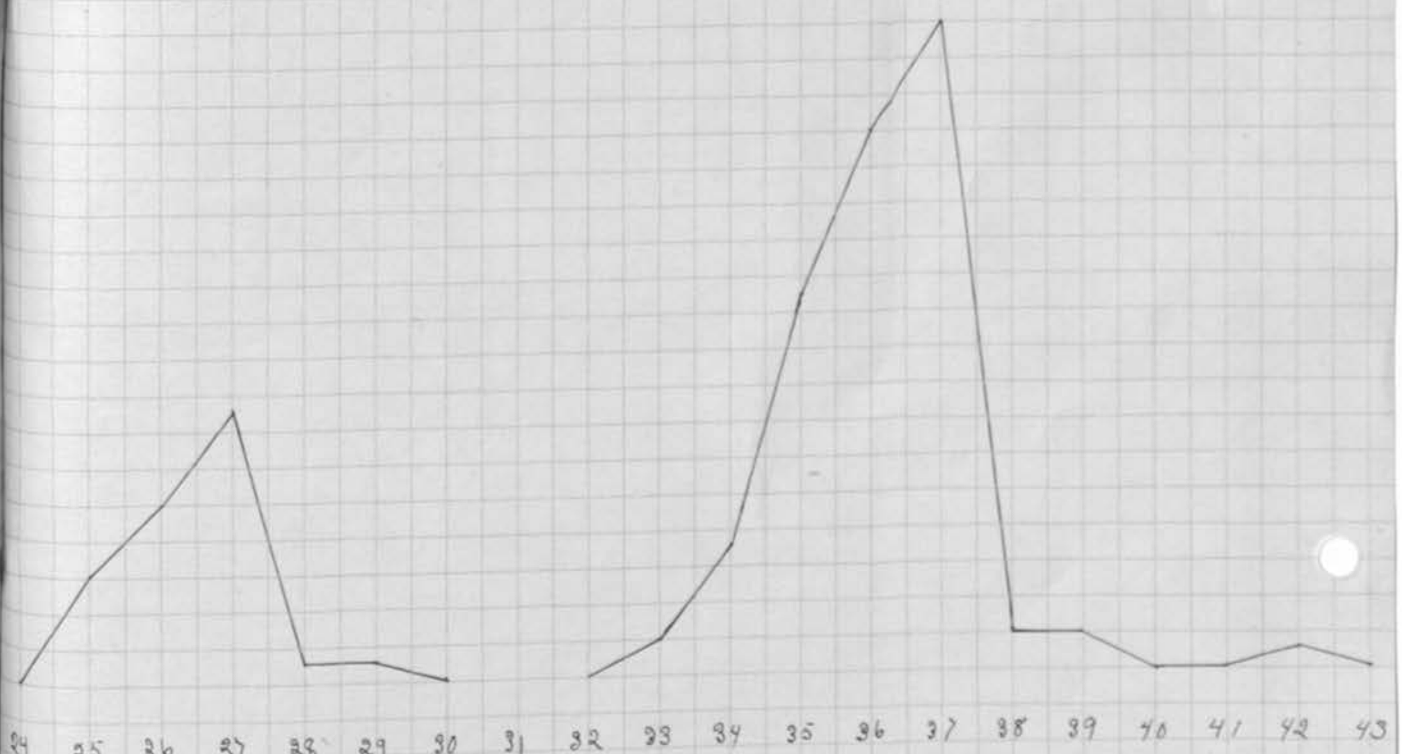
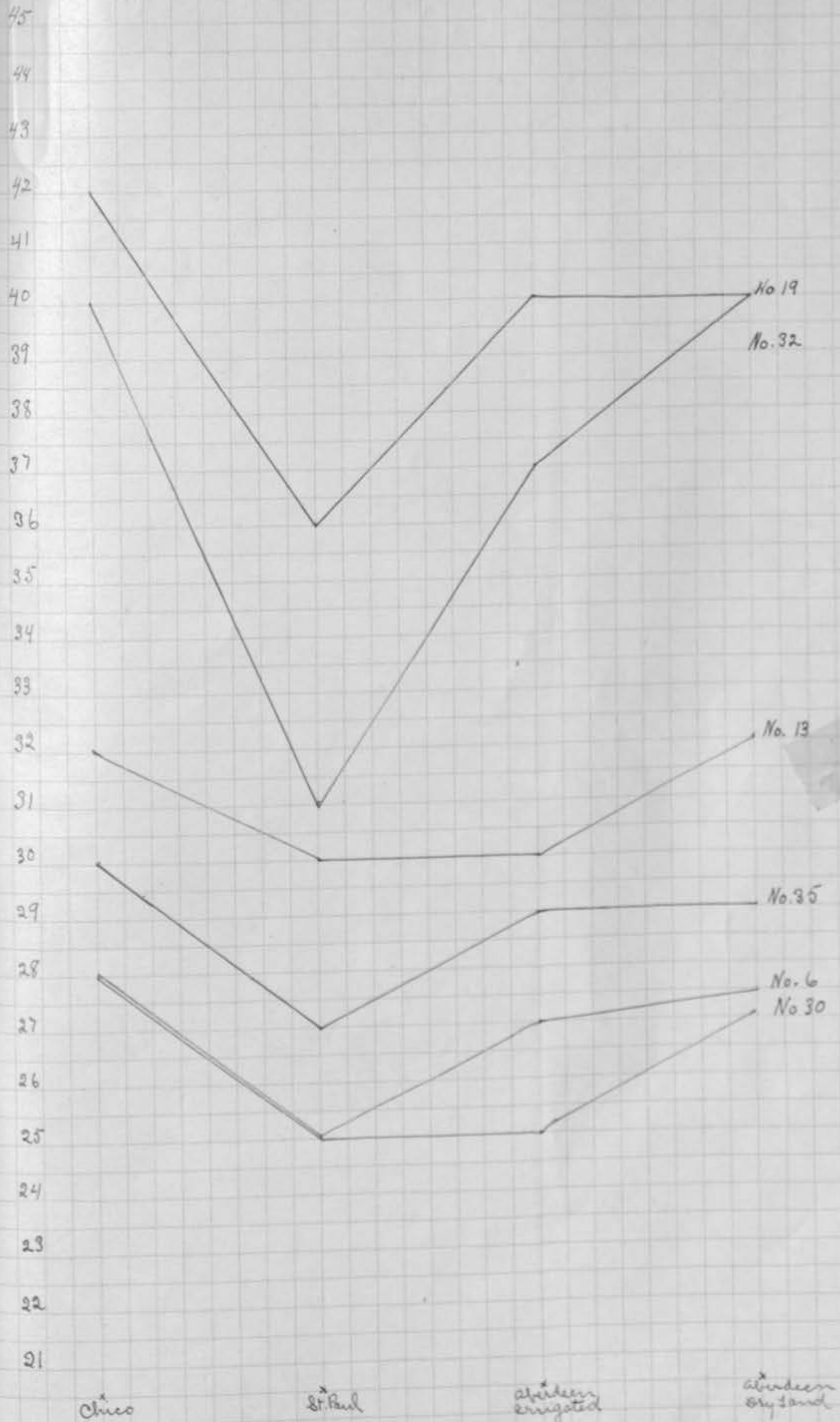

24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43

Fig. 15.- The Average Density of Six Selections of Barley Grown at Chico, Calif., St. Paul, Minn., and at Aberdeen, Idaho. At the Latter Place Upon Both Irrigated and Unirrigated Land.


45
44
43
42
41
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
25
24
23
22
21
No 19
No. 32
No. 13
No. 35
No. 6
No 30
Chico
St. Paul
Aberdeen irrigated
Aberdeen dry land

Harry Vaughn Harlan was born in London Mills, Ill., February 19, 1882; attended the graded schools of Walnut, Kans., from 1888 until 1892 and of London Mills, Ill., from 1893 until 1896; received a high school education at Walnut, Kans., from 1896 until 1900, graduating in the latter year; attended the Agricultural College at Manhattan, Kans., from 1901 to 1904, receiving the degree of Bachelor of Science; entered the employ of the Philippine Government in 1905 as an agricultural instructor, remaining in this capacity until 1908; carried on studies in absentia for a Master's degree at the Kansas Agricultural College during 1906 and 1907, completing the work by one year's resident study in 1908 and 1909; entered the employ of the U. S. Department of Agriculture as an assistant in special barley investigations in 1909; accepted full charge of these studies in 1910 and of all barley investigations in 1912; began work leading to the degree of Doctor of Science in 1911, spending the greater part of the years 1911-1912 and 1913 at the University of Minnesota; left the United States October, 1913, to undertake a six-months' study of the Peruvian Andes.