A PHYSIOLOGICAL STUDY OF THE AWNS OF RED WINTER WHEAT

by

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INTRODUCTION

The function of the awns of cereals has long been a topic of interest, particularly to the followers of applied science. It is generally agreed that in certain regions the awned varieties outyield awnletted or awnless ones. Although the exact physiological role of the awns is not well-established, it is generally agreed that under certain climatic conditions, the awns of wheat are useful structures. Thus awned varieties have been selected and grown in regions of limited rainfall, for awnless types are apparently not well-adapted to such areas. As the awn constitutes one of the chief morphological differences between awned and awnless wheats, it was considered important that a physiological study of the awns should be made. Some investigations have already been made in this regard but the data are frequently contradictory, sometimes inadequate, and occasionally the result of questionable methods. In an attempt to clarify and supplement certain present conceptions of the subject, the study herein discussed was undertaken.

REVIEW OF LITERATURE

Researches on Wheat

The earliest work pertaining directly to the awn was that of Hickman (21), in Ohio, who stated that in averaging the yields of experimental plots at Wooster in 1889, 31 varieties of awned wheat gave an average of 40.5 bushels per acre, while the 36 awnless wheats yielded an average of 37.4 bushels per acre. Later he (22) reported that the average yield of 162 trials of awned wheat and of 234 trials of awnless wheat, extending over a period of 10 years, showed but six-tenths of a bushel difference in favor of the awned varieties. He suggested that the one is equal to the other as regards productivity in Ohio.

The influence of the awns on the development of the grain in red, winter, awned wheat was studied at the Poltava experiment field by Treyakov (39) who reported that ripening began two days earlier in the case of those spikes deprived of their awns. The absence of awns was accompanied by a smaller-size grain and less weight. The grain from the awnless spikes was richer in ash but poorer in nitrogen and phosphorus. Treyakov concluded that awned varieties give smaller yields of grain, but that the individual grain possesses a higher absolute weight. The fluctuations in the size of the grains of awned wheats were less than those of the awnless varieties.

Grantham and Groff (12), in Delaware, found that awned varieties of wheat as a class have a higher percentage of sterile spikelets than the awnless varieties. Of the 188 varieties examined, the smallest number of sterile spikelets was found on an awnless variety and the largest number on an awned variety. Grantham (13) reported that based on the yields of 26 tests made in Delaware, including 1,986 varieties and strains, the awned wheats outyielded the awnless by 3.31 bushels per acre. The awned types yielded better than the awnless regardless of the fertilizer treatment. The shrinkage in yield of the awned wheats when grown without fertilizer was 30 per cent and that of the awnless wheats 41 per cent. Later work by Grantham (14) substantiated his earlier findings in that awned wheats outyielded awnless types. In the latter study, grain of awned and awnless wheats was taken at random from farms in Delaware, and an average of 285 grains (from awned spikes) and 412 grains (from awnless spikes) constituted 10 gm. of wheat. Where fertilizer was used the uniformity of size in the grain of the awned variety was significant. Without the application of fertilizer, awned wheats seemed to have the capacity for utilizing the plant food to better advantage as was indicated by the more consistent and increased plumpness of grain. Excess of nitrogen affected the awnless wheat more adversely than the awned type.

As quoted by Rosenquist (32), Fleischmann isolated from native Hungarian wheat three types of awnedness classes and propagated them.

Type A was awnless or slightly spurred, type B had awns as long as the glumes or shorter, while type C had awns longer than the glumes. Type A was generally inferior to the other two types, gave a lower yield and produced lighter grains. Type C was slightly better in most respects than type B and much better than type A.

Hayes (18), using Marquis x Preston hybrids, found that in each of the generations from the F_3 to the F_5, the awned families gave a higher yield per plant than the awnless families. In Minnesota during the favorable seasons of 1918 and 1920, the awned families yielded seven to eight per cent more grain than the awnless ones, while in the unfavorable season of 1919, the difference in yield was 17 per cent in favor of the awned families. The awned families averaged somewhat higher than the awnless ones in length of grain, percentage of plumpness of grain, and yield per plant. He considered, therefore, that the awn of wheat is an important organ, and that the present tendency to breed only awnless wheats should not be adopted in entirety without further experimental studies. From a cross between Marquis and Kota wheats, Hayes and Aamodt (19) found that the grain of the F_2 awned plants averaged 0.1 mm. longer than the grain from awnless plants. The grain of the awnless plants was slightly harder but was somewhat inferior in plumpness to that from the awned plants. They concluded, therefore, that the awns of wheat lead to the production of a somewhat better developed seed. Hayes, Aamodt, and Stevenson (20) showed from a study of spring and winter wheats that awned strains on the average excelled in plumpness of grain. As plumpness of grain and yield are strongly correlated, it seems that awned wheats yield better on the average than awnless wheats when grown under southern Minnesota conditions.

Working with crosses between Bobs, Hard Federation, and Propo wheats, Clark, Florell, and Hooker (3), of California, discovered imperfect dominance of awnlessness. Inheritance of awnedness in some crosses was very simple and in others very complex. In general it appeared that in the hybrids the extent of shattering increased with the length of the awns, although in all awnedness classes resistant plants may be present. There was a tendency toward increased yields in awned over true-breeding awnless or awnless-segregating hybrid strains. Clark and Quisenberry (4), in their studies on crosses of Marquis and Kota spring wheats in Montana, showed imperfect dominance of awnlettedness. In the F_2 generation the average yield of the awnletted hybrid plants exceeded that of the awned plants by 1.30 $\pm$ 0.33 grams. Shattering estimates taken on a row basis at harvest time showed that the awnletted strains shattered 8.25 per cent, whereas the awned rows shattered 14.38 per cent. The difference in yield was due in part to greater shattering among the awned plants although had no shattering occurred, the awnletted strains apparently still would have outyielded the awned. The grain of Kota, the awned parent, had a slightly higher crude-protein content than that of Marquis, the awnless parent. Working with Hope x

Hard Federation crosses, Clark, Quisenberry, and Powers (5) found no relationship existing between awnedness and grain yield in Montana.

It was reported by Conti (6) in Italy that the awns of durum wheats consume some food in their development, but that they are responsible for the larger and more glutinous caryopses of the southern hard wheats. The contributory factors toward this end were considered to operate through the increased transpiration of the awns.

Goulden and Neatby (11) in Canada studied the association between awns and grain yield in rod-row trials of awned and awnless strains of H-44-24 x Marquis. They obtained a P value of 0.0004, which indicates a very high probability of association between the presence of awns and high grain yield.

A rather limited study by Meister, Shekhurdin, and Plotnikov (25), in Russia, led the investigators to the conclusion that with Triticum durum, after the wheat is fully headed, removal of the awns has no influence on the dry matter of the grain.

According to Aamodt and Torrie (1), Moskalenko studied in winter wheat hybrids the relation between awnedness and productivity. He concluded that under the conditions of the Ukranian steppe durring the years of 1922, 1925, 1926, and 1927, there was no genetic relationship between awnedness and yield.

Stevens (36), in Kansas, made some comparisons of awnless and awned segregates in the F_2 generation populations grown in the crop improvement nursery at Manhattan, Kansas, in 1929. In the F_2 generation, awned segregates excelled the awnless ones by 7.8 per cent in plumpness of grain, by 0.9 gm. of grain per plant, and by 3.4 bushels per acre.

The results of Gemmell's (10) studies in 1921, which, however, were not published until in 1933, showed the effect of wheat awns on yield when he removed all of the awns in some cases and half of them in others. Totally de-awned and partially de-awned spikes were compared to fully-awned spikes as controls. De-awning was performed at the blossoming stage, June 1; one week later, June 8; and June 16, four days before harvest. The data show that the awned spikes and spikelets yielded more than those from which all or half of the awns had been removed. The differences were always less the nearer the date of de-awning approached maturity. These facts have been reported by Parker (27) in a popularized article.

Studies by Aamodt and Torrie (1), at the University of Alberta, using a number of F_2 lines of Reward x Caesium and also awned and awnletted strains of Marquillo x Marquis-Kanred, did not reveal a significant relationship between the presence of awns and grain yield.

Rosenquist (32) worked with segregates of the F_2 progeny of a cross between Garnet (a variety with spur-like awns on a few of the upper lemmas) and Prelude (a fully-awned variety). This cross produced spikes that were awnless, fully-awned, and intermediate, i.e., having long awns on the upper lemmas, shorter ones near the center of the spike, and no awns on the lower half of the spike. By comparing grains from awned and awnless florets borne on the same intermediate F_2 spikes, errors due to injury and to varietal, plant, and spike differences were practically eliminated. Due to the fact that grain size is somewhat dependent upon the position of the grain in the spike, it was necessary to compare homologous grains of the awnless spike with those of the "paired", intermediately-awned spike. Grains from awned florets averaged about 1.4 per cent heavier than those from awnless florets in the same spike. Furthermore, grains from intermediately-awned F_2 spikes averaged 3.2 per cent heavier than those from awnless F_2 spikes, while grains from fully-awned F_2 spikes were 4.9 per cent heavier. Rosenquist thus concluded that the presence of awns on the florets of wheat tended toward the production of heavier grains.

Researches on Wheat and Barley

Vasilyev (40), of Russia, studied the function of awns by using as experimental plants, rye, Stipa capillata, and several species each of wheat and barley. In experiments with Bieloturka wheat it was found that 63.3 per cent of the water transpired by the spike was from the awns, and in another variety 60.3 per cent of the total transpiration of the spike was due to the awns. The maximum transpiration by the awns was at the time of flowering. In one experiment the removal of awns from one-half of the spike lowered the weight of the grain as much as nine per cent. This indicated that the presence of the awns is favorable to the proper filling of the grain. Vasilyev concluded from his studies on the transpiration of awns that when awns are fully developed, they evaporate the greater amount of water given off by the spike, and that the removal of the awns strikingly diminishes the amount of transpiration.

One of the earlier, thorough investigators of the physiological function of the awns was Schmid (34), in Germany, who presented much data to substantiate his findings. He stated that the awns are very actively concerned in transpiration, assimilation, and respiration. The de-awning of a wheat plant lowered its transpiration 10 to 30 per cent. The awned spikes transpired relatively more water by night than by day while with awnless spikes, as well as with the lamina of the leaf, the reverse was true. Since both the awn and the lamina have numerous stomata, he considered that the stomata of the lamina opened wider during the day than did those of the awn. The weight of grain was decreased six to eight per cent by total de-awning. De-awning on only one side of the spike did not produce equally one-half of the value obtained by total de-awning because the de-awned side was thought to receive some nourishment from the awned half of the spike. The decrease in weight was directly proportional to the length of awn removed by de-awning. Little or no starch was found in the chlorenchyma of the wheat or barley awns. He reported that grain of warmer climates as a rule had a higher protein content and less starch than the grain grown in cooler regions.

Based on dry weight, grain from awned spikes had 0.05 per cent more nitrogen than grain from de-awned ones, but he did not deduce a relationship between awnedness and protein content. Schmid concluded that the awns in general have a biological and physiological role -- the first manifested in seed dispersal and protection against grazing; the second shown in the production of a larger, heavier grain. He also concluded that generally the importance of the awn stands in direct proportion to its size.

The morphology and anatomy of awns, outer and inner glumes, and palea were studied thoroughly by Perlitius (29) in Germany. His study shows that the awned varieties of wheat and barley yielded more grain by weight and volume than did the awnless types. The grain of awned spikes had less nitrogen but more ash and starch than that of the de-awned or awnless ones. The awned spikes had more stomata and a greater transpiration than awnless spikes. The length of awns and length of growing season were inversely related, and the awned varieties consequently ripened earlier. This, in many cases, was believed to explain the difference in yielding ability of these two types of wheat.

Researches on Barley

Zoebl and Mikosch (41) stated that the awns of barley are definite organs for transpiration. Awned spikes transpired four to five times more water than awnless ones. At the time of functioning of the awns, about one-half of the total transpiration of the plant was from the spikes. Transpiration of the awns was most intense during the period of greatest development of the grain, that is, at the time of the greatest migration of reserve materials into the grain. They also noted a general periodicity in the transpiration of the spikes -- as for the entire plant -- and they stated that light had a particular influence on this periodicity. It has been shown by unknown workers (37) that the transpiration of barley spikes is decreased by a removal of the awns.

Experimenting with barley plants, Schulze (35) showed that awned plants transpired much more than those that had been de-awned or were naturally awnless. The peak of transpiration was reached at the milk stage of the grain.

Tedin, as quoted by Rosenquist (32), compared awned plants of barley with those from which all the awns had been naturally removed shortly before ripening. The naturally de-awned spikes ripened earlier and produced 10 per cent less grain than did the awned spikes.

According to the work of Harlan and Anthony (15), at Aberdeen, Idaho, grains from de-awned spikes of barley have smaller volume and a lower weight of dry matter than do those from awned spikes. This difference in yield was not thought to be due to injury or to the shock of removing the awns because development of the grain proceeded normally after the de-awning. About one week after flowering, which is about the time that rapid starch infiltration begins, the deposit of dry matter in the grain of the awned spike began to exceed that in the grain of the de-awned spike. The daily deposit of nitrogen and ash was more nearly equal in the two classes of spikes than was the deposit of starch. In awned spikes at Aberdeen, Idaho, barley awns contained more than 30 per cent of ash at maturity. Hooded and awnless barleys generally yielded less and shattered more than awned varieties, which seemed to indicate that the barley awn has some physiological function. Harlan and Pope (16), at Chico, California, stated that the awns of barley receive a very large deposit of ash, comprising over 30 per cent of the dry weight in some varieties. This extremely heavy deposit of ash indicates that the awns, or parts of the awns, are used as a depository for the excess ash absorbed by the roots. The fact that some varieties contain much more ash in the awns and rachises than others is due no doubt to a difference in the amount of water transpired and to a difference in the selective functions of the roots of different varieties. The rachises of hooded and awnless varieties are usually high in ash and this increases the brittleness and promotes shattering.

It was concluded by Aumüller (2) that the awns of barley possess transpirational and assimilatory functions.

It is reported (7) by the South Carolina Experiment Station that their selections of awnless barleys outyielded Tennessee Beardless and made only slightly less grain than the Bearded Winter variety.

GENERAL DISCUSSION OF THE AWN, AND OTHER PARTS OF THE SPIKE

General Description of the Spike

Percival (28) defines the inflorescence or "head" of wheat as "a distichous compound spike, the primary axis bearing two opposite rows of lateral, secondary spikelets and a single fertile terminal spikelet, except in the case of T. monococcum in which the latter is rudimentary and barren, or missing". The spike is frequently referred to as the "head", and, in Europe, as the "ear".

A lemma, palea, and the sexual organs constitute a floret, of which there may be from three to nine in a spikelet; aggregates of spikelets make up the spike (see fig. 1). One or more of the upper florets in a spikelet are usually sterile. Each spikelet consists of a delicate, flattened and jointed rachilla which bears two opposite rows of alternately solitary flowers between chaffy bracts or outer glumes. The florets of a spikelet are thus subtended by two outer glumes one being attached to the rachilla at a slightly higher level than the other.

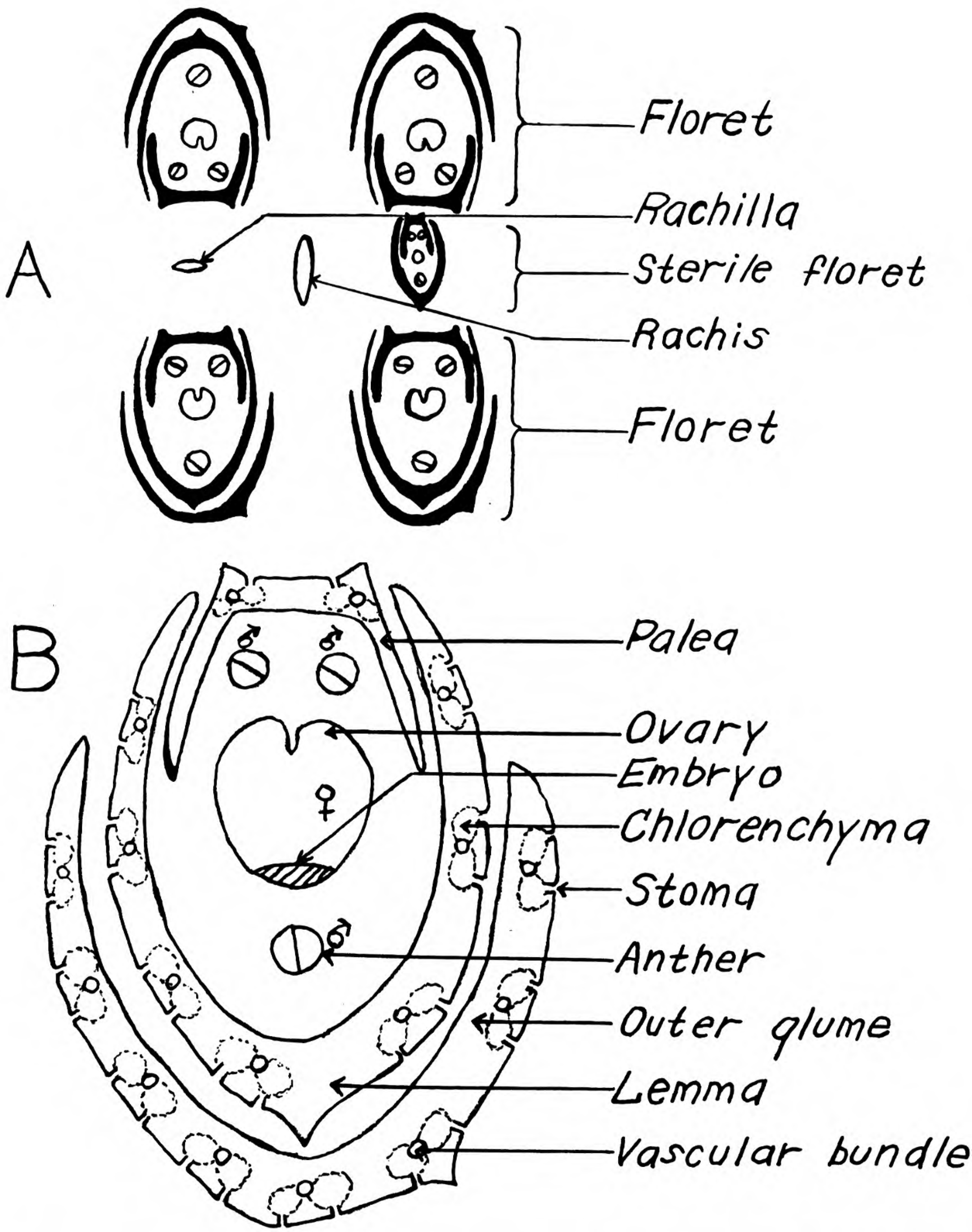

Fig. 1.--A, Diagrammatic cross-section of a wheat spike showing the arrangement of florets and floret parts; B, Detailed, diagrammatic drawing of a floret showing the arrangement of its various parts.

Outer Glumes

The outer glumes are variously designated as "empty glumes", "bracts", "first and second bracts", "first and second scales", "first and second glumes", "Gluma" (German), and "Hüllspelze" (German). They are the two opposite, rigid, boat-shaped structures subtending the spikelet. The outer glumes are shorter than the rest of the spikelet, and in lateral spikelets the parts right and left of the midrib are dissimilar in size and shape (see figs. 1, B, and 2, A). The form of the apex varies from a blunt extension (beak) of the midrib to the possession of a terminal scabrid awn with a length of two to five centimeters. The shape of the cross-section of a beak differs slightly from that of the awn but the anatomy of the beak and the awn is the same, as shown in fig. 3, A and B. The outer glumes of the terminal spikelet differ from those of the lateral in that the former are rarely keeled and always symmetrical. The midrib may be well-defined or missing, in which case two strong lateral veins are present, one on each side of the central line, the apex being notched or divided sometimes to near the base of the glume. In the glumes of lateral spikelets, there are eight bundles with five in the larger side and three in the smaller. The stomata are in double rows over the chlorenchymatous strands; the latter being in contact with a vascular bundle (see figs. 1, B, and 2, A). On the peripheral strands, stomata extend from the apex to the base but approaching the midrib, the stomata extend down the bundles progressively shorter distances. There are a few stomata on the inner (upper) surface near the apex. According to Perlitius (29), there are about 1,000 stomata on each outer glume of winter wheat.

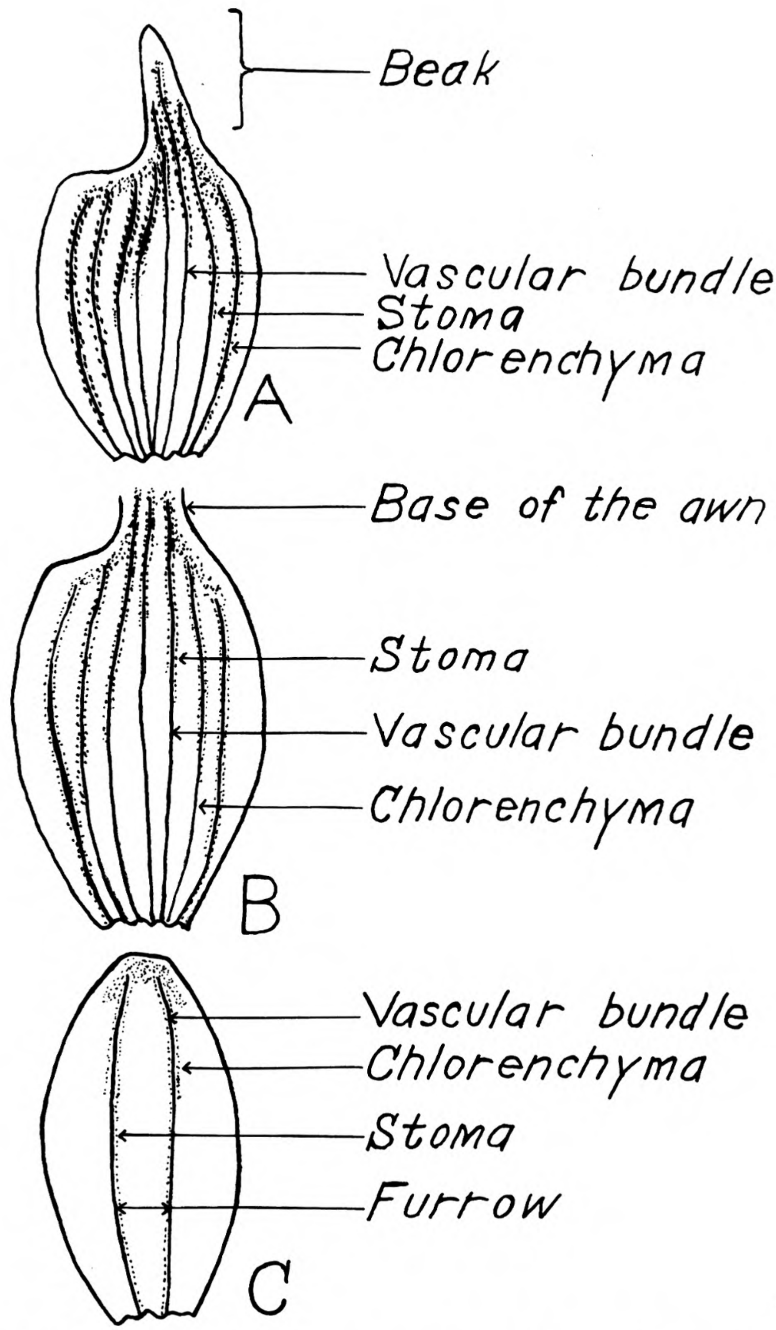

Fig. 2.--Diagrammatic drawings of: A, Outer glume of wheat spikelet, showing outer (lower) surface view; B, Basal part of lemma, showing outer (lower) surface; and C, Palea in outer (lower) surface view.

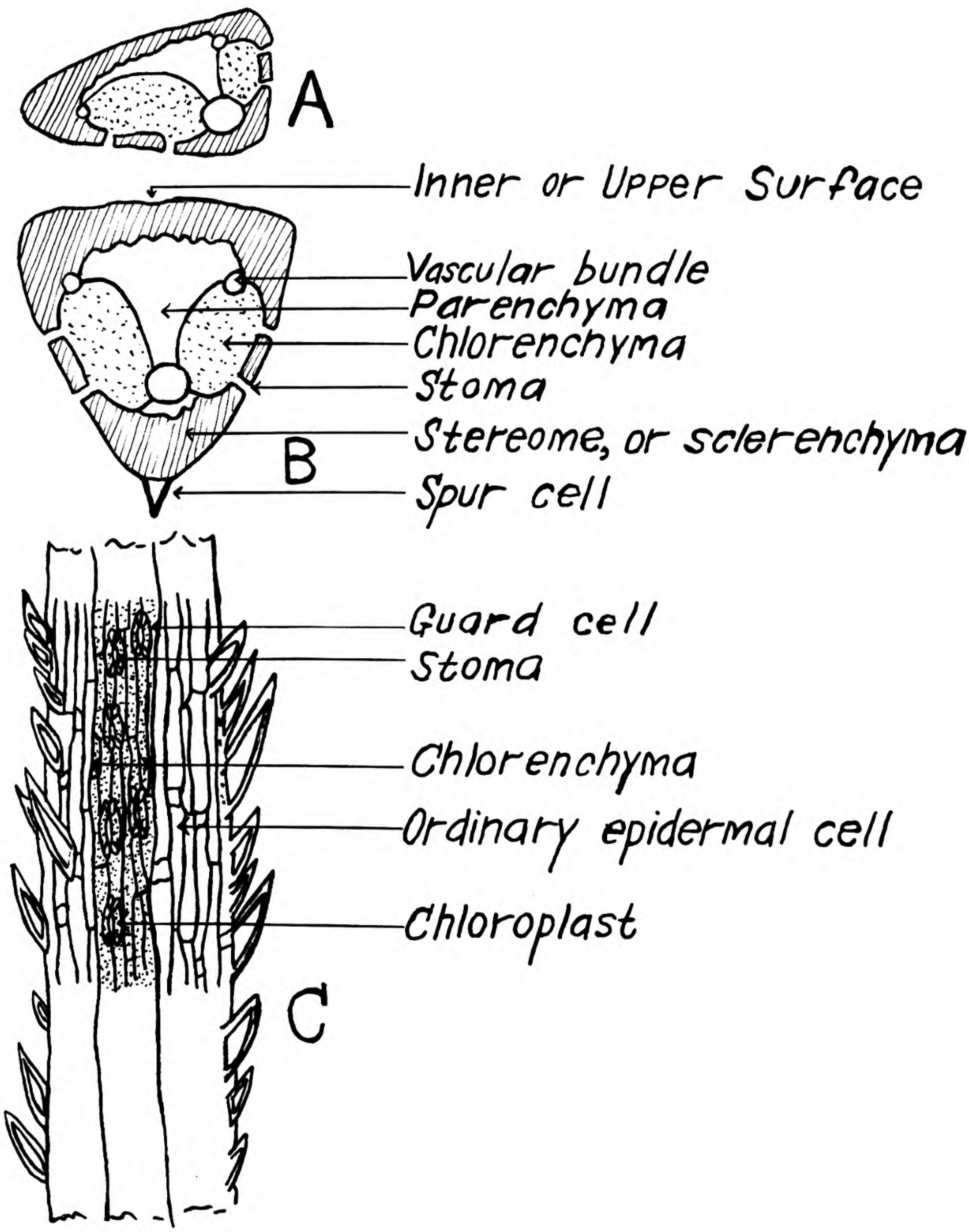

Fig. 3.--Diagrammatic drawings: A, Cross-section of beak on outer glume of wheat; B, Cross-section of the awn of wheat; and C, Longitudinal, surface view of the awn of wheat.

Fittbogen (8) states that, according to Dr. Grönland, the glumes and awns are devoid of stomata or that they have them only occasionally. Observations in these experiments, however, substantiate the presence of stomata in approximately the numbers given by Perlitius (29).

The awns may be either glabrous, or more or less clothed with hairs.

Lemma

Inserted alternately on opposite sides of the short rachilla are the lemmas, or the flowering glumes, in the axils of which the flowers arise (see figs. 1, B, and 2, B). The lemma is boat-shaped, many-nerved, and without a keel, the upper part notched and ending in a point or long awn.

Only about one-fourth to one-sixth of the stomata of the lemma are on the basal part, while the rest of them are on the awn. For example, Perlitius (29) cites a winter wheat with a total of 3,086 stomata on the lemma; of this number, 686 stomata were on the basal part of the lemma, and 2,400 were on the awn.

Synonyms for the lemma include "flowering glume", "inner glume", "palea inferior", "third scale", "bract", "third bract", and "Deckspelze" (German).

Basal Portion (Less Awn). In the strictly awnless types there is only this basal portion with a beak or very short extension.

There are seven bundles, only the central three of which continue into the awn. The stomata are in double rows associated with the chlorenchymatous strands which, in turn, adjoin the vascular bundles. On the peripheral strands, stomata extend from the apex to the base but, approaching the center of the lemma, the stomata extend down from the apex progressively shorter distances (see fig. 2, B). According to Schmid (34) stomata, when present on the inside surface of the lemma, do not extend downward from the apex more than one-third of its length. According to Perlitius (29), there may be on the lemma from 2,400 to 3,700 stomata, with one-fifth of them on the basal part and the other four-fifths on the awn.

Awn. Hayes and Garber (17) define the awn, or "beard", as "an extension of the flowering glume" (see fig. 3, B and C). Schmid (34), and others, consider that it is a metamorphosed leaf particularly because of the presence of stomata. According to Gates (9), the awn should be considered as a vein. The presence of stomata cannot be used as the criterion of a foliar structure, he maintains, since organs other than leaves may have stomata. The awns are tapering and triquetrous, with forward-pointing, scabrid projections running longitudinally along the angles. They are generally straight, but may be sinuous or even bent into the form of a hook or spiral, as in some Asiatic forms of T. vulgare (28). Frequently the side of the awn turned toward the rachis is somewhat flattened. This irregularity is chiefly in the lower portion of the awn and is not found in the upper part (34). In a Persian form of T. vulgare the awn has a pair of thin membranous and colorless outgrowths which are leaf-like in appearance (28).

Schmid (34), as well as the author, observed that the awns are formed early, so that by the time the ovary cavity is beginning to differentiate, the awns are as long as the spikelets.

In truly awned spikes the awns are uniformly distributed from the top to the bottom of the spike with the longest never at the apex, while in awnless spikes whatever awns are present are longest near the apex of the spike. The rest rapidly diminish in length towards the base, where they are rarely more than 1-3 mm. long. The length of awns on the commonly-grown, awned varieties in Kansas varies from 2.5 to 11 cm., depending on the location of the awn on the spike and the variety of wheat.

Percival (28) describes the awn as consisting of four types of tissue, viz., epidermis, mechanical tissue or stereome, vascular bundles, and chlorenchyma (see fig. 3). The epidermis is composed of (a) narrow, elongated cells with walls showing wavy thickening and numerous, simple pits, (b) small, oval or squarish, "dwarf" cells often projecting as papillae, and (c) short, thick-walled, unicellular hairs with fine points which are directed forwards and give the awn its scabrid character. All epidermal cells have a high content of silicon, and by careful handling a single cell wall will retain its skeletonal form when ashed with sulphuric acid on a platinum wire. The outside of the epidermal cell is very thick-walled and frequently perforated with canals or pits, which reach to the cuticle (34). In the epidermis on the two outer faces of the awn are longitudinal lines of stomata which communicate with the chlorenchymatous strands within the awn. Near the base of the awn, the stomata may be three to five rows wide while near the tip of the awn they are reduced to but a single row. Thus for most of the awn, the stomata are in double rows, one row associated with each chlorenchymatous strand. Perlitius (29) states that on an average-length awn of 6 cm., there averages a total of 2,400 stomata. The long axis of the stomatal pore is always parallel to the long axis of the awn (see fig. 3, C).

The cells of chlorenchyma are densely packed with chloroplasts. This tissue consists of two separate strands of chlorophyllous parenchyma, which traverse the awn from the base to near the apex, where they unite into a single, central strand. Immediately within the epidermis, at the three angles and around the inner face of the awn, is strongly-developed stereome, while the center is occupied by thin-walled parenchyma and the two chlorenchymatous strands. The stereome is particularly well silicified. It has two functions: (a) those cells nearest the epidermis have a mechanical function; (b) the mechanical cells toward the center, because of their numerous pits, serve to conduct substances, e.g., water (34). Three vascular bundles are found in each awn, viz., one large bundle, continuous with the midrib of the lemma, in the angle between the two strands of chlorenchyma and, at the sides, two smaller bundles also from the lemma. According to Schmid (34), the middle vascular bundle is of the typical monocotyledenous type, while the two side ones, especially in the upper parts of the awn, are often reduced to but a few cells. Only the central, large bundle continues to the very tip of the awn.

Schmid (34) stated that some awns are colored and that the coloring matter is in the cell sap. He further added that it is not known whether the coloring matter acts as a protection against light (according to Kerner), against intense heat followed by increased transpiration (according to Stahl), or whether it performs some other function.

The awns are white, red, or black, those of the two former tints being found only on white or red glumes respectively; black awns are met with on glumes of all colors, white, red, or black (28). According to Kadam and Nazareth (24) the black color of Kala-Khapli 568 (Triticum dicoccum) and the red color of Bansi 103 (T. durum) were found to be due to two separate genes. B produces black color of awns and is epistatic of the gene R, which causes red awns. Both are dominant to white. R simultaneously causes red coloration of glumes and awns, while the action of B is confined to the awns.

Inheritance of Awnedness. Wheats have been classified as awned and awnless but this is not genetically correct. The common wheats, like Marquis and Harvest Queen, are not truly awnless for there is a short extension of the lemma particularly in the spikelets at the top of the spike. Truly awnless varieties are rare. Ratios of 3:1 have generally been obtained in crosses between awned and so-called awnless (actually tip-awned) wheats. According to Hayes and Garber (17), the Howards have carefully worked out the inheritance of awnedness. The Howards have explained results by supposing two factors, A and B, to be present in a homozygous condition in awned wheats. They have found two kinds of very short-awned wheats, one like the tip-awned Marquis or Bluestem, and the other with somewhat longer tip awns. Each of these varieties was found to contain one of the factors A or B in a homozygous condition. In crossing a tip-awned wheat like Marquis with awned varieties, the F_1 generation, as a rule, shows an extension of the tip awns and it is frequently possible to separate these F_1 plants from the tip-awned parent. In crossing awned with true awnless, the F_1 is apparently awnless and there is a range in the F_2 from completely awned to awnless. Fully-awned plants breed true for this character. They separated the F_2 progeny into six classes and grouped all awned and tip-awned classes together as awned, which in comparison with the complete awnless gave a 15:1 ratio. They thus concluded that the awned character is dominant. The predominance of workers has reported the awned character as dominant thus verifying the very careful work of the Howards. Clark, Florell, and Hooker (3) have reported imperfect dominance of awnlessness in the crosses they made between Bobs, Hard Federation, and Propo wheats. In some cases, they found awnedness inheritance might be very simple and in others very complex. Likewise, Clark and Quisenberry (4) illustrated imperfect dominance of awnletedness.

Palea

Opposite each flowering glume, but attached to the very short floral branch with its back to the rachilla, is the palea -- a symmetrical, thin, membranous glume with two prominent lateral veins, along which runs a line of stiffish hairs. The part between the veins -- the furrow -- is concave, and the two semi-transparent margins curve inwardly around the flower (see fig. 1, B). Plant breeders often experience difficulty in removing two of the stamens which are located within the enclosure of the semi-transparent margins of the palea. The palea is of simple structure and the furrow is only two or three cells thick. The epidermis is composed chiefly of elongated cells and circular "dwarf" cells with sinuous walls; over the keels, the margins and surfaces of the apical portions of the palea are simple hairs 50-130 μ long.

Double rows of stomata serve the two strands of chlorenchyma which, in turn, are in contact with vascular strands. There are numerous stomata at the apex on the outside (lower) surface, and also rows of stomata extend down each of the two bundles -- the two inner rows (in the furrow) extending to the base of the palea, and the outer rows extending about two-thirds of the way from the apex to the base (see fig. 2, C). There are no stomata on the upper (inner) surface of the palea.

Synonyms for the palea include "palea superior", "bract", "fourth bract", "scale", "fourth scale", "palet", and "Vorspelze" (German).

Rachis

Although the vascular bundles are arranged in a circle in the rachis, the chlorenchymatous strands and stomata occur only on the convex side; the more or less flattened side is underlaid with a thick, sclerenchymatous layer, the stereome.

Rachilla

The rachilla is delicate and flattened with an arrangement of tissues similar to that found in the rachis. The epidermal cells have straight walls not greatly thickened. Numberous hairs are usually present. There are generally three slender vascular bundles running through the thin-walled ground tissue (34).

EXPERIMENTAL METHODS

Field Studies of Awns

<u>Experimental Plot</u>. The plants used in this study were grown at Manhattan, Kansas on one of the experimental plots maintained by the Department of Botany and Plant Pathology of Kansas State College. For a number of years, this particular plot has been sown to wheat. The soil is a fertile loam typical of this region. Soon after the wheat harvest of 1935, the ground was plowed, cultivated, and put in good tilth for the fall wheat sowing of 1935.

<u>Varieties of Wheat</u>. The wheat was sown on October 11, 1935, with a small, single-row, nursery drill. The seed was sown in rows one foot apart at the rate of one and one-half bushels to the acre. Fine stands were obtained and the wheat made a good fall growth. There was sufficient moisture in the soil so that evident wilting did not occur at any time during the growing season.

The seed was obtained from the grain nursery of the Department of Agronomy, Kansas State College, through Dr. John F. Parker who suggested the varieties which were used. In table 1 are listed the varieties which were chosen as being representative of the types grown in Kansas. Representative spikes of each of these varieties are shown in Plate I. Kawvale represented the semi-hard wheats, and Fulcaster the soft wheats; the other five varieties were selected as representative of the awned hard red winter wheats.

Table 1.--Variety, C. I. number, and description of the wheats sown October 11, 1935, for the field studies at Manhattan, Kansas.

Variety	C. I. No.	Description
Kanred x Hard Federation.......	10092	Awned, hard red winter
Tenmarq...........	6936	" , " " "
Kanred............	5146	" , " " "
Turkey............	1558	" , " " "
Early Blackhull...	8856	Similar to Blackhull; matures 8 days earlier.
Kawvale...........	8180	Awned, semi-hard red winter.
Fulcaster.........	6471	Awned, soft red winter

<u>Technique of De-awning</u>. With the exception of Kawvale and Fulcaster, de-awning was performed on each variety at four stages of growth, viz., "I-- before flowering", "II -- at flowering", "III -- 3-8 days after flowering", and "IV -- 9-12 days after flowering". In the case of the two varieties named above, de-awning was performed for only the first three periods.

In the experiments in which all of the awns were removed from the de-awned spikes, the treatment is referred to as "total de-awning"; in the other experiments, in which only the awns from one side of the spike were removed, the treatment is referred to as "partial de-awning". In the presentation of data, the Roman numerals signify stages; the letters "t" or "p" signify "total" or "partial" de-awning, respectively. The spikes in Plate II illustrate an "awned" spike (control), a "partially de-awned", and a "totally de-awned" spike.

De-awning of each variety at the different stages of growth involved both total and partial removal of awns. When at all possible, total and partial de-awnings were made the same day; often the one type of de-awning was followed immediately by the other. Occasionally the lack of time did not permit performing both sets the same day, but usually bad weather or a shortage of plants of the right age were the limiting factors. The dates of total and partial de-awnings, as well as the stage of growth for each variety at the time, are given in table 2.

Table 2.--The date and degree of de-awning at the various stages, and the date of harvest for the wheat plants grown at Manhattan, Kansas, during 1935-36.

Date of de-awning	Total (T) or partial (P) de-awning	Stage of growth	Date of harvest	Notes
		KANRED		
May 27	T	Before flowering	June 20	
" "	P	" "	" 24	
" 29	T	Flowering	" 21	
" "	P	"	" 24	
June 4	T	Milk-ripe	" 20	
" "	P	"	" 24	
" 9	T	Late milk-ripe	" 22	
" "	P	" " "	" "	
		TENMARQ		
May 25	T	Before flowering	June 24	
" 26	P	" "	" "	
" 25	T	Flowering	" 20	
" 26	P	"	" 21	
June 3	T	Milk-ripe	" 20	
" "	P	"	" 21	Culms yellow-green at harvest.
" 9	T	Late milk-ripe	" 24	
" "	P	" "	" 22	
		KANRED x HARD FEDERATION		
May 19	T	Before flowering	June 18	
" 21	P	" "	" 17	Considerable stem-rust.
" 20	T	Flowering	" 18	
" 21	P	"	" 17	
" 30	T	Milk-ripe	" 18	
" "	P	"	" 17	
June 8	T	Late milk-ripe	" "	
" "	P	" "	" "	
		EARLY BLACKHULL		
May 20	T	Before flowering	June 22	About all lodged
" 22	P	" "	" "	Not lodged
" 19	T	Flowering	" "	About all lodged
" 22	P	"	" "	" " "
" 30	T	Milk-ripe	" 19	
" "	P	"	" "	
June 8	T	Late milk-ripe	" 22	
" "	P	" "	" "	
		TURKEY		
May 22	T	Before flowering	June 22	About all lodged
" 26	P	" "	" 21	
" 27	T	Flowering	" 20	
" 26	P	"	" 22	
June 1	T	Milk-ripe	" 20	
" "	P	"	" "	
" 10	T	Late milk-ripe	" 24	
" "	P	" "	" 22	
		FULCASTER		
May 28	T	Before flowering	June 21	
" "	P	" "	" 24	
" 29	T	Flowering	" "	
" "	P	"	" "	
June 6	T	Milk-ripe	" 22	
" "	P	"	" "	
		KAWVALE		
May 28	T	Before flowering	June 22	
" "	P	" "	" "	
" 29	T	Flowering	" "	Some shattering at harvest
" "	P	"	" 18	
June 5	T	Milk-ripe	" "	
" "	P	"	" "	

In de-awning, two spikes were selected at the same time, care being used to get two as nearly identical in appearance as possible. In some instances the two spikes originated from the same group of tillers, while in others the spikes were of adjoining groups of tillers. Only one of the two spikes was de-awned, either partially or totally as the case might be, while the other was kept as a control. One awned and one de-awned spike constituted a "pair". De-awning was accomplished by clipping the awn at the apex of the lemma with small, sharp-pointed scissors. Care was taken not to cut or injure the rest of the lemma. The beak of the outer glume was removed at the same time as the awn. The culm of the de-awned spike was labeled with a tag showing the date of de-awning and a symbol to signify total or partial de-awning. The culm of the intact, awned or control spike was likewise labeled.

A "set" usually consisted of 150 awned spikes, and 150 de-awned (total or partial) spikes, in order that at least 100 spikes of each type could be recovered at harvest time. Regardless of the number (usually 300) of spikes treated and labeled, there were the same number of awned and de-awned spikes in any one particular set. A set thus consisted of (a) a "group" of 150 awned spikes of the variety to function as controls, and (b) a "group" of 150 spikes, of the same variety, which had been either totally or partially de-awned. A total of 16,500 spikes, including an equal number of awned and de-awned spikes, was used in these experiments. Of this number, over

14,400 spikes were recovered at harvest. The failure to recover all of the spikes was due to some lodging, failure to locate the tagged plants, and to other unavoidable factors.

Harvesting. In order to prevent shattering, the entire culm was cut at the yellow-ripe to ripe stage, brought into the laboratory and the intact culm permitted to ripen on drying racks. No shriveling of the grain was evident after this treatment. Each series of plants was harvested at as nearly the same stage of ripening as possible and treated in the above manner before threshing. The plants were harvested from June 17 to June 24, 1936, inclusive.

Threshing. If the number of awned and de-awned spikes was unequal when the set was harvested, the number of the larger group was decreased to equal that of the smaller. Each group of spikes was threshed separately by hand in a small, head-thresher. By this method no grain was lost. In experiments with Tenmarq and Kanred, in which the spikes were separated into grain, chaff, awns, and rachises, the awns were removed by clipping before threshing. The rachises were sorted out of the chaff and grain mixture, and the chaff separated from the grain by light blasts of air. The rachises tended to remain intact and to break up but very little. Care was taken to recover all of the segments of the few rachises which broke. A picture of the spikes and the parts, into which some varieties were lated resolved, is shown in Plate III.

Calculation of the Weight and Number of Grains. The number of grains produced by the de-awned and awned spikes of each group was determined by actual, duplicate counting.

During the summer of 1936, the samples of grain were weighed to the tenth-gram on a Milvay double-beam trip scale. The weight of grain per hundred spikes and per thousand grains was calculated for each group. The weight of the grain was divided by the number of spikes from which it was derived and then multiplied by one hundred in order to obtain the weight of grain per hundred spikes. As the weight of grain per group was known, and the number of grains in each group had been counted, the weight per thousand grains could thus be calculated.

Greenhouse Studies on the Transpiration of Awns

These experiments were conducted in the greenhouse at Manhattan, Kansas, during the winters of 1935-36 and 1936-37. A continuous account of the temperature in the greenhouse was recorded by the automatic, temperature-recording instrument so that the range of temperature for each experimentwas known. The evaporating power of the air was determined by a spherical, porous-cup atmometer. The wheat plants were grown in porcelain jars, with special precautions to reduce the loss of water from the apparatus.

Cultural Methods. The plants were grown in glazed porcelain jars of one-gallon capacity. These jars were made equal in weight by the addition of stones to the lighter ones and the same amount of soil was added to each. In order to facilitate the distribution of water, cores of gravel and sand were placed in the soil as shown in fig. 4. The central, main core was filled with coarse gravel while the three smaller lateral ones were filled with sand. In the center of the jar a three-inch, paraffined flower pot was set on top of the core of gravel and made firm by packing soil around it. Water was added through the pot, which was kept covered by a small petri dish. Melted paraffin was poured over the soil forming a layer about one-fourth of an inch in depth. After the plants were a couple of inches high, a layer of fine, white sand was added to protect the paraffin from the sun and thus prevent melting of the layer. This apparatus was very efficient in preventing the loss of water from the soil as is attested by the fact that the control jars lost less than three grams during any period of 48 hours.

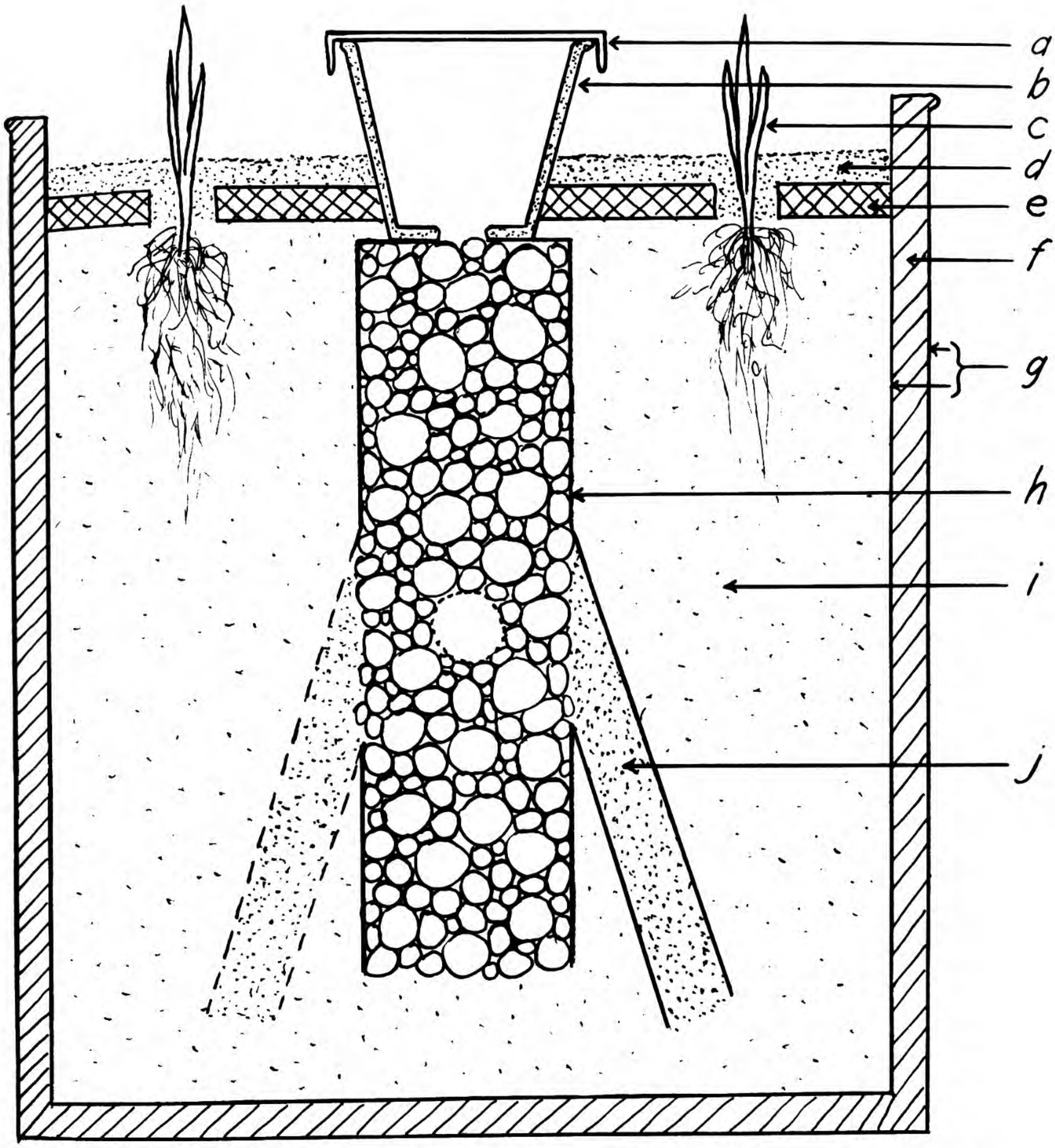

Fig. 4.--Diagrammatic section of a jar in which wheat plants were grown for transpiration studies under greenhouse conditions. a, Petri dish; b, Paraffined flower pot; c, Wheat seedling; d, Layer of fine sand; e, Layer of paraffin; f, Wall of the jar; g, Glazed surfaces; h, Central core of coarse gravel; i, Soil; and j, One of the three radiating channels of sand.

A fertile loam soil was mixed with sand in the proportion of four parts of soil to one of sand in order to make it more friable. Sufficient water was added to the soil to establish its moisture content at 45 per cent of the moisture-holding capacity. At regular intervals, varying according to the stage of growth, the jars were weighed and water was added to bring them to their original weight.

Before planting, a half-inch cork borer was heated and used to make five equidistant holes in the paraffin layer above the soil. A germinating grain of wheat, with a radicle one-fourth of an inch long, was planted in the soil beneath each of these holes. The grain was planted on October 25, 1935, and on November 2, 1936.

The general appearance of the plants when they had attained their full vegetative growth is shown in Plate V.

Materials. In the preliminary study, 1935-36, seed was used that had been produced in the greenhouse during the previous season by Mr. C. O. Johnston. He (23) suggested the use of the following varieties: Pusa 4 (awnless), Reward (awnless), Prelude (awned), and Pusa 52 x Federation (awned). These varieties were used because of their early-maturing characteristic.

Reward and Prelude proved undesirable as experimental plants because of their prostrate habit of growth so that, for the year 1936-37, the study was made only on Pusa 52 x Federation.

Development of the Plants, 1936-37. During 1935-36, the pairs of spikes used in the transpiration experiments were matched as closely as possible but it was difficult or impossible to select them except for size. The exact stage of growth of the spike was not definitely known except at the time when the spikes were in flower. During 1936-37, however, a detailed record of 215 spikes was kept so that in all experiments spikes of the same size and stage of growth could be selected.

As soon as the awns protruded visibly from the boot, the culm of the spike was tagged and detailed notes were taken at two-day intervals thereafter. Some spikes were used for observational purposes and spikelets were removed from these from time to time in order to determine the progress or rate of grain formation. By this method it was not necessary to remove any spikelets from the spikes used in the transpiration studies in order to determine their stage of development.

Technique of De-awning. Four apparently similar spikes were selected for each experiment. Two of the spikes were used as "controls" and the other two were de-awned, as shown in Plate IV. The culms of the spikes were labeled so that the same spikes could be identified and tested in later determinations of transpiration.

Freeman Method. The Freeman method was used in determining the transpiration of the awns. The method, as described by Miller (26), was altered somewhat to meet the specific requirements of this experiment. Plate V' shows the Freeman apparatus as used in the greenhouse during the first year, 1935-36.

An aspirator provides the suction which draws the air over the enclosed plant parts and through the weighed U-tubes where the transpired water is absorbed by calcium chloride and the amount later determined by weighing. The moisture in the air itself is also carried into the U-tubes and must be determined in order to obtain the transpiration of the spikes. This was determined by the use of a control apparatus in which the same amount of air, as used above, was drawn into the calcium chloride tubes without passing over any plant parts. The moisture thus collected was deducted from that obtained from the same volume of air passing over the spikes, and the net amount of water lost in transpiration was thus determined. The apparatus of the control is shown at the extreme left in Plate V. At the center and right are units which determined the transpiration of two awned spikes and two de-awned spikes, respectively. Two 18-litre aspirators and a one-gallon aspirator were used in each of the units. Dr. E. C. Miller suggested the use of the small aspirators which were run while the spikes were being inserted in the glass chambers to prevent an accumulation or condensation of moisture within the glass chamber during that time. When the spikes were in position, and the experiment was ready to begin, the three small aspirators were closed, all U-tubes were opened, and one of the 18-litre aspirators was started for each unit. The time of starting the experiment was then recorded and a reading was made of the porous-cup atmometer (see Plate V, center). When the first aspirators had finished, their inlet tubes were clamped, and the second one of each unit was immediately started. The first aspirators were refilled while the second ones were running. Thus for any length of time, a constant suction could be provided. In most experiments each of the two aspirators of a unit was emptied twice, so that 72 litres of water were used. As the 72 litres of water siphoned from the aspirators, 72 litres of air was necessarily drawn in to replace it. In order to reach the aspirator, the air had to enter around the peduncles at the base of the spikes (see fig. 5), flow upward around the spikes, down the outlet tube, and then through the weighed U-tubes before it could enter the aspirator where the vacuum was created. Since it took approximately 15 minutes for an aspirator to empty, the experiment had a duration of about one hour. By adjusting the screw clamps on the outlet tube of the aspirators, the units could be made to finish at approximately the same time. In experiments lasting more or less than one hour, the transpiration values were reduced to that of an hourly period. At the close of the experiment, the atmometer was read and its evaporation likewise calculated to the hourly basis.

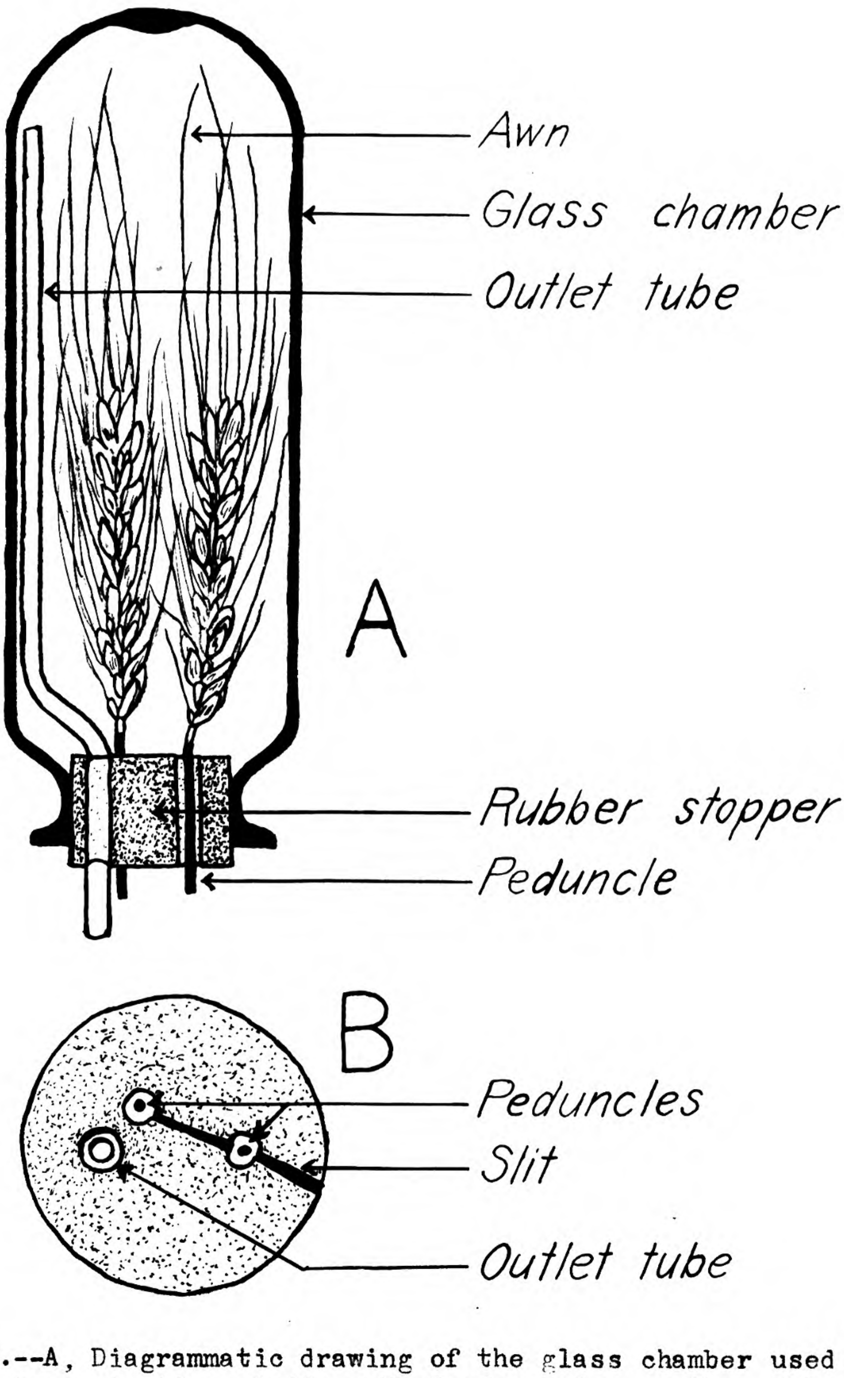

Fig. 5.--A, Diagrammatic drawing of the glass chamber used in the transpiration studies; B, Surface view of the rubber stopper, showing the slit between two holes to permit insertion of the peduncles, and cross-sections of the outlet tube and of the peduncles around which air entered.

The glass chamber (see fig. 5) employed in these experiments was a type of small specimen jar with the desired characteristics of size and shape. The size of this chamber was seven by two and one-half inches, outside measurements, and had a capacity of 500 cubic centimeters. It was fitted with a number eight, three-holed rubber stopper, which was slit between two of the holes to permit the introduction of the peduncles. The portion of the peduncles of the spikes which protruded into the chamber was thinly-vaselined to prevent transpiration. After each experiment this coating was removed to prevent injury to the peduncles.

At the beginning of an experiment water was added to each jar to bring it to the original weight and thus provide a sufficiency of water to the plant during the course of the experiment.

At the start of a series of experiments, the amount of transpiration from two pairs of intact spikes was determined for a given period of time. The ratio of the rate of transpiration of one pair of spikes to that of the other could thus be calculated. This ratio is herein termed the "initial ratio" of transpiration. After this initial ratio had been determined, one pair of spikes was de-awned and its rate of transpiration compared with that of the intact pair in various experiments. This new ratio thus obtained was compared with the initial ratio, and any differences in the rate of transpiration incurred by a removal of the awns was calculated on a percentage basis.

During 1936-37, some changes were made in the apparatus (see Plates VI and VII). One of the innovations was the installation of a double set of U-tubes in connection with each unit (see Plate VII, to the left of center). For any one experiment, however, only one pair of U-tubes was open at one time. At the end of an experiment, the used pairs of U-tubes were closed and a new experiment was started immediately by opening the unused pairs. Without the use of such a set-up, it is necessary to remove the three pairs of U-tubes and install new ones at the end of each experiment. Under such conditions, the spikes must be removed in order to prevent an accumulation or condensation of moisture within the glass chambers. By the new method, it was possible to make as many as four, one-hour determinations of transpiration without molesting the spikes or pausing between experiments.

The aspirators were filled by the use of a garden hose suspended conveniently in the center of the group.

As the water siphoned from the aspirators, it emptied into a trough and was carried to a nearby drain.

Technique Relating to a Study of the Grain. In the greenhouse, the effects of de-awning on the yield and water content of the grain were studied in a limited way on 120 spikes, the exact flowering dates of which were known. For each date of flowering, equal numbers of awned and de-awned spikes were used. The spikes were in varying stages of growth, ranging from flowering to the soft dough stage when de-awned on February 6, 1937. Sixty intact spikes were used as controls and 60 others were totally de-awned.

The spikes which had flowered on January 21 were harvested on February 24th. Inasmuch as these spikes had matured in 34 days from the day of flowering, each of the other groups was harvested on the 34th day after flowering. Thus each group had the same length of time in which to produce its grain.

EXPERIMENTAL RESULTS

Field Studies

Introduction. The seed bed had sufficient moisture to enable germination and permit good growth so that no evident wilting occurred at any time. Detailed climatological data for May and June, 1936, are given in table 3.

Table 3.--Climatological data for May and June, 1936, at Manhattan, Kansas.

Date -- 1936	Rainfall, in inches	Temperature, in degrees Fahrenheit Max.	Min.	Date -- 1936	Rainfall, in inches	Temperature, in degrees Fahrenheit Max.	Min.
May 1	1.86	76	54	June 1	-	90	69
" 2	.01	68	43	" 2	-	85	61
" 3	-	78	43	" 3	-	78	47
" 4	-	88	59	" 4	-	77	48
" 5	-	91	67	" 5	.12	73	60
" 6	T	86	71	" 6	.45	82	57
" 7	-	80	65	" 7	-	87	57
" 8	.27	72	58	" 8	-	97	67
" 9	.44	71	60	" 9	-	90	69
" 10	.08	69	53	" 10	-	76	57
" 11	-	71	49	" 11	-	82	49
" 12	T	72	54	" 12	-	84	50
" 13	.17	70	53	" 13	-	92	53
" 14	-	75	44	" 14	-	100	66
" 15	-	87	57	" 15	-	100	66
" 16	-	89	68	" 16	-	100	73
" 17	-	82	64	" 17	.18	98	62
" 18	T	83	60	" 18	-	101	62
" 19	-	83	46	" 19	-	108	79
" 20	-	84	59	" 20	-	101	64
" 21	-	87	64	" 21	-	104	68
" 22	-	88	69	" 22	-	94	65
" 23	.08	73	65	" 23	-	88	55
" 24	2.72	66	62	" 24	-	91	50
" 25	.15	75	58	" 25	-	101	58
" 26	-	84	56	" 26	-	108	76
" 27	-	86	59	" 27	T	105	78
" 28	-	83	63	" 28	-	105	66
" 29	-	87	57	" 29	--	105	83
" 30	-	88	58	" 30	T	93	74
" 31	-	87	60				
"	Total	Mean			Total	Mean	
	5.78	80	58		0.75	93.2	63.0

It was necessary to have some standard by which to determine the stage of growth of the plants at the time of de-awning and harvest. Thus Percival's (28) description of stages was used, with definitions as follows:

"In the 'milk-ripe' stage the crop has a green appearance. The lower leaves of the plants are dead, but the blades of the three upper leaves, the higher internodes, and the ears are living and green; only on the edges or tips of the leaves are there any visible signs of ripening in the form of yellowish spots and stripes. The leaf-sheaths are green and their swollen nodal portions plump and sappy. The glumes and pericarp of the grain are also green, the chlorophyllous layer of the latter showing through the outer colourless tissue. At this stage the grain has attained its maximum volume and highest water content; the vacuoles of the endosperm tissue contain watery sap, and starch grains are abundant in the cells; from it can be squeezed a milk-like liquid whose whiteness is due to numerous starch grains present in it. The several parts of the embryo are completely differentiated, but have not quite reached their full development, and although grains harvested now germinate readily, the young plants are somewhat weak.

"In the 'yellow-ripe' stage the crop has changed to a golden tint except in the purple-strawed forms which are a pinkish purple colour. The straw is smooth and shining, tough and pliable. The chlorophyll has disappeared from all parts of the leaves, except the thick nodal portions of the upper leaf-sheaths, which still remain swollen and green, those of the lower leaf-sheath being shrunken and brownish. The glumes have assumed their characteristic ripe tint. As ripening proceeds, the chlorophyll in the pericarp of the grain gradually disappears, first from the upper part and dorsal side, and later, from the lower part and the furrow; in the yellow-ripe stage it is no longer to be seen. The grain can be crushed between the thumb and finger-nail, the contents, however, are not milky, but soft, and they knead like dough. This is the best stage of ripeness in which a crop of wheat should be cut; assimilation is at an end, and there is no gain in weight by leaving it longer. The danger of losing some of the grain by 'shattering' is also reduced by harvesting at this period of development."

In one row of each variety, from three to seven spikes were loosely grouped together and, from time to time, the development was recorded on the attached tags. The data thus collected are given in table 4.

Table 4.--The rate of development of the wheat plants grown on the field plot at Manhattan, Kansas, during 1935-36.

Variety	In boot	Flowering	Milk	Soft dough	Ripe
Turkey		5/25-5/30	6/1-6/4	6/18	6/20
Kawvale	5/21	5/26-5/30	6/3-6/5	6/15	"
Kanred x Hard Federation		5/22-5/28	6/1	6/3-6/5	6/17
Tenmarq		5/25-5/30	6/1-6/4	6/13	6/20
Kanred		5/25-5/30	6/1-6/6	6/12	"
Fulcaster	5/22	5/25-5/30	6/3-6/6	6/15	"
Early Blackhull		5/22-5/28	6/1-6/5	6/15	"

Weight of Grain per 100 Spikes. One of the objects of this study was to determine what role, if any, was played by the awn in the production or the maturing of the grain. In order to determine the effect of the awn, de-awning experiments were carried out according to the method previously described. Total and partial de-awnings were performed on each of the seven varieties before flowering, at flowering, and at one or two later dates.

Equal numbers (usually around 150) of awned and de-awned spikes were used for each group. When more awned than de-awned spikes were recovered, or vice versa, the larger number was decreased to equal the smaller so that equal numbers of each group were threshed. In table 5 are given the numbers of spikes recovered at harvest and upon which the weight of grain per 100 spikes is based. For each variety, the weights of grain produced by 100 awned and 100 de-awned spikes are also given.

Table 5.--A comparison of the yield of grain from awned and de-awned spikes of wheat, and the influence of the time of de-awning upon the yield, at Manhattan, Kansas, 1935-36.

Period of de-awning -1936-	No. of spikes per group	Air-dry weight of grain from 100 spikes: From awned spikes	From de-awned spikes	Weight-decrease	Per cent-decrease
		Gm.	Gm.	Gm.	
		KANRED			
I-t 5/27	137	57.1	47.3	9.8	17.16
I-p "	140	58.2	55.9	2.3	3.95
II-t 5/29	145	63.4	54.8	8.6	13.56
II-p "	140	66.3	66.3	0.0	0.00
III-t 6/4	139	57.7	49.9	7.8	13.52
III-p "	144	62.4	58.7	3.7	5.93
IV-t 6/9	152	63.4	58.8	4.6	7.26
IV-p "	158	64.3	61.6	2.7	4.20
		TENMARQ			
I-t 5/25	135	73.6	63.7	9.9	13.45
I-p 5/26	133	69.8	58.1	11.7	16.76
II-t 5/25	141	69.5	60.2	9.3	13.38
II-p 5/26	144	66.0	60.7	5.3	8.03
III-t 6/3	147	58.2	52.2	6.0	10.31
III-p "	143	62.4	59.6	2.8	4.49
IV-t 6/9	140	65.6	59.8	5.8	8.84
IV-p "	144	69.4	67.4	2.0	2.88
		KANRED x HARD FEDERATION			
I-t 5/19	120	45.4	37.3	8.1	17.84
I-p 5/21	140	42.7	38.8	3.9	9.13
II-t 5/20	135	56.5	47.4	9.1	16.11
II-p 5/21	140	58.9	54.4	4.5	7.64
III-t 5/30	148	48.7	44.9	3.8	7.80
III-p "	140	57.1	56.4	0.7	1.23
IV-t 6/8	145	43.9	43.2	0.7	1.59
IV-p "	137	45.8	43.2	2.6	5.68
		EARLY BLACKHULL			
I-t 5/20	126	43.7	34.5	9.2	21.05
I-p 5/22	132	51.4	44.9	6.5	12.65
II-t 5/19	118	52.8	43.0	9.8	18.56
II-p 5/22	92	47.9	42.4	5.5	11.48
III-t 5/30	146	61.4	55.4	6.0	9.77
III-p "	138	59.0	56.0	3.0	5.08
IV-t 6/8	142	56.2	51.9	4.3	7.65
IV-p "	145	56.4	54.1	2.3	4.08
		TURKEY			
I-t 5/22	125	55.9	44.9	11.0	19.68
I-p 5/26	139	52.9	47.1	5.8	10.96
II-t 5/27	136	58.2	50.1	8.1	13.92
II-p 5/26	137	72.8	70.6	2.2	3.02
III-t 6/1	146	69.4	63.2	6.2	8.93
III-p "	129	65.3	60.2	5.1	7.81
IV-t 6/10	132	59.5	54.7	4.8	8.07
IV-p "	139	60.9	59.3	1.6	2.62
		FULCASTER			
I-t 5/28	145	58.1	50.0	8.1	13.94
I-p "	144	66.0	61.5	4.5	6.82
II-t 5/29	134	76.1	66.3	9.8	12.88
II-p "	143	73.1	68.5	4.6	6.29
III-t 6/6	143	69.0	63.8	5.2	7.54
III-p "	145	69.3	67.4	1.9	2.74
		KAWVALE			
I-t 5/28	131	71.6	59.8	11.8	16.48
I-p "	137	64.5	59.9	4.6	7.13
II-t 5/29	135	75.3	61.6	13.7	18.19
II-p "	141	59.6	58.9	0.7	1.17
III-t 6/5	148	69.6	65.7	3.9	5.60
III-p "	145	69.3	68.0	1.3	1.88

It is apparent that the weight of grain produced by the awned spikes of a given variety, at the various stages of growth, is not the same. For example, in Kanred, Kanred x Hard Federation, and Fulcaster, the weights of awned spikes for the first periods are approximately the same within a variety. The weights of the awned spikes for the second periods are approximately the same in each variety, but these weights are higher than those for the first periods. This was due to the fact that the de-awning of the spikes before flowering was performed at or near the same date. The earliest spikes that develop in wheat are from the oldest tillers, hence are larger and produce more grain than those spikes subsequently developed. In selecting spikes in the flowering stage, only the older and larger ones were available. Those which were selected for the pre-flowering stage were of necessity chosen from the younger tillers and were smaller than those used in the flowering stage. However, such variations do not alter materially the results of the experiments since comparable spikes constituted both the awned and de-awned groups of any set. No appreciable error was thereby introduced, as is shown by the fact that although the weights of 100 awned spikes differed by as much as 20 grams in one variety (Turkey), there was no case in which the weight of grain from de-awned spikes was greater than the weight of grain produced by the corresponding control group.

Inasmuch as the sets yield various-sized lots of grain, sets with larger quantities of grain might show a large weight-decrease although the actual, percentage-decrease may be comparatively low when compared with others in the series. Therefore, the percentage-decrease serves as a more accurate index in interpreting the results.

The results shown in table 5 are more clearly summarized by the use of table 6, and on that account the latter table is used in the following discussion. The varieties are grouped into three "types", viz., type I -- varieties showing progressively greater weight- and percentage-decrease of grain the earlier the date of de-awning; type II -- varieties showing greatest weight- and percentage-decrease of grain when de-awned at flowering; and, type III -- varieties that agree with neither type I nor type II, and are thus irregular. The table shows that by total de-awning either (1) the greatest decrease in weight of grain is produced by de-awning at flowering time, or (2) the decrease in weight of grain is greater the earlier the date of de-awning.

Table 6.--A summary of the effects of the time of de-awning upon the yield of grain.

Weight-decrease			Percentage-decrease		
Total (T)	Partial (P)	$P = \frac{1}{2} T$	Total (T)	Partial (P)	$P = \frac{1}{2} T$
Type I. Varieties showing progressively greater decreases of grain the earlier the date of de-awning by					
Kanred Tenmarq Turkey	Tenmarq E. Black-hull Turkey	Tenmarq	Kanred Tenmarq Kanred x H. Fed. E. Black-hull Turkey Fulcaster	Tenmarq Kanred x H. Fed. E. Black-hull Turkey Fulcaster	E. Black-hull Fulcaster Tenmarq
Type II. Varieties showing greatest decreases of grain when de-awned at flowering stage.					
Kanred x H. Fed. E. Black-hull Fulcaster Kawvale	Kanred x H. Fed. Fulcaster	E. Black-hull Fulcaster	Kawvale		
Type III. Varieties that agree with neither Type I nor Type II, and are thus irregular					
	Kanred Kawvale	Kanred Kanred x H. Fed. Turkey Kawvale		Kanred Kawvale	Kanred Kanred x H. Fed. Turkey Kawvale

By partial de-awning, two varieties exhibited the greatest decrease in weight of grain when de-awned at flowering, three varieties showed that the earlier the de-awning the greater the decrease of grain, and two varieties did not conform with either of those types.

In type I, Tenmarq showed a weight-decrease, by partial de-awning, of approximately one-half the value obtained by total de-awning. In type II, two varieties showed weight-decreases by partial de-awning to be approximately one-half the values obtained by total de-awning. Type III showed that four of the seven varieties came in the irregular group, so that with most of the varieties, weight-decreases by partial de-awning were not approximately one-half the values obtained by total de-awning.

With the exception of Kawvale (in type II), all varieties showed that the percentage-decrease of grain was greater the earlier the total de-awning was performed.

With the exception of Kanred and Kawvale (which came in the irregular group III), the varieties showed that the percentage-decrease of grain was greater the earlier the partial de-awning was performed.

According to percentage-decrease in grain production, three varieties showed decreases by partial de-awning that were approximately one-half the values obtained by total de-awning, but the other four varieties did not show such a relationship.

All varieties which received treatment, at any one period, are grouped together in table 7. The values for any one variety tend to deviate somewhat from the average but, as presented later, an average of all varieties eliminates the fluctuations and shows clearly the general trends. This table presents table 5 under different arrangement, and shows to better advantage the varietal fluctuations in the amount of grain produced by awned and de-awned spikes.

Table 7.--A comparison of the yield of grain from the awned and de-awned spikes of different varieties of wheat grown at Manhattan, Kansas, during 1935-36.

Period of de-awning -1936-		Variety	Air-dry weight of grain, 100 spikes: From awned spikes	From de-awned spikes	Weight decrease	Per cent decrease.
			Gm.	Gm.	Gm.	
I-t	5/27	Kanred	57.1	47.3	9.8	17.16
I"	5/25	Tenmarq	73.6	63.7	9.9	13.45
"	5/19	Krd.x H.Fed.	45.4	37.3	8.1	17.84
"	5/20	E. Blackhull	43.7	34.5	9.2	21.05
"	5/22	Turkey	55.9	44.9	11.0	19.68
"	5/28	Fulcaster	58.1	50.0	8.1	13.94
"	5/28	Kawvale	71.6	59.8	11.8	16.48
		Average--	57.9	48.2	9.7	17.09
I-p	5/27	Kanred	58.2	55.9	2.3	3.95
"	5/26	Tenmarq	69.8	58.1	11.7	16.76
"	5/21	Krd.x H.Fed.	42.7	38.8	3.9	9.13
"	5/22	E. Blackhull	51.4	44.9	6.5	12.65
"	5/23	Turkey	52.9	47.1	5.8	10.96
"	5/28	Fulcaster	66.0	61.5	4.5	6.82
"	5/28	Kawvale	64.5	59.9	4.6	7.13
		Average--	57.9	52.3	5.6	9.63
II-t	5/29	Kanred	63.4	54.8	8.6	13.56
"	5/25	Tenmarq	69.5	60.2	9.3	13.38
"	5/20	Krd.x H. Fed.	56.5	47.4	9.1	16.11
"	5/19	E. Blackhull	52.8	43.0	9.8	18.56
"	5/27	Turkey	58.2	50.1	8.1	13.92
"	5/29	Fulcaster	76.1	66.3	9.8	12.88
"	5/29	Kawvale	75.3	61.6	13.7	18.19
		Average--	64.5	54.8	9.8	15.23
II-p	5/29	Kanred	66.3	66.3	0.0	0.00
"	5/26	Tenmarq	66.0	60.7	5.3	8.03
"	5/21	Krd.x H. Fed.	58.9	54.4	4.5	7.64
"	5/22	E. Blackhull	47.9	42.4	5.5	11.48
"	5/26	Turkey	72.8	70.6	2.2	3.02
"	5/29	Fulcaster	73.1	68.5	4.6	6.29
"	5/29	Kawvale	59.6	58.9	0.7	1.17
		Average--	63.5	60.3	3.3	5.38
III-t	6/4	Kanred	57.7	49.9	7.8	13.52
"	6/3	Tenmarq	58.2	52.2	6.0	10.31
"	5/30	Krd.x H. Fed.	48.7	44.9	3.8	7.80
"	5/30	E. Blackhull	61.4	55.4	6.0	9.77
"	6/1	Turkey	69.4	63.2	6.2	8.93
"	6/6	Fulcaster	69.0	63.8	5.2	7.54
"	6/5	Kawvale	69.6	65.7	3.9	5.60
		Average--	62.0	56.4	5.6	9.07
III-p	6/4	Kanred	62.4	58.7	3.7	5.93
"	6/3	Tenmarq	62.4	59.6	2.8	4.49
"	5/30	Krd.x H. Fed.	57.1	56.4	0.7	1.23
"	5/30	E. Blackhull	59.0	56.0	3.0	5.08
"	6/1	Turkey	65.3	60.2	5.1	7.81
"	6/6	Fulcaster	69.3	57.4	1.9	2.74
"	6/5	Kawvale	69.3	68.0	1.3	1.88
		Average--	63.5	59.5	2.6	4.17
IV-t	6/9	Kanred	63.4	58.8	4.6	7.26
"	6/9	Tenmarq	65.6	59.8	5.8	8.84
"	6/8	Krd.x H. Fed.	43.9	43.2	0.7	1.59
"	6/8	E. Blackhull	56.2	51.9	4.3	7.65
"	6/10	Turkey	59.5	54.7	4.8	8.07
		Average--	57.7	53.7	4.0	6.68
IV-p	6/9	Kanred	64.3	61.6	2.7	4.20
"	6/9	Tenmarq	69.4	67.4	2.0	2.88
"	6/8	Krd.x H. Fed.	45.8	43.2	2.6	5.68
"	6/8	E. Blackhull	56.4	54.1	2.3	4.08
"	6/10	Turkey	60.9	59.3	1.6	2.62
		Average--	59.4	57.1	2.4	3.89

Partial de-awning was done primarily to see if the removal of half of the awns from the spikes would produce approximately one-half the difference effected by a removal of all the awns. Although within a variety, partial de-awning did not consistently produce exactly one-half as great a weight- or percentage-decrease as did total de-awning, an average of all the varieties gives values which are in accordance with theoretical expectations (see table 8).

Table 8.--A general summary of the effects of the time and degree of de-awning upon the yield of wheat grown at Manhattan, Kansas, during 1935-36.

Period of de-awning -1936-	Air-dry weight of grain from 100 spikes			
	From awned spikes	From de-awned spikes	Weight decrease	Percent decrease
	Gm.	Gm.	Gm.	
I-t	57.9	48.2	9.7	17.09
I-p	57.9	52.3	5.6	9.63
II-t	64.5	54.8	9.8	15.23
II-p	63.5	60.3	3.3	5.38
III-t	62.0	56.4	5.6	9.07
III-p	63.5	59.5	2.6	4.17
IV-t	57.7	53.7	4.0	6.68
IV-p	59.4	57.1	2.4	3.89

The volume of grain produced by awned and de-awned spikes is illustrated in Plates VIII, IX, X, and XI. The reductions in the volume of grain produced by Kanred wheat when totally and partially de-awned on May 27, May 29, and June 9, are shown in Plates VIII and IX, respectively. Similarly the reductions in the volume of grain produced by Fulcaster wheat when totally and partially de-awned on May 28, May 29, and June 6, are shown in Plates X and XI, respectively. The glass tubes were used in the same order of arrangement for each of the four plates, to which reference has just been made.

The partially de-awned spikes of Kawvale and Turkey were threshed in a special manner. The de-awned spikelets of these spikes were first removed, and thus threshing of the two lots of spikelets separated the grain into that produced by awned spikelets and that produced by de-awned ones. Turkey wheat was de-awned at four periods of growth. In that variety, the dates of greater weight-decreases in grain production came at the second and third periods of de-awning, with the maximal decrease incurred by de-awning at flowering. Similarly the dates of greater percentage-decreases in grain production came at the first and second periods of de-awning, with the maximal decrease again incurred by de-awning at flowering, as shown in table 9. Thus, in the spikes of Turkey wheat, total de-awning at flowering produced the greatest weight- and percentage-decrease in the amount of grain.

Table 9.--A comparison of the air-dry weight of grain from awned and de-awned sides of the same 100 partially de-awned spikes of wheat, grown at Manhattan, Kansas, 1935-36.

Period of de-awning -1936-	Air-dry weight of grain from 100 spikes*			
	From awned half of spikes	From de-awned half of spikes	Weight decrease	Percent decrease
	Gm.	Gm.	Gm.	
		KAWVALE		
I-p 5/28	65.4	54.4	10.0	16.82
II-p 5/29	62.2	55.4	6.8	10.93
III-p 6/5	69.6	66.4	3.2	4.60
		TURKEY		
I-p 5/26	52.6	41.4	11.2	21.29
II-p "	79.2	61.8	17.4	21.97
III-p 6/1	67.0	53.4	13.6	20.30
IV-p 6/10	64.8	53.8	11.0	16.98

*For the purpose of comparison with other tables, these values are double the original figures which recorded the weights of only half as much grain as used in all other sets.

Kawvale was de-awned at three periods. In this variety, it is shown that the earlier the date of de-awning the greater the weight- and percentage-decrease of grain. Thus total de-awning at the first period -- before flowering -- caused the greatest weight- and percentage-decrease in the amount of grain.

The weight-decreases of grain for Turkey remain consistently high for all four periods. The reason for this is not known. In general, the contrast between the grain of awned and de-awned spikelets is greater than the contrast between the grain of awned and de-awned spikes for the corresponding periods.

For the variety, Turkey, Plate XII illustrates the volumetric reduction in the amounts of grain from de-awned spikelets as compared to the awned spikelets of the same partially de-awned spikes. In this case, the greatest reduction in the volume of grain was produced by de-awning at the time of flowering. Similar results were obtained by Gemmell (10). Stevens (36) reported that the average per cent of plumpness of kernels from awned and awnless wheats was 69.1 and 61.3 per cent, respectively for the plants with which he worked.

Weight of Grain per 1000 Grains. The weight of 1000 grains gives some indication of the size and weight of the individual grain and is thus one of the measures of yield.

The weight of 1000 grains is shown in tables 10 and 11. The data of these tables are summarized in table 12. In the latter table, the varieties are grouped into three "types": type I -- varieties showing progressively greater weight- and percentage-decrease the earlier the date of de-awning; type II -- varieties showing the greatest weight- and percentage-decrease when de-awned at flowering; and, type III -- varieties that belong to neither type I nor type II, and are considered irregular in that regard.

Table 10.--Air-dry weight of 1000 grains from awned and de-awned spikes of wheat grown at Manhattan, Kansas, during 1935-36.

Period of de-awning -1936-	Air-dry weight of 1000 grains From awned spikes	From de-awned spikes	Weight-decrease		Per cent-decrease	
	Gm.	Gm.	Gm.			
		KANRED				
I-t 5/27	28.0	26.1	1.9		6.79	
I-p "	28.2	27.2		1.0		3.55
II-t 5/29	29.6	27.0	2.6		8.78	
II-p "	31.0	30.1		0.9		2.90
III-t 6/4	28.8	25.0	3.8		13.19	
III-p "	29.2	27.7		1.5		5.14
IV-t 6/9	31.5	29.6	1.9		6.03	
IV-p "	31.5	30.0		1.5		4.76
		TENMARQ				
I-t 5/25	31.7	30.3	1.4		4.42	
I-p 5/26	29.9	28.2		1.7		5.69
II-t 5/25	32.0	29.5	2.5		7.81	
II-p 5/26	33.2	30.9		2.3		6.93
III-t 6/3	27.5	24.6	2.9		10.55	
III-p "	30.6	28.6		2.0		6.54
IV-t 6/9	30.0	28.3	1.7		5.67	
IV-p "	32.3	31.2		1.1		3.41
		KANRED X HARD FEDERATION				
I-t 5/19	24.2	21.2	3.0		12.40	
I-p 5/21	25.9	24.8		1.1		4.25
II-t 5/20	28.4	25.0	3.4		11.97	
II-p 5/21	31.7	29.9		1.8		5.68
III-t 5/30	25.8	24.0	1.8		6.98	
III-p "	30.3	30.0		0.3		0.99
IV-t 6/8	26.0	24.9	1.1		4.23	
IV-p "	28.8	28.1		0.7		2.43
		EARLY BLACKHULL				
I-t 5/20	25.5	22.5	3.0		11.76	
I-p 5/22	30.3	29.3		1.0		3.30
II-t 5/19	26.9	23.9	3.0		11.15	
II-p 5/22	26.5	25.1		1.4		5.28
III-t 5/30	33.1	30.3	2.8		8.46	
III-p "	33.1	31.9		1.2		3.63
IV-t 6/8	32.5	31.0	1.5		4.62	
IV-p "	32.1	31.7		0.4		1.25
		TURKEY				
I-t 5/22	25.0	24.6	0.4		1.60	
I-p 5/26	27.4	25.3		2.1		7.66
II-t 5/27	28.5	26.3	2.2		7.72	
II-p 5/26	30.9	29.6		1.3		4.21
III-t 6/1	28.8	26.7	2.1		7.29	
III-p "	30.5	29.3		1.2		3.93
IV-t 6/10	28.5	26.8	1.7		5.96	
IV-p "	30.3	29.4		0.9		2.97
		FULCASTER				
I-t 5/28	29.9	28.7	1.2		4.01	
I-p "	32.6	32.0		0.6		1.88
II-t 5/29	36.5	35.1	1.4		3.84	
II-p "	36.4	34.8		1.6		4.39
III-t 6/6	36.4	33.5	2.9		8.66	
III-p "	36.5	35.7		0.8		2.24
		KAWVALE				
I-t 5/28	30.0	28.9	1.1		3.66	
I-p "	29.8	28.7		1.1		3.83
II-t 5/29	31.6	28.8	2.8		9.72	
II-p "	29.9	28.9		1.0		3.46
III-t 6/5	31.8	29.7	1.9		6.40	
III-p "	32.2	31.5		0.7		2.22

Table 11.--A comparison of varieties in regard to the air-dry weight of 1000 grains from awned and de-awned spikes of wheat grown at Manhattan, Kansas, during 1935-36.

Period of de-awning -1936-		Variety	Air-dry weight of 1000 grains: From awned spikes	From de-awned spikes	Weight-decrease	Per cent-decrease
			Gm.	Gm.	Gm.	
I-t	5/27	Kanred	28.0	26.1	1.9	6.79
"	5/25	Tenmarq	31.7	30.3	1.4	4.42
"	5/19	Krd. x H.Fed.	24.2	21.2	3.0	12.40
"	5/20	E. Blackhull	25.5	22.5	3.0	11.76
"	5/22	Turkey	25.0	24.6	0.4	1.60
"	5/28	Fulcaster	29.9	28.7	1.2	4.01
"	5/28	Kawvale	30.0	28.9	1.1	3.81
		Average--	27.8	26.0	1.7	6.40
I-p	5/27	Kanred	28.2	27.2	1.0	3.55
"	5/26	Tenmarq	29.9	28.2	1.7	5.69
"	5/21	Krd. x H. Fed.	25.9	24.8	1.1	4.25
"	5/22	E. Blackhull	30.3	29.3	1.0	3.30
"	5/23	Turkey	27.4	25.3	2.1	7.66
"	5/28	Fulcaster	32.6	32.0	0.6	1.88
"	5/28	Kawvale	29.8	28.7	1.1	3.83
		Average--	29.2	27.9	1.2	4.31
II-t	5/29	Kanred	29.6	27.0	2.6	8.78
"	5/25	Tenmarq	32.0	29.5	2.5	7.81
"	5/20	Krd. x H. Fed.	28.4	25.0	3.4	11.97
"	5/19	E. Blackhull	26.9	23.9	3.0	11.15
"	5/27	Turkey	28.5	26.3	2.2	7.72
"	5/29	Fulcaster	36.5	35.1	1.4	3.84
"	5/29	Kawvale	31.6	28.8	2.8	9.72
		Average--	30.5	27.9	2.6	8.71
II-p	5/29	Kanred	31.0	30.1	0.9	2.90
"	5/26	Tenmarq	33.2	30.9	2.3	6.93
"	5/21	Krd. x H. Fed.	31.7	29.9	1.8	5.68
"	5/22	E. Blackhull	26.5	25.1	1.4	5.28
"	5/26	Turkey	30.9	29.6	1.3	4.21
"	5/29	Fulcaster	36.4	34.8	1.6	4.39
"	5/29	Kawvale	29.9	28.9	1.0	3.46
		Average--	31.4	29.9	1.5	4.69
III-t	6/4	Kanred	28.8	25.0	3.8	13.19
"	6/3	Tenmarq	27.5	24.6	2.9	10.55
"	5/30	Krd. x H. Fed.	25.8	24.0	1.8	6.98
"	5/30	E. Blackhull	33.1	30.3	2.8	8.46
"	6/1	Turkey	28.8	26.7	2.1	7.29
"	6/6	Fulcaster	36.4	33.5	2.9	8.66
"	6/5	Kawvale	31.8	29.7	1.9	6.40
		Average--	30.3	27.7	2.6	8.79
III-p	6/4	Kanred	29.2	27.7	1.5	5.14
"	6/3	Tenmarq	30.6	28.6	2.0	6.54
"	5/30	Krd. x H. Fed.	30.3	30.0	0.3	0.99
"	5/30	E. Blackhull	33.1	31.9	1.2	3.63
"	6/1	Turkey	30.5	29.3	1.2	3.93
"	6/6	Fulcaster	36.5	35.7	0.8	2.24
"	6/5	Kawvale	32.2	31.5	0.7	2.22
		Average--	31.8	30.7	1.1	3.53
IV-t	6/9	Kanred	31.5	29.6	1.9	6.03
"	6/9	Tenmarq	30.0	28.3	1.7	5.67
"	6/8	Krd. x H. Fed.	26.0	24.9	1.1	4.23
"	6/8	E. Blackhull	32.5	31.0	1.5	4.62
"	6/10	Turkey	28.5	26.8	1.7	5.96
		Average--	29.7	28.1	1.6	5.30
IV-p	6/9	Kanred	31.5	30.0	1.5	4.76
"	6/9	Tenmarq	32.3	31.2	1.1	3.41
"	6/8	Krd. x H.Fed.	28.8	28.1	0.7	2.43
"	6/8	E. Blackhull	32.1	31.7	0.4	1.25
"	6/10	Turkey	30.3	29.4	0.9	2.97
		Average--	31.0	30.1	0.9	2.96

Table 12.--Summary of the data given in table 10.

Weight-decrease			Percentage-decrease		
Total (T)	Partial (P)	$P = \frac{1}{2}T$	Total (T)	Partial (P)	$P = \frac{1}{2}T$
Type I. Varieties showing progressively greater weight- and percentage-decrease of grain the earlier the date of de-awning by					
E. Black-hull	Turkey Kawvale		Kanred x H. Fed. E. Black-hull	Turkey Kawvale	
Type II. Varieties showing greatest weight- and percentage-decrease of grain when de-awned at flowering stage.					
Kanred x H. Fed. Turkey Kawvale	Tenmarq Kanred x H. Fed. E. Black-hull Fulcaster	Kanred x H. Fed. Turkey	Turkey Kawvale	Tenmarq Kanred x H. Fed. E. Black-hull Fulcaster	Turkey
Type III. Varieties that agree with neither Type I nor Type II, and are thus irregular.					
Kanred Tenmarq Fulcaster	Kanred	Kanred Tenmarq E. Black-hull Fulcaster Kawvale	Kanred Tenmarq Fulcaster	Kanred	Kanred Tenmarq Kanred x H. Fed. E. Black-hull Fulcaster Kawvale

According to table 12, it is apparent that on the basis of weight of 1000 grains, most varieties show the greatest weight- and percentage-reductions in the amounts of grain when totally or partially de-awned at flowering. In most instances, partial de-awning did not produce one-half the value obtained by the corresponding total de-awning. Despite the fact that the latter relationship did not hold consistently within a variety, such a relationship does exist between total and partial de-awning when the results of the seven varieties are averaged, as shown in the summary in table 13. According to that table, the greatest weight reductions of grain are incurred by total or partial de-awning at the second and third periods; the greatest percentage-reduction by total de-awning is incurred by de-awning at the second and third periods, and by partial de-awning at the first or second periods, with the maximal reduction in the first period.

Table 13.--Summary, of the seven varieties, showing the average air-dry weight of 1000 grains from awned and de-awned spikes of wheat grown at Manhattan, Kansas, during 1935-36.

Period of de-awning -1936-	Air-dry weight of 1000 grains: From awned spikes	From de-awned spikes	Weight-decrease	Per cent decrease
	Gm.	Gm.	Gm.	
I-t	27.8	26.0	1.7	6.40
I-p	29.2	27.9	1.2	4.31
II-t	30.5	27.9	2.6	8.71
II-p	31.4	29.9	1.5	4.69
III-t	30.3	27.7	2.6	8.79
III-p	31.8	30.7	1.1	3.53
IV-t	29.7	28.1	1.6	5.30
IV-p	31.0	30.1	0.9	2.96

As mentioned under "weight of grain per 100 spikes", two varieties, Kawvale and Turkey, were threshed in a special manner which separated the grain from awned and de-awned spikelets of partially de-awned spikes into two separate lots of grain (see table 14). The greatest weight- and percentage-decrease of grain for Kawvale was the decrease occasioned by de-awning at flowering. For Turkey, the weight- and percentage-decreases were greater the earlier the date of de-awning. From the data thus presented it is evident that the individual grain of awned spikelets is heavier than that of the de-awned spikelets. Some inconsistencies are noted in that early de-awnings did not always cause the greatest decrease in the weight of grain. Schmid (34) states that, in some cases, de-awning at late dates often produced lighter-weight grains than did earlier de-awning, but he was unable to offer an explanation to account for his observation.

Table 14.--Air-dry weight of 1000 grains from awned and de-awned spikelets of the same partially de-awned spikes of wheat grown at Manhattan, Kansas, during 1935-36.

Period of de-awning -1936-	Air-dry weight of 1000 grains: From awned half of spikes	From de-awned half of spikes	Weight-decrease	Percent-decrease
	Gm.	Gm.	Gm.	
		KAWVALE		
I-p 5/28	29.0	28.4	0.6	2.07
II-p 5/29	29.9	27.8	2.1	7.02
III-p 6/5	31.8	31.2	0.6	1.89
		TURKEY		
I-p 5/26	26.3	24.2	2.1	7.98
II-p 5/26	30.5	28.6	1.9	6.23
III-p 6/1	29.7	28.8	0.9	3.03
IV-p 6/10	29.5	29.3	0.2	0.68

In Plates VIII, IX, X, XII, the reductions in the volume of grain from de-awned spikes are due largely to the fact that the de-awned spikes produced fewer grains to the spike, as will be discussed later. The constant weight-reductions, in the grain of de-awned spikes, is the most important information resulting from this phase of the study.

Number of Grains per 100 Spikes. According to tables 15 and 16, the general statement can be made that the earliest de-awning produced the greatest actual number- and percentage-decrease in the number of grains formed by de-awned spikes. There are considerable fluctuations within a variety but when the results of all varieties are averaged together, these variations disappear and the general trend becomes apparent, as shown in table 17. The maximum decrease by total or partial de-awning resulted from de-awning at the first period. The percentage-decreases, by partial de-awning, are approximately the same in the second, third, and fourth periods. Little significance should be attached to the small percentage-decrease caused by total or partial de-awnings at the third and fourth periods for if all of the spikes had finished flowering, de-awning should not have affected the number of grains set. The small percentage-decreases recorded for these periods might be due to the inclusion of some flowering spikes, since it is difficult to determine accurately when a spike has finished flowering.

Table 15.--The number of grains produced by 100 awned, partially de-awned, and totally de-awned spikes of wheat grown at Manhattan, Kansas, during 1935-36.

Period of de-awning -1936-	Number of grains from 100 spikes					
	Awned spikes	De-awned spikes	Number-decrease		Per cent-decrease	
			KANRED			
I-t 5/27	2035	1814	221		10.86	
I-p "	2061	2059		2		0.10
II-t 5/29	2143	2032	111		5.18	
II-p "	2135	2204		-69*		-3.23*
III-t 6/4	2004	1999	5		0.25	
III-p "	2138	2118		20		0.94
IV-t 6/9	2011	1985	26		1.29	
IV-p "	2040	2049		-9*		-0.44*
			TENMARQ			
I-t 5/25	2320	2100	220		9.48	
I-p 5/26	2336	2064		272		11.64
II-t 5/25	2172	2043	129		5.94	
II-p 5/26	1990	1967		23		1.15
III-t 6/3	2117	2118	-1*		-0.05*	
III-p "	2038	2078		-40*		-1.96*
IV-t 6/9	2184	2114	70		3.21	
IV-p "	2149	2163		-14*		-0.65*
			KANRED X HARD FEDERATION			
I-t 5/19	1877	1759	118		6.29	
I-p 5/21	1651	1566		85		5.15
II-t 5/20	1993	1899	94		4.95	
II-p 5/21	1856	1817		39		2.10
III-t 5/30	1890	1870	20		1.06	
III-p "	1887	1884		3		0.16
IV-t 6/8	1688	1737	-49*		-2.90*	
IV-p "	1587	1539		48		3.02
			EARLY BLACKHULL			
I-t 5/20	1715	1532	183		10.67	
I-p 5/22	1694	1531		163		9.62
II-t 5/19	1959	1795	164		8.37	
II-p 5/22	1812	1691		121		6.68
III-t 5/30	1855	1829	26		1.40	
III-p "	1783	1754		29		1.63
IV-t 6/8	1727	1675	52		3.01	
IV-p "	1756	1708		48		2.73
			TURKEY			
I-t 5/22	2235	1826	409		18.30	
I-p 5/26	1930	1858		72		3.88
II-t 5/27	2043	1903	140		6.85	
II-p 5/26	2358	2381		-23*		-0.97*
III-t 6/1	2408	2366	32		1.33	
III-p "	2139	2054		85		3.97
IV-t 6/10	2087	2042	45		2.16	
IV-p "	2006	2016		-10*		-0.50*
			FULCASTER			
I-t 5/28	1939	1743	196		10.11	
I-p "	2025	1924		101		4.99
II-t 5/29	2086	1893	193		9.25	
II-p "	2007	1972		35		1.74
III-t 6/6	1896	1906	-10*		- 0.53*	
III-p "	1900	1888		12		0.63
			KAWVALE			
I-t 5/28	2387	2072	315		13.20	
I-p "	2164	2084		80		3.70
II-t 5/29	2383	2138	245		10.28	
II-p "	1994	2037		-43*		-2.16*
III-t 6/5	2188	2214	-26*		-1.19*	
III-p "	2154	2158		-4*		-0.19*

*Represents an increase rather than a decrease.

Table 16.--A comparison of the seven varieties in regard to the number of grains produced by 100 awned, partially de-awned, and totally de-awned spikes of wheat grown at Manhattan, Kansas, during 1935-36.

Period of de-awning -1936-	Variety	Number of grains from 100 spikes: Awned spikes	De-awned spikes	Number-decrease	Per cent-decrease
I-t 5/27	Kanred	2035	1814	221	10.86
" 5/25	Tenmarq	2320	2100	220	9.48
" 5/19	Krd. x H. Fed.	1877	1759	118	6.29
" 5/20	E. Blackhull	1715	1532	183	10.67
" 5/22	Turkey	2235	1826	409	18.30
" 5/28	Fulcaster	1939	1743	196	10.11
" 5/28	Kawvale	2387	2072	315	13.20
	Average--	2073	1835	237	11.27
I-p 5/27	Kanred	2061	2059	2	0.10
" 5/26	Tenmarq	2336	2064	272	11.64
" 5/21	Krd. x H. Fed.	1651	1566	85	5.15
" 5/22	E. Blackhull	1694	1531	163	9.62
" 5/23	Turkey	1930	1858	72	3.88
" 5/28	Fulcaster	2025	1924	101	4.99
" 5/28	Kawvale	2164	2084	80	3.70
	Average--	1980	1869	111	5.58
II-t 5/29	Kanred	2143	2032	111	5.18
" 5/25	Tenmarq	2172	2043	129	5.94
" 5/20	Krd. x H. Fed.	1993	1899	94	4.95
" 5/19	E. Blackhull	1959	1795	164	8.37
" 5/27	Turkey	2043	1903	140	6.85
" 5/29	Fulcaster	2086	1893	193	9.25
" 5/29	Kawvale	2383	2138	245	10.28
	Average--	2111	1958	154	7.26
II-p 5/29	Kanred	2135	2204	-69*	-3.23*
" 5/26	Tenmarq	1990	1967	23	1.15
" 5/21	Krd. x H. Fed.	1856	1817	39	2.10
" 5/22	E. Blackhull	1812	1691	121	6.68
" 5/26	Turkey	2358	2381	-23*	-0.97*
" 5/29	Fulcaster	2007	1972	35	1.74
" 5/29	Kawvale	1994	2037	-43*	-2.16*
	Average--	2022	2010	12	0.76
III-t 6/4	Kanred	2004	1999	5	0.25
" 6/3	Tenmarq	2117	2118	-1*	-0.05*
" 5/30	Krd. x H. Fed.	1890	1870	20	1.06
" 5/30	E. Blackhull	1855	1829	26	1.40
" 6/1	Turkey	2408	2366	32	1.33
" 6/6	Fulcaster	1896	1906	-10*	-0.53*
" 6/5	Kawvale	2188	2214	-26*	-1.19*
	Average--	2051	2043	7	0.32
III-p 6/4	Kanred	2138	2118	20	0.94
" 6/3	Tenmarq	2038	2078	-40*	-1.96*
" 5/30	Krd. x H. Fed.	1887	1884	3	0.16
" 5/30	E. Blackhull	1783	1754	29	1.63
" 6/1	Turkey	2139	2054	85	3.97
" 6/6	Fulcaster	1900	1888	12	0.63
" 6/5	Kawvale	2154	2158	-4*	-0.19*
	Average--	2006	1991	15	0.74
IV-t 6/9	Kanred	2011	1985	26	1.29
" 6/9	Tenmarq	2184	2114	70	3.21
" 6/8	Krd. x H. Fed.	1688	1737	-49*	-2.90*
" 6/8	E. Blackhull	1727	1675	52	3.01
" 6/10	Turkey	2087	2042	45	2.16
	Average--	1939	1911	29	1.35
IV-p 6/9	Kanred	2040	2049	-9*	-0.44*
" 6/9	Tenmarq	2149	2163	-14*	-0.65*
" 6/8	Krd. x H. Fed.	1587	1539	48	3.02
" 6/8	E. Blackhull	1756	1708	48	2.73
" 6/10	Turkey	2006	2016	-10*	-0.50*
	Average--	1908	1895	13	0.83

*Represents an increase rather than a decrease

Table 17.--Summary of the seven varieties showing the average number of grains produced by 100 awned, partially de-awned, and totally de-awned spikes of wheat grown at Manhattan, Kansas, during 1935-36.

Period of de-awning -1936-	Number of grains from 100 spikes					
	Awned spikes	De-awned spikes	Number-decrease		Percent-decrease	
I-t	2073	1835	237		11.27	
I-p	1980	1869		111		5.58
II-t	2111	1958	154		7.26	
II-p	2022	2010		12		0.76
III-t	2051	2043	7		0.32	
III-p	2006	1991		15		0.74
IV-t	1939	1911	29		1.35	
IV-p	1908	1895		13		0.83

Apparently the determiner of the number of grains is very sensitive and the effect of the de-awning will depend on whether it is performed at the critical stage in the production or development of the grain. The greatest reduction in the number of grains is produced by de-awning before flowering. It is a question, however, whether the failure to set fruit is due to injury, shock, or to a change in nutrition affected by a removal of the awns.

By noting, in the spike, the location of each grain, it was possible to determine which florets are most affected by de-awning. As has been stated, each spikelet may consist of from three to nine florets but the usual number is two, and sometimes three. The third floret, which sometimes develops, is the central, small, upper floret which ordinarily produces a smaller-sized grain than the side florets. Usually the two side florets produce grain simultaneously so that the fertility of the central floret ultimately determines how many grains will be set by the spike. According to the above method, it was found that in the case of Kanred de-awned at flowering, May 29, 100 awned spikes produced 68 fertile middle florets, while 100 totally de-awned spikes produced only 6 fertile middle florets. The total number of grains from 100 awned spikes was 2,171, as compared to 2,052 grains from the totally de-awned spikes.

In the case of partial de-awning of Kanred before flowering, May 27, 100 awned spikes produced 38 fertile middle florets, while 100 partially de-awned spikes produced 53 fertile middle florets. The total number of grains from 100 awned spikes was 2,041, as compared to 1,735 from the 100 partially de-awned spikes of Kanred. Thus the totally and partially de-awned groups had, respectively, 119 and 306 fewer grains than the corresponding groups of awned spikes. The critical time in the setting of fruit was before flowering, since the removal of awns at that period produced the greatest reduction in the number of grains formed. The two, above-mentioned sets cannot be compared fairly, since the total de-awning was performed at flowering and the partial de-awning before flowering. Had the total and partial de-awnings been of the same date, one might have expected partial de-awning to produce one-half the effect of total de-awning.

In order to supplement this conception, further work in that regard is necessary.

The percentage-decrease in the number of grains produced by Turkey run consistently high for all four periods, while in Kawvale the values approximate the theoretical expectations, as shown in table 18.

Table 18.--The number of grains produced by the awned and de-awned sides of the same 100 partially de-awned spikes of wheat grown at Manhattan, Kansas, during 1935-36.

Period of de-awning -1936-	Number of grains from 100 spikes			
	Awned half of spikes	De-awned half of spikes	Number-decrease	Percent-decrease
		KAWVALE		
I-p 5/28	1126	958	168	14.92
II-p 5/29	1041	996	45	4.32
III-p 6/5	1092	1066	26	2.38
		TURKEY		
I-p 5/26	1002	856	146	14.57
II-p "	1300	1081	219	16.85
III-p 6/1	1127	927	200	17.75
IV-p 6/10	1098	918	180	16.39

In regard to the number of sterile spikelets in wheat, Grantham and Groff (12) reported that the bearded varieties as a class have a higher percentage of sterile spikelets than the beardless varieties. It is well to keep that fact in mind for de-awning may not necessarily mean that fewer grains will be produced, i.e., de-awning produces spikes which artificially approximate awnless spikes and awnless spikes have been reported as more fertile.

Schmid (34) stated that de-awning reduced the number of grains formed by a spike.

Weight and Water Content of Awns. Turkey wheat was used as the experimental plant in a study of the changes in fresh weight, dry weight, and percentage of water in the awns at weekly intervals from the time of heading until harvest. Samples were taken on May 23, 1936, and at weekly intervals thereafter. One hundred spikes were brought into the laboratory and the awns immediately removed by clipping with scissors. As shown in table 19, the wet weight of the awns reached maxima on June 6 and June 20. The rains, during June of 1936, of 0.12, 0.45, and 0.18 inches occurred on June 5, 6, and 17, respectively. Thus both maximal wet weights were preceded by rains. The greatest wet weight occurred on June 6, which is what one would expect because of the rains at that time; the second maximum is explainable only on the basis of the rain of June 17, which again served to increase the available moisture and reduce transpiration. The wet weight reached a minimum at maturity on June 27, 1936.

Table 19.--Changes in the wet and dry weights of 100 spikes, and their awns, at different stages of growth from heading to maturity at Manhattan, Kansas, during 1935-36.

Date -1936-	Turkey wheat (100 spikes)				
	Wet weight of awns	Dry weight of awns	Water content	Wet weight of spikes (less awns)	Per cent* of water in awns
	Gm.	Gm.	Gm.	Gm.	
May 23	14.0	5.300	8.700		62.14
" 30	14.5	5.925	8.575		59.13
June 6	17.0	10.367	6.633	111.0	39.02
" 13	15.0	10.852	4.147	161.4	27.64
" 20	16.5	12.900	3.600	181.7	21.81
" 27	11.5	10.717	0.783	110.0	6.80

*Based on the wet weight.

The oven-dry weight of the awns increased to a maximum on June 20. A week later, the dry weight of the awns had dropped from 12.9 gm. to 10.7 gm. -- a decrease of 2.2 grams. This seems to indicate that between June 20 and June 27 there was a pronounced translocation of materials from the awns, for such a marked decrease could not be accounted for by variation in samples. If such translocation does occur, it is suggested that these materials may enter the grain and aid in increasing its weight.

The water content decreased steadily from the first date of sampling until the marked reduction during the week preceding maturity.

Beginning with June 6, the wet weight of the spikes was recorded. In these data, the maximal weight is reached on June 20 -- the date of the maximal dry weight of the awns and the date of the second maximal wet weight of the awns. The last sample weighed considerably less than that of the maximal weight of the preceding week. As these values are of wet weight, most of this decrease is explainable by the drop in percentage of moisture.

The per cent of moisture in the awns (based on wet weight) decreased progressively from 62.14 on May 23 to 6.80 per cent on June 27. The greatest reduction came during the week preceding maturity.

Dry Weight of the Awns, Glumes, and Rachises. The spikes of Kanred and Tenmarq were resolved into grain, awns, glumes, and rachises at the time of threshing. The changes in the weight and number of grains have been previously discussed.

In the case of partially de-awned spikes, only half of the awns remained, and on that account the weight of the awns was doubled for comparison with the fully-awned spikes used as controls (see table 20).

Table 20.--Oven-dry weight of the awns, glumes, and rachises of 100 spikes of wheat grown at Manhattan, Kansas, during 1935-36.

Period of de-awning -1936-	Oven-dry weight of awns from 100 spikes					
	From awned spikes	From de-awned spikes*	Weight-increase		Per cent-increase	
	Gm.	Gm.	Gm.			
			KANRED			
I-t 5/27	9.15					
I-p "	9.58	10.23	0.65		6.83	
II-t 5/29	10.99					
II-p "	10.49	11.73	1.24		11.83	
III-t 6/4	9.54					
III-p "	9.82	10.13	0.31		3.16	
IV-t 6/9	8.87					
IV-p "	9.25	9.20	-0.05**		-0.56**	
			TENMARQ			
I-t 5/25	11.46					
I-p 5/26	11.44	10.87	-0.57**		-5.03**	
II-t 5/25	10.71					
II-p 5/26	11.09	10.83	-0.26**		-2.40**	
III-t 6/3	9.89					
III-p "	9.71	9.85	0.14		1.47	
IV-t 6/9	10.66					
IV-p "	10.99	11.45	0.46		4.26	
	Oven-dry weight of glumes from 100 spikes					
			KANRED			
I-t 5/27	12.01	12.08	0.07		0.58	
I-p "	11.74	12.43		0.69		5.88
II-t 5/29	11.45	12.63	1.18		10.31	
II-p "	12.28	13.44		1.16		9.45
III-t 6/4	11.33	11.75	0.42		3.71	
III-p "	12.15	12.31		0.16		1.32
IV-t 6/9	11.09	11.18	0.09		0.81	
IV-p "	11.25	11.45		0.20		1.78
			TENMARQ			
I-t 5/25	15.87	16.11	0.24		1.51	
I-p 5/26	15.93	14.47		-1.46**		-9.17**
II-t 5/25	13.42	14.16	0.74		5.51	
II-p 5/26	12.83	13.51		0.68		5.30
III-t 6/3	12.96	13.54	0.58		4.48	
III-p "	12.66	12.72		0.06		0.47
IV-t 6/9	14.69	14.60	-0.09**		-0.61**	
IV-p "	14.78	14.81		0.03		0.20
	Oven-dry weight of rachises from 100 spikes					
			KANRED			
I-t 5/27	2.66	2.65	-0.01**		-0.40**	
I-p "	2.71	3.08		0.37		13.65
II-t 5/29	2.99	3.10	0.11		3.68	
II-p "	2.99	3.32		0.33		11.04
III-t 6/4	2.91	2.94	0.03		1.03	
III-p "	2.92	2.97		0.05		1.71
IV-t 6/9	2.70	2.80	0.10		3.70	
IV-p "	2.72	2.80		0.08		2.94
			TENMARQ			
I-t 5/25	3.19	3.74	0.55		17.24	
I-p 5/26	3.29	2.95		0.66		20.06
II-t 5/25	2.98	3.14	0.16		5.37	
II-p 5/26	2.83	2.92		0.09		3.18
III-t 6/3	2.80	2.93	0.13		4.64	
III-p "	2.90	2.97		0.07		2.41
IV-t 6/9	3.20	3.16	-0.04**		-1.25**	
IV-p "	2.82	3.20		0.38		13.48

*For comparison, these weights are double the original weights which involved only half as many awns as of other groups.

**Represents a decrease rather than an increase.

It has been stated by Harlan and Pope (16) that in barley the awns function as repositories for excess ash. Thus in wheat it was expected that a removal of half of the awns might increase the dry weight of the remaining, intact awns. Similarly it would appear that the earlier the awns were removed from half of the spikelets in the spike, the greater would be the increase in the weight of the remaining awns. The weights in table 20 are oven-dry weights and not weights of ash, so that differences in ash content were apparently masked by the presence of other substances.

The greatest increase in the weight of the awns of Kanred was occasioned by a partial de-awning at the time of flowering. In Tenmarq, however, no significant values were obtained. However, these awns were removed at harvest, so that their weights would be expected to compare more closely with the controls if translocation of materials from the awns occurs previous to that time. The small fluctuations obtained might be due to a difference in the samples.

The weight of the glumes was also studied in order to determine whether they become repositories for ash upon the removal of the awns. In Kanred it was shown that the weight of the glumes increased on the de-awned spikes. There was no definite relationship between the increase in the weight of glumes and the number of awns removed. The glumes of Tenmarq showed no definite response to the removal of awns. The maximal increase in the weight of glumes in both varieties was occasioned by de-awning at flowering.

With but two minor exceptions, the data show that the rachis increases in weight following total and partial removal of the awns. In general the data indicate that the earlier the date of de-awning the greater the increase in the weight of the rachis.

Greenhouse Studies on the Transpiration of Awns

Transpiration Studies. During 1935-36, fifty-five, one-hour determinations of transpiration were made on the variety, Pusa 52 x Federation. Since the experiments performed the first year were of a more or less preliminary nature, the detailed data are not presented here. However, one particularly interesting observation is worthy of note. In one set, determinations of transpiration were made immediately following de-awning, and at 3-, 4-, 22-, 23-, 26-, 27-, and 96-hour intervals thereafter. For the first hour following de-awning, transpiration was reduced by 36 per cent, but three hours later this reduction had reached 60 per cent. From the fourth hour after de-awning until the end of the experiments, the reduction remained constant at approximately 36 per cent. This observation is mentioned because similar results were not obtained in any of the numerous experiments which were subsequently performed. Scarth (33) has shown that stomatal closing is effected only within close proximity to a cut or injured surface.

During the year 1936-37, 108 one-hour determinations of transpiration were made on the same variety of wheat as used the first year.

The detailed data of these experiments are tabulated in table 21. The determinations of transpiration are plotted according to the number of days after flowering (see fig. 6). This is considered to be the most accurate arrangement of the data because the amount of transpiration is correlated with the age and stage of development of a plant or plant part. With but few exceptions, the determinations have been grouped into three-day units. The value was obtained by averaging together the results of all experiments occurring within the time limit of any unit. Thus, in the unit of one to three days after flowering, the values representing the transpiration of awned and de-awned spikes are averages of 13 one-hour determinations. The transpiration of the awned spikes is represented by the total height of the column; the transpiration of the two de-awned spikes by the height of the shaded portion only of the column.

Table 21.--Data relative to the transpiration experiments in the greenhouse with awned and de-awned spikes of Pusa 52 x Federation wheat, during 1936-37.

Exp. No.	Date 1937	Temp. °F.	Time of day	Evap. from atmometer cc/hr.	Amt. of water in each 72 l. of air Mgm.	Net water loss of 2-awned spikes Mgm/hr.	Net water loss of 2 de-awned spikes Mgm/hr.	Stage of growth	Number of days from first flowering	Time since de-awned	Ratio de-awned/awned	Per cent decrease due to de-awning	Notes
1a	Jan.19	71	10:40-11:40	1.4	305.5	220.7	222.3	Flowering	0	-	1.01	-	Sun
1b	" "	72	3:05- 4:12	"	391.3	161.3	113.0	"	"	5 min.	0.71	29.7	Cloudy
1c	" 20	75	9:01-10:10	"	459.3	201.6	132.0	"	1	1 day	0.65	35.6	"
1d	" "	74	10:32-11:34	1.3	276.2	825.2	461.4	"	"	"	0.56	44.6	Sun
1e	" "	68	1:42- 2:44	1.1	318.5	376.2	280.5	"	"	"	0.75	25.7	Cloudy
1f	" "	68	3:05- 4:05	1.0	448.7	184.4	132.5	"	"	"	0.72	28.7	"
1g	" 21	73	9:20-10:24	1.4	471.3	183.1	155.4	"	2	2	0.85	15.8	"
1h	" 22	73	8:17- 9:17	1.5	410.5	195.8	125.3	"	3	3	0.64	36.6	"
1i	" 23	68	8:17- 9:21	1.3	428.1	167.1	120.8	"	4	4	0.72	28.7	Sun
1j	" 24	78	8:02- 9:01	1.3	532.3	188.8	144.5	"	5	5	0.77	23.8	"
1k	" 25	67	8:59- 9:57	0.8	507.9	318.6	205.2	"	6	6	0.64	36.6	"
1l	" 26	70	8:39- 9:40	1.3	447.0	290.2	172.0		7	7	0.59	41.6	"
1m	" 27	67	8:04- 9:03	1.0	530.5	178.9	112.0		8	8	0.63	37.6	"
1n	" "	70	9:03-10:04	1.4	433.5	338.8	188.7		"	"	0.56	44.6	"
10	" "	72	2:59- 3:59	1.9	314.7	359.7	200.8		"	"	0.56	44.6	"
1p	" "	72	3:59- 5:00	1.0	446.5	213.5	125.6		"	"	0.59	41.6	"
1q	" 28	63	7:55- 8:55	"	459.2	102.2	31.6	Early milk	9	9	0.31	69.3	Cloudy
1r	Feb. 4	65	8:45- 9:44	"	406.2	294.8	123.6	Soft dough	16	16	0.42	58.4	Sun
1s	" 8	74	12:02- 1:00	2.0	396.6	337.3	170.2	" "	20	20	0.50	50.5	"
1t	" 15	72	9:59-10:57	1.2	555.1	215.1	132.4	Hard "	27	27	0.62	38.6	"
1u	" 19	67	12:39- 1:37	0.8	654.6	94.3	34.6		31	31	0.37	63.4	Cloudy
1v	" 22	75	8:45- 9:44	1.5	495.2	15.4	11.9	Grain ripe	34	34	0.77	23.8	"

Table 21.--Data relative to the transpiration experiments in the greenhouse with awned and de-awned spikes of Pusa 52 x Federation wheat, during 1936-37.

Exp. No.	Date 1937	Temp. °F.	Time of day	Evap. from atmometer cc/hr.	Amt. of water in each 72 l. of air Mgm.	Net water loss of 2-awned spikes Mgm/hr.	Net water loss of 2 de-awned spikes Mgm/hr.	Stage of growth	Number of days from first flowering	Time since de-awned	Ratio de-awned / awned	Per cent decrease due to de-awning	Notes
2a	Jan.21	74	10:52-11:54	1.4	459.9	247.5	252.7	Flowering	0	-	1.02	-	Cloudy
2b	" "	75	2:41- 3:41	1.2	494.7	202.2	130.9	"	"	6 min.	0.65	36.3	"
2c	" "	70	3:41- 4:43	1.1	451.5	178.2	114.6	"	"	1 hr.	0.64	37.3	"
2d	" 22	72	9:34-10:35	1.5	393.5	221.6	188.9	"	1	1 da.	0.85	16.7	Sun
2e	" 23	68	9:40-10:40	1.4	404.2	314.6	235.9	"	2	2	0.75	26.5	"
2f	" 25	73	10:11-11:11	1.5	475.2	349.0	226.7	"	4	4	0.65	36.3	"
2g	" 26	73	1:26- 2:26	2.0	322.2	287.5	167.8	"	5	5	0.58	43.1	"
2h	" "	73	2:26- 3:27	1.7	309.7	331.2	196.2	"	"	"	0.59	42.2	"
2i	Feb. 4	71	9:57-10:55	2.2	363.7	366.9	238.3	Milk	14	14	0.65	36.3	"
2j	" 8	70	1:06- 2:06	1.8	364.3	307.8	187.1	Soft dough	18	18	0.61	40.2	"
2k	" 15	73	11:04-12:02	1.8	520.2	279.2	229.4	Hard dough	25	25	0.82	19.6	Cloudy
2l	" 19	70	1:43- 2:42	0.9	646.4	109.1	81.2		29	29	0.74	27.5	"
2m	" 22	77	9:49-10:49	1.9	391.9	262.0	122.6	Ripe	32	32	0.47	53.9	Sun
3a	Jan.22	75	1:30- 2:30	1.5	404.6	374.1	319.9	Flowering	1		0.86		Sun
3b	" "	77	2:30- 3:30	1.6	473.0	451.0	356.7	"	"		0.79		"
3c	" 23	70	1:34- 2:35	1.5	366.0	367.3	199.5	"	2	4 min.	0.54	34.1	"
3d	" "	68	2:35- 3:35	1.6	346.1	412.2	213.0	"	"	1 hr.	0.52	36.6	"
3e	" 24	71	9:20-10:21	1.6	468.7	376.8	216.6	"	3	1 da.	0.57	30.5	"
3f	" "	70	11:11-12:11	1.6	380.4	468.2	273.6	"	"	"	0.58	29.3	"
3g	" "	73	12:11- 1:11	2.0	360.7	440.7	293.1	"	"	"	0.67	18.3	"
3h	" 25	67	1:16- 2:15	1.6	280.6	268.5	182.6	"	4	2	0.68	17.1	"
3i	" "	67	2:15- 3:17	1.8	262.6	355.4	186.5	"	"	"	0.52	36.6	"
3j	" 26	68	9:53-10:53	1.4	364.2	326.9	216.2	"	5	3	0.66	19.5	"
3k	Feb. 4	73	1:26- 2:24	1.8	372.3	307.2	155.4	Milk	14	12	0.51	37.8	"
3l	" 8	68	2:13- 3:11	1.6	339.8	375.7	199.8	Soft dough	18	16	0.53	35.4	"
3m	" 15	75	1:50- 2:49	1.4	516.7	340.9	165.9	Hard dough	25	23	0.49	40.2	Cloudy
3n	" 19	70	2:47- 3:46	0.9	618.2	122.0	64.8		29	27	0.53	35.4	"
3o	" 22	73	1:25- 2:24	1.9	311.6	231.7	103.3	Ripe	32	30	0.46	43.9	Sun

Table 21.--Data relative to the transpiration experiments in the greenhouse with awned and de-awned spikes of Pusa 52 x Federation wheat, during 1936-37.

Exp. No.	Date 1937	Temp. °F.	Time of day	Evap. from atmometer cc/hr.	Amt. of water in each 72 l. of air Mgm.	Net water loss of 2-awned spikes Mgm/hr.	Net water loss of 2 de-awned spikes Mgm/hr.	Stage of growth	Number of days from first flowering	Time since de-awned	Ratio de-awned / awned	Per cent decrease due to de-awning	Notes
4a	Jan.28	67	9:27-10:26	0.9	581.0	121.8	122.9		9	-	1.01	-	Cloudy
4b	" "	74	1:04- 2:04	1.4	503.5	221.4	116.1		"	4 min.	0.52	48.5	"
4c	" "	73	2:04- 3:04	1.5	480.7	222.2	117.8		"	64 "	0.53	47.5	"
4d	" 29	73	8:17- 9:16	1.1	579.9	102.8	66.8		10	1 da.	0.65	35.6	"
4e	" "	68	9:16-10:16	0.9	606.9	375.0	67.9		"	"	0.18	82.2	"
4f	" "	67	1:27- 2:28	0.8	562.4	166.5	116.1		"	"	0.70	30.7	"
4g	" "	66	2:28- 3:28	0.7	549.9	132.6	76.8		"	"	0.58	42.6	"
4h	" 30	67	8:31- 9:30	1.0	536.9	124.3	100.0		11	2	0.80	20.8	"
4i	" "	68	9:30-10:29	1.1	560.2	161.2	123.2		"	"	0.76	24.8	"
4j	" "	73	1:22- 2:21	1.2	634.3	226.9	124.3		"	"	0.55	45.5	"
4k	" "	73	2:21- 3:20	1.2	639.4	227.4	125.3		"	"	0.55	45.5	"
4l	Feb. 4	73	2:38- 3:37	1.5	402.5	245.1	157.4	Soft dough	16	7	0.64	36.6	Sun
4m	" 8	68	3:16- 4:14	1.5	357.3	302.3	191.0	" "	20	11	0.63	37.6	"
4n	" 15	75	2:54- 4:53	1.4	500.1	246.0	125.5	Hard "	27	18	0.51	49.5	Cloudy
4o	" 19	71	3:56- 4:55	0.9	641.4	64.9	37.8		31	22	0.58	42.6	"
4p	" 22	72	2:29- 3:29	2.0	300.8	103.3	28.3	Ripe	34	25	0.27	73.3	Sun

Table 21.--Data relative to the transpiration experiments in the greenhouse with awned and de-awned spikes of Pusa 52 x Federation wheat, during 1936-37.

Exp. No.	Date 1937	Temp. °F.	Time of day	Evap. from atmometer cc/hr.	Amt. of water in each 72 l. of air Mgm.	Net water loss of 2-awned spikes Mgm/hr.	Net water loss of 2 de-awned spikes Mgm/hr.	Stage of growth	Number of days from first flowering	Time since de-awned	Ratio de-awned / awned	Per cent decrease due to de-awning	Notes
5a	Jan.31	66	8:32- 9:30	0.9	553.7	234.8	229.3		10	-	0.98	-	Sun
5b	" "	70	9:36-10:36	1.3	555.6	295.8	199.1		"	6 min.	0.67	31.6	"
5c	" "	70	10:36-11:37	1.6	527.4	406.4	250.7		"	66 "	0.62	36.7	"
5d	" "	72	11:37-12:35	2.0	450.7	393.4	198.7		"	2 hrs.	0.51	48.0	"
5e	Feb. 1	68	9:00- 9:59	1.1	554.4	477.9	275.2		11	1 da.	0.58	40.8	"
5f	" "	72	11:00-11:59	0.9	493.2	522.4	328.5		"	"	0.63	35.7	"
5g	" "	72	12:00-12:58	1.9	437.2	498.2	307.3		"	"	0.62	36.7	"
5h	" "	72	2:00- 3:00	1.9	364.6	407.1	237.8		"	"	0.58	40.8	"
5i	" 2	70	8:00- 8:59	1.2	552.1	203.7	158.4	Milk	12	2	0.78	20.4	"
5j	" "	73	10:00-10:58	2.1	435.6	442.3	273.5	"	"	"	0.62	36.7	"
5k	" "	70	1:00- 1:59	1.4	379.1	336.9	219.8	"	"	"	0.65	33.7	Cloudy
5l	" "	73	3:00- 4:00	1.3	496.4	403.4	216.7	"	"	"	0.54	44.9	"
5m	Feb. 5	70	9:00- 9:58	1.0	548.2	217.3	123.4	"	15	5	0.57	41.8	"
5n	" "	73	9:58-10:57	1.7	458.3	301.9	173.2	"	"	"	0.57	41.8	"
5o	" "	70	3:37- 4:35	1.1	458.3	205.3	141.3	"	"	"	0.69	29.6	"
5p	" "	70	4:35- 5:33	0.8	599.5	175.0	101.2	"	"	"	0.58	40.8	"
5q	" 9	68	10:23-11:21	1.0	472.8	203.6	111.0	Soft dough	19	9	0.55	43.9	"
5r	" 16	75	11:56-12:53	2.2	276.5	464.7	243.2	Hard "	26	16	0.52	46.9	Sun
5s	" 20	67	9:24-10:23	0.9	518.0	140.6	72.6	" "	30	20	0.52	46.9	Cloudy
5t	" 23	73	12:37- 1:36	1.9	389.5	273.6	140.0	Ripe	33	23	0.51	48.0	Sun

Table 21.--Data relative to the transpiration experiments in the greenhouse with awned and de-awned spikes of Pusa 52 x Federation wheat, during 1936-37.

Exp. No.	Date 1937	Temp. °F.	Time of day	Evap. from atmometer cc/hr.	Amt. of water in each 72 l. of air Mgm.	Net water loss of 2-awned spikes Mgm/hr.	Net water loss of 2 de-awned spikes Mgm/hr.	Stage of growth	Number of days from first flowering	Time since de-awned	Ratio de-awned/awned	Per cent decrease due to de-awning	Notes
6a	Feb. 6	67	8:44- 9:43	0.8	492.2	332.9	277.8	Milk	14	-	0.83	-	Sun
6b	" "	70	9:50-10:49	1.3	458.5	521.4	323.6	"	"	5 min.	0.62	25.3	"
6c	" "	67	1:42- 2:40	0.9	384.5	332.1	204.3	"	"	4 hrs.	0.62	25.3	"
6d	" "	70	2:40- 3:38	1.2	426.4	505.4	296.8	"	"	5 "	0.59	28.9	"
6e	" 7	72	8:45- 9:43	1.0	690.5	164.2	123.2	"	15	1 da.	0.75	9.6	Cloudy
6f	" "	73	9:43-10:44	1.3	629.9	198.1	141.5	"	"	"	0.71	14.5	"
6g	" "	75	1:45- 2:43	1.7	449.9	297.3	189.6	"	"	"	0.64	22.9	"
6h	" "	74	2:43- 3:43	1.2	518.5	268.8	164.5	"	"	"	0.61	26.5	"
6i	" 9	73	1:03- 2:02	1.0	566.3	270.8	178.2	Soft dough	17	3	0.66	20.5	"
6j	" "	75	2:03- 3:01	1.2	568.2	350.4	218.9	" "	"	"	0.62	25.3	Sun
6k	" "	73	3:01- 4:00	1.9	403.2	397.0	265.6	" "	"	"	0.67	19.3	"
6l	" 16	75	1:00- 1:59	2.3	268.5	334.5	226.9	Hard "	24	10	0.68	18.1	"
6m	" 20	68	10:30-11:29	1.1	535.5	131.8	136.8	" "	28	12	1.04	+2.5	Cloudy
6n	" 23	78	1:41- 2:41	2.2	375.9	372.2	240.0		31	15	0.64	22.9	"
6o	" 26	71	1:45- 2:45	1.3	399.5	166.8	106.7	Ripe	34	18	0.64	22.9	"

Table 21.--Data relative to the transpiration experiments in the greenhouse with awned and de-awned spikes of Pusa 52 x Federation wheat, during 1936-37.

Exp. No.	Date 1937	Temp. °F.	Time of day	Evap. from atmometer cc/hr.	Amt. of water in each 72 l. of air Mgm.	Net water loss of 2-awned spikes Mgm/hr.	Net water loss of 2 de-awned spikes Mgm/hr.	Stage of growth	Number of days from first flowering	Time since de-awned	Ratio de-awned / awned	Per cent decrease due to de-awning	Notes
7a	Feb.12	67	9:18-10:16	0.8	607.7	39.8	46.2	Soft dough	20	-	1.16	-	Cloudy
7b	" "	70	10:17-11:21	1.5	446.7	251.4	199.0	" "	"	2 min.	0.79	31.9	"
7c	" "	73	3:05- 4:03	1.4	426.6	187.6	137.5	" "	"	5 hrs.	0.73	37.1	"
7d	" "	72	4:03- 5:02	1.3	451.5	192.4	133.1	" "	"	6 "	0.69	40.5	"
7e	" 13	72	2:45- 3:43	2.4	245.0	464.2	295.6	" "	21	1 da.	0.64	44.8	Sun
7f	" "	68	3:43- 4:43	1.7	253.5	367.4	244.5	" "	"	"	0.67	42.2	"
7g	" "	70	4:43- 5:42	1.1	450.3	219.1	151.7	" "	"	"	0.69	40.5	"
7h	" 14	66	8:05- 9:04	0.7	619.3	174.3	118.4	Hard dough	22	2	0.68	41.4	"
7i	" "	70	9:04-10:03	1.4	530.3	351.8	225.1	" "	"	"	0.64	44.8	"
7j	" 16	75	2:05- 3:04	3.8	264.5	409.1	252.4	" "	24	4	0.62	46.6	"
7k	" "	75	3:04- 4:03	1.7	338.3	346.3	193.3	" "	"	"	0.56	51.7	"
7l	" 20	65	3:25- 4:25	1.0	468.7	217.2	120.7	" "	28	8	0.56	51.7	Cloudy
7m	" "	68	4:25- 4:55	1.2	497.6	171.6	124.4	" "	"	"	0.72	37.9	"
7n	" 23	73	2:46- 3:45	2.2	369.9	265.0	140.8		31	11	0.53	54.3	"
7o	" 26	71	2:50- 3:51	1.4	348.4	165.6	83.4	Ripe	34	14	0.50	56.9	"

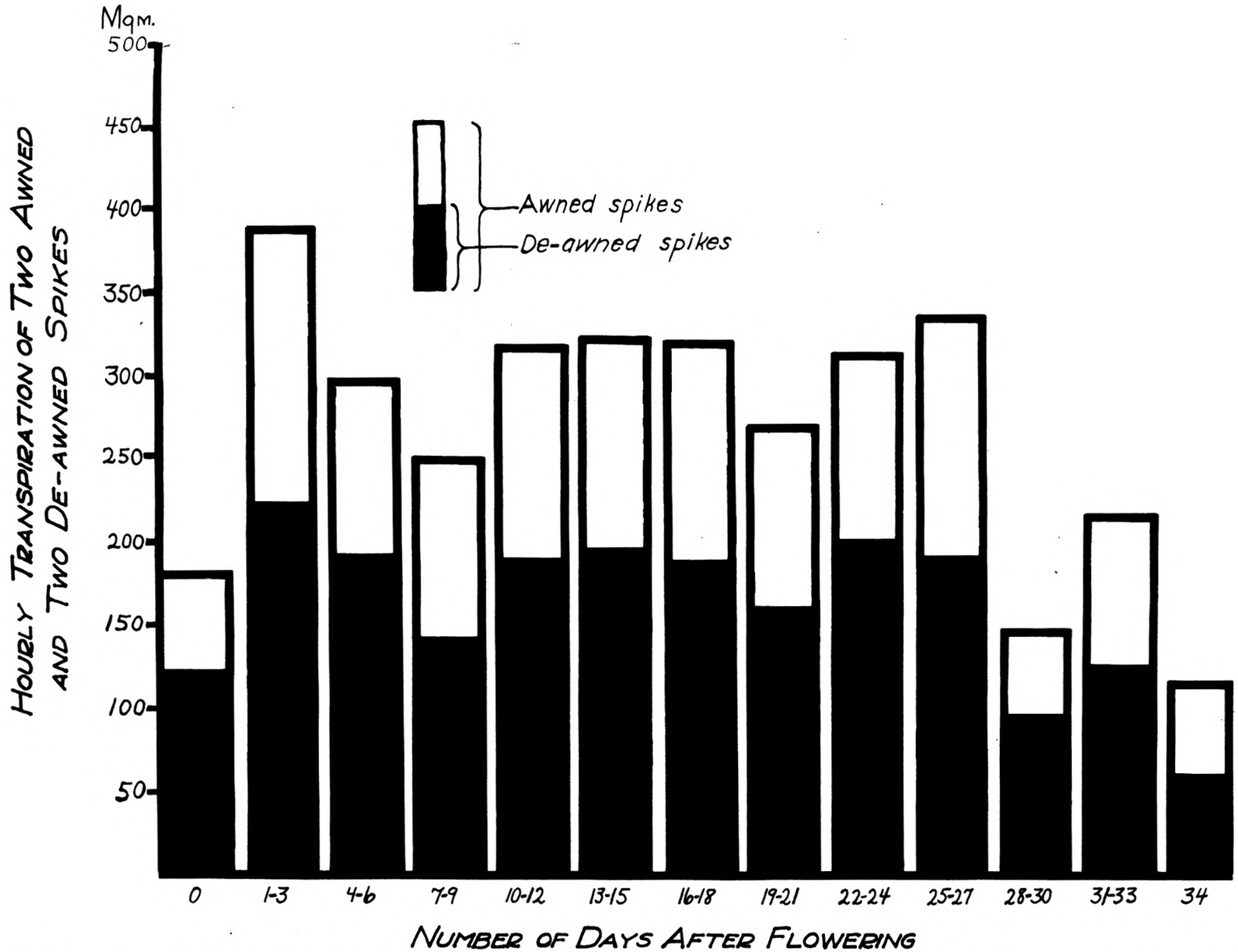

Fig. 6.--The total transpiration of awned and de-awned spikes of wheat at three-day intervals from flowering to maturity.

The transpiration curves for the awned and de-awned spikes are shown by a line graph in fig. 7, which presents the data of fig. 6 in a different form. This graph shows that the amount of transpiration rose rapidly to a maximum during the period of one to three days after flowering. Following this first maximum, there was a rather sudden decline until about the eighth day after flowering. The rate of transpiration then gradually rose to a second maximum which was maintained at approximately the same level until the 26th day after flowering. There was then a marked decrease until the 29th day. During the last five days there was a sudden rise in the amount of transpiration to a third maximum which, in turn, was followed by a very rapid decline.

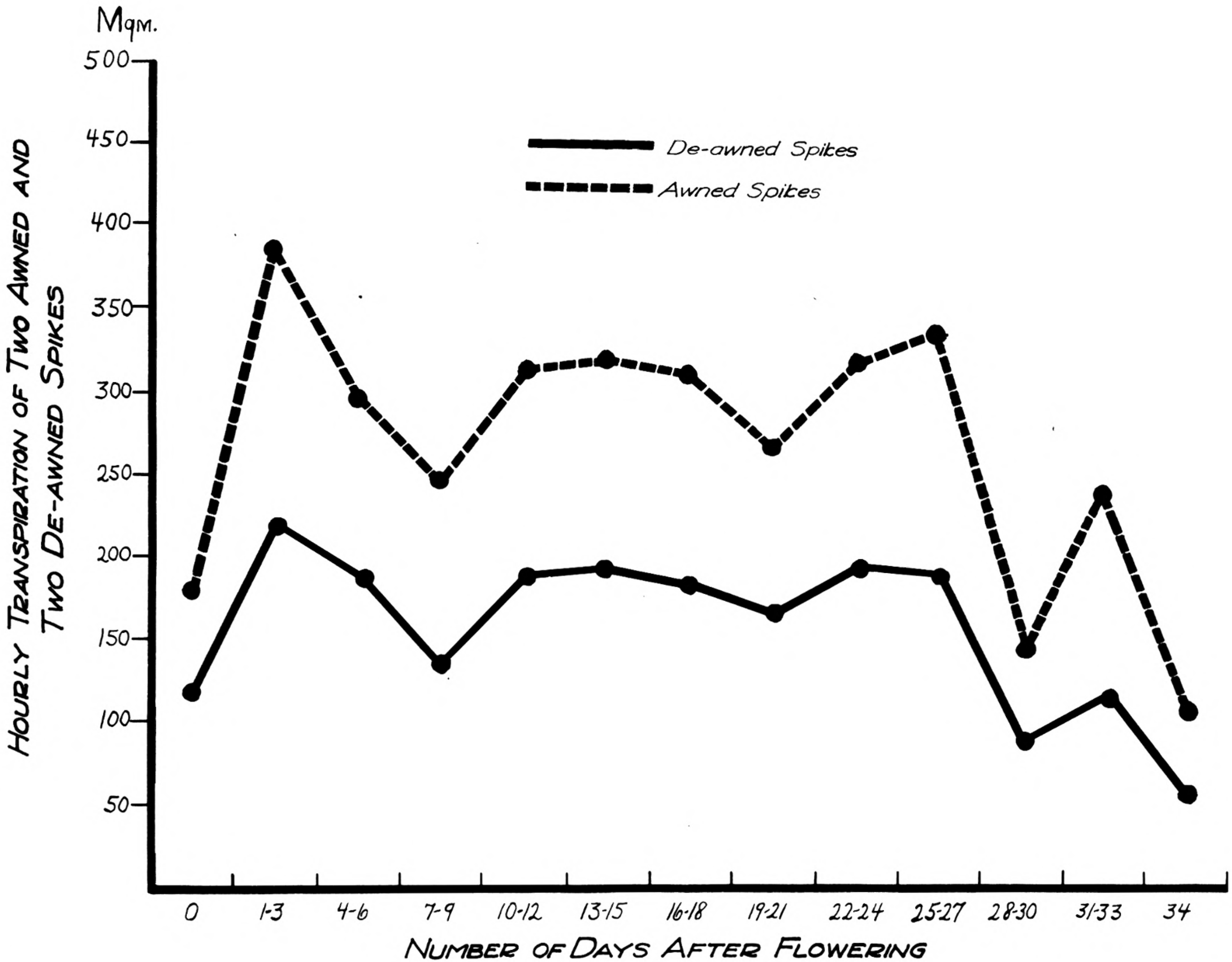

Fig. 7.--Line graphs of the transpiration of awned and de-awned spikes of wheat at three-day intervals from flowering to maturity.

The maximum of the first curve may be explained by assuming that when the florets are flowering, nearly all of the surface of the parts composing them is freely exposed to the atmosphere. Or, it may be due to the nature of the plant that the transpiration of the spike reaches a maximum at the time of flowering. Vasilyev (40) reported that the maximum transpiration by the awns of Bieloturka wheat was at the time of flowering.

That portion of the curve which represents the rate of transpiration from the eighth to the 29th day after flowering corresponds with the simple curve reported by Perlitius (29) for spring wheat. For winter wheat, he obtained a double curve with maxima occurring at the onset of fruit formation and just preceding the milk stage. Since he made determinations at only six periods between heading and maturity, he did not have data to indicate whether other fluctuations occurred previous to or after his periods. At present, no explanation can be given for the second maximum in the transpiration of the spikes.

Johnston (23) suggested that the low transpiration preceding the last rise was due to the fact that the leaves had ceased active transpiration by that time, and since the lower portion of the awn was still green and functioning, the spikes assumed the major role in transpiration for the short time just preceding the ripening of the awns. With a quick maturing of the awns, the transpiration of the spike dropped rapidly to the minimum. The maximum of the last curve was below that of the two previous maxima. Apparently as the spikes approached maturity, the awns then played a slightly greater role in the transpiration than at any other time (see fig. 8), despite the fact that the total amount of transpiration was low. At that time, the awn was the only living and functional part of the spike, so that they transpired a greater proportion of the water lost from the spike. As stomatal transpiration decreased, cuticular transpiration became proportionately greater, since the awns increase considerably the surface through which cuticular transpiration may occur.

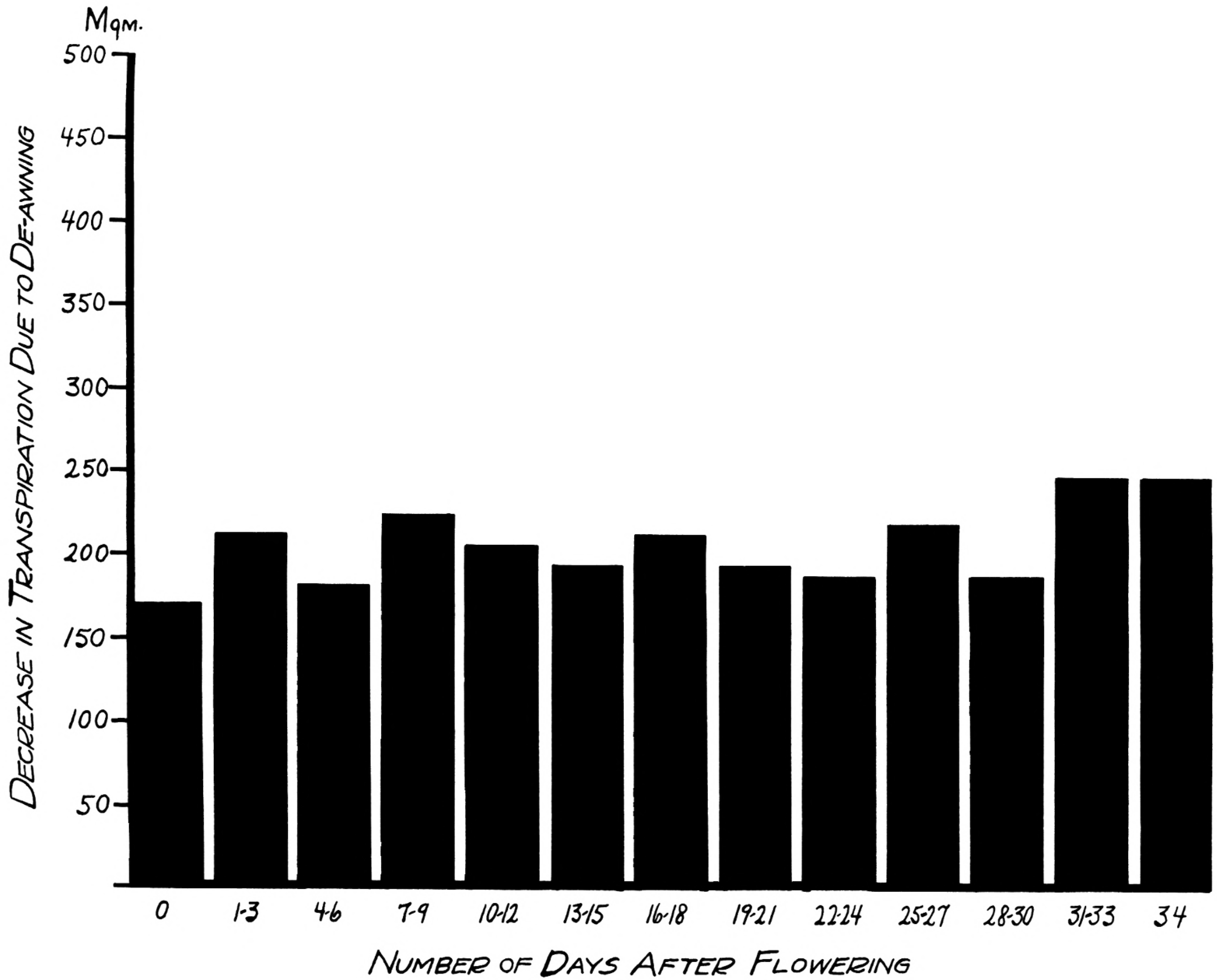

Fig. 8.--Decrease in transpiration of wheat spikes, as effected by de-awning.

<u>Miscellaneous Studies of the Grain</u>. A detailed record was kept of the development of 221 spikes, of which number 120 were used in an experiment designed to determine the effect of de-awning on the weight and water content of the grain. In this experiment, 60 spikes were totally de-awned and 60 intact, awned spikes were used as controls.

The spikes flowered over a period of about five days, reached the milk-ripe stage by the 12th day, the soft dough stage by the 16th, the hard dough stage by the 22nd, and were considered in the yellow-ripe stage on the 34th day after flowering. The spike became entirely free of the boot about six days after the first protrusion of the awns. In some spikes, flowering began when the spike was only one-third free of the boot but, generally, flowering occurred after the spike had entirely emerged. The spikes emerged from the boot at the rate of about one-half inch or more per day.

De-awning was performed on February 6, 1937. At that time, some spikes were in the flowering stage, some in the milk stage, and still others were in the soft dough stage.

The spikes were all harvested 34 days from the date of flowering, and since the dates of flowering were different, the dates of harvest were correspondingly different. Although spikes were de-awned at the three stages of development, each spike had exactly the same number of days in which to produce its grain.

As shown in table 22, de-awning produced a 11.3 per cent decrease in the fresh weight of the grain, and a 5.6 per cent decrease in the oven-dry weight of grain. The grain from awned spikes had 69.9 per cent of moisture (on a dry basis), and the grain from de-awned spikes, 59.2 per cent. The weight-reduction of grain, due to de-awning, compared in a general way with the results of the more extensive study made under field conditions. It is interesting to note that the grain from awned spikes had 10 per cent more water than the grain from de-awned spikes.

Table 22.--The effect of de-awning on the yield and water content of grain from spikes of wheat* grown in the greenhouse, 1936-37.

Date of flowering -1937-	No. of days between de-awning and harvest	Stage of growth at time of de-awning	Number of spikes	Fresh weight of 1000 grains gm.		Oven-dry weight of 1000 grains gm.		Per cent of water in grain (Dry basis)		Per cent decrease in fresh weight of grain, due to de-awning	Per cent decrease in oven-dry weight of grain due to de-awning
				From awned spikes	From de-awned spikes	From awned spikes	From de-awned spikes	From awned spikes	From de-awned spikes		
Jan. 21	18	Soft dough	6	63.2	64.9	36.8	37.8	71.7	71.7	+2.7	+0.2
" 23	20	" "	6	66.4	56.9	38.9	33.3	70.7	70.9	14.3	14.4
" 25	22	Milk	16	56.2	54.7	31.9	31.6	76.2	73.1	2.7	1.0
" 27	24	"	20	57.7	50.0	33.2	29.9	73.8	67.9	13.3	10.0
" 29	26	"	18	59.6	45.7	44.5	36.4	76.1	25.5	23.3	+5.2
" 31	28	"	12	59.9	52.4	33.5	31.7	77.6	65.2	12.5	5.4
Feb. 2	30	Flowering	16	57.4	52.2	34.3	31.8	67.3	64.2	9.1	7.3
" 4	32	"	18	46.1	43.2	30.0	30.2	53.7	43.0	6.2	+0.7
" 6	34	"	8	58.0	44.6	35.8	29.5	62.0	51.2	23.1	17.6
		Average--		58.3	51.6	34.9	32.5	69.9	59.2	11.3	5.6

*Pusa 52 x Federation

Although this study involved only a limited number of spikes, it supports the fact that there is an evident difference in the water content of the grain from awned and de-awned spikes. The de-awned spikes did not appear more mature than the awned spikes at the time of harvest. As the presence or absence of the awns was the only known variable factor in the two classes of spikes, it would seem that the awns function to increase the percentage of water in the grain. It may be that the activity of the awns as transpiring organs augmented the transpirational stream of awned spikes, while in the de-awned spikes the stream was less and drying out of the grain occurred more in the latter than in the former.

This study can serve only as a lead to a study which should be carried further with a large number of awned, de-awned, and awnless spikes under field conditions.

SUMMARY AND CONCLUSIONS

The awns of wheat were studied to determine (a) their role in the production of grain, and (b) their role in transpiration. The first of these studies was performed under field conditions at Manhattan, Kansas, during 1935-36; the latter, under greenhouse conditions during 1935-36 and 1936-37.

In the field studies, seven varieties of awned red winter wheat were used. The hard wheats were represented by Kanred, Tenmarq, Early Blackhull, Turkey, and Kanred x Hard Federation; the semi-hard wheats by Kawvale; and, the soft wheats by Fulcaster. In the greenhouse, the transpiration of the awns was studied on the variety, Pusa 52 x Federation.

Field Studies

In order to determine the function of the awns in the formation of grain, either half or all of the awns were removed by clipping at the periods of "before flowering", "at flowering", "3-8 days after flowering", and "9-12 days after flowering". Awned spikes served as controls.

The results of these studies showed that:

1. On the basis of 100 spikes, total de-awning produced the greatest weight- and per cent-decreases of grain when performed early, i.e., before or during flowering. The same was true for partial de-awning.

2. On the basis of 1000 grains, total de-awning produced the greatest weight- and per cent-decreases of grain when performed at flowering or the first period thereafter. Partial de-awning produced the greatest decreases when performed at or before flowering.

3. On the basis of 100 spikes, total and partial de-awning before flowering produced the greatest reduction in the number of grains.

4. The awns reached their maximum fresh weight on June 6; their maximum oven-dry weight on June 20.

5. The marked reduction in the oven-dry weight of awns just preceding maturity suggested the translocation of materials from the awns into the grain or other plant parts.

6. The amount and percentage of water in the awns decreased steadily from the maximum of the first weekly sample taken May 23 to a minimum in the sample taken at maturity on June 27.

7. The awns of wheat are believed to be photosynthetic organs which furnish manufactured foods for the nutrition of the grain.

8. The awns are probably storage places for certain inorganic nutrients which are later translocated to the developing grain.

Greenhouse Studies

The transpiration of the awns was determined by the Freeman method, which had been modified and improved to meet the specific requirements of this experiment. This method determined quantitatively the net transpiration of awned and de-awned spikes, and thus indicated the amount of transpiration attributable to the awns. The rate of transpiration of the spikes was followed daily from the first day of flowering through a period of 34 days until maturity. The results of these studies showed that:

1. The transpiration of the spike was decreased about 40 per cent by the removal of the awns. Although the total amount of transpiration for an awned or de-awned spike varied according to the stage of growth, the amount of transpiration attributable to the awns remained nearly constant until just preceding maturity. This variation may be due to the fact that the cuticular transpiration of the awns is greater in proportion to the stomatal transpiration as the spike approaches maturity.

2. The transpiration curves of awned and de-awned spikes from the time of flowering until maturity showed marked fluctuations. The peak of transpiration occurred about the third day after the onset of flowering. This peak was followed by a decrease which reached a minimum about the 8th day after flowering. The rate of transpiration then gradually increased to a second maximum which was maintained at a constant level until the 29th day after flowering, at which time the transpiration was again low. After that date, it increased to a third maximum and then again decreased to the minimum.

3. Although the awns of wheat are very active in the transpiration of the spike, they do not ordinarily transpire more than one to five per cent of the total amount of water lost from the wheat plant.

4. In arid regions the awns may be beneficial to the plant by aiding it to draw water up the stem to the spike.

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REFERENCES

(1) Aamodt, O. S., and Torrie, J. H.
The relation between awns and yield in spring wheat. Can. Jour. Res. 11(2):207-212. 1934.

(2) *Aumüller, Fr.
Die Bedeutung der Gerstengrannen [The significance of the beards in barley (In German) .] Illus. landw. Ztg. 41: 273-274. 1921. [Reviewed in Bot. Absts. 11(2):145. 1925.]

(3) Clark, J. Allen, Florell, Victor H., and Hooker, John R.
Inheritance of awnedness, yield, and quality in crosses between Bobs, Hard Federation, and Propo wheats at Davis, California. U.S. Dept. Agr. Tech. Bul. 39, 40 p. 1928.

(4) ________, and Quisenberry, Karl S.
Inheritance of yield and protein content in crosses of Marquis and Kota spring wheats grown in Montana. Jour. Agr. Res. 38(4):205-217. 1929.

(5) ________, __________, and Powers, LeRoy.
Inheritance of bunt reaction and other characters in Hope wheat crosses. Jour. Agr. Res. 46(5): 413-425. 1933.

(6) *Conti, Giuseppe.
Sulla funzione delle reste nei grani duri [Function of beards in hard wheats]. Ann. Tecnica Agrar. [Roma] 1(4): 419-422. (Latin abstract, p. 496.) 1929. [Reviewed in Biol. Absts. 7(4):800. 1933.]

(7) Field crop experiments in South Carolina. S. C. Exp. Sta. 42nd Ann. Rpt. 1929:22-23.

(8) Fittbogen, J.
Ueber die Beziehungen zwischen Wasserverdunstung und Assimilationsthätigkeit der Pflanzen. Die landw. Versuchs-Stat. 23:59-60. 1879.

(9) Gates, F. C.
Private communication. 1937.

(10) Gemmell, Geo.
Relation of the awn to yield in Kansas wheat. Kans. Acad. Sci., Trans. 36:89-90. 1933.

(11) Goulden, C. H., and Heatby, K. W.
A study of disease resistance and other varietal characters of wheat -- Application of the analysis of variance, and correlation. Sci. Agr. 9(9): 575-586. 1929.

(12) Grantham, A. E., and Groff, Frazier.
Occurrence of sterile spikelets in wheat. Jour. Agr. Res. 6(6): 235-250. 1916.

(13) ________.
Wheat investigations -- varieties. Del. Agr. Exp. Sta. Bul. 121, 49 p. 1918.

(14) ________.
Some observations on the behavior of bearded and smooth wheats. Amer. Soc. Agron., Jour. 14(3): 57-62. 1922.

(15) Harlan, Harry V., and Anthony, Stephen.
Development of barley kernels in normal and clipped spikes and the limitations of awnless and hooded varieties. Jour. Agr. Res. 19(9): 431-472. 1920.

(16) ________, and Pope, Merrit N.
Ash content of the awn, rachis, palea, and kernel of barley during growth and maturation. Jour. Agr. Res. 22(8):433-449. 1921.

(17) Hayes, Herbert Kendall, and Garber, Ralph John.
Breeding crop plants. New York. McGraw-Hill, 328 p. 1921.

(18) ________.
Inheritance of kernel and spike characters in crosses between varieties of _Triticum vulgare_. Minn. Univ. Studies in Biol. Sci. No. 4, p. 163-183. 1923.

(19) ________, and Aamodt, O. S.
A study of rust resistance in a cross between Marquis and Kota wheats. Jour. Agr. Res. 24(12): 997-1012. 1923.

(20) ________, ________, and Stevenson, F. J.
Correlation between yielding ability, reaction to certain diseases, and other characters of spring and winter wheats in rod-row trials. Amer. Soc. Agron., Jour. 19(10): 896-910. 1927.

(21) Hickman, J. F.
Comparative test of varieties of wheat. X. Ohio Agr. Exp. Sta. Bul., Sec. ser., 2(5): 121-132. 1889.

(22) Hickman, J. F.
Comparative tests of varieties of wheat. XV. Ohio Agr. Exp. Sta. Bul., Sec. ser., 3(6):184-205. 1890.

(23) Johnston, C. O.
Private communication. 1937.

(24) *Kadam, B. S., and Nazareth, B.
Inheritance of awn colour in wheat. Indian Jour. Agr. Sci. 1(6):663-670. 1931. [Reviewed in Exp. Sta. Rec. 67:229. 1933.]

(25) * [Meister, G. K., Shekhurdin, A. P., and Plotnikov, N. IA.]
[Increase in dry substance in seed of different spring wheats and utilization of poorly developed seed in seeding (In Russian) (With German resume)]. Jour. Exp. Landwirtsch. Sudösten Russl. 3(2):134-153. 1927. [Reviewed in Biol. Absts. 3(1-3):70. 1929.]

(26) Miller, Edwin C.
Plant physiology. New York and London. McGraw-Hill, 900 p. 1931.

(27) Parker, John H.
Relation of the awn to yield in Kansas wheat. Northwestern Miller, 178:180. 1934.

(28) Percival, John.
The wheat plant -- A monograph. New York. E. P. Dutton, 463 p. 1921.

(29) Perlitius, Ludwig.
Der Einfluss der Begrannung auf die Wasserverdunstung der Ahren und die Kornqualität. Inaug.-Diss., Univ. of Breslau, Merseberg. 77 p. 1903.

(30) * ________.
Einfluss der Begrannung auf die Wasserverdunstung der Aehren und die Kornqualität. Deut. landw. Presse 30 (50):450. 1903. [Reviewed in Bot. Cent. 93:141-142. 1903.]

(31) * ________.
Influence of the awns on the transpiration of the spike and the quality of the grain. Mitt. landw. Inst., Univ. of Breslau, 2(2):305-381. 1903. (Abst.) Deut. landw. Presse 30(50):450-451. 1903. [Reviewed in Exp. Sta. Rec. 15:247. 1904.]

(32) Rosenquist, C. E.
The influence of the awn upon the development of the kernel of wheat. Amer. Soc. Agron., Jour. 28(4):284-288. 1936.

(33) Scarth, George W.
Mechanism of the action of light and other factors on stomatal movement. Plant Physiol. 7(3):481-504. 1932.

(34) Schmid, B.
Bau und Funktionen der Grannen unserer Getreidearten. Bot. Cent. 76:1-9, 36-41, 70-76, 118-128, 156-166, 212-221, 264-270, 301-307, 328-334. 1898.

(35) *Schulze, E. W.
Comparative investigations on the transpiration of barley with and without awns. Mitt. landw. Lehrkanz. K. K. Hochsch. Bodenkul. Wien, 1(3):285-308. 1913. [Reviewed in Exp. Sta. Rec. 29:135. 1914.]

(36) Stevens, Harland.
The value of the awn in wheat and barley. Kans. Agr. Student, 10(2):35-36. 1930.

(37) *The function of awns on an ear of barley. (Abst.) Fühling's landw. Ztg. 43(23):745. 1894. [Reviewed in Exp. Sta. Rec. 6:506. 1896.]

(38) *The lower price of beardless wheats in comparison with bearded wheats. Coltivatore, 56(34):503. 1910. (Abst.) Int. Inst. Agr. Rome , Bul. Bur. Agr. Intel. and Plant Diseases, 2(1):81-82. 1911. [Reviewed in Exp. Sta. Rec. 26:43. 1912.]

(39) *Treyakov, S.
Influence of the awns of grasses.. Khozyaēne, 1902(6): 188-191. (Abst.) Zhur. Opuitn. Agron. [Jour. Expt. Landwirtsch.] 3(2):239-240. 1902. [Reviewed in Exp. Sta. Rec. 14:839. 1903.]

(40) *Vasilyev, N. I.
On the role of the awns of Gramineae. Zap. Novo-Alexandri Inst. Selsk. Khoz. i Lyesov. 10(2):119-168. 1897. [Reviewed in Exp. Sta. Rec. 10:718. 1899.]

(41) *Zoebl, A., and Mikosch, C.
Die Function der Grannen der Gerstenähre. Sitzungsber. d. k. Akad. d. Wissensch. in Wien. 1892. Math.-naturw. Cl. 101(1):1033-1060. (Abst.) Ann. Agron. 21(3):143-144. [Reviewed in Bot. Cent. 54:240. 1893.]

*Note: Original article not seen.

Plate I. Representative spikes of the varieties of wheat used in the field studies. 1, Kawvale; 2, Fulcaster; 3, Kanred; 4, Tenmarq; 5, Turkey; 6, Early Blackhull; and, 7, Kanred x Hard Federation. Taken June 11, 1936.

(Length of Kawvale spike, 6.5 inches)


1
2
3
4
5
6
7
06260

Plate II. Spikes of Kawvale wheat on June 11, 1936. 1, Typical, awned spike (control); 2, Partially de-awned spike; and 3, Totally de-awned spike.

(Length of the awned spike, 6.0 inches)

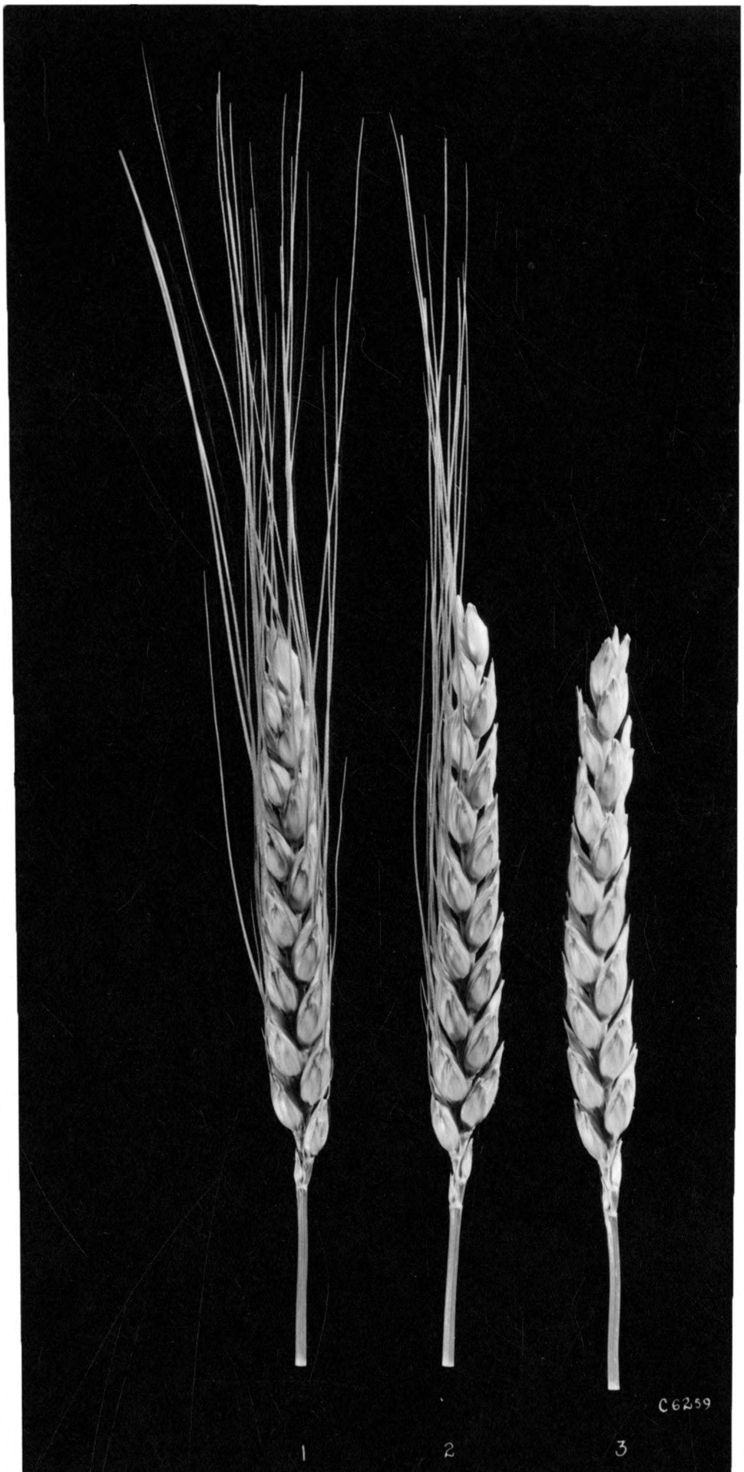
C6259
1
2
3

Plate III. Intact, awned spikes, de-awned spikes, detached and intact awns, rachises, grain, and glumes.


6
5
4
3
2
1
C 6330

Plate IV. Totally de-awned and intact, awned spikes of Pusa 52 x Federation wheat, as grown in the greenhouse at Manhattan, Kansas. (Taken February 15, 1936.)


INCHES

Plate V. Typical jars of Pusa 52 x Federation wheat, showing the condition of the plants on February 8, 1936, when the plants were 75 cm. high.

(Planting date, October 25, 1935.)


15
45

Plate V'. The Freeman apparatus, as used in the transpiration experiments of 1935-36. Description in text.

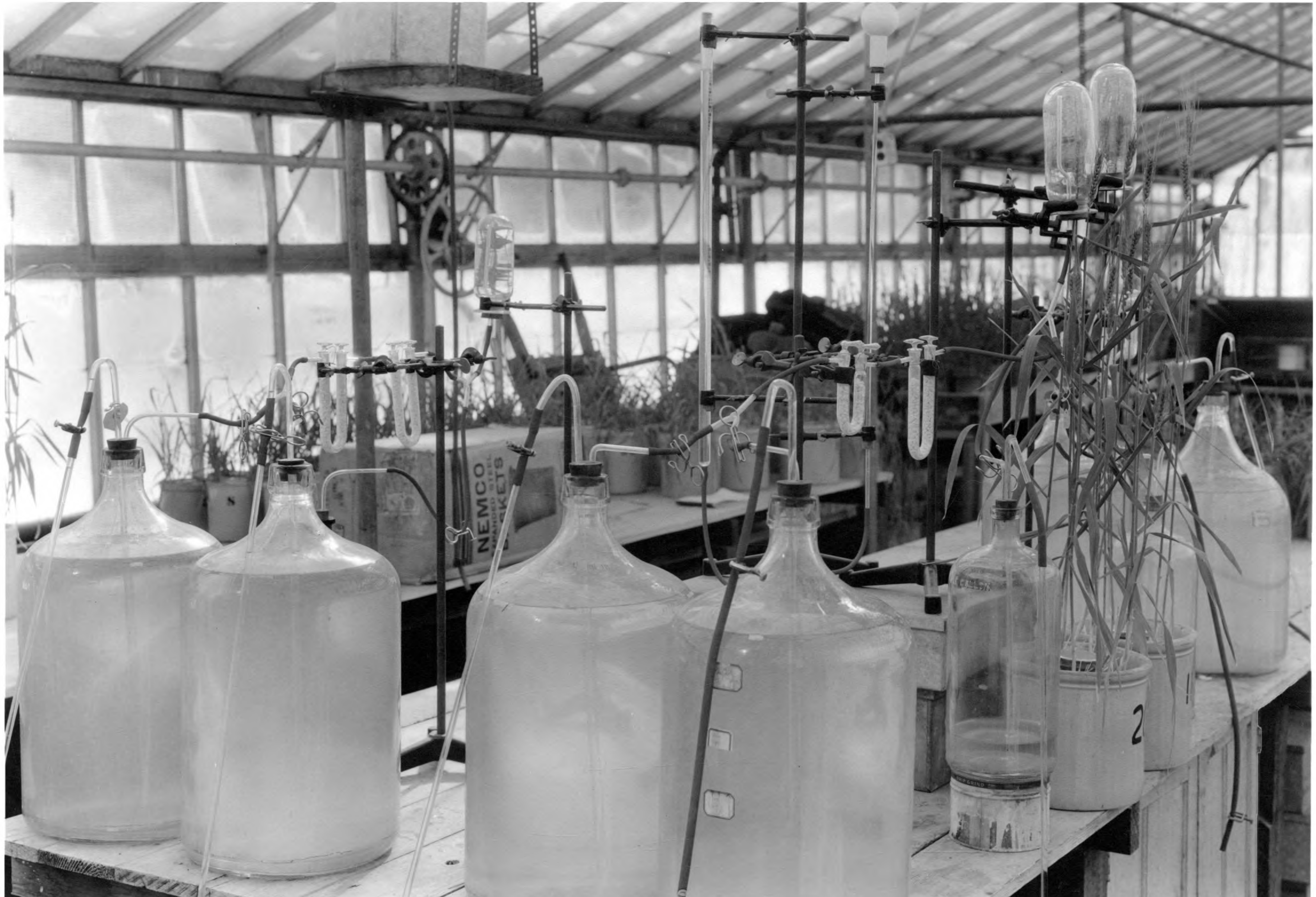
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Plate VI. The Freeman apparatus as used during 1936-37 in a study of the transpiration of the wheat awns, under greenhouse conditions. The modifications of this apparatus, as compared with that used in the experiments of 1935-36, are described in the text.


15

Plate VII. Another view of the Freeman apparatus, as used during 1936-37 in a study of the transpiration of wheat awns under greenhouse conditions. (Description same as that given for Plate VII, in text.)


23

Plate VIII. Volumetric comparison of the grain from awned and totally de-awned spikes of Kanred wheat grown at Manhattan, Kansas, during 1935-36.

Reading from left to right: May 27, May 29, and June 9, 1936.

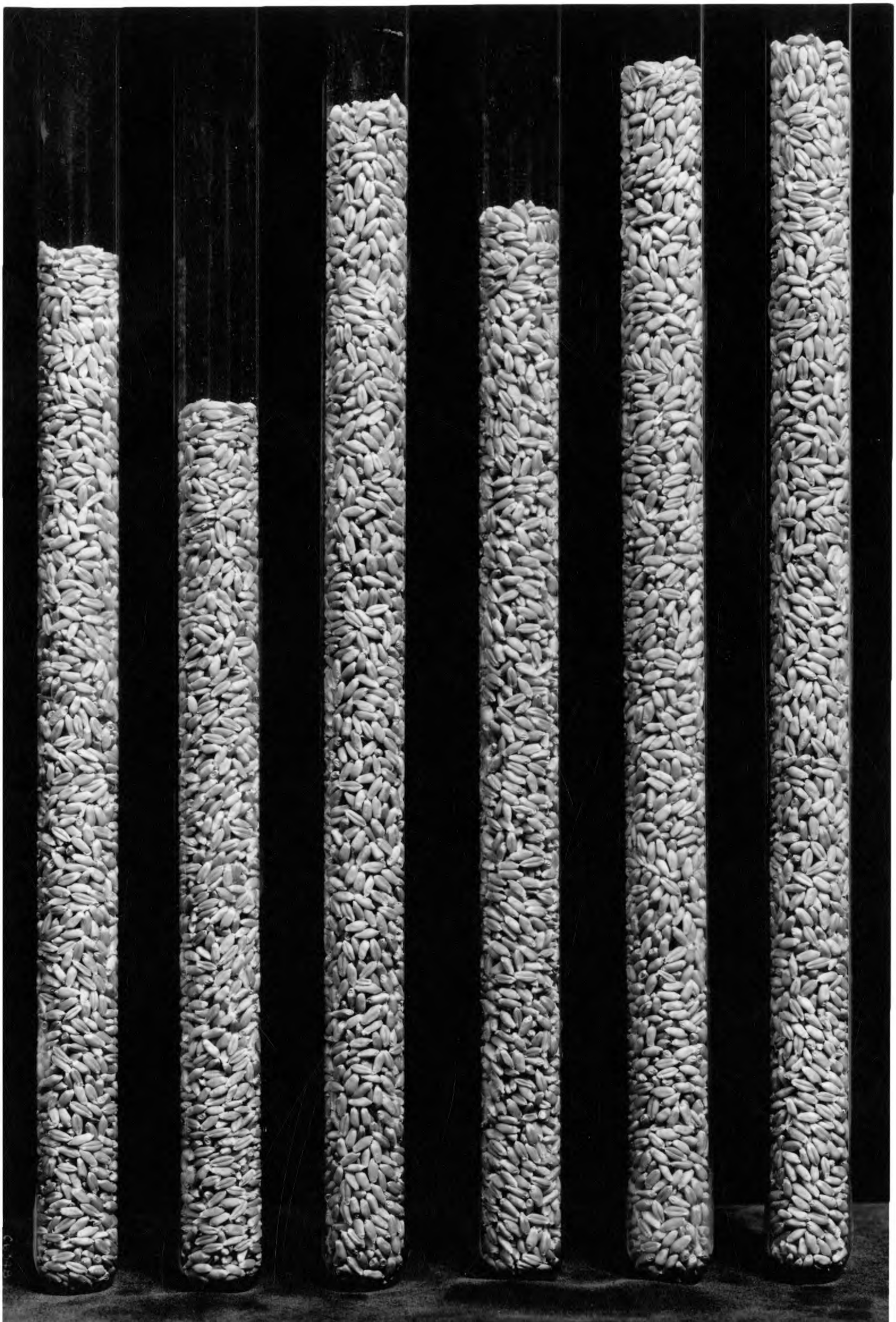

Plate IX. Volumetric comparison of the grain from awned and partially de-awned spikes of Kanred wheat grown at Manhattan, Kansas, during 1935-36.

Reading from left to right: May 27, May 29, and June 9, 1936.

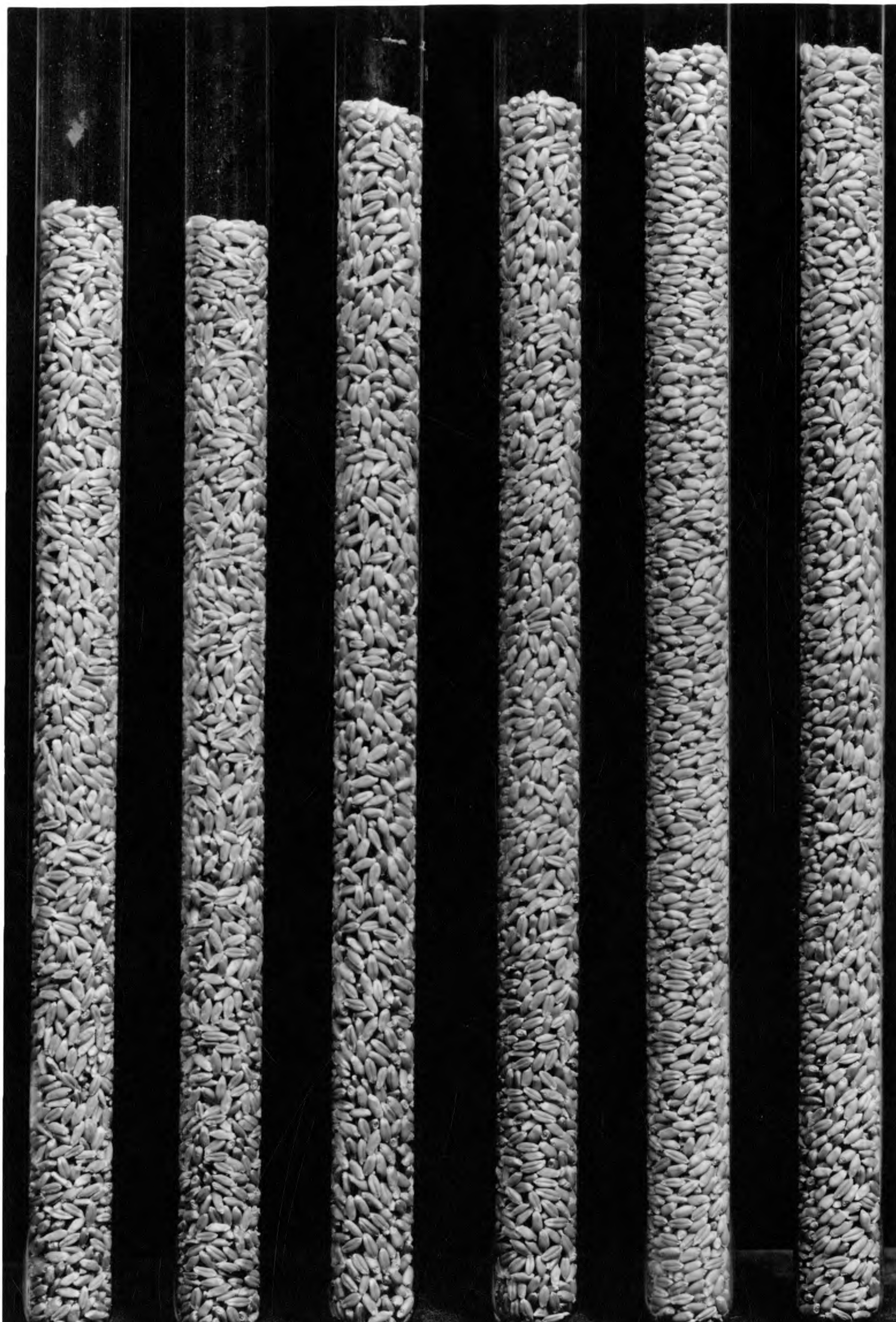

Plate X. Volumetric comparison of the grain from awned and totally de-awned spikes of Fulcaster wheat grown at Manhattan, Kansas, during 1935-36.

Reading from left to right: May 28, May 29, and June 6, 1936.

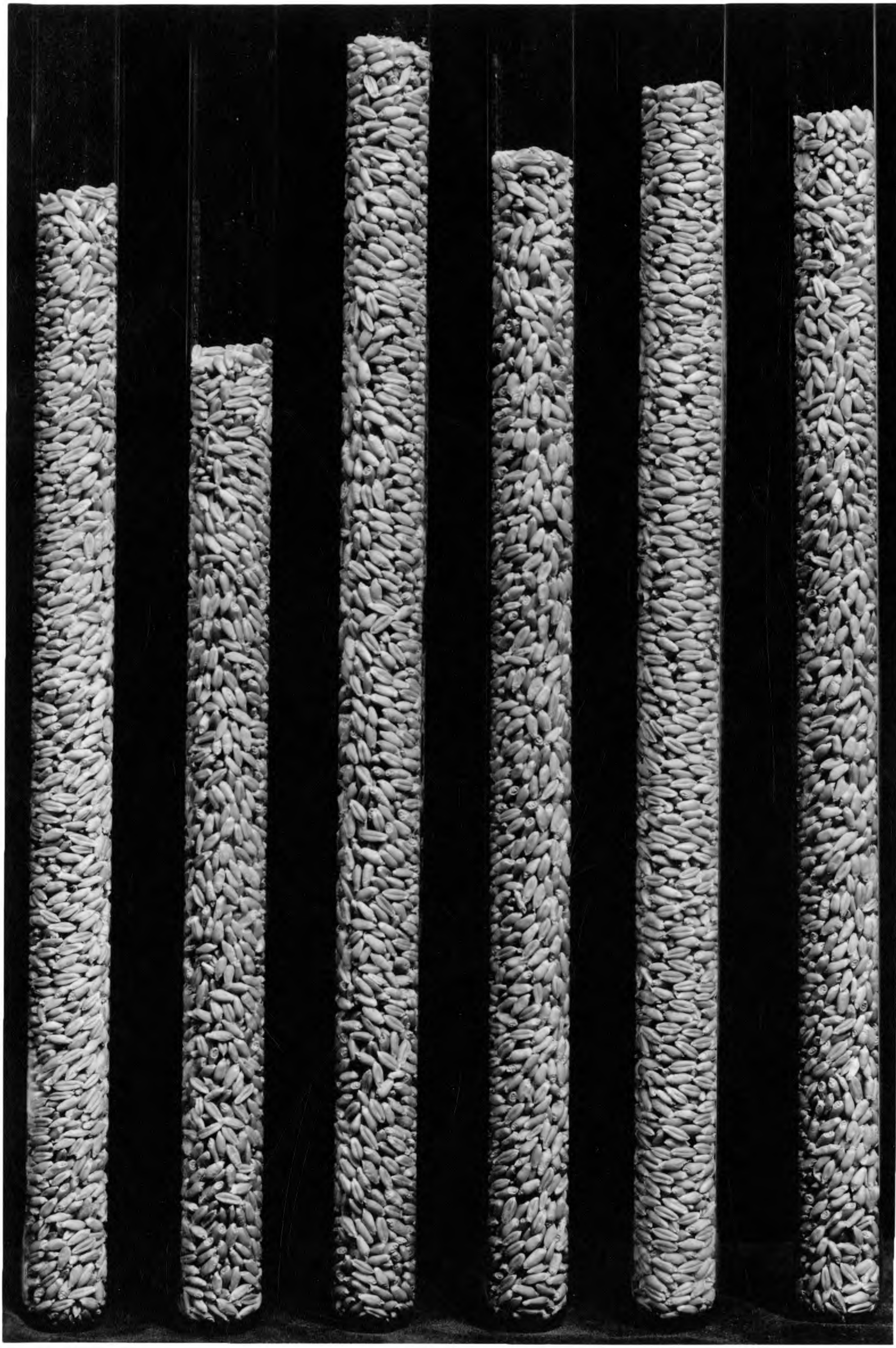

Plate XI. Volumetric comparison of the grain from awned and partially de-awned spikes of Fulcaster wheat grown at Manhattan, Kansas, during 1935-36.

Reading from left to right: May 28, May 29, and June 6, 1936.

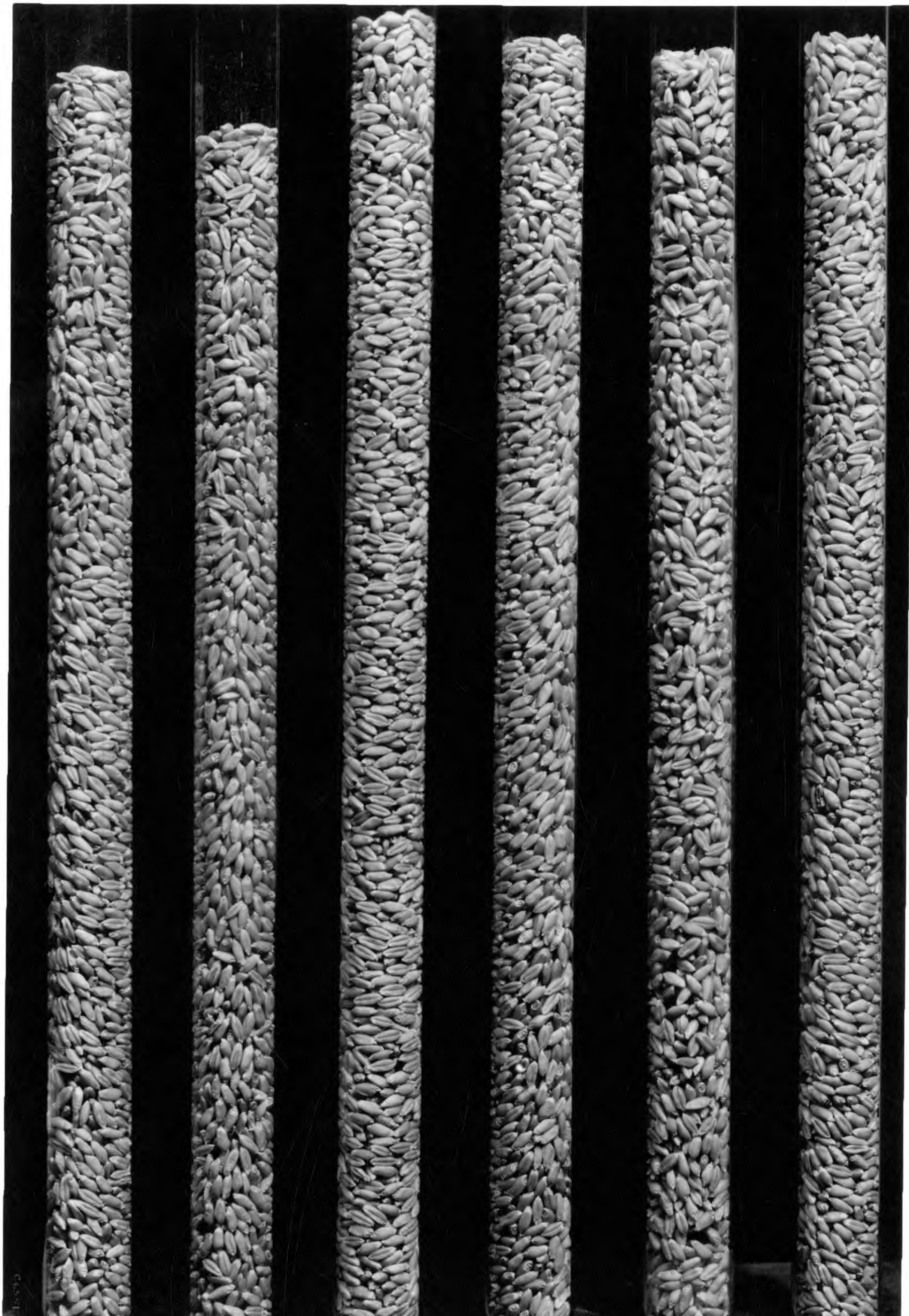

Plate XII. Volumetric comparison of the grain from the awned and de-awned florets of the same 100 partially de-awned spikes of Turkey wheat grown at Manhattan, Kansas, during 1935-36.

Reading from left to right: May 26, May 26, and June 10, 1936.