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Yellow-berry in Wheat
ITS CAUSE AND PREVENTION

By WM. P. HEADDEN

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YELLOW-BERRY IN WHEAT—ITS CAUSE AND PREVENTION

By Wm. P. Headden

In the prosecution of the study of Colorado wheats which we now have been carrying on for two years, we find that the condition designated as yellow-berry constitutes one phase of it which we think is of sufficient interest to justify us in presenting it at this time.

The question is in no way a new one, still there seems to be considerable confusion regarding it, while its cause has been assigned to very different agencies and no positive claim made to any direct means for its prevention.

The term "yellow-berry" is used to designate a condition of the wheat kernel which gives it a mottled appearance, due to internal white spots. In bad cases, the whole berry may be affected, when its color will vary from white to a light yellow according to the color of the outer layers or covering of the kernel. Such kernels are more or less opaque when viewed in transmitted light. Normal kernels are uniformly flinty or glassy in appearance and are translucent when viewed in transmitted light.

I do not know when the first mention of it was made, but it evidently existed in Hungary in 1900, for Kosutany in his work on "Der Ungarische Weizen und das Ungarishe Mehl" makes definite mention of flinty, mealy and half-mealy kernels. I take it further that his expression "degree of mealinness," as applied to wheat, is probably nothing else than the extent to which the grain was affected by what we call yellow-berry. I suppose that it was well known before this, for it is spoken of in such matter of fact way, without further description or definition, that one assumes it to have been considered by the author as a familiar subject. This, however, is the first mention of it that I know of in such a way as to indicate a general condition of a crop. As just stated, there is no further comment on its characteristics. The grain is specified as flinty, mealy and half-mealy. There is no question but that these different kinds of kernels occur in the same variety and lot of wheat for the percentage of each kind of kernel is given. Schinder in Der Getreidebau, 1907, also mentions mealy and half-mealy kernels.

The next definite mention that I find of it was by H. L. Bolley. South Dakota Station Report 1904, pp. 35-36. Next by Lyon and Keyser, Nebraska Bulletin 89, 1905. These authors seem to have
had their attention directed to the subject by the complaints of farmers, grain dealers, and millers. Their statement is that the investigation of this subject was begun in 1902. Following this in 1908, Bulletin 156 of the Kansas Experiment Station on "The Yellow-berry Problem in Kansas Hard Wheats" appeared. It would appear that others, among them Prof. H. Snyder of Minnesota Experiment Station, had discussed the same question without designating it by any special name.

The first and most important question regards its effects upon the quality of the grain. I find no definite data given upon this subject. Lyon and Keyser give a measure of the injury to the Nebraska crop in terms of loss to the farmer. This is put down at from one-half to one million dollars annually. This was the estimated loss on a market where the wheat was not sharply graded, many of the millers making no difference at all in the price. I have been informed that Kansas and Oklahoma at times have suffered to a much greater extent in the matter of market values than Nebraska, because their wheat sought a market where the grading was much stricter. I have found an instance in Colorado in which a mill would not buy yellow-berry wheat, at any price. The reason given me was that one could not be sure of the quality of the flour turned out. This particular mill was blending winter and spring wheats. The sample in question was a winter wheat, Turkey Red, and was very badly affected by yellow-berry. That the generally accepted effect of this affection on the value of the wheat is a detrimental one, is indicated by the use of the term "deteriorated wheat." We find this term used quite frequently when it is difficult to know just what is meant by it.

Lyon and Keyser established the fact that the yellow-berry kernels contained less nitrogen than the flinty or horny ones, so that there is more in the problem than a prejudice on the part of the wheat-buyers. If we are correct in using the percentage of nitrogen present in wheat as a measure of its value, these yellow-berrys are really inferior to the flinty ones, and this is a good reason why they should command a lower price.

If there is any sharp and satisfactory distinction between the use of the terms yellow-berry and soft wheats, I have failed to notice it. I am strongly inclined to think that such a distinction should be made, but it does not seem to have been made and there is certainly some confusion. The California and Oregon wheats are spoken of as soft, starchy wheats. The yellow-berry wheats are spoken of in the same way, but that the same thing is meant in the two cases is not clear. It is, however, true, I think, that they are low in protein, high in starch, and light in color. Wheats af-
fected by yellow-berry are, especially when the whole berry is involved, white, or, if the outer covering is highly colored, yellowish. They are always opaque. This is an extreme condition. The whole of the berry may not be involved, and then the portion not involved is translucent. The Defiance, a spring wheat, is normally a medium amber colored, translucent wheat, but when affected by the yellow-berry may be wholly of a dull white color and opaque. I really do not know the proper classification of our Defiance wheat. It certainly belongs to the light colored spring wheats, but it cannot be said to be low in nitrogen as it ranges from 1.8 to 2.4 per cent, for samples taken over two consecutive years. If we express this in terms of protein we have, using 6.25 as our factor, from 11.25 to 15.0 percent protein, or using 5.7 as a factor, we have from 10.26 to 13.08 percent protein, so that there seems to be a satisfactory amount of protein present and the starch cannot be excessively high. Still a normal kernel of this wheat is a very different thing from one wholly affected with the yellow-berry which is white, opaque, and has a certain roughness, the appearance of a loose structure. All such kernels when crushed between the teeth are soft and mealy.

The affection may occur in one or in both halves of the kernel as a sharply defined spot, either large or small, so that we find the kernels designated as “spotted.” One-half of the kernel may be involved throughout or there may be a strip along the back of the kernel. When viewed in transmitted light, we often observe the affection as small, opaque spots, or one-half of the berry is either opaque or more or less strongly clouded. It follows that when viewed in transmitted light, we have kernels wholly translucent, translucent with dark spots, one-half translucent, or cloudy and wholly opaque.

Writers on this subject are agreed that it is a more or less serious affection. They also agree in regard to its appearance, but when they come to consider the cause of it they are not agreed at all. So far as I can find, only three of the works mentioned assign any cause. Prof. H. L. Bolley in the North Dakota Station report, 1904, part I, pp. 35-36, seems to have been the first to assign a definite cause for it. It seems, however, to have been referred to before this, but in such a general way that subsequent explanation is required to definitely relate the statements to this affection. Prof. Bolley says:

"Considerable attention has been given to the cause of starchy, spotted grains in hard winter wheats, the trouble being known locally as 'White belly.' Grains of this character are generally graded as soft wheats and are believed to be inferior to the hard wheats of the North-
west. A number of experiments were carried on in which germination trials, microscopical tests, and cross-fertilization trials were made and also the effect studied of exposure of harvested bundles to the ordinary weather conditions."

"From the results the author believes that the white spots are not due to crossing, nor are they matters of heredity, but that this peculiar mottling is due to the action of moisture, air and sun upon the grain while it is yet in the chaff. If the weather action is long continued the grains become evenly bleached over the entire surface. The color and hardness of the grain can be maintained by proper care in harvesting and curing."

It must be borne in mind that Prof. Bolley's conclusions are based upon the results of experiments and observations made for the purpose of discovering the cause of this affection and these conclusions exclude crossing and heredity as causes of it, but predicate the action of moisture, air and sun as its cause and care on the part of the owner as its cure or rather that it can thereby be avoided.

Lyon and Keyser arrived at a similar conclusion based upon very similar experiments. Lyon and Keyser, Nebraska Bul. 89, (1900), p. 27, say:

"To see if the Yellow-berries were due to bleaching by sun and weather after harvest, sheaves were taken from the same portion of the same plot, one-half being left exposed and the other half cured in a dry room which was only moderately lighted. The sheaves were cut July 10, 1903. The exposed bundle was left out until Aug. 21, 1903, the only protection given being a frame of wire netting having a mesh small enough to keep out sparrows. In September the bundles were carefully thrashed and the grain separated into two portions, 'Yellow Berry' and 'Horny Red,' keeping each bundle by itself. The bundle kept in a dry dark room had twenty-five per cent of yellow-berries, while the exposed bundle had ninety-seven and two-tenths per cent yellow-berries."

"Other noticeable changes took place. The grain from the protected bundle was bright and of good, clear color. The grain from the exposed bundle was very much discolored and so badly bleached as not to be marketable."

This experiment was repeated in 1904 with practically the same result. These authors also investigated the effect of the degree of maturity or the time of cutting upon the amount of yellow-berry. The result was that grain cut 7 July, 1904, contained seven and six-tenths percent, and that cut when over-ripe nineteen percent, an increase of eleven percent. The relation of the weather, character of the season, was also considered. On investigating this subject they arrived at the following conclusions:

"In the crop of 1901 there was 10.5 per cent; in the 1902 crop 4.3 per cent; in the 1903 crop 25 per cent of yellow-berries, and in the crop of 1904, 20 per cent of yellow-berries. There is quite a definite relation between the per cent of yellow-berries in the crop and the character of
the season in so far as the latter affects the date of ripening, the composition and the yield of wheat."

The authors base a suggestion for the lessening of the percentage of yellow-berries upon these observed facts, recommending early cutting and prompt stacking. They further discuss the composition of the 'Horny Red' and the 'Yellow Berries,' showing that there is a decided difference in this respect, the horny kernels being the richer in nitrogen and also the heavier; further, that the yellow-berries had larger starch grains and more air spaces, vacuoles, and cite Nowachi¹ as suggesting "as early as 1870 that the difference in appearance between mealy and horny wheat kernels is due to the presence in the former of a larger volume of air spaces than in the latter." Again they say: "It appears that large starch granules and large and numerous vacuoles are associated in yellow kernels, the white appearance of the endosperm being due doubtless to the latter."

They also quote Hackel² as follows:

"If the albumenoids so fill up the intervals between the starch grains that the latter seem to be imbedded in cement, the albumen appears translucent and the fruit is called corneous; but if the union is less intimate, there remain numerous small air cavities and the albumen is opaque and the fruit is mealy. Both conditions may occur in the same variety (wheat) and they seem to be occasioned by differences in climate and soil."

In their summary, p. 50, they again formulate these conclusions admirably as follows:

"'Yellow-berry' in hard winter wheat causes an annual loss to the wheat raisers of Nebraska of from one-half to one million of dollars. The chief cause of this condition is allowing wheat to become over-ripe and failure to stack the sheaves.

"'Yellow-berries' as compared with hard, red ones have a lower gluten content, and are lighter in weight."

In 1908, Professors Roberts and Freeman, Kansas Bul. 156 discussed the subject under the title, "The Yellow-berry Problem in Kansas Hard Winter Wheat." This yellow-berry is considered the most serious problem confronting the wheat growers of Kansas and the characteristics of the affection are described in detail. The yellow-berry is sharply distinguished from berries bleached by exposure, which seems to me a fair distinction and one not heretofore made. The authors say:

"It should further be emphasized that the bleached, opaque grains due to weathering are not yellow-berries. In weathered kernels the grain has an opaque and rather dirty, grayish yellow aspect which ap-

¹. Untersuchungen über das Reifen des Getreides. Halle, 1870, pp. 76-77.
appearance affects the grading of the grain adversely, but is not necessarily associated with an inferior condition of the kernel, although such frequently is the result of exposure to the weather."

While this statement stands in opposition to the conclusions of the preceding investigators, it seems to me to be worthy of consideration. If I understand Lyon and Keyser aright, they claim that there was a decided increase of yellow-berry after the grain was cut, but do not claim that all of the weathering effects are to be classed as yellow-berry. On the contrary, the statements that they make tend to convey the idea that they attribute the increase in the amount of yellow-berry after cutting to the continued absorption of carbohydrates from the plant after cutting, still their statement of the chief cause includes weathering after cutting. The view presented in the Kansas bulletin is that the yellow-berry is caused by some physiological condition and is a heritable quality as the following statements show:

"The yellow-berry, then, appears to be distinctly a physiological growth product due to certain conditions thus far not clearly analyzed or satisfactorily explained. The essential thing, from the practical standpoint is to discover whether pure stocks of wheat can be found which produce constantly a minimum amount of yellow-berry in the hard wheat region and in localities in which the yellow-berry ordinarily occurs."

These writers consider the subject an important one for Kansas and refer to it as a factor in the deterioration of their wheat.

"Any factor that brings about deterioration in the grade of this wheat (Kansas winter wheat, H.) calls for serious investigation. The yellow-berry is such a factor. The presence of the yellow-berry in any quantity in our hard wheat affects unfavorably its commercial grading and its market price."

As to the cause of it, or to what they believe to be the cause of it, they are not as definite as could be desired. I have already stated that they consider it a "physiological growth product" and that it is an heritable character, still, as is readily understood, climate and growing conditions in general, are not without influence. These authors evidently consider them of great importance for they approvingly quote Schindler, Der Weizen, Berlin, 1895, as follows:

"With the length of the vegetative period, especially with the extent of the interval between blossoming and ripening, not only the dimensions of the kernel increase but also the quantity of carbohydrates stored therein, while the protein content diminishes." * * *

"It is not justifiable to speak of the size of the kernel and the protein content of the berry as 'race characters.' They may be such to a certain limited extent, but the influence of the race will in this connection be far exceeded by the influence of the climate and partly also by the soil and cultivation."
The quotation continues to set forth the dependence of the character of the grain, i.e., whether it is starchy or rich in protein upon conditions of growth, especially upon weather conditions. It also discusses the effects of transferring a wheat, “endemic” to a given climate, to a different one, especially to a hotter and drier one. The application of this quotation seems to depend upon its bearing upon the relative quantities of protein and starch produced in the berry. The fundamental distinction between the flinty and yellow-berry is plainly considered to be their relative richness in protein or in starch. I do not understand from the quotation that the author, Schindler, had the yellow-berry condition specifically in mind but the relation of the protein content to that of the starch. This may be a part of the yellow-berry problem. It evidently is, but we may have high or low protein without our special affection of yellow-berry. Two different samples of the same variety of wheat, each equally free from yellow-berry, may vary quite as much in their protein content as two samples, one of which is affected with the yellow-berry and the other not. Still, it must be acknowledged, that the chief difference effected in the composition of the wheat is, so far as we know, precisely this, i.e., a lower protein and a higher starch content, but the physical characters of the kernels are very different from normal berries. There can be no doubt about Schindler’s attaching great importance to the weather conditions, for he is quoted as saying:

"From these considerations it undisputably follows that even in one and the same locality and with the same variety, the relation between protein and starch must be a variable one according to the weather conditions, even though it is to be admitted that individual sorts or races, as the case may be, may possess for themselves an especially different energy of assimilation. It is certain, however, that this latter in its final effect stands far behind that of climate and of the weather."

There can be no doubt that the author intends to attribute a determinative influence upon the composition of wheat to the climatic factors whether he had the yellow-berry in mind or not. The authors, Roberts and Freeman, evidently consider the yellow-berry something more than an abnormal ratio between the protein and starch content of wheat, for they say that:

"The yellow-berry is a case of not merely a failure to form the normal amount of gluten but probably also of a corresponding failure on the part of the plant to compensate by a relative increase in the starch content."

It is not evident upon what they base this opinion, at least, I have found no definite data given except the nitrogen determinations made and given in the Nebraska Bulletin 89. I suppose that this judgment is based upon their knowledge of the physical prop-
erties of the berries. These would appeal to most persons familiar with them as quite sufficient to justify the opinion expressed. But, whatever the composition and properties of these berries may have been, they (Roberts and Freeman) assume that climatic factors are, above all others, important in determining these and set themselves the task of finding out the critical period in the development of the grain, or that period when it is most susceptible to the action of those factors determining the yellow-berry. They experimented with winter wheat and consequently have two periods of growth, the autumn and spring periods. They find that the longer the autumnal period, especially with favorable conditions in the early part of the period, the higher the percentage of yellow-berry. In the season 1905-06, they found for wheat planted 28 September in moist soil 53.80 percent yellow-berry; for wheat planted 16 October in rather dry soil 19.58 percent yellow-berry. They find in these results, the two quoted are the extremes of a series, a relation between the length of the autumn growing period and the amount of yellow-berry produced. In 1906-07 they obtain results of the same significance; a difference of thirteen days in planting is followed by a difference of 12 percent in the yellow-berries. This difference was, as in the preceding year, in favor of the late planting, this giving the lower percentage of yellow-berry. They divided the spring into practically three periods, and studied the effect of the mean temperature and rainfall and also considered the whole of the spring growing period; so that they treated of the whole period from first heading to maturity, for three weeks before maturity, and for two weeks before maturity. I can do no better than to give their own words to state their results.

"If we attempt to interpret the effect of these combined influences in terms of the rapidity of growth of the plants and of the ripening of the grain, and to correlate them with the percentage production of yellow-berry, we shall find, as previously stated, that the prevalent idea that slow ripening is correlated with high percentages of yellow-berry is apparently justified by the data collected from our wheat cultures for 1906-07 when the total averages for the two years are compared. When, however, the data for the different varieties within a given season are considered, this rule does not hold. Now, since it is improbable that influences that would operate as between different seasons to bring about such a result would fail to operate in a given season, there must, therefore, be other factors which complicate the results, and which are not analyzable without taking into consideration data with reference not alone to climatological conditions but also to the hereditary tendencies of the varieties concerned."

These sentences state as clearly as can be stated the conclusion at which Roberts and Freeman arrived, though they subsequently.
and perhaps concurrently, with the experiments on which this conclusion is based, made quite a series of experiments upon, "Individual and varietal inheritance of yellow-berry," the conclusion of which does not seem to be altogether satisfactory or decisive. Not being, perhaps, a competent judge, I will not venture to formulate a conclusion, but will again give the authors' own language.

"In view of the fact that but one head from each plant of the pedigree stocks had to furnish the grains on which an estimate of the percentage yield of yellow-berry in the plant as a whole was based, the result is really surprisingly confirmatory of our hypothesis that the yellow-berry is a 'tendency' which finds expression in certain strains or races more markedly than in others, and is heritable."

"In so far as this is the case, the yellow-berry problem is one which is capable of being handled by the breeder with a view to the propagation of pure strains of wheat which may be found free from the yellow-berry under all conditions. It, therefore seems reasonable to hope that from a group of pure strains of pedigree wheats producing no yellow-berry for two successive years—which we have—a race of wheat may be derived which will go entirely wide of this tendency to deterioration in the product."

I believe that this quotation presents the conclusion which the authors would have us draw from their results as clearly and fairly as they have anywhere stated it. One thing seems clear, that is, that while they admit that the weather influences the development of yellow-berry they sought throughout their work some specific cause for it and think that it is to be found in some inherent quality in the strain or race of wheat which may be strengthened by climatic conditions and the length of the growing season.

In 1913 Prof. H. L. Bolley of North Dakota returns to the subject in Bulletin 107 of that station entitled "Wheat; Soil Troubles and Seed Deterioration; Causes of Soil Sickness in Wheat Lands; Possible Methods of Control; Cropping Methods in Wheat." We are concerned only with what he says regarding the subject of yellow-berry. Prof. Bolley throughout this bulletin speaks of deteriorated wheat and seems to include under this term a variety of things which evidently may have different causes, for, as Prof. Bolley himself states, the problem is a complex one, but he gives us no clear analysis of the deterioration had in mind and appeals to diseases of the plant to account for deterioration in general. There is no doubt but that Prof. Bolley is entirely correct in maintaining that disease may cause the death of plants or curtail their productiveness, but he seems to attribute practically all deterioration to disease, or infestation of some kind, and to minimize the current teaching relative to the importance of those questions of food supply in the soil, generally had in mind when we speak of
fertility. He seems to take exception to the stress laid, by chemists in particular, upon these questions, with which I have no quarrel, and it is not my intention, in this place at least, to take any exceptions to his views. This is in no way my purpose, but simply to give such quotations as may faithfully present his views upon the question forming the subject of this bulletin. Under the caption "Symptoms of Deterioration as noted in Soil and Seed," he uses the following language:

"The history of wheat cropping shows that at first new lands yield bounteously in quantity and quality, but in a comparatively few years an evident deterioration of the seed produced sets in. The fall in bushelage per acre is not more marked or more rapid than the deterioration in quality as to plumpness of grain, flour content, hardness, color and other characteristics. By almost common consent, many agriculturists, chemists, biologists, millers and farmers have assumed, when such conditions of the crop arise after more or less continuous cropping to wheat and other cereals, that the lands have 'deteriorated.' The symptoms as observed in the slow growth of the crop, the dying out of young plants, the blighting, 'tip-burning,' 'sun-scalding' and discoloration of the young plants, the weakness of the straw, the shrivelled seed, the common deficiency in proteid content of the grain have all been taken as indicating improper food relations."

"I think I am safe in saying that it has been quite commonly assumed that lost nitrogen, phosphate, lime or other plant food deficiencies are to be expected under such cropping conditions. Furthermore, chemists, as they measure availability of plant food, have found that such old soils often show more or less change in the available plant food. The writer, knowing as he does that a wheat plant can extract essentially all of the available material of a particular food element from the soil before showing noticeable change in its growth relations has always doubted that the general conclusions of soil deterioration under such cropping conditions is justifiable; for there are many fertile soils which fail to produce normal wheat, and there are some very poor, weak soils which produce nice, properly colored milling wheat. These, so-called, deteriorated wheat soils produce high yields and quality in other crops."

It is evident that the deterioration here had in mind includes plumpness of the grains, the flour that they will yield, their color and hardness. In the quotation given, and also in other portions of the bulletin, he plainly questions the correctness of the general assumption that there is a relation between the food supply in the soil and these conditions, especially that there has been a soil deterioration in this respect, or, as it is commonly expressed, in soil fertility. The author even goes further and asserts that the application of farmyard manure may even produce "disastrous results" in the nature of soft, overgrown straw and shrivelled, off-grade grain. His interpretation of this is that it shows that the land
has not deteriorated. The author further strengthens his position by discussing new and virgin lands, still to be found in their wheat-growing sections, but I will quote his own words.

"New and virgin lands remaining in the wheat belt unplowed, even though they represent select areas of land, when plowed and sowed to wheat, under present conditions, cannot now as in early days be relied upon to produce the quality of wheat then produced on immediately adjacent lands. As often as otherwise the crop is apt to produce light weight, off-colored, 'spotted,' 'white-bellied,' 'black-pointed,' 'pie-bald,' shrivelled grain upon a rag-like, light weight straw. Because of these facts, many of our most able, old-time wheat growers have been inclined to contend that there must have occurred changes in climatic conditions. No one can have the hardihood to contend that these native lands, never before plowed, have only sufficient fertility to maintain the normal yield and quality of grain for but one or two years. These lands certainly are as fertile as the adjacent areas which were broken in the early days of wheat culture. It can be seen at a glance that these present new lands are now subject to wheat diseases coming through poor seed and by dust and dirt from the adjacent old worked wheat lands."

The cause of deterioration, as the author sees it, is here distinctly attributed to diseases coming through poor seed and by dust and dirt from the adjacent, old-worked, infected wheat lands. The deterioration consists in the kernels being of light weight, off-colored "black-pointed," "spotted," "pie-bald," "white-bellied," and shrivelled. This is on new or virgin land after one or two years. At least I so understand it, for he says that:

"No one can have the hardihood to contend that these native lands, never before plowed, have only sufficient fertility to maintain the normal yield and quality of grain for but one or two years."

In summarizing the symptoms on a subsequent page, he is quite as explicit and his statements are more general. He says:

"All complain of much straw and light grain, yet find, when the yield is reasonably high in bushels, the grade is off whether it is well harvested or not. This does not, as one might suspect, indicate lack of nitrates in soil, but rather the contrary; for this immature shrivelled grain is apt to have a comparatively high proteid content, its deficiency being chiefly the starch products. Grains are often found to be off-color, 'pie-bald,' 'blighted,' 'black-pointed,' also showing pink, brown, and other colorations of the berries even though there has been no moisture at harvest time. These peculiar, shrivelled and discolored grains we find to be internally attacked by fungi. The color is either due to the presence of the fungi or to changes caused by them."

Later the author explains the cause of young plants dying, ascribing this cause to genera of Fusarium and Colletotrichum. In so doing, he says:
"Each of the various types of injured grains as pink-colored, black-pointed, white-bellied, etc., breed true, reproduce themselves. Certain conditions of soil, weather and variety, however, seem to largely affect the development of these features."

It is certainly difficult to reconcile the conclusion of the former publication of this station, North Dakota, with the statement just made, for in the conclusion drawn from previous work the same author says:

"From the results (of experiments made.—H.) the author believes that the white spots are not due to crossing nor are they matters of heredity, but that this peculiar mottling is due to the action of moisture, air and sun upon the grain while it is yet in the chaff."

It is possible that the author had reason for changing his opinion before writing Bulletin 107, North Dakota Experiment Station. If so, he failed to state the reason or even to take any cognizance of the statements of the earlier bulletin. In a lecture delivered before the agricultural students of the University of Wisconsin, which appeared in Science, July, 1913, he maintains, or rather asserts, the findings of the later bulletin. The author may have an object, worthy and well advised in North Dakota, but it is not effective in shedding light upon the question that I have in hand, though he evidently includes the condition of yellow-berry as constituting a symptom of deterioration.

The four bulletins from which these statements have been given constitute about all of the literature to be found in our station publications touching upon yellow-berry.

I am not at all sure that the California bulletins on the wheats of California have this question in view at all. A white wheat is by no means a diseased wheat or an abnormal one, though at times it would seem almost as though they were really describing wheats which were so badly affected that every kernel was mealy or starchy. These wheats are spoken of by some as white, soft, starchy wheats. Dr. G. W. Shaw and A. J. Gaumnitz describe White Australian as follows:

"Grain large, long, plump, white, soft, opaque, starchy interior; Little Club, grain medium large, short, white, irregular in shape, very soft and starchy interior; Sonora, short, round, plump, white starchy interior."

It would be difficult to give a better description of kernels of our wheats wholly affected by yellow-berry. I may be mistaken, but I do not understand the California bulletins to deal with their wheat as diseased or deteriorated wheats, but that they consider these wheats as normally white, soft wheats. If they consider them abnormal wheats, diseased wheats, they assign no cause, and sug-
gest no remedy and so far as the yellow-berry question is concerned, or better so far as our present discussion of the yellow-berry question is concerned, the Californian wheats may be neglected simply because the study of these wheats as presented in their bulletins is not parallel to the phase of our work presented in this bulletin. As stated, no better description of wheat kernels, wholly affected with yellow-berry, could be given than the descriptions of the various California wheats furnish,—large, white, plump, soft, opaque, starchy,—these are the only adjectives one could properly use in describing some samples of our Defiance, whereas for the description of other varieties, we could not use them truthfully at all. The Defiance kernel in its normal condition is a short, plump, light-amber colored, translucent, flinty kernel. Even the term soft, if used to express the ease with which the kernel may be crushed between the teeth, would apply to the abnormal, but not to the normal kernels of Defiance wheat. I think there is no reservation to be made in stating that a kernel wholly affected with yellow-berry is much softer than a normal, flinty berry of the same variety, and it is certainly very different in appearance.

There is a perfect agreement in the descriptions of yellow-berry given by the different authors so that there is no question but that they have written about the same condition. The best description is, perhaps, given by Roberts and Freeman. "By the term 'yellow-berry' is meant the appearance" (in wheat of a hard flinty grain), "of grains of a light yellow color, opaque, soft and starchy. These opaque yellow grains constituting what are called 'yellow-berries,' may have this character throughout, but sometimes from a small fraction to half of a grain will be yellow and starchy, while the remainder of the kernel will be hard, flinty and translucent."

It very often happens that the only imperfection in a kernel will be a sharply defined spot in one or the other half, or in both halves of the kernel; again the affection is more diffused and may involve one-half of the kernel or a streak along the back of the kernel. Owing to the fact that these spots and areas are less translucent than the surrounding flinty portion, often being quite opaque, the best manner of observing the kernels is by transmitted light. In this way it will be discovered that many kernels which by reflected light one would consider free from the affection, are in reality quite badly affected. When the berry is wholly affected its general color will be affected by the color of the bran or outer coating and will vary from dull white with a tinge of yellow, to yellow. Such kernels are usually, if not always, plump and when cut transversely, exhibit a white, starchy interior without any horny portion
THE COLORADO EXPERIMENT STATION whatever. Such kernels are soft and starchy. If such kernels as show small yellow spots be cut through transversely, these spots will show in the section as white, mealy, or starchy circles imbedded in a horny, translucent matrix. (See inserted Plate).

The plate needs but little explanation. It represents six varieties of wheat, three spring and three winter. The top row in each case represents normal flinty berries, the second row mildly affected berries and the bottom row badly affected berries.

While authors are agreed, so far as they attempt to describe the appearance of yellow-berry, they are not agreed as to its cause. Two different causes are assigned for it in North Dakota bulletins. In the one first published, the cause was stated definitely to be the action of moisture, air and sun upon the berries while still in the chaff. Prof. Bolley, the author, said:

"From the results the author believes that the white spots are not due to crossing, nor are they matters of heredity, but that this peculiar mottling is due to the action of moisture, air and sun upon the grain while it is yet in the chaff. If the weather action is long continued, the grains become evenly bleached over the entire surface. The color and hardness of the grain can be maintained by proper care in harvesting and curing."

This statement is definite in regard to both cause and remedy.

In Nebraska Bul. 89, we have essentially the same conclusion:

"The chief cause of this condition is allowing wheat to become overripe and failure to stack the sheaves. 'Yellow-berries' as compared with hard, red ones have a lower gluten content and are lighter in weight."

The authors of the Kansas bulletin 156, do not agree with these views for they state definitely:

"It should be further emphasized that the bleached, opaque grains due to weathering are not yellow-berries. In weathered kernels the grain has an opaque and rather dirty, grayish yellow aspect, which appearance affects the grading of the grain adversely, but is not necessarily associated with an inferior condition of the kernel, although such is frequently the result of exposure to the weather."

This statement is not in accord with the statements of the two bulletins previously quoted. The Nebraska bulletin gives the actual increase in yellow-berry produced by exposure. I assume, as there is no statement to the contrary, that Lyon and Keyser sorted their kernels in reflected and not transmitted light and in this way failed to count many affected kernels in the protected wheat which would have become easily recognized on bleaching the grain. In other words, I think that the yellow-berry was rendered more easily recognized, more evident, by the bleaching, but not caused by it. There is, however, a fact which would appear to
support the assumption of an increase after cutting, i.e., that the deposition of starch may continue for a time after cutting at the expense of material accumulated in the plant, but this would seem to apply to the protected as well as to the exposed wheat.

After having written the above, I received a note from Prof. Keyser, a portion of which pertains to this subject and reads as follows:

"It is stated in Bulletin 89 of the Nebraska Experiment Station that exposure to weather conditions, increases the amount of yellow-berry present in the grain. I think, perhaps, in view of a fuller experience with yellow-berry, that a slightly different statement of the facts observed would come more nearly to stating what actually took place. The bulletin states that exposure increased the yellow-berry. What actually occurred seems to be, that exposure increased the readiness with which yellow-berry present was detected. In other words, exposure enabled us to see yellow-berry in cases where it was not visible in the bright, freshly thrashed, or freshly harvested grain. In other words, exposure enabled us to detect yellow-berry in those cases which were on or near the boundary line of yellow-berry and clear, corneous grain."

This leaves no doubt in my mind but that the apparent increase of the yellow-berry on exposure to the weather, was due not to the formation of the yellow spots in the grain, but that the effect of the bleaching was simply to reveal yellow-berry in many kernels in which it was not readily detected in their fresh, unbleached condition. The continued deposition of starch after cutting, especially of grain not fully ripe, remains a possibility.

The Kansas bulletin goes further and states:

"The yellow-berry then appears to be distinctly a physiological growth product due to certain conditions thus far not clearly analyzed or satisfactorily explained."

After having studied the problem, in apparently all of its physiological phases, the conclusion of these investigators, Roberts and Freeman, is succinctly given in these words:

"In view of the fact that but one head from each plant of the pedigree stock had to furnish the grains on which an estimate of the percentage yield of yellow-berry in the plant as a whole was based, the result is really surprisingly confirmatory of our hypothesis that the yellow-berry is a 'tendency' which finds expression in certain strains or races more markedly than in others and is heritable."

This statement is the nearest approach to a formulated conclusion, embodying the results of their extended experiments that I have found. This conclusion is positively opposed to that arrived at by Prof. Bolley in the Annual Report of the North Dakota Station for 1904, in which he states:
"That the white spots are not due to crossing, nor are they matters of heredity, but this peculiar mottling is due to the action of moisture, air and sun upon the grain while it is still in the chaff."

Prof. Bolley himself practically repudiates the conclusion here stated, especially in regard to the direct cause of the affection, in North Dakota Bulletin 107, and again in a lecture given before the agricultural students of the University of Wisconsin and published in Science, July, 1913. Prof. Bolley in discussing the deterioration of wheat makes the following statements bearing upon the causes of it:

"All complain of much straw and light grain, yet find, when the yield is reasonably high in bushels, the grade is off whether it is well harvested or not. This does not, as one might suspect, indicate lack of nitrates in soil, but rather the contrary, for this immature shrivelled grain is apt to have comparatively high proteid content, its deficiency being chiefly the starch products. Grains are often found to be off-color, 'pie-bald,' 'blighted,' 'black-pointed,' also showing pink, brown and other colorations of berries even though there has been no moisture at harvest time. These peculiar, shrivelled and discolored grains we find to be internally attacked by fungi. The color is either due to the presence of fungi or to changes caused by them."

Again he says:

"Each of the various types of injured grains as pink colored, 'black-pointed,' 'white-bellied,' etc., breed true, reproduce themselves."

It is evident from these passages and others given, that Prof. Bolley now holds the "pie-bald", "yellow or white bellied", condition to be due to the action of fungi. He puts these yellow-berries in the same class with black-pointed berries, with pink or brown colored berries, and assumes that they all have the same cause, namely fungi. Concerning the black-pointed berries he is certainly correct and also in regard to the pink and brown berries alluded to, but he includes the spotted and yellow-berries with these, which is wrong. This presents the subject as treated of in our American literature so far as the stations are concerned. The United States Department of Agriculture has given a full statement, a fair reproduction, of Kansas Bulletin 156 in one of its accounts of station work. This is a matter of the distribution of the results of station work, so I have not mentioned it.

As I have before intimated, I am not sure but that all of the work of the California Station on the white wheats do not deal with yellow-berry, but Dr. Shaw and his collaborators have confined themselves to a study of the wheats as they grow and not to the question of why they are mealy or starchy.

I have some samples of Idaho wheats which are very white and starchy, in fact, I can see no distinction between the physical
properties of these samples and some samples of Colorado wheats which I fear must be acknowledged to present samples of wheat badly affected by yellow-berry. As I think many of our wheat growers will be interested, I will state these cases a little more fully. Our Colorado Defiance, a spring wheat, is normally a medium-amber colored wheat with a rather short, plump, flinty kernel. I have a number of samples of this wheat every kernel of which is almost white, wholly opaque, and has a dead, porous appearance, and when broken between the teeth simply crushes down and does not break with any life, and creates a sensation of mealiness on the tongue. When such kernels are cut they appear to be a mass of starch. Such samples scarcely bear any resemblance at all to normal Defiance wheat. I have samples of Red Chaff of which this is true in a very high degree. I have also seen just as extreme cases in kernels of Turkey Red and Kubanka. While I have samples of Turkey Red in which it is difficult to find a single kernel that is not affected, I have no samples of either Turkey Red or of Kubanka as bad as the Defiance and Red Chaff samples described. I have samples of Dicklow Spring wheat from Idaho which, if possible, are even worse than our Colorado samples of Defiance and Red Chaff. The kernels of these samples are plump, white, opaque, soft and starchy. I also have samples of Marquis grown in Idaho and also elsewhere in which it is very difficult, if not quite impossible, to find any kernels entirely free from the affection. It is for such reasons that I am convinced that if we find the cause of yellow-berry we will find at the same time the cause for the whiteness, opaqueness, starchiness and softness of all of the western wheats whether they grow in Colorado or in California.

In this place it should be emphasized that under yellow-berry is understood a condition indicated by yellow or white spots which may involve the whole kernel, with a greater or less degree of opacity, starchiness and softness. There may be soft wheats which do not show this condition at all, but this softness is another thing which is distinct from the softness of these kernels. Our Colorado Defiance is a softer wheat than the Red Fife, whether it should be classed as a soft wheat or not, is not my purpose to decide, but even in its best condition, it is a softer wheat than some others. It is not in this sense that we use the term soft as applied to these yellow-berry wheats. When we speak of softness due to yellow-berry, we mean that they are yellow or white, opaque, starchy and easily crushed; more easily crushed than flinty berries of the same variety of wheat grown under the same conditions.
I am strengthened in my surmise that the Californian wheats belong to this class of yellow-berry wheats by the description of Californian wheats given by Mr. Henry F. Blanchard in Bulletin 178 of the Bureau of Plant Industry, U. S. Department of Agriculture, in which he describes thirty-six varieties, all of which are characterized as spotted or starchy. In this description as well as in that given by Dr. Shaw and Mr. Gaumnitz, we are strongly reminded of our yellow-berry.

I have mentioned this for no other reason than to suggest that the condition of yellow-berry is not a local phenomenon to be explained by some local condition of climate, coastal or continental.

There is ample evidence in the literature of wheat that this condition is neither new nor confined to this country. This is true even after we make allowance for possible misapprehensions due to accidental coincidences in description. Reference has already been made to mention of starchy berries as early as 1870. In 1904 we find starchy berries mentioned by H. von Feilitzen in Jour. Landw., also by F. Moertlbauer, Ills. Landw. It is further mentioned by Dr. Thomas Kosutany in his work on Hungarian wheats and flour, Der Ungarische Weizen und das Ungarishe Mehl, printed in 1907. In discussing the quality of wheat produced on large estates, and that produced on small estates, and by the peasant farmer, he says:

"I take the weight per hectolitre, the weight per 1,000 kernels and the degree of mealiness, together with the protein and gluten content into consideration in making the comparison."

Dr. Kosutany again refers to this subject in discussing the effects of the weather. After stating that very significant variations in the gluten content of grains were to be attributed to the weather conditions, he explains that the weight of 1,000 kernels of the weaker wheats is greater than that of 1,000 kernels of the strongest wheats, which he also considers as an effect of the weather conditions. He adds:

"The mealiness in the weaker wheats is 36.78 per cent; in the better wheats 23.25 per cent, from which it follows that the protein-rich wheats are altogether the glassier which is intimately connected with that which I have already discussed and considered necessary to mention in connection with the weight per 1,000 kernels."

The occurrence of starchy and spotted kernels is evidently very common in the Hungarian wheats. Dr. Kosutany gives the record of mealy kernels in the harvests of seven years, for 1890, and from 1899 to 1905. Out of eighty-three samples given in the harvest of 1890 there is only one sample entirely free from mealy or half-mealy, starchy or spotted kernels, and only 24 out of the
remaining 82 samples that contain less than 15 percent of affected kernels. In the harvest of 1899, 38 samples, the average number of glassy, flinty kernels was 51.4 percent (Max. 78, Min. 9), of mealy kernels 16.3 percent (Max. 64, Min. 2), of half mealy, 32.5 percent (Max. 45; Min. 19); harvest of 1900, 53 samples, average mealiness 41.86 percent; 1901, 53 samples, 24.56 percent; 1902, average mealiness 44.85 percent; 1903, average mealiness 33.71 percent; 1904, average mealiness 24.09 percent, and in 1905, 26.08 percent mealiness. There were some samples in each year entirely free from this affection; in 1904 nine of the fifty-three samples, or 17 percent, were entirely free from affected berries. This affection is also mentioned as occurring in Roumanian wheat. Thirty samples are given for each of the three years, 1900, 1901 and 1902. The average of affected kernels for the three years is slightly over 91 percent.

These data will certainly suffice to indicate that “yellow-berry” has a very wide distribution whether this condition is identical with the starchiness of the Pacific coast wheat and all due to the same cause, which I think is the case, or not. That the same cause is operative in all cases seems probable, whether it is in Roumania, California or Colorado.

It seems to be customary to consider this mealiness as necessarily a sign of deterioration. I am not prepared to accept this view unreservedly. The term deteriorated wheat may at times be used advisedly, but it is very often used in a very loose, and in so general a signification as to mean nothing to the reader. The Pacific coast wheats are considered soft, weak wheats, this may be true and still it may be a question whether the starchy character of the wheat is indicative of deterioration. The Hungarian wheats are certainly considered among the very strongest wheats to be obtained and yet starchy and spotted berries make up a very considerable percentage of the average crop, in some few cases constituting the whole of some of the individual crops. Dr. Kosutany stoutly maintains that the Hungarian wheats have not deteriorated, though such claim has been made. It seems to me very probable that they may always have had starchy and spotted kernels in their wheat, but this does not necessarily follow from anything that is stated. Whether starchy kernels are necessarily kernels of inferior quality or not, I do not know. It is evident that millers object to them and, at least, the more advanced of these millers base their judgment upon the result of baking tests so it seems that the quality of the gluten must be inferior. Its quantity in slightly affected kernels is not necessarily low; on the contrary, it may be nearly or quite as high as in wheats of high quality.
In badly affected kernels I do not think that there can be any question but that the total nitrogen and the washed gluten are lower than in flinty kernels grown under apparently identical conditions of soil and weather. This question, however, is entirely beyond the purpose of the present bulletin.

Concerning the cause of mealiness in the Hungarian wheats, Dr. Kosutany makes no explicit statements, incidentally, however, he does, but considers it with other qualities of the wheat. In discussing the qualities of wheat produced upon larger estates compared with such as is produced by small growers, he says:

"Judged by the determination of the degree of mealiness, the balance swings likewise in favor of the large land-owner and more thorough soil culture, which at first sight is surprising, for if the small owner's wheat is smaller grained, then according to the theory which we have proposed it should not only be protein-richer but also more glassy, because the wheat plant with shallow culture ends its assimilative activity earlier and therefore should contain less starch and more gluten in its kernels, which must be characterized by a greater glassiness. That this is not so can only be explained by this, that the fields in the smaller estates were not sufficiently manured and the wheat plants were not supplied with a sufficiency of nitrogen by the soils to form therefrom the protein corresponding to the (other) conditions. Furthermore, it is possible that a less advantageous rotation plays a part in it, in that the small owner has planted his wheat after a plant (crop) that has exhausted the available nitrogen of the soil so that the wheat grown after it, even with an ordinary manuring, must be relatively low in its nitrogen content."

The conclusion here stated in reference to the cause of mealiness is at variance with the opinions previously given. The previous views have disregarded the soil as a possible cause of starchiness or have dragged it in in the most incidental manner, apparently for the purpose of conceding that the soil has some influence, but the manner of statement always carries with it the intimation that the soil is at best a minor factor.

One of the tasks that Dr. Kosutany has set himself is to show that the Hungarian wheats have not deteriorated. I understand him to adopt the evidently correct view that mealy kernels are apt to be lower in proteins than flinty kernels and that a wheat rich in protein is probably better than one poorer in protein. With these views in mind his statements in the following quotations are readily understood. These statements are made near the close of his discussion of the relative desirability of wheat grown on large, well cultivated and fertilized estates and on smaller ones.

"I can, therefore, emphatically assert that the statement of those who claim to find the reason for the decreasing gluten content of (our) wheat in the intensive cultivation is erroneous and on the contrary it can
be declared as a principle that through more careful soil-culture, heavier manuring, etc., not only more wheat can be grown upon the respective wheat-soils but (wheat) richer in gluten and for this reason better and more valuable. The statement that the quality, that is, protein-gluten content, of the wheat diminished with increased harvests has ceased to be valid as a rule. Cases may occur, as follows from the above (reference is here made to the results of experiments.—H.) that we can, by means of manures, especially slowly acting nitrogenous manures, and cultivation, within certain limits, not only increase the yield of wheat, but also increase its value which is closely related to its protein—respectively, gluten content.

"A proof of this is furnished by mills with an extended experience which place a higher value upon the wheat from the larger estates, provided the seed has not come from foreign lands, than upon the peasant's wheat; further, (by the fact) that in certain sections of the country, particularly in Banat, the quality of the wheat has actually deteriorated in consequence of the exhaustion of the soil, of ill-advised rotation of crops, of poor cultivation, etc., whereas the quality in other sections * * * according to the mills has increased in consequence of more careful cultivation and manuring."

Our own observations of the occurrence and cause of the yellow-berry are, so far as they are parallel, in harmony with those of Dr. Kosutany. Our observations now extend over two years and involve seventy-two experiments with field observations in other sections of the state, together with twenty-four samples from another state.

I do not think that there can be any question of the identity of the affection of our wheat with that of Kansas, Nebraska or North Dakota, and almost no question but that the starchy, opaque wheats of California, and the Pacific coast states, in general, are identical in their character with extreme cases of yellow-berry in Colorado and have the same cause.

In 1913 we had twelve plots of one-tenth acre each, i. e., four plots of each of three varieties. These plots were not planted for the purpose of studying yellow-berry, but yellow-berry developed very plentifully in some plots and not in others. In 1914 the experiments were repeated, no change whatever being made in the experiments, the same variety being planted on each set of plots and the individual plots received the same treatment. Owing to force of circumstances which no one could change, the ground was plowed in the Spring of 1913 instead of in the Fall of 1912. The land was turned to a depth of 12 inches and sub-soiled to a depth of 16 inches. These statements will suffice to indicate our purpose to give the ground a thorough cultivating. It is scarcely necessary to give further details of the cultivation in this connection.
The varieties used in our experiments were all spring wheats. Defiance, a variety originated at this station thirty-odd years ago; Red Fife, seed obtained from South Dakota Experiment Station; Kubanka, seed also obtained from South Dakota Experiment Station.

In 1913 the plots were all sowed on 25 and 26 of April. The Fife was harvested on 6 August, 103 days from planting. The Kubanka was harvested 13 August and the Defiance on 14 August, or 110 and 111 days respectively, from the date of planting. The period of vegetation was short and the ripening took place in clear warm weather. The soil was quite dry, ten of the twelve plots which we shall discuss had received but little, so good as no water, since 12 June. All of the wheat was threshed on 21 and 22 August without having so much moisture as a heavy dew fall upon it after cutting.

In 1914 all plots were sowed on the afternoon of 6 and morning of 7 April, and harvested 6, 7 and 8 August. Fife was rather over-ripe. All of the plots were cut 122 or 123 days from planting. The irrigating water applied was one foot on all except plots 4 and 8, which received two irrigations, amounting to one and one-half acre-feet. In these statements I am making no note of a few hundredths of a foot either way. For our present purposes we omit the rainfall during the vegetative period. It may, however, be taken as six inches per year for the two years. This is very nearly correct. The time and manner of rainfall is of much more consequence to us than the amount that we usually have. We threshed all of the lots on 21 and 22 August. So far as the harvesting and threshing of these wheats are concerned the weather conditions were perfect. The Fife was unfortunately ripe enough to shatter a little but had stood not more than two days longer than was desirable. While the Defiance and Kubanka are normally about eight to ten days later in maturing than the Fife, they were not more than one or two days later than this variety in 1914. This abnormally early ripening was due to a shower that fell, 28 July accompanied by some wind. The shower was of short duration but violent. It beat these varieties down rather badly, the leaves and stems, especially on some of the plots of Defiance, rusted and the crop was very materially injured. The same was true of the Kubanka but not to the same extent as of the Defiance. The Fife was scarcely injured at all by this shower because it was somewhat nearer maturity.

In order to facilitate the understanding of the experiments I add a plan of the experiments and the results obtained in 1913 on the plots considered in this bulletin.
### Experimental Wheat Plots, 1913.

<table>
<thead>
<tr>
<th></th>
<th>Treatment Description</th>
<th>Yellow-berry Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Defiance</strong>&lt;br&gt;Nitrogen, 80 lbs. per acre in two applications.&lt;br&gt;Yellow-berry, none.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td><strong>Defiance</strong>&lt;br&gt;Soluble phosphorus, 40 lbs. per acre. One application.&lt;br&gt;Yellow-berry, 10 percent.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td><strong>Defiance</strong>&lt;br&gt;Potassium, 150 lbs. per acre, one application.&lt;br&gt;Yellow-berry, 30 percent.</td>
<td></td>
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<tr>
<td>4</td>
<td><strong>Defiance</strong>&lt;br&gt;Check. Yellow-berry, 24 percent.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td><strong>Red Fife</strong>&lt;br&gt;Nitrogen, 80 lbs. per acre in two applications.&lt;br&gt;Yellow-berry, none.</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td><strong>Red Fife</strong>&lt;br&gt;Soluble phosphorus, 40 lbs. per acre. One application.&lt;br&gt;Yellow-berry, 24 percent.</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td><strong>Red Fife</strong>&lt;br&gt;Potassium, 150 lbs. per acre, one application.&lt;br&gt;Yellow-berry, 42 percent.</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td><strong>Red Fife</strong>&lt;br&gt;Check. Yellow-berry, 31 percent.</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td><strong>Kubanka</strong>&lt;br&gt;Nitrogen, 80 lbs. per acre.&lt;br&gt;Yellow-berry, none.</td>
<td></td>
</tr>
</tbody>
</table>
10. KUBANKA
   Soluble phosphorus, 40 lbs. per acre.
   Yellow-berry, 35 percent.

11. KUBANKA
   Potassium, 150 lbs. per acre.
   Yellow-berry, 37 percent.

12. KUBANKA
   Check. Yellow-berry, 31 percent.

The above diagram is self explanatory. The grains used were Defiance, Red Fife and Kubanka; the fertilizers were nitrogen, phosphorus, and potassium.

The percentages of yellow-berry obtained are indicated on each plot. Note the variations in each variety, depending upon the kinds and proportions of fertilizers used.

While we made thirty-six experiments in each of the years we will consider only twelve plots for three reasons: First, it will shorten the statement of our data; Second, the other twenty-four sets of data would simply confirm the twelve sets which we give, and, Third, I do not wish to anticipate, any further than is necessary for my present purpose, the data bearing upon the principal object of the real project in hand, which is not to discover the cause and prevention of yellow-berry in wheat, though this may be the most far-reaching and practical result which I shall obtain.

The land used in these experiments has been cropped continuously for six years without fertilization. It is now seven years since it was in alfalfa. The soil proper varies from eight to twelve inches in depth. While the subsoil is a little richer in lime salts, it differs less from the soil above it than is usually the case. This subsoil is capable of forming a very desirable soil when brought to the surface, aerated and permitted to become enriched in nitrogen. Only the principal features of the composition of this soil and subsoil is given, but these are sufficient for our purpose, namely, to give as correct an account of our conditions as is possible; for this purpose the amounts of phosphoric acid, potash and nitrogen are all that we deem necessary.
The last determination, the portion of the soil soluble in water, is given because I believe that this is an important factor in the agriculture of the semiarid regions. To some, the figures 0.388 and 0.345 may convey only a slight notion of the mass of salts involved. The samples of soil and subsoil together were taken to a depth of a little more than one and three-quarters feet, but the wheat plant under favorable conditions sends its roots down to a distance of more than twice this depth. The amount of water soluble material in the soil represented by our samples amounts to 3,670 pounds as the average for each million pounds of soil, which gives us from 12 to 13 tons of soluble salts per acre taken to this depth of one and three-quarters feet. While the salts actually dissolved out of this soil by the water may not be capable of acting as plant foods, it seems improbable that they are indifferent or take no part in the changes which are constantly going on in the soil. Our theory for instance of the action of lime includes its ability to liberate potassium salts, likewise it is believed that soda salts may in some cases also act to make the potassium which may be too firmly held to be readily taken up by the plants, more available and in this way exercise a beneficial action on the growing crop. If these views be correct it would seem probable that this large amount of soluble salts may constitute an important factor in the question of the fertility of the soil.

The supply of the plant foods which it is usually considered necessary to take into account is ample in this soil to produce abundant crops. This is not a matter of theory, but of fact. It would be very bad for the theory if it indicated a contrary conclusion, for this soil will yield from 30 to 40 bushels of wheat without the application of manures of any kind, chemical or farmyard.
The experiments mentioned were made in sets of three and a check. Inasmuch as we used three varieties we have a series of twelve experiments on each of three sections of land. In this place I will give the results from one section only, but I will give the results for two years, in which we have wheat after wheat. The varieties used were, as stated, Defiance, Red Fife and Ku­banka. I applied liberally each of the desirable elements, nitrogen, phosphorus and potassium, singly but not in combination. My reason for doing this has nothing to do with the object of this bulletin. I have stated the quantities applied but I wish to divorce the subject of yellow-berry from all questions of yield and quality in so far as I possibly can. I will give the yield and weight per bushel for the two years to remove any impression of exhausted soil or unfavorable cultural conditions.

**YIELD AND WEIGHT PER BUSHEL, CROPS OF 1913 AND 1914.**

<table>
<thead>
<tr>
<th>Variety</th>
<th>Designation of plot</th>
<th>Area of plot</th>
<th>Bushels per acre</th>
<th>Wt. lbs. per bu.</th>
<th>Bu. per acre</th>
<th>Wt. lbs. per bushel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defiance</td>
<td>Nitrogen Plot........</td>
<td>1-10 acre</td>
<td>42</td>
<td>60</td>
<td>29</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>Phosphorus Plot.....</td>
<td>1-10 acre</td>
<td>40</td>
<td>62</td>
<td>39</td>
<td>58½</td>
</tr>
<tr>
<td></td>
<td>Potassium Plot......</td>
<td>1-10 acre</td>
<td>43</td>
<td>62</td>
<td>37</td>
<td>59½</td>
</tr>
<tr>
<td></td>
<td>Check Plot...........</td>
<td>1-10 acre</td>
<td>38</td>
<td>62½</td>
<td>33</td>
<td>56</td>
</tr>
<tr>
<td>Red Fife</td>
<td>Nitrogen Plot........</td>
<td>1-10 acre</td>
<td>39</td>
<td>63</td>
<td>52</td>
<td>64¼</td>
</tr>
<tr>
<td></td>
<td>Phosphorus Plot.....</td>
<td>1-10 acre</td>
<td>33</td>
<td>63½</td>
<td>45</td>
<td>63½</td>
</tr>
<tr>
<td></td>
<td>Potassium Plot......</td>
<td>1-10 acre</td>
<td>33</td>
<td>63½</td>
<td>44</td>
<td>64¼</td>
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<td></td>
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<td>1-10 acre</td>
<td>31</td>
<td>63½</td>
<td>43</td>
<td>63¾</td>
</tr>
<tr>
<td>Kubanka</td>
<td>Nitrogen Plot........</td>
<td>1-10 acre</td>
<td>39</td>
<td>63</td>
<td>49</td>
<td>64¾</td>
</tr>
<tr>
<td></td>
<td>Phosphorus Plot.....</td>
<td>1-10 acre</td>
<td>38</td>
<td>64½</td>
<td>47</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>Potassium Plot......</td>
<td>1-10 acre</td>
<td>37</td>
<td>64¾</td>
<td>45</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>Check Plot...........</td>
<td>1-10 acre</td>
<td>36</td>
<td>63½</td>
<td>43</td>
<td>65</td>
</tr>
</tbody>
</table>

These yields including the Fife check 1913, and all of the Defiance plots for 1914, give no hint of exhausted soil and only by comparison with the yields of the other plots do they hint of any unfavorable conditions.

Some of these wheats are badly affected with yellow-berry and the most of them, almost all of them in fact, are affected in some degree. The only other affections at all noticeable in these samples are now and then a berry discolored brown and a few black-ended berries. The black-ended and brown berries are due to infection by fungi. The number of such berries was not greater in 1914 than in 1913, though I used the crop of 1913 for seed in 1914 and used the same plots for the respective varieties. Neither the seed nor the soil was treated in any manner. This is simply a statement of
YEL-LOW-BERRY IN WHEAT

fact. It is not intended to commend this procedure, but we had little or no reason to treat our seeds. The only reason that we would have had for treating it would have been to combat the Altenaria which is the principal cause of our black-pointed berries, and the ordinary treatment usually given seed grain is of little or no value in this case. There is no question but that the soil may become seriously infected with fungi injurious to crops and all reasonable means should be used to prevent or correct such a condition, but our grain is not injured by fungi.

As already stated, the weather conditions during the growing period of these crops were favorable, only one unfortunate feature appearing in the two seasons. This was a violent shower on 28 July 1914; this shower was of short duration but did considerable injury to my crop. The only question which concerns us in regard to this injury is, did it play any part in the production of the yellow-berry? This question can be answered in the negative, especially if we consider the question to refer to the cause of this affection. The reason is conclusive, because the yellow-berry had already appeared in the wheat, that is in some of it, before this, besides in 1913 we had perfect weather conditions and we had yellow-berry, not so badly as in 1914, but badly enough to give a definite, negative answer to the question suggested in this connection.

The only causes, heretofore, assigned for the appearance of this affection in wheat are over-ripeness of the wheat, standing too long in shock, exposure to the action of moisture, air and sunshine, a heritable "tendency", the action of fungi, and climatic and weather conditions,—no one of which can be considered as the cause in our case. In 1913 the wheat was cut just as soon as we considered it safe to do so, and likewise in 1914, except that the Fife was a day or two earlier than the Kubanka and Defiance, and they were cut on the same day. The wheat was allowed to stand in shock not more than twelve days either year and no rain beyond a trace, less than four-hundredths of an inch during the twelve days, fell upon it, so we considered over-ripeness or late cutting and exposure after cutting as sufficiently answered by the elimination of both, besides the yellow-berry appeared in the most pronounced fashion while the berries were still green. That adverse climatic conditions had nothing to do with it, is evident from the record, for we had clear, warm, dry weather conditions for the whole growing periods of the two years, with the slight exception already mentioned.

We have no proof at all of any fungous trouble with either the wheat or the plants other than that already mentioned which is not significant and has no relation at all to the yellow-berry.
The two things are entirely distinct. We have flinty berries, wholly unobjectionable in any respect except that of having a blackened end, we also have spotted or yellow-berries both with and without such ends. The blackened ends are due to fungi; this fact is quite easily established by placing the black-ended berries in a culture dish under proper conditions when an abundant growth of the fungus affecting the berry will be obtained. Simple cases of yellow-berry do not afford this proof of fungous affection.

The question of a "tendency" which is heritable is fully set aside by the fact that we can, from the same lot of seed, under identical conditions of climate, grow crops affected with or free from yellow-berry.

Furthermore, the question is not one of the total supply of plant food. I have given the yields per acre for two succeeding years for the same varieties of wheat planted on the same sections of ground, every fourth one of which is a check plot. The minimum crop on any check plot for the two years is 31 bushels per acre, with the wheat weighing 63½ pounds per bushel. The same plot the succeeding year, without the application of any fertilizer and planted to the lowest yielding variety experimented with, yielded 43 bushels, weighing 63¾ pounds per bushel. This yield and weight per bushel does not indicate any deficiency of fertility and yet this wheat is badly affected with yellow-berry. I deem it altogether justifiable to conclude that yellow-berry is not a matter of total available plant food in the soil. It is no more a matter of starvation than of fungous trouble, which has nothing whatever to do with it, nor of a total excessive supply, but evidently a question of the ratio in which these food elements are present. In our case it is evidently the ratio between the potassium and nitrogen which determines the absence or presence of yellow-berry. I am satisfied that this is the cause of our yellow-berry and believe that the explanation is applicable to all cases. We have red wheats from some sections of Colorado which are white and mealy or starchy. These samples are as white and as mealy as any white wheat that I have seen. We have all degrees of this affection from a single, minute, yellow spot set in a flinty mass to the degree just designated in which the whole kernel is mealy. The cause of this is the one just stated, the ratio of the available potassium to the available nitrogen.

While it is possible that mealy wheat grown in Idaho or California might owe its mealiness or starchiness to some other cause, I hold it as quite certain that this is not the case, but that it is due to the fact that in these soils the ratio of available potassium to the available nitrogen is too high. There may be, as in our case
there is, as shown by the yield of the check plots, an ample supply of nitrogen to grow bountiful crops, 38 and 33, 31 and 43, and 36 and 43 bushels for the checks with different varieties for the respective years, but the degree of mealiness or starchiness, the yellow-berry, in the wheat depends upon the relative available supply of these two elements.

The object of this bulletin is to show this cause and to offer some suggestions regarding the prevention of yellow-berry, and not to discuss the quality of the wheat. This feature is reserved for presentation with further results of our study which may not appear for some time. This much may, however, be stated at this time. The composition of the wheat, whether it involves quality or not, is profoundly affected. This result is independent of "climatic conditions." What modifying influence "climatic conditions" may exercise I will not at this time attempt to discuss, but it is subordinate so far as yellow-berry and its effects are concerned, to the influence of the soil,—in this case, specifically to the potassium-nitrogen ratio.

The record of yellow-berry for the two years 1913 and 1914 on the twelve plots taken into consideration in this bulletin is given below, together with the record of "black-pointed" berries for 1913.

**Percentage of Yellow-berry in Crops of 1913 and 1914.**

<table>
<thead>
<tr>
<th>Variety</th>
<th>Fertilizer</th>
<th>Black-pointed berries</th>
<th>Yellow-berry berries</th>
<th>Yellow-berry berries</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>percent</td>
<td>percent</td>
<td>percent</td>
</tr>
<tr>
<td>Defiance</td>
<td>Nitrogen</td>
<td>6.7</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td></td>
<td>Phosphorus</td>
<td>12.9</td>
<td>10.0</td>
<td>50.0</td>
</tr>
<tr>
<td></td>
<td>Potassium</td>
<td>15.3</td>
<td>30.0</td>
<td>63.0</td>
</tr>
<tr>
<td></td>
<td>Check</td>
<td>13.0</td>
<td>24.0</td>
<td>36.0</td>
</tr>
<tr>
<td>Red Fife</td>
<td>Nitrogen</td>
<td>2.0</td>
<td>none</td>
<td>24.0</td>
</tr>
<tr>
<td></td>
<td>Phosphorus</td>
<td>5.0</td>
<td>24.0</td>
<td>97.0</td>
</tr>
<tr>
<td></td>
<td>Potassium</td>
<td>5.0</td>
<td>42.0</td>
<td>98.0</td>
</tr>
<tr>
<td></td>
<td>Check</td>
<td>5.0</td>
<td>31.0</td>
<td>98.0</td>
</tr>
<tr>
<td>Kubanka</td>
<td>Nitrogen</td>
<td>5.0</td>
<td>none</td>
<td>23.0</td>
</tr>
<tr>
<td></td>
<td>Phosphorus</td>
<td>12.6</td>
<td>35.0</td>
<td>94.0</td>
</tr>
<tr>
<td></td>
<td>Potassium</td>
<td>9.5</td>
<td>37.0</td>
<td>96.0</td>
</tr>
<tr>
<td></td>
<td>Check</td>
<td>16.0</td>
<td>31</td>
<td>97.0</td>
</tr>
</tbody>
</table>

Results observed in field culture

Turkey Red Land affected by nitre ......................... 25.0
Land not affected by nitre ............................... 100.0

The statement of these results in percentages of spotted and yellow-berries conveys no adequate notion of the differences noticeable between these samples. The potassium not only increased the
number of yellow-berries, but imparted to the grains grown with its application a fullness of form and a paleness or deadness of color that are very marked, together with the appearance of meali­ness or opacity.

We see that, in every case, the application of nitrogen which was in the form of sodic nitrate, greatly reduced the amount of yellow-berry, in some cases even preventing it altogether.

To my mind the two samples representing actual field conditions in another portion of the state are more interesting than any of my experiments, for in the one we have the natural, if I may use the term, development of nitrates in the soil, and in the other we have the ordinary cultural conditions obtaining on a farm well kept by a thrifty owner. In the one we have seventy-five percent of the berries translucent or entirely free from yellow-berry, in the other we have none entirely free, but nearly all badly affected. These grains are so different that the manager of the local mill stated that they spoke of such samples as constituting different varieties. In fact, this manager himself spoke of them as distinct varieties, and this too, in spite of the fact that he knew that the same lot of seed, Turkey Red, had been distributed to these parties. These facts pertaining to the effects of the nitrate are entirely consonant with observations already on record. H. von Feilitzen, (Abs. Expt. Sta. Record, Vol. XVII, p. 24) says:

"Two years' experiments on four different kinds of soils show that glassy, hard kernels of spring wheat or barley are richer in protein than those of a mealy consistency. Glassiness or meali­ness in the seed produced no effect upon the yield and size of the kernel, but apparently exerted a slight effect upon the glassiness or meali­ness of the grain. The proportion of glassy kernels was found to be greater and the protein of the grain was higher, as a rule, on moor soil than on soil of mineral origin. The climatic conditions are considered as producing a marked effect on the quality of the grain. Nitrogenous fertilizers in general, increased the percentage of glassy kernels."

Also F. Moerthbauer (Abs. Exp. Sta. Record, Vol. XXV. p. 334) says:

"Very early applications (of sodic nitrate) on winter wheat decreased the flintiness of the kernels, late applications increased it. In every case where a part was applied late the hardness was improved. A top dressing when the heads began to form invariably produced a marked increase in the flintiness. * * * The protein content varied with the flintiness. The correlation was not a close one. Flintiness is not the only condition which determines the protein content."

These are the most direct and definite statements that I have found bearing upon the effect of the available plant food upon the
prevalence of yellow-berry, the observation of Feilitzen that moor soils which are usually low in potassium produce a larger proportion of flinty berries than mineral soils, is suggestive of the views presented in this bulletin. The quotations from Dr. Kosutany have a similar significance but are not so explicit.

I have carefully avoided any discussion of the differences in the composition and quality of flinty and yellow-berries in this bulletin as being beyond its purpose. These subjects will be dealt with in a subsequent bulletin.

A question will naturally arise in regard to the part played by water and the condition of the plant at the time this may be applied. While I hold this to be the first and most important question in irrigation, I do not know that anyone has actually studied it. I have made some observations in regard to its effect upon the production of yellow-berry. The observations are not wholly consistent in details, but are concordant in showing that neither the time of application nor the total amount applied stands in any casual relation to the development of the yellow-berry. I have samples of "dry land" wheat raised without irrigation in which it is difficult to find a single kernel entirely free from this affection and I have also samples of wheat grown with the application of three acre-feet of water plus some rainfall and this, too, is very badly affected. Some of my own samples were grown with the application of two acre-feet, some with one and one-half acre-feet, and some with one acre-foot, and I can discover no relation whatsoever between the amount of water applied and the prevalence or absence of yellow-berry. I have stated very plainly and the plainness was intentional, that the giving of the percentage of affected berries does not adequately express the differences between samples grown with the application of nitrates and those grown with the application of potassium. The appearance of the kernels is different, the one is translucent and the other is opaque. This holds too in the case of irrigation, i.e., while the yellow-berry may be very bad heavy irrigation seems to slightly improve the appearance of the berries. I have two sets of three samples each which received one, two and three acre-feet of water respectively, and those samples receiving the three feet of water are the better appearing samples, while they are practically all affected with yellow-berry, I feel perfectly justified in stating that the application of irrigating water up to three acre-feet, does not produce the yellow-berry and also that the withholding of all water will not prevent it; for the yellow-berry is independent of this factor.

The remedy is plain, increase the ratio of nitrogen to that of potassium in the soil. This does not mean that it is necessary to
add nitrogen because there is a deficiency of it to grow a crop. Our check plots grew good crops, from 31 to 43 bushels per acre, but the wheat from the check plots was badly affected with yellow-berry, while the wheat from our nitrogen plots was all practically free from it.

I have my doubts whether it will ever be feasible for our farmers, and probably it will not be feasible for many farmers anywhere to use sodic nitrate to prevent the formation of yellow-berry. There are other considerations to be weighed besides the cost, but this alone is probably prohibitive. This, however, will depend upon the amount which may be found necessary to apply.

The minimum amount necessary to apply will be found to vary greatly depending upon the soil and the time of application.

The observation of Moertlba der that an early application of nitrates to winter wheat increased the mealy or yellow-berries does not apply, according to our observations, to spring wheat for we have had very favorable results in suppressing the yellow-berry by making but one application at the time of sowing the seed. I do not know but that better results would have been attained, in fact, I think that we would have attained much better results, had this same application been made after the grain had set, but this would have required us to apply water enough to carry the nitrate into the soil. Our plots received two applications of nitrate. There are other phases to the question which would take us too far afield to attempt to discuss in this place, but it may be stated, that it is an easy matter to add too much nitrate. I am not prepared at this time to suggest the minimum quantity likely to be effective, the best time to apply it, or the maximum which may be used without disadvantageous results. The quantity to be added will vary with the soil, and it may be that but few farmers could wisely follow any definite rule with the same results.

A point which demands mention in this place is, that as soon as the ratio of the nitrogen is too high, we obtain shrunken wheat irrespective of other conditions, and also abnormal ripening. The top and bottom portions of the straw will turn yellow while the middle portion and the leaves are too green to cut without danger of the sheaves rotting. This is a condition which I understand is frequently complained of by our farmers. The appearance of shrunken kernels without any apparent, adequate cause has also been noted very often.

Wheat seems to be very sensitive to these conditions, though almost all of our writers on this subject have attributed only a minor importance to them, claiming that climatic conditions almost wholly determine the character of the grain. While we cannot
make ourselves independent of climatic conditions, however much or little we may mean by the term, it is evident that our data given do not fit into this view. I have omitted any detailed discussion of the composition of the yellow-berry wheat on purpose to avoid a premature discussion of these points. It seems wise, however, to make the above statements lest some one should be led to expect too much from the adoption of our suggestions for the prevention of yellow-berry.

Wheat affected with yellow-berry is considered inferior in quality and is graded low on the market. The removal of this affection will certainly cause the wheat to be graded higher and probably also actually improve the quality, but this seems to be an open question, for the Hungarian wheat is of the best quality though, as we have seen, the wheat is very far from being free from this affection.

There is another way of combating the trouble, the one suggested by Dr. Kosutany, i.e., through thorough cultivation and manuring, also by a proper rotation of crops. In offering an explanation for the smallness of the kernels and the inferior quality of wheat grown on small farms, as compared with wheat grown on large estates in Hungary, he uses the following language:

"The balance swings in favor of the large landowner and intensive, thorough culture, according to the determination of the degree of meali- ness which at first sight is rather surprising, for if the wheat grown by the small landowner is smaller-grained, then it should, according to the theory which we have proposed, not only be richer in protein but also flintier, because the wheat planted with shallower culture ends its assimilative activity earlier and should contain less starch and more gluten and, therefore, should be characterized by a higher degree of flintiness. That this is not so can be explained only by this, that the fields on smaller estates were not sufficiently manured and the wheat plants were not supplied with a sufficiency of nitrogen by these soils to form therefrom the protein corresponding to the (other) conditions. Furthermore, it is possible, that a less advantageous rotation plays a part in it, in that the smaller owner has planted his wheat after a plant (crop) that has exhausted the available nitrogen of the soil so that the wheat grown after it, even with an ordinary manuring must be low in its nitrogen content. Accordingly we can draw the conclusion that the wheat grown upon small farms, is of lower value, because it has a lower weight per hectolitre, is smaller grained and less flinty, contains less gluten and less protein. Here a wide province opens up to intensive, thorough cultivation, since with the deepening of the soil the vegetative period of the wheat is lengthened, the kernels do not shrink, the plant is more richly supplied with nitrogen, its roots penetrate deeper into the soil and can take up a richer supply of nourishment. The heavier manuring provides the wheat with richer nitrogenous food and contributes to the formation of a wheat richer
in gluten, flintier, with great absolute weight and a higher weight per hectolitre."

The effect of crop rotation is well illustrated by a case observed by Prof. Keyser while he was connected with the U. S. Department of Agriculture and stationed in Nebraska. Prof. Keyser has fully stated this case in a letter addressed to me on the subject and with his permission I state it in his own words:

"A certain field in York county, Nebraska, had grown corn for a number of years. A portion of the field had been seeded down to clover. The year the clover was broken up the corn land was seeded to oats. The clover and oat stubble were broken up and the entire field seeded to Turkey Red winter wheat. The year was favorable to good production and a good yield was returned on both parts of the field. The wheat from the land which had been in corn a number of years, however, contained a very high percentage of yellow-berry, although it was otherwise of good quality. The wheat on the clover sod, however, had very little yellow-berry, although there was an occasional kernel in evidence. Aside from this difference there was very little difference to be detected in the wheat from both parts of the field.

"The owner sent the wheat to the Nebraska State Fair, sending samples from each portion of the field. There was no appreciable inferiority of the yellow-berry wheat except the presence of the yellow-berry, both samples being unusually good. As I remember it, this wheat was seeded in the fall of 1902, harvested in 1903 and exhibited that fall."

It is altogether in keeping with what we believe about the effects of various crops to assume that the corn and oats had exhausted the available nitrogen in that portion of the field which had been planted successively to these crops, while the clover had actually added nitrogen to the soil increasing the ratio of the nitrogen supply to that of the potassium with the results above given. Prof. Keyser states that the yield was a good one and that the samples of wheat exhibited were unusually good, therefore, we are free to infer that the land had not been exhausted so far as crop production was concerned nor was the wheat affected with any other trouble than yellow-berry.

There is still another way to reduce or prevent the trouble, it is to cultivate the land fallow for one season during which some of our lands will acquire nitrates enough to produce a crop of wheat but little affected with yellow-berry. The department of agronomy under Prof. Keyser is conducting experiments with wheat on land sixteen feet to the west of that on which I am conducting my experiments. I am cropping continuously and he is cropping and cultivating fallow alternate years. The grain on my check plots comparable to his land produced wheat in 1914 having 97 and 98 percent yellow-berry, his wheat showed 14 percent yellow-berry.
The wheats received essentially the same treatment throughout the season, irrigation and care, except that his was harvested by hand and mine with a reaper. This comparison is of Red Fife with Marquis. In comparing Kubanka grown from my own seed on fallowed ground and grown on my check plot, I find that grown on fallowed ground to contain 13 per cent of affected berries and that grown on my cropped ground is practically all affected, by actual count 97 percent. It may be argued that my land was deficient in nitrogen because I had grown a crop of wheat on it the preceding year and had added no nitrogen to compensate for what I had taken off; this is true, but I had not affected the producing capacity of the soil, as the crop harvested was 43 bushels of wheat weighing 65 pounds per bushel. On the other hand we know that this land rapidly enriches itself in nitric nitrogen, so much so, that in October 1914, fallowed land, now planted to wheat contained nitric nitrogen equivalent to 518 pounds of sodic nitrate taken to a depth of seven inches. Such land will not produce yellow-berry.

It is evident that different pieces of land will require different treatment and no rule can take the place of intelligent observation and some experimentation on the part of the grower himself. The difference in composition and quality of flinty and yellow-berry kernels have been reserved for later discussion.

SUMMARY.

The appearance of yellow or white, mealy or half-mealy, or spotted kernels in wheat, otherwise without apparent blemish and known as Yellow-berry, is not due to over-ripeness, nor to exposure after cutting, nor to the action of fungi, nor is it a "tendency" heritable in the wheat, as has been claimed by different authors.

We have no substantiation of the claim sometimes made that climatic conditions favorably influence the development of, or cause yellow-berry.

Yellow-berry can be very much lessened or entirely prevented by the application of a sufficient quantity of available nitrogen.

Yellow-berry can be greatly intensified or increased by the application of available potassium.

The application of available phosphorus has no appreciable effect upon its prevalence.

Yellow-berry is not indicative of an exhausted soil, that is, one which will not produce abundant yields.

Yellow-berry indicates that potassium is present in excess of what is necessary to form a ratio to the available nitrogen present, advantageous to the formation of a hard, flinty kernel.
Yellow-berry should not be mistaken for or confused with black-ended berries or with brown or other discolorations in the berries. These affections are not general affections as the yellow-berry is and are not produced by the same cause.

Yellow-berry is under the control of the grower. If there be sufficient difference in the price of grain produced he can control it with a margin of profit.

The means at his disposal for its control are:

First: The judicious use of sodic nitrate.

Second: The thorough cultivation of his soil with the application of nitrogenous manures.

Third: A rotation of crops in which a clover and possibly other legumes precede the wheat.

Fourth: Fallow cultivation.

These observations apply to all of our western soils, rich in potassium and relatively, not absolutely, poor in available nitrogen.