clusters of red drupes might not be so improved as to make them profitable to cultivate for this pleasant acid. I commend this pretty bush, with its dense clusters of sour red drupes, to your careful consideration.

HAWTHORNS.

Now-a-days the botanist who does not refer to the Hawthorns (of the genus *Crataegus*) in any paper of his is a rarity, but you need not fear that I am going to lead you into the maze and confusion of the recent systematic botany of the species. I wish merely to call your attention to the fact that some of the species have fruits which are very sweet and palatable. I bear in mind now one bush in the sand hills of central Nebraska from which I ate the most deliciously sweet fruits that I have ever found on the hawthorns. There are very good reasons for believing that the hawthorns are very pliant in nature (hence the many forms which have been interpreted, erroneously I think, as species), and no doubt they will continue to be so in the hands of the intelligent breeder.

BREEDING CEREALS.

By Prof. C. A. ZAVITZ, *Ontario Agricultural College, Guelph, Canada.*

There is probably no subject which is engaging the attention of the scientific world to a much greater extent at the present time than that of breeding. It is a subject among subjects, and one which is deserving of deep thought and thorough, painstaking, close and persistent investigation. Not only does it concern the affairs of the world from a financial standpoint, but it has an influence on life everywhere, whether of animals or of plants. Although the principles of breeding have been extensively studied in the past, I am firmly of the opinion that more will be learned regarding the underlying principles of breeding during the twentieth century than was learned during the previous one thousand years. The fact that this meeting, which is now being held at Lincoln, Nebraska, is composed of practical farmers and stockmen from over the State and of scientific investigators from throughout the whole of the American Union, augurs well for the deep interest manifested in the great problem now under consideration. May the discussions which are taking place at this convention stimulate others in different parts of the land to assist more and more in the work of obtaining that information which will enable the people everywhere to better understand the principles of breeding, so that improvements can be made in those forms of life which come so much under the influence of man.

That phase of the general subject of plant breeding allotted to me for discussion deals more particularly with the breeding of cereals. I shall confine my remarks to this subject, referring incidentally in

only a few cases to other farm crops, such as field peas, roots, and rape. I shall discuss the subject under four headings, each of which I consider essential in order to do the best work in the breeding of cereals: (1) The selection of varieties; (2) the selection of seeds; (3) the selection of plants: and (4) the production of hybrids.

SELECTION OF VARIETIES.

I am convinced that the proper selection of varieties of cereals is of great importance, not only from the farmers' standpoint, but also as the basis of work for the improvement of cereals by plant breeding. After growing and examining over two thousand varieties of farm crops in each of five years, and afterwards observing the behavior of some of these varieties in general cultivation, I wish to emphasize strongly the importance of *variety* in this work. As some breeds of live stock have been bred for many years to fulfil certain purposes, so have certain varieties of farm crops been raised for long periods of time with different objects in view. Some varieties are well adapted to rich, loamy soils, others to heavy clay land, and still others to soil of a light character. For instance, in Ontario, it would be unwise to grow the Joannette oats on a light weak soil or the Black Tartarian oats on a rich bottom land. It would be equally unwise to grow the White Wonder peas on a poor soil or the Prussian Blue variety on land which naturally produces a large amount of straw. The best results could not be expected from growing the Turkey Red winter wheat where the crop is apt to lodge, or the Black Hulless barley on rich alluvial soil. Decidedly better results can be obtained from growing the Longfellow corn in northern Ontario and the Leaming variety in southern Ontario than if this order were reversed. Much greater yields can nearly always be expected from the Siberian than from the Black Tartarian oats; from the Dawson's Golden Chaff than from the Surprise winter wheat; from the Mandscheuri than from the Common Six-rowed barley; from the Early Britain than from the Golden Vine peas, from the White Wonder than from the common, small, white field bean, etc. Certainly great differences exist between different varieties of grain crops in length of straw, strength of straw, susceptibility to rust, and quality of grain, as well as in yield per acre and in many other respects. In regard to the yield per acre, there is a very great difference in different varieties. For instance, we have grown a number of varieties of oats and barley under uniform conditions in each of sixteen years, and, for the sake of illustration, I wish to say that the results of these experiments show an average yield of grain per acre of 88 bushels from the Siberian and of 72 bushels from the Black Tartarian, a difference of 16 bushels per acre per annum in favor of one variety over another. Again, in the case of barley, the Mandscheuri gave an average of 70 bushels and the Mensury an average of 59 bushels per acre during the same period of sixteen years. Here we have a difference of 11 bushels per acre per annum between two strains of the six-rowed barley. When we see such marked differences between varieties, we are led to the conclu-

sion that *variety* has an important place in the work of plant breeding as well as in the practice of the farm. Mr. Hugo de Vries, of Holland, after visiting the noted Luther Burbank in 1904, wrote an account of his trip, and, among other things, he stated that "as a general rule, it holds true that the results of crossing depend primarily on the selection of the varieties used for that purpose. These indicate the list of possibilities from which the choice and the combinations have later to be made. Outside of this list, very little good is obtained, and then only by accident. This occurs very seldom in Burbank's cultures."

SELECTION OF SEEDS.

Within the past twelve years, we have done a large amount of very careful work in order to determine the influence of different selections of seed upon the resulting crop. Fresh seed has been taken each year from the general crop of grain grown on the farm, or from seed of the leading varieties of roots and rape as obtained from some of the best seedsmen. The results, therefore, represent one year's influence from seed selection, but in order to obtain the influence from one year's work of this selection, the experiments have been repeated from season to season, in order to secure a good average of conditions of soil, temperature, and rainfall.

For the large seed of the cereals, none but well-developed grains were selected; for the medium-sized sample, the grains selected were of a uniform character, plump and of medium size; and for the small, none but sound, plump, and apparently good seeds of small size were used. In the selection of large plump grain, one-half pound of each class was carefully weighed and counted. A corresponding number was then taken of the medium-sized and of the small, plump grains. The different selections were sown upon plats of similar size.

Four tests were made annually with the different selections of seed of both the root and the rape crops. Duplicate experiments were conducted, in which the seeds of the different selections were planted separately, and a duplicate experiment was also conducted by dibbling 3 large, 5 medium, and 8 small seeds at each place where it was desirable for a root or a rape plant to grow. The plants were afterwards thinned, leaving one in each place and having the plants of the different selections of each class an equal distance apart. The results of the duplicates of each method were then averaged and afterwards those of the two methods were averaged together. It will therefore be seen that the results of all the selections with roots and rape are those of four distinct tests made in each of the years in which the experiment was conducted.

Results of seed selection with cereals and other crops.

CROP.	Length of tests.	Yield of crop per acre from—		
		Large seed.	Medium sized seed.	Small Seed.
Grains :	Years.	Bush.	Bush.	Bush.
Oats	7	62.0	54.1	46.6
Barley	6	53.8	...	50.4
Spring Wheat	8	21.7	...	18.0
Winter Wheat	6	46.9	...	40.4
Field Peas	6	28.1	...	23.0
Field roots:		Tons.	Tons.	Tons.
Mangels	5	33.2	29.6	21.5
Sugar Beets	5	22.9	21.9	14.3
Swede Turnips	5	17.1	15.2	8.7
Fall Turnips	4	25.4	21.7	16.2
Field Carrots	5	24.5	22.2	16.2
Rape	5	17.4	15.0	12.4

From the figures here presented in tabulated form, it is most interesting to observe the marked influence of one year's selection of seed on each of the 11 different crops here enumerated. The large, well-formed seeds produced stronger and more vigorous and more productive plants.

In other experiments along similar lines, we have obtained better results from plump as compared with shrunken seed, from sound seed as compared with that which was injured in the process of threshing, from grain which was perfect in comparison with that which had sprouted in the field, and from seed which was thoroughly ripened in comparison with that which was harvested while it was still immature.

An interesting experiment has been conducted for thirteen years in succession, in a systematic selection of seed oats. The selections were made of large, plump, black seeds and also of light-weighting and light-colored seeds. The test was commenced in the spring of 1893, by selecting seed from the general crop of the Joannette black oats of the previous year. The selection made in each of the following years was from the product of the selected seed of the previous year. The selections each year were composed of an equal number of grains and were sown on plats of uniform size. As the selection for this experiment has been continuous, the seed each year being selected from the crop produced in the year previous, the average results are of but little value, but the yearly results are interesting, valuable, and quite suggestive. In the crop of 1905, it was found that large plump seed produced 65.5 bushels and the light seed 44.7 bushels per acre. In each of the past few years, the results have been much the same as those for 1905. In weight per measured bushel, the crop produced from the large plump seed weighed 35.5 pounds and that from the light seed 24.3 pounds. It is interesting to notice that of the crop produced from the large plump seed it required only 1149 grains to

weigh an ounce, while of the crop produced from the light seed it required 2066 grains to make the same weight.

It will be seen from the results here presented, that the selection of the seeds themselves has a considerable influence on the production of the crop and should form a factor in the process of breeding.

SELECTION OF PLANTS.

In the spring of 1903, some very choice grain of 6 varieties of oats, barley, and spring wheat was selected from the crops grown at the Ontario Agricultural College in 1902. Of each of these 6 varieties, one-sixteenth of an acre was sown with a grain drill in the ordinary way; one-sixteenth of an acre was sown with a grain drill by using every second tube of the drill; one-sixteenth of an acre was planted by hand, placing the seeds 8 inches apart both ways; and one-sixteenth of an acre was planted by hand, placing the seeds 1 foot apart each way. It will, therefore, be seen that one and one-half acres were devoted to this work in 1903. No less than 9,972 seeds of each variety, or a total of 59,832 seeds of the 6 varieties, were planted by hand. The 4 methods of planting were used in order that a comparison might be made as to the best method to use in plant selection. It was found that the grain which was sown with a grain drill, either from every tube or from every second tube, gave a very poor opportunity for plant selection. From grain sown with a drill, heads may be selected, but it is practically impossible to make a satisfactory selection of plants, owing, largely, to the uneven distribution of the seed. When plants are grown at unequal distances apart, they vary greatly, owing to the relative amount of soil, moisture, and air, furnished the individual plants by the uneven way in which the seeds were distributed in the soil. On a careful examination of the plants obtained from the drilled seed, it was found that some of them would be separated from all other plants by 10 or 12 inches; while in other cases 2 or 3 plants would be growing so close together and their roots and stems had become so much entangled that to ascertain whether there was simply one plant or two or three or four plants required a considerable amount of time and labor in making the examination. It was therefore decided to make a few selections of heads, but not to make a selection of plants from the crop produced from the seed sown with a machine. The grains which were sown by hand, however, gave an excellent opportunity for the plants to grow under uniform conditions. As all the plants in each of the two methods of hand planting were at equal distances apart, it afforded an excellent opportunity for studying the stooling properties, the comparative strength of straw, and the size and uniformity of the heads, etc., of the individual plants. When the crops of each variety on the hand-planted plats had reached the proper stage of maturity, careful examinations were made and the results recorded for reference. After this was done, a few of the very best plants were selected and harvested separately. All of the seed of the most promising plant of each variety was sown in the spring of 1904, and nearly all the grain produced in 1904 was sown in the spring

of 1905. A number of the other choice plants of each variety was also selected and harvested separately and afterwards the best seed was selected and sown in single rows in the spring of 1904. From those strains which gave the best satisfaction in 1904, a sufficient amount of seed was selected and sown on uniform plats in the spring of 1905, and the yield and the quality of the crops produced were carefully recorded. The results so far are encouraging. A statement of a few of the records are here given.

Increased stooling properties.—The crops grown from the seeds planted 1 foot apart each way showed the average number of heads per plant from the selected seed in 1903, and from the seeds produced from the selected plants in 1904, to be as follows:

Development of stooling by selection.

Crop.	Average number of heads per plant.	
	1903	1904
Six-zowed Barley (Mandscheuri).....	10.8	13.5
Two rowed barley (Chevalier).....	26.3	31.7
White oats (Siberian):.....	13.6	18.4
Black oats (Joanette).....	27.6	46.9

As the seeds were planted exactly the same distance apart in each of those two years, it is quite probable that the influence of the selection made in 1903 is largely the cause of the increase in the average number of heads per plant in the crop of 1904, as compared with that of the previous year.

Improved strains of leading varieties of spring grain.—Upwards of 100 selected strains of leading varieties of winter wheat and spring grains were grown in the experimental grounds on uniform plats in 1905. Of these plats 56 contained selected strains of spring crops described previously. Some of these strains are promising, as they indicate a greater yield of grain per acre than was obtained from seed produced from plats which had not been specially selected. The table which follows gives the highest yields per acre obtained in 1905 from seed resulting from the plants selected in 1903, as previously described. In comparison with these yields are those produced from selected seed from plants which were not specially selected.

Improvement in yield resulting from selection of plants.

Crops.	Yield of straw per acre from—		Yield of grain per acre from—	
	Selected seed from plants not specially selected.	Selected seed from plants specially selected.	Selected seed from plants not specially selected.	Selected seed from plants specially selected.
	Tons.	Tons.	Bush.	Bush.
Six-rowed Barley (Mandscheuri)	1.8	2.0	68.4	78.5
Two-rowed barley (Chevalier)	2.1	2.4	44.8	58.6
Hulless barley (Guy Mayle)	1.6	2.0	47.3	48.6
White oats (Siberian)	2.3	2.1	86.1	91.3
Black oats (Joanette)	2.1	1.9	79.3	89.0
Spring wheat (Wild Goose)	1.4	1.8	29.7	36.4

Although there is a slight irregularity in the yield of straw per acre, it will be seen that in every case the yield of grain from seed obtained from selected plants was higher than that produced from seed obtained from plants which were not selected.

The production of one seed grain in a period of two and a half years.—As previously stated, the most promising plant of the thousands of plants of each of six varieties of spring grain grown in 1903, was saved and the seed produced was all sown by hand in 1904, from which crop the grain was carefully saved and was sown with an ordinary grain drill in the spring of the present year. The following table represents the yield of grain in 1903, and the yield of both straw and grain in 1904 and in 1905:

Yield of a single seed in three seasons.

Crop.	Yield of grain 1903.	Yield of crop 1904.		Yield of crop 1905.	
		Straw.		Straw.	
		Grain.	Grain.	Grain.	Grain.
	Ounces	Pounds	Pounds	Pounds	Pounds
Six-rowed barley (Mandscheuri)	2.3	148	68	2887	1929
Two-rowed barley (Chevalier)	2.4	112	56	3265	1119
Hulless barley (Guy Mayle)	2.9	184	98	2178	2109
White oats (Siberian)	1.6	171	61	3553	2102
Black oats (Joanette)	1.2	196	74	8748	3439
Spring wheat (Wild Goose)	1.0	46	15	542	241

From these results, it will be seen that we obtained in 1905 fully 101 bushels of Joanette oats, 61 bushels of Siberian oats, 40 bushels of Mandscheuri barley, 35 bushels of Guy Mayle Hulless barley, 27 bushels of Chevalier two-rowed barley, and 4 bushels of Wild Goose spring wheat, as the direct result in every case of one seed planted in the spring of 1903. When we realize the fact that one single grain of the Joanette oats planted in the spring of 1903 produced over 100 bushels of grain in 1905, on about 2 acres of land, we learn something of the importance of securing even single grains of the highest possible value. In comparison with 100 bushels of the Joanette oats, we have

only about 4 bushels of the Wild Goose spring wheat under just as favorable conditions. The Wild Goose spring wheat has only a few heads per plant and a comparatively small number of grains per head. The crops which are here reported were greatly admired by thousands of farmers who visited the college and examined the experimental plats in the month of June of the present year.

Oats and barley grown on the same farm for sixteen years without change of seed.—The question of the advisability of making a frequent change of seed is one which has claimed the attention of farmers for long periods of time. It is a problem which is exceedingly difficult to solve; in fact, it is practically impossible to find a solution which will comply with all cases. Any information, however, which can throw light upon this perplexed question should be welcome. If it is necessary to change seed grains every two or three years in order to keep up the vigor of the plants, the problem of seed selection is an exceedingly difficult one. We find at the present day a considerable number of the very best farmers who think that good results may be obtained by growing the same varieties on the same farm for several years in succession without the introduction of fresh seed from other farms, soils, or localities. At the Ontario Agricultural College, 8 varieties of oats and 8 varieties of barley have been grown for sixteen years without change of seed. Care has been exercised each year to select the best grain for seed purposes. The crops have been grown on soil which might be termed an average clay loam, and in no one year out of the sixteen were the crops produced on either a light sandy or a heavy clay soil. The land received no commercial fertilizers whatever, but was manured about with 12 tons of farmyard manure per acre every four years. It has been cropped heavily with grain, roots, corn, potatoes, etc., and has probably changed but little in its productive capacity. As accurate records have been kept regarding the comparative yields per acre of each variety in each of these years, we are in a position to present results for comparison. The following table gives the average yields per acre per annum for each of the four periods of four years each; also the average yield per acre per annum for the whole period of sixteen years:

Yields of oats and barley on same farm for sixteen years without change of seed.

Crop and variety.	Average yield per acre per annum for each of four periods of four years each.				Average annual yield per acre for 16 years.
	1890-93	1894-97	1898-01	1902-05	
Oats:	<i>Bush.</i>	<i>Bush.</i>	<i>Bush.</i>	<i>Bush.</i>	<i>Bush.</i>
Joanette	84.8	88.7	84.9	102.4	90.2
Siberian	72.9	83.9	90.4	105.4	88.2
Waterloo	74.3	84.1	85.6	105.9	87.5
Oderbrucker	74.6	85.1	85.8	102.9	87.1
Probsteier	75.7	81.6	88.1	100.3	86.4
Bavarian	70.6	79.9	86.6	103.3	85.1
Egyptian	70.7	71.4	76.4	88.5	76.7
Black Tartarian	67.2	60.5	66.5	91.9	71.5
Averages	74.0	79.0	83.0	100.0	84.0
Barley:					
Mandscheuri	60.3	72.2	70.3	76.4	69.8
Oderbrucker	53.1	61.6	68.4	68.9	63.0
Common six-rowed	50.5	56.7	68.4	68.9	61.1
French Chevalier	54.6	55.8	68.3	61.2	60.0
N. Z. Chevalier	49.6	56.7	68.2	64.7	59.8
Mensury	48.4	53.4	73.9	59.0	58.7
Black hullless	38.8	39.1	47.5	50.1	43.9
Hungarian	42.7	34.8	42.2	50.8	42.6
Averages	50.0	54.0	63.0	63.0	57.0

The results are very interesting and quite suggestive. Without one exception, the average yield per acre for the last four years is greater than for the first four years for each variety grown during the sixteen year period. It will be seen that the average yield per annum for all varieties for the last four years surpassed that of the first four years by 26 bushels per acre for the oats and 13 bushels per acre for the barley. The figures here presented show quite clearly that it is possible to grow the same varieties of grain on the same farm for a considerable number of years without change of seed, providing great care is exercised each year in the selection and the sowing of the seed and in the handling of the crop.

THE PRODUCTION OF HYBRIDS.

Even though we take great pains in selecting the best seed from the best plants of the best varieties of cereals, we find that the plants produced, although greatly improved in many respects, have weaknesses. We observe that some varieties are specially strong in certain characteristics, while other varieties are equally strong in others. With the hope of originating new varieties possessing the good qualities and free from the weak features of some of the best kinds, efforts have been made to obtain the desired results through artificial cross fertilization. With the aid of the investigations made by Mendel, de Vries, Correns, Bateson, and others, we are obtaining new light upon this problem which we hope to be able to apply to excellent advantage. In former years when crosses of cereals were made, it was

thought necessary to continue growing the crosses for six, eight, or ten years before the varieties became fixed. It is hoped that, with the new information obtained, more definite results may be secured in considerably less time. At our agricultural college, we have crossed a few of our best varieties of spring wheat, winter wheat, oats, and barley. The work has been largely accomplished during the last four years. The results in 1905 are certainly very encouraging. We had, in all, about 8000 hybrids the past season. In all our crosses, we are working along definite lines with the hope of securing what we are after, as for instance, we have crosses between the Siberian and the Joannette varieties of oats. Of about 250 varieties of oats which we have had under experiment, the Joannette black has produced the greatest yield of grain per acre, has been the greatest stooler, and has furnished grain which was exceedingly thin in the hull. This variety, however, is very short in the straw and unsuitable for general cultivation. The Siberian variety possesses straw of good quality and grain which is white in color, but the yield per acre is slightly less, the percentage of hull rather greater, and the stooling properties not nearly as highly developed as in that of the Joannette. We now have hybrids which are long in the straw, possess good stooling properties, and furnish grain white in color and exceedingly thin in the hull. We hope that these properties may be retained, so that a variety may be secured which will be constant in its possession of the good characteristics obtained from these two prominent varieties of oats. We also have crosses and hope to unite in the same varieties the good qualities of the Dawson's Golden Chaff and the Turkey Red varieties of winter wheat, the Herison Bearded and the Red Fife varieties of spring wheat, the Mandscheuri and the two-rowed Chevalier varieties of barley, the Common Emmer and the Red Spelt, etc. Although there is a great difference of opinion at the present time as to the outcome of the recent investigations in plant breeding, we believe, from what we have been able to learn from the work of others and from our own practical experience, that tremendous strides will be made along the line of plant improvement through artificial cross fertilization within the next few years.

It will be seen from what has already been said, that the work of breeding cereals, in its best form, means careful systematic work, conducted along definite lines over a long period of time, by first selecting the best seed from the best plants of the best varieties, in order to secure a foundation stock for crossing for the production of new varieties and then eliminating as many of the poor qualities and incorporating as many of the best characteristics as can be brought together in any one variety to fulfill a certain and definite purpose.