M.Sc. Agronomy

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A COMPARISON OF GRAIN CROPS GROWN SINGLY AND IN COMBINATION

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Abstract of thesis

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A COMPARISON OF GRAIN CROPS GROWN SINGLY AND IN COMBINATION

Trials involving the comparison of oats and barley grown singly with their mixtures in three different proportions were conducted in randomized blocks at six points in Quebec, during periods from two to five years. Percentages of each species in the crop, by weight, as well as their actual and expected yields were computed.

Data show evidence of the complexity of phenomena involved in the competition between species in mixture, brought about by such factors as varieties, proportions, stations and years. Gains in one species were made usually at the other's detriment. The barley species has benefited generally from being grown in mixture.

Mixtures have given yields intermediate between those of pure crops. However, some results indicate the possibility of yield increases with selected varieties in some districts.

Notwithstanding the fact that growing barley and oat mixtures does not definitely increase yields, the practice is acceptable.

I. INTRODUCTION

Cereal mixtures, mainly barley and oat mixtures are grown fairly extensively in the province of Quebec and Ontario. According to the agricultural statistics (12)[x], grain mixtures acreage in 1942, in Quebec, was 272,000 acres which is twice as much as that for barley. This acreage was doubled since 1937. In Ontario (11), the mixture acreage was a little over 1,100,000 acres in 1942 which is more than three times that for barley. There too, the mixture acreage has steadily increased since 1937 which was lower than in 1931.

Cereal mixtures are grown for feeding purposes. They are especially destined for hog fattening. Agriculturists have contributed much in popularizing them since more barley is desirable for hog production. Quebec, particularly, has a low acreage in barley and mixtures are an intermediate condition between oats and barley.

Furthermore, it has been the general consensus of opinion that grains grown in combination yield more than when grown singly. This belief is based on the following reasons: a better utilization of soil nutrients, moisture and light by mixtures than by crops grown singly. Mixtures are believed to be an assurance against a failure of one crop caused by epidemics or adverse conditions. When

x - Figures in parenthesis refer to literature cited.

two crops are grown together, it is thought that a part failure of one of them is compensated by the other's success.

Agricultural statistics of Ontario (11) and Quebec (12) seem to give reason to that theory. The average yield in Ontario for the period 1932-1941, for barley, oats and mixtures, was respectively: 29.7, 33.8 and 34.1 bushels per acre while in Quebec, for the eleven-year period (1932-42), it was for barley, oats and mixtures, respectively: 24.8, 26.7 and 27.8 bushels per acre. Even if these figures are only approximates, they militate in favour of mixtures.

11. REVIEW OF LITERATURE.

Research on mixtures in comparison with grain grown singly has not been very extensive during the last twenty-five years. In United States, a few experiments were conducted at scattered points from 1921 to 1937. Cardon (6) experimented five years with oat, wheat, barley and pea mixtures involving various proportions. He stated: "It seems, therefore, that so far as total feed is concerned nothing was gained by growing the crop mixtures. The grain produced from some of the mixtures may have had a higher feeding value..." Martin (8) conducted tests on barley, oat and wheat mixtures for three years and stated: "The three-year average yields show very little advantage

in growing the grain mixtures... Under the conditions of the experiment the growing of grain mixtures would not be advisable". Arny et al. (3) working with flax cropped in mixture with wheat, oats and barley concluded after four or more years of experiments in Minnesota, North Dakota, Montana, Wisconsin and Ohio that "when rainfall and other weather conditions are favourable a somewhat higher relative yield per acre is obtained from the mixed crop than from the two crops grown separately". But the chief advantage of the mixed crop, from the flax standpoint, was the checking of common seeds. Morrish (9) on the other hand, after three years of experiments in Michigan concluded: "It should be noted that frequently one of the crops grown alone outyields the mixture. In some instances this is the oats and in others the barley, depending on which crop was most favored by seasonal and environmental conditions. In all instances, the mixtures of oats and barley as grown in the field outyielded a mixture produced by growing the two crops separately and mixing them for feed afterwards. Thus, the feeder growing a mixture may eliminate the guess work as to whether the season will favor oats or barley". The Ohio Agricultural Experiment Station, after 10 years' trials with oats and barley mixtures states in a special circular (1): "In these tests conducted on a soil limed to a reaction of about pH 6.5, barley and oats have yielded practically the same and no advantage was obtained

by mixing the two". Bussell (5) conducted trials of mixtures of oats and barley in six counties over periods of five to ten years. "In Cattaraugus County the mixtures of oats and barley outyielded oats alone by 7 bushels to the acre and barley alone by about one bushel (average of 5 years). Likewise the mixture outyielded oats by about 2 bushels to the acre in Franklin and Monroe Counties while the situation was reversed in Oneida, Delaware, and Washington counties". In all trials except in Oneida, yields of oats and mixed barley were close to the higher yielding species, either oats or barley.

In Canada, considerable work was done on grain mixtures at the Ontario Agricultural College, by Zavitz (17). In 1902 an experiment was started with twelve different kinds of grain grown in mixture to determine which one would produce the greatest percentage in the crop. Average figures for a 20-year period showed that barley gave the highest proportion in the crop followed by oats and spring rye. Other species such as wheat and rye, decreased as compared with their proportion in the seed mixture. At the same time, barley, oats, wheat and peas were grown separately and in various combinations. "It will be seen that with but one exception (peas and wheat) the grains grown in combination gave higher returns than the same grains when grown separately. For

instance, when oats and barley were grown together they gave a higher yield than was produced on an equal area, one-half of which was used for pure oats and the other half for pure barley". After 16 years' trials, the mixture 50% oats and 50% barley, by weight, gave the highest average yield.

At the Cereal Division of the Central Experimental Farm, Ottawa (10), considerable time was spent on trials with grain mixtures. "Three years of plot tests with grain mixtures (have) demonstrated that when varieties are used that mature approximately at the same time, the yields of mixtures of barley and oats; barley, oats and peas and of oats and peas have been equally as high and in some cases slighly higher than any of the above crops grown alone, at Ottawa. Further, that the addition of one-half bushel of peas to a mixture of oats and barley increased the yield of protein per acre by over thirty per cent". The Nappan Experimental Farm (4) also conducted a number of trials on grain mixtures. "In these tests the addition of wheat to oats and barley has not appeared to be of any benefit". In general, the Experimental Farms have undertaken considerable work on mixtures with the purpose, however, to ascertain the most profitable species for seeding in mixtures and to find the most satisfactory rates of seeding from the standpoint of yield and maturity. The Superintendant at Ste-Anne-de-

la-Pocatière wrote in his Progress Report (14): "While not very extensively practiced, the growing of mixed grains for feeding purposes is becoming increasingly important, as the advantages derived from this system become widely known".

III. PURPOSE OF EXPERIMENTS

Conclusions of research on mixtures are very contradictory as shown by the review of literature. It seems that the value of mixture depends largely on the local environmental conditions. In Canada, data of Zavitz at the Ontario Agricultural College show evidence of the superiority of some mixtures of species over grain grown singly. His results are confirmed partly by experiments conducted at the Central Experimental Farm, at Ottawa.

In Quebec, little work was done to determine the value of mixtures from the yield standpoint, as compared with grain grown singly. Yet, it is generally believed that mixtures yield more than grain grown singly. This belief is probably the consequence of the results obtained elsewhere and of the observations at the Experimental Farms. Besides, the same results may well have biased the figures mentioned above from the Quebec Statistical Yearbook showing the superiority of grain mixtures.

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In spite of all those facts and because there has been no extensive work done on the mixture problem under Quebec conditions, many agronomists were inclined to be somewhat skeptical about the yield increase due to the growing of grain in mixture. Consequently, experiments with mixtures were undertaken in 1941 at Macdonald College and in 1942 at other stations, with the purpose of finding out if grain grown in combination yields more than when grown separately.

IV. MATERIAL AND METHODS

Experiments on mixtures were conducted at six points in the province of Quebec, namely: Macdonald College (45°25'N, 73°59W), the School of Agriculture of Ste-Martine (45°15'N, 73°45W), the Dairy School of St-Hyacinthe (45°37'N, 72°58'W) and the Experimental Stations of Lennoxville (45°25'N, 71°57'W), Ste-Anne-de-la-Pocatière (47°25'N, 70°3'W) and Normandin (48°38'N, 72°29'W). The first three points are of that region called the plain of Montreal where climatic conditions are similar. At Macdonald College, the soil varies from medium to sandy loam while at Ste-Martine it is a heavy clay and at St-Hyacinthe, a sandy clay. The Lennoxville Station is situated in the physiographic

region called the Eastern Townships. Soil is a silty loam. The Ste-Anne Station is on the South Shore of the Esturian Region of the St.Lawrence River on a heavy Champlain clay while the Normandin Station is in the Lake St.John region where soil is a heavy silty clay. Climatic conditions at these three last stations differ much from each other and from the stations in the plain of Montreal.

This study of mixtures was confined to oat and barley species as these two crops are by far the most extensively grown in the province and their mixtures, the most popular.

As varieties of oats and barley differ widely in their adaptation to soil and climatic conditions and in their competitive ability, several oat and barley varieties were used in this study. Thus, the reaction of varieties to locality and to the variable competition with different varieties can be studied.

At Macdonald College, three varieties of oats were chosen, namely Mabel, Vanguard and Banner. They were mixed with the OAC 21 and Charlottetown 80 barleys. At all other stations, the Mabel-OAC 21 combination was used. At Ste-Martine and St-Hyacinthe, it was only the latter. The three Experimental Stations added a combination which was thought to be better adapted and superior to the Mabel-OAC 21 mixtures. It was Vanguard-Peatland at Lennoxville, Banner-Charlottetown 80 at Ste-Anne-de-la-Pocatière and Erban-Velvet at Normandin.

All these varieties are commonly grown in the province. Banner is renowned for its wide range of adaptation; it is late maturing, and it makes a good mixture with Charlottetown 80. It is much too late to be mixed with OAC 21. Vanguard is a relatively new variety; it is intermediate in maturity between Banner and Mabel. It mixes fairly well with Charlottetown 80 and Peatland. The latter barley variety is slightly earlier than Vanguard while Charlottetown 80 ripens a few days later in most years. It is, however, too late maturing to be mixed with OAC 21. The Mabel-OAC 21 combination is probably the best one for harmony as to maturity; it is also widely adapted for which reason it was seeded at all stations. The Erban variety combines well with Velvet and both varieties are well adapted to the Lake St.John area.

Besides having several mixtures of oat and barley varieties, the experiment included several proportions of oats and barley in mixture. With every varietal combination, oats and barley were seeded as checks to evaluate yields of grain grown singly and serve as basis of comparison with grain grown in combination. With the pure seedings three mixtures with various proportions of oats and barley were compared: 75% oats-25% barley, 50% oats-50% barley, 25% oats-75% barley. The percentages of oats and barley are percentages of the rates of pure seeding of oats and barley, which were 100 pounds per acre.

All these tests were carried in randomized blocks. At Macdonald College, mixtures were replicated twice because there were six mixtures. Four replications were used at all other points. The experimental technique used differed in details between stations. Size of plot is one of those factors. However, all data have been expressed on a common basis: yield in pounds of grain per acre. The percentages of oats and barley, by weight, were also evaluated for every proportion of each mixture at all stations.

The analysis of variance method (7) was used to analyse the data. St-Hyacinthe data were analysed according to the method devised by Snedecor for proportional subclass numbers (15).

The coefficient of variability $\frac{(\text{standard error} \times 100)}{(\text{mean yield of experiment})}$ which gives a good picture of the accuracy of the trial and of its reliability was computed for every test. Necessary differences for significance at the 5% level of significance were calculated for all means liable of comparisons.

However, the analysis of gross yields of grain with the aid of statistical methods is not sufficient to solve this complex problem of the value of grain grown in combination. Mixture yields may excel only one of the pure species and still be superior to grain grown alone. The point to elucidate is the following: (example 50-50 mixture of oats and barley) do a one-acre field of oats and a one-acre field of barley yield more pounds of grain than a two-acre field seeded with a mixture

made up of half oats and half barley, by weight?

To answer such a question, research workers have in the past used various methods to estimate the value of mixtures. Arny (2) working with flax and wheat placed all yields on a relative basis with one crop. He "divided the yield of flax grown alone by the yield of the wheat grown alone. The yield per acre of wheat grown alone and in each combination crop was then multiplied by this factor which reduced the wheat yields to a flax basis. The wheat yield in each combination reduced to a flax basis, was then added to the flax yields from the same combination (which) placed all yields on a relative basis with flax grown alone as 100". Arny et al (3) used a different method. "Yields of each crop grown in a mixture (were divided) by the yield of each crop grown alone. These quotients express the percentage yields of each crop in a mixture with the crops grown alone as 100. The percentages thus obtained were added for any mixture and the sum express (ed) the percentage or relative yield of the mixture as compared with each crop grown alone". Morrish (9) dealing with oats and barley used the same method as Arny et al. The Ohio Agricultural Experiment Station (1) converted yields of grain into yields of protein. Martin (8) and Zavitz) (17) designed the following method. Theoretical mixture yields were calculated by multiplying the yields of the crops grown alone by the percentage at seeding of each crop in the mixture. The

sum obtained by adding the two yields is the therotical yield. For instance, for the mixture 75% oats-25% barley, the theoretical yield would be: 75% of yield of pure oats + 25% of yield of pure barley. If the theoretical yield for any mixture is higher than the obtained yield, it means that grain grown in combination gives lower yields than grain grown singly and conversely; if theoretical yields are excelled by observed yields, mixtures give superior yields over grain grown alone. The method is based on the assumption that there is a direct ratio between the yields of one species in a mixture and that of the same species when grown singly in proportion to the rate of seeding used for the pure species.

This last method has been adopted in this study. Besides being simple and easy to understand because yields are in common terms, it allows the study of individual yields of oats and barley grown in mixture, which is the only way of studying their intimate behaviour. The necessary differences for significance were calculated for these individual yields. They were computed by multiplying the necessary differences for significance of means of proportions by the percentage of grain at seeding in the proportions. For instance, if the difference for significance between means of proportions for a given trial is 200 pounds, it will be for the percentage 75% in the proportion 75%-25% or 25%-75%: 200 pounds x .75 or 150 pounds. In doing so, we are computing the differences for significance

for theoretical yields of mixtures.

Although the main object of this study is to determine if oats and barley yield more pounds of grain when grown in combination, an elementary analysis of grain yields is made from the standpoint of total digestible nutrients. The study is limited to average yields for each station. On page 25 further details are given on the difficulties involved with this approach.

V. EXPERIMENTAL RESULTS

Experimental results are given by stations for each year with a summary of all data for each station. Moreover, data from the three Dominion Experimental Farms are summarized in one table. With every table, corresponding analyses of variance are given together with statistical data to evaluate the significance of differences.

Macdonald College Results:-

Weather conditions varied to a great extent during the five-year period of experiments; some of which were more or less favourable to one or the other species or to both.

The 1941 season was not particularly favourable for grain production. Spring was dry and continued so until July. Yields of both barley and oats were below average. In 1942, moisture conditions were not too good at the beginning: early

spring was wet and the month of June had very abundant rainfalls. However, a normal month of July allowed the grain to mature well. Yields were satisfactory. On the contrary, spring in 1944 was dry. But June and July had about normal precipitation and temperature was favourable. Yields were about normal. The season of 1945 was the most abnormal of them all. Early spring was nice but suddenly rainfalls became so abundant that grain could hardly be seeded. Conditions improved but yields were below average.

Results at Macdonald College in 1941, 1942, 1943, 1944, 1945 and the 5-year averages are given respectively in tables 1, 2, 3, 4, 5 and 6 with the corresponding analyses of variance for each year in tables 1a, 2a, 3a, 4a, 5a and 6a. The coefficients of variability for the different years are respectively: 8.8%, 6.4%, 7.0%, 12.2% and 7.6%. They are relatively low, with the exception of 12.2%, if the greater number of treatments is taken into consideration. They are a guarantee of the accuracy and reliability of the results.

Analyses of variance for each year and for the five-year averages show that differences between proportions were significant in all cases. In fact, pure oats excelled pure barley in every combination, in all years. However, those differences between pure oat and barley yields were not always significant if the required differences for significance are used.

If average yields of proportions for the six mixtures in any one year, or for each mixture during the five-year period are compared, pure oat yields excelled pure barley yields significantly in all instances by using the least difference for significance for means of 12 and 10 plots respectively.

Is the superiority of oat yields over barley yields an indication of the better adaptation of oats to local conditions? It is hard to say because the exact yield response of oats or barley to optimun or minimum conditions is not known for this particular area, or elsewhere.

If comparative yields of species can hardly be a measure of their respective adaptation to the environment, percentages of grain in the crop, of each species grown in mixture, may throw some light on those phenomena of adaptation and of competitive ability. It is impossible to isolate the effects of those two factors when one deals with species mixtures. If there were no competition between species, oats and barley would yield, when grown in mixture, in the same ratio as are their pure yields. This seldom occurs since there is competition between species, which changes the whole picture. Unquestionably, a species must be well adapted to the environment if it is to compete effectively, for the competitive ability is made up largely of adaptation. However, species as such have their own power of competition. Even if they are very successful

crops when grown alone some species may be very bad competitors when grown in mixture, depending on their growing habits and the agressiveness of the species associated with them. Consequently, deviations of percentages of grain in the crop from percentages at seeding will be considered as the resultants of the adaptation and competitive ability of species.

In 1941, where generally pure oats yielded significantly more than pure barley, the percentages of oats and barley in the crop were approximately in the same ratio as oat yields were to barley yields. With the exception of the Vanguard-Charlottetown 80 mixtures, percentages of oats in the crop increased over those at seeding in every proportion while percentages of barley in the crop were necessarily lower than those seeded. The oat crop, in that particular year, seemed to have been favoured by weather conditions and it has competed successfully with barley. In 1942, the situation was completely reversed. Percentages of oats in the crop were lower than at seeding with the exception of the mixture Banner-OAC 21, whereas automatically percentages of barley at harvest were higher than in the seeded mixture. Yet, pure yields of oats in pounds of grain were superior to pure barley yields, in all mixtures, although most of them were not significantly superior. In 1943, 1944, and 1945 the tendency was much the same as in 1942. Yields of oats grown singly excelled everywhere yields of

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barley seeded singly, and very often significantly. In spite of that, percentages of barley in the crop increased over those at seeding in the majority of cases. The extent of increases varied with mixtures and proportions. With some varietal combinations, like Mabel-Charlottetown 80 and Vanguard-Charlottetown 80, increases were larger while with the Banner-OAC 21 and Vanguard-OAC 21 combinations, they were smaller. In the latter two combinations, there were a few decreases of barley percentages in the crop. It is also noticeable that increases of either oats or barley were more marked in the lower proportions of seeding. Also, in some instances, the rates 25% and 50% gave increases whereas the rate 75% produced decreases, for both crops.

It is obvious that mixtures have behaved differently as regards the percentages of grain in the crop. This behaviour is normal since the combination of varieties was different with every mixture, and because varieties have not the same power of competition. Suneson and Wiebe (16) have found "that the relative yield of a variety is not necessarily a criterion of its ability to survive in competition with other varieties (same species) grown in mixtures in the same locality". Good yielding varieties are not always good competitors. This point is well illustrated in these experiments. Although all varieties were well adapted and good yielders, they differed widely in their competitive ability.

The competitive ability of species grown in mixture is closely linked with the differences in maturity between species. A glance at the percentage of grain data illustrates clearly what is meant. In the following mixtures, namely Banner-OAC 21, Vanguard-OAC 21, Mabel-Charlottetown 80 and Vanguard-Charlottetown 80 where differences between days for maturity of varieties in mixture are fairly great, the later-maturing variety in those mixtures has given bigger percentages of grain in the crop than in the seeded mixture. It means that generally the variety which ripens the last in a mixture has a marked advantage over the other from the competition standpoint.

With the above considerations in mind, the specific competitive ability of varieties used in these experiments can be better studied. Banner, in mixture with Charlottetown 80 which usually matures one day or so earlier, has increased its percentages in the crop over those at seeding only once (1941) in all proportions, and twice (1943 and 1944) in the proportion 25% of oats. Mixed with OAC 21 which is much earlier, its percentages were always bigger in the crop than at seeding, except in one proportion in 1942. Since it is slighly later than Charlottetown 80, and much later than OAC 21, Banner would not seem, therefore, to be too good a competitor.

Vanguard has not shown up too well, either. In mixture with Charlottetown 80 which is a few days later, it has in-

creased only once (1943) in two proportions and once (1941) in one proportion. With OAC 21 earlier by a few days, it has decreased once (1942) in all proportions and twice (1943) and 1944) in two proportions.

The early Mabel variety has competed more successfully with barley and would seem to possess a high competitive ability. In mixture with the late Charlottetown 80, Mabel has given increased percentages in the crop over the seeded, in all proportions in 1941 and in one proportion in 1943. With OAC 21, which ripens in about the same.time, Mabel has produced increased percentages over seeding in all proportions in 1941, 1944 and 1945; in 1943, oat percentages at harvest were close to those at seeding.

The comparative competitive ability of the barley species is difficult to appreciate because Charlottetown 80 is a late variety while OAC 21 is early. Both varieties have competed very successfully under the conditions of the experiment. However, Charlottetown 80 would seem to be slightly superior to OAC 21 from that standpoint.

Differences in the percentages of grain in the crop from the expected are almost entirely an indication of the competition between the species in mixture. A variety may have competed favourably in mixture with another, as expressed by its increased percentages in the crop, and yet it may not

have competed successfully if the actual yield is lower than the expected yield as determined by the method outlined previously, and vice versa. The true measure of the effect of competition, lies chiefly in the comparison of the actual yield of each species in any mixture with its corresponding theoretical or expected yield. Thus, increases from expected yields will signify that species have benefited from being grown in mixture; on the other hand, decreases from expected yields will mean that competition from the other species was detrimental. The competition between species can be favourable or detrimental to both.

It is convenient to point out once again, before examining the data, that treatments were only duplicated and, consequently, off-figures are liable to occur here and there. Little attention should be paid to these since the answer to our problem will lie more on general trends than on outstanding results or differences in exceptional instances.

The fifth column in tables 1, 2, 3, 4, 5 and 6 contains differences between actual and expected yields of oats and barley. The next column gives the total differences between actual and expected yields. Differences that are followed by an x are significantly different at the 5% level of significance as determined by using the least difference for significance calculated

for yields of every proportion and for all means, and given in tables 1a, 2a, 3a, 4a, 5a and 6a.

In 1941 (table 1), the differences between actual and expected yields of oats and barley did not follow any definite trend except that in few cases were there increases or decreases, with both oats and barley in the same proportion. On the whole, there were as many yield decreases as increases: actual yields of barley excelled expected yields ten times out of eighteen possible. This is rather surprising since the environment was favourable to the oat crop during that particular year. Total differences did not exhibit any definite tendency, either. None of the decreases or increases was significant. It is remarkable how combinations differed widely in their response. The Banner-Charlottetown 80 mixtures, for instance, gave three yield increases while Vanguard-Charlottetown 80 gave three yield decreases. The summary for all mixtures gave no significant difference.

In 1942 (table 2), the same trend could be observed as in the preceding year: in very few proportions were there increases or decreases of both oats and barley. Furthermore, actual yields of oats were lower than expected yields in all proportions except for one combination; the opposite was true with barley, except in the Banner-OAC 21 combination. Differences were mostly significant. Decreases of oat yields were generally bigger than increases of barley yields, which led to total

yield decreases in pounds of grain as compared with yields of grain grown singly.

In 1943 (table 3), the behaviour of mixtures resembled much that in 1942. However, results were not as consistent and responses of oats and barley in combination varied greatly with mixtures. Increases of barley yields generally were that year bigger than decreases of oat yields which produced total yield increases as compared with total yield decreases in 1942. Differences were not significant, in general, although the 6-mixture summary indicated a strong tendency toward a yield increase due to the growing of grain in mixtures.

In 1944 (table 4), the same tendencies as detected in previous years could be observed. In general, barley gave yield increases while oats gave decreases, in mixture. Most often, decreases were bigger than increases. Few differences were significant.

Results in 1945 (table 5) partly corroborated the preceding remarks about the behaviour of oats and barley in mixture. However, the Mabel-OAC 21 and Vanguard-OAC 21 mixtures behaved differently: they gave yield increases as compared to grain grown singly. The Mabel-OAC 21 mixture, in this connection, produced increases in both barley and oats in all proportions: oat increases were significant but barley increases were not. This comportment has seldom occurred during the five-year period of experiment: a significant increase by

the most favoured species in a particular year and a slight increase or a very slight decrease by the less-favoured species. Such a behaviour would be the condition for obtaining increased yields with mixtures.

Throughout the five-year period of experiments, it is obvious that barley in mixture has given usually yield increases whereas oats have behaved the opposite way. It seems that yield increases and decreases have followed, on the whole, some kind of a pattern which is clearly emphasized in the five-year averages for each mixture (table 6), and still more in the 6-mixture means of the five-year averages of each mixture. The pattern would be as follows: the higher was the oat proportion in the seed mixture, the greater were yield decreases, and the lower were the barley proportions, the larger were increases. The Banner-OAC 21 mixture was an exception: oats gave yield increases and these were bigger with lower proportions of oats in the seed.

The five-year averages (table 6) for each mixture corroborated the general tendencies observed with individual year results. In all but one mixture, barley has produced yield increases over expected while oats have given yield decreases in the same mixtures. In a few proportions, where the percentage of either oats or barley was 25%, the behaviour was different but the gradation trend (noted above) remained the same. In two combinations, oat decreases were higher than barley

increases whereas in three others, oats decreases were sometimes higher, sometimes lower than barley increases. In the Banner-OAC 21 mixture, the oat increases exceeded barley decreases. The differential response of varieties when grown with different varieties of another species does not surprise after what has been said about the variations in the competitive ability of varieties and the influence of differences in maturity between varieties forming a mixture.

However, none of the differences of total yields was significant whereas the individual oat and barley yield differences were significant in many cases. Averages of all mixtures for the five-year period show that proportions 75%-25% and 50%-50% gave small yield decreases and the proportion 25%-75%, a small yield increase. Here again, these differences were not significant.

With such results, it is clear that, from the yield standpoint, there is no advantage to grow oats and barley in mixture under the conditions of the experiment. It is still more evident during the five-year period that mixtures have not been a way of "eliminating the guess work as to whether the season will favour oats or barley" as stated by Morrish (9).

Results in Pounds of Total Digestible Nutrients (T.D.N.):-

Pounds of grain are a common and easy way to express yields of a given crop. It serves well the purpose of comparing different varieties of the same species or of evaluating the fertility of a given field, etc. But it is only approximative when one deals with different species since the nutritive value of various species is quite different. The contents of total digestible nutrients are one of those measures which serve better the purpose of comparing different species.

The Quebec Feed Board (13) fixes approximately the average percentage of T.D.N. in oats and barley to 67.8 and 78.3% respectively. This difference gives a great superiority to barley over oats from that standpoint. However, analyses made by the Chemistry Division at Ottawa on oat and barley varieties grown in mixture at Lennoxville, Ste-Anne-de-la-Pocatière and Normandin show that the margin between the T.D.N. percentage in oats and barley is not always as big, and that the T.D.N. content of oats varies a great deal with varieties. For instance, in 1942, the chemical analyses gave the following results:

Varieties	Lennoxville	Ste-Anne-de-la-Poc.	Normandin
Oats			
Mabel	71.2	71.8	71.5
Vanguard	63.7		
Banner		65.6	
Erban			69.5
Barley			
OAC 21	73.5	73.7	73.7
Peatland	74.3		
Ch'town		74.5	
Velvet			73.7

Unfortunately, chemical analyses of T.D.N. were made only once, in 1942, on the Experimental Farms data. At Macdonald College, there were no chemical analyses made on these tests. Consequently, we are forced to utilize the Quebec Feed Board data. There are obvious discrepancies between such an average estimate and the actual value of each variety but this should not be too prejudicial to our study. If we had intended to compare the feeding value of the various varieties or mixtures, chemical analyses would have been essential but since we want to know if such a study of T.D.N. yields will modify the final conclusions drawn from yields in pounds of grain, the hypothesis that the margin between the nutritive value of oats and barley is always big, will be useful for it will exaggerate possible differences (that some people would expect) between a study of yields in pounds of grain and in pounds of T.D.N.

The five-year average yields in T.D.N. for each mixture and average yields for all mixtures for each year are reported in tables 7 and 8, respectively.

Data show evidence that grain grown in mixture has not produced more pounds of total digestible nutrients than has grain grown singly. Five proportions from various varietal combinations have produced slightly more than the higher yielding species whereas four have given less pounds of T.D.N. than the lower-yielding species but most proportions have given intermediate yields between oats and barley.

With the six-mixture summary for each year, the very same picture is obvious. The relation of oat to barley yields may change but the tendency of mixtures to give intermediate yields between pure oat and pure barley remainsthe same.

On the whole, tendencies were the same whether expressed in pounds of grain or in T.D.N. It is clear that there is no advantage in growing oats or barley in mixture from the standpoint of yields in pounds of grain or total digestible nutrients, under the conditions of the experiment.

St-Hyacinthe Results:-

Experiments were conducted at St-Hyacinthe during the years 1942, 1943 and 1944. In 1942, climatic conditions were excellent for grain production: precipitation was fairly abundant and well distributed. Yields were very high. In 1943,

early spring was wet and June had abundant rainfalls but July was nice and allowed harvesting under good conditions. Yields were good. In 1944, weather conditions were about normal and yields were high.

Results are summarized in table 9 with the corresponding values for significance in table 9a. The coefficients of variability for 1942, 1943 and 1944 are respectively 2.1%, 6.9% and 3.8%. They are relatively low and they testify of the accuracy and reliability of the data.

Yields of pure oats and pure barley did not differ significantly in 1942, 1943 and for the 3-year averages butbarley yielded significantly more than oats in 1944.

The behaviour of the two species in mixture was different from that at Macdonal College. Although pure barley yielded about the same as oats in 1942 and 1943, percentages of barley in the crop were less than when seeded. Moreover, actual yields of barley in every proportion in those two years were less than expected which is entirely different from what was seen at Macdonald College. In 1944, where pure barley outyielded pure oats, the barley percentages in the crop were higher than at seeding and barley yields were significantly higher than expected. The same trend as observed at Macdonald College is noticeable here: yield increases in the most-favoured species are reduced or counterbalanced or excelled by corre-

sponding yield decreases in the less-favoured species. The non-significant yield increases in 1944 are remarkable since they occurred in the poorest year and would tend therefore to smooth yield variations between years, if this behaviour did not occur by chance. Three-year results are not sufficient to draw definite conclusions, but this behaviour suggests strongly that there is little advantage in growing oats and barley in mixture, under the conditions of the experiment.

Results in Pounds of T.D.N.:-

Results in pounds of T.D.N. are summarized in table 10. Yields of T.D.N. generally increased gradually as the percentages of barley were higher in the mixtures. In no case, did any proportion yield more pounds of T.D.N. than barley grown alone. However, in 1944, yields of the proportions 50-50 and 25-75 were close to pure barley yields.

This behaviour of mixtures in pounds of T.D.N. is much in line with that of yields in pounds of grain and does not change to the conclusions drawn above.

Ste-Martine Results:-

Experiments at Ste-Martine were conducted in 1942, 1943 and 1944 but the 1944 plots were discarded on account of bad damage caused by adverse weather conditions and diseases. In 1942, moisture conditions were very good in springtime but the

following months were dry. Yields were fair. In 1943, spring was early and conditions were excellent. May and June were wet but July allowed a normal harvesting of a very good crop.

Results are summarized in table 11 and the analyses of variance are given in table 11a. The low coefficients of variability, 3.4% and 3.6%, testify of the great homogeneity of the soil and the accuracy of those trials. Using the least significant difference, it is clear that pure barley has outyielded pure oats in both years.

In 1942, percentages of barley in the crop were higher than at seeding and the actual yields surpassed expected yields. Oats bahaved the opposite way. In 1943, it was altogether different. In spite of the tremendous superiority of pure barley yields over oat yields, barley percentages in the crop were only slightly higher than in the seeded mixture and its actual yields were lower than expected; oats on the other hand, gave significant yield increases over expected.

This behaviour is rather mysterious. There is no doubt that barley was more favoured by the environmental conditions in 1943 than in 1942. Yet, it gave yield decreases, in mixture with oats, in 1943. This induces us to believe that the species more favoured by environment is not necessarily the one that benefits when being grown in mixture. The more favoured species when grown singly was not the more favoured when grown in combination.

At Ste-Martine, the same tendency as observed at St-Hyacinthe and Macdonald College was obvious: significant yield increases in one species were lessened, or counterbalanced, or exceeded by corresponding yield decreases with the other species, which led to small non-significant total yield increases or decreases. At this location, the tendency, observed at St-Hyacinthe, of mixtures to give yield increases in the poorest year, did not materialize.

Two-year data seem to suggest that, under the conditions of the experiment, grain grown in combination does not yield more than grain grown alone.

Results in Pounds of T.D.N.:-

Results in pounds of T.D.N. are given in table 12. Yields of T.D.N. increased gradually with heavier barley rates of seeding. No proportion yielded more pounds of T.D.N. than pure barley. This analysis does not change any conclusions drawn above from the study of yields in pounds of grain.

Lennoxville Results:-

Trials on mixtures were conducted at the Experimental Station of Lennoxville in 1942, 1943 and 1944 with the Mabel-OAC 21 and Vanguard-Peatland mixtures. In 1942, the season was very favourable. Spring opened early and very good conditions were met. June was wet but crops were harvested in good con-

dition and high yields were obtained. In 1943, spring was backward. Seeding was done 2 weeks later than usual. Very catchy weather was met all through the season, that rendered the harvesting difficult. In 1944, May and June were dry and crops suffered from drought but in July and August, moisture conditions improved and crops looked better.

Results are summarized in tables 13, 14, 15 and 16 with the corresponding analyses of variance in tables 13a, 14a, 15a and 16a. A first striking fact in the Lennoxville results was the different behaviour of the two species in the two combinations. The Vanguard-Peatland mixtures behaved the same way as mixtures generally did at Macdonald College. Vanguard pure plots yielded significantly more than Peatland plots in 1942 and 1943, and were the same in 1944. Nevertheless, barley percentages in the crop were higher than at seeding in all proportions every year; similarly, actual yields of barley excelled expected yields all through. Oats behaved the opposite way. With the Mabel-OAC 21 combination, it was quite different even if, here also, when grown singly oats outyielded barley in 1942 and 1943. In those two years, oat percentages were higher in the crop than at seeding and actual yields of oats were sometimes higher and sometimes lower than expected. In 1944, when pure barley outyielded pure oats, barley percentages were higher in the crop and its actual yields excelled significantly expected yields.

However, in spite of those differences, both combinations showed the same significant trend as was observed at Macdonald College, St-Hyacinthe and Ste-Martine: significant yield increases in the most-favoured species were lessened, or counterbalanced, or exceeded by corresponding yield decreases in the less-favoured species. The consequences were small non-significant total yield decreases or increases.

Results in Pounds of T.D.N.:-

Results in pounds of T.D.N. at Lennoxville are summarized in table 17. Yields in pounds of T.D.N. followed the same trends as yields in pounds of grain: the proportions that produced yield increases seemed advantageous with the T.D.N. analysis and the proportions that produced yield decreases are close to the low-yielding species in the T.D.N. analysis. It is therefore evident that, here again, mixtures did not yield more pounds of T.D.N. than did the pure species.

Results at Ste-Anne-de-la-Pocatiere:-

Experiments on mixtures, at the Experimental Station of Ste-Anne-de-la-Pocatiere, were conducted in 1942, 1943 and 1944 with the early Mabel-OAC 21 and the late Banner-Charlottetown 80 mixtures. The 1942 season was quite favourable to grain production: May, June and August were dry but June had abundant rainfall. Straw was strong and yields excellent.

In 1943, the season was normal except that August was rainy. Yields were fair. In 1944, spring was early and dry: crops suffered from drought at the end of May and beginning of June. On the other hand, July was very wet. Yields were fair.

Experimental results are summarized in tables 18, 19 20 and 21, and the corresponding analyses of variance in tables 18a, 19a, 20a and 21a. Coefficients of variability were respectively 5.1%, 9.3% and 5.4%, in 1942, 1943 and 1944. They are relatively high and off-figures are likely to be met.

Data show evidence of the completely different behaviour of the varietal combinations although both of them are very well adapted to the local conditions. In fact, the three-year averages of the Banner and Mabel oats were not significantly different although they did differ significantly every year. With barley, it was quite different: Charlottetown 80 and OAC 21 did not differ significantly in any one year but their three-year averages were significantly different.

The Banner-Charlottetown 80 mixtures behaved along the same line as was observed at other stations. Percentages of barley in the crop were higher than at seeding in each year and in all proportions, even in 1942, where the pure oat yield excelled significantly the pure barley yield. Similarly, actual yields of barley when grown in mixture were much higher significantly than expected yields, in every proportion in each year whereas actual yields of oats when grown in mixture were

definitely lower than expected yields everywhere. Such a decisive comportment is seen for the first time. Thus again, yield increases of the more-favoured species were counterbalanced generally by yield decreases in the less-favoured species. Yet, at this station, the yield increases and decreases of the two species in the Banner-Charlottetown 80 combination were tremendous, and in 1943, total yield increases in the proportions 50-50 and 25-75 were so high that they produced total significant yield increases in their three-year averages, notwithstanding that these proportions gave non-significant differences in 1942 and 1944.

The Mabel-OAC 21 combination behaved differently as was stated above. In no way was its behaviour as consistent as that of the other combination. Percentages of barley in the crop were higher than at seeding but gains were less pronounced than with the Banner-Charlottetown 80 combination. In the proportion 25-75, they were lower than at seeding in two years. Unlike in the other combination actual yields of barley in mixture did not excel expected yields in all cases; on the other hand, actual yields of oats in mixture excelled expected yields only a few times. In 1943, where two proportions of the Banner-Charlottetown 80 combination gave significant yield increases over grain grown singly, the three proportions of the Mabel-OAC 21 combination gave non-significant yield decreases. In 1944, the proportions 75-25 and 50-50 gave tremendous

yield decreases as compared with grain grown singly whereas the three proportions of the other varietal combination had given non-significant differences. Consequently, the three-year averages of the proportions 75-25 and 50-50 of Mabel-OAC 21 gave two significant yield decreases.

Such significant differences are met for the first time in these experiments. Moreover, the differential behaviour of species in those two varietal combinations cannot be more decisive. It strengthens the opinion already expressed that the complexity of phenomena involved in the competition between species grown in combination is very difficult to interpret. It is surely impossible with such results to make general recommendations, even for one station. Data seem to suggest that some varietal combinations might give yield increases in some districts.

Results in Pounds of T.D.N.:-

Yields in pounds of T.D.N. at Ste-Anne-de-la-Pocatière are summarized in table 22. It is evident that the proportions 50-50 and 25-75 of the Banner-Charlottetown 80 combination have outyielded pure species whereas the proportions 75-25 and 50-50 of Mabel-OAC 21 have yielded about the same as the low yielding species. Averages of the two mixtures show that the various proportions have given about intermediate yields between oats and barley grown singly.

The same tendencies as observed with yields in pounds of grain are obvious with the analysis expressed in pounds of T.D.N., which does not change the conclusions drawn above.

Normandin Results:-

Trials on mixtures at the Experimental Station of Normandin were conducted in 1942, 1943 and 1944 with the early Mabel-OAC 21 and the medium-maturing Erban-Velvet mixtures. The 1942 season was favourable to grain production but the harvesting was rendered difficult by rainy weather. Yields were excellent. In 1943, spring was late, and June, July and August were wet. Yields were below average. In 1944, spring conditions were excellent and the following months were normal. But September was wet and harvesting conditions were very bad. Yields were good.

Experimental results are summarized in tables 23, 24, 25 and 26 with the corresponding analyses of variance and the estimates for significance in tables 23a, 24a, 25a and 26a. Coefficients of variability are respectively 8.5%, 15.1% and 6.8% for 1942, 1943 and 1944. They are relatively high especially in 1943. Consequently, it will be necessary to be cautious in arriving at conclusions.

It is evident that by using the appropriate least differences for significance the Erban-Velvet combination was superior to the Mabel-OAC 21 during the three-year period. How-

ever, the behaviour of species was very similar in the two mixtures. The Mabel oats gave in mixture with OAC 21 lower percentages of grain than did Erban with Velvet. This is rather surprising for everywhere else Mabel had shown up very well and proved to be a good competitor in mixture with OAC 21.

Both mixtures followed the same trends as observed elsewhere. Barley percentages in the crop were generally higher than at seeding, and similarly, actual yields of barley in mixture were higher than expected yields in all but one instance. Here again, very few yield increases in both species could be seen. Nevertheless, in 1944, barley yield increases excelled significantly the oat yield decreases in the proportions 75-25 and 50-50 in the two combinations. The yield increases in 1944 were so big with the Mabel-OAC 21 mixture that the three-year averages of two proportions gave significant total yield increases as compared with grain grown singly.

The fact that the less-adapted combination to the local environment gave significant yield increases whereas the better-adapted one did not, looks queer and again emphasizes the complexity of those phenomena of competition between species grown in mixtures. As mentioned above, caution is necessary in the analysis of these results: the low yield of Mabel oats, in 1944, may not be truly representative. If such

is the case, the total yield increases of mixtures would be less pronounced but the tendency would remain for mixtures to give yield increases as compared with grain grown singly, under the conditions of the experiment. It is worthy of note that the significant yield increases have occurred neither in the best year, nor in the poorest.

Results in Pounds of T.D.N.:-

Results in pounds of T.D.N. are summarized in table 27. Yields in pounds of T.D.N. followed closely the tendencies of yields in pounds of grain. The proportions 50-50 and 25-75 of both combinations have yielded more pounds of T.D.N. than the top-yielding species. However, this yield increase is more striking with Mabel-OAC 21 because of the bigger margin between pure oats and pure barley yields. In 1942 and 1943, the two mixtures have given on the whole intermediate yields between those of pure oats and pure barley whereas, in 1944, yields of mixtures were higher than either pure oats or pure barley yields. As in the preceding study, the tendency of mixtures to give higher yields than pure species is definite but it is advisable to be cautious on account of the great yield variation between and within years, and the short experimental period.

Summary of Yields of the Three Dominion Experimental Stations:-

Data from the Experimental Stations of Lennoxville, Ste-Anne-de-la-Pocatière and Normandin have been summarized for the three-year period: the results secured with the Mabel-OAC 21 mixtures form one group, and the combinations chosen by each station make the other group. This, to allow the comparison of the general behaviour of a mixture of wide adaptation with the mixtures that are supposed to be better adapted to the local conditions. Summaries of yields in pounds of grain and T.D.N. are presented respectively in tables 28 and 29, with the estimates for significance in table 28a.

Average yields in pounds of grain of the groups of combinations have exhibited the same trends. Percentages of oats and barley in the crop were about in the same proportion in both combinations. Actual yields of barley in mixture excelled significantly expected yields in all proportions whereas oats in mixture gave significant yield decreases in all but one proportion. Barley yield increases were larger with lower barley rates of seeding while oat yield decreases were larger with heavier oat rates of seeding. Yield increases or decreases were bigger with the chosen combinations than with Mabel-OAC 21. None of the three proportions of the two gave any significant total yield increase or decrease but it is evident that, as the barley rate of seeding was heavier, there was a gradual tendency toward total yield increases. This trend was still more obvious

in the summary of both mixtures where the proportion 75-25 gave a small yield decrease, the proportion 50-50 a small yield increase, and the proportion 25-75 a significant yield increase.

Yields in pounds of T.D.N. (table 29) corroborate the conclusions drawn from the preceding table. The proportion 25-75 has slightly outyielded the top-yielding species in both combinations and in the summary of both combinations. It is evident that the yields in pounds of T.D.N. tend to be larger with higher rates of seeding barley.

VI. GENERAL DISCUSSION.

The first general impression that is left by the analysis of each year results at the six stations under study is one of great variability in the results and of unsuspected complexity of the behaviour of species grown in combination. Mixtures of species are believed to produce yield increases on the assumption that species benefit of a better utilization of light, soil moisture and nutrients, etc, when grown in combination since their requirements are supposedly different. In practice, this is by no means that simple.

Data show evidence that species do not always benefit from being grown in combination, and when one does, it is most usually at the other's detriment. This is illustrated clearly by the fluctuations in the percentages of harvested grain of each species, in comparison with those at seeding, and by the approximately equal number of barley and oat yield decreases

and increases, when in mixture, In most instances, a yield increase in the most-favoured species was lessened, or neutralized, or exceeded by a corresponding decrease in the less-favoured species, which means definitely that only one species in the mixture usually benefits from being grown in combiration.

How a species is more favoured than an other one, so as to compete successfully in mixture, is hard to determine. It is definite, however, that the better-adapted species or varieties to the environmental conditions are not always the more-favoured when grown in mixture, as shown by the behaviour of mixtures made up of the best adapted varieties to the local conditions. The comparative inferiority or superiority of yields of two pure species is not either an indication of their future behaviour in a mixture because in many occasions barley has benefited from being grown in mixture even though it had been yielding significantly less than pure oats, and in one instance, (Ste-Martine), oats have competed successfully in mixture with barley in spite of the great superiority of pure barley yields over oat yields.

A general glance over the data at the six stations show that on the whole, barley has competed very successfully when grown in combination with oats. Percentages of barley in the crop were most often superior to those at seeding, and similarly actual yields of barley exceeded, in general, significantly

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A general glance over the data at the six stations show that on the whole, barley has competed very successfully when grown in combination with oats. Percentages of barley in the crop were most often superior to those at seeding, and similarly actual yields of barley exceeded, in general, significantly

the expected yields. On the other hand, the oat behaviour was exactly the opposite. It is, therefore, evident that, under the conditions of the experiments, the barley species is generally at an advantage when grown in combination with oats.

However, the degree of success of barley in competing with oats varied a great deal. Variations were brought about by such factors as varieties, proportions, years, stations and the interactions of these factors.

The variety factor has contributed enormously to variations as evidenced by the different behaviour of the barley and oat species when the combination of varieties was different, and that in the same year and at the same station. This may be accounted for by the variable specific ability of varieties to compete when grown in combination with an other species, independently of their adaptation or specific value from the yield standpoint. Furthermore, differences in maturity between species grown in combination are important for it was observed that the variety that matures the last in a mixture has a marked advantage from the competition standpoint.

Proportions have also affected the competitive ability of species grown in mixture in some way or other. It was remarkable that the oat yield decreases were larger where the oat rates of seeding were heavier, and the barley yield increases were larger with lower barley rates of seeding. Furthermore,

where the oat rate of seeding was lower, it seemed that the oat yield decreases were proportionately smaller, which has produced in the proportion 25-75 total lower yield decreases or greater total yield increases than those in the proportions 75-25 and 50-50. This trend which is variable in each year results shows up more definitely in average yields. In common terms, this behaviour would mean that the competition of barley over oats tends to decrease as the percentage of barley in the seed is greater.

Years and stations naturally have a great influence on the behaviour of mixtures. The veracity of this assertion can be demonstrated thoroughly by the comparison of results of individual years and stations. This is quite normal after what was said above about the specific competitive ability of species and varieties of the same species, and when one knows of the tremendous station and annual variations of the variety and species yields, which are caused by the fluctuations of climatic conditions and the changes of environment.

The above considerations on the intimate phenomena involved in the competition between species grown in mixture are very helpful for an intelligent understanding and interpretation of the response of species mixtures on yields in pounds of grain or T.D.N., as compared with grain grown singly.

Total yield decreases or increases, such as determined according to differences between actual and expected species yields, were found to be the best measure of yield differences between grain grown singly and in combination.

The total differences between actual and expected yields by no means followed a definite pattern at any station. This is a normal consequence of the complicated picture of the competition between species grown together. However, it is obvious that there was a general tendency for the varietal combinations to behave one way or the other. In a few instances, mixtures have produced significant yield decreases, and in more instances, yield increases, as compared with grain grown singly, but these were exceptions if the great number of non-significant yield increases or decreases is considered. Therefore, the present widespread belief that mixtures give yield increases whatever combinations are used and wherever they are grown in the province, is not substantiated. Some mixtures may produce yield increases at some definite points but according to the studies herein reported this is exceptional as regards the general behaviour of mixtures in the province as a whole.

Mixtures were believed also to be an assurance against a failure of one of the species in the combination. Data show evidence that this was not the case under the conditions of these experiments.

At Macdonald College, the length of the experimental period, supported by the use of six varietal combinations, is long enough to draw definite conclusions on the value of mixtures at this particular point. It is evident that mixtures have yielded neither less nor more than have oats and barley grown singly, in pounds of grain. Total differences between expected and actual yields did not tend to behave one way or the other, for any mixture for the whole period, or for most mixtures in any one year. Neither did mixtures tend to produce yield increases in the poorer years.

At the five other stations, the experimental period is not sufficient to judge decisively of the value of mixtures at any particular point. However, these trials together with those conducted at Macdonald College are sufficient to give a broad picture of the value of mixtures as compared with grain grown singly, for the whole province.

The behaviour of mixtures at St-Hyacinthe, Ste-Martine and Lennoxville was much in line with that at Macdonald College but the stations of Ste-Anne-de-la-Pocatière and Normandin brought in some variations. The yield increases in one combination at the two stations and the yield decreases in one of them at one station might suggest the possibility of getting yield increases with the growing of barley and oats in combination, at definite points, if proper varieties are used.

The significant yield increase in the proportions 25-75 of the average yields of all data from the three Dominion Experimental Stations is one more dissident sound, and it illustrates clearly what was said previously about the general tendency of proportions to give yield increases when the barley rate of seeding is higher.

The conversion of yields in pounds of grain into T.D.N. has not been of much help in the analysis of the value of mixtures. Yields of mixtures in T.D.N. were generally intermediate between pure oat and pure barley yields, or they followed closely the tendencies expressed by the total yield differences of the grain analysis.

VII. CONCLUSIONS

1.- Data show evidence of the complexity of phenomena involved in the competition between species grown in mixture, as illustrated by the variations of grain percentages in the crop and of differences between actual and expected yields of each species. Such factors as varieties, proportions, stations and years are mainly responsible for these variations.

2.- The great extent to which oats and barley have competed between themselves, when grown in mixture, is clearly evidenced by the general occurence of significant differences between the actual and expected yields of each species. It is noteworthy that a yield increase in one species of the mixture

was most often counterbalanced by a corresponding decrease in the other species. This means that the strong competition that takes place between oats and barley is ordinarily detrimental to one of the species.

3.- The barley species has benefited from being grown in mixture with oats. Its grain percentages in the crop were generally higher than at seeding and its actual yields exceeded significantly expected yields in more instances than oats have, at most stations. The barley yield increases were bigger as the barley percentage in the seeded mixture was lighter.

4.- Mixtures of oats and barley have, on the whole, given intermediate yields in pounds of grain between the pure crop yields. Mixtures did not display any general tendency to produce yield increases in the poorest year so as to lessen the yield fluctuations from year to year, and thus, they cannot be considered as an assurance against a part failure of one crop.

However, the proportion 25% oats-75% barley has shown a great tendency to give yield increases. Moreover, data obtained with the Banner-Charlottetown 80 mixtures at Ste-Anne-de-la-Pocatière, and the Mabel-OAC 21 mixtures at Normandin, would indicate the possibility of securing yield increases from mixtures, at definite points, if varieties used in the mixtures are well selected.

5.- At Macdonald College, it is evident that the mixtures of oats and barley do not yield neither more nor less pounds of grain than pure crops do, under the conditions of the experiment.

6.- The conversion of yields in pounds of grain into T.D.N. was done on the average yields of every station. Yields in pounds of T.D.N. followed sensibly the same tendencies as expressed by the differences between actual and expected yields of grain.

7.- Although there is no advantage from the yield standpoint in growing grain mixtures, the practice is acceptable.

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Table 1- Yields in lb. of grain per acre, at Macdonald College, in 1941.-Averages of 2 replications.

Mixtures & Proportions in seeding	% in crop by weight	Actual yields		Expected yields on the basis of pure yields	Differences from expected yields	
		Total	Oats & barley		Oats & barley	Total
Banner-Charl'town 80 oats 100%	100.	2080	2080	2080		

Table 1a- Analysis of variance of yields in lb. per acre, at Macdonald College, in 1941.

Source	D.F.	Variance	F value	Standard Error	
				lb.	%
Between mixtures	5	402 042	1.44		
" replicates	1	1 289 200	4.60		
Error (A)	5	278 365		527	33.9
Between proportions	4	252 237	13.51 xx		
Mixtures x proportions	20	15 168	----		
Error (B)	24	18 672		136.6	8.8
Total	59				

xx- Significant at the 1% level of significance.

Error (B)

	Means of 2 plots (each mixture)				Means of 12 plots (averages of 6 mixtures)			
	100%	75%	50%	25%	100%	75%	50%	25%
Necessary differences for significance at the 5% level :	280	210	140	70 lb.	115	86	58	29 lb.

Table 2a- Analysis of variance of yields in lb. per acre, at Macdonald College, in 1942.

Source	D.F.	Variance	F value	Standard Error	
				lb.	%
Between mixtures	5	12 035	0.16		
" replicates	1	1 180 204	15.5 x		
Error (A)	5	76 312		276	10.8
Between proportions	4	172 002	6.41 xx		
Mixtures x proportions	20	19 778	.74		
Error (B)	24	26 846		164	6.4
Total	59				

x - Significant at the 5% level of significance.
xx- " " " 1% " " "

Error (B)

	Means of 2 plots (each mixture)				Means of 12 plots (averages of 6 mixtures)			
	100%	75%	50%	25%	100%	75%	50%	25%
Necessary differences (lb.) for sign. at the 5% level :	338	254	169	84	138	104	69	34

Table 3a- Analysis of variance of yields in lb. per acre, at Macdonald College, in 1943.

Source	D.F.	Variance	F value	Standard Error	
				lb.	%
Between mixtures	5	440 244	7.64 x		
" replicates	1	164 955	2.86		
Error (A)	5	57 599		240	12.5
Between proportions	4	412 903	23.04 xx		
Mixtures x proportions	20	45 142	2.52 x		
Error (B)	24	17 924		134	7.0
Total	59				

x - Significant at the 5% level of significance.
xx - " " " 1% " " "

Error (B)	Means of 2 plots (each mixture)				Means of 12 plots (averages of 6 mixtures)			
	100%	75%	50%	25%	100%	75%	50%	25%
Necessary differences (lb) for sign. at the 5% level :	277	208	138	69	113	85	56	28

Table 4a- Analysis of variance of yields in lb. per acre, at Macdonald College, in 1944.

Source	D.F.	Variance	F value	Standard Error	
				lb.	%
Between mixtures	5	365 163	1.65		
" replicates	1	297 651	1.35		
Error (A)	5	220 876		470	22.6
Between proportions	4	256 185	3.97 x		
Mixtures x proportions	20	43 212			
Error (B)	24	64 548		254.1	12.2
Total	59				

x - Significant at the 5% level of significance.

Error (B)	Means of 2 plots (each mixture)				Means of 12 plots (averages of 6 mixtures)			
	100%	75%	50%	25%	100%	75%	50%	25%
Necessary differences (lb.) for sign. at the 5% level :	525	394	262	131	214	160	107	54

Table 5a - Analysis of variance of yields in lb. per acre, at Macdonald College, in 1945.

Source	D.F.	Variance	F value	Standard Error	
				lb.	%
Between mixtures	5	109 141	5.21		
" replicates	1	133 058	6.35 x		
Error (A)	5	20 952		145	9.7
Between proportions	4	280 855	21.27 xx		
Mixtures x proportions	20	27 349	2.07		
Error (B)	24	13 201		115	7.7
Total	59				

x - Significant at the 5% level of significance.
xx- Significant at the 1% level of significance.

Error (B)	Means of 2 plots (each mixture)				Means of 12 plots (averages of 6 mixtures)			
	100%	75%	50%	25%	100%	75%	50%	25%
Necessary differences (lb.) for sign. at the 5% level :	237	178	118	59	97	73	48	24

Table 6a- Analysis of variance of yields in lb. per acre, at Macdonald College, from 1941 to 1945 inclusively.

Source	D.F.	Variance	F value	Standard Error	
				lb.	%
Between mixtures	5	358 943	2.74 x		
" years	4	10 860 386	83.02 xx		
" replicates	5	608 230	4.65 xx		
Years x mixtures	20	248 400	1.90		
Error (A)	25	130 821		362	18.8
Between proportions	4	1 236 693	43.79 xx		
Years x proportions	16	34 372	1.22		
Mixtures x proportions	20	33 718	1.19		
Years x mixt. x prop'ns	80	29 196	1.03		
Error (B)	120	28 238		168	8.7

x - Significant at the 5% level of significance.
xx - " " " 1% " " "

Error"B"	Means of 10 plots (each mixture)				Means of 60 plots (averages of 6 mixtures)			
	100%	75%	50%	25%	100%	75%	50%	25%
Necessary differences (lb.) for sign. at the 5% level :	149	112	74	37	61	46	30	15

Table 9a- Analyses of variance of yields of grain in lb. per acre, at St-Hyacinthe.

in 1942

Source	D.F.	Variance	F value	Standard Error	
				lb.	%
Proportions	4	74 793	20.02 xx		
Replicates	1	678 082	181.55 xx		
Error	4	3 735		61.1	2.1

	Means of 2 plots			
	100%	75%	50%	25%
Nec. diff. for sign. at 5% :	170	127	85	42 lb.

in 1943

Source	D.F.	Variance	F value	Standard Error	
				lb.	%
Proportions	4	52 481	1.33		
Replicates	3	36 668	----		
Error	12	39 508		198.8	6.9

	Means of 4 plots			
	100%	75%	50%	25%
Nec. diff. for sign. at 5% :	306	230	153	76 lb.

in 1944

Source	D.F.	Variance	F value	Standard Error	
				lb.	%
Proportions	4	50 741	6.29 xx		
Replicates	3	9 070	1.12		
Error	12	8 068		89.8	3.8

	Means of 4 plots			
	100%	75%	50%	25%
Nec. diff. for sign. at 5% :	138	104	69	35 lb.

in 1942-43-44

Source	D.F.	Variance	F value	Standard Error	
				lb.	%
Proportions	4	43 561	2.08		
Years	2	1 996 316	95.41 xx		
Years x prop'ns	8	67 227	3.21 x		
Replicates	7	105 994	5.06 xx		
Error	28	20 924		144.6	5.3

	Means of 10 plots			
	100%	75%	50%	25%
Nec. diff. for sign. at 5% :	132	99	66	33 lb.

x- Significant at the 5% level of significance.
xx- " " " 1% " " "

Table 11a- Analyses of variance of yields of grain in lb. per acre, at Ste-Martine.

in 1942

Source	D.F.	Variance	F value	Standard Error	
				lb.	%
Proportions	4	27 352	6.83 xx		
Replicates	3	24 779	6.19 xx		
Error	12	4 003		63.3	3.4

	Means of 4 plots				
	100%	75%	50%	25%	
Nec. diff. for sign. at 5% :	97	73	49	24	lb.

in 1943

Source	D.F.	Variance	F value	Standard Error	
				lb.	%
Proportions	4	795 883	79.65 xx		
Replicates	3	56 493	5.65 x		
Error	12	9 993		99.6	3.6

	Means of 4 plots				
	100%	75%	50%	25%	
Nec. diff. for sign. at 5% :	154	115	77	38	lb.

1942-43

Source	D.F.	Variance	F value	Standard Error	
				lb.	%
Proportions	4	553 381	79.08 xx		
Years	1	7 668 505	1095.87 xx		
Years x prop.	4	269 853	38.56 xx		
Replicates	6	40 636	5.81 xx		
Error	24	6 998		83.7	3.6

	Means of 8 plots				
	100%	75%	50%	25%	
Nec. diff. for sign. at 5% :	86	65	43	22	lb.

x - Significant at the 5% level of significance.
xx- Significant at the 1% level of significance.

Table 12- Average yields with the Mabel-OAC 21 mixture in lb. of T.D.N. per acre, in 1942 and 1943, at Ste-Martine.

Years & Proportions in seeding	Actual yields		Yields in lb. of T.D.N.[z]	
	Total	Oats & barley	Oats & barley	Total
1942				
oats 100%	1792	1792	1215	1215
oats 75%	1803	1181	801	1288
barley 25%		622	487	
oats 50%	1896	749	508	1406
barley 50%		1147	898	
oats 25%	1938	384	260	1477
barley 75%		1554	1217	
oats 100%	1980	1980	1550	1550
1943				
oats 100%	2150	2150	1458	1458
oats 75%	2528	1868	1266	1783
barley 25%		660	517	
oats 50%	2749	1254	850	2021
barley 50%		1495	1171	
oats 25%	3089	748	507	2340
barley 75%		2341	1833	
barley 100%	3271	3271	2561	2561
Averages of 1942-1943				
oats 100%	1971	1971	1336	1336
oats 75%	2165	1524	1033	1535
barley 25%		641	502	
oats 50%	2323	1002	679	1713
barley 50%		1321	1034	
oats 25%	2513	566	384	1909
barley 75%		1947	1525	
barley 100%	2625	2625	2055	2055

z- oats: 67.8%; barley: 78.3%.

Table 17- Average yields with the two mixtures, in lb. of T.D.N. per acre, at Lennoxville, in 1942, 1943 and 1944.

Mixtures & Proportions in seeding	Actual yields		Yields in lb. of T.D.N.[z]	
	Total	Oats & barley	Oats & barley	Total
Mabel-OAC 21				
oats 100%	2556	2556	1733	1733
oats 75%	2448	1763	1195	1731
barley 25%		685	536	
oats 50%	2350	1106	750	1724
barley 50%		1244	974	
oats 25%	2482	680	461	1872
barley 75%		1802	1411	
barley 100%	2417	2417	1893	1893
Vanguard-Peatland				
oats 100%	2907	2907	1971	1971
oats 75%	2887	1821	1235	2070
barley 25%		1066	835	
oats 50%	2638	959	650	1965
barley 50%		1679	1315	
oats 25%	2569	474	321	1961
barley 75%		2095	1640	
barley 100%	2504	2504	1961	1961
Averages of 2 mixtures				
oats 100%	2732	2732	1852	1852
oats 75%	2667	1791	1214	1900
barley 25%		876	686	
oats 50%	2494	1033	700	1844
barley 50%		1461	1144	
oats 25%	2526	577	391	1917
barley 75%		1949	1526	
barley 100%	2461	2461	1927	1927

z- oats: 67.8%; barley: 78.3% .

Table 18- Yields in lb. of grain per acre, at Ste-Anne de la Pocatière, in 1942.- Ave. of 4 replic.

Mixtures & Proportions in seeding	% in crop by weight	Actual yields		Expected yields on the basis of pure yields	Differences from expected yields	
		Total	Oats & barley		Oats & barley	Total
Mabel-OAC 21 oats 100%	100.	3150	3150	3150		

Table 27- Average yields with the two mixtures, in lb. of T.D.N. per acre, in 1942, 1943 and 1944, at Normandin.

Mixtures & Proportions in seeding	Actual yields in lb. of grain		Yields in lb. of T.D.N.[z]	
	Total	Oats & barley	Oats & barley	Total
Mabel-OAC 21				
oats 100%	1930	1930	1309	1309
oats 75%	2029	1201	814	1462
barley 25%		828	648	
oats 50%	2205	869	589	1635
barley 50%		1336	1046	
oats 25%	2195	447	303	1672
barley 75%		1748	1369	
barley 100%	2001	2001	1567	1567
Erban-Velvet				
oats 100%	2522	2522	1710	1710
oats 75%	2362	1493	1012	1692
barley 25%		869	680	
oats 50%	2443	989	671	1809
barley 50%		1454	1138	
oats 25%	2451	553	375	1861
barley 75%		1898	1486	
barley 100%	2249	2249	1761	1761
Averages of 2 mixtures				
oats 100%	2226	2226	1509	1509
oats 75%	2196	1347	913	1577
barley 25%		849	664	
oats 50%	2324	929	630	1722
barley 50%		1395	1092	
oats 25%	2323	500	339	1766
barley 75%		1823	1427	
barley 100%	2125	2125	1664	1664

z- oats: 67.8%; barley: 78.3%.

Table 29- Summary of yields in lb. of T.D.N. of the two mixtures, at the three Dominion Stations, from 1942 to 1944 inclusively.

Mixtures & Proportions in seeding	Actual yields in lb. of grain		Yields in lb. of T.D.N.[z]	
	Total	Oats & barley	Oats & barley	Total
Mabel-OAC 21				
oats 100%	2494	2494	1691	1691
oats 75%	2433	1634	1108	1733
barley 25%		799	625	
oats 50%	2435	1065	722	1795
barley 50%		1370	1073	
oats 25%	2550	621	421	1931
barley 75%		1929	1510	
barley 100%	2464	2464	1929	1929
Own mixture				
oats 100%	2794	2794	1895	1895
oats 75%	2725	1725	1170	1953
barley 25%		1000	783	
oats 50%	2730	1079	732	2025
barley 50%		1651	1293	
oats 25%	2680	525	356	2043
barley 75%		2155	1687	
barley 100%	2521	2521	1974	1974
Averages of 2 mixtures				
oats 100%	2644	2644	1793	1793
oats 75%	2579	1680	1139	1843
barley 25%		899	704	
oats 50%	2582	1072	727	1910
barley 50%		1510	1183	
oats 25%	2615	573	389	1987
barley 75%		2042	1598	
barley 100%	2492	2492	1952	1952

z- oats: 67.8%; barley: 78.3%.

Table 29- Summary of yields in lb. of T.D.N. of the two mixtures, at the three Dominion Stations, from 1942 to 1944 inclusively.

Mixtures & Proportions in seeding	Actual yields in lb. of grain		Yields in lb. of T.D.N.[z]	
	Total	Oats & barley	Oats & barley	Total
Mabel-OAC 21				
oats 100%	2494	2494	1691	1691
oats 75%	2433	1634	1108	1733
barley 25%		799	625	
oats 50%	2435	1065	722	1795
barley 50%		1370	1073	
oats 25%	2550	621	421	1931
barley 75%		1929	1510	
barley 100%	2464	2464	1929	1929
Own mixture				
oats 100%	2794	2794	1895	1895
oats 75%	2725	1725	1170	1953
barley 25%		1000	783	
oats 50%	2730	1079	732	2025
barley 50%		1651	1293	
oats 25%	2680	525	356	2043
barley 75%		2155	1687	
barley 100%	2521	2521	1974	1974
Averages of 2 mixtures				
oats 100%	2644	2644	1793	1793
oats 75%	2579	1680	1139	1843
barley 25%		899	704	
oats 50%	2582	1072	727	1910
barley 50%		1510	1183	
oats 25%	2615	573	389	1987
barley 75%		2042	1598	
barley 100%	2492	2492	1952	1952

z- oats: 67.8%; barley: 78.3%.