THE EFFECTS OF SEEDPIECE SIZE AND SPACING RELATIONSHIPS ON THE YIELD AND QUALITY OF THREE POTATO VARIETIES

A Thesis

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INTRODUCTION

Potatoes occupy an important place in the agricultural economy of Manitoba. Averages of the last ten years' production figures indicate that more than 32,000 acres are grown annually, producing a crop valued at around $1,750,000. This is generally absorbed by the local markets with occasional surpluses being exported.

While general recommendations are made, no experimental data are available on the best rate of planting in this province. The results of the comparatively few experiments dealing with this subject reported in the literature do not necessarily apply to any other region than that in which the work was carried on. Recommendations across Canada and in the United States show that the rate of planting is dependent primarily on the fertility and moisture condition of the soil. The need for determining the most profitable rate of planting has often been noted since a slight variation in rate affects considerably the initial outlay for planting a required area.

During the last few years Bacterial Ring Rot has become a major threat to the Manitoba potato industry. It is recommended that the only way to avoid the serious consequences of this and other tuber-born diseases is by the use of Government Certified disease-free seed. However, this is very scarce and costly at the present time. It is estimated that there is only sufficient certified seed available in Manitoba to plant two percent of the 1945 crop. Therefore, the most economical use of this seed is of prime importance.

There is considerable evidence to suggest that there may be differences in varietal response to rate of seeding. It has been pointed out by several authorities that some of the new potato varieties which produce shallow-eyed, fine appearing tubers respond differently to treatments than the older varieties. The reaction of these varieties to rate of seeding under Manitoba conditions has never been determined. There is also reason to believe that the rate of planting affects the quality of the tubers.

To seek a solution to these various angles of the problem an experiment was designed to study the effects of the two most important factors which constitute rate of planting, namely, the size of the seedpiece and the spacing of the sets in the row. Commonly grown varieties, cut seedpieces, and practical spacings were used in order that the results would apply to average conditions.

I THE EFFECTS OF SEEDPIECE SIZE AND SPACING RELATIONSHIPS ON THE TOTAL AND MARKETABLE YIELDS

REVIEW OF LITERATURE

(A) Seedpiece Size and Spacing Relationships

Zavitz (51) carried on extensive experiments with potatoes in Ontario among which was one of the first recorded investigations dealing with seedpiece size and spacing relationships. In reporting five years results using 1-, 1½-, and 2-ounce seedpieces spaced at 12, 18, and 24 inches he concluded that the total yield was directly proportional to the amount of seed used and that the most profitable rate depended largely on the cost of the seed, but favored the 1½-ounce set planted at 12 inches.

From investigations carried on in North Dakota, Werner (45) also concluded that the 1½-ounce seedpiece spaced at 9-12 inches gave the best results. Weston (47) planted 1-, 1½-, 2-, and 2½-ounce seedpieces at spacings of 12, 18, 24, and 36 inches respectively so that all four combinations were sown at the rate of 15 bushels per acre. He found the 1-ounce seedpiece spaced at 12 inches to be much superior.

Sprague and Evaul (34) reported the results of three years rate of planting experiments using the Green Mountain variety in central New Jersey. They used ½-, 1½-, and 2-ounce cut seedpieces each with at least one strong eye and spaced these at from 6 - 22½ inches to give 12 combinations. They likewise observed that the total yields increased directly with planting rate and pointed out that the relationship between seedpiece size and spacing was such that large seedpieces should be planted at wide spacings and smaller sets at closer spacings. In general the authors found the 1-ounce set at 9 inch spacing to be the most profitable. They pointed out that it was impractical to cut ½-ounce seedpieces and that small sets were more likely to suffer from desiccation because of the relatively greater cut surface exposed. These investigators concluded that all treatments were equal in their effect on the percentage marketable and that increased yields from increased rates were due to the larger number of marketable tubers produced per hill and not to size of individual tubers.

Bushnell (6) in Ohio reported the results of planting 1- and 2-ounce sets at 3 - 24 inches. He disagreed with Sprague and Evaul, stating that higher rates of seeding produced a larger percentage of small tubers, and thus increased yields from increased rates were largely made up of unmarketable tubers. He favored 1-ounce sets at 9- to 12-inch spacing. Jensen and Morris (21) in Washington concluded from investigations on irrigated land that 1-ounce seedpieces at 6 - 12 inches gave the best results.

According to Miller and Kimbrough (27) of Louisiana who ran tests using ½- to 2½-ounce seedpieces and spacings of 8 - 16 inches, the 1½-ounce set at 14"was most suitable.

In 1938, Findlay and Sykes (14) in England reported three years results from a rate of planting experiment using the Variety King Edward VII. The experiment was designed as a latin square and the data was statistically analysed. In this investigation whole seed was graded as small (1-ounce), medium ($1\frac{1}{2}$-ounces), and large ($2\frac{1}{2}$-ounces) and these were spaced at 12, 15, 18, and 21 inches. They showed that the total yield increased with the weight of seed used but that the increase was made up largely of small tubers. No significant differences were found in the yields of ware (marketable). This is also contradictory to the results of Sprague and Evaul. These workers considered the increase in seedpiece size an essential consequence of increasing the spacing. When the seed was deducted from the ware to give "net ware" larger seedpieces gave significant increases over small but spacing had no significant effect. In this report they proposed that it would be more economical to separate small potatoes out and plant the 1-ounce tubers at 12 inches, $1\frac{1}{2}$- at 15, and $2\frac{1}{2}$- at 21 inches than planting them all at one distance.

The authors summed up their work by stating that wide spacing reduced the total yields and yields of small tubers but increased the yields of large ware and average-sized tubers. Yields of ware and "net ware" were not significantly affected by spacing. On the other hand large seed produced the greatest total yield and the greatest net of ware and seed. Seed size didn't influence the yield of the large ware but the average size of these was greatest from small seed.

Singh and Wakankar (30) working in India, explained that the lack of cold storage facilities make seed very scarce and extremely costly during the planting season. Therefore, they planned an experiment to determine the most suitable seed size and spacing which would be economically suitable and profitable under conditions prevailing at Benares, India. The Darjeeling red variety and $\frac{1}{2}$-, 1-, and $1\frac{1}{2}$-ounce sets spaced at 6, 9, and 12 inches were used in a split-plot design. These authors agreed with Findlay and Sykes that the size of the seed and the spacing affected only the yields of small tubers. They found that the yield was reduced with 12-inch but not with 9-inch spacing when compared to the 6-inch planting distance, and concluded that a $\frac{1}{2}$-ounce set placed at 9 inches was the most economical under their conditions.

An experiment showing varietal differences to seeding rate was reported by Smith, Hommel and Kelly (32) working at Cornell University which showed that the old Pioneer Rural variety was best when a $1\frac{1}{2}$-ounce seedpiece was spaced at 14 inches. However, with Sebago, one of the new varieties, they found that a seedpiece of 2 ounces planted at 11 inches gave much superior results. An increase in total yield of 121 bushels per acre was noted when a 2-ounce set was spaced at 11 inches rather than a $1\frac{1}{2}$-ounce seedpiece at 14-inch spacing. These investigators emphasized that Sebago and several other new varieties of the same type required heavier planting rates.

(B) Weight of the Seedpiece

Hume (19) of South Dakota compared small, medium, and large seedpieces from the same tuber and found that the yield increased directly with the size of the set. From Ontario Zavitz (51) reported the results of five-year investigations using seedpieces ranging from 1/16- to 2-ounces in weight. He favored the 1-ounce sets although the marketable and net total yields increased directly with the seedpiece size. Rosa (28) also advocated the use of 1-ounce seedpieces and found the increase in marketable yield insignificant with the heavier sets.

Stewart (38) of the U.S.D.A. reviewed the literature on the size of sets dating from 1793 - 1922. He presented the results from experiments in several States and concluded that seasonal conditions greatly influenced the size of set and that with abundant moisture and plant food maximum returns could be expected from large-sized sets but when conditions were less favorable, smaller sets were better because fewer tubers were formed. Hurst (20) in Prince Edward Island, agreed that larger sets gave greater yields but also greater percentages of culls.

Tingey and Stewart (39) used sets of 1-8 ounces in weight and concluded that the 2-ounce seedpiece gave the best all-round results. They also observed that as the size of the set increased, tubers per hill and weight of hill increased, while percentages of marketable tubers, weight of individual tubers, and the number of tubers per stem decreased.

That seedpieces from 1½ - 2 ounces in weight were a factor in considerably reducing hollow heart in wet seasons was observed by Wheeler (49) of Michigan. Ware (41) noted that the recovery of the plants after frost damage was almost wholly dependent on the set size. Seedpieces of 1½ - 2 ounces in weight showed much better recovery than smaller ones. Scannel (29) reported from Saskatchewan that "potato eyes" weighing 0.65 ounces gave much better yields than those weighing 0.4 or 0.2 ounces. Miller and Kimbrough (27) agreed with Ware that plants from large seedpieces due to their greater food reserve made a much better recovery from frost damage.

Ware (43) showed the relation between seedpiece size and the rate of applying fertilizer in Alabama when he used ½- to 1½-ounce seedpieces and 1000 - 2000 pounds per acre of fertilizer. He found the 1½-ounce set used with 1500 pounds of fertilizer gave the greatest return above the cost of materials but claimed this would vary depending on the various costs.

(C) Comparison of Whole and Cut Seed

Conflicting opinions have resulted from the many investigations concerning the relative value of whole and cut seedpieces. Zavitz (51), reporting the results of six years experiments in Ontario, preferred small whole seed to cut seedpieces.

It was claimed by Aicher (1) of Idaho that whole sets emerged more quickly and produced larger tops than cut seed. He showed that total yields from whole sets were almost 15% greater than those from cut seed but that cut seedpieces yielded 18% more marketable tubers. Welch (44), also in Idaho, agreed with Aicher but claimed that whether the seed was whole or cut had no effect on the time of emergence. Rosa (28) found little difference between whole and cut seed in Missouri except that whole sets produced a larger percentage of culls. A report from New York by Stewart (36) stated that "for seed purposes uncut tubers between 1 and 2 ounces in weight are at least as good as and probably a little better than pieces of equal weight cut from large tubers of the same plant".

Albright (3) of the Beaverlodge Station, Alberta, obtained greater yields but a larger percentage of culls from whole seed. Stewart (38) of the U.S.D.A. gave an extensive review of literature and a report of investigations in several states in 1924 from which he concluded that whether whole or cut sets were superior depended largely on seasonal conditions. Hurst (20) of Prince Edward Island compared whole and cut sets of various sizes and found that while the whole tubers produced heavier and more vigorous plants, they gave a much larger percentage of culls. His $1\frac{1}{2}$-ounce cut set produced almost as great a marketable yield as the 3-ounce whole seed. He thus favored cut sets and advised that small whole tubers be used only when seed was scarce or high-priced.

Gardner (15) showed that cut seed was much more perishable in storage than whole seed. This was very important in Kentucky because conditions often demanded that seed be cut several weeks before planting. Butler (9), working in New Hampshire, ran experiments to determine whether leaf roll and mosaic were more common in fields grown from small whole tubers than from sets which had been cut from large tubers. He concluded that the percentage of disease in plants grown from good quality certified seed was not affected by the size of the seed.

Bushnell (7 and 8) of Ohio claimed that cut seed gave a poor stand due to drying out, while small whole tubers made excellent seed if free from disease. The four years results obtained by MacLeod (25) in the Canadian Fraser Valley showed that whole seed gave a much better stand and greatly increased yields especially in seasons having cold and damp spring weather. He reported an increase of 4.0 tons per acre in total and 3.1 tons per acre in marketable yields when whole and cut seed were compared. He used his results to support certification being given to small-sized seed because he considered it very important that this seed be disease-free. Edmundson (12) of the U.S.D.A. produced evidence to prove that cut seed was injured by direct exposure to sunlight during planting operations while whole seed was uninjured.

(D) The Number of Eyes per Seedpiece

The question has often arisen whether it was the weight of the set or the number of eyes it contained that exerted the greatest influence on the yields obtained.

Zavitz (51) reported experiments in which he used one-eyed sets of different weights and sets of the same weight containing from 1 - 5 eyes. He concluded that the weight of the seedpiece had a much greater effect than the number of eyes present. The same conclusions were reached by Werner (45) and Albright (3) working in North Dakota and Alberta respectively. Stewart (38) concluded that the increase in vigor with larger sets was due to a greater number of eyes as well as the larger weight.

However, Wakankar (40), working in India, concluded that large seedpieces gave higher yields due to their capacity to produce more sprouts per hill. From the results of chemical tests he presumed that the amount of stored food had no effect on the resultant yields.

(E) Comparison of Fresh and Suberized Seedpieces

Recommendations vary as to the advisability of using freshly cut or suberized (corked over) seedpieces. Westover (48) of West Virginia reported that five years results showed freshly cut seed to give better total and marketable yields than those cut and stored for various periods.

Lombard (23) reviewed the literature on suberization and found the results to be very contradictory. He reported the results from six years investigations in several states. Freshly cut sets were compared with those cut and stored 10, 20, 30, 40, and 50 days. He concluded that seedpieces could be stored under normal conditions for 10 - 30 days but not longer without injurious effects.

Edmundson (12) of the U.S.D.A. compared 1½- and 2-ounce sets, fresh and suberized, planted immediately and placed in the sun for 2 and 4 hours. He showed that freshly cut seed was much more severely injured during planting operations than suberized sets depending on the length of exposure.

(F) Comparison of Apical and Basal Seedpieces

For many years there has been much controversy over the relative value of potato seedpieces cut from the apical and basal ends of the tuber. Zavitz (51), in a five year test in Ontario compared one-ounce, one-eyed seedpieces from the stem end, seed end, and middle portion of the tuber. He showed that the sets from the middle portion were superior in every respect but could find little to choose between those from the stem and seed ends. These sets were not sprouted before planting.

From the results of experiments carried on in New York, Stewart (37) concluded that apical sets were much superior to basal sets in many respects. He cut both the apical and basal seedpieces from the same sprouted tuber. Smith (31), in reviewing Stewart's work, stated that the results of experiments he had carried on indicated that the type and extent of sprout growth at the time of planting and not the position of the eye on the tuber accounted for the differences obtained between apical and basal sets and that these differences would not be noted if the tubers were cut before sprouting.

In a report presented in 1936, Lombard and Stewart (24) of the U.S.D.A. reviewed the literature on this question and concluded that the contradictory results were due either to the experiments being on too small a scale or to the fact that the workers were not careful in controlling other variables. Therefore the authors ran extensive tests for three years using the Irish Cobbler and Green Mountain varieties. They were especially careful to control all the errors by using weighed seedpieces from tubers of uniform size with sprouts of equal strength. The latter were obtained by cutting the seedpieces first and sprouting them later. Their results were statistically analysed and showed that when errors were removed, basal and apical sets were equally productive.

These investigations seemed to solve the problem and prove that differences were due wholly to variation in dormancy between eyes on the same tuber. However, Ellis, (13) working in Indiana, claimed that Stewart's results did not apply to the new type of tuber such as in the Chippewa variety. His data showed much higher yields were obtained from apical than from basal sets when Chippewa was used. He suggested that there may be a varietal difference in the reaction to apical dominance but stated that the problem required further investigation.

(G) Spacing as Affected by Other Factors

Several investigators have found optimum spacings to vary depending on moisture conditions, fertility, date and depth of planting, variety etc. Martin (26) planted 1-ounce seedpieces at 9- to 12-inch spacings, and at various depths. He found that with shallow planting the greatest yields and net returns over the cost of seed but the lowest percentage of marketable tubers were obtained at 9-inch spacing. He therefore recommended 9- to 11-inch spacings depending on the fertility.

Bird (5) ran an experiment to correlate spacing, fertilizers, and date of planting. He found that closer spacing (12-18 inches) gave a higher yield and a greater percentage marketable even in drought years and also cut down the amount of hollow heart. He preferred early planting and found that the use of fertilizer gave good results even during drought periods.

Wessels (46) of New York quoted Hardenburg in stating that it was the general opinion that "in regions where mineral nutrients and moisture are likely to be limited, wider spacing of plants and less seed per acre are recommended". However, he concluded from one year's investigations, in which he used four spacings and various fertilizers, that the level of fertility did not influence optimum spacing.

Edmundson (11) reported a spacing test carried on by the U.S.D.A. in which spacings from 8 - 14 inches and the varieties Rural New Yorker #2 and Triumph were used. He found that yields of tubers between 3 and 12 ounces increased with closer planting and that hollow heart and growth cracking increased with distance. He observed that Triumph was not as susceptible to hollow heart as Rural New Yorker and could thus be planted at a greater distance.

Ware (42) of Alabama showed that there was a definite relationship between spacing and the amount of fertilizer used. He spaced his sets at from 8 - 20 inches and used fertilizers at the rate of 1000 - 2000 pounds per acre. He concluded that 2000 pounds per acre of fertilizer and 12-inch spacing was the most desirable and economical.

White-Stevens and Wessels (50) showed results contrary to Wessel's former work. They concluded that on irrigated land, 15-inch spacing was best with low fertility applications but a distance of 11 inches was superior when fertilizer was applied at the rate of 2000 pounds per acre.

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x CURRENT RECOMMENDATIONS FOR THE CANADIAN PROVINCES

Prince Edward Island

Authorities recommend a $1\frac{1}{2}$-ounce seedpiece spaced at 10-12 inches in the row and a distance of 36 inches between the rows. However, for the varieties Katahdin and Sebago, 9-inch spacing has been found more satisfactory because it is claimed that these varieties "miss badly" due to having relatively few and weak eyes.

Nova Scotia

A seedpiece size of $1\frac{1}{2}$-2 ounces planted at 9-12 inches for Irish Cobbler and 12-15 inches for Green Mountain in rows 33 inches apart are the recommendations given. It is suggested that the varieties Katahdin and Sebago, while late, be planted at a spacing not greater than 12 inches because fewer and over-sized tubers are common at the wider spacings.

New Brunswick

In this province the use of $1\frac{1}{2}$- to 2-ounce seedpieces, preferably of the latter weight, is advised. Sets were formerly spaced at 12 inches but as the majority of potato growers use 2000 pounds of high-grade complete fertilizer per acre it was found that over-sized tubers were common. Thus 9-inch spacing is now suggested for all varieties.

Quebec

Small whole tubers or cut pieces both on the large side of 1 ounce are recommended. Planting at 10 - 12 inches in rows 36 Inches apart is favored for all varieties.

x This information was obtained by correspondence with Dominion Experimental Stations and Universities across Canada.