# Effect of Planting Interval and Seed Tuber Size on the Gross and net Potato Yield

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## Introduction

The potato yield can be regulated by changing the seed rate: by means of the planting density or by the size of the seed tubers. Planting density affects the competition between the individual potato plants. When competition is reduced the potato plants grow more vigorously and more tubers are produced although the yield calculated per unit area decreases. If greater quantities are used in planting, the unsorted gross yield of potatoes has been found to increase (Holmes, 1966; Svensson, 1966; Gustafsson, 1968). In this respect, the potato follows the general laws concerning competition between plants (De Wit, 1960).

As the size of the seed tubers is increased, the number of sprouts and stems which are produced by them is also increased. Thus the potato plant is soon able to produce a leaf surface area which is sufficient to attain maximum net photosynthesis. A large seed tuber also contains much of the carbohydrates necessary for the initial development of the shoot. The gross potato yield has been found to increase when the size of the seed tubers is increased (Roer, 1955; Svensson, 1966).

The net potato yield is usually regarded as the difference between the gross yield and the seed rate. The net yield quickly attains the maximum value if the seed rate is increased. The planting distance which gives the maximum net yield depends, in addition to the size of the seed tubers, on the variety used (Svensson, 1966) and on environmental factors such as fertilization (Bodlaender & Reestman, 1968).

Svensson (1970) has carried out research in Sweden on the planting interval which gives the maximum net yield. When the size of the seed tubers varied from the class <30 mm to the class 55–60 mm, the optimum planting interval varied from 15 cm to 40 cm.

The purpose of this study was to determine the effect of planting interval and seed tuber size on the gross and net potato yields. An attempt was also made to find a method for determining the planting distance which would give the maximum net yield.

## Material and Methods

Field experiments were carried out at the Department of Plant Husbandry, University of Helsinki, during the years 1964–67 which were designed to determine the effect of planting interval and seed tuber size on the potato yield. The variety 'Akvila' was used in the experiments. The soil type of the experimental area was fine sand and sandy clay. It was dressed with normal amounts of a compound fertilizer recommended for potato.

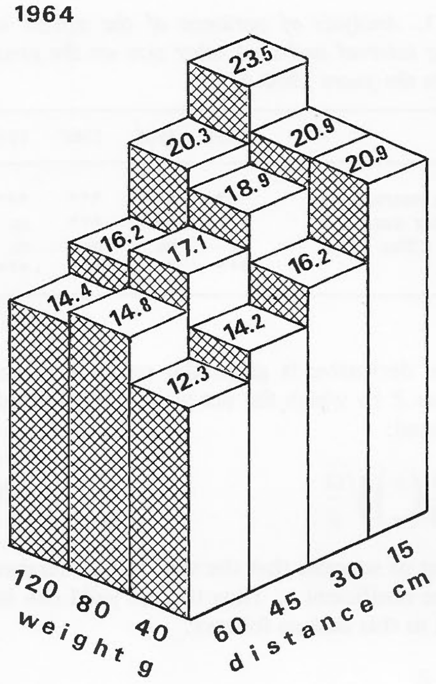
The experimental design used was a completely randomized block trial where the treatments were as follows:

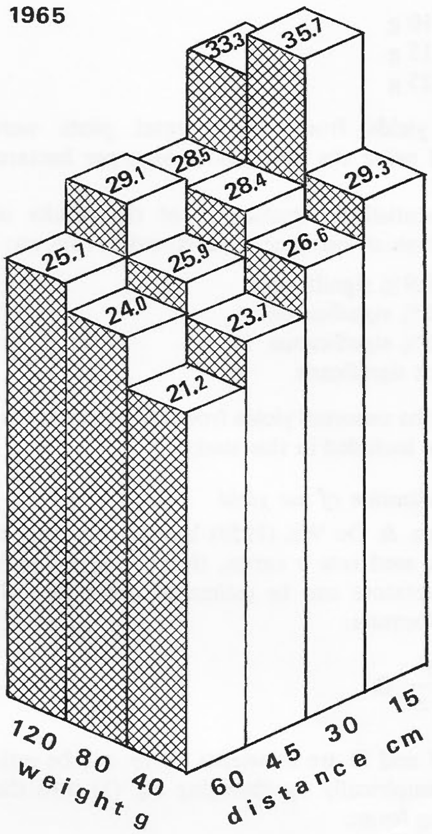
A. *Planting distance*
1. 15 cm
2. 30 cm
3. 45 cm
4. 60 cm

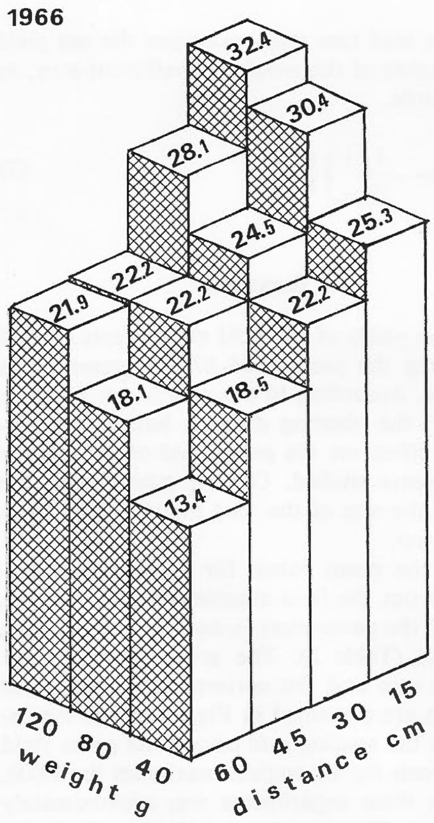
B. *Seed tuber size*
1. 40 g
2. 80 g
3. 120 g

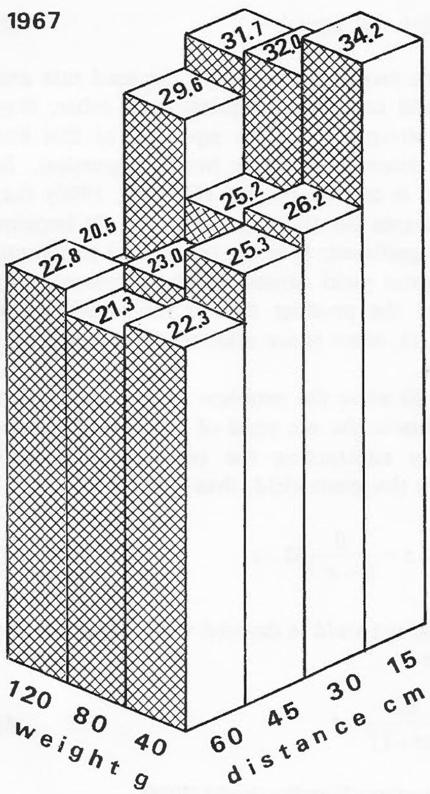
Each plot consisted of one row, the distance between the rows being 65 cm. The size of the experimental plot varied in different years from 9.75 $m^2$ to 11.70 $m^2$. Number of replications was four.

The seed tubers were obtained by weighing them individually. The following deviations were permitted:




*Figs. 1–4.* Effect of planting interval and seed tuber size on the gross yield of potatoes (mt ha$^{-1}$) in the years 1964, 1965, 1966, and 1967.

40 g ± 10 g
80 g ± 15 g
120 g ± 25 g

The yields from experimental plots were weighed using the unit metric tons per hectare, mt $ha^{-1}$.

The statistical significance of the results of the analysis of variance is expressed as follows:

*** = 99.9 % significance
** = 99 % significance
* = 95 % significance
ns = not significant

Only the unsorted yields from the experimental plots are included in this study.

*Maximalization of net yield*

Reestman & De Wit (1959) have shown that if only the seed rate $z$ varies, then the gross yield $O_s$ of potatoes can be estimated using the following formula:

$$O_s = \frac{\beta}{\beta + z^{-1}} \Omega \quad (1)$$

where $\beta$ and $\Omega$ are constants. They can be estimated empirically by changing eq. (1) into the following form:

$$O_s^{-1} = \Omega^{-1} + (\beta \cdot \Omega)^{-1} \cdot z^{-1} \quad (2)$$

When the reciprocal values of the seed rate and gross yield are plotted against each other, they form a straight line. The equation of this line can be determined using linear regression. In addition, it can be proved (De Wit, 1960) that the constants for the regression eq. (2) become clearly significant: $\Omega$ is the theoretical maximum of the gross yield caused by the increased seed rate, and the product $\beta \cdot \Omega$ is the reproductive rate ($O_s/z$), when space allotted to one seed unit increases.

Now, to solve the problem of maximalization let $O_n$ denote the net yield of potatoes. It is obtained by subtracting the corresponding seed rate from the gross yield, thus

$$O_n = O_s - z = \frac{\beta}{\beta + z^{-1}} \Omega - z \quad (3)$$

When the net yield is derived with respect to the seed rate

$$\frac{dO_n}{dz} = \frac{\beta\Omega}{(\beta z + 1)^2} - 1 \quad (4)$$

and the derivative is given the value zero, the seed rate $Z$ by which the net yield is maximized, is obtained:

$$Z = -\frac{1}{\beta}\binom{+}{-}\sqrt{\frac{\Omega}{\beta}} \quad (5)$$

Next, let us suppose that the seed rate is weighed by some coefficient $a$. Thus the net yield can be defined in this case as follows:

$$O_n = \frac{\beta}{\beta + z^{-1}} \Omega - az \quad (6)$$

Now the seed rate that maximizes the net yield is a function of the weighing coefficient $a$ or, in other words,

$$Z = Z(a) = -\frac{1}{\beta}\binom{+}{-}\sqrt{\frac{\Omega}{a\beta}} \quad (7)$$

Table 1. *Analysis of variance of the effects of planting interval and seed tuber size on the gross yields in the years 1964–67*

| | 1964 | 1965 | 1966 | 1967 |
|---|---|---|---|---|
| Planting interval | *** | *** | *** | *** |
| Seed tuber size | * | ** | *** | ns |
| Interval × Size | ns | ns | ns | ns |
| Blocks | *** | * | *** | *** |

## Results

The gross yields of the field experiments carried out during the years 1964–67 are presented in Figs. 1–4. According to the analysis of variance (Table 1) the planting distance had a very significant effect on the gross yield of potatoes in all the years studied. On the other hand, the effect of the size of the seed tubers varied from year to year.

Next, the mean values for 4 years were calculated from the field experiment data and the values of the parameters in eqs. (1) and (2) were calculated (Table 2). The gross yields against the seed rate and the corresponding reciprocal approach are presented in Figs. 5 and 6. An increase in the seeding rate caused the gross yield to approach the theoretical maximum limit ($\Omega$), which in these experiments was approximately 35 mt $ha^{-1}$. The size of the seed tubers had only a slight effect on it.

Table 2. *The parameters of Equation (1) as calculated with the help of Equation (2)*

| Seed tuber size | $\Omega$ mt ha$^{-1}$ | $\beta$ ha mt$^{-1}$ | $\beta \cdot \Omega$ |
|---|---|---|---|
| 40 g | 33.8 | 1.05 | 35.3 |
| 80 g | 34.2 | 0.67 | 22.9 |
| 120 g | 35.3 | 0.46 | 16.1 |

The dependence of the net yield on the seed rate is presented in Fig. 7. The optimum planting distance for tubers weighing 40 g, 80 g and 120 g was found, with the help of eq. (5) to be 13.0 cm, 21.8 cm and 28.0 cm respectively (Fig. 8).

The dependence of the optimum planting distance on the weighing coefficient $a$ of the seed rate was tested using eq. (7) (Fig. 9). If, for instance, a medium-sized seed tuber weighing about 80 g is to be planted then the optimum planting interval if it is estimated as being twice as expensive as a crop potato, would be about 35 cm.

## Discussion

The gross yield of potatoes varied noticeably from year to year owing to the effect of the environmental conditions of the field experiments, for example the water economy of the soil. These factors also regulate the optimum planting distances presented in this study. They are also dependent on the variety of potato used. Thus the results should be examined in the first place as an analysis technique with which the maximalization problem of the net yield can under certain circumstances be solved, and only in the second place as mean values based upon 4 years' experiments.

When the experimental results for 4 years were combined, the planting distance and gross yield followed eq. (1) quite closely. The number of observations used in calculating the regression eq. (2), i.e. four planting intervals, is small but the degree of explanation in every size of seed tuber was so high that regression obviously exists.

The maximum net yield which was achieved in these experiments was approximately 20 mt ha$^{-1}$. When the seed rate varied from the optimum value for instance by $\pm 2$ mt ha$^{-1}$, the net yield decreased only slightly. The maximum value which was obtained is thus not affected by slight variations in the seed rate.

The results of this investigation show that the size of the seed tubers would appear to have a linear effect on the optimum planting distance (Fig. 8). However, the regression cannot be the same as the straight line estimated according to

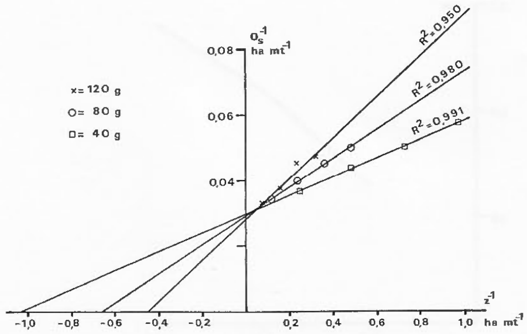



*Fig. 6.* Effect of the reciprocal value $z^{-1}$ of the seed rate on the reciprocal value $O_s^{-1}$ of the gross yield according to Eq. (2).

*Fig. 5.* Effect of seed rate $z$ on the gross yield $O_s$ of potatoes according to Eq. (1).

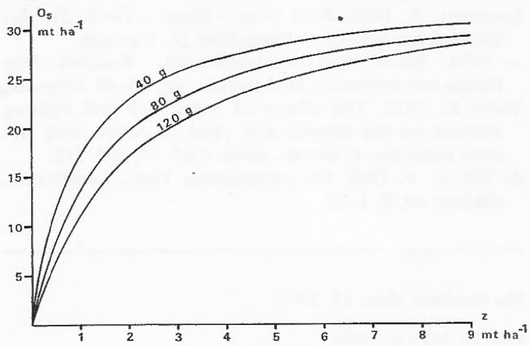
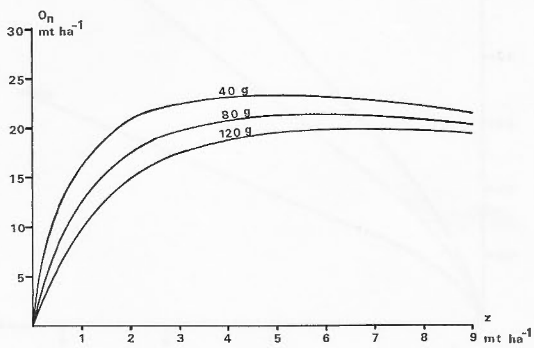



*Fig. 7.* Effect of seed rate $z$ on the net yield $O_n$ of potatoes according to Eq. (3).



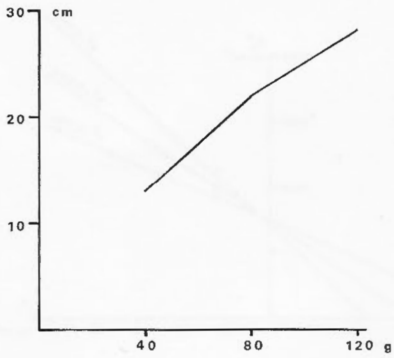
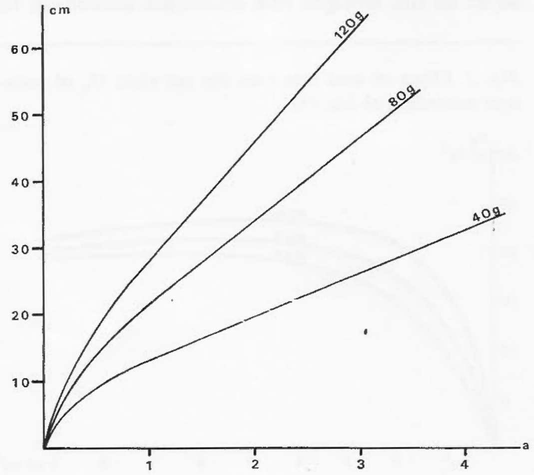



*Fig. 8.* Effect of seed tuber size (x-axis) on the optimum planting distance (y-axis).

Fig. 8. There is, in other words, a seed tuber size somewhere between 0–40 g below which a seed tuber will give no yield. In this case, the regression line should intersect the x-axis between the interval 0–40 g. As there are so few observations, only three sizes of seed tubers, non-linear regression could not be calculated. Reestman & De Wit (1959), Bleasdale (1964) and Varis (1973) have also concluded that there is non-linear regression between the seed tuber size and the yield.

When the seed tuber and crop tuber were estimated at different values, the effect on the optimum planting distance was clear. If the weighing coefficient *a* of the seed rate is 1, then the optimum planting interval obtained would be surprisingly small. However, if the seed rate

*Fig. 9.* Effect of the weighing coefficient *a* of the seed rate (x-axis) on the optimum planting distance (y-axis).




is weighed by 2, then the optimum planting interval would rise to a level which is close to that used in practice.

The basic data used in this study was unsorted gross yields. In further studies, the size distribution of the gross yields will also be examined.

## Summary

The effect of the planting distance and the size of the seed tubers was studied in field experiments carried out in 4 successive years. The gross yield increased when the planting distance was decreased. An analytical solution was derived for determining the maximum net yield. The optimum planting distances for seed tubers weighing 40, 80 and 120 g were 13.0 cm, 21.8 cm and 28.0 cm respectively, the distance between the rows being 65 cm. The dependence of the optimum planting distance on different values of seed tubers was examined. When a seed tuber was estimated as being twice as expensive as a crop tuber, the optimum planting distance rose to level which was close to that used in practice.

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