ACTA AGROBOTANICA
Vol. 50 (1-2) – 1997
221-229

# Effects of plant density and cultivar on yield responses in onions (*Allium cepa* L.) grown from seeds

**JAN RUMPEL and KAZIMIERZ FELCZYŃSKI**

Research Institute of Vegetable Crops, 96-100 Skierniewice, Poland

(Received: 20.12.1997)

## Abstract

Two field experiments were conducted to study the effect of plant density on yield, size grading and maturity of onion bulbs grown from seeds. In the first experiment carried out during 1991-1993, three onion cultivars (Hysam $F_1$, Mercato $F_1$ and Sochaczewska) were sown for intended densities of 20, 40, 60, 80,100 and 140 plants $m^{-2}$, whereas in the second one, in 1996, six onion cultivars (Spirit $F_1$, Summit $F_1$, Hyduro $F_1$, Armstrong $F_1$, Renate $F_1$ and Robusta) were sown for intended densities of 40, 60 and 80 plants $m^{-2}$. The onions were grown on beds, 1.35 m wide, in 4 rows per bed (27+27+27+54 cm).

Marketable yield increased with plant density, and depending on year was highest at 80 or 100 plants $m^{-2}$. The average marketable yield of the 1991-1993 experiment increased from 20.5 $t \cdot ha^{-1}$ at 20 plants $m^{-2}$ to 32.8 $t \cdot ha^{-1}$ at 80 plants $m^{-2}$, whereas that of the 1996 experiment increased from 48.9 $t \cdot ha^{-1}$ at 40 plants $m^{-2}$ to 59.0 $t \cdot ha^{-1}$ at 80 plants $m^{-2}$, respectively. Yield of large bulbs decreased with density and was highest at 20-40 plants $m^{-2}$, oposite to the yield of small bulbs, which was highest at the highest density of 140 plants$\cdot m^{-2}$. The medium bulb yield increased with density, at the some way as compared the total marketable yield. No greater effect of cultivar on bulb size grades was found and the existing differences were proportional to the total marketable yield.

Plant density hastened maturity of onions, and at density of 140 plants $m^{-2}$ the leaf fall-over occurred 9-10 days earlier as compared at density of 20 plants $m^{-2}$. The cultiwars used, can be placed in the following order of decreasing productivity: 1. Mercato $F_1$, 2. Hysam $F_1$ and 3. Sochaczewska, – in the first experiment (1991-93) and 1. Armstrong $F_1$, 2. Spirit $F_1$, 3. Robusta, 4. Renate $F_1$, 5. Hyduro $F_1$ and 6. Summit $F_1$ – in the second experiment (1996), respectively.

**Key words**: onion, *Allium cepa* L., plant, density, cultivar, bulb size grade, maturity.

## INTRODUCTION

Bulb onions are grown in Poland almost entirely from seeds on an area fluctuating between 30 and 35 thousand hectares. A growing industrial use creates preference for large bulbs in onion trade. Thus growers are interested in obtaining high proportion of large bulbs in onion yield.

Plant population density is one of the most important factors influencing yield and size of onions (Austin et al., 1962; Bleasdale, 1966; Frappell, 1973; Hatridge-Esh and Bennett, 1980; Boelt and Henriksen 1991).

The optimum size of onion bulbs depends on the purpose for which the crop is produced. Onions for fresh consumption have usually bulbs of diameter 4-6 cm, whereas for industrial use, bulbs of diameter greater than 6 cm are prefered (Boelt and Henriksen, 1991).

Plant population may also affect bulb development and maturity of onions. At high plant density the time to leaf fall-over is shorter and the occurrence of thick – necked onions lower, as compared at low plant density (Böttcher et al. 1985; Mondial et al. 1986; Boelt and Henriksen, 1991; Weerasinghe and Fordham, 1993). The present paper describes the effect of plant density on yield and bulb size of several onion cultivars.

## MATERIALS AND METHODS

Work on the effect of plant density in onions was carried out in 2 separate experiments conducted in the Research Institute of Vegetable Crops in Skierniewice. The soil of the site was a sandy – loam, of pH 6.5 and organic matter content of 1.2%.

In the first experiment, conducted for 3 years during 1991-1993, three onion cultivars (Hysam $F_1$, Mercato $F_1$ and Sochaczewska) were seeded with the intention of establishing, at the third true leaf stage, densities of about 20, 40, 60, 80, 100 and 140 plants $m^{-2}$. In the second experiment, conducted in the 1996 season, six onion cultivars (Spirit $F_1$, Summit $F_1$, Hyduro $F_1$, Armstrong $F_1$, Renate $F_1$ and Robusta) were seeded for plant densities of about 40, 60, and 80 plants$\cdot m^{-2}$. The aim of that, one season lasting experiment was to test the response to plant density of some other popular onion cultivars. In calculating of the seeding rate for a given plant density, the laboratory germination of each seed lot was determined and afterwards reducted by 20 per cent points, to compensate for losses during field establishment (Grudzień and Rumpel, 1989).

Sowing was performed with a pneumatic Nodet Gougis drill on the $4^{th}$, $9^{th}$, $16^{th}$ and $23^{d}$ of April, for the years 1991, 1992, 1993 and 1996, respectively. A flat bed system was used. Each bed, 1.35 m wide, was planted with 4 single rows at distance of 27 cm and wheeling interrow of 54 cm (27 + 27 + 27 + 54 cm ).

Plots of $6.75\cdot m^{-2}$ each (1.35 x 5 m) with 4 replications, were set in a randomized two – factorial, split-plot. block design, with plant density as first factor and cultivar as a second one.

The weather conditions in the years of the experiments were rather normal, except for the 1992 season, in which the summer months had higher average temperatures and lower precipitation than the many years averages (Table 1).

Standard cultural and plant protection practices were applied. Phosphorus and potassium were applied preplant, according to soil analysis, whereas nitrogen, in a rate

Table 1 – Tabela 1

Monthly air temperature and monthly rainfall during the growing season of onions for the years of trials and the multi-year averages for Skierniewice

| Month | Mean monthly temperature (°C) | | | | | Monthly rainfall (mm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1991 | 1992 | 1993 | 1996 | Mean 1922--1992 | 1991 | 1992 | 1993 | 1996 | Mean 1922--1992 |
| April | 7.7 | 7.8 | 9.0 | 7.7 | 7.4 | 22.1 | 32.7 | 30.0 | 46.4 | 36.3 |
| May | 10.6 | 13.9 | 16.5 | 14.9 | 13.0 | 60.0 | 21.3 | 38.2 | 59.4 | 52.3 |
| June | 15.8 | 18.6 | 16.3 | 16.7 | 15.8 | 57.1 | 21.8 | 39.2 | 59.2 | 61.6 |
| July | 19.4 | 20.6 | 17.1 | 16.5 | 17.8 | 59.7 | 27.0 | 61.6 | 131.0 | 79.1 |
| August | 18.5 | 22.2 | 17.1 | 18.3 | 17.1 | 51.1 | 7.4 | 47.2 | 45.9 | 70.1 |
| Mean or total | 14.2 | 16.6 | 15.2 | 14.8 | 14.2 | 250.0 | 160.2 | 316.2 | 341.9 | 299.4 |

of 100 kg N·ha$^{-1}$, as preplant, and 50 kg N·ha$^{-1}$, as top dressing, in the 3$^{d}$ true leaf stage of onions. Irrigation was applied only in spring 1993. The first phase of onion harvest (windrowing) commenced at 60-80% of leaf fall-over, what depending on year and cultivar occured between August 13$^{th}$ and September 4$^{th}$. After 7-10 days of field curing, the onions were transfered to a shed for further curing (about 1 month) and after that the foliage was removed and bulbs were graded into 3 size fractions of marketable yield: 1. large bulbs (∅ > 6 cm), 2. medium bulbs (∅ 4-6 cm) and 3. small bulbs (∅ 3-4 cm). All yield fractions were subjected to analysis of variance by standard statistical procedures for a two – factorial, split plot design and mean differences were tested by Newman-Keuls test at the 5% significance level.

## RESULTS

### 1. Yield

The occurrence of nonmarketable bulb fractions, i.e. very small (diam. below 3 cm), thick – necked, bottle shaped and diseased bulbs was very low, so the total yield consisted almost entirely of marketable yield (96.4 % in the first experiment and 99.7 % in the second one ).

In the first experiment (Table 2) marketable yield increased with plant density up to 80 plants·m$^{-2}$ (1992 and 1993) or to 100 plants·m$^{-2}$ (1991). At further density increases the marketable yield remained either on the same level of significance, or declined. In the second experiment (1996), marketable yield attained highest level at density of 60 plants·m$^{-2}$ (Table 3).

Marketable yield of onion was also affected by cultivars. In the first experiment the cv. Mercato $F_1$ gave highest yield in 1991 and 1993 and for the 1991-1993 period. Second in productivity was cv. Sochaczewska, and third the cv. Hysam $F_1$. The cultivar Hysam $F_1$, however, gave highest marketable yield in 1992 (Table 4).

Table 2 – Tabela 2
Effect of plant density on marketable yield of onions
(averages for 3 cultivars in the 1991-1993 period)

| Plant density (plants m $^{-2}$) | Marketable yield (kg 10 m $^{-2}$) | | | |
|---|---|---|---|---|
| | 1991 | 1992 | 1993 | Mean 1991-1993 |
| 20 | 18.8 e | 18.0 d | 23.4 d | 20.5 |
| 40 | 26.5 d | 22.5 c | 30.3 c | 26.4 |
| 60 | 30.8 c | 25.6 b | 33.0 b | 29.8 |
| 80 | 34.7 b | 28.5 a | 35.1 ab | 32.8 |
| 100 | 38.8 a | 22.0 c | 36.9 a | 32.6 |
| 140 | 36.7 ab | 21.6 c | 34.9 ab | 31.1 |

Mean differences were tested by Newman-Keuls test at the 5% significance level. Means within a column followed by the same letter are not significantly different.

Table 3 – Tabela 3
Effect of plant density on marketable yield of onions (averages for 6 cultivars in 1996 trial)

| Plant density (plants m $^{-2}$) | Yield (kg · 10 m $^{-2}$) | | | |
|---|---|---|---|---|
| | Total marketable | Large bulbs (>6 cm) | Medium bulbs (4-6 cm) | Small bulbs (3-4 cm) |
| 40 | 48.9 b | 39.6 a | 8.9 c | 0.4 c |
| 60 | 57.6 a | 33.6 a | 22.4 b | 1.6 b |
| 80 | 59.0 a | 20.9 b | 35.5 a | 2.6 a |

Mean differences were tested by Newman-Keuls test at the 5% significance level. Means within a column followed by the same letter are not significantly different.

Among cultivars in the second experiment, cv. Spirit $F_1$ and cv. Armstrong $F_1$ gave highest marketable yield, next were cvs. Renate $F_1$, Robusta and Hyduro $F_1$, and third, but still on high level, the cv. Summit $F_1$ (Fig. 1).

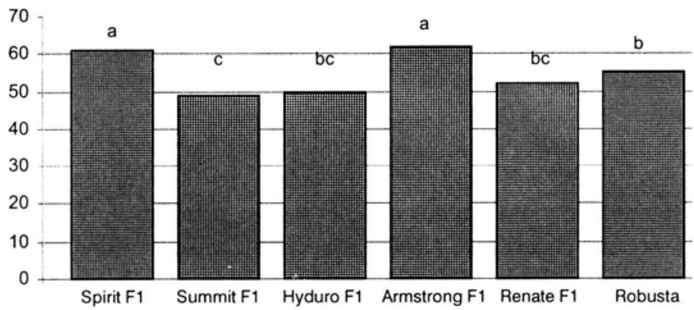


Fig. 1. Marketable yield of 6 onion cultiwars (averages for 3 densities in the 1996 trial)
Mean differences were tested by Newman-Keuls test at 5% significance level.
Means of columns followed by the same letter are not significantly different.

Table 4 – Tabela 4

Yield of marketable, large, and small onion bulbs as affected by cultivar (averages from 6 plant densities)

| Cultivar | Yield (kg ·10 m$^{-2}$) | | | 1991-1993 mean | |
|---|---|---|---|---|---|
| | 1991 | 1992 | 1993 | Yield kg 10 m$^{-2}$ | % |
| | Marketable bulbs (diameter > 3 cm) | | | | |
| Hysam $F_1$ | 27.6 c | 24.4 a | 28.7 c | 26.9 | 100 |
| Mercato $F_1$ | 34.6 a | 22.7 b | 35.7 a | 31.0 | 100 |
| Sochaczewska | 31.1 b | 21.9 b | 32.4 b | 28.5 | 100 |
| | Large bulbs (diameter > 6 cm) | | | | |
| Hysam $F_1$ | 6.8 b | 4.9 a | 6.7 c | 6.1 | 22.7 |
| Mercato $F_1$ | 9.2 a | 4.4 a | 10.0 a | 7.9 | 25.5 |
| Sochaczewska | 7.4 b | 4.8 a | 8.5 b | 6.9 | 24.2 |
| | Medium bulbs (diameter 4-6 cm) | | | | |
| Hysam $F_1$ | 16.5 c | 14.4 a | 17.6 b | 16.2 | 60.2 |
| Mercato $F_1$ | 21.9 a | 11.6 b | 22.9 a | 18.8 | 60.6 |
| Sochaczewska | 19.3 b | 11.0 b | 20.0 b | 16.8 | 58.9 |
| | Small bulbs (diameter 3-4 cm) | | | | |
| Hysam $F_1$ | 4.3 a | 5.1 b | 4.4 a | 4.6 | 17.1 |
| Mercato $F_1$ | 3.5 b | 6.7 a | 2.8 b | 4.3 | 13.9 |
| Sochaczewska | 4.4 a | 6.1 a | 3.9 a | 4.8 | 16.8 |

Mean differences were tested by Newman-Keuls test at the 5% significance level. Means within a column followed by the same letter are not significantly different.

## 2. Bulb size

Plant density influenced strongly the size grades of onion bulbs. As shown in Figure 2, highest large bulb yield was obtained at intended plant density of 20 and in a lesser degree, also at density of 40 plants·m$^{-2}$. At higher plant densities the large bulb yield rapidly decreased. For example the highest average large bulb yield for the 1991-93 period (15.5 kg ·10 m$^{-2}$) obtained at density of 20 plants·m$^{-2}$, decreased by 72.3% and by 97.4% at densities of 80 and 140 plants·m$^{-2}$ respectively (Fig. 2d). Yield of medium bulbs increased with plant density up to 80 or 100 plants·m$^{-2}$, whereas that of small bulbs increased up to the highest density of 140 plants·m$^{-2}$.

A similar effect of plant density was observed in the second experiment, carried out in 1996, where yield of large onion bulbs was highest at the lowest density of 40 plants·m$^{-2}$. In the same conditions the yield of medium and small bulbs was highest at the highest density of 80 plants·m$^{-2}$ (Table 3).

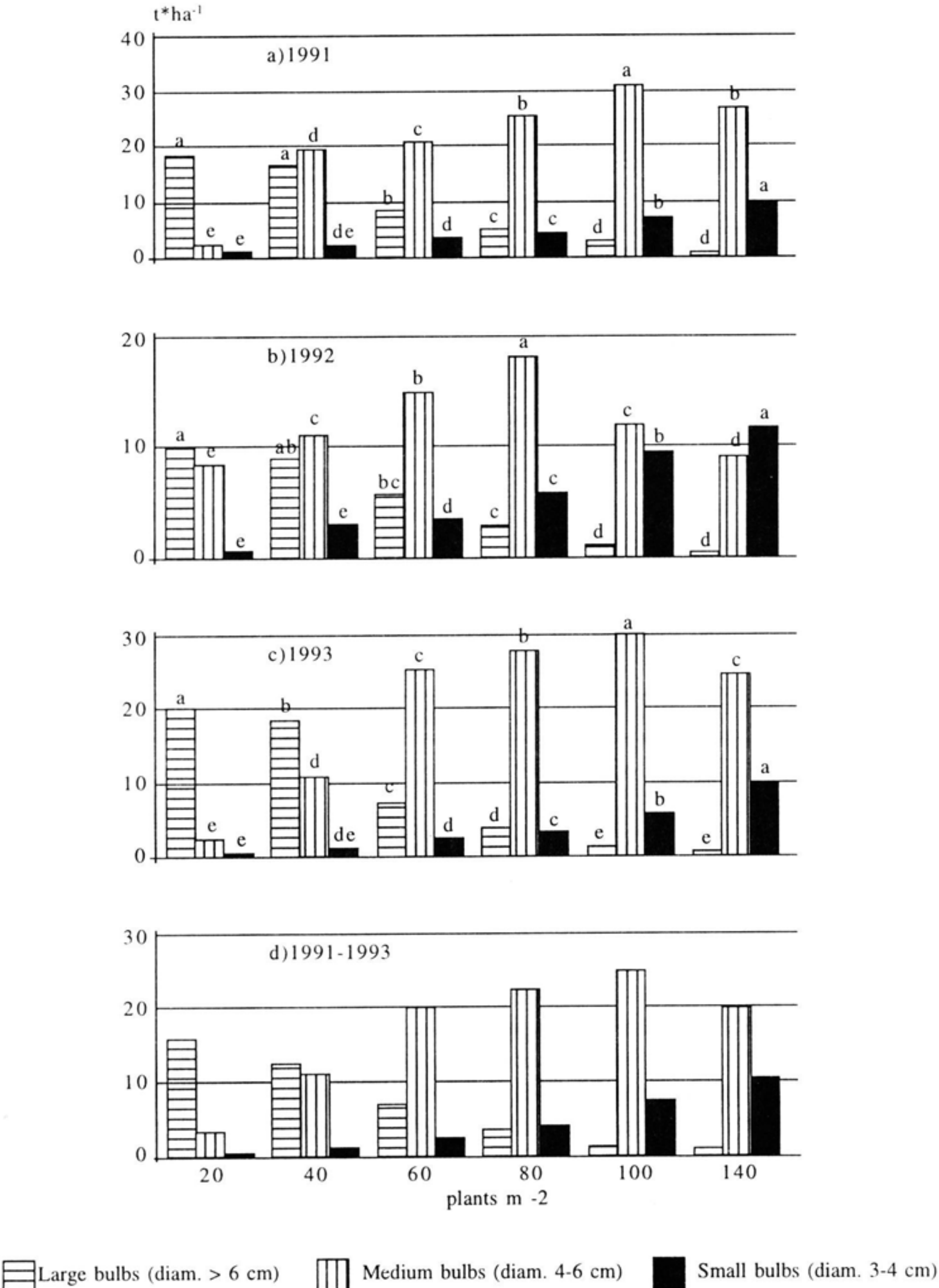


Fig. 2. (a, b, c, d) Yield of large, medium and small onion bulbs as affected by plant density (averages for 3 cultivars of the 1991-1993)

Mean differences were tested by Newman-Keuls test. Means of columns followed dy the same letter are not significantly different.

The bulb size grading was also in some extent affected by cultivar. As shown in Table 4, highest yield of large bulbs was produced by the cv. Mercato $F_1$, next was cv. Sochaczewska and third the cv. Hysam $F_1$. Differences in the yield of medium bulbs were less consistent, but also here the cv. Mercato $F_1$ gave higher yield as compared the other two cultivars. The yield of small bulbs was very low, so differences in yield between cultivars were considered as meaningless. It was also evident that the existing differences in yield of particular bulb grades were very low when expressed in per cent share of the total marketable yield (Table 4).

3. Plant maturity

There was a clear evidence that high plant density accelerates bulb maturity, understood as time to 50 % leaf fall-over.

As shown in Table 5, presenting the 3 year observations from the first experiment, earliest 50 % leaf fall-over occurred in density of 140 plants·$m^{-2}$. With each plant density increment, maturity was 1 or 2 days later. The final difference to 50 % leaf fall-over, between highest density of 140 plants·$m^{-2}$ and lowest one of 20 plants·$m^{-2}$ was 10 days.

Table 5 – Tabela 5

Effect of plant density on maturity of onion bulbs (averages from 1991-1993 experiment)

| Plant density (plants $m^{-2}$) | Acceleration of time to 50% leaf fall-over compared to density of 20 plants $m^{-2}$ (days) |
|---|---|
| 20 | 0 |
| 40 | 1-2 |
| 60 | 3-5 |
| 80 | 6-7 |
| 100 | 8-9 |
| 140 | 9-10 |

All 3 cultivars from the first experiment (Hysam $F_1$, Mercato $F_1$ and Sochaczewska) belong to the same group of earliness and in all densities were pulled and windrowed at the same time, i.e. after 154, 134 and 126 days from sowing, for the years 1991, 1992 and 1993 respectively. Among the 6 cultivars of the second experiment, Spirit $F_1$ and Summit $F_1$ were pulled and windrowed after 113 days from sowing, whereas the other cultivars, i.e. Armstrong $F_1$, Hyduro $F_1$, Renate $F_1$ and Robusta were harvested – after 135 days from sowing.

## DISCUSSION

Marketable yield of onion bulbs increased with plant density and the results are consistent with earlier findings (e.g. Bleasdale, 1966. Boelt and Henriksen, 1991). The present study shows also clearly that onions grown on 1.35 m beds in

4 rows increased yield with plant density up to the range of 60 to 100 plants·m$^{-2}$. Above these density limits, the yield decreased. It is likely that in a relatively warm and dry growing season, like that in 1992, the onion yield after attaining highest level, may decrease faster than in conditions of lower air temperature and adequate soil moisture.

Observations show that the desired bulb size distribution for commercially grown onions, is an equal share in yield of medium bulbs (diameter 4-6 cm) and large ones (diameter above 6 cm). This proportion is expected to cover the growing demand for large bulbs of the processing industry and the needs of the fresh consumption. Present results show that a close to equal distribution of these two bulb size grades occurs in densities ranging from 40 to 60 plants·m$^{-2}$. Highest yield of large bulbs (>6cm) was found at density of 20-40 plants·m$^{-2}$, whereas yield of medium bulbs (4-6 cm) was highest at density of 80-100 plants·m$^{-2}$. These results, although generally consistent with earlier works (Bleasdale, 1966; Hatridge-Esh and Bennett, 1980; Boelt and Henriksen, 1991) show that not only total marketable yield but also yield of large and medium bulbs attained highest level at a lower plant density as compared in the mentioned works. This might be an effect of the specific climatic conditions of the experiments. Nevertheless the present work forms a basis for producing onions of desired size grades.

The cultivars in trial showed a similar percentage distribution of bulb size grades, thus the occurring differences seem to be more result of the total yield than an attribute of cultivar for producing bulbs of a specific size grade.

There was a clear evidence for an advance in maturity under high plant population. At highest plant density of 140 plants·m$^{-2}$ onion maturity was advanced up to 10 days, compared to density of 20 plants·m$^{-2}$. This is in agreement with ealier findings (Böttcher et al. 1985, Boelt and Henriksen, 1991; Mondial et al. 1986).

## REFERENCES


Austin, R. B., Dakin J. C., and Wright R. C. M., 1962. Growing onions for pickling experiments during 1957-1960. Experimental Horticulture 7: 22-23.

Bleasdale, J. K. A., 1966. The effects of plant spacing on the yield of bulb onions (*Allium cepa L.*) grown from seeds. J. Hort. Sci. 41: 145-153.

Boelt, B. and Henriksen, K., 1991. The effect of plant density and plant arrangement on yield, bulb maturity and 'thick – necking' in onions (*Allium cepa L.*). Danish J. Plant Soil Science 95: 205-215.

Böttcher, H., Hibner, C. and Fröhlich, H., 1985. Einfluss der Aussaatsmenge auf die Lagereigenschaften von Dauerzwiebeln (*Allium cepa L.*). Archiv Gartenbau 33: 285-294.

Frappell, B. D., 1973. Plant spacing of onions. J. Hort. Sci. 48: 19-28.

Grudzień K. and Rumpel J. 1989. Próba ustalenia normy siewu nasion cebuli(Attempt of determining the sowing rate in onions). Ogrodnictwo 6: 13-15.

Hatridge-Esh, K. A. and Bennett, J. B., 1980. Effects of seed weight, plant density and spacing on yield responses in onions. J. Hort. Sci. 55: 247-252.

Mondial, M. F., Brewster, J.L., Morris, G.R.L. and Butler, H., 1986. Bulbs development in onion *(Allium cepa L.)*. I. Effects of plant density and sowing date in field conditions. Annals of Botany 58: 187-195.

Weerasinghe, S. S. and Fordham, R., 1993. The effects of plant density on onions established from multiseeded transplants. Acta Horticulturae 371; 97-104.

# Wpływ zagęszczenia roślin i odmiany na plonowanie cebuli (*Allium cepa L.*) uprawianej z siewu


## Streszczenie

Wpływ zróżnicowanego zagęszczenia na plon i wielkość cebuli uprawianej z siewu badano w dwóch doświadczeniach. W pierwszym, przeprowadzonym w latach 1991-1993, trzy odmiany cebuli (Hysam $F_1$, Mercato $F_1$ i Sochaczewska) wysiewano pod planowane zagęszczenie 20, 40, 60, 80, 100 i 140 roślin·$m^{-2}$, podczas gdy w drugim, w 1996 roku, sześć odmian cebuli (Spirit $F_1$, Summit $F_1$, Hyduro $F_1$, Armstrong $F_1$, Renate $F_1$ i Robusta) wysiewano pod planowane zagęszczenie 40, 60 i 80 roślin·$m^{-2}$. Cebulę uprawiano na płaskich zagonach, szerokości 1.35 m, w 4 rzędach na zagonie (27+27+27+54 cm).

Plon handlowy wzrastał wraz z zagęszczeniem roślin i zależnie od roku był najwyższy przy zagęszczeniu 80 lub 100 roślin·$m^{-2}$. Średni plon handlowy w doświadczeniu z okresu 1991-93 wzrósł z 20.5 t·$ha^{-1}$ do 32.8 t·$ha^{-1}$ odpowiednio dla zagęszczenia 20 i 80 roślin·$m^{-2}$, zaś w doświadczeniu z 1996 roku plon handlowy wzrósł z 48.9 t·$ha^{-1}$ do 59.0 t·$ha^{-1}$ odpowiednio dla zagęszczenia 40 i 80 roślin·$m^{-2}$.

Plon cebul dużych (>6 cm) był najwyższy przy zagęszczeniu 20 lub 40 roślin·$m^{-2}$ i wynosił odpowiednio 15.5 t·$ha^{-1}$ dla okresu 1991-93 oraz 39.6 t·$ha^{-1}$ dla roku 1996, po czym malał wraz z zagęszczeniem. Plon cebul średnich (4-6 cm), podobnie jak cały plon handlowy, był najwyższy przy zagęszczeniu 80-100 roślin·$m^{-2}$ i wynosił średnio 24.3 t·$ha^{-1}$ dla okresu 1991-93 oraz 35.5 t·$ha^{-1}$ dla 1996 roku. Plon cebul małych (3-4 cm) wzrastał wraz z zagęszczeniem i wynosił przy najwyższym zagęszczeniu 140 roślin·$m^{-2}$ (10.8 t·$ha^{-1}$ dla okresu 1991-93).

Wzrastające zagęszczenie przyspieszało dojrzewanie cebuli. Okres do 50% załamania szczypioru był przy zagęszczeniu 140 roślin·$m^{-2}$ o 9-10 dni wcześniejszy w porównaniu do zagęszczenia 20 roślin·$m^{-2}$. Porównywane odmiany cebuli różniły się wysokością plonu handlowego i wczesnością. W doświadczeniu z lat 1991-93 najplenniejszą była odmiana Mercato $F_1$(31.0 t·$ha^{-1}$), a następnie Sochaczewska (28.5 t·$ha^{-1}$) i Hysam $F_1$(26.9 t·$ha^{-1}$). W doświadczeniu 1996 roku, plenność odmian kształtowała się następująco: 1. Armstrong $F_1$ (62.6 t·$ha^{-1}$), 2. Spirit $F_1$(61.4 t·$ha^{-1}$), 3.Robusta (55.2 t·$ha^{-1}$), 4. Renate $F_1$(52.2 t·$ha^{-1}$), 5. Hyduro $F_1$ (50.9 t·$ha^{-1}$) i 6. Summit $F_1$ (48.8 t·$ha^{-1}$). Odmiany Spirit $F_1$ i Summit $F_1$ dojrzewały około 3 tygodnie wcześniej od pozostałych odmian w doświadczeniu.