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# THE INFLUENCE OF SELECTED AGRONOMIC PRACTICES ON THE YIELD AND CHEMICAL COMPOSITION OF WINTER GARLIC

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Summary

The studies were carried out in 2002-2005 on evaluation of covers application (a perforated film with 100 holes·m$^{-2}$ and polypropylene non-woven) as well as the influence of different plant density (250, 125, 83 and 63 plants·m$^{-2}$) on the yield and chemical composition of winter garlic cv. Arkus for bunch-harvest.

Covering the plants with perforated film and polypropylene non-woven increased the marketable yield by 30.7% in comparison to open field cultivation. Moreover, the covers had a favourable effect on the weight and leaf length as well as on plant weight and bulb diameter. The plants grown under covers showed significantly higher dry weight content in bulbs, total sugars in leaves, but simultaneously less amount of L-ascorbic acid. The increase of plant density from 63 to 250 per m$^2$ caused a significant increase of marketable yield. However, the plants grown at the highest density had the lowest weight and their edible parts had the least amount of total sugar and L-ascorbic acid.

key words: garlic, covers, plant density, yield, chemical composition

## INTRODUCTION

Garlic, due to its high biological activity and specific flavour is a very valuable vegetable widely cultivated throughout the world (Doruchowski 2006). Due to very rich chemical composition of bulbs it belongs to the plants of highest salubrious- properties (Lutomski 2001). It is widely known that garlic bulbs are rich in vitamin C, but they are also great source of vitamin $B_1$, $B_2$, E, PP as well as macro- and microelements: Mg, Cu, Fe, Zn and Se. Moreover, garlic contains other valuable compounds such as flavonoids, fructans, and saponins (Nartowska 2007). In our country, the consumers have used mostly garlic bulbs whereas cultivation of garlic for an early bunch-harvest is still not very popular.

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However, at this stage both bulbs and young leaves which are rich in minerals and vitamins, (mostly vitamin C and pro-vitamin A) are suitable for consumption. Garlic leaves can be consumed fresh or lyophilized and used in food industry as an additive to meat and milk products.

Considering vegetable cultivation meant for an early harvest, the application of different methods enabling timing of plant growth and yield is an important factor (Tendaj & Gruszecki 2002). Planting cloves in autumn enables to obtain 2-week earlier yield compared to an early spring-planting. Furthermore, application of different types of covers to obtain an earlier cropping from field cultivation is very often used in practice. As demonstrated by Tendaj & Mysiak (2006) the use of polypropylene non-woven for cultivation of shallots used for harvest with leaves resulted in the higher crop of spring planted onions compared to cultivation without covers. On the other hand, Kołota & Adamczewska-Sowińska (2003) observed that a perforated film used for leek cultivation used for an early harvest showed a better effectiveness than a polypropylene non-woven. According to Siwek & Libik (2005), a forced growth and development of plants as well as higher yield obtained from plants grown under covers results from a favourable modification of microclimate conditions around plants.

The usage of covers is especially justified in West Pomerania region where spring often comes 2-weeks later comparing to central Poland.

Plant density is one of the most important factors determining both yield and its quality. Orłowski & Rekowska (1989) studying the effect of clove density on the yield of garlic found that the yield significantly increased as plant density in row increased from 12 to 6 cm. However, in this case a deterioration of bulbs quality was also observed.

The aim of this study was to evaluate the influence of some agricultural practices on the yield and chemical composition of garlic cultivated for bunch-harvest with green leaves.

## MATERIAL AND METHODS

The field experiments were carried out in 2002-2005 in the Department of Vegetable Crops Agricultural University of Szczecin. The winter cultivar Arkus of Polish breed garlic was used. Weather conditions in all years of experiments were favourable for good overwintering and early start of vegetation in spring (Table 1). Only, in the period of intensive plant growth (that occurred in April of 2003, 2004, and 2005 and in May of 2003 and 2004) the precipitations were lower than multiannual average that enforced watering of the plantation. In general, the average air temperatures and sums of precipitations did not differ considerably for analyzed months in consecutive years of the experiment.

The study was a 2-way split-plot design with four replicates. The area of one replicate was 28.8 $m^2$.

Table. 1. Total amounts of precipitation and mean values of air temperature in years 2002-2005, according to data given by Mete orological Station in Szczecin Dąbie

| Years | Months | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | X | | XI | | XII | | I | | II | | III | | IV | | V | |
| | Precipi -tation (mm) | Tempe- rature (°C) | Precipi -tation (mm) | Tempe- rature (°C) | Precipi -tation (mm) | Tempe- rature (°C) | Precipi -tation (mm) | Tempe- rature (°C) | Precipi -tation (mm) | Tempe- rature (°C) | Precipi -tation (mm) | Tempe- rature (°C) | Precipi -tation (mm) | Tempe- rature (°C) | Precipi -tation (mm) | Tempe- rature (°C) |
| 2002/2003 | 105.4 | 7.3 | 43.2 | 3.4 | 28.0 | 3.6 | 34.6 | -0.8 | 33.3 | -2.1 | 16.7 | 3.1 | 15.4 | 8.3 | 25.3 | 14.7 |
| Deviation from multiannual mean | 66.4 | -1.6 | 5.2 | -1.0 | -10.0 | 2.6 | -1.6 | 0.4 | 7.0 | -1.4 | -11.3 | 0.6 | -19.6 | 1.1 | -25.7 | 2.5 |
| 2003/2004 | 35.4 | 6.3 | 26.7 | 6.1 | 35.7 | 3.2 | 46.7 | -2.3 | 39.4 | -2.2 | 24.4 | 4.9 | 31.7 | 9.2 | 31.8 | 12.6 |
| Deviation from multiannual mean | -3.6 | -2.6 | -11.3 | 1.7 | -2.3 | 2.2 | 13.7 | -1.1 | 13.4 | -1.5 | -3.6 | 2.4 | -3.3 | 2.0 | -19.2 | 0.2 |
| 2004/2005 | 36.1 | 10.2 | 61.7 | 4.6 | 35.7 | 2.9 | 49.6 | 3.1 | 42.1 | -0.6 | 28.0 | 2.3 | 20.5 | 9.2 | 90.4 | 13.1 |
| Deviation from multiannual mean | -2.9 | 1.3 | 23.7 | 0.2 | -2.3 | 1.9 | 16.6 | 4.3 | 16.1 | 0.1 | 0.0 | -0.2 | -14.5 | 2.0 | 39.4 | 0.7 |
| Multiannual mean (1951-1980) | 39.0 | 8.9 | 38.0 | 4.4 | 38.0 | 1.0 | 33.0 | -1.2 | 26.0 | -0.7 | 28.0 | 2.5 | 35.0 | 7.2 | 51.0 | 12.4 |

The first experimental factor was the type of cover; a perforated film with 100 holes per $m^2$ and polypropylene non-woven P-17 were used. The second tested factor was plant density (250, 125, 83, and 63 plants per $m^2$). The soil management, mineral fertilization, post emergence treatment, and plant protection were carried out according to the recommendations for the species. Garlic cloves were planted on 20th October at the depth of 6 cm prior to dressing with the 20% benzimidazol + 45% ditiokarbaminate (Zaprawa Funaben T) at the dose of 4 $g \cdot kg^{-1}$ cloves. The plots were covered with flat covers at the third decade of March and were taken off 3 weeks later. The non-covered plots constituted the control group. The harvests in consecutive years were as follows: 6th May 2003, 4th May 2004, and 2nd May 2005. After harvest a marketable yield of bulbs and leaves, mean plant height, number of leaves, as well as mean leaf length and width were measured. Also, mean plant weight, leaf and bulb weight were determined.

Chemical analyses, both for bulbs and leaves comprised of dry weight content (with a gravimetric method based on drying at 105ºC to a constant weight), L-ascorbic acid (the Tillmans method), total sugars and reducing sugar content (the Luff-Schoorl method) and total ash content (according to Krełowska-Kułas 1993). The results were subjected to the analysis of variance and the means were separated with the Tukey test at a significance level P=0.05.

## RESULTS AND DISCUSSION

Independently on experiment factors, no substantial differences were noted regarding garlic yield in particular years. It resulted mostly from similar weather conditions during garlic vegetation in 2002-2005.

The statistical analyses showed that both tested factors had significant influence on garlic yield quantity and quality (Table 2).

In the 1st year of experiment the favourable effect of covers application was observed. No significant differences in yield were found for plants covered with a perforated film and a polypropylene non-woven. Significantly higher yields were observed at the highest plant density (250 plants per $m^2$). For garlic cultivated under perforated film significantly lowest yield was obtained at the density of 63 plants per $m^2$. Whereas, for plants grown at the plots covered with the polypropylene non-woven and in the open field a lower yield was obtained when plant density was 83 and 63 plants per $m^2$.

In 2004 and 2005 significantly highest yield was obtained from the plots covered with the perforated film (4.03 and 4.40 $kg \cdot m^{-2}$, respectively). An increase of plant density from 63 to 250 per $m^2$ caused a significant yield enhancement. Both for the garlic grown under covers and in open field the lowest yield was noted at plant density of 63 per $m^2$.

On average for 3 years of experiment, it was found that application of flat covers increased the marketable yield by 30.7% in comparison to open field cultivation. However, the type of covers did not affect the obtained yield considerably. The favourable effect of covers usage was observed in cultivation of kohlrabi, leeks, and shallots by Pessala (1994), Adamczewska-Sowińska &

Kołota (2001), and Orłowski *et al*. (2005), respectively. However, there are also reports that flat covers despite of their positive effect on early yielding, did not affect significantly the amount of yield for some plants (Krężel & Kołota 2000, Tendaj & Gruszecki 2002). In this experiment, the usage of perforated film and polypropylene non-woven had also an advantageous effect on mean mass of all plants including leaf mass and onions mass, as well as on plant height, leaf number and their length and width (Table 3, Fig. 1).

Table 2. The effects of cover type and plant density on the yield of winter garlic

| Type of covers | Plant density (pcs·m$^{-2}$) | Marketable yield (kg·m$^{-2}$) | | | |
|---|---|---|---|---|---|
| | | 2003 | 2004 | 2005 | 2003-2005 |
| Perforated film | 250 | 6.58 | 6.80 | 7.17 | 6.85 |
| | 125 | 3.83 | 4.00 | 4.50 | 4.11 |
| | 83 | 2.60 | 3.13 | 3.24 | 2.99 |
| | 63 | 2.12 | 2.17 | 2.67 | 2.32 |
| | Mean | 3.78 | 4.03 | 4.40 | 4.07 |
| Non-woven polypropylene | 250 | 6.00 | 6.09 | 6.95 | 6.35 |
| | 125 | 4.59 | 3.97 | 4.22 | 4.26 |
| | 83 | 2.95 | 2.67 | 3.08 | 2.90 |
| | 63 | 2.89 | 2.04 | 2.39 | 2.44 |
| | Mean | 4.11 | 3.69 | 4.16 | 3.99 |
| No covers (control) | 250 | 4.89 | 5.02 | 5.21 | 5.04 |
| | 125 | 3.23 | 3.16 | 3.81 | 3.40 |
| | 83 | 1.78 | 2.06 | 2.28 | 2.04 |
| | 63 | 1.53 | 1.77 | 1.98 | 1.76 |
| | mean | 2.86 | 3.00 | 3.30 | 3.06 |
| Mean for plant density | 250 | 5.82 | 5.70 | 6.44 | 6.08 |
| | 125 | 3.88 | 3.71 | 4.18 | 3.92 |
| | 83 | 2.44 | 2.62 | 2.87 | 2.64 |
| | 63 | 2.18 | 1.99 | 2.35 | 2.17 |
| $LSD_{0.05}$ for: | type of covers | 0.386 | 0.244 | 0.182 | 0.158 |
| | plant density | 0.213 | 0.315 | 0.249 | 0.148 |
| | interaction | 0.369 | 0.546 | 0.382 | 0.225 |

The increase of plant density from 63 to 250 per m$^2$ enhanced the marketable yield by 176%. Similar findings were obtained by Jadczak & Orłowski (2001). The authors observed a significant decrease of shallot yield along with a decrease of spacing in rows from 12 to 6 cm. Also, in the research carried out by Rekowska & Słodkowski (2008) it was found that the increase of plant density (a decrease of spacing between the rows from 30 to 20 cm) for red beets used for bunch-harvest significantly increased the yield. However, higher weight of leaves was obtained at spacing 30 cm between the rows.

However, in this experiment at highest plant density (250 plants per m$^2$ responding to the spacing 20×2 cm) the plants showed the lowest weight, including the lowest weight of leaves, as well as the lowest weight and diameter of bulbs (Table 3).

Table 3. The effect of cover type and plant density on some quality characteristics of winter garlic yield (mean for 2003-2005)

| Type of covers | Plant density (pcs·m$^{-2}$) | Mass of plant (g·plant$^{-1}$) | Mass of leaves (g·plant$^{-1}$) | Mass of bulb (g·plant$^{-1}$) | Bulb diameter (mm) |
|---|---|---|---|---|---|
| Perforated film | 250 | 25.2 | 18.0 | 7.2 | 17.8 |
| | 125 | 27.9 | 19.1 | 8.8 | 20.4 |
| | 83 | 27.5 | 18.7 | 8.8 | 20.3 |
| | 63 | 29.1 | 20.2 | 8.9 | 20.4 |
| | mean | 27.4 | 19.0 | 8.4 | 19.7 |
| Non-woven polypropylene | 250 | 26.4 | 18.5 | 7.9 | 17.8 |
| | 125 | 27.5 | 18.8 | 8.7 | 20.0 |
| | 83 | 28.1 | 19.2 | 8.9 | 20.7 |
| | 63 | 28.5 | 19.5 | 9.0 | 20.8 |
| | mean | 27.6 | 19.0 | 8.6 | 19.8 |
| No covers (control) | 250 | 22.6 | 15.8 | 6.8 | 17.4 |
| | 125 | 23.3 | 15.7 | 7.6 | 17.7 |
| | 83 | 24.9 | 17.5 | 7.4 | 18.4 |
| | 63 | 24.7 | 17.6 | 7.1 | 18.7 |
| | mean | 23.9 | 16.7 | 7.2 | 18.1 |
| Mean for plant density | 250 | 24.7 | 17.4 | 7.3 | 17.7 |
| | 125 | 26.2 | 17.9 | 8.4 | 19.4 |
| | 83 | 26.8 | 18.5 | 8.4 | 19.8 |
| | 63 | 27.4 | 19.1 | 8.3 | 20.0 |
| $LSD_{0.05}$ for: type of covers | | 2.37 | 1.39 | 0.91 | 1.72 |
| plant density | | 1.41 | 0.69 | 0.74 | 1.22 |
| interaction | | 2.44 | 1.19 | 1.18 | 2.46 |

The leaves of onion plants are characterized by a high content of dry weight, L-ascorbic acid, and minerals that was demonstrated in the studies of Smoczkiewiczowa *et al*. (1981) and Kunachowicz *et al*. (2003). Also, Żurawik & Jadczak (2008) studied the effect of cultivation methods on the quality and yield of garlic chive (*Allium tuberosum*). The one-year old leaves of garlic chive contained 51 mg of vitamin C · 100 g$^{-1}$ fresh weight.

As demonstrated by Dyduch & Najda (2000) garlic cultivated for bunch-harvest with green leaves contains many valuable compounds. The authors performed laboratory analyses to estimate the dynamics of absorption of selected chemical components in false stem and leaves of garlic producing flowering shoots. Higher dry weight, total sugar, L-ascorbic acid and total fiber content were found in false stem than in leaf blades.

Our results confirm these observations (Table. 4). Nevertheless the factors tested, garlic leaves were more abundant in L-ascorbic acid, reducing sugars and ash compared to the bulbs. On the other hand, the bulbs showed higher dry weight and higher total sugar content.

Garlic plants grown under covers showed significantly higher dry weight content in bulbs, as well as total sugar content in leaves; however it was accompanied by considerably lower amount of L-ascorbic acid in leaves.

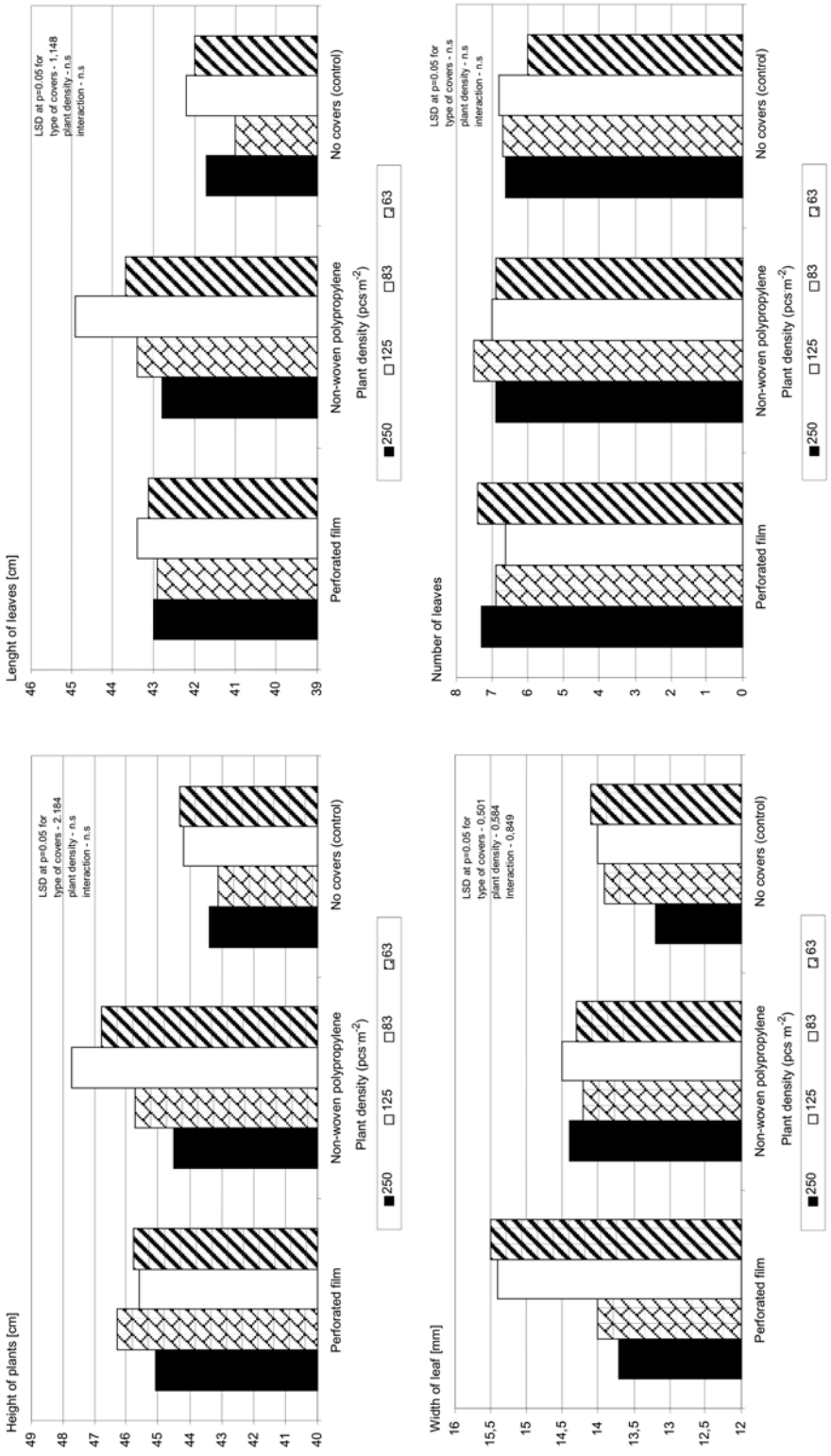



Fig. 1. The effect of cover type and plant density on some biometric features of garlic cv. Arkus (mean for years 2003-2 005)

Table 4. Chemical composition of garlic edible parts in dependence on cover type and plant density (mean for 2003-2005)

| Type of covers | Plant density (pcs·m$^{-2}$) | Dry matter (%) | | L-ascorbic acid (mg·100g$^{-1}$ f.m) | | Total sugar (% f.w) | | Reducing sugar (% f.w) | | Total ash (% d.m) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | leaves | bulb | leaves | bulb | leaves | bulb | leaves | bulb | leaves | bulb |
| Perforated film | 250 | 14.32 | 23.76 | 88.2 | 11.4 | 4.75 | 16.20 | 3.10 | 0.60 | 1.24 | 0.90 |
| | 125 | 14.55 | 23.18 | 97.8 | 12.3 | 4.98 | 16.15 | 3.19 | 0.58 | 1.16 | 0.87 |
| | 83 | 14.35 | 22.50 | 103.2 | 13.5 | 4.72 | 16.18 | 3.30 | 0.59 | 1.20 | 0.83 |
| | 63 | 13.68 | 21.97 | 98.6 | 15.3 | 4.84 | 16.17 | 3.24 | 0.63 | 1.23 | 0.89 |
| | mean | 14.23 | 22.85 | 97.0 | 13.1 | 4.82 | 16.18 | 3.21 | 0.60 | 1.21 | 0.87 |
| Non-woven polypropylene | 250 | 14.48 | 22.98 | 91.2 | 13.5 | 4.20 | 17.02 | 3.14 | 0.50 | 1.30 | 0.88 |
| | 125 | 14.65 | 22.71 | 89.0 | 15.9 | 4.78 | 17.40 | 3.22 | 0.48 | 1.20 | 0.94 |
| | 83 | 14.43 | 23.80 | 98.6 | 14.7 | 4.91 | 18.00 | 3.28 | 0.51 | 1.25 | 0.90 |
| | 63 | 15.24 | 24.00 | 100.2 | 15.0 | 4.74 | 17.84 | 3.30 | 0.50 | 1.28 | 0.82 |
| | mean | 14.70 | 23.37 | 94.8 | 14.8 | 4.66 | 17.57 | 3.24 | 0.50 | 1.26 | 0.89 |
| No covers (control) | 250 | 14.14 | 21.68 | 96.6 | 11.7 | 3.80 | 16.98 | 2.70 | 0.62 | 1.20 | 0.98 |
| | 125 | 15.20 | 22.59 | 103.8 | 14.7 | 4.18 | 17.30 | 2.84 | 0.60 | 1.28 | 0.91 |
| | 83 | 14.16 | 21.90 | 99.8 | 12.8 | 4.02 | 17.03 | 2.88 | 0.70 | 1.32 | 0.88 |
| | 63 | 14.82 | 22.42 | 99.0 | 16.2 | 3.95 | 17.40 | 2.86 | 0.64 | 1.35 | 0.90 |
| | mean | 14.58 | 22.15 | 99.8 | 13.9 | 3.99 | 17.18 | 2.82 | 0.64 | 1.29 | 0.92 |
| $LSD_{0.05}$ for: type of covers | | n.s | 0.132 | 2.773 | 0.731 | 0.199 | 0.159 | n.s | n.s | n.s | n.s |
| plant density | | n.s | n.s | 1.471 | 0.826 | 0.097 | 0.055 | 0.156 | n.s | n.s | n.s |
| interaction | | n.s | n.s | 2.373 | 1.142 | 0.161 | 0.116 | n.s | n.s | n.s | n.s |

It was also found that decrease of plant density from 250 to 63 per $m^2$ caused an increase in total sugar content in bulbs and L-ascorbic acid both in leaves and bulbs. On the other hand, the number of plants per area unit had no effect on dry weight and ash content in both edible parts of garlic plants.

## CONCLUSIONS

1. The flat covers applied in garlic cv. Arkus cultivation increased the marketable yield by 30.7% in comparison to open field cultivation. Moreover, the covers had a favourable influence on unit weight and leaf length, weight and diameter of bulbs and the number of leaves.
2. The plants grown under covers showed significantly higher amount of dry weight in bulbs and total sugar in leaves but simultaneously decreased L-ascorbic acid content compared to plants cultivated without covers.
3. Significantly highest marketable yield of garlic was observed at the highest plant density (250 plants per $m^2$).
4. Planting of garlic cloves at the spacing of 250 plants per $m^2$ resulted in obtaining the plants with the lowest mean mass of leaves as well as lowest weight and diameter of bulbs. Additionally, the plants obtained from this spacing showed significantly lowest total sugar and L-ascorbic acid content in both edible parts .

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# WPŁYW NIEKTÓRYCH CZYNNIKÓW AGROTECHNICZNYCH NA PLONOWANIE ORAZ SKŁAD CHEMICZNY CZOSNKU OZIMEGO W UPRAWIE NA ZBIÓR PĘCZKOWY

Streszczenie

W latach 2003-2005 przeprowadzono badania, w których oceniano wpływ stosowania osłon (folia perforowana o 100 otworach na $1m^2$ i włóknina polipropylenowa) oraz zagęszczenia roślin (250, 125, 83 i 63 szt. na $1m^2$) na plon oraz skład chemiczny czosnku odmiany Arkus uprawianego na zbiór pęczkowy.

Osłanianie roślin folią perforowaną oraz włókniną PP przyczyniło się do wzrostu plonu o 30,7% w porównaniu z uprawą na polu odkrytym. Miało również korzystny wpływ na masę jednostkową i długość szczypioru oraz masę i średnicę cebuli. W tym przypadku wykazano istotnie większą zawartość niż w uprawie polowej suchej masy w główkach, cukrów ogółem w szczypiorze, ale jednocześnie mniej kwasu L-askorbinowego. Zagęszczanie roślin z 63 do 250 na powierzchni $1m^2$ spowodowało istotny wzrost plonu handlowego. Jednak przy największym zagęszczeniu rośliny charakteryzowały się najmniejszą masą, a w częściach jadalnych stwierdzono najmniej cukrów ogółem i kwasu L-askorbinowego.