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Optimisation of the density of chufa (*Cyperus esculentus* L.) plants in the Kyiv region

Abstract. To achieve the optimal compromise between yield and soil fertility that will help balance two important aspects of agricultural production – high crop yields and long-term soil fertility – it is necessary to understand the impact of changing row spacing on vegetable crop growth and the soil environment. The research aims to determine the adaptive properties of the "Pharaoh" variety by studying the feeding area and plant density to obtain high-quality chufa nodules in the Kyiv region. The main research methods were field studies and analysis of the variance of morphological traits and economically valuable indicators of chufa. It was found that different plant densities had an impact on the development of vegetative organs of chufa due to competition for resources during the growing season. The variety "Pharaoh" showed a high intensity of aboveground mass formation in sparse crops with a plant density in the range of 28-33 thousand plants per hectare, with the number

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of leaf bundles reaching 145.2-147.4 pieces, and their average height is 50.4-52.3 centimetres. At the same time, the size of the nodules increased with a lower plant density, since with a larger feeding area, plants formed more powerful ones with thicker leaf bundles. Plants arranged in a 60×60 cm spacing (28 thousand plants/ha) formed larger nodules with the largest dimensions: 3.1 cm in length, 1.0 cm in width, and 1.2 cm in thickness. It has been substantiated that chufa of the "Pharaoh" variety was characterised by higher economic and valuable indicators under the schemes of planting 60×50 and 60×60 cm nodules. The high marketable yield of freshly harvested nodules was formed at a plant density of 28-33 thousand units/ha and amounted to 4.2-4.6 t/ha. The highest average yield of nodules after drying was obtained under the plant spacing of 60×60 and 60×50 cm, which was 3.35 and 2.99 t/ha, which was 20.9 and 7.8% higher than the control, respectively. Chufa is a promising crop in terms of food security and income generation, and precise management of plant placement will help to balance yield and soil fertility

Keywords: nodules; arrangement; bush, leaf bundles; rhizome; productivity; yield

INTRODUCTION

Chufa or earth almonds (*Cyperus esculentus* L.) are one of the less common crops that are valued for their high dietary and medicinal properties. The sweetish and nutty-flavoured nodules are used raw, boiled, and fried. They can replace peanuts, almonds, and soybeans in the confectionery industry. Flour made from chufa is used to make cakes, biscuits, and pastries. In cooking, it is used to make high-quality halva and sweets. In the processing industry, chufa is used to produce sugar, starch, and oil, which is as good as olive oil in terms of quality. Chufa products are a source of important physiologically active substances that are not available in other foods. Chufa oil is also valued in cosmetics and perfumery (Guo *et al.*, 2021; Oyedara *et al.*, 2022).

Chufa first became known in Ukraine in the 1930s. At that time, more than 100 hectares of chufa were grown in the Kherson region for the Odesa Confectionery Factory (Zavadska *et al.*, 2021). The crop remains promising for the southern regions of Ukraine. *C. esculentus* is the only species of the cultivated genus *Cyperus*. No wild forms of the species have been recorded in Ukraine. The National Botanical Garden named after M. Hryshko of the National Academy of Sciences of Ukraine has been introducing chufa since its foundation in 1945-1946. The first to start researching the culture in the scientific institution was a prominent Ukrainian breeder, Professor D. Lykhvar. The research results showed that growing the crop was also promising in the Forest-Steppe region of Ukraine. The selection of chufa was started, the varieties of which were included in the State Variety Testing and planting material was propagated (Marchyshyn *et al.*, 2021).

M. Druzhynina in the 1950s and V. Hryn in the 1970s studied the elements of the technology of growing and using chufa. On the fields of the Glevakha research farm, the National Academy of Sciences, together with scientists from the Institute of Mechanisation and Electrification of Agriculture of the National Academy of Agrarian Sciences, researched the technological processes of mechanised cultivation and harvesting of chufa. To date, the varieties "Pharaoh" and "Novinka" are known for the Forest-Steppe and "Ingulskyi" and "Snihurivskyi" for the Steppe of Ukraine (Ivasiuk *et al.*, 2019; Marchyshyn *et al.*, 2020).

Before the war with Russia, chufa production in Ukraine was gradually reviving. Increasing the yield of the crop is possible by improving its cultivation technology. One of the most important technological elements that result in higher yields of high-quality nodules is the optimal density of chufa plants. Different plant densities create different conditions for the growth and development of tuberous crops, including chufa. Previous studies have shown that with an increase in plant density, the productivity of each plant decreases (Bobos *et al.*, 2019).

The increase in the number of plants in a row contributed to a smaller growth of the chufa plant bush, which is reflected in the change in this indicator. Plant height is an important indicator that reflects the characteristics of crop growth and development and can change under the influence of environmental factors and elements of cultivation technology (Asare *et al.*, 2020).

The plasticity and stability of chufa influence its high economic value, along with the diverse use of fresh and processed nodules and deserves to be introduced in Ukraine. The soil and climatic conditions of the Forest-Steppe of Ukraine are favourable for growing high-quality chufa products. However, irrigation is required to ensure high yields. Moisture deficit is a limiting factor in obtaining a high and high-quality nodule yield (Abano *et al.*, 2021; Pascual-Seva & Pascual, 2021). Under unfavourable growing conditions, the right variety and density of chufa plants are important. These facts prompted us to conduct a study on the selection of the optimal feeding area for chufa plants for the conditions of the Kyiv region for cultivation in non-irrigated conditions.

The research aims to determine the adaptive properties of plants of the "Pharaoh" variety based on the study of the feeding area and plant density to obtain high-quality chufa nodules in the Kyiv region. The study of economically valuable traits of the crop will improve the technology of chufa cultivation, which will make it possible to provide the population with valuable and high-quality nodules for fresh consumption and the processing industry.

MATERIALS AND METHODS

The study was conducted in the educational laboratory (EL) "Fruit and Vegetable Garden" of the National University of Life and Environmental Sciences of Ukraine for three years – from 2019 to 2021. The training laboratory is located in the northern part of the Forest-Steppe and has soddy-medium podzolic soils (Zavadska *et al.*, 2021).

The research object was the chufa of the "Pharaoh" variety, which was created in the M.M. Gryshko National Botanical Garden (2009). Different schemes of nodule placement on the vegetable field of the Department of Vegetable Growing and Indoor Ground were studied. These schemes were as follows: 60×30, 60×40 (control), 60×50, 60×60 cm. The plant density, depending on the arrangement scheme, ranged from 28 to 56 thousand plants/ha.

The area of the experimental plot was 5 m^2. In all variants, row spacing was the same (60 cm). The feeding area in the experiment was regulated by the number of plants in a row. During the experiment, the phenological phases of plant growth were determined, the yield was recorded and the resistance of plants to diseases and pests was studied according to the methodology developed by G.L. Bondarenko & K.I. Yakovenko (2001).

During the growing season, which lasted from 05 June to 05 August 2019-2021, biometric measurements of plants were carried out. In particular, the height of the shoots was determined by measuring the length of the largest leaf using a ruler. The number of leaves on each plant was also counted. The surveys were carried out three times during the growing season – every month during the growth of vegetative mass. The dynamics of vegetative mass growth of plants of different chufa variants were determined. During the growing season, no diseases or pests were found on the chufa crops. The technology of chufa cultivation was used, which is generally accepted in production conditions without irrigation. Bulbs were planted to a depth of 5-6 cm on 10 May 2019-2021. 3 bulbs were sown in each hole.

After harvesting, which was carried out on 28-30 September after the leaves had turned yellow, the plants were dug up and the nodules were shaken off. They were then separated from the rhizomes and the remaining soil was sieved through a sieve and washed in running water. Then the nodules were cleaned, dried, and weighed to determine their average weight and weight of 1000 pcs. The size of the nodules was also analysed by measuring their length, width, and thickness. To analyse the data, we performed an analysis of variance using the XLSTAT add-in in MS Excel. The study was conducted following the requirements of the Convention on Biological Diversity (1992). The technology of chufa cultivation was used, which is generally accepted in production conditions and was carried out without irrigation. The bulbs were planted on 10 May during 2019-2021 to a depth of 5-6 cm, with 3 bulbs sown in each hole.

RESULTS AND DISCUSSION

It was found that the density of plants in chufa influenced the formation of aboveground mass.

During the entire growing season, the plants were characterised by different intensities of vegetative mass formation. The results of the research show that the lowest bush height was at a plant density of 56 thousand plants/ha, and with a decrease in density it increased. Chufa plants were very sensitive to changes in the feeding area. The thickened crops of chufa of the "Pharaoh" variety were characterised by lower dynamics of vegetative mass formation (Fig. 1, 2).

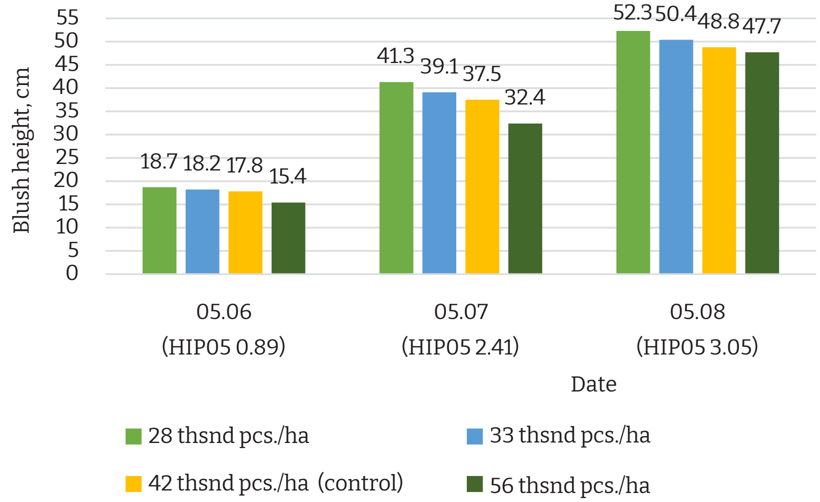

Figure 1. Influence of plant density on the height of the chufa bush of the "Pharaoh" variety (average for 2019-2021), cm

Source: compiled by the authors

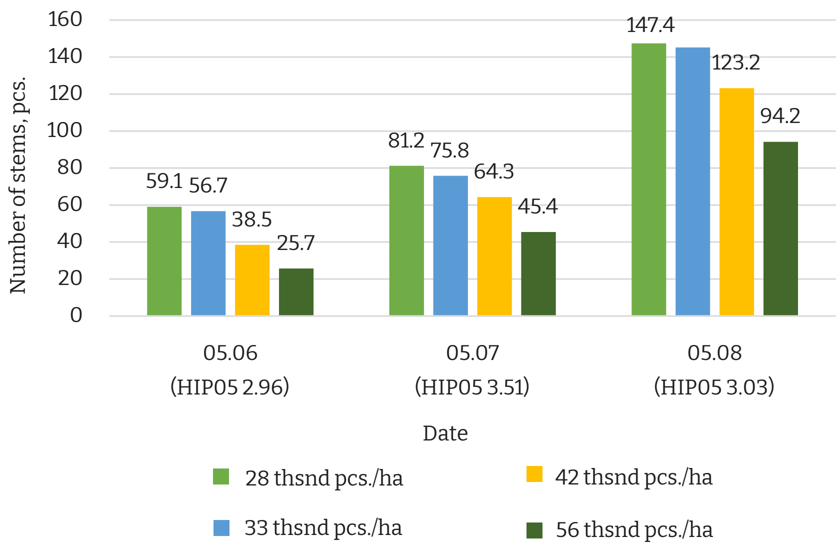

Figure 2. Influence of plant density on the number of stems of chufa variety "Pharaoh" (average for 2019-2021), pcs.

Source: compiled by the authors

After analysing the biometric parameters of chufa plants under different sowing schemes, it is possible to note that plants with the lowest plant density (28 thousand units/ha) had a more developed vegetative mass. This tendency was observed for all the dates of accounting, which were conducted in the research.

The chufa variety "Pharaoh" was characterised by a lower bush height at the highest density of 56 thousand plants/ha. At the same time, the density of plants also affected the number of stems, which was higher in plants with a lower density of 28 thousand units/ha, where thicker leaf bunches were formed. In thickened crops, shorter leaves of the bush were formed with a length of 47.7 cm, which is 1.1 cm more than in the control. However, the height of the bush and the number of leaves in sparse sowings (60×60 cm) increased to 52.3 and 147.4 pcs, respectively, which is 4.6 cm and 53.2 pcs less than in the control.

Thus, the study results indicate that different plant densities had an impact on the development of chufa vegetative organs. This is explained by the fact that during the growing season, plants competed with each other for access to light, moisture, and nutrients. A greater accumulation of leaf mass was found in chufa in sparse crops with a plant density of 28-33 thousand plants/ha, where the number of leaf bundles was 145.2-147.4 pcs. with a bush height of 50.4-52.3 cm.

Valuable economic indicators of chufa are the result of complex physiological transformations of organic and mineral substances in plants through their photosynthetic activity. The main factors that determine the intensity of photosynthesis and crop productivity are the degree of plant density in the area. It is the combination of plant density and placement in the cultivation technology that creates favourable optimal growing conditions and ensures that plants have uniform access to light, water, nutrients, and carbon dioxide in the topsoil.

The economic organ of chufa is the formation of nodules on the rhizome. The plant develops 150-200 nodules (up to 1000 pcs.) under one plant. The size of the nodules ultimately determines the productivity and yield of the plants.

The size of chufa nodules was found to be influenced by the placement of plants in the area (Fig. 3).

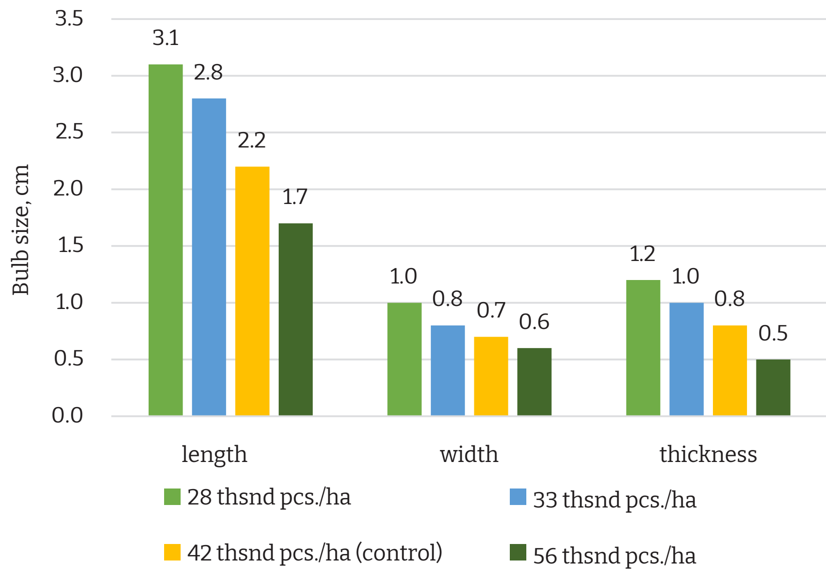

Figure 3. Effect of plant density on chufa nodule size (average for 2019-2021)
Source: compiled by the authors

The size of the nodules affected the productivity of the chufa and depended on their width, length and thickness. On average, over three years, the length of the nodules was 1.7-3.1 cm. Moreover, on crops with a lower plant density (28 thousand plants/ha), the length increased to 3.1 cm. This trend was also observed for other biometric parameters, namely the width of the nodules was 0.6-1.0 cm. At the same time, a larger width (1.0 cm) was found in the 60×60 cm planting scheme, which is 0.3 cm higher than the control.

With a decrease in the density of chufa plants, an increase in the size of their nodules was observed. This is due to the larger feeding area of the plants, which formed a better-developed rosette of leaves consisting of thicker leaf bundles (Fig. 4).

The thickness of the chufa nodules also depended on the plant density and ranged from 0.5-1.2 cm. At the same time, the lowest value of 0.5 cm was found on crops with a plant density of 56 thousand plants/ha under the 60×30 cm spacing scheme. A greater nodule thickness of 1.2 cm was observed on sparse crops (60×60 cm), which is 0.4 cm higher than the control.

Thus, reducing the density of chufa plants increased the size of the nodules. The largest size of nodules developed on the plant in the 60×60 cm spacing (28 thousand units/ha) with the largest length (3.1 cm), width (1.0 cm) and thickness (1.2 cm).

Figure 4. Formation of the vegetative mass and root system of chufa depending on the area of plant placement

Note: 1 – 60×30 cm; 2 – 60×40 cm; 3 – 60×50 cm; 4 – 60×60 cm

Following the research results, the density of chufa plants influenced the yield of nodules, which depended on their average number and plant productivity (Table 1). Significantly higher average plant productivity was also found at a plant density of 33 thousand plants/ha, which was 127 g, which is 32 g more than the control. The lower productivity of 72 g is characterised by plants with a spacing of 60×30 cm and a plant density of 56 thousand plants/ha.

Table 1. Influence of the timing and depth of planting of nodules on the economically valuable indicators of chufa (2019-2021)

Plant layout, cm	Plant density, thousand plants/ha	Average number of nodules, pcs.				Average productivity per bush, g				Weight of 1000 pieces of raw bulbs, g			
		years			Average	years			Average	years			Average
		2019	2020	2021		2019	2020	2021		2019	2020	2021	
60×30	56	168	170	175	171	70	71	74	72	415	420	425	420
60×40 (c)*	42	180	185	187	184	92	97	97	95	510	525	520	518
60×50	33	211	215	218	215	123	128	129	127	584	595	590	590
60×60	28	262	280	278	273	157	172	170	166	598	614	610	607
HIP_{05}					9.86				8.02				11.44

Note: (c)* – control
Source: compiled by the authors

The variety "Pharaoh" is characterised by a large mass of 1000 pcs. 420-607 g of nodules under all plant placement schemes. However, at a plant density of 28-33 thousand units/ha, bulbs were formed of a larger size with a weight of 1000 units 590-607 g, which is 72-89 g more than the control. A higher mass of nodules influenced higher plant productivity and yield. A greater weight of 1000 bulbs of 607 g were characterised by plants with a 60×60 cm arrangement, which influenced their high yield. Lower economically valuable indicators were found in thickened crops. The bulbs under the 60×30 and 60×40 cm arrangement schemes were formed of smaller sizes with the lowest weight of 1000 seeds, which was 420-518 g.

The productivity of nodules from one bush and their number and size influenced the marketable yield of chufa. At a higher density of 42-56 thousand units/ha, chufa of the **"**Pharaoh" variety had the lowest marketable yield of freshly harvested nodules of 4.0 t/ha (Fig. 5). At the same time, the highest yield increase was obtained in the variety with a lower plant density of 28 thousand plants/ha, where the marketable yield was 4.6 t/ha, which is 0.6 t/ha more than in the control. This is due to the formation of a larger bush, where a larger number of bulbs were found.

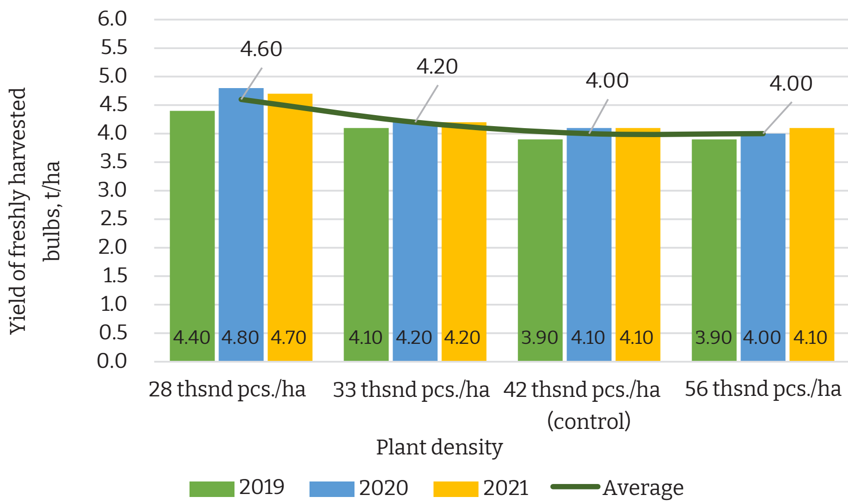

Figure 5. The yield of freshly harvested bulbs (2019-2021) (HIP_{05} 0.15), t/ha
Source: compiled by the authors

Thus, chufa of the "Pharaoh" variety is characterized by high economic and valuable indicators under the schemes of 60×50 and 60×60 cm with a plant density of 28-33 thousand units/ha, where the highest marketable yield of freshly harvested bulbs was formed at 4.2-4.6 t/ha with a weight of 1000 units of 590-607 g.

X. Yang *et al.* (2022) and Y. Yu *et al.* (2022), the moisture content of freshly harvested chufa nodules reached about 43.5-47.4%. Due to the high moisture content, chufa is susceptible to rancidity and mould growth in the presence of enzymes and fungi, which, accordingly, reduced its quality and commercial value. Therefore, after harvesting, the tubers were dried to a moisture content of 15%.

During 2019-2021, the highest average yield of nodules after drying was obtained in variants with a plant density of 28 and 33 thousand units/ha with a spacing of 60×60 and 60×50 cm and was 3.35 and 2.99 t/ha, which was 0.58 and 0.22 t/ha or 20.9 and 7.8% significantly higher than the control, respectively (Fig. 6).

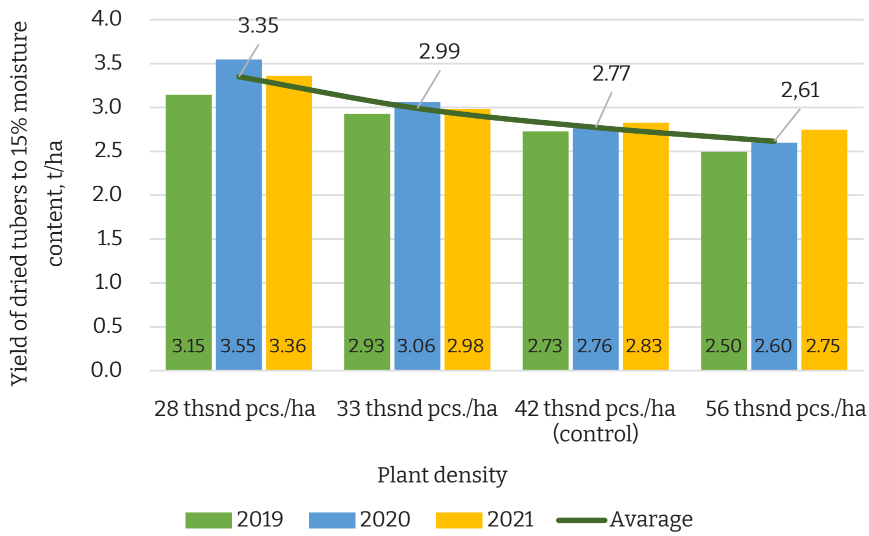

Figure 6. Yield of tubers dried to 15% moisture content (2019-2021) (HIP_{05} 0.18), t/ha
Source: compiled by the authors

Understanding the impact of changing row spacing on crop growth and the soil environment is essential to balancing yields and soil sustainability. It will also provide a basis for future soil moisture and fertiliser management (Schmidt *et al.*, 2021). Chufa can return more organic matter to the soil earlier and faster than traditional crops such as maize in R. Yang *et al.* (2020). Tests show that the heterogeneous distribution of nutrients in the soil has a significant impact on the underground organs of plants. In the case of chufa, this heterogeneity can have an important impact on planting in the following year by promoting root growth (Zhang *et al.*, 2020). A row spacing of 30 cm resulted in the highest yield of chufa nodules, but the highest spatial heterogeneity of soil nutrients. The row spacing of 50 cm had the lowest spatial heterogeneity of nutrients in the soil. At the same time, the 40 cm row spacing had no obvious advantages and was not a suitable choice for planting. Therefore, to achieve the same yield and reduce the spatial heterogeneity of soil nutrients, it is better to use a row spacing of 50 cm (Tan *et al.*, 2020). In addition, the results showed that the highest yield of chufa nodules was with 60 cm row spacing and 50 and 60 cm plant spacing in the row. This may be because more intense interspecific competition contributes to lower plant yields when the plant feeding area is reduced.

High temperatures, infertile soils, and severe wind erosion limit the development of crops in extremely arid regions. T. Wube *et al.* (2020) and J. Zhang *et al.* (2021), suggested that row spacing can play an important role in increasing crop yields by changing microclimatic conditions and improving soil quality. In addition, narrow row spacing can reduce wind speeds and improve soil surface roughness, enhancing plant growth (Pan *et al.*, 2021). Plant height, plant density and number of bushes, and leaf carbon concentration were highest at 30 cm row spacing, indicating that narrow row spacing favoured chufa growth and development. There was also a relationship between plant height and wind erosion, which supports the previous view that plant height is one of the main reasons that can reduce wind erosion (Liu *et al.*, 2022). However, while narrow row spacing can have a positive impact on plant yields in arid regions, plant densification can lead to soil moisture deficits. Sparse crops also cause drought by increasing soil evaporation, so a balance between plant cover and soil evaporation is important to reduce wind erosion and improve soil quality. However, in the years of these studies, the weather conditions were unstable in terms of moisture and were characterised by high air temperatures during the growing season, and we observed a greater accumulation of chufa leaf mass with a plant density of 28-33 thousand units/ha.

Chufu is mainly grown by ridge planting or conventional flat planting (Zhao *et al.*, 2019). For planting the nodules, ridges 20 cm high and 60 cm apart were used, with an interval of 10 cm within the ridge (corresponding to 120 kg/ha of nodules), three nodules per hole (equally spaced 10 cm apart) (Pascual-Seva & Pascual, 2021). Ridges can also be formed as follows: the width of the bottom is 60 cm, the distance between ridges is 60 cm, the distance between rows on the ridges is 20 cm, the distance between hills is 15 cm and the height of ridges is 13 cm. Two rows are placed on each ridge and three bulbs are planted in one hole. The depth at which the chufa nodules grow is between 8 and 12 cm. Therefore, the outer dimensions of the crawler belts on both sides and the width of the digging devices of the chufa harvester should be 18 cm, and the digging depth of the digger blades should be adjusted between 0 and 20 cm (Qu *et al.*, 2023). Existing chufa harvesters require a lot of labour and assistance during harvesting, resulting in low harvesting efficiency. In addition, the harvested nodules need to be re-sieved as they do not meet current market requirements (Wang *et al.*, 2022). Therefore, the development of chufa harvesters should combine the digging, lifting, harvesting, screening and sorting of the nodules. Further research should investigate the applicability of the basic mechanisms in different soil zones and consider the suitability and reliability of the machinery in different working conditions to meet market demands to improve the overall usability and versatility of the harvesters.

In a study of the effect of row spacing (30 cm, 60 cm, 90 cm, 120 cm) on chufa growth and soil quality in an extremely arid area in the South Tarim Basin of Xinjiang, it was found that the yield of vegetative mass and nodules initially decreased and then increased with increasing row spacing (Guo *et al.*, 2021). The highest values of plant height, leaf, nodule, and root biomass yields were observed at 30 cm row spacing, the lowest at 90 cm row spacing, and there were no obvious differences between 60 cm and 120 cm row spacing. At 30 cm row spacing, the amount of N, P and K absorbed was significantly higher than in the other treatments, but the availability of N, P and K in the soil in the 0-20 cm layer was lower than in the other treatments. The chufa plantation reduced soil salinity at a depth of 20-40 cm. In the 0-20 cm row spacing, soil salinity increased to moderate salinity in the 90 cm and 120 cm row spacings, while there were no significant changes in the 30 cm and 60 cm row spacings. The results showed that a row spacing of 30 cm could improve the yield of chufa leaves and nodules as well as soil salinity, and therefore, Y. Liu *et al.* (2021) recommended using it for chufa planting. In general, the study showed that to obtain a consistently high yield of chufa in the northern part of the Forest-Steppe on soddy-medium podzolic soil, it is recommended to adhere to the planting scheme of 60×50 and 60×60 cm. The 60×30 cm plant spacing demonstrates the highest values of plant height, leaf and nodule yields and root biomass. The trial highlights the importance of proper chufa plant placement to achieve optimal yield results and ensure soil quality in this region.

CONCLUSIONS

Different density of chufa plants affects the formation of their vegetative organs since during the growing season there is competition for light, moisture, and nutrients between plants. In the variety "Pharaoh", it was found that the intensity of aboveground mass formation was higher in sparse crops with a plant density of 28-33 thousand plants/ha, where the number of leaf bundles was 145.2-147.4 with a height of 50.4-52.3 cm. A decrease in plant density led to an increase in the size of the nodules. The largest nodules developed on plants with a spacing of 60×60 cm (28 thousand pcs./ha) with the largest length (3.1 cm), width (1.0 cm) and thickness (1.2 cm).

The chufa plants of the "Pharaoh" variety are characterised by a high weight of 1000 pieces of nodules 420-607 g under all schemes of placement. At the same time, a larger size of nodules was found in the variety with a plant density of 28-33 thousand units/ha 590-607 g, which is 72-89 g more than the control. On crops with the indicated density, a higher mass of nodules influenced their higher productivity and yield. A significantly higher weight of 1000 nodules (607 g) were obtained in the 60×60 cm plant spacing, which influenced their higher yield. Lower economically valuable indicators were found in chufa on thickened crops. Under the 60×30 and 60×40 cm planting schemes with a plant density of 42-56 thousand plants/ha, smaller nodules were formed with a weight of 1000 seeds of 420-518 g.

The variety of chufa "Pharaoh" was distinguished by high economic and valuable indicators under the schemes of plant placement 60×50 and 60×60 cm with a density of 28-33 thousand pcs./ha, which resulted in the highest marketable yield of freshly harvested bulbs of 4.2-4.6 t/ha with an average weight of 1000 pcs. 590-607 g and dried bulbs of 3.35 and 2.99 t/ha, which was 0.58 and 0.22 t/ha or 20.9 and 7.8% higher than the control, respectively. Promising areas for research are molecular genetic studies aimed at obtaining the maximum size of chufa nodules to optimise processing technology and medical studies of the impact of chufa products on the human body to improve the nutritional structure of the population and increase the share of natural and environmentally friendly products in the daily diet.

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None.

CONFLICT OF INTEREST

None.

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Оптимізація густоти рослин чуфи (*Cyperus esculentus* L.) в Київській області

Анотація. Для того, щоб досягти оптимального компромісу між врожайністю та родючістю ґрунту, який допоможе збалансувати дві важливі аспекти сільськогосподарського виробництва – високий врожай культур і збереження родючості ґрунту на тривалий період, необхідно розуміти вплив зміни ширини міжрядь на ріст овочевих культур та ґрунтове середовище. Метою досліджень було встановлення адаптивних властивостей рослин сорту «Фараон» шляхом вивчення площі живлення й густоти рослин для отримання якісних бульбочок чуфи в Київській області. Провідні методи досліджень – польові дослідження та дисперсійний аналіз морфологічних ознак та господарсько-цінних показників чуфи. Встановлено, що різна густота рослин мала вплив на розвиток вегетативних органів чуфи через конкуренцію за ресурси під час вегетаційного періоду. Сорт «Фараон» показав високу інтенсивність формування надземної маси в розріджених посівах з густотою рослин в діапазоні 28-33 тисячі штук на гектар, при чому кількість листкових пучків досягає 145,2-147,4 штук, а їхній середній зріст складає 50,4-52,3 сантиметри. Водночас, розмір бульбочок збільшувався з меншою густотою рослин, оскільки за більшої площі живлення рослини формувалися більш потужніші з листкових пучків товстішого розміру. На рослинах, розміщених за схемою 60×60 см (28 тис. шт./га), утворювалися більші бульбочки, які мали найбільші розміри: довжину – 3,1 см, ширину – 1,0 см та товщину – 1,2 см. Обґрунтовано, що вищими господарсько-цінними показниками характеризувалась чуфа сорту «Фараон» за схем висаджування бульбочок 60×50 і 60×60 см. Висока товарна врожайність свіжозібраних бульбочок формувалась за густоти рослин 28-33 тис. шт./га та становила 4,2-4,6 т/га. За схеми розміщення рослин 60×60 та 60×50 см отримано й найвищу середню урожайність бульбочок після висушування, яка становила 3,35 та 2,99 т/га, що відповідно на 20,9 і 7,8 % істотно перевищувало контроль. Чуфа є перспективною культурою з точки зору продовольчої безпеки та створення доходу, а точний менеджмент розміщення рослин допоможе збалансувати врожайність і родючість ґрунту

Ключові слова: бульбочки; схема розміщення; кущ; листкові пучки; кореневище; продуктивність; урожайність