selection is significant – 135 varieties or 40 %, which confirms the effectiveness of the selection work of Ukrainian breeders. For effective management in the industry, the author conducted an analytical review of the history of the use and expansion of soybean production on a global scale. As a result of the analytical review, it was established that over the period since 1961, thanks to breeding and technological development, the productivity of soybeans on average in the world has increased by 2.3 times, the global sown area – by 5.6 times, and the gross harvest of grain by almost 13 times . In Ukraine, since 1992, soybean productivity has increased by 2.9 times, the sown area by almost 15 times, and the gross harvest by 44 times. The world leaders in soybean production are the USA, Brazil, and Argentina, whose total production is 81.56 % of the global production. At the same time, the share of the United States is 33.36 % or 92.6 million tons, for which only 6 % of the country's arable land is allocated.

Key words: *soybean, Register of varieties, maturity group, productivity, crop area.*

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FORMATION OF THE LEAF APPARATUS OF APPLE TREES DEPENDING ON THE SHAPE OF THE CROWN AND THE TIME OF PRUNING

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Проаналізовано вплив різних строків обрізування та форм крони на показники листкової пластинки, кількості листків та загальної площі листкової поверхні дерев сортів яблунь Хоней Кріспі Фуджі. Встановлено, що найбільша площа листків спостерігалася у дерев сорту Хоней Кріспі, з максимальним значенням 31,4 см² при формуванні крони "французька вісь" за двократного обрізування. Формування крони французька вісь та значне зменшення її габаритів, призвело до зменшення на 20 % кількості листків порівняно з кроною балерина та на 17 % стрункому веретену (вплив фактора 40,9 %). Загальна площа листкової поверхні суттєво переважала у дерев сорту Хоней Кріспі у порівнянні з сортом Фуджі на 26 %. Обрізування досліджуваних дерев взимку та повторно влітку сприяло зменшенню кількості листків на деревах на 8 % та на 4 % загальної площі листової поверхні.

Ключові слова: *яблуня, форма крони, обрізування, листок, строк обрізування.*

State of the problem. The apple tree is one of the most popular fruit crops in the world. Its ability to adapt allows apples to be grown in different climatic conditions – from temperate to subtropical zones. This tree produces fruits that are valued for their

nutritional properties, taste, versatility in use and storage. Today, quality is one of the most important aspects of fruit production and marketing. Different crown shapes create different structures, which affects the distribution and level of light interception and, as a result, the level of productivity and quality of the crop [1, 2]. It is known that high quality apples do not develop in areas of the tree that receive less than 50 % of the total energy of incident light [3]. Photosynthesis is the process by which light energy is used to synthesise reduced carbon compounds. Photosynthesis takes place in chloroplasts, double membrane organelles. In the process of photosynthesis, light energy is captured by pigment molecules and transferred to reaction centres, where photochemical reactions take place. [4]

Analysis of recent research and publications. There are numerous studies on improving the level of plant illumination as a result of crown pruning. The interception of light by leaves and fruits was significantly increased, and the penetration of light to the center and lower side of the crown was significantly enhanced after pruning [5].

Improving the light regime leads to an increase in the rate of photosynthesis by increasing stomatal conductance [6], mesophyll conductance, maximum electron transport rate, etc. However, too much light is detrimental to photosynthesis [8]. Under high light conditions, only a small part of the absorbed light energy can be used in photosynthesis [9]. Changes in the light regime in the plant crown affect the quality of the fruit. The weight of an individual fruit, soluble dry matter content, soluble sugar content, and sugar-acid ratio are significantly higher in the spindle crown due to the favorable light conditions received by the leaves in the lower and middle part of the crown [10, 11].

Total dry matter production and crop yields are closely correlated with the partial interception of total seasonal light energy [12]. The annual growth of total dry weight and the productivity of plant systems depend on the partial interception of total seasonal light energy. With intensive horticulture technologies, the maximum light utilization is ~60 % of partial interception. This limitation is determined by the arrangement of rows and crown structure, which limits the productivity of an apple orchard to a maximum of 100–120 t/ha [13]. In addition, a high ratio of crown height to free inter-row space is associated with the highest level of light interception [14].

The aim of the research was to determine how different terms of pruning and crown formation affect the development of leaf apparatus of apple trees grown in intensive plantations on dwarf rootstock M.9 in the conditions of the Right-Bank Forest-Steppe of Ukraine.

Research methodology. The research, which began in the spring of 2019 in the experimental garden of the Uman National University of Horticulture, is aimed at assessing the impact of different methods of crown formation and the timing of their pruning on the productivity of Fuji and Honey Crisp apple trees on dwarf rootstock M.9. This study is conducted in the conditions of the Right-Bank Forest-Steppe of Ukraine on chernozem sod-podzolic soils.

Trees were planted in a 4 × 1 m spacing. Two factors were studied: crown shape and pruning time. The crown shapes were slender spindle, ballerina and French axis. The pruning was carried out in two periods: in winter (0 BBCH) and in summer after

the June ovary shedding (II decade of June, 74 BBCH). The system of soil maintenance in the aisles was sod and humus tillage, and herbicide steam was used in the trunk strips. Phytometric parameters were evaluated according to the recommendations and methods of Kondratenko P. V. and Bublyk M. O. [15].

The average annual indicators were collected and analysed using the standard deviation. For the statistical processing of the results, analysis of variance was used using Statistica 10. The Tukey's test (p = 0.05) was used to compare the mean values between the options, which helps to identify statistically significant differences between pairs of options. Pearson's method was used to determine correlation dependencies, with error levels of p = 0.01.

Research results. According to the results of the experiment, the influence of the studied pruning dates and crown shapes on the size of the leaf blade was recorded. The leaf area was higher in the trees of the Honey Crisp variety and at the maximum value of 31.4 cm² obtained as a result of pruning the French axis crown in winter and summer (Table 1).

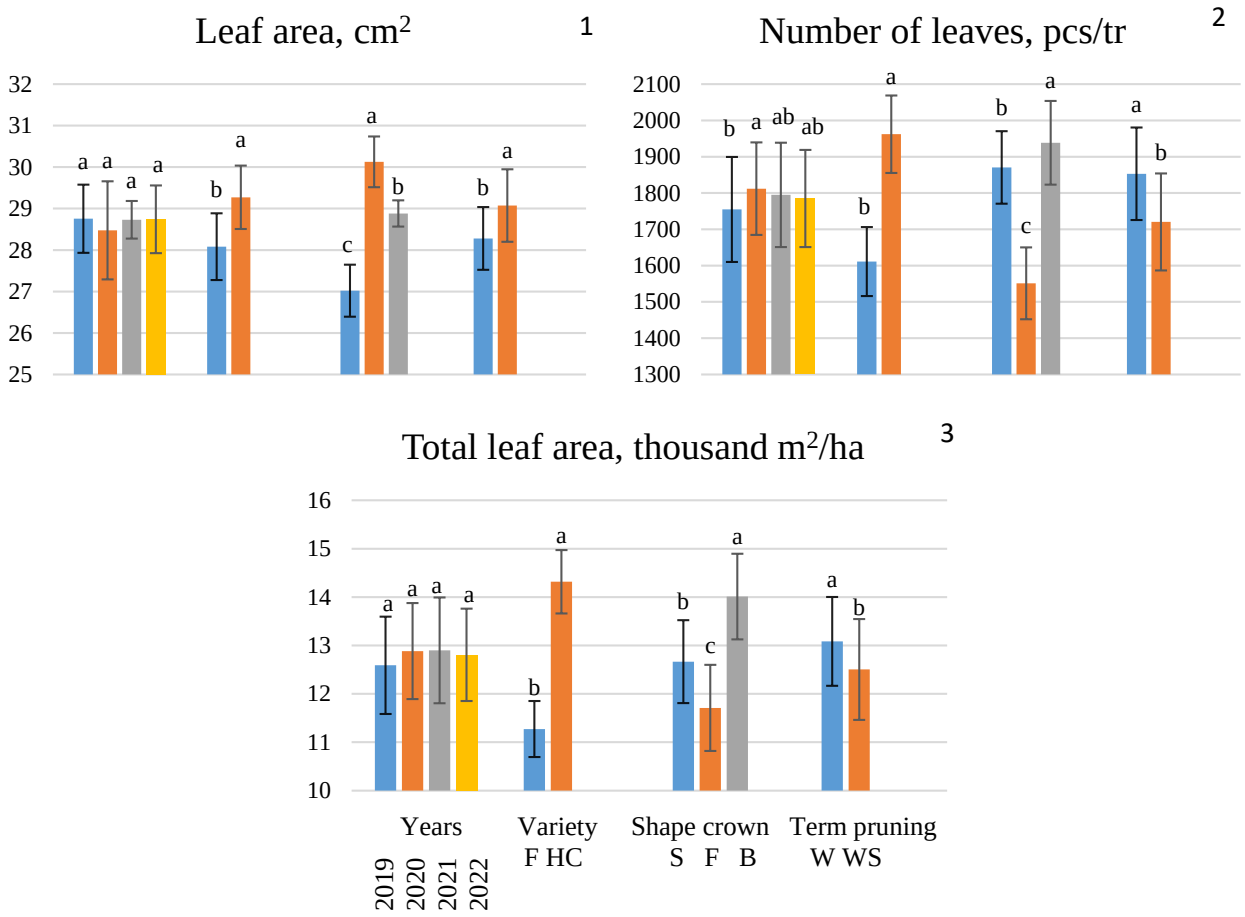
Table 1. Characteristics of the leaf apparatus of apple trees of Fuji and Honey Crisp varieties depending on the shape of the crown and the term of tree pruning (average 2019–2022)

Pomological variety	Crown shape	The term of pruning	Leaf area, cm^2	The number of leaves, pcs./tr	Total leaf area, thousand m^2/ha
Fuji	Slender spindle	In winter (control)	25.9±1,1 ^{d*}	1760 ± 72 ^{cde}	11.4 ± 0,9 ^{d}
		In winter and summer	26.4±0,7 ^{cd}	1654 ± 131 ^{e}	10.9 ± 0,9 ^{de}
	French axis	In winter	29.1±0,2 ^{b}	1485 ± 127 ^{f}	10.8 ± 0,9 ^{de}
		In winter and summer	29.8±0,9 ^{b}	1307 ± 39 ^{g}	9.7 ± 0,4 ^{e}
	Ballerina	In winter	28.3±0,4 ^{bc}	1803 ± 64 ^{c}	12.8 ± 0,4 ^{bc}
		In winter and summer	28.9±0,7 ^{bc}	1659 ± 63 ^{e}	12.0 ± 0,6 ^{cd}
Honey Crisp	Slender spindle	In winter	27.5±1,2 ^{c}	2126 ± 46 ^{a}	14.6 ± 0,6 ^{ab}
		In winter and summer	28.3±0,2 ^{bc}	1942 ± 48 ^{b}	13.7 ± 0,4 ^{b}
	French axis	In winter	30.1±0,5 ^{ab}	1749 ± 80 ^{cde}	13.2 ± 0,5 ^{bc}
		In winter and summer	31.4±1,6 ^{a}	1664 ± 132 ^{de}	13.1 ± 1,7 ^{bc}
	Ballerina	In winter	28.7±0,2 ^{bc}	2195 ± 9 ^{a}	15.8 ± 0,1 ^{a}
		In winter and summer	29.6±0,4 ^{b}	2097 ± 92 ^{a}	15.5 ± 0,7 ^{a}

*Note. * - mean values (mean ± SD) of indicators, the presence of the same letters in a pair of options indicates the absence of a statistically significant difference according to the Tukey's test (p = 0.05).*

A significant decrease in the value of the indicator was found in the formation of the crown of a slender spindle in the trees of the Fuji where the lowest value of the studied indicator was recorded at the winter term of crown pruning at the level of 25.9 cm², which is 17.5 % lower than the maximum value.

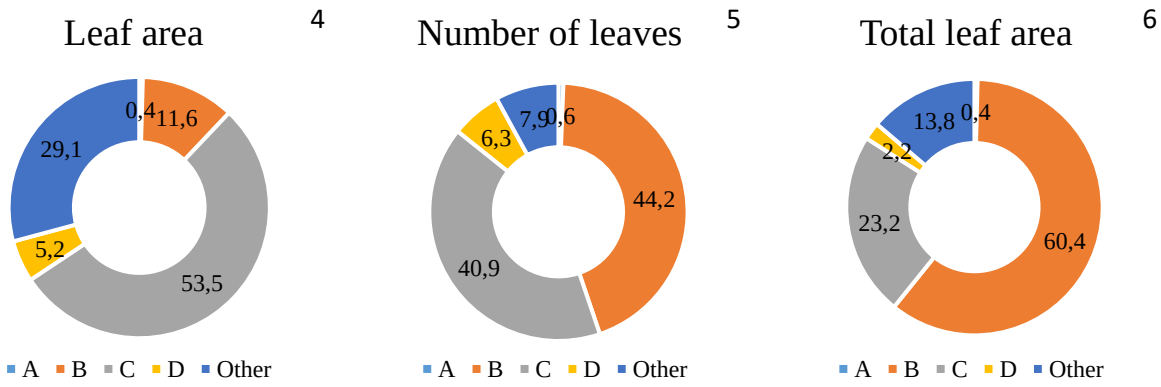
Among the studied factors, no significant difference in leaf blade area was found during the four years of research and ranged from 28.5–28.8 cm² (Fig. 1).



Figs. 1–3. Averaged data on the factors of indicators: leaf blade area (Fig. 1), number of leaves (Fig. 2), total leaf surface area (Fig. 3) of apple trees for 2019–2022, depending on the crown shape and pruning time.

Note/ Variety: Fuji (F), Honey Crisp (HC); crown shape: slender spindle (S), French axis (F), ballerina (B); pruning period: W - in winter (W), in winter and summer (WS)

At the same time, in Honey Crisp trees, regardless of the shape of the crown and the timing of their pruning, the area of leaf blades exceeded the corresponding indicator of Fuji trees by 5 %. The most significant difference among the studied variants was caused by the factor ‘crown shape’ at the level of 53.5 % (Fig. 4). As a result of the crown formation, the French axis obtained the highest value of leaf blade area at 30.1 cm². A 10 % lower value was obtained as a result of the formation of a slender spindle. The value of the indicator in the formation of the ballerina crown took an intermediate position at the level of 29.8 cm².



Figs. 4–6. Strength of influence of the studied factors: A - year, study B - pomological variety, C - crown shape, D - pruning time. Leaf area (Fig. 4); Number of leaves (Fig. 5); Total leaf surface area (Fig. 6).

The factor of the time of pruning also had a significant impact on the leaf blade area. As a result of the combination of winter and summer pruning, the leaf blade area increased by 5 %. There was also a strong direct correlation between the leaf blade area and the percentage of useful ovary and fruit weight. During the experiment, a significant decrease in the number of leaves was found during the formation of the French axis crown, which is associated with a significant decrease in the size of the crown as a result of formation (Table 1). The value of the number of leaves prevailed as a result of the formation of the crown of a slender spindle in winter and the crown of a ballerina on average for both studied varieties.

Analysing the data on the studied factors (Fig. 2), a slight fluctuation in the number of leaves on the trees over the years of research was revealed. However, Honey Chris trees significantly exceeded the Fuji variety in terms of leaf number by 22 % due to the peculiarities of the pomological variety (factor influence 44.2 %). As a result of crown formation, the French axis and a significant reduction in its dimensions led to the lowest value of the number of leaves per tree and amounted to 1551 pcs/der, which was 20 % lower than the value obtained as a result of ballerina crown formation and 17 % of slender spindle (factor influence 40.9 %). Pruning of the studied trees in winter and again in summer contributed to a decrease in the number of leaves on the trees by 8 %. The number of leaves is directly correlated with the diameter of the crown, its volume, crown projection and total leaf surface, but an inverse correlation between the number of leaves and specific productivity per crown volume and feeding area was also found.

The total leaf surface area, which characterises the photosynthetic potential of the plant, significantly depended on the studied agricultural practices. On average, among the studied varieties, the highest value of leaf surface area was found in the trees of the Honey Crisp variety at the maximum value as a result of the formation of the ballerina crown in winter – 15.8 thousandm^2/ha. As a result of the formation of a smaller number of leaves in a tree formed in the form of a French axis, the leaf surface area of both studied varieties was the lowest.

Analysing the data within the factors (Fig. 3), the total leaf surface area did not differ significantly during the experiment and was significantly higher in Honey Crisp trees compared to Fuji by 26 %. As a result of the French axis crown formation and a significant reduction in tree habitus, the lowest value of leaf surface area was obtained at 11.7 thousand m²/hectare. While forming the ballerina crown, the value of the indicator increased by 16.5 % and took a dominant position. Two-time crown pruning contributed to a 4 % reduction in the total leaf surface area. The greatest influence on the values of the studied indicators was caused by the factor 'pomological variety' by 60.4 %, and 'crown shape' by 23.2 %. A strong correlation between the total leaf area and the number of leaves was found.

Conclusion. The article presents the results of experimental studies focused on the influence of different crown shapes and pruning dates on the change in the leaf surface of apple trees of Fuji and Honey Crisp varieties grafted on dwarf rootstock M.9. Studies have shown that crown shape and pruning time significantly affect leaf area, which is a critical factor in photosynthesis and overall tree productivity. Accordingly, different methods of crown formation contribute to optimising light inside the crown in different ways, which in turn affects the quantity and quality of leaves.

As a result of the research, it was found that the formation of the crown according to the French axis system gave the largest value of the leaf blade area – 30.1 cm². This indicates that such a crown shape promotes better development of the leaf apparatus, which is important for ensuring high photosynthetic activity and tree productivity. In contrast, when the crown was formed using the slender spindle system, the leaf blade area was 10 % smaller. An inverse relationship was found with the number of leaves and total leaf area, where the French axis crown formation resulted in the lowest values. Performing crown pruning in winter and summer increases the area of the leaf blade, but the number and total area of the leaf blade decreases.

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Annotation

Chaploutskyi A., Holovatyi P, Butsyk R.

Formation of the leaf apparatus of apple trees depending on the shape of the crown and the time of pruning

The present study investigates the influence of crown formation and pruning timing on the development of leaf apparatus of apple (Malus domestica) varieties Fuji and Honey Crisp grown on dwarf rootstock M.9 in the Right-Bank Forest-Steppe of Ukraine. Given that apple is one of the most popular fruit crops, special attention is paid to the importance of improving the lighting and leaf condition as a result of crown pruning. The experiment evaluated different crown shapes: slender spindle, ballerina and French axis, as well as the timing of pruning: winter and its combination with summer. The aim of the experiment was to determine which agronomic measures contribute to maximum plant productivity, in particular through the impact on leaf area, number of leaves and total leaf area.

The largest leaf blade area (31.4 cm²) was recorded in Honey Crisp trees when the crown was formed in the French axis with pruning in winter and summer. The lowest value of the index (25.9 cm²) was observed in Fuji trees when forming the 'slender spindle' crown in winter, which is 17.5 % lower than the maximum value. In

general, Honey Crisp trees showed larger leaf blade areas than Fuji trees, exceeding them by an average of 5 %.

Crown formation also affected the number of leaves. A decrease in the number of leaves was observed in the formation of the French axis crown (1551 leaves per tree), which is 20 % less than in the formation of the ballerina crown. Trees of the Honey Crisp variety outnumbered the Fuji variety by 22 %. Pruning in winter and summer reduced the number of leaves by 8 %. The maximum leaf surface area was achieved in the formation of the 'ballerina' crown in the Honey Crisp variety – 15.8 thousand m²/ha. against 11.7 thousand m²/ha of the 'French axis' crown, which is associated with a decrease in the number of leaves and crown dimensions. The total leaf area of Honey Crisp trees was 26% higher than that of Fuji.

It was found that the greatest influence on the leaf blade area and number of leaves was the crown shape factor (53.5 % and 40.9 %, respectively), as well as the pruning time factor (3–5 %). In addition, the effect of pomological variety was one of the key factors, influencing 60.4% of the total leaf area. The study also found a strong direct correlation between leaf area and traits such as percentage of usable ovary and fruit weight. Leaf number was correlated with crown diameter, volume and total leaf area, but also showed an inverse correlation with specific productivity per crown volume and feeding area.

Key words: *apple tree, crown shape, pruning, leaf, pruning time*