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COMPARATIVE ANALYSIS OF THE CORRELATIONS OF MAIN PARAMETERS AND PRODUCTIVITY OF HIGH OLEIC SUNFLOWER HYBRIDS IN THE FOREST-STEPPE OF UKRAINE

This study shows that under the conditions of the Forest-steppe of Ukraine, productivity of sunflower plants depend on morphological and seed quality parameters and in the context of high oleic hybrids has its own peculiarities. In particular, for the PR64H32 hybrid, a strong dependence (r = 0.77-0.89) was found between the mass of seeds and quantity of seeds as well as stem diameter while average connection (r=0.76) was established for 1000-seed weight. Oplot and Ballistic showed average to very strong relationship (r=0.66-0.95) for the following morphological and seed quality parameters: length of 7th leaf, leaf surface area, width of 7th leaf, stem diameter, head diameter, quantity of seeds and 1000-seed weight. Precisely, the strongest correlations were noted in Oplot hybrid for quantity of seeds (r=0.95) and 1000-seed weight (r=0.95). Generally, SPAD-502 plus readings (relative chlorophyll content), number of leaves and plant height had weak correlation with mass of seeds. Higher correlation coefficient (r) value suggests stronger/greater dependence of the measured parameter on productivity. Hence, for higher seed yield and quality in new hybrids, Breeders should focus on improving these morphological and quality parameters: length of 7th leaf, width of 7th leaf, leaf surface area, stem diameter, head diameter, quantity of seeds and 1000-seed weight.

Keywords: Productivity, high oleic sunflower, hybrid, correlation, morphological parameters, quality, SPAD-502 plus

Introduction. Sunflower is an industrial crop that is predominantly cultivated for oil, and for a long period, research largely focused on the increase and expression of genetic potential for high seed yield and oil content in seed of new hybrids. Just recently, it became necessary for scientists to tackle oil quality as one of the significant challenges in the vegetable oil market (Jocić et al., 2015), [1, p. 34]. Regarding diet, higher oleic acid (70 %) and lower linoleic acids (20 %) are desired. Hence, breeding for oil quality in sunflower has mostly concentrated on changing the comparative amount of fatty acids by raising oleic acid to have stable and healthy oil and increasing stearic acid for a stable and healthy fat (Zambelli et al., 2015), [10, p. 51].

Currently, standard linoleic type and high oleic or mid oleic type are two major sunflower types in the world market. Standard sunflower oil correspondingly comprises on average about 70 % and 20 % polyunsaturated linoleic acid and monounsaturated oleic acid. High oleic sunflower oil has the highest oleic acid content (above 90 %) compared to all vegetable oils

existing in the global market (Jocić et al., 2015), [1, p. 36], and it has superior oil resistance to auto-oxidation, which prevents the accumulation of poisonous products during oil processing, storage, and direct consumptions (Kaya et al., 2015), [2, p. 652]. Additionally, it is very suitable for food purposes such as, oil for spraying of snacks, crackers, and dry breakfast cereals; frying oil; food products for toddlers and aged; and for enhancing oxidation stability. Still, high oleic sunflower produces high yields and is besides tolerant to the main diseases, weeds, and broomrape, which are limiting factors on high oleic sunflower field [1, p. 36; 2, p. 652].

According to the Ukrainian State Register for Plant Varieties (SRPV), in 2017, there are presently 740 varieties and hybrids of sunflower registered, of which 51 are categorized as high oleic [8]. Recently, Melnyk et al., (2016) investigated the relationship between productivity (mass of seeds) and morphological parameters of three confectionery sunflower in the forest steppe of Ukraine [4, p. 120]. types based on their genetics and hence may possess unique correlation between productivity and morphological parameters along with seed quality parameters that are yet to be discovered.

Objective. The present study therefore investigates the correlation between productivity (mass of seeds) and morphological parameters in addition to seed quality parameters of three high oleic sunflower hybrids in the forest steppe of Ukraine. We also correlated mass of seeds with SPAD-502 plus chlorophyll meter readings. Briefly, the SPAD-502 Plus chlorophyll meter is a hand-held device that is used for accurate, quick and non-destructive in situ measurements of chlorophyll concentrations for several plant species (Richardson et al. 2002). The numerical SPAD value (reading) indicates the relative content of chlorophyll within the sample leaf [6, p. 185, 186].

Materials and methods. A two-year (2016 and 2017) field research was conducted in Poltava (Ukraine) on black soil, characteristic for coarse-medium loam. Three hybrids of high oleic sunflower (PR64H32, Oplot, and Ballistic) were sown on May 12 and May 20 and respectively harvested on September 14 and September 27 in 2016 and 2017. Seeds were sown at a plant density of 60,000 plants/ha with 4 rows in each plot and 70 cm between rows. Fertilizer was applied at the rate of $N_{30}P_{30}K_{30.}$ Harvesting was done manually at maturity by harvesting two inner rows in each plot. Data on the following morphological and seed quality parameters were collected and/or determined from 30 typical tagged plants in each of the three hybrids: Plant Height (PH), Stem Diameter (SD), Number of leaves (NL), Width of 7th leaf (WL), Length of 7th leaf, Surface Area of leaf (SA), Head Diameter (HD), Quantity of Seeds (QS), Mass of Seeds (MS), 1000-Seed Weight (TSW). An estimate of the chlorophyll content (Chl) was also determined with SPAD-502 plus chlorophyll meter (Spectrum Technologies, 2011) [7].

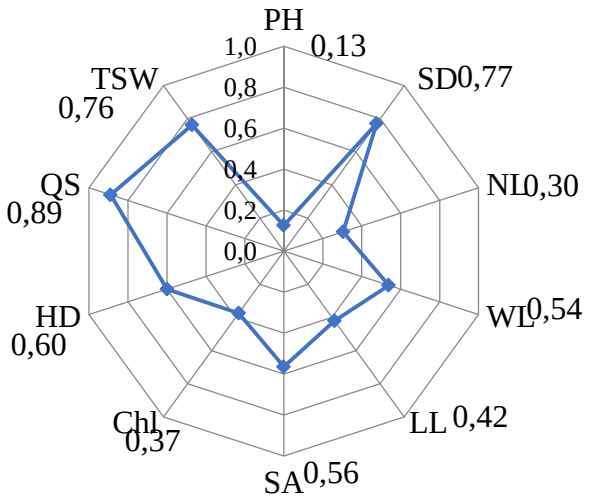
Parameters of the experiment: l_a=*3, n=3,* accounting area of 50.0 m^2. Option–randomized. Accounting, measurement, and related observations were carried out in accordance with the "Field Experiments Method" (1983) [3], using the following techniques:

-The leaf surface area - in accordance with the method described by L. S. Osipova, P. P. Litun, (1988) [5];

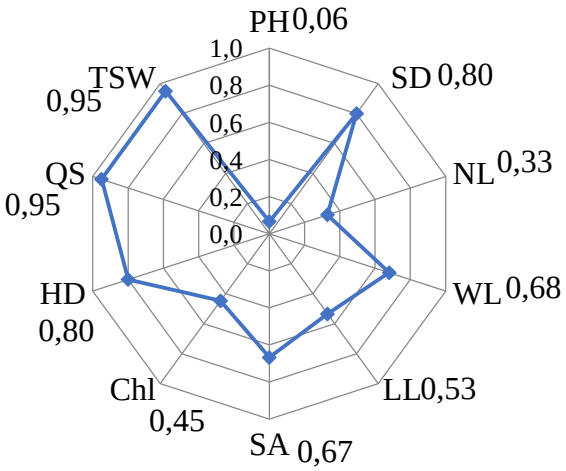
- Humidity, weight of 1000 seeds - according to SSTS-4138-2002 (State Standard of Ukraine, 2003) [9].

Analysis of weather conditions, particularly Hydrothermal coefficient (HTC) as described by (G. T. Selyaninov), revealed that the vegetative period of 2016 had a normal moisture (HTC =1.00), while the year 2017 was dry (HTC=0.45). Hydrothermal coefficient (HTC) (G. T. Selyaninov) were determined by the formula: HTC= $K/\ T \times 10$, where ∑K is the amount of precipitation, mm, for a period with an average daily air temperature above 10 ° C; ∑T is the sum of the temperatures, ° C, for the period with the average daily air temperature above 10 ° C. Correlation analysis was performed at 5% level of probability with the statistical software STATISTICA (version 12).

Results and Discussion. For a detailed study of the nature of connections of plant productivity with morphological and seed quality parameters as well as relative chlorophyll content, a correlation analysis was performed within each sample hybrid. For clarity of presentation of the results obtained, we constructed graphs for the correlation coefficients (r) between the main productivity indicator (mass of seeds) and other parameters under investigation, namely, Plant Height (PH); Stem Diameter (SD); Number of leaves (NL); Width of 7th leaf (WL); Length of 7th leaf; Surface Area of leaf (SA); Head Diameter (HD); Quantity of Seeds (QS); 1000-Seed Weight (TSW); Chlorophyll content (Chl) (Figure 1). To determine the strength of the influence of the studied parameters on the mass of seeds, we used a five-point scale proposed by E. L. Lyubarsky (1974). Firstly, the hybrid PR64H32, revealed a very strong/close dependence (5 points) on the quantity of seeds (r = 0.89); strong dependence (4 points) on stem diameter (r = 0.77), and average connection (3 points) on 1000-seed weight (r=0.76).



a



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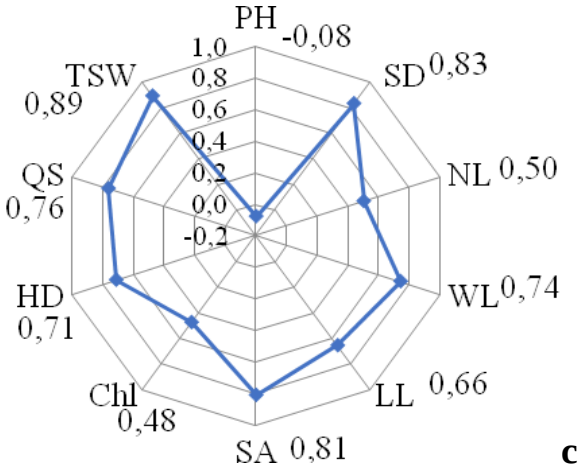

c

Figure 1. Structure of correlation of productivity with morphological parameters and relative chlorophyll content of the investigated hybrids: a–PR64H32, b–Oplot, c–Ballistic

Additionally, there was a weak dependence (2 points) on head diameter (r=0.60), surface area of leaf (r=0.56), width of 7th leaf (r=0.54),

length of 7th leaf (r=0.42), number of leaves (r=0.30), relative chlorophyll content (r=0.37).

The peculiarities in the structure of correlation between morphological parameters, seed quality parameters, relative chlorophyll content and productivity of plants of the second hybrid, Oplot, are revealed. Thus productivity depended very strongly (5 points) on quantity of seeds (r=0.95) and 1000-seed weight (r=0.95). In addition, there was a strong dependence on stem diameter (r=0.80) and head diameter (r=0.80). However, for this hybrid, average dependence were discovered for width of 7th leaf (r=0.68) and surface area of leaf (r=0.67), while weak dependence were exhibited by length of 7th leaf (r=0.53), relative chlorophyll content (r=0.45) and number of leaves (r=0.33). Like PR64H32, Oplot also shown very weak link with productivity with respect to plant height (r=0.06).

Finally, Ballistic, the third hybrid, displayed a very strong correlation (5 points) between productivity and 1000-seed weight (r=0.89), while a strong connection (4 points) was observed in stem diameter (r=0.83) and leaf surface area (r=0.81). Going forward, quantity of seeds (r=0.76), width of 7th leaf (r=0.74), head diameter (r=0.71) and length of 7th leaf (r=0.66) demonstrated average (3 points) dependence. Furthermore, a weak relationship was observed for both number of leaves (r=0.50) and relative chlorophyll content (r=0.48). Generally, among the three hybrids investigated, Oplot and Ballistic showed greater correlation between morphological parameters, SPAD-502 plus readings (relative chlorophyll content) and productivity than PR64H32, except for quantity of seeds where PR64H32 displayed very strong (5 points) correlation (r=0.89) compared with strong (4 points) connection in ballistic (r=0.76).

The greatest correlation was observed in Oplot for seed quality parameters; quantity of seeds (r=0.95) and 1000-seed weight (r=0.95). Recently, similar observations were noted in three confectionery sunflower varieties with the greatest correlation (Lakomka, r=0.89; Konfeta, r=0.77; Oniks, r=0.69) observed for quantity of seeds (Melnyk et al., 2016) [4, p. 120]

Largely, weak correlation between productivity (mass of seeds) and number of leaves, relative chlorophyll content, and plant height were evident among the three hybrids. Thus, for number of leaves, the following weak links were uncovered: PR64H32 (r=0.30); Oplot (r=0.33); Ballistic (r=0.50). Earlier, similar weak correlations were observed in three confectionery sunflower varieties (Konfeta, r=0.17; Oniks, r=0.24; Lakomka, r=0.52). Regarding relative chlorophyll content, weak correlations were as follows: PR64H32 (r=0.37); Oplot (r=0.45); Ballistic (r=0.48). Clearly, the weakest connection among the parameters studied is plant height. Both Oplot and PR64H32 respectively had very weak correlations, r=0.06 and r=0.13. However, for Ballistic, a very weak negative correlation (r=-0.08) is

noticed between plant height and productivity. This was not surprising because earlier, Melnyk et al., (2016) [4, p. 120] also reported similar relationship for two confectionery sunflower varieties, oniks (r=-0.4) and konfeta (r=-0.04), though a positive correlation was shown in the third variety, lakomka (r=0.48).

Conclusion. This study shows that under the conditions of the Forest-steppe of Ukraine, productivity of sunflower plants depend on morphological and seed quality parameters and in the context of high oleic hybrids has its own peculiarities. In particular, for the PR64H32 hybrid, a strong dependence (r = 0.77-0.89) was found between the mass of seeds and quantity of seeds as well as stem diameter while average connection (r=0.76) was established for 1000-seed weight. Oplot and Ballistic showed average to very strong relationship (r=0.66-0.95) for the following morphological and seed quality parameters: length of 7th leaf, leaf surface area, width of 7th leaf, stem diameter, head diameter, quantity of seeds and 1000-seed weight. Precisely, the strongest correlations were noted in Oplot hybrid for quantity of seeds (r=0.95) and 1000-seed weight (r=0.95). Generally, SPAD-502 plus readings (relative chlorophyll content), number of leaves and plant height had weak correlation with mass of seeds. Higher correlation coefficient (r) value suggests stronger/greater dependence of the measured parameter on productivity. Hence, for higher seed yield and quality, Breeders should focus on improving these morphological and quality parameters: length of 7th leaf, width of 7th leaf, leaf surface area, stem diameter, head diameter, quantity of seeds and 1000-seed weight.

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Сравнительный анализ корреляций основных параметров растений и продуктивности високоолеиновых гибридов подсолнечника в лесостепной зоне Украины

Исследованиями установлено, что в Лесостепи Украины продуктивность растений подсолнечника зависит от морфологических параметров и показателей качества семян. В частности, для гибрида PR64H32 установлена сильная зависимость массы и количества семян, а также диаметром корзинки, (r = 0,77-0,89). У гибридов Оплот и Балистик выявлена средняя и очень сильная зависимость (r=0,66−0,95) по следующим морфопараметрам: длина и ширина 7-го листа, площадь листовой поверхности, диаметр стебля, диаметр корзинки, количество семян и масса 1000 шт. семян. Сильная корреляционная зависимость наблюдалась у гибрида Оплот по количеству семян (r=0.95) и массе 1000 шт. семян (r=0.95). Следовательно, для повышения урожайности и качества семян селекционеры должны учитывать необходимость отбора по следующим морфологическим параметрам: длина и ширина 7-го листа, площадь листовой поверхности, диаметр стебля, диаметр корзины, количество семян и масса 1000 шт. семян.

Ключевые слова: продуктивность, високоолеиновый подсолнечник, гибрид, корреляция, морфологические параметры, качество, SPAD-502 plus.

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Порівняльний аналіз кореляцій основних пареметрів рослин і продуктивності високоолеїнових гібридів соняшнику в лісостеповій зоні України

Експериментальні дослідження проводили у 2016−2017 рр. в польових умовах АФ «Грига» Полтавського району Полтавської області. Ґрунт дослідної ділянки – чорнозем типовий глибоко середньогумусовий крупнопилувато-середньосуглинковий на лесових породах. Предметом досліджень були три гібриди високоолеїнового соняшника (PR64H32, Оплот та Балістік).

Форма ділянок прямокутно видовжена, у чотирикратному повторенні. Сівбу здійснювали 12 та 20 травня. Спосіб сівби широрядний (70 см), норма висіву – 60 тис. насінин/га. Фон живлення – $N_{30}P_{30}K_{30}$. Збирання проводили 14 та 27 вересня відповідно. Урожайність визначали вручну під час повного дозрівання шляхом збирання двох внутрішніх рядків з кожної ділянки. Вміст хлорофілу (Chl) визначали за допомогою N-tester SPAD-502 plus. У досліді відбирали по 30 типових рослин з подальшим визначенням їх морфопараметрів та продуктивності, а саме: висоти рослин (PH), діаметра стебла (SD), кількості листків (NL), ширини та довжини 7-го листка (WL), площі листкової поверхні (SA), діаметра кошика (HD), кількості і маси насіння з кошика (QS та MS), маси 1000 шт. насінин (TSW). Для визначення сили впливу досліджуваних параметрів на масу насіння використовували п'ятибальну шкалу, запропоновану Е. Л. Любарським (1974).

Аналіз погодних умов, зокрема гідротермічного коефіцієнта (ГТК), виявили, що нормальним за зволоженням був вегетаційний період 2016 р. (ГТК=1,00), сухим – 2017 р. (ГТК=0,45).

Дослідженнями встановлено, що в Лісостепу України продуктивність рослин соняшнику залежить від морфологічних параметрів та показників якості насіння. Зокрема у гібрида PR64H32 виявлено сильну залежність маси насіння, кількості насіння та діаметра кошика, (r=0,77−0,89). У той же час для гібридів Оплот та Балістік середня та дуже сильна залежність (r=0,66−0,95) була за такими морфопараметрами: довжина і ширина 7-го листку, площа листкової поверхні, діаметр стебла, діаметр кошика, кількості насіння та маси 1000 шт. насінин. Сильну кореляційну залежність спостерігали в гібрида Оплот за кількістю насіння (r=0.95) та масою 1000 шт. насінин (r=0.95).

Отже, для підвищення врожайності та якості насіння селекціонери повинні зосередити увагу на поліпшенні таких параметрів, як довжина та ширина 7-го листа, площа листкової поверхні, діаметр стебла, діаметр кошика, кількість насіння та маса 1000 шт. насінин. Також вивлено, що вміст хлорофілу, кількість листків та висота рослини слабо впливають на подальшу масу насіння. Установлено, що вищий коефіцієнт кореляції (r) визначає більший вплив вимірюваного параметра на продуктивність рослин.

Ключові слова: продуктивність, високоолеїновий соняшник, гібрид, кореляція, морфологічні параметри, якість, SPAD-502 plus.