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Correlation of Seed and Vegetative Productivity Elements in Collection Samples of White Lupine

Abstract. The purpose of the study was to establish the strength and general pattern of correlations between quantitative traits that form vegetative and seed productivity in white lupine. Research methods used included field, weighing and measuring, and mathematical and statistical methods. A significant positive correlation was found between the average strength of seed productivity and such traits as plant height, number of lateral shoots, number of beans from central and lateral clusters, etc. A strong positive correlation was detected with the vegetative development of plants, and a weak one with the number of seeds per bean and the weight of 1000 seeds. A significant strong positive correlation of vegetative productivity with such quantitative traits as the weight of beans from the central cluster and the weight of leaves and stems was established. A positive correlation of average strength was found with the number of beans from central and lateral clusters, weight of beans from lateral shoots, root weight, etc. It was found that the seed productivity of white lupine plants is mainly conditioned by the development of such traits as the number of beans from lateral clusters, weight of leaves and roots, number of seeds and weight of seeds from the central and lateral clusters. The formation of vegetative productivity primarily depends on the weight of beans from the central cluster and the weight of leaves and stems. The

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use of the established regularities of productivity formation will enhance the effectiveness of the selection of selective material according to the specified parameters

Keywords: correlations, central and lateral clusters, seed weight, number of beans and seeds, number of seeds per bean, the weight of 1000 seeds

RELEVANCE

The method of correlation analysis is widely used to determine the relationship between quantitative traits, the variability of which is caused by phenotypic and genotypic factors. The correlation coefficients between the same traits can vary depending on the species and even the variety of plants and growing conditions. Such patterns of variability in the correlation between individual traits are fully consistent with the basic principles of the genetics of quantitative traits and their phenotypic manifestation in the genotype-environment interaction (Litun *et al.*, 2004). Selection of high-yielding genotypes requires extensive knowledge on the patterns of plant productivity. This fully applies to white lupine, the yield level of which is determined by indicators that form seed and vegetative productivity.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Correlation analysis has been used by many scientists to evaluate the selection material of different crops (Usyk, 2009; Kobyzieva, 2009; Tryhub, 2002; Katsan, 2014; Bulintsev *et al.*, 2015; Marchenko *et al.*, 2019; Carpici & Celic, 2012). It has been established that the formation of lupine yields depends to a greater extent on such components as the number of beans and seeds per plant, the number of seeds per bean, the weight of seeds per plant, and the number of productive shoots (Friehiwot *et al.*, 2019; Sozinov & Khalimullina, 2019; Vitko & Vanga, 2015). Thus, the study of the interrelationships of various plant productivity traits with each other is a topical issue, since on the basis of the established patterns it is possible to determine the direction of the selection of selective breeding material to create new varieties that can meet modern production requirements. This will allow predicting of the selection process and increase its efficiency.

Purpose of the study. To establish the strength and direction of correlations between quantitative traits that form vegetative and seed productivity in white lupine.

MATERIALS AND METHODS

Field and laboratory studies were conducted in 2016-2019 at the Institute of Agriculture of the National Academy of Sciences of Ukraine. The fields of selection crop rotation are located in the Fastiv district of Kyiv Oblast. The years of the research differed in temperature and moisture availability, which made it possible to evaluate the manifestation of seed productivity traits in white lupine under different growing conditions. The weather conditions in 2016 were generally relatively favourable for the growth and development of lupine plants and the formation of good seed productivity. The hot and dry weather during the growing season in 2017, and especially the drought during flowering and bean setting, led to a significant decrease in plant productivity. Sufficient moisture and

optimal temperature conditions in 2018 contributed to the good development of lupine plants and high seed yields. The lack of moisture during the period of flowering, seeding, and filling of beans in 2019 led to accelerated maturation and reduced seed productivity.

The subject of the research was 50 collection samples of white fodder lupine. The field experiments were conducted using the standard technology of lupine cultivation. Winter grain crops preceded the lupine sowing. Sowing was done in wide rows (row spacing was 45 cm). The plot area was 6.0 m^2, the repetition is fourfold. The study used field, weighing and measuring, and mathematical and statistical methods. The correlation analysis was carried out according to the relevant methods described by B.O. Dospekhov (Dospekhov, 1985).

RESULTS AND DISCUSSION

The number of lateral shoots is the main factor determining the formation of seed and vegetative productivity of white lupine due to the development of lateral clusters. It has a strong correlation with lateral cluster traits such as the number of beans, the number and weight of seeds, and the average bean weight. A weak negative correlation was found with the number and weight of seeds from the central cluster, and with the number of seeds per bean from both the central and lateral clusters. Thus, the enhanced development of lateral shoots can lead to a decrease in the productivity of the central cluster and also reduce the size of the seeds.

The number of beans from the central cluster primarily determines its productivity, so it is closely positively correlated with the weight of shiny beans, number, and weight of seeds. The correlation of average strength was established with the traits of leaf, stem, and root weight. The number of beans from lateral shoots showed strong correlations with the weight of shiny beans, the number and weight of seeds from lateral clusters.

For lupine as a feed crop used for green fodder for animals, it is important to determine the features of vegetative mass formation, including correlations between the elements of its productivity. A strong correlation was established between the weight of shiny beans from the central shoot and the number and weight of seeds from the central clusters, between the weight of beans from the lateral shoots and the number and weight of seeds from the lateral clusters, and between the weight of leaves and stems. Positive correlations of medium strength were found between most of the other traits (Table 1).

The analysis of the relationships between the structural elements of seed productivity revealed a weak correlation in most cases, with both positive and negative values. The weight of the seeds from the central and lateral clusters directly depends on the number of seeds formed on them, so the value of the correlation strength is close to one. The value of the correlation coefficients between the number of seeds from the central clusters and the number and weight of seeds from the lateral clusters was almost zero, which proves the possibility of creating varieties with seed yields achieved by the development of both lateral and central clusters.

Establishing patterns of productivity formation based on determining its correlations with the constituent structural elements will help to increase the accuracy of evaluation and the effectiveness of the selection of selective material according to specified parameters. It was found that seed productivity with most traits (plant height, number of lateral shoots, number of beans from the central clusters and

lateral clusters, etc.) had an average positive significant correlation (Fig. 1). A strong positive correlation was detected with the vegetative development of plants, and a weak one with the number of seeds per bean and the weight of 1000 seeds.

Table 1. Matrix of paired correlation coefficients between traits of seed and vegetative productivity of white lupine plants, 2016-2019

No.	General plant structure			Green mass productivity structure (shiny bean phase)					Seed productivity structure					
	number of lateral shoots	number of beans		beans		leaves	stems	roots	number of seeds		weight of seeds		number of seeds per 1 bean	
		central cluster	lateral clusters	central cluster	lateral clusters				central cluster	lateral clusters	central cluster	lateral clusters	central cluster	lateral clusters
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
2	-0.04													
3	0.78	-0.02												
4	0.16	0.78	0.22											
5	0.67	0.12	0.88	0.28										
6	-0.01	0.36	0.09	0.39	0.21									
7	0.10	0.37	0.16	0.41	0.27	0.79								
8	0.27	0.38	0.38	0.38	0.44	0.57	0.67							
9	-0.14	0.84	-0.08	0.70	0.09	0.56	0.49	0.43						
10	0.77	0.02	0.94	0.29	0.86	0.19	0.25	0.44	-0.02					
11	-0.24	0.82	-0.21	0.72	0.03	0.58	0.52	0.38	0.91	-0.15				
12	0.78	0.04	0.93	0.33	0.84	0.25	0.30	0.46	-0.01	0.97	-0.11			
13	-0.17	-0.25	-0.08	-0.05	-0.01	0.44	0.30	0.11	0.25	-0.02	0.25	0.03		
14	-0.17	0.21	-0.22	0.24	-0.08	0.46	0.37	0.19	0.29	0.05	0.28	0.04	0.14	

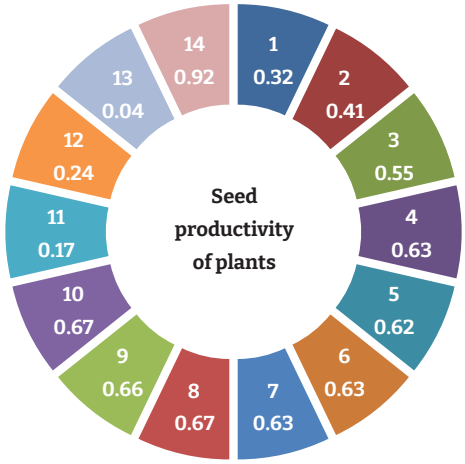

Figure 1. Correlation of seed productivity of plants with elements of its structure and other traits

Note: *1 – plant height, 2 – number of lateral shoots, 3 – number of beans from the central cluster, 4 – number of beans from the lateral clusters, 5 – leaf weight, 6 – root weight, 7 – number of seeds from the central cluster, 8 – number of seeds from the lateral clusters, 9 – weight of seeds from the central cluster, 10 – weight of seeds from lateral clusters, 11 – number of seeds in 1 bean from the central cluster, 12 – number of seeds in 1 bean from lateral clusters, 13 – weight of 1000 seeds, 14 – vegetative productivity of plants*

The established average correlations between seed productivity and leaf weight indicate that increased photosynthetic activity associated with the development of the leaf surface contributes to its growth. Besides, a well-developed root system of plants ensures the formation of increased seed productivity. The high correlation of seed productivity with a green mass of plants proves that good overall plant development leads to the formation of increased seed productivity.

The high correlation of seed productivity with a green mass of plants proves that favourable overall plant development contributes to the generation of higher seed productivity. A significant strong positive correlation of vegetative productivity with such quantitative traits as the weight of beans from the central cluster and the weight of leaves and stems was established (Fig. 2). The weight of the beans from the central cluster during the shiny bean phase, which is the best for harvesting lupine for green fodder, has a stronger correlation with vegetative productivity compared to the beans of the lateral clusters, because the latter are not yet sufficiently developed during this period. A strong correlation with the weight of leaves and stems determines their influence on the formation of productivity and fodder qualities of green mass.

A positive correlation of average strength was found with plant height, number of lateral shoots, number of beans from the central and lateral clusters, weight of beans from lateral shoots, and root weight. A weak positive correlation was established with the dry matter content. An important feature is the almost complete absence of a correlation between vegetative productivity and protein content, which suggests that research should be directed toward creating forms that can combine high yields of green mass with high protein content.

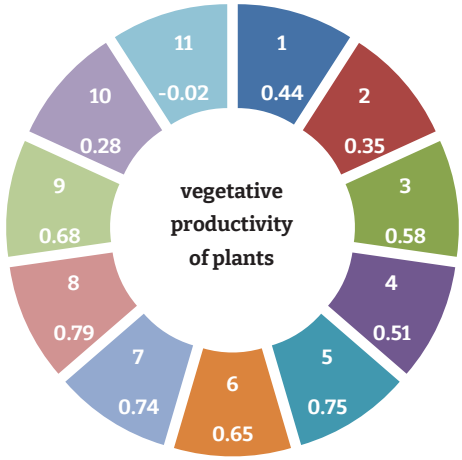

Figure 2. Correlation of vegetative productivity of plants with elements of its structure and other traits

Note: *1 – plant height, 2 – number of lateral shoots, 3 – number of beans from the central cluster, 4 – number of beans from the lateral clusters, 5 – weight of beans from the central cluster, 6 – weight of beans from the lateral clusters, 7 – weight of leaves, 8 – weight of stems, 9 – weight of roots, 10 – dry matter content, 11 – protein content*

The study of correlations between quantitative traits in white lupine was also conducted by scientists from the Institute of Fodder Crops (Bulgaria) and the Lupine Research Institute (Russian Federation) (Kosev & Vasileva, 2020 (a); Kosev & Vasileva, 2020 (b); Zaharova *et al.*, 2014). Bulgarian scientists have found a strong positive correlation between seed productivity and the number of seeds per plant and plant height, and a close relationship between vegetative productivity and plant height, number and weight of leaves, and root weight. According to the data collected by Russian scientists, there is a strong correlation between seed weight and bean weight, plant weight, and number of seeds, and a weak correlation with the weight of 1000 seeds. The conclusions of these authors are consistent with the results of this study and validate its findings.

CONCLUSIONS

The seed productivity of white lupine plants is largely determined by the development of such traits as the number of beans per lateral cluster, weight of leaves and roots, number of seeds per central and lateral cluster, and weight of seeds per central and lateral cluster. Therefore, when evaluating selection material, it is especially relevant to consider the values of these traits, which will facilitate the targeted selection of highly productive genotypes. When evaluating the vegetative productivity of white lupine plants, selection should be based on higher values of such traits as the weight of beans from the central cluster and the weight of leaves and stems. The second most important traits in the formation of green mass are the number of beans per plant, the weight of beans from the lateral clusters and the weight of roots. The

application of the established patterns of productivity formation will contribute to the efficiency of the selection of selective material according to the specified parameters.

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Співвідношення елементів насіннєвої та вегетативної продуктивності у колекційних зразків люпину білого

Анотація. Метою досліджень було встановлення сили та загального характеру кореляційних зв'язків між кількісними ознаками, що формують вегетативну та насіннєву продуктивність люпину білого. Методи дослідження включали польовий, вагово-вимірювальний та математично-статистичний методи. Виявлено достовірну позитивну кореляцію між середньою силою насіннєвої продуктивності та такими ознаками, як висота рослин, кількість бічних пагонів, кількість бобів з центральної та бічних китиць тощо. Сильну позитивну кореляцію виявлено з вегетативним розвитком рослин, а слабку - з кількістю насінин у бобі та масою 1000 насінин. Встановлено достовірну сильну позитивну кореляцію вегетативної продуктивності з такими кількісними ознаками, як маса бобів з центральної китиці та маса листя і стебел. Позитивний кореляційний зв'язок середньої сили виявлено з кількістю бобів з центральної та бічних китиць, масою бобів з бічних пагонів, масою коренів тощо. Встановлено, що насіннєва продуктивність рослин люпину білого в основному обумовлена розвитком таких ознак, як кількість бобів з бічних пагонів, маса листя і коренів, кількість насінин і маса насіння з центральних і бічних пагонів. Формування вегетативної продуктивності в першу чергу залежить від маси бобів з центральної китиці та маси листя і стебел. Використання встановлених закономірностей формування продуктивності дозволить підвищити ефективність добору селекційного матеріалу за вказаними параметрами

Ключові слова: кореляційні зв'язки, центральна та бічні китиці, маса насіння, кількість бобів і насінин, кількість насінин у бобі, маса 1000 насінин