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INFLUENCE OF MORPHOLOGICAL AND PHYSIOLOGICAL CHARACTERISTICS OF LENTIL (LENS CULINARIS MEDIK) SAMPLES ON YIELD COMPONENTS AND CORRELATION ANALYSES OF SOME CHARACTERISTICS

Oybek Kholliyev
PhD student, Institute of Genetics and Plant Experimental Biology, Academy of Sciences of Uzbekistan

Farrukh Matkarimov
PhD student, Institute of Genetics and Plant Experimental Biology, Academy of Sciences of Uzbekistan

Sevara Baboeva
Senior Researcher, Institute of Genetics and Plant Experimental Biology, Academy of Sciences of Uzbekistan

Sultonova Dilfuza
Teacher, Chirchik State Pedagogical University, Uzbekistan

Saidmurat Baboev
Professor, Institute of Genetics and Plant Experimental Biology, Academy of Sciences of Uzbekistan

Dilafruz Qulmamatova
Head of laboratory, Institute of Genetics and Plant Experimental Biology, Academy of Sciences of Uzbekistan

Abstract
The aim of the research is to study the correlation between crop capacity and physiological characteristics of Lentil (Lens culinaris Medik). Determination of correlation between physiological characteristics and crop indicators, and assessment of their influence on grain yield give an opportunity to select genotypes with high crop capacity.

According to the results of the analysis, strong positive correlation was detected among the valuable economic characters of lentil genotypes, i.e. between indexes such as number of grains per plant with grain weight per plant r=0.88*** and grain productivity per plant r=0.71***; between grain weight per plant and grain productivity in 1m2 plot r=0.79***; among chlorophyll 'a', chlorophyll 'b' and carotenoid content in leaves (r=0.92***, r=0.81*** respectively); between net photosynthetic productivity and biomass in 1m2 plot (r=**0.67;). Moreover, moderate positive correlation was detected among the indicators of grain number per plant (r=*0.54) and grain weight (r=**0.57) and grain productivity (r=*0.62). Among the lentil genotypes, K-72015 genotype, which has a good result based on the analysis of morphological-physiological and productivity characteristics, gives the opportunity to grow it as a new promising variety in the republic and obtain a higher yield.

Keywords Lentile, grain productivity, morphological- physiological analysis, correlation, net photosynthetic productivity, chlorophyll amount.

INTRODUCTION

By 2050 demands of world population for protein increases two times. Plant protein sources may be an economically effective way to meet protein demand of population and improve the overall quality of nutrition in future [2, 6]. Plant proteins serve to improve environmental sustainability, benefit human health, and in some cases reduces the risk of death [28].

Lentil (Lens culinaris Medik.) is a representative of the Leguminosae family with low-calorie and high-protein quality [10]. Lentil is a dietary food source with its content, depending on its different varieties, up to 30% protein [26] and rich in microelements such as iron (Fe), selenium (Se), manganese (Mn), copper (Cu) as well [12,27,]. Protein content of this grain has high concentration of essential amino acid such as lysine, leucine, isoleucine, valine and phenylalanine. Including, according to the content of the grain (rich in methionine, tryptophan, etc.), in addition to meeting the protein requirements of the world's vegetarian population [1, 18], is considered as a "meat for poor men" [22].

Agrotechnical importance of lentil is high, due to symbiotic peculiarities with legume bacteria as other leguminous plants, it is considered as a nitrogen fixer plant, assimilates free nitrogen from air and contributes its role in nitrogen cycle [28]. Including leguminous plants into crop rotation helps to protect environment and nature, as well as to improve soil fertility and the diversity of rhizosphere in consequence of biologically extraction of N2 [12].

Lentil, in the condition of Uzbekistan, is included into the list of nontraditional agricultural crops and is notable for its nutritional value, easy to digest, rich in protein and at present is mainly imported. Nowadays, the increase of demand for organic products requires the creation and implementation of new productive varieties of lentil.

Grain productivity is the main complex characteristic which appears in the result of interrelation of plant characteristics and changes under the influence of environment [30].

In studying agricultural crops, breeders are rarely interested in studying a single trait of a plant, in addition, it is important to study the correlation between different traits, especially the correlation between yield and other traits. Selection is an integral part of breeding, and with the help of selection, genotypes with high productivity can be obtained. Determining the correlation between agronomic characteristics, their correlation with yield productivity and their direct effect on grain yield allows selection of varieties with high productivity [30].

Improvement of breeding processes plays an important role in increasing crop productivity. Statistical analysis of the correlation among the characters that ensure productivity is widely used in breeding processes.

In selection and genetic research, various research methods are used in complex assessment of initial materials. Direct assessment of the selected character is difficult in some cases, and in this case correlation analysis is used [26]. Correlation is a relationship that describes the degree of relationship between two variables. It shows how strongly a pair of variables is correlated [5].

With the help of the correlation coefficient, it is possible to evaluate the relationships between different characters at the genotypic and phenotypic level, the connection of a certain character with environmental factors, the laws of passing of the character from the parental forms to the next generations [16].

The laws of variation of traits and the correlation of quantitative indicators allow to determine the value of each trait to use in selection processes [3]. Information on the genetic diversity among various parameters of lentil, and correlation between economical and physiological characteristics, in the conditions of our Republic, was not studied enough. It is important to analyze the correlation between crop capacity and physiological characteristics of lentil. Based on this, the purpose of the research is to study the correlation between the productivity of lentil and the physiological characteristics of the plant.

MATERIALS AND METHODS

The experiments were conducted in 2022-2023 in "Durman" field experimental base of the Institute of Genetics and Plant Experimental Biology of the Academy of Sciences of the Republic of Uzbekistan.

In order to study and use the collection samples of gene pool of promising and high-value leguminous plants, as well as valuable economic characters and resistance to adverse climatic conditions of lentil, like other leguminous plants, correlation analyses of valuable economic and physiological characteristics were conducted on nineteen genotypes. These samples were selected from the experimental nursery-gardens "Lentil International Elite Nursery Global 2021" (LIEN-GLO) and "Lentil International Drought tolerant Nursery 2020" (LIENDT-20) of ICARDA. The variety "Oltin don" was used as a control variety (Table 1).

Table 1.

List of lentil genotypes used in the present study

№	CROSS	№	CROSS
72001	ILL590XILL8461	72021	ILL7531XILL8461
72004	ILL7978XILWL 118	72023	ILL4605XILL6002
72008	ILL6002XILL7716	72027	ILL358XILL10870
72011	ILL8114XILL7663	72030	ILL6002XLIRL-21-50-1-1-1
72014	ILL8114XILL10956	72032	ILL10012XILL2585
72015	ILL7978XLIRL-21-50-1-1-1	72036	ILL10866XILL10174
72016	Oltin don	60001	ILL10675xILL8461
72017	ILL4380XILL4372	60003	ILL75xILL7700
72019	ILL6994XILL10141	60010	LRIL-21-50-1-1-1xDPL 62
72020	ILL4605XILL6002	60020	ILL10690

A randomized complete block design (RCBD) was used in the experiment with two replications using 60 cm spacing and four-row plots with four meters of row length. The plot size measured 0.6 m × 1.6 m rows (1 m2). Samples of lentil were sown in the second decade of February and harvested at the end of May and the beginning of June.

Physiological processes and amount of pigments were analyzed on the third leaves from the top of the plants during the flowering and podding phases. Pigments in the leaf content, i.e. chlorophyll 'a', chlorophyll 'b' and carotenoid amount were determined according to the method of Lichtenthaler [14].

Transpiration rate was determined according to Ivanov's method [9], water holding capacity was determined with the method by Kushnirenko [13], and Tretyakov's method [31] was used in determining the total amount of water in leaves.

Harvest index was calculated according to the following formula:

$$Harvest\ index(\%) = \frac{Seed\ yield}{Biological\ yield} \times 100$$

The obtained data were analyzed on the statistical software ANOVA STATGRAPHICS-18 [33].

RESULTS AND DISCUSSIONS

The positive correlation among the crop indicators leads to an increase in grain productivity, depending on the morpho-physiological characteristics of yield elements. The effect of genotypes on morpho-physiological characteristics showed significant differences in lentil plants (Table 2).

Plant height had higher results in genotypes K-72001 (41.4 cm), K-72020 (41.2 cm), K-72011 (38.8 cm), K-72023 (38.59 cm). In the other genotypes plant height was between 29.86-36.7 cm. 45 % of the studied genotypes of lentil showed higher results on dry matter than the control variety "Oltin don", whereas on K-72027, K-72036 and K-60001 had lower level of secondary branching compared to other lentil genotypes.

Within the research, physiological processes were studied during the overall flowering period.

Water holding capacity in leaves was determined in genotypes K-60003 (17.85%) and K-60010 (16.11%), which were selected from samples of LIENDT. Total chlorophyll amount and net photosynthetic productivity were measured in genotypes K-72008 (4.16 mg/g; 3.21 gr/m2/day) and K-72023 (4.06 mg/g; 3.70 gr/m2/day respectively).

Average transpiration rate of lentil genotypes was equal to 50.78 mg/g/h. Acceleration of transpiration process was higher in K-72021 genotype (87.95 mg/g/h) than the control variety "Oltin don" (68.99 mg/g/h). Whereas the genotypes K-72004 (68.99 mg/g/h), K-72001 (62.05 mg/g/h) and K-72023 (68.57 mg/g/h) showed almost similar results to the control variety. The other genotypes showed moderate indicators. The height of the plant, the number of fruiting branches, the physiological processes and the photosynthesis rate determine the high productivity indicators [19,23].

Table 2.

Morphological and physiological characteristics of lentil samples

Genotype	Plant height, sm.	Total dry matter of plants, gr.	Secondary branching	Water holding capacity in branches, %	Transpiration rate, mg/g/h	Chlorophyll, mg/g	Net photosynthetic productivity, $gr/m^2/day$
72001	41,4	33,22	11,2	15,30	62,05	2,94	2,51
72004	34	49,31	12,3	9,45	68,99	3,21	2,13

72008	35,6	46,73	15,4	15,56	32,69	4,16	3,21
72011	38,8	50,11	13,5	12,03	44,56	3,01	3,17
72014	33,6	41,79	13,7	9,39	53,48	3,67	2,76
72015	36,7	44,85	11,8	12,20	51,23	3,16	3,13
Oltin don	36,8	41,98	13,2	8,94	69,44	3,84	2,09
72017	33,4	33,12	13,3	9,86	71,77	3,32	2,66
72019	31,5	37,21	15,3	10,39	61,45	3,11	2,68
72020	41,2	44,05	13,7	15,01	45,41	3,16	2,78
72021	36,85	42,38	14,8	12,24	87,95	3,29	3,17
72023	38,59	46,80	12,9	10,47	68,57	4,06	3,70
72027	32,35	43,91	8,8	12,87	41,84	3,33	2,34
72030	36,6	40,35	13,2	13,04	49,43	3,42	2,81
72032	33,36	44,59	15,3	15,36	35,22	3,41	2,08
72036	29,86	40,85	8,2	14,11	41,52	3,42	2,04
60001	34,23	36,81	9,3	14,56	27,55	3,09	1,46
60003	33,08	40,66	11,83	17,85	30,34	3,93	1,74
60010	32,41	35,52	10,16	16,11	36,64	2,55	1,74
60020	30,26	41,07	10,17	13,42	35,42	3,16	1,69
Sx	**35,05**	**41,77**	**12,40**	**12,91**	**50,78**	**3,36**	**2,50**
LSD (0,05)	**0,74**	**1,08**	**2,19**	**0,58**	**3,72**	**0,09**	**0,14**
CV%	**9,41**	**11,54**	**17,63**	**8,91**	**60,40**	**11,87**	**2,24**

Crop indicators of lentil genotypes, including number of pod and grain per plant, grain weight per plant and weight of 1 000 grains, biological and seed productivity, as well as yield indices were analyzed (Table 2). High diversity was noted among the genotypes on these indicators, which ensure high crop productivity. The results of the research show that, number of pods per plant was between 67 and 128.67 pieces; number of grains per plant was between 71.67 and 197.67 pieces; grain weight per plant varied between 3.18 gr and 8.13 gr; weight of 1 000 grains was between 33.12 gr and 50.11 gr; biomass was 237.7-423 gr; seed productivity in 1 m2 was 105.5-196 gr; as well as yield index varied from 42.12% to 54.96% respectively. Lentil genotypes with high productivity showed higher number of pods and grains per plant, and higher grain weight per plant. It was determined, that in genotypes K-72001, K-72014, K-72015 and K-72036 number of pods was 105.33-128.67 pieces, number of grains made up 146-197.67 pieces, grain weight was from 62.5 to 8.13 grams. Number of pods in genotypes K-72017, K-72020, K-60003, K-60020 and K-60020 was from 67 to 76 pieces and had lower indicators compared to other genotypes, whereas genotype K-60010 showed the lowest indicators on the overall yield attributes. Significant diversity among the lentil genotypes on yield attributes depends on the genetic differences of the varieties. In the researchers of A.Ouji [20] significant genetic differences was detected among the lentil varieties.

On the weight of 1 000 grains, genotypes K-72004 (49.31 grams) and K-72011 (50.11 grams) recorded the highest rate depending on the grain size. Despite the high number of pods and grains per plant and grain weight in genotype K-72001, it was observed that the weight of 1 000 grains was lower and made up 33.22 grams due to grain fineness. Among lentil genotypes, it was noted that

1 000 grain weight depended on grain shape and size [32].

The grain yield per 1 m2 was equal to 161.32 grams on average, and 141.3 grams in the control variety "Golden grain". In 70% of the lentil genotypes, the crop yield per 1 m2 was higher than the control variety, and the indicators of the genotypes were in the range of 164-196 grams.

K-72014, K-72015 and K-72020 genotypes had the highest biological (385.6; 347.0; 420 grams) and seed productivity (196.0; 180.3 grams) compared to other varieties.

The longer the growing season of plants, the higher the grain yield and the yield index, or the higher the biomass, the lower the yield index [22]. The yield index was higher than 54% in K-72001 and K-72008 lentil genotypes depending on biological and seed productivity.

When agrotechnic activities are properly implemented, plant nutrient uptake in sufficient level leads to improved biological and grain yield [25].

Table 3.

Harvest indexes of lentil samples

Genotypes	Number of pods	Number of grains	Grain weight, gr	Weight of 1 000 grains, gr	Biological Yield	Seed Yield	HI
72001	128,67	197,67	6,25	33,22	304,5	167,3	54,96
72004	95,67	128,00	6,37	49,31	346,9	178	51,35
72008	84,33	144,00	6,62	46,73	307,7	168	54,62
72011	92,67	157,33	7,38	50,11	349,1	170,7	48,88
72014	114,33	194,33	8,13	41,79	385,9	196	50,77
72015	111,00	146,00	6,25	44,85	347	180,3	52,03
72016 (Oltin don)	86,67	109,67	4,53	41,98	261,7	141,3	53,99
72017	74,00	112,33	3,95	33,12	244,7	121	53,67
72019	88,33	136,00	5,11	37,21	332,3	166	50,06
72020	76,67	99,67	4,39	44,05	420	196	46,66
72021	100,00	124,67	4,92	42,38	393,3	176	44,78
72023	78,00	135,67	6,30	46,80	423	178	42,12
72027	90,67	120,67	5,40	43,91	360	158	43,85
72030	96,67	154,32	6,22	40,35	373	189,9	50,84
72032	90,33	123,00	5,79	44,59	324	164,6	50,75
72036	105,33	155,67	6,61	40,85	382	190,3	49,82
60001	83,67	89,33	3,47	36,81	237,7	119,9	50,4
60003	76,00	97,33	4,13	40,66	247,7	131,3	53,1
60010	67,00	71,67	3,18	35,52	242	105,5	43,6
60020	75,00	78,00	3,95	41,07	253	128,3	50,7
Sx	**90,75**	**128,77**	**5,45**	**41,77**	**326,78**	**161,32**	**49,85**
LSD (0,05)	**3,46**	**7,58**	**0,30**	**1,08**	**39,34**	**6,12**	**0,85**
CV%	**17,05**	**26,33**	**4,95**	**16,99**	**547,65**	**16,98**	**7,61**

According to the results of the correlation analysis, strong positive correlation was detected among the valuable economic characters of lentil genotypes, i.e. between indexes such as number of grains per plant with grain weight per plant r=0.88*** and grain productivity per plant r=0.71***, between grain weight per plant and grain productivity in 1m2 plot r=0.79*** accordingly. As well as among the physiological characteristics strong positive correlation was noted, i.e. among chlorophyll 'a', chlorophyll 'b' and carotenoid content in leaves (r=0.92***, r=0.81*** respectively) (Figure 1).

Number of pods per plant has positive influence on lentil crop productivity from phenotipical and genetic point of view [29]. A strong positive correlation (r=0.92 r=0.68) was detected among crop indicators of lentil grown under different conditions [17, 18, 30]

Researches on the lentil crop was mainly carried out according to the components of seed productivity, such as the number of pods per plant, the number of grains, the weight of grains per plant and the weight of 1000 grains [11]. The number of grains per plant plays an important role in determining productivity elements, while the weight of 1 000 grains has a partial effect [6].

The weak positive correlation between the weight of 1 000 grains and the number of grains per plant (r=0.12) can be explained by the fact that despite the large number of grains in a plant, they were not fully ripened and became small in size, due to hot temperature during the ripening period of the grain or unfavorable climatic conditions.

The number of grains per plant, being one of the main indicators of crop, has weak positive correlation in genotypic level with physiological characteristics such as chlorophyll "a" (r=0.16) and "b" (r=0.17), amount of carotenoid (r = 0.14), as well as transpiration rate (r = 0.28). And the change of physiological processes depending on the environment does not have a high impact on the increase or decrease of crop productivity.

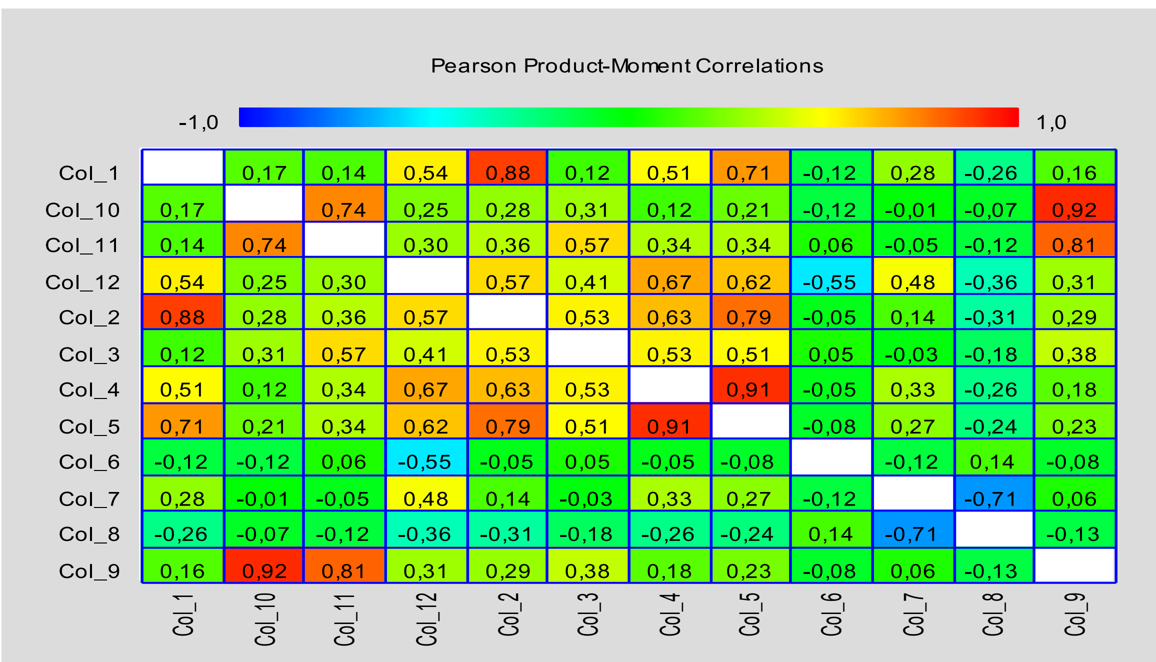

Figure 1. Correlation of some crop and physiological characteristics in lentil genotypes

Col_1 – number of grains per plant; Col_2 – grain weight per plant; Col_3 – weight of 1 000 grains; Col_4 – biomass; Col_5 – seed productivity; Col_6 – total amount of water; Col_7 – transpiration rate; Col_8 – water capacity of leaves; Col_9 – chlorophyll "a"; Col_10 – chlorophyll "b"; Col_11 – amount of carotenoid; Col_12 – photosynthetic productivity;

Note: *p<0.05, **p<0.01, ***p<0.001

The indicators of total amount of water and water holding capacity of leaves showed negative correlation with the crop characteristics such as the number of grains per plant (r=-0.12; r=-0.26), grain weight (r=-0.05; r=-0.31), biomass (r=-0.05;

r=-0.26) and seed productivity (r=-0.08; r=-0.24). And this can be connected with the reduction of water in plant cells and decrease of assimilation processes. In order to determine in detail the effect of each character on the yield structure of any crop, it is important to know the interrelationship among the characters, because the effectiveness of selection can be positive for one character and negative for another one at the same time [16].

The increase in the rate of transpiration in the leaves partially affected the decrease in the total amount of water, and the correlation between the traits (r=-0.12) was weakly negative. Depending on the characteristics of the plant variety, a decrease in the water holding capacity of the leaves (r=-**0.71) led to an increase in the rate of transpiration.

In increasing the grain yield of lentils, it is essential to study the important physiological processes that determine the photosynthetic productivity.

Net photosynthetic productivity is the formation and accumulation of organic matter in 1 m2 area for one hour. The amount of organic matter accumulated during one day varies from a very small amount to 15-18g/m2 during the vegetation period [4].

Net photosynthetic productivity showed a strong and moderate positive correlation with crop characteristics such as biomass per 1 m2 (r=**0.67), number of grains per plant (r=*0.54), grain weight (r=**0.57) and seed productivity (r=*0.62). The increase in net photosynthetic productivity led to an increase in organic matter synthesis in lentil genotypes and a positive correlation of valuable economic characters. A high dry matter weight accumulated during daily photosynthesis is associated with a significant increase in productivity.

The organic matter formed and accumulated during photosynthesis is divided into biological (the total amount of dry matter synthesized during the growing season) and economic (grain, seed, root crop) yield [4].

A small part of the amount of water spent in the process of transpiration was used for the synthesis of organic matter, leading to the accumulation of dry matter during photosynthesis, which showed a moderate positive correlation between net photosynthetic productivity and the rate of transpiration (r =*0.48).

A weak positive correlation was determined between net photosynthetic productivity and amount of pigments in leaves, i.e. chlorophyll “a” (r=0.31), chlorophyll “b” (r=0.25) and amount of carotenoid (r=0.30).

The rate of photosynthesis determines the high productivity indicators of plants. The change in the rate of photosynthesis is related to the activity of photosynthetic pigments in the leaves, and these pigments are directly involved in the synthesis of organic matter. [15].

As a result of the increase in transpiration rate, due to the activation of organic matter synthesis, the water holding capacity and the total amount of water in leaves decrease. There is a negative correlation between the rate of transpiration and the water holding capacity of leaves [18]. Moderate negative correlation was found between net photosynthetic productivity and total amount of water (r=-*0.55) and water holding capacity of leaves (r=-0.36) as well. Herein, activation of organic matter synthesis caused a change in water exchange in the leaves.

According to the results of the analysis, strong and moderate positive correlation of some traits has a positive effect on the formation of lentil productivity and helps to genetically improve the productivity of lentil varieties created in the conditions of our republic. In the process of selection, it allows for the appropriate selection of productive lentil varieties.

In addition to the high yield capacity in optimal conditions, morpho-physiological characteristics of varieties and their resistance to biotic and abiotic stresses are also of great importance.

Among the lentil genotypes, based on the analysis of morpho-physiological and crop characteristics, genotype K-72015 showed a good results, and cultivation of the this genotype as a new promising variety in our republic gives an opportunity to obtain a high yield.

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