Scientific Papers. Series A. Agronomy, Vol. LXVIII, No. 2, 2025
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

RESEARCH ON THE RELATIONSHIP BETWEEN THE VEGETATION PERIOD IN CEREAL SPECIES AND THE FLAG LEAF AREA THROUGH THE YIELD, ON THE CHERNOZEM OF CARACAL

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Abstract

In 2024, a bifactorial experiment was set up on the chernozem of Caracal, where A factor was the species: wheat, triticale, barley and B factor was the vegetation period: early, medium, late. The yield and flag leaf area were determined for each combination of factors in 3 repetitions. The highest yield was obtained for wheat – 61.92 q/ha. Compared to the control - yield of wheat species, only barley was significantly lower. There were no differences in yield between the vegetation periods, regardless of the species. The correlation coefficient between yield and flag leaf area recorded a value of 0.331, lower than the P5% limit for 27 studied cases, therefore insignificant. There were both varieties with small flag leaf area but with high yields (such as: medium-early triticale with flag leaf area of 1307.27 cm^2 and yield of 68.54 q/ha and late wheat with area of 1840.27 cm^2 and yield of 68.25 q/ha) but also varieties with large flag leaf area and high yields (such as: medium-early wheat with flag leaf area of 2951.07 cm^2 and yield of 66.08 q/ha).

***Key words**: wheat, triticale, barley, flag leaf area, vegetation period.*

INTRODUCTION

Cereals represent the phytotechnical group of agricultural plants with the largest distribution area in all cultivated areas of the globe, with an age of about ten thousand years. Grains of straw cereals (wheat, triticale, barley) are an important source of nutrition throughout the world, being rich in non-nitrogenous extractive substances but also proteins, fats, vitamins, etc. Also, cereal crops, specially wheat, contribute to economic stability and growth in rural communities.

Along with climate change, a series of regional and global political and economic factors have intensified food insecurity and long-term vulnerability in certain regions (Bonciu, 2023; Bonciu et al., 2021a; Mirzabaev et al., 2023; Păunescu and Păunescu, 2019). Drought affects plant growth, productivity, and their quality. Genetic engineering can increasing resilience and improving crop adaptation (Bonciu et al., 2021b; De Souza et al., 2022; Liu et al., 2024).

Food security has a fundamental importance for human existence, and increasing cereals production under climate change is, from this point of view, one of the permanent challenges for farmers (Bonciu et al., 2021; Dihoru et al., 2023; Rosculete et al., 2023). From this point of view, wheat is one of the safest crops, being genetically structured to withstand low winter temperatures. They exhibit a remarkable ecological plasticity, being cultivated even in unfavorable climatic and soil conditions.

Production in cereal crops is due to complex physiological and biochemical processes, but is essentially associated with the process of carbohydrate accumulation during the grain filling phase, which in turn is attributed to leaf functionalities (Biswal and Kohli, 2013). In this sense, the key components underlying cereal productivity are positively correlated with flag leaf size estimated by length, width and area (Khaliq et al., 2008; Wang et al., 2012), the flag leaf length-to-width ratio (Sohrabi et al., 2012) and the flag leaf basal angle (Isidro et al., 2012).

The flag leaf is one of the primary sources of carbohydrates in cereals (Liu et al., 2021). Flag leaf traits are considered to play an important role in grain filling of strawy cereals under drought conditions. Thus, physiological, morphological and biochemical traits of flag leaves are involved in determining grain yield and biomass (Biswal and Kohli, 2013; Liu et al., 2015; Racz et al., 2022).

The flag leaf plays an essential role in establishing production and therefore it must benefit from protection throughout the vegetation period. Thus, in order for the plants to remain healthy until harvest, it is necessary to apply additional treatments that protect the grass cereals in all phases of vegetation. Maintaining the green state of the flag leaf is a trait that allows grass cereals to maintain their photosynthetic capacity for a longer period of time after anthesis, especially under conditions of drought and heat stress.

The flag leaf provides the main source of assimilates necessary for plant growth and ear development in straw cereals. The contribution rate of flag leaves to daily photosynthetic products ranges from 50% to 60% (Towfiq et al., 2015), while its defoliation generated yield losses ranging from 18% to 30% (Banitaba et al., 2017). In wheat, removal of the flag leaf affected grain production under normal or water-limited conditions (Cruz-Aguado et al., 1999; Ma et al., 2021).

According to Niu et al. (2022), the flag leaf plays a vital role in seed development. Thus, the flag leaf thickness showed significantly positive correlations with grain size in barley.

Many results suggest that cereal species will continue to play an essential role in ensuring food security and an accessible intake of calories and protein (Grote et al., 2021; Pandey et al., 2020; Paunescu et al., 2021, 2023; Tadesse et al., 2018).

MATERIALS AND METHODS

The aim of this work was to determine the influence of the flag leaf area on the production of 3 species of straw cereals, on the chernozem of Caracal.

In 2024, a bifactorial experiment was set up on the chernozem of Caracal in which factor A was the species: wheat, triticale, barley and factor B was the vegetation period: early, medium, late. The production and flag leaf area were determined for each combination of factors in 3 repetitions.

Based on the results, was studied the factors influence (factor A – species with 3 graduations – wheat, triticale, barley; factor B – vegetation period with 3 graduations: early, medium, late) and their interactions (species *x* vegetation period, vegetation period *x* species) on the production and flag leaf area. Correlations were performed and the simulated flag leaf area was calculated based on the correlation coefficient equation. This was compared with the real flag leaf area simultaneously, depending on the production classes within the interval obtained within the experiment.

The used materials were:

- Wheat varieties with differentiated: DUSK (early); CAROM (medium/+3-4 days); BOGDANA (late/+7-8 days)
- Triticale varieties with differentiated earing: line 11588T2-23 (early); UTRIFUN (medium/+4-5 days); INSPECTOR (late/+14-15 days)
- Barley earing with differentiated earing: line F 8-4-12 (early); AMETIST (medium/+3-4 days); ONIX (late/+7-8 days)

The statistical processing of the experiment was done with the statistical analysis program specific to bifactorial experiments based on the methodology presented by Săulescu (PSUB 2).

RESULTS AND DISCUSSIONS

The climatic conditions manifested in the 2023-2024 agricultural year in Caracal showed a lack of precipitation throughout the vegetation period (-32.3 mm) but with a surplus in May when grain filling took place (Table 1).

From the point of view of the species, there were differences between the yields, but only that of barley was significantly reduced in relation to the yield obtained in wheat (Figure 1). In contrast, yield did not differ according to the average vegetation period of the 3 species analyzed (Figure 2).

Table 1. Evolution of the main climatic factors during the vegetation period of straw cereal genotypes

Specification		X	XI	XII	I	II	III	IV	V	VI	Total growing season
Temperature °C	Monthly minimum	0.6	-4.4	-3.2	-9.6	-6.7	-3.3	2.0	5.4	12.5	
	Monthly maximum	33.4	21.4	18.2	15.3	21.9	28.3	32.7	30.8	39.4	
	Monthly average	16.0	8.1	3.9	1.0	8.0	8.9	15.0	17.2	25.9	
	NORMAL	11.7	5.1	0.3	-1.3	0.8	6.0	12.0	17.7	21.6	
	Difference ±	+4.3	+3.0	+3.6	+2.3	+7.2	+3.9	+3.0	-0.5	+4.3	
Rainfall mm	Monthly total	21.4	124.2	21.4	26.8	11.6	22.4	26.0	71.8	31.6	**357.2**
	Multiannual average	46.0	37.0	39.1	30.8	26.3	34.2	47.8	58.6	69.7	**389.5**
	Difference±	-24.6	+87.2	-17.7	-4.0	-14.7	-11.8	-21.8	+13.2	-38.1	**-32.3**
Solar radiation	Average	123	59	36	52	86	126	196	211	273	
Relative humidity of the air %	Average	66.9	91.1	93.8	95.4	84.7	85.3	70.8	77.8	61.3	

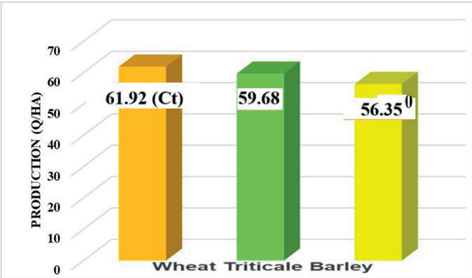

Figure 1. The influence of the species on production on the chernozem of Caracal

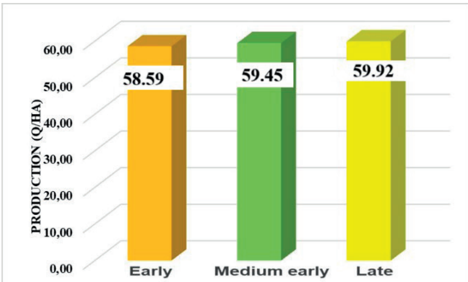

Figure 2. The influence of the vegetation period on production on the chernozem of Caracal

The species x vegetation period interaction has a limited influence on production. The only combination that significantly exceeded the control was late-growing barley. The increase was 16.8%, substantial, which made this species obtain a production almost equal to that of wheat (Table 2). The highest production was obtained with mid-early growing wheat (63.3 q/ha) and the lowest with early barley (52.44 q/ha).

The coefficient of variability of production values, regardless of the studied interactions, was 9.14%, therefore below 10% - the limit for stability. Thus, under Caracal conditions, all species can be cultivated regardless of their vegetation period, the results being within the limit of optimal stability.

If reporting is done on the control considered as the early wheat species, there are two combinations of factors where production is

significantly reduced: early barley and medium-early growing season barley.
In terms of flag leaf area, triticale and barley showed distinctly significantly, respectively very significantly reduced values compared to wheat - the control species (Figure 3). As in the case of production, the growing season did not influence the surface of the flag leaf under Caracal conditions (Figure 4).

Table 2. The influence of the species *x* vegetation period interaction on production on the chernozem of Caracal

Factor A (Species)	Factor B (Growing period)	Production (Q/Ha)	Difference	Significance
WHEAT	Early	63.00	Ct	
	Medium early	63.30	0.30	
	Late	59.47	-3.53	
TRITICALE	Early	60.33	Ct	
	Medium early	61.46	1.13	
	Late	57.27	-3.06	
BARLEY	Early	52.44	Ct	
	Medium early	53.59	1.15	
	Late	63.02	10.58	*
LD 5%			**9.03**	
LD 1%			**12.68**	
LD 0.1%			**17.9**	

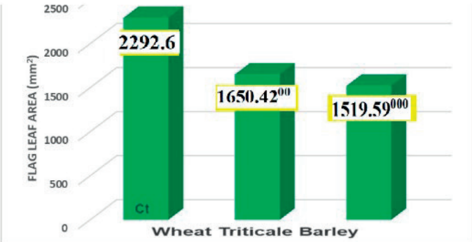

Figure 3. The influence of species on the flag leaf surface on the Caracal chernozem

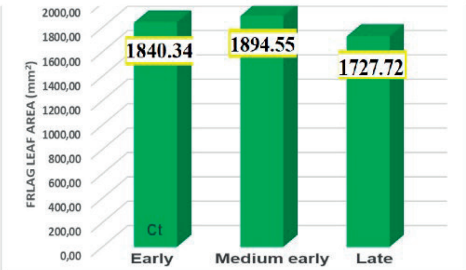

Figure 4. The influence of the vegetation period on the flag leaf area on the Caracal chernozem

The species x vegetation period interaction influenced the flag leaf area (Table 3).

In wheat and triticale, there were statistically significant interactions. While medium early wheat showed a significant increase in area compared to early wheat, late wheat showed a distinctly significant decrease compared to the same control. In triticale, at the average vegetation period as earliness, a significant decrease of 20% was recorded compared to the control - early triticale. The limits of the values determined for the flag leaf area were between 1352.83 mm^2 in early barley and 2671.94 mm^2 in medium-early wheat. These corresponded to the limits for production in the pedo-climatic conditions of Caracal.
The coefficient of variability of the flag leaf area values, regardless of the studied interactions, was 25.6%, therefore over 20% - the limit for character instability.
Unlike the production results, in the flag leaf area, in relation to early wheat, all interaction variants presented statistically significant differences - very significant decreases, except for medium-early wheat (Figure 5).
The correlation coefficient between production and flag leaf area, regardless of species and vegetation period, recorded a value of 0.331, lower than the P5% threshold for the 27 cases studied, therefore insignificant (Figure 6).

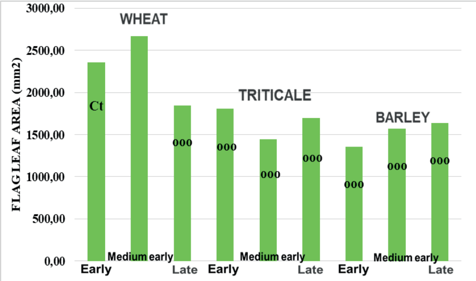

Figure 5. Flag leaf area x vegetation period interaction in relation to the control variant – wheat species with early vegetation period

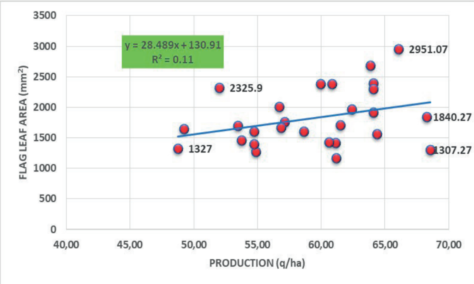

Figure 6. The relationship between production and flag leaf area in the variants studied at Caracal

There were both varieties with small flag leaf area but with high yields (example: triticale with medium precocity with flag leaf area of 1307.27 mm^2 and production of 68.54 q/ha and late wheat with area of 1840.27 mm^2 and production of 68.25 q/ha) but also varieties with large flag leaf area and high yields (example: wheat with medium precocity with flag leaf area of 2951.07 mm^2 and production of 66.08 q/ha).

The determination coefficient shows us that the first studied character explains the variability of the other in proportion of 11%. The linear equation showed that each 100 kg/ha increase in production is due to an increase in flag leaf area of about 28.5 mm^2, for the range studied.

By comparing the real and simulated results for the flag leaf area according to the production classes, it is noted that most of the variants where the difference between real and simulated is below DL 5% (307.72 mm^2) are below the average production of 59.32 q/ha.

Results over several years would allow obtaining simulations close to the real values, so that a simple determination would give predictions regarding the productions that can be obtained depending on the flag leaf area. Also, from these determinations it emerged that the greatest matches between real and simulated were recorded at lower productions, especially those of barley (Table 4).

Table 3. The influence of the species x vegetation period interaction on the flag leaf area on the Caracal chernozem

FACTOR A (Species)	FACTOR B (Growing period)	FLAG LEAF AREA (mm^2)	DIFFERENCE	SIGNIFICANCE
WHEAT	Early	2358.49	0.00	
	Medium early	2671.94	313.45	*
	Late	1847.39	-511.10	oo
TRITICALE	Early	1809.70	0.00	
	Medium early	1443.42	-366.28	o
	Late	1698.13	-111.57	
BARLEY	Early	1352.83	0.00	
	Medium early	1568.30	215.47	
	Late	1637.63	284.80	
LD 5%			**307.72**	
LD 1%			**431.93**	
LD 0.1%			**609.78**	

Table 4. Results of the simulation of the flag leaf area according to the linear equation of the production – flag leaf area relationship reported to the real flag leaf area by production classes

Production Classes	Real Production	Leaf Surface Simulation (mm^2)	Real Leaf Surface (mm^2)	Difference
48-48.99	48.73	1519.038	1327	192.04
49-49.99	49.21	1532.886	1648.4	-115.51
50-50.99				0.00
51-51.99				0.00
52-52.99	52.02	1612.794	2325.9	-713.11
53-53.99	53.46	1654.023	1696.83	-42.81
	53.73	1661.661	1462.1	199.56
54-54.99	54.71	1689.602	1392	297.60
	54.72	1689.791	1608.13	81.66
	54.86	1693.837	1269.4	424.44
55-55.99				0.00
56-56.99	56.70	1746.269	2005.07	-258.80
	56.86	1750.708	1664.5	86.21
57-57.99	57.10	1757.716	1756.2	1.52
58-58.99	58.62	1801.071	1600.2	200.87
59-59.99	59.96	1839.025	2385.47	-546.45
60-60.99	60.59	1857.094	1431.1	425.99
	60.83	1863.951	2380.93	-516.98
61-61.99	61.12	1872.068	1414.87	457.20
	61.16	1873.317	1168.3	705.02
	61.50	1883.019	1706.7	176.32
62-62.99	62.37	1907.864	1966.2	-58.34
63-63.99	63.85	1950.002	2679.27	-729.27
64-64.99	64.08	1956.443	2299	-342.56
	64.09	1956.718	1915.9	40.82
	64.09	1956.77	2395.53	-438.76
	64.38	1964.914	1565.9	399.01
65-65.99				0.00
66-66.99	66.08	2013.559	2951.07	-937.51
67-67.99				0.00
68-68.99	68.25	2075.323	1840.27	235.05
	68.54	2083.629	1307.27	776.36
	59.32			-0.42

CONCLUSIONS

With a growing world population and, at the same time, every scarce resource, food security is one of the key challenges for present and future generations.

The earliness-yield relationship can be highlighted with much greater accuracy by experimenting with cultivars differentiated in terms of earing date.

The species *x* growing season interaction has a reduced influence on production. The only combination that significantly exceeded the control was barley with a late growing season. The increase was 16.8%, almost equal to that of wheat.

The highest production was obtained with wheat with a medium-early growing season (63.3 q/ha) and the lowest with early barley (52.44 q/ha).

The coefficient of variability of production values, regardless of the studied interactions, was 9.14%, therefore below 10% - the limit for stability. Thus, under the conditions at Caracal, all species can be cultivated regardless of their vegetation period, the results being within the limit of optimal stability.

The correlation coefficient between production and flag leaf area, regardless of species and vegetation period, was insignificant. There were both varieties with small flag leaf area but high yields (example: medium-early triticale with flag leaf area of 1307.27 mm^2 and production of 68.54 q/ha and late wheat with area of 1840.27 mm^2 and production of 68.25 q/ha) and varieties with large flag leaf area and high yields (example: medium-early wheat with flag leaf area of 2951.07 mm^2 and production of 66.08 q/ha).

REFERENCES

Banitaba, A., Naderi, M., Javanmard, H., Emami, B. (2007). Effect of flag leaf and awn removal on vegetative traits, grain yield and yield components of bread wheat (*Triticum aestivum L.*). *Res. Agric. Sci., 2*, 73–86.

Biswal, A.K., Kohli, A. (2013). Cereal flag leaf adaptations for grain yield under drought: knowledge status and gaps. *Mol. Breeding 31*(4): 749-66.

Bonciu, E. (2023). Some sustainable depollution strategies applied in integrated environmental protection management in agriculture. *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development*, *23*(3): 69-76.

Bonciu, E., Păunescu, G., Roșculete, E., Roșculete, C.A., Olaru, A.L. (2021a). Study of the influence of interaction variety × year × location on winter wheat yield cultivated in different locations in the period 2018-2020. *Scientific Papers. Series A. Agronomy, LXIV*(1): 225-230.

Bonciu, E., Liman, R., Cigerci, I.G. (2021b). Genetic Bioengineering in agriculture-A model system for study of the mechanism of programmed cell death. *Scientific Papers: Management, Economic Engineering in Agriculture and Rural Development*, *21*(4): 65-70.

Cruz-Aguado, J., Reyes, F., Rodes, R., Perez, I., Dorado, M. (1999). Effect of source-to-sink ratio on partitioning of dry matter and 14 C-photoassimilates in wheat during grain filling. *Ann. Bot., 83*, 655–665.

De Souza, C.P., Bonciu, E. (2022). Use of molecular markers in plant bioengineering. *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development*, *22*(1): 159-166.

Dihoru, E., Bonciu, E., Păunescu, G., Roșculete, C.A., Păunescu, R.A., Roșculete, E. (2023). The wheat plant ideotype and its specific morphological and physiological traits - a brief overview. *Annals of the University of Craiova-Agriculture, Montanology, Cadastre Series, 53*(1): 83-90.

Grote, U., Fasse, A., Nguyen, T.T., Erenstein, O. (2021). Food Security and the Dynamics of Wheat and Maize Value Chains in Africa and Asia. Front. Sustain. Food Syst. 4:617009.

Isidro, J., Knox, R., Clarke, F., Singh, A., Depauw, R., Clarke, J. et al. (2012). Quantitative genetic analysis and mapping of leaf angle in durum wheat. *Planta. 236* (6):1713–23.

Khaliq, I., Irshad, A., Ahsan, M. (2008). Awns and flag leaf contribution towards grain yield in spring wheat (*Triticum aestivum L.*). *Cereal Res Commun. 36* (1): 65–76.

Liu, J., Si, Z., Li, S., Wu, L., Zhang, Y., Wu, X., Cao, H., Gao, Y., Duan, A. (2024). Effects of water and nitrogen rate on grain-filling characteristics under high-low seedbed cultivation in winter wheat. *Journal of Integrative Agriculture, 23*(12): 4018-4031.

Liu, X.J., Yin, B., Hu, Z., Bao, X., Wang, Y., Zhen, W. (2021). Physiological response of flag leaf and yield formation of winter wheat under different spring restrictive irrigation regimes in the Haihe Plain, China. *Journal of Integrative Agriculture 20*(9): 2343-2359.

Liu, L., Sun, G., Ren, X., Li, C., Sun, D. (2015). Identification of QTL Underlying Physiological and Morphological Traits of Flag Leaf in Barley. *BMC Genet., 16*, 29.

Ma, C., Pan, X., Ke, Z., Junxing, Y., Xuanzhen, L., Fuyong, L., Lin, L., Hongzhong, Z. (2021). Contribution of the flag leaf to lead absorption in wheat grain at the grain-filling stage. *Ecotoxicology and Environmental Safety, 225*, 112722.

Mirzabaev, A., Bezner Kerr, R., Hasegawa, T., Pradhan, P., Wreford, A., Tirado von der Pahlen, M.C., Gurney-Smith, H. (2023). Severe climate change risks to food security and nutrition. *Climate Risk Management, 39*, 100473.

Niu, Y., Chen, T., Zheng, Z. et al. (2022). A new major QTL for flag leaf thickness in barley (*Hordeum vulgare* L.). *BMC Plant Biol., 22*, 305.

Pandey, M., Shrestha, J., Subedi, S., Kumari Shah, K. (2020). Role of Nutrients in Wheat: A Review. *Tropical Agrobiodiversity, 1*(1): 18-23.

Paunescu, R.A., Bonciu, E., Rosculete, E., Paunescu, G., Rosculete, C.A. (2023). The Effect of Different Cropping Systems on Yield, Quality, Productivity Elements, and Morphological Characters in Wheat (*Triticum aestivum*). *Plants, 12*, 2802.

Paunescu, R.A., Bonciu, E., Rosculete, E., Paunescu, G., Rosculete, C.A., Babeanu, C. (2021). The Variability for the Biochemical Indicators at the Winter Wheat Assortment and Identifying the Sources with a High Antioxidant Activity. *Plants, 10*(11): 2443.

Păunescu, R.A., Păunescu, G. (2019). Genetic variability for cuticular transpiration indicators in terms of initial water content and rate of water loss of the flag leaf to an assortment of wheat tested at Simnic. *European Cereals Genetics Cooperative Newsletter, Proceedings of the 17TH EWAC International Conference,* 83-90.

Racz, I., Hirişcău, D., Berindean, I., Kadar, R., Muntean, E., Tritean, N., Russu, F., Ona, A., Muntean, L. (2022). The Influence of Flag Leaf Removal and Its Characteristics on Main Yield Components and Yield Quality Indices on Wheat. *Agronomy 12*, 2545.

Rosculete, C.A., Paunescu, R.A., Rosculete, E., Paunescu, G., Florea, D., Bonciu, E. (2023). The influence of foliar fertilizer application on the macro and micro nutrient content and yield of wheat plants (*Triticum aestivum*). *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 23*(3): 786-795.

Sohrabi, M., Rafii, M.Y., Hanafi, M.M., Akmar, A.S.N., Latif, MA. (2012). Genetic diversity of upland rice germplasm in Malaysia based on quantitative traits. *Sci. World J., 1*: 1–9.

Săulescu, N., Săulescu, N.N. (1967). Câmpul de experienţă (Field of experience). Agro-Silvica Editure, Bucharest: 259-323.

Tadesse, W., Bishaw, Z., Assefa, S. (2018). Wheat production and breeding in Sub-Saharan Africa. Challenges and opportunities in the face of climate change. *Int. J. Climate Change Strategies Manage. 11*, 696–715.

Towfiq, S.I., Abdulqader, S.H., Ahmad, K.R., Hama, S.J. (2015). Response of grain yield and its components to organic matter and removal of some photosynthetic organs of durum wheat (*Triticum aestivum* L.) in two years of Sulaimani - Iraq region. *Int. J. Plant Anim. Environ. Sci., 5*, 134–140.

Wang, P., Zhou, G., Cui, K., Li, Z., Yu, S. (2012). Clustered QTL for source leaf size and yield traits in rice (*Oryza sativa* L.). *Mol Breeding. 29*(1): 99–113.