Journal of Plant Biota

Original Research Article
ISSN: 3048-4863
Journal homepage: https://plant.researchfloor.org/

Triticale Varieties: The Effect of Fertilizer Rates on Changes in Leaf Pigment Content

Maftuna Raimqulova[1]*, Akmal Sanakulov[1], Mahliyo Usmonova[2]

[1]Department of Plant Physiology and Microbiology, Samarkand State University named after Sharof Rashidov, Uzbekistan
[2]Uzbekistan-Finland Pedagogical Institute, Samarkand, Uzbekistan

Abstract

This study investigates the changes in leaf pigments—chlorophyll a, chlorophyll b, and carotenoids—in various triticale cultivars grown under the conditions of the Samarkand region in response to different nitrogen fertilizer rates. The pigment system of plants is one of the key factors determining the efficiency of the photosynthesis process. The results of the study showed that applying nitrogen at optimal rates enhances the synthesis and accumulation of pigments, thereby improving the physiological state of triticale cultivars. The obtained data are of significant importance for increasing triticale yield through the efficient use of nitrogen fertilizers. The nitrogen application rates tested in the experiment included: Control (unfertilized), N_{150}, N_{200}, N_{250}, and N_{300}. The study was conducted on two triticale cultivars—Odyssey and Sardor.

Keywords: *Triticale, Odyssey, Sardor, nitrogen rates, pigments, chlorophyll a, chlorophyll b, carotenoids.*

Introduction

Nowadays, the rapid growth of the world population is leading to an increased global demand for food. As a result, the need for plant-based products is also rising. In this context, special attention is being paid to the evaluation and application of the physiological and biochemical characteristics of new plant species with high productivity and nutritional potential, especially in arid and water-deficient regions. Research conducted in this direction is considered a solution to some of the most important and urgent problems. Therefore, studies aimed at producing high-quality, low-cost, and environmentally friendly agricultural products are among the most pressing issues today [1, 2].

Triticale (× *Triticosecale*) is a man-made cereal crop developed by crossing wheat and rye [2]. The name "Triticale" is derived from the combination of the scientific names of wheat (*Triticum*) and rye (*Secale*) [6].

The first hybridization was carried out in the late 1870s in Scotland, and the first fertile wheat–rye amphidiploids were obtained in 1888 by the German scientist Rimpau. A widespread triticale improvement program began in 1964, and today it is considered the main supplier of improved germplasm for national and international programs worldwide [11, 3, 8].

Triticale is a crop that is resistant to adverse environmental conditions, diseases, and high temperatures, and it adapts well to unfavorable soils and climates [5, 13]. Currently, triticale occupies a strong position in agricultural production across various countries [4]. It is mainly cultivated for grain feed and green fodder. However, in recent years, triticale grain has increasingly been used in the food and alcoholic beverage industries [7].

Photosynthesis occurs primarily in green leaves, and to a lesser extent in young shoots and unripe fruits, due to the presence of chloroplasts. Pigments found in plant tissues play a vital role in this process. In particular, chlorophylls are directly involved in all primary reactions of photosynthesis [9, 15].

Literature Review

In Uzbekistan, research on cultivating autumn triticale as a forage crop on irrigated lands, including studies on optimal sowing times, seeding rates, and fertilizer norms, has been conducted by I.V. Massino (1989). On rainfed lands, studies by M. Khayitboev (2019) and K.T. Isokov (2020) have focused on developing early-maturing breeding materials to ensure stable yields. J. Doschanov (2021) and colleagues have assessed the salt tolerance of triticale cultivars, highlighting growing scientific interest in this crop.

Several foreign and CIS scientists have also made significant contributions to triticale research. These include P. Gupta (1982), M. Mergoom (2004), A. Blum (2014), R. Agil (2014), E. Arseniuk (2015), and V.Yu. Kovtunenko (2019). In the CIS, contributions have been made by A.I. Grabovets (2000), N.V. Rogozhkina (2006), N.N. Zezin (2010), S.A. Gorchin (2012), T.A. Goryanina (2017), N.P. Shishlova (2018), and B.B. Boronchikhin (2019).

Research Object and Applied Methods

The triticale cultivars *Odyssey* and *Sardor* were selected as the experimental objects. The study was conducted under field conditions in the Samarkand region during the 2024–2025 growing seasons. All analyses, phenological observations, and calculations were carried out in accordance with established methodological guidelines. The content of pigments in the leaves was determined using the method developed by V.F. Gavrilenko, M.E. Ladigina, and L.M. Khandobin, utilizing an SF-26 spectrophotometer.

20 March 2025: Received | 19 April 2025: Revised | 18 May 2025: Accepted | 22 June 2025: Available Online

Citation: Maftuna Raimqulova, Akmal Sanakulov, Mahliyo Usmonova (2025). Triticale Varieties: The Effect of Fertilizer Rates on Changes in Leaf Pigment Content. *Journal of Plant Biota.* **147 to 150. DOI: https://doi.org/10.51470/JPB.2025.4.1.147**

Usha Nandhini Devi Harinarayanan | drushajana@rediffmail.com

Results and Discussion

Chlorophyll *a* and *b* are considered the primary pigments involved in the photosynthesis process. Additionally, carotenoid pigments—yellow, orange, and red—are present and play key roles in various physiological functions. Carotenoids protect plants from harmful environmental factors and help transfer short-wavelength light energy to chlorophyll molecules [12, 14, 16].

It was found that the content of plastid pigments and carotenoids in the leaves of triticale cultivars *Odyssey* and *Sardor* varied depending on the nitrogen fertilizer rates. The experimental data are presented in Tables 1 and 2.

The amount of plastid pigments in fresh triticale leaves changed across the different growth stages. Total chlorophyll content increased from the tillering stage to the flowering stage, then decreased during the grain ripening stage. It was also revealed that the amount of chlorophyll *a* was higher than that of chlorophyll *b* in both triticale cultivars studied.

Table 1: Content of plastid pigments (mg/g) in the leaves of the Sardor cultivar at different growth stages

Sardor cultivar						
Experimental variants	Growth stages	Chlorophylls		Carotenoids	Chl. a + Chl. b	Chl. a + Chl. b Carotenoids
		a	b			
Unfertilized control	Tillering stage	2,52	1,79	1,51	4,31	2,85
$N_{150}P_{105}K_{75}$		2,69	1,92	1,57	4,61	2,93
N_{200} $P_{140}K_{100}$		2,83	2,02	1,68	4,85	2,88
N_{250} $P_{175}K_{125}$		2,92	2,09	1,79	5,01	2,79
N_{300} $P_{210}K_{150}$		2,99	2,13	1,84	5,12	2,78
Unfertilized control	Tillering stage	2,81	1,88	1,57	4,69	2,98
$N_{150}P_{105}K_{75}$		2,99	2,13	1,63	5,12	3,14
N_{200} $P_{140}K_{100}$		3,12	2,41	1,76	4,88	2,77
N_{250} $P_{175}K_{125}$		3,18	2,44	1,86	5,62	3,02
N_{300} $P_{210}K_{150}$		3,22	2,69	1,92	5,91	3,07
Unfertilized control	Heading stage	3,04	2,34	1,61	5,38	3,34
$N_{150}P_{105}K_{75}$		3,17	2,44	1,69	5,61	3,31
N_{200} $P_{140}K_{100}$		3,29	2,35	1,81	5,64	3,11
N_{250} $P_{175}K_{125}$		3,42	2,64	1,92	6,06	3,15
N_{300} $P_{210}K_{150}$		3,56	2,75	1,99	6,31	3,17
Unfertilized control	Flowering stage	3,12	2,41	1,70	5,53	3,25
$N_{150}P_{105}K_{75}$		3,32	2,55	1,78	5,87	3,29
N_{200} $P_{140}K_{100}$		3,47	2,66	1,89	6,13	3,24
N_{250} $P_{175}K_{125}$		3,60	2,76	1,99	6,36	3,19
N_{300} $P_{210}K_{150}$		3,73	2,86	2,07	6,59	3,18
Unfertilized control	Grain ripening stage	2,73	1,96	1,82	4,69	2,57
$N_{150}P_{105}K_{75}$		2,89	2,06	1,89	4,95	2,61
N_{200} $P_{140}K_{100}$		2,96	2,11	2,01	5,07	2,52
N_{250} $P_{175}K_{125}$		3,03	2,16	2,11	5,19	2,45
N_{300} $P_{210}K_{150}$		3,11	2,22	2,19	5,33	2,43

The amount of carotenoid pigments was initially lower than that of chlorophyll *a* and *b*, but it gradually increased throughout the vegetation period. In the Sardor cultivar of triticale, during the tillering stage, total chlorophyll content varied across treatments from 4.31 mg/g to 5.12 mg/g. Chlorophyll *a* ranged from 2.52 mg/g to 2.99 mg/g, while chlorophyll *b* ranged from 1.79 mg/g to 2.13 mg/g. Carotenoid content varied from 1.51 mg/g to 1.84 mg/g depending on the fertilizer treatment. The ratio of total chlorophyll (*a + b*) to carotenoids ranged between 2.85 and 2.93.

During the stem elongation stage, the total chlorophyll content in the Sardor cultivar increased, ranging from 4.69 mg/g to 5.91 mg/g. Chlorophyll *a* content ranged from 2.81 mg/g to 3.22 mg/g, and chlorophyll *b* from 1.88 mg/g to 2.69 mg/g. Carotenoid content was lowest in the control (1.57 mg/g) and highest in the $N_{300}P_{210}K_{150}$ treatment (1.92 mg/g). Intermediate values were observed in the other variants. The chlorophyll *a + b* to carotenoid ratio ranged from 2.98 to 3.07.

At the heading stage, further increases in pigment content were recorded. Chlorophyll *a* was lowest in the control (3.04 mg/g) and highest in N_{300} $P_{210}K_{150}$ (3.56 mg/g). Chlorophyll *b* ranged from 2.34 mg/g (control) to 2.75 mg/g ($N_{300}P_{210}K_{150}$). Carotenoid levels remained lower than those of chlorophylls, ranging from 1.61 mg/g to 1.99 mg/g.

Total chlorophyll content increased from 5.38 mg/g (control) to 6.31 mg/g ($N_{300}P_{210}K_{150}$). The ratio of total chlorophyll (*a + b*) to carotenoids ranged from 3.11 to 3.34.

During the flowering stage, total chlorophyll content reached its peak compared to the other growth phases. In all treatments, pigment content increased. Total chlorophyll levels were 5.53 mg/g in the control (0.15 mg/g higher than at the heading stage), 5.87 mg/g in $N_{150}P_{105}K_{75}$ (+0.26 mg/g), 6.36 mg/g in $N_{200}P_{140}K_{100}$ (+0.30 mg/g), 6.13 mg/g in $N_{250}P_{175}K_{125}$ (+0.49 mg/g), and 6.59 mg/g in $N_{300}P_{210}K_{150}$ (+0.28 mg/g). Chlorophyll *a* content ranged from 3.12 mg/g to 3.74 mg/g, while chlorophyll *b* ranged from 2.41 mg/g to 2.86 mg/g.

At the grain ripening stage, total chlorophyll content declined across all treatments, ranging from 4.69 mg/g to 5.33 mg/g. Chlorophyll *a* content varied from 2.73 mg/g to 3.11 mg/g, and chlorophyll *b* from 1.96 mg/g to 2.22 mg/g. Carotenoid content increased, ranging from 1.82 mg/g to 2.19 mg/g depending on the fertilizer treatment. The ratio of total chlorophyll (*a + b*) to carotenoids ranged from 2.43 to 2.57.

During the tillering stage of the Odyssey cultivar, chlorophyll *a* content ranged from 2.61 mg/g to 3.04 mg/g depending on the treatment. Chlorophyll *b* content ranged from 1.87 mg/g to 2.17 mg/g, and carotenoids from 1.58 mg/g to 1.93 mg/g, indicating their active role in photosynthesis.

Total chlorophyll content varied from 4.48 mg/g to 5.21 mg/g. The ratio of total chlorophyll (*a + b*) to carotenoids ranged between 2.69 and 2.85.

In the stem elongation stage, pigment content continued to increase. Total chlorophyll ranged from 4.71 mg/g to 5.53 mg/g. Chlorophyll *a* content ranged from 2.79 mg/g to 3.31 mg/g, and chlorophyll *b* from 1.92 mg/g to 2.22 mg/g. Carotenoid content was between 1.64 mg/g and 1.99 mg/g. The ratio of total chlorophyll (*a + b*) to carotenoids ranged from 2.77 to 2.88.

Table 2: Plastid pigment content (mg/g) in leaves of the Odyssey cultivar at different growth stages

Odyssey cultivar						
Experimental variants	Growth stages	Chlorophylls		Carotenoids	Chl a + Chl b	Chl a + Chl b Carotenoids
		a	b			
Unfertilized control	Tillering stage	2,61	1,87	1,58	4,48	2,83
$N_{150}P_{105}K_{75}$		2,73	1,95	1,67	4,68	2,80
N_{200} $P_{140}K_{100}$		2,91	2,11	1,76	5,02	2,85
N_{250} $P_{175}K_{125}$		2,99	2,14	1,86	5,13	2,75
N_{300} $P_{210}K_{150}$		3,04	2,17	1,93	5,21	2,69
Unfertilized control	Tillering stage	2,79	1,92	1,64	4,71	2,87
$N_{150}P_{105}K_{75}$		2,92	1,96	1,75	4,88	2,78
N_{200} $P_{140}K_{100}$		3,19	2,14	1,85	5,33	2,88
N_{250} $P_{175}K_{125}$		3,23	2,18	1,93	5,41	2,80
N_{300} $P_{210}K_{150}$		3,31	2,22	1,99	5,53	2,77
Unfertilized control	Heading stage	3,09	2,22	1,71	5,31	3,10
$N_{150}P_{105}K_{75}$		3,22	2,31	1,82	5,53	3,03
N_{200} $P_{140}K_{100}$		3,41	2,44	1,93	5,85	3,03
N_{250} $P_{175}K_{125}$		3,51	2,51	2,02	6,02	2,98
N_{300} $P_{210}K_{150}$		3,65	2,63	2,11	6,28	2,97
Unfertilized control	Flowering stage	3,19	2,29	1,79	5,48	3,06
$N_{150}P_{105}K_{75}$		3,41	2,45	1,88	5,86	3,11
N_{200} $P_{140}K_{100}$		3,58	2,57	2,01	6,15	3,05
N_{250} $P_{175}K_{125}$		3,71	2,65	2,10	6,36	3,02
N_{300} $P_{210}K_{150}$		3,84	2,75	2,20	6,59	2,99
Unfertilized control	Grain ripening stage	2,81	2,02	1,91	4,83	2,52
$N_{150}P_{105}K_{75}$		2,96	2,13	2,02	5,09	2,51
N_{200} $P_{140}K_{100}$		3,07	2,21	2,12	5,28	2,49
N_{250} $P_{175}K_{125}$		3,12	2,22	2,23	5,34	2,39
N_{300} $P_{210}K_{150}$		3,21	2,28	2,31	5,49	2,37

During the heading stage, the pigment content continued to increase. Compared to the stem elongation stage, the total chlorophyll content in the control (unfertilized) variant increased by 0.6 mg/g, reaching 5.31 mg/g. In the Odyssey cultivar, the $N_{150}P_{105}K_{75}$ variant reached 5.53 mg/g—an increase of 0.65 mg/g over the stem elongation stage. In the $N_{200}P_{140}K_{100}$ variant, the total chlorophyll content was 6.02 mg/g, an increase of 0.61 mg/g. The $N_{300}P_{210}K_{150}$ variant showed the highest increase of 0.75 mg/g, reaching 6.28 mg/g. In the $N_{250}P_{175}K_{125}$ variant, the total chlorophyll content was 5.85 mg/g, which is 0.52 mg/g higher than in the previous stage. Carotenoid content during this stage ranged from 1.71 mg/g to 2.11 mg/g, depending on the treatment.

In the flowering stage, chlorophyll content increased further. The amount of chlorophyll *a* ranged from 3.19 mg/g to 3.84 mg/g across the variants. Chlorophyll *b* content ranged from 2.29 mg/g to 2.75 mg/g. Carotenoid content varied from 1.79 mg/g to 2.20 mg/g, depending on the treatment. The ratio of total chlorophylls (*a + b*) to carotenoids ranged from 2.99 to 3.11.

At the grain ripening stage, a decrease in chlorophyll content and an increase in carotenoids were observed. Total chlorophyll content ranged from 4.83 mg/g to 5.49 mg/g. Chlorophyll *a* ranged from 2.81 mg/g to 3.21 mg/g, while chlorophyll *b* ranged from 2.02 mg/g to 2.28 mg/g in different Odyssey variants. Carotenoid content ranged from 1.91 mg/g to 2.31 mg/g. The ratio of total chlorophylls to carotenoids during this stage ranged from 2.37 to 2.52.

Conclusion

In conclusion, the pigment content in the Triticale cultivars Odyssey and Sardor was analyzed. The amount of pigments varied depending on the growth stage. The flowering stage showed the highest chlorophyll content. As nitrogen levels increased, the amount of pigments also increased, with the $N_{300}P_{210}K_{150}$ variant yielding the best results.

References

1. Agil, R. et al. (2014). Determination of water-extractable polysaccharides in triticale bran. *Journal of Food Composition and Analysis*, pp. 12–17.

2. Эшмуродова А.А., Бўронов А.Қ. (2022). Тритикале морфологияси ва унинг келиб чиқиши. *Academic Research in Educational Sciences*, 2022–2, 496–501.

3. Galeffi, P. (2015). Food for Sustainability and Not Just Food. Florence SWIF 2015, *Agriculture and Agricultural Science Procedia*, 8, 609–616.

4. Kendal, E., Sayar, M.S., Tekdal, S., Aktas, H., & Karaman, M. (2016). Assessment of ecological factors on yield and quality in triticale using GGE biplot and AMMI analysis. *Pakistan Journal of Botany*, 48(5), 1903–1913.

5. Mergoum, M., Gómez-Macpherson, H. (2004). *Triticale Improvement and Production.* FAO.

6. Mergoum, M., Sapkota, S., El-Fatih, A., ElDolieify, A., Naraghi, M., Pirseyedi, S., Mohammed, S., Alamri, M.S., & AbuHammad, W. (2019). *Triticale (×Triticosecale Wittmack) Breeding.* Springer Nature Switzerland AG.

7. Mergoum, M., Singh, P.K., Peña, R.J., Lozano-del Río, A.J., Cooper, K.V., Salmon, D.F., Gómez Macpherson, H. (2009). Triticale: A "new" crop with old challenges. In: *Cereals*. New York: Springer, pp. 1–21.

8. Oettler, G. (2005). The fortune of a botanical curiosity—Triticale: Past, present, and future. *Journal of Agricultural Science*, 143, 329–346.

9. Oripov, R., Xalilov, N. (2006). *O'simlikshunoslik.* Toshkent: Sharq, 395 p.

10. Randhawa, H.S., Bona, L., Graf, R.J. (2015). Triticale Breeding—Progress and Prospect. In: Eudes, F. (ed.) *Triticale*, Springer, pp. 15–32.

11. Voronchikhin, V.V., Voronchikhina, I.N., Rubets, V.S., Pylnyev, V.V. (2019). Влияние наличия нижнего узла кущения на зимостойкость и урожайность озимой тритикале (×Triticosecale Wittm.). *Кормопроизводство*, №9, 31–35.

12. Xo'jayev, J.X. (2004). *O'simliklar fiziologiyasi.* Toshkent: Mehnat, 223 p.

13. Fraś, A., Golebiewska, K., Golebiewski, D., Wisniewska, M., Gzowski, M., Mankowski, D.R. (2021). Utilisation of triticale (×Triticosecale Wittmack) and residual oat flour in breadmaking. *Czech Journal of Food Science*, 39.

14. Randhawa, H.S., Bona, L., Graf, R.J. (2015). Triticale Breeding—Progress and Prospect. In: Eudes, F. (ed.) *Triticale*, Springer, pp. 226–233.

15. Tratwal, A., Bocianowski, J. (2021). Suitability of winter triticale varieties for composing crop mixtures. *Current Plant Biology*, 25, 100182.

16. Грабовец, А.И., Крохмаль, А.В. (2018). *Тритикале. Монография*. Ростов-на-Дону: Издательство Юг, 240 с.