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Effect of precipitation on the nutrient reaction of triticale varieties

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Abstract:Triticale is the first man made genus hybrid of wheat and rye. The basic aim of its production was to combine yield potential and grain quality of wheat with the disease and environmental tolerance of rye. In the past decades, triticale crop area has been increasing in Hungary, which climate change has also contributed. The triticale is produce well in dry climatic conditions, so it becomes more and more popular among farmers. Our country is the one of the top 10 triticale producing countries in the World. In the long-term fertilization experiment, at Fülöpszállás, on calcic meadow chernozem soil we carried out experiments in three growing seasons (2018/2019, 2019/2020, 2020/2021) with three winter triticale varieties (Hungaro, Mv Talentum, GK Maros,) in 4 replications, on 20 square meter random layout plots. In our experiment, we examined 15 different fertilization treatments, in every year, which can be used as different fertilization strategies. From the results of our experiments, we concluded that the yield of triticale is largely determined by genotype and nutrient supply, which is strongly influenced by the average annual precipitation. In the dry year, the effect of nutrients on yield was greater than in the rainy growing season.

Keywords: triticale, variety, nutrient supply, climatic condition, yield

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Introduction

Triticale (× *Triticosecale* Wittmack) is the first man made genus hybrid by the crossing of wheat (*Triticum* sp.) and rye (*Secale cereale*), which has been cultivated (Darvey et al., 2000; Stace, 1987). The purpose of creating triticale was to combine the productivity and good quality of wheat with the resilience of rye (Randhawa et al., 2015). Triticale has a remarkably high Mg, K, P, S, Ca, Mn, Zn, Fe, Se content (Bóna et al., 2006; Hajós, 2008; Kruppa et al., 1999). Its protein content is 12–16%, usually higher than that of wheat with low gluten proportion. The amino acid composition is good, e.g. lysine content is high (Heger & Eggum, 1991). Triticale is primarily used as feed (grain, forage, forage-mixes) (Bona et al., 2014; Gill & Omokanye, 2016; Kruppa, 2004; Wrigley & Bushuk, 2017), but it has a potential in the production of products for human consumption (Cooper, 1985; Dennett et al., 2009; Fraś et al., 2016; Woś & Brzeziński, 2015), such as flour, bread, pastas, doughs, biscuits, flakes, branas well as energy and biomass crop (Demirbas, 2007; McGoverin et al., 2011). The growing area of triticale is in the word 3.8 million ha, in Hungary 7,3 thousand ha (FAO, 2020). It has 3–6 t ha^{-1} yield, depending on production conditions (soil, climate, agrotechnic parameters etc.).

Regarding optimal growing conditions, it is between wheat and rye. Triticale prefers cool and humid climate but it has a good adabtibility: it can be grown under conditions suitable for wheat or rye (Erekul & Köhn, 2006). Earlier cultivars were grown on poor sandy soils due to their long stem but current varieties can be grown on soils of better quality without facing the problem of lodging (Kruppa, 2004). Triticale is more modest to soil than most cereals. It is usually worth growing on less favorable wheat soils, such as brown forest soils, medium-compact, meliorated meadow soils, sandy soils, and alkaline soils.

According to Kruppa (2004), triticale can be grown with extensive technology, even with small doses of N. It adapts well tot he specifics of the production area and thanks to its good nutrient utilization, we can also grow it in a production area siutable for rye. However, Kádár et al. (1999) found that triticale cannot be grown economically on acidic sandy soil without nutrient supply. Pure doses of N, P, K and NK were ineffective in themselves, but the crop increased with the NPK, NPK–Ca and NPK–Ca–Mg combinations. However, they say, increasing doses of nutrients did not cause an increase in triticale yield. According to Radics and Pusztai (2011), the nutrient supply of triticale also depends on the purpose of the farmer, as it reacts to increasing nutrient rations with an excess of yield. In a more modest area, even with smaller inputs, it is able to produce a stable crop, similar to rye. On the other hand, it is better off, and it repays the extra costs with a higher yield, similar to wheat. In line with this, statement of (Arseniuk, 2014): under high input and rainfall environments, the best triticales and wheats have comparable grain yield, with some advantage for the triticales. Therefore, more and more farmers in Hungary are growing triticale in a precision system in order to exploit the conditions of the production area, to use the input materials rationally and to manage them more cost-effectively. Knowledge of the topography, nutrient supply and water management of growing area is the basis for the precision cultivation of triticale (Habib-ur-Rahman et al., 2021).

Precipitation, nutrient supply to plants and yield are closely interrelated (Márton, 2002b). According to Kádár et al. (1999), the amount of precipitation affects the yield of triticale more than the nutrient supply. Márton (2002a); Márton (2008) found that the precipitation supply of the years has a major impact on the effectiveness of fertilization: yields of triticale decrease even in drought years and in case of excessive rainfall supply.

The aim of our study was to determine how the yield of triticale is affected by variety, nutrient supply, and year of cultivation. We were also interested in the extend to which the amount of precipitation at different times of the growing year affects the yield.

Materials and Methods

In the long-term fertilization experiment, at Fülöpszállás, on calcic meadow chernozem soil we carried out experiments in three growing seasons (2018–2019, 2019–2020, 2020–2021) with three winter triticale variety (Hungaro, Mv Talentum, GK Maros) in 4 replications, on 20 square meter random layout plots. In our experiment, we examined 15 different fertilization treatments (Table 1), in every year, which can be used as different fertilization strategies. With the applied nutrient treatments used, we can study not only the effect of the amount of nutrients, but also the effect of the ratio of nutrients.

Treatment 1 indicates plots that have been unfertilized for 40 years (untreated control). Treatments 2, 3 and 4 show nitrogen-free, phosphorus and potassium fertilization in 3 nutrient doses. Treatments 5, 6, 7 indicate plots without PK fertilized with nitrogen alone, in 3 doses. Treatments 8, 9, 10 contain a 1:1:1 ratio of N:P:K at different nutrients doses. Treatments 11., 12., 13. contain a 2:1:1 ratio of N:P:K at different doses. Treat-

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Table 1: Fertilization treatments in the experiment

No. of the treatment	Sign of treratment	N	P_2O_5	K_2O
		kg ha^{-1} active agent		
1.	$N_0P_0K_0$	0	0	0
2.	$N_0P_{30}K_{30}$	0	30	30
3.	$N_0P_{60}K_{60}$	0	60	60
4.	$N_0P_{90}K_{90}$	0	90	90
5.	$N_{30}P_0K_0$	30	0	0
6.	$N_{60}P_0K_0$	60	0	0
7.	$N_{90}P_0K_0$	90	0	0
8.	$N_{30}P_{30}K_{30}$	30	30	30
9.	$N_{60}P_{60}K_{60}$	60	60	60
10.	$N_{90}P_{90}K_{90}$	90	90	90
11.	$N_{60}P_{30}K_{30}$	60	30	30
12.	$N_{120}P_{60}K_{60}$	120	60	60
13.	$N_{180}P_{90}K_{90}$	180	90	90
14.	$N_{90}P_{30}K_{30}$	90	30	30
15.	$N_{180}P_{60}K_{60}$	180	60	60

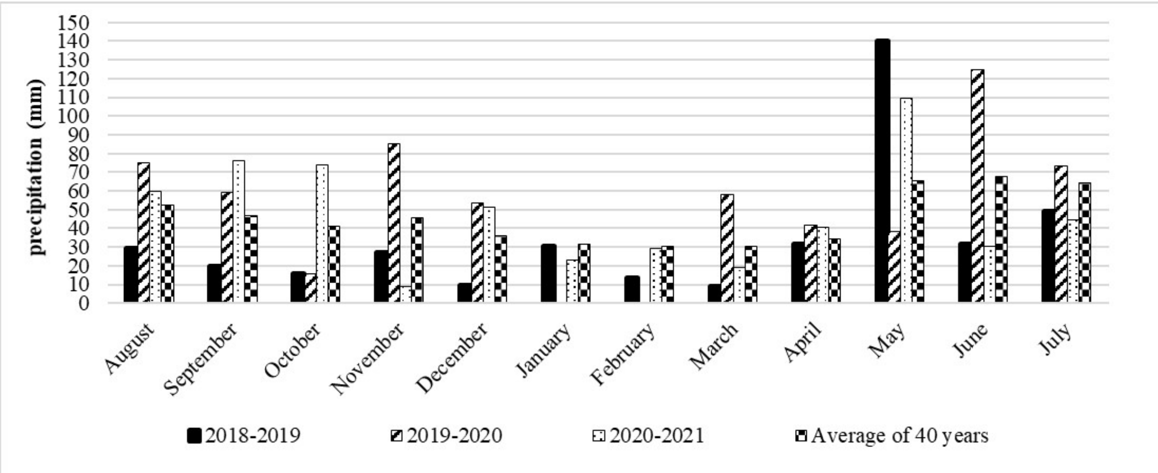

Figure 1: Monthly precipitation in 2018–2019, 2019–2020, 2020–2021 and 40 years of experimental area

ments 14., 15. contain a 3:1:1 ratio of N:P:K at different nutrients doses.

Sowing was carried out in mid-October each year at a seeding density of 4.5 million germs ha^{-1}. Sowing was carried out using a Wintersteiger type parcel seeding machine, which is suitable for sowing 8 rows simultaneously. The agrotechnical and chemical treatments of the plots in the experiment did not differ. Harvesting was performed with a Wintersteiger-type parcel harvester during the full maturation of the triticale. The monthly precipitation of the study years and the average of many years is shown in Figure

1.
The two-factor variance analysis of the annual yields (varieties and nutrient doses) and the three-factor variance analysis of the years effect were carried out using the SPSS 22 programme, the regression analysis was performed using the excel programme.

Results

Table 2 shows the precipitation discrepancies compared to 40 years average. Looking at the total vegetation period of the study years, the year 2018–2019 was drier and the year 2019–2020 more rainy than the average of many year.

In terms of precipitation supply in the autumn–winter period, the first two years were particularly lacking in precipitation, a trend that has increased in the last decade. In the spring of each study year, however, more rainfall fell than the long-term average. There was a severe lack of precipitation in 2018 and 2019 at the time of germination and one month before. There were signs of drought in the pre-harvest period: June 2019 and June 2021.

The data of the variance analysis of yield per year are shown in Table 3. In 2018–2019, the variety (A) and nutrient (B) were significant at 0.1%, while the interaction of the two factors (A×B) was not significant for yield per hectare. In the years 2019–2020 and 2020–2021, nutrient supply had a significant impact on the yield at a level of 0.1%, while the interaction between the variety and the variety × nutrient supply was not significant.

Table 4 shows the yield of three triticale varieties in 2018–2019. In terms of average nutrient treatments for varieties Hungaro and GK Maros achieved significantly higher yields than MV Talentum.

Analyzing the effect of nutrient supply on the average of varieties, it can be stated that the lowest yield was formed in unfertilized control treatment (1.40t ha^{-1}). The yield of unilateral N treatments was not statistically different from the yield of unfertilized control, however, the yield of PK treatments without N was significantly higher than that of unfertilized and unilateral N treatments. As a result of NPK treatments, the yield of triticale quadrupled compared to control, and the dose increase of complex NPK treatments increased the yield more and more. The highest yield was measured in the highest dose 2:1:1 N:P:K (180kg ha^{-1} N, 90kg ha^{-1} P, 90kg ha^{-1} K) (5.66t ha^{-1}), but from this the 90, 90, 90kg ha^{-1} NPK, 120, 60, 60kg ha^{-1} NPK, 180, 60, 60kg ha^{-1} NPK complex treatments did not differ significantly.

In 2019–2020, there was no significant difference in the yield of varieties (Table 5). The lowest yield was still measured on unfertilized parcels (1.89t ha^{-1}) and the largest yields were registered on the highest dose of 3:1:1 ratio of N:P:K treatment plots (5.96t ha^{-1}). This is little more than a triple increase in yield in a relatively rainy growing year.

In 2020–2021, there was no significant difference in the yield of varieties (Table 6). On average of varieties, the 30–30kg ha^{-1} PK treatment had the lowest yield of triticale (1.84t ha^{-1}). The yields of PK and N treatments were not statistically different from the yield of unfertilized treatment. In contrast, complex NPK treatments resulted in significantly higher yields compared to incomplete (unfertilized, N and PK) treatments. The yield decreased with increasing the dose of one-sided N treatments. In contrast, the dose increase of 1:1:1, 2:1:1 and 3:1:1 N:P:K treatments caused an increase in the yield of triticale. In our 3rd study year with average precipitation supply, the yield of triticale on the parcels 180kg ha^{-1} N, 60kg ha^{-1} P, 60kg ha^{-1} K (5.67t ha^{-1}) increased tripled compared to control.

Regarding the yield of study years in the average of varieties and nutrient treatments (Figure 2), it can be stated that the high-

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Table 2: Precipitation discrepancies compared to many years average (mm, %)

Year	Total vegetation period (October–June)		Autumn–winter period (October–February)		Spring period (March–June)		Sowing period (September–October)		Month prior to harvest (June)	
	mm	%	mm	%	mm	%	mm	%	mm	%
2018–2019	–72.24	81.09	–87.44	52.54	15.21	107.69	–52.50	40.54	–35.79	47.05
2019–2020	34.76	109.10	–29.94	83.75	64.71	132.73	–13.70	84.49	56.91	184.20
2020–2021	3.46	100.91	1.66	100.9	1.81	100.91	61.80	169.99	–37.29	44.83

Table 3: Analysis of variance for annual yields (MS)

	df	2018–2019	2019–2020	2020–2021
Repeat	3			
Total treatment	180			
Variety (A)	2	5.66***	1.0ns	0.151ns
Nutrient (B)	14	32.014***	21.935***	26.673***
Intercept: (A×B)	26	0.24ns	0.289ns	0.231ns
Error	129	0.258	0.709	0.366

*The mean difference is significant at the $P = 5\%$ level.
**The mean difference is significant at the $P = 1\%$ level.
***The mean difference is significant at the $P = 0.1\%$ level.
ns: The mean difference is non- significant.

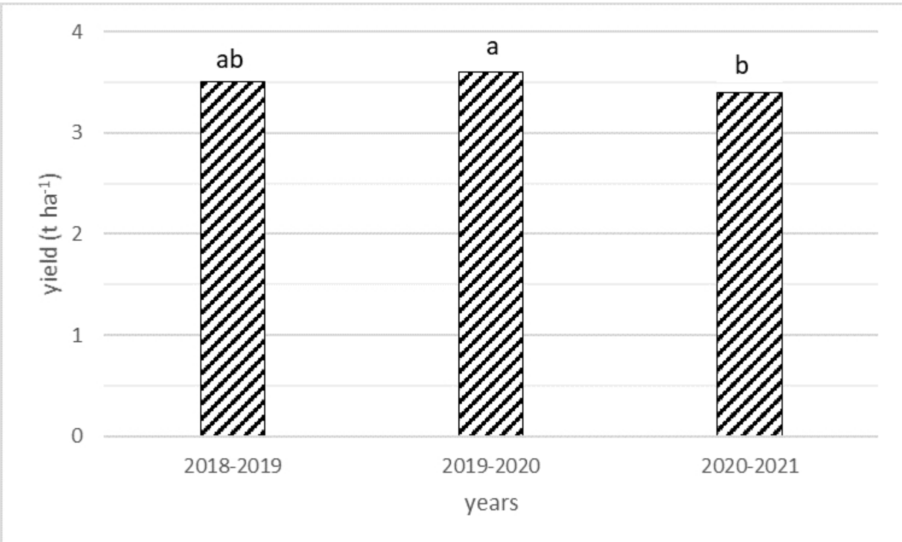

Figure 2: Yield (t ha^{-1}) of triticale in the studied years, on the average of nutrient treatments and varieties

est yield was registered in 2019–2020, from which significantly less yield was produced in 2020–2021. The yield in 2018–2019 was not statistically different from the yield of the

Table 4: Yield (t ha^{-1}) of three triticale varieties in 2018–2019

Fertilizer	Hungaro	MV Talentum	GK Maros	Average
$N_0P_0K_0$	1.40	1.37	1.44	1.40^a
$N_0P_{30}K_{30}$	2.66	2.29	2.65	2.53^b
$N_0P_{60}K_{60}$	2.96	2.55	3.17	2.89^b
$N_0P_{90}K_{90}$	2.80	2.39	2.97	2.72^b
$N_{30}P_0K_0$	1.58	1.45	1.70	1.58^a
$N_{60}P_0K_0$	1.47	1.33	1.64	1.48^a
$N_{90}P_0K_0$	1.36	1.28	1.65	1.43^a
$N_{30}P_{30}K_{30}$	4.04	3.44	4.06	3.85^c
$N_{60}P_{60}K_{60}$	4.98	3.90	4.90	4.59^d
$N_{90}P_{90}K_{90}$	6.05	4.83	5.54	5.48^e
$N_{60}P_{30}K_{30}$	4.01	3.79	4.02	3.94^c
$N_{120}P_{60}K_{60}$	5.62	4.97	6.33	5.64^e
$N_{180}P_{90}K_{90}$	6.23	5.13	5.62	5.66^e
$N_{90}P_{30}K_{30}$	4.01	3.64	4.28	3.98^c
$N_{180}P_{60}K_{60}$	5.64	5.03	5.90	5.52^e
Average	3.65^A	3.16^B	3.72^A	

Table 5: Yield (t ha^{-1}) of three triticale varieties in 2019–2020

Fertilizer	Hungaro	MV Talentum	GK Maros	Average
$N_0P_0K_0$	1.77	1.81	2.10	1.89^a
$N_0P_{30}K_{30}$	1.90	2.20	2.23	2.11^{ab}
$N_0P_{60}K_{60}$	2.33	2.82	3.44	2.86^c
$N_0P_{90}K_{90}$	2.08	2.31	3.24	2.54^{ac}
$N_{30}P_0K_0$	2.60	2.69	2.81	2.70^{bc}
$N_{60}P_0K_0$	2.44	2.28	2.62	2.45^{ac}
$N_{90}P_0K_0$	2.38	2.46	2.57	2.47^{ac}
$N_{30}P_{30}K_{30}$	3.09	2.69	3.37	3.05^{cd}
$N_{60}P_{60}K_{60}$	4.11	4.53	4.35	4.33^e
$N_{90}P_{90}K_{90}$	5.13	5.07	4.85	5.02^f
$N_{60}P_{30}K_{30}$	3.81	3.64	3.52	3.66^d
$N_{120}P_{60}K_{60}$	5.04	5.15	4.98	5.06^{fg}
$N_{180}P_{90}K_{90}$	5.39	5.83	5.92	5.71^{gh}
$N_{90}P_{30}K_{30}$	4.43	4.26	3.95	4.21^{ed}
$N_{180}P_{60}K_{60}$	5.62	6.24	6.02	5.96^h
Average	3.47^A	3.60^A	3.73^A	

next two years.

In Table 7, we can study the results of the regression analysis (r^2 values) of precipitation and the yield of triticale at different de-

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Table 6: Yield (t ha^{-1}) of three triticale varieties in 2020–2021

Fertilizer	Hungaro	MV Talentum	GK Maros	Average
$N_0P_0K_0$	1.85	1.98	1.83	1.89^{ab}
$N_0P_{30}K_{30}$	1.87	1.78	1.87	1.84^{ab}
$N_0P_{60}K_{60}$	1.95	1.83	2.08	1.95^{ab}
$N_0P_{90}K_{90}$	1.75	1.59	1.86	1.74^{a}
$N_{30}P_0K_0$	2.13	2.57	2.19	2.30^{b}
$N_{60}P_0K_0$	1.94	2.62	2.16	2.24^{ab}
$N_{90}P_0K_0$	1.81	2.17	2.05	2.01^{ab}
$N_{30}P_{30}K_{30}$	3.24	3.28	3.59	3.37^{c}
$N_{60}P_{60}K_{60}$	3.90	3.55	4.25	3.90^{d}
$N_{90}P_{90}K_{90}$	4.33	4.19	4.12	4.21^{def}
$N_{60}P_{30}K_{30}$	4.61	4.39	4.37	4.46^{ef}
$N_{120}P_{60}K_{60}$	5.73	5.11	5.31	5.38^{g}
$N_{180}P_{90}K_{90}$	5.64	5.2	5.50	5.59^{g}
$N_{90}P_{30}K_{30}$	4.37	4.48	4.58	4.48^{f}
$N_{180}P_{60}K_{60}$	5.06	6.09	5.86	5.67^{g}
Average	3.34^{A}	3.42^{A}	3.44^{A}	

velopmental periods depending on fertilizer treatments. Based on the average of fertilizer treatments, it can be stated that the amount of precipitation in the spring period, that is, during the period of intensive growth of plant, basically determines the amount of yield. If the herd is in drought during this period, it will not be able to compensate for it later. The amount of precipitation in the month before the harvest, the ripening period (June), also strongly influences the yield of triticale. The effect of the ripening period on yields can be observed mainly in drought years. Extreme high temperature and drought in the early stages of crop development can lead to forced ripening, incomplete grain filling and to the formation of poor quality shrivelled grains of low 1000 kernel weight. The data of Table 7 show that the Autumn–Winter period and the sowing period are even less determinant in terms of triticale yield. The lack of precipitation during these periods can be compensated some extent by the autumn cereals with a large supply of precipitation later on. It can be stated that the amount of precipitation in each period (critical periods), the distribution of precipitation is much more important for the yield of triticale than the amount of precipitation for the entire growing season. It can be seen from the data in the Table 7 that the result of the correlation between precipitation and yield (r^2 values) is significantly determined by the fertilizer treatments, ie the negative effects of precipitation can be offset by the appropriate nutrient supply.

Discussion

In addition to the soil conditions, the climate fundamentally determines the ecological potential of the given production area, such as the range of plants that can be grown there and the efficiency of cultivation. The impact of climate change are increasingly being felt in crop production: the frequency of drought and excessively rainy periods is increasing, adverse weather effects often occur during the critical development stages of

Table 7: Correlation between the amount of precipitation in certain periods and the yield of triticale (r^2 value) in different fertilization treatments (2018–2021)

Fertilizer treatments	Total vegetation period (October–June)	Autumn–winter period (October–February)	Spring period (March–June)	Sowing period (September–October)	Month prior to harvest (June)
$N_0P_0K_0$	0.1618	0.1058	0.8701	0.2478	0.5669
$N_0P_{30}K_{30}$	0.1973	0.0962	0.8983	0.1121	0.6082
$N_0P_{60}K_{60}$	0.1683	0.1131	0.7235	0.2369	0.6063
$N_0P_{90}K_{90}$	0.1555	0.0807	0.7523	0.1298	0.6709
$N_{30}P_0K_0$	0.2947	0.2968	0.7664	0.2319	0.5854
$N_{60}P_0K_0$	0.2931	0.2512	0.7157	0.3748	0.5295
$N_{90}P_0K_0$	0.2721	0.2910	0.6717	0.3571	0.6768
$N_{30}P_{30}K_{30}$	0.3848	0.1467	0.6160	0.3906	0.6347
$N_{60}P_{60}K_{60}$	0.3432	0.1290	0.9132	0.4213	0.6974
$N_{90}P_{90}K_{90}$	0.3210	0.1241	0.8994	0.4287	0.6993
$N_{60}P_{30}K_{30}$	0.4136	0.2544	0.7774	0.6923	0.7036
$N_{120}P_{60}K_{60}$	0.4145	0.3454	0.7186	0.6757	0.7901
$N_{180}P_{90}K_{90}$	0.4249	0.3190	0.8110	0.6512	0.7439
$N_{90}P_{30}K_{30}$	0.5423	0.3541	0.9615	0.6020	0.7770
$N_{180}P_{60}K_{60}$	0.5359	0.3366	0.9309	0.6249	0.7788
Average of fertilizer treatments	0.3892	0.1683	0.8587	0.4869	0.6541

our plants, which leads not only to crop decline, but also to uneconomical cultivation. Recently, mainly the autumn-winter precipitation is lower than usual (Márton, 2002b), which is confirmed by our research data. Farmers need to adapt to the changed conditions, so they need to grow crops and mitigate climate damage by using appropriate species or varieties and using agrotechnical factors. Farmers who can adapt to the changed conditions can not only reduce the damage, but also gain a significant competitive advantage over other farmers. Growing triticale is a very good choice for farmers in the face of climate change. It is produce well in dry climatic and poorer soil conditions, so it becomes more and more popular among farmers (Kruppa, 2004; Radics & Pusztai, 2011). At the same time, the variety selection may also be important, as Abdelaal et al. (2019) showed that different triticale varieties had different nutrient reactions. Although we used three different varieties of genetic origin in our experiment, we found that the effect of the variety was much less pronounced in crop yields than the effect of the nutrient or the precipitation supply of the years. That is, the applied agrotechnical element, the nutrients supply significantly determines the yield of triticale. This is in line with the findings of Gill and Omokanye (2016); Kádár et al. (1999); Kruppa (2004). In our study, the yield loss of crops of the unfertilized control and one-sided N-managed parcels was relatively large in the 2018–2019, the rain-deficient year, but the mitigation effect of the complex NPK treatments prevailed. The yield of triticale in the complex NPK-treated parcels compared to the control increased fourfold in the dry year,

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while increased only tripled in the average or rainy year. So, in the drier year, the relative effect of nutrients on yield was greater than in the rainy growing season.

However, based on our results, we can state that the precipitation volume of the whole vegetation period is less decisive for the yield of triticale than the precipitation of the individual periods (critical periods). That is, during the growing season, the distribution of precipitation plays a much greater role in the production of triticale than the amount of precipitation for the entire growing season.

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