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ORIGINAL PAPER

THE DYNAMICS OF UPTAKE AND UTILISATION OF NITROGEN FROM MINERAL FERTILISER BY SPRING TRITICALE CALCULATED BY ISOTOPIC DILUTION METHOD[1]

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Abstract

Nitrogen is a macronutrient that increases crop yields the most, but its high doses and low uptake by plant may have a negative impact on the environment. The aim of the study was to evaluate the dynamics of nitrogen uptake and utilisation from the mineral fertiliser and from the soil by spring triticale (*Triticosecale* Wittm. ex A. Camus) calculated by the isotopic dilution method. The first experimental factor was the application of the total nitrogen dose of 120 kg N ha^{-1} as follows: a whole dose 120 kg N ha^{-1} pre-sowing, 60 kg pre-sowing and 60 kg at 35 BBCH, 40 kg pre-sowing and 40 kg at 22 BBCH and 40 kg at 51 BBCH. The second factor was the growing stage of triticale, according to BBCH: 22, 34, 51, 65, 75 and 92. Nitrogen was applied in the form of $(NH_4)_2SO_4$ with excess of isotope ^{15}N of 5%. Following the application of a single nitrogen dose, spring triticale took up 65.05 kg N ha^{-1} from the fertiliser, and the utilisation coefficient of N amounted to 54.3%. The split application of the total amount of fertiliser divided into two and three doses increased the amount of nitrogen taken up from the fertiliser by 7.31 and 14.90 kg N ha^{-1}, respectively, and the value of the coefficient of its utilisation rose by 6.0 and 12.4%, respectively. The amount of this element taken up from the soil reserves was not dependent on the test variants of nitrogen fertilisation. A significant increase of the uptake and utilisation of nitrogen from the fertiliser by triticale was obtained from BBCH stage 22 to stage 65. From BBCH stage 65 to stage 92, no significant increase in the amount of nitrogen taken up from these sources or in the value of the coefficient of utilisation was noted.

Keywords: ammonium sulphate, field experiment, isotope ^{15}N, mineral fertiliser, nitrogen accumulation, nitrogen uptake, triticosecale.

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INTRODUCTION

An adequate level of nitrogen nutrition significantly influences the intensity of plant photosynthesis and biomass accumulation (Sieling et al. 2016). In the cultivation of cereals, achieving an optimal supply of nitrogen is most frequently possible by means of providing this component in the form of mineral fertilisers (Gulmezoglu, Aytac 2010, Nefir, Tabără 2011). In the production of spring triticale, the dose of 90-120 kg N ha^{-1} is assumed to be an economically and environmentally optimal amount of nitrogen (Knapowski et al. 2009, Janušauskaitė 2013, Wojtkowiak et al. 2014). A portion of nitrogen that is not taken up by plants can be moved with precipitation water down the soil profile, and then it poses a threat to the natural environment (Sestak et al. 2014, Zheng et al. 2016). The problem of nitrogen migration can be particularly evident in agricultural farms specialising in the intensive production of cereals with large inputs of nitrogen fertiliser. In order to determine the utilisation of nitrogen from fertiliser applied to the soil by plants, the differential method which assumes that both a fertilised plant and a non-fertilised plant takes up equal amounts of this element from the soil reserves can be applied. This is the so-called apparent utilisation. More specifically, the value of the nitrogen utilisation coefficient can be determined by applying the isotopic dilution method based on the introduction of ^{15}N isotope into the soil (Kalembasa 1989, Unkovich et al. 2008, Kalembasa et al. 2015).

Scenarios for 2050 predict that the demand for cereals in the world will increase by 42-59%, and that the prices will rise by 13-30% (Fischer et al. 2014). Spring triticale arouses considerable interest in farmers cultivating cereals for feed, as it is more tolerant of poorer soil and phytosanitary conditions as well as the poorer position in the crop rotation than spring wheat. In addition, the spring form is sometimes better adapted to the local conditions than the winter form (Santiveri et al. 2004).

The aim of the study was to determine the dynamics of uptake and utilisation of nitrogen from mineral fertiliser by spring triticale, by the isotopic dilution method and with ^{15}N used in the experiment.

MATERIAL AND METHODS

The study was carried out in 2015 - 2017, in Siedlce (N52°17′, E22°30′), eastern Poland. The experiment was conducted on slightly acidic soil representing the textural class of loamy sand (Table 1). Plots of an area of 4 m^2 (2 × 2 m) were marked out in a field of spring triticale grown in a traditional soil cultivation system. The triticale variety Milewo was cultivated in a two-factor experiment set up in a split-plot arrangement with three replications. The first factor (A) was the application of a dose of 120 kg N ha^{-1} to the soil

Table 1

Selected properties of sand soil

Parameter	Unit	Years		
		2015	2016	2017
pH in1 mol KCl dm^{-3}	–	5.8	5.8	5.9
C_{org}	(g kg^{-1})	10.5	10.4	10.2
N_{total}		0.69	0.62	0.67
P_{Egner}	(mg kg^{-1})	51.6	47.2	48.5
K_{Egner}		90.9	94.3	88.1
$Mg_{Schachtschabel}$		37.6	33.8	37.0

supplied as follows: A1 – a single treatment, immediately before grain sowing, 120 kg N ha^{-1}; A2 – the application of 2 equal parts, of 60 kg N ha^{-1} each, as a pre-sowing application and at BBCH stage 34; and A3 – the application of 3 equal parts of 40 kg N ha^{-1} each, as a pre-sowing application, at BBCH stages 22 and 51. The second factor (B) was the growth stages of triticale (according to the BBCH scale): B1-22, B2-34, B3-51, B4-65, B5-75, and B6-92. Mineral nitrogen was introduced into the soil in the form of $(NH_4)_2SO_4$ with ^{15}N excess of 5%. Phosphorus and potassium were applied pre-sowing at doses of 40 kg P ha^{-1} (triple superphosphate), and 120 kg K ha^{-1} (potassium salt). Seed sowing was carried out in the beginning of April in an amount of 2000 germinating seeds per 4 m^2. Weed control spraying was applied at BBCH stage 22 with a mixture of MCPA and dicamba. The plants were harvested manually by digging them up from the soil with a spade, to the depth of 25 cm. The plants harvested from BBCH stage 22 to stage 51 were separated into the roots and the aerial parts; those harvested at BBCH stage 65 were separated into the roots, stems, and flowering spike; while those harvested at BBCH stages 75 and 92 were separated into the roots, straw, chaff and grains. In each plant sample, the following were determined: dry matter yield (DM in 105°C), nitrogen content (Kjeldahl method) and ^{15}N excess (NOI-6e emission spectrometer, Carl Zeiss Jena).

The amount of nitrogen taken up by spring triticale from the fertiliser and soil, and the values of its utilisation coefficient were calculated by the isotope dilution method according to the formulas provided by Kalembasa (1989).

Nitrogen uptake from fertiliser (*NUff*):

$$NUff = TNUf\,\frac{A-B}{C}$$

TNUf – total nitrogen uptake by plants fertilised with nitrogen,
A – excess of ^{15}N in the plants fertilised with nitrogen,
B – excess of ^{15}N in the plants not fertilised with nitrogen, in our study assumed “0”,
C – excess of ^{15}N in applied fertiliser.

Nitrogen uptake from soil (*NUfs*):

$$NUfs = TNUf - NUff$$

TNUf – total nitrogen uptake by plants fertilised with nitrogen,
NUff – nitrogen uptake from fertiliser

Utilisation coefficient of nitrogen (wwN[%]):

$$\text{wwN}[\%] = \frac{NUff}{Naf} \cdot 100,$$

NUff – nitrogen uptake from fertiliser,
Naf – the amount of nitrogen applied with fertiliser.

Nitrogen utilisation by triticale was calculated for its total dose that was introduced into the soil in the studied growth stage. The amount of this macronutrient taken up by triticale from other sources than mineral fertiliser is described in the study as originating from the soil reserves.

The results of the experiments were analysed by ANOVA. The significance of sources of variation was checked with the Fisher-Snedecor test, and mean values were separated with the Tukey's test at the significance level of $P \leq 0.05$. For these calculations the Statistica 12 PL (StatSoft) and MS Excel software were used.

The growing seasons in 2015 - 2017 were average for the growth, development and yielding of spring triticale (Figure 1). The total amount of precipitation was satisfactory for meeting the plant's needs, although it was not properly distributed in particular months. The least favourable year was 2016, when, besides a significant water deficit during the intensive growth of triticale (May - June), slightly higher temperatures than those in 2015 and 2017 were additionally noted during this growing season.

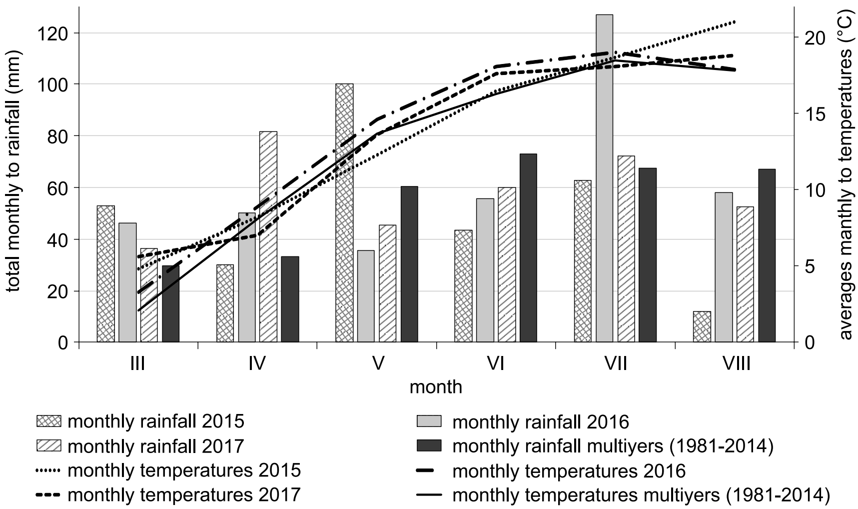

Fig. 1. Rainfall and air temperatures in Siedlce, IMGW PIB Warszawa

RESULTS

Spring triticale weight

The split application of the nitrogen dose had no significant effect on the weight of the roots and on the total mass of spring triticale harvested at the full maturity stage (Table 2). The largest mass of flowering spikes, chaff and grains was obtained following the application of nitrogen at three doses of 40 kg ha^{-1} each, while the most straw was obtained following the pre-sowing application of the whole dose of nitrogen (120 kg ha^{-1}). An increase in the amount of mass of the roots and stems was observed to the stage of milky maturity of the grain. The weight of these organs of the triticale harvested at the full maturity stage was lower than that at the milky maturity stage and was similar to that at the flowering stage. The total amount of triticale mass increased from the tillering stage to the full maturity stage. The yield of the grain, the weight of flowering spike and chaff, and the total mass of triticale were the greatest in 2015 and the smallest in 2017.

Table 2

The amount of dry mass (DM) of spring triticale (Mg ha^{-1})

Treatment		Part of plant					Total mass
		root	straw	spike	chaff	grain	
Growth stage BBCH	22	0.276*a*	0.459*a*				0.735*a*
	35	1.073*b*	2.125*b*				3.198*b*
	51	1.447*c*	3.627*c*				5.074*c*
	65	1.632*d*	4.012*d*	1.623			7.267*d*
	75	1.890*e*	4.669*e*		0.530*b*	2.338*a*	9.427*e*
	92	1.513*cd*	4.390*ed*		0.441*a*	4.245*b*	10.589*f*
Nitrogen dose division (data refer to 92 BBCH, spike in 65 BBCH)	A1	1.498*a*	4.583*b*	1.609*a*	0.426*a*	3.989*a*	10.496*a*
	A2	1.529*a*	4.292*a*	1.597*a*	0.444*ab*	4.274*ab*	10.539*a*
	A3	1.512*a*	4.311*a*	1.662*b*	0.460*b*	4.482*b*	10.765*a*
Years of study (data refer to 92 BBCH, spike in 65 BBCH)	2015	1.685*b*	4.744*b*	1.812*c*	0.541*c*	5.187*c*	12.157*c*
	2016	1.453*a*	3.925*a*	1.420*a*	0.368*a*	3.318*a*	9.064*a*
	2017	1.401*a*	4.518*b*	1.636*b*	0.420*b*	4.239*b*	10.578*b*

a, *b*, *c*, …– averages with different letters in the columns are significantly different

Nitrogen content and ^{15}N isotope excess in the spring triticale's mass

The distribution of the nitrogen dose and its application into the soil on various dates had no significant effect on the nitrogen content, on the ^{15}N isotope excess of all organs and, on average, on the entire plant of triticale harvested at the full maturity stage (Tables 3 and 4). The ^{15}N isotope enrichment in the test plant was not significantly dependent on the growth stage

Table 3

The content of nitrogen (N) in spring triticale (g kg^{-1})

Treatment		Part of plant					Meanly in plant*
		root	straw	spike	chaff	grain	
Growth stage BBCH	22	16.32*d*	49.16*f*				36.95*d*
	35	17.32*d*	26.58*e*				23.56*c*
	51	16.93*d*	23.00*d*				21.42*c*
	65	13.16*c*	19.40*c*	20.41			18.31*b*
	75	9.70*b*	13.60*b*		17.02*b*	21.34*a*	14.96*a*
	92	7.49*a*	7.86*a*		11.61*a*	21.97*a*	13.68*a*
Nitrogen dose division (data refer to 92 BBCH, spike in 65 BBCH)	A1	7.13*a*	7.60*a*	18.63*a*	11.47*a*	21.43*a*	12.98*a*
	A2	7.53*a*	7.80*a*	20.20*a*	11.57*a*	22.03*a*	13.75*a*
	A3	7.80*a*	8.17*a*	22.40*b*	11.80*a*	22.43*a*	14.27*a*
Years of study (data refer to 92 BBCH, spike in 65 BBCH)	2015	8.13*a*	8.37*a*	21.17*a*	12.67*b*	21.60*a*	14.56*b*
	2016	6.90*a*	7.47*a*	19.47*a*	10.53*a*	21.80*a*	12.67*a*
	2017	7.43*a*	7.73*a*	20.60*a*	11.63*ab*	21.97*a*	13.50*ab*

* weighted averages

Table 4

Excess of ^{15}N isotope in spring triticale (% ^{15}N)

Treatment		Part of plant					Meanly in plant*
		root	straw	spike	chaff	grain	
Growth stage BBCH	22	2.37*a*	2.37*a*				2.37*a*
	35	2.50*a*	2.58*a*				2.55*a*
	51	2.51*a*	2.53*a*				2.52*a*
	65	2.55*a*	2.59*a*	2.61			2.59*a*
	75	2.52*a*	2.53*a*		2.52*a*	2.53*a*	2.53*a*
	92	2.47*a*	2.51*a*		2.52*a*	2.53*a*	2.51*a*
Nitrogen dose division (data refer to 92 BBCH, spike in 65 BBCH)	A1	2.36*a*	2.40*a*	2.53*a*	2.42*a*	2.42*a*	2.40*a*
	A2	2.46*a*	2.50*a*	2.59*a*	2.52*a*	2.54*a*	2.51*a*
	A3	2.59*a*	2.64*a*	2.71*a*	2.62*a*	2.64*a*	2.63*a*
Years of study (data refer to 92 BBCH, spike in 65 BBCH)	2015	2.28*a*	2.29*a*	2.42*a*	2.31*a*	2.31*a*	2.30*a*
	2016	2.61*a*	2.69*a*	2.71*a*	2.66*a*	2.71*a*	2.68*a*
	2017	2.52*a*	2.57*a*	2.70*a*	2.59*a*	2.58*a*	2.57*a*

* weighted averages

or on the years of the study. The average nitrogen content in the triticale decreased from BBCH stage 22 to stage 75. The average content of this nutrient in the whole plant at the milky maturity and full maturity stages was similar. The nitrogen content of the stems decreased steadily from

BBCH stage 22 to stage 92. The content of this element in the roots decreased from BBCH stage 51 to stage 92, while at BBCH stages from 22 to 51 it was similar.

The amount of nitrogen taken up by spring triticale from the fertiliser and from other sources

The division of the total dose of nitrogen applied in the fertilisation, and its introduction into the soil in different growth stages had no significant effect on the amount of nitrogen taken up from the soil reserves (other sources then fertiliser) (Table 5). Most nitrogen from the fertiliser was taken up by triticale fertilised in the 40+40+40 kg N ha^{-1} variant on 3 dates (79.95 kg N ha^{-1}), less in the 60+60 kg N ha^{-1} variant on 2 dates (72.36 kg N ha^{-1}) and the least following the pre-sowing application of the entire dose (65.05 kg N ha^{-1}) – Table 6. The amount of nitrogen from the fertiliser, accumulated in particular organs of this cereal, was also the largest after nitrogen fertilisation in three doses of 40 kg ha^{-1} each, while being the smallest after the introduction of the whole dose as a pre-sowing application. The amount of nitrogen taken up from the fertiliser as well from soil resources increased from BBCH stage 22 to stage 65 (from 12.96 to 68.59 kg ha^{-1} from the fertiliser, and from 14.20 to 64.46 kg ha^{-1} from the soil reserves). At BBCH stages from 65 to 91, the amount of nitrogen taken up from both sources did not change significantly. Approximately two thirds of the amount of nitrogen taken up from the fertiliser (64.8%) and from the soil reserves (64.5%) were accumulated by triticale in the grain. The largest amount of nitrogen from both sources in question was taken up by the triticale cultivated in 2015, a smaller amount in 2017, and the smallest amount in 2016.

Table 5

The amount of nitrogen (N) taken up by spring triticale from fertiliser (kg ha^{-1})

Treatment		Part of plant					Total
		root	straw	spike	chaff	grain	
Growth stage BBCH	22	2.14*a*	10.82*a*				12.96*a*
	35	9.31*c*	29.33*b*				38.64*b*
	51	12.20*d*	42.38*c*				54.58*c*
	65	10.95*cd*	40.34*c*	17.30			68.59*d*
	75	9.25*c*	32.02*b*		4.53*b*	25.15*a*	70.95*d*
	92	5.59*b*	17.29*b*		2.59*a*	46.99*b*	72.46*d*
Nitrogen dose division (data refer to 92 BBCH, spike in 65 BBCH)	A1	5.03*a*	16.66*a*	15.10*a*	2.36*a*	41.00*a*	65.05*a*
	A2	5.66*b*	16.68*a*	16.66*a*	2.58*ab*	47.44*b*	72.36*b*
	A3	6.07*c*	18.52*b*	20.14*b*	2.84*b*	52.52*c*	79.95*c*
Years of study (data refer to 92 BBCH, spike in 65 BBCH)	2015	6.27*b*	18.16*b*	18.63*b*	3.17*c*	54.03*c*	81.63*c*
	2016	5.23*a*	15.72*a*	14.98*a*	2.06*a*	38.84*a*	61.85*a*
	2017	5.26*a*	17.97*b*	18.30*b*	2.55*b*	48.09*b*	73.87*b*

Table 6

The amount of N taken up by spring triticale from soil, other sources than fertiliser (kg ha^{-1})

Treatment		Part of plant					Total
		root	straw	spike	chaff	grain	
Growth stage BBCH	22	2.37*a*	11.83*a*				14.20*a*
	35	9.27*b*	27.45*c*				36.72*b*
	51	12.35*c*	41.78*d*				54.13*c*
	65	10.63*bc*	37.87*d*	15.96			64.46*d*
	75	9.16*b*	31.46*c*		4.54*b*	24.92*a*	70.08*d*
	92	5.79*a*	17.33*b*		2.62*a*	46.71*b*	72.45*d*
Nitrogen dose division (data refer to 92 BBCH, spike in 65 BBCH)	A1	5.70*a*	18.26*a*	14.98*a*	2.56*a*	44.62*a*	71.14*a*
	A2	5.92*a*	16.90*a*	15.73*a*	2.62*a*	47.12*a*	72.56*a*
	A3	5.77*a*	16.85*a*	17.18*a*	2.67*a*	48.39*a*	73.68*a*
Years of study (data refer to 92 BBCH, spike in 65 BBCH)	2015	7.44*b*	21.5*c*	19.79*c*	3.69*c*	62.79*c*	95.42*c*
	2016	4.79*a*	13.56*a*	12.62*a*	1.82*a*	32.85*a*	53.02*a*
	2017	5.15*a*	16.95*b*	15.46*b*	2.35*b*	44.49*b*	68.94*b*

Nitrogen utilisation from the fertiliser by spring triticale

The greatest utilisation of nitrogen from the fertiliser by triticale was noted following fertilisation in the 40+40+40 kg N ha^{-1} variant (66.7%), smaller in the 60+60 kg N ha^{-1} variant (60.3%), and the smallest following the pre-sowing application of the entire dose of 120 kg N ha^{-1} (54.3%) – Table 7. Nitrogen utilisation increased from BBCH stage 22 to stage 51 of triticale. Having analysed the utilisation of nitrogen from the BBCH growth stage 51 to stage 92, significant differences were only noted for the first and the last value considered, which amounted to 53.1 and 60.5%, respectively. Between BBCH development stage 75 and stage 91, the noted value of the coefficient of nitrogen use for the grain increased almost two-fold (from 21.0 to 39.2%). The value of this coefficient was the highest in 2015, lower in 2017 and the lowest in 2016.

DISCUSSION

The yield of grain of spring triticale depends on the level of agrotechnology applied and the weather conditions, and most often ranges from 2.50 to 5.50 Mg ha^{-1} (Nieróbca 2002, Jaśkiewicz 2009, Janušauskaitė 2013). Lestingi et al. (2010) report that in the conditions of their experiment the yield of 4.0 Mg ha^{-1} can be obtained already after an application of 50 kg N ha^{-1}, but increasing the dose of this nutrient up to 100 kg N ha^{-1} did not significantly increase the amount of triticale's grain. In the current study,

Table 7

The values of nitrogen utilisation coefficient by spring triticale (%)

Treatment		Part of plant					Total
		root	straw	spike	chaff	grain	
Growth stage BBCH	22	3.4*a*	16.9*a*				20.3*a*
	35	11.4*c*	35.4*c*				46.8*b*
	51	11.9*c*	41.2*d*				53.1*c*
	65	9.1*bc*	33.6*c*	14.4			57.1*cd*
	75	7.7*b*	26.7*b*		3.8*b*	21.0*a*	59.2*cd*
	92	4.7*a*	14.4*a*		2.2*a*	39.2*b*	60.5*d*
Nitrogen dose division (data refer to 92 BBCH, spike in 65 BBCH)	A1	4.2*a*	13.9*a*	12.6*a*	2.0*a*	34.2*a*	54.3*a*
	A2	4.7*b*	13.9*a*	13.9*a*	2.2*ab*	39.5*b*	60.3*b*
	A3	5.1*c*	15.4*b*	16.8*b*	2.4*b*	43.8*c*	66.7*c*
Years of study (data refer to 92 BBCH, spike in 65 BBCH)	2015	5.2*b*	15.1*b*	15.5*b*	2.6*c*	45.0*c*	67.9*c*
	2016	4.4*a*	13.1*a*	12.5*a*	1.7*a*	32.4*a*	51.6*a*
	2017	4.4*a*	15.0*b*	15.2*b*	2.1*b*	40.1*b*	61.6*b*

the yield of the grain of almost 4 Mg ha^{-1} was obtained following the pre-sowing application of the entire dose of nitrogen (120 kg ha^{-1}). The division of this dose of nitrogen into three parts of 40 kg·ha^{-1} each, and its application on three dates resulted in an increase in the yield of the grain by approximately 0.5 Mg ha^{-1}. Triticale is regarded as a plant with relatively small water requirements (Uprety, Sirohi 1987, Okuyama 1990, Jessop 1996). A decrease in the amount of the harvested grain of spring triticale is caused by the very dry and extremely dry weather conditions, both during the period from the heading stage to the waxy ripeness stage and during the entire period from sowing to the waxy ripeness stage (Kalbarczyk 2010, Janušauskaitė 2013). According to Koziara (1996) and Koziara et al. (2007), the yield of triticale grain is mostly determined by the amount of rainfall in the months of May and June, and not by the thermal conditions. The lowest yields of the grain as well as the smallest amount of nitrogen taken up from both sources and the use of nitrogen from the mineral fertiliser were noted in 2016, in which the total precipitation in May and June was the lowest (91.1 mm). On the other hand, the highest yields of the grain as well as the highest amount of nitrogen taken up from both sources and the use of nitrogen from the fertiliser were noted in 2015, in which the total precipitation in the months of May and June was significantly higher (143.5 mm). The yields of the grain obtained in these years (in kg ha^{-1}), divided by the total rainfall (in mm) in May and June, provided similar values that amounted to 36.4 and 36.2, respectively.

In the studies conducted by Wysokiński (2013), Wysokiński et al. (2014), and Kalembasa et al. (2015), the largest amounts of nitrogen were taken up by spring triticale from the soil reserves, irrespective of the preceding crop or the dose of this macronutrient applied in fertilisers. The authors indicated the high nitrogen content of the soil on which the test crop was cultivated as the cause of such a situation. In addition, favourable weather conditions (e.g. humidity, temperature) during the growing period could have been conducive to the mineralization of organic compounds present in the soil, and additionally increased the pool of nitrogen available to the plants, as indicated by Porporato et al. (2003) and by Robertson and Groffman (2007). In our study carried out on soil with a rather low nitrogen content, the amounts of this element taken up by spring triticale from the soil reserves and from mineral fertiliser were similar. Under these conditions, the amount of nitrogen taken up from the fertiliser, and thus the values of the coefficient of the use, were favourably affected by splitting the entire dose of nitrogen and its use at various stages of growth. Wysokiński (2013) and Kalembasa et al. (2015) reported that the use of nitrogen by spring triticale cultivated on soil with a high nitrogen content, and following the pre-sowing application of the entire dose of N, ranged from 40.3 - 46.4%. In our experiment, which was conducted under conditions of a low nitrogen content of the soil, the use of nitrogen from the fertiliser applied pre-sowing at the entire dose was 54.3%. The division of the entire dose of nitrogen into two or three parts, and its split application for top dressing during the growing period, increased the use of this macronutrient from the fertiliser to 60.3 and 66.7%, respectively. Sobkowicz and Śniady (2004) calculated the value of apparent recovery fraction of nitrogen (utilisation of N by differential method) from doses 25 and 50 kg ha^{-1} obtaining values of 55.6 and 47.6%, respectively.

CONCLUSION

From the tillering phase (22 BBCH) up to the flowering stage (65 BBCH), a significant increase of nitrogen uptake and its utilisation from mineral fertiliser by spring triticale was observed. In subsequent growth stages (65-92 BBCH), no significant increase of the uptake and utilisation of nitrogen from this source was obtained.

After the application of a single nitrogen dose (120 kg N ha^{-1}), spring triticale took up 65.05 kg N ha^{-1} from the fertiliser, and the utilisation coefficient of N amounted to 54.3%. The split application of the total dose of nitrogen into two and three parts increased the uptake by 7.31 and 14.90 kg N ha^{-1}, respectively, and the utilisation of nitrogen from the fertiliser rose by 6.0 and 12.4%, respectively.

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