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EFFECT OF RATE AND TIME OF NITROGEN FERTILIZATION ON YIELD QUALITY OF RED FESCUE GROWN FOR SEEDS

WPŁYW DAWEK I TERMINÓW NAWOŻENIA AZOTEM NA JAKOŚĆ PLONU KOSTRZEWY CZERWONEJ UPRAWIANEJ NA NASIONA

Abstract: Nitrogen rates of 20, 40 or 60 kg · ha^{-1} were applied in autumn, and 40, 60 and 80 kg · ha^{-1} in spring in production years (in a single rate or in two parts: 40 kg · ha^{-1} at the start of growth and 40 kg · ha^{-1} at the beginning of stem formation). In the first year of seed harvesting, the spring nitrogen rate did not have an effect on the proportion of normally germinating, hard, fresh and dead seeds in the preliminary or final assessments in germination test. In the second year, the application of part of nitrogen for vegetative growth, with limited formation of generative organs, contributed to lowering of seed yield quality. Division of a rate of 80 kg N · ha^{-1} applied in spring resulted in a decrease in the proportion of normal seedlings as compared with a single application at the start of growth. In conditions of the lowest rate of autumn fertilization, a reduction in seed number in spikelets and an increase in thousand seed weight were accompanied by a decrease in dead seed proportion in yield.

Keywords: red fescue, seed germination, nitrogen fertilization

Fast and even germination is an essential condition of success in establishment of grass surfaces. The quality of sowing material has a direct influence on the rate of sod formation. Minimal requirements of germination capacity for grasses are within the range from 70 to 80 %, depending on species [1]. In the study of red fescue it was indicated that not only cultivars, but even seed batches are differentiated in respect of thousand seed weight and seed germination parameters [2, 3]. The objective of grass seed production should be to obtain a high yield, but also to ensure its best possible quality. This is determined by habitat [4] and agrotechnical factors [5, 6] and their interaction. A balance between the number per area unit or per inflorescence and the conditions prevailing during their filling can be considered as the basis for good grain filling [7]. As the main nutrient, nitrogen exerts an impact on the number of autumn

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shoots which can become generative in the following year, after vernalization. Excessive rates of mineral nitrogen before winter cannot be used due to a risk of leaching [8]. Spring nitrogen fertilization should satisfy the needs for developing generative shoots and seeds. It is difficult to determine the rate based on the content of mineral nitrogen in soil, since fertilizers must be applied very early, and the relation between yielding and the amount of this component in soil is relatively low [9]. Rowarth et al [10] in their study of perennial ryegrass indicated that nitrogen used in very early stages of spikelet initiation increases the weight of seedlings and germination capacity, but its application at flowering does not have such an effect. Meijer and Vreeke [9] report that in conditions of fertilizing red fescue with higher rates of nitrogen the proportion of stalks from late tillering is increased, which results in a higher proportion of light seeds in yield and a decrease in thousand seed weight. An increase in plant density brings about a similar effect [7]. The means of nitrogen application should favour seed filling, since a larger thousand seed weight is accompanied by a higher germinating capacity and shorter germinating time [11].

The research hypothesis assumed that the amount of available nitrogen during autumn tillering before vernalization and the growth and development of generative shoots from the following spring had an effect on the size of aboveground biomass and changes in yield structure elements. Consequently, this affects the quality of the obtained yield of red fescue in the first and second production years. The aim of this study was to estimate the effect of amounts and division of mineral nitrogen fertilization rates on the yield quality of red fescue seeds in two successive years of seed harvesting.

Methods

The study was based on a strict field experiment established in Chrzastowo ($53^{o}09'$ N; $17^{o}35'$ E), in two series: the first in 2004 and the second in 2005. Red fescue was used for seeds for two successive years, in 2005 and 2006 and in 2006 and 2007, respectively. The experiment was located on the podsolic soil of the very good rye complex, quality class IV with granulometric composition of silty heavy loamy sand. It was characterized by neutral reaction (pH in KCl 6.62, Hh 6.83), the high content of phosphorus, and average of potassium and magnesium (15.9 P_2O_5; 13.3 K_2O; 5.4 Mg mg 100 g of soil). Before the establishment of the experiment the amount of nitrogen determined by the distillation method [12] was 10.2 $N\text{-}NO_3^-$ and 3.57 $N\text{-}NH_4^+$ mg · kg d.m. of soil. The split-block design was used in four replications. The area of plots was 15 m^2. The lawn cultivar Nimba of red fescue (*Festuca rubra* ssp. *commutata*) was sown in mid-April, in an amount of 8 kg · ha^{-1}, at a depth of 1 cm, with a row spacing of 24 cm, 2–3 days after the spring barley sowing used as a cover crop. In autumn, after harvesting of the cover crop in the establishment year and of seeds in the first production year doses of 26 kg P and 66 kg K were applied. Moreover various rates of nitrogen fertilization were applied ie 20, 40 or 60 kg N · ha^{-1} (the second factor). In the spring in production years, rates of nitrogen fertilization (the first factor) were: 40, 60 and 80 kg N · ha^{-1} sown in a single rate or divided into two parts, of which one (40 kg · ha^{-1}) was applied at the start of growth, and the other (40 kg · ha^{-1}) 30–40 days later, at the beginning of stem formation. Due to the shallow root system of grasses [13], the nitrogen which was available in spring was assumed to be the content of $N\text{-}NO_3^-$ and $N\text{-}NH_4^+$ in the soil layer 0–30 cm directly before the start of growth, and nitrogen from mineral fertilizers (ammonium nitrate(V)) applied in spring, assuming 70 % utilization of this component by plants [14]. Nitrogen uptake was determined based on its content in seed and straw yield. Nitrogen in the plant material was determined by the Kjeldahl method [15]. On the last days of June or in the first week of July the harvest was carried out by the two-phase method. In December or January, after 5–6 months from harvest, based on a sample of 100 seeds, in four replications, a germination test was carried out [16]. At the beginning of the test, blotting paper was soaked with 0.2 % KNO_3. The preliminary assessment of germination was carried out after 7 days, determining the proportion of normal seedlings (germinating energy). Final counting was performed after 21 days from sowing, the following categories being determined: normal seedlings (including those intact, with small defects and with secondary infection), abnormal seedlings, fresh seeds, hard seeds and dead seeds. The analysis of variance (at $\alpha = 0.05$) was carried out after transformation of the results. In the estimation of significant differences Tukey's test was used. No significant interaction was found between autumn and spring fertilization. Thus, only mean values for the tested factors have been presented.

Results and discussion

The weather conditions in full production years (2005–2007) of red fescue were varied. The most favorable conditions were in 2005, when the abundant rainfall in May (a total precipitation of 78.8 mm) favored the development of generative shoots. Heavy water deficiency in June 2006 (a total precipitation of 14.6 mm) resulted in growth stunting, drying of leaves, stems and seeds. In 2007 the growing season already started in the middle of March. Unfortunately, only 16.6 mm of rain fell down in April, in the course of red fescue shooting. Heavy precipitation at the end of June and at the beginning of July made it difficult to harvest the plants.

In the first production year, the nitrogen uptake by red fescue in seed and straw yield was almost equal to the amount considered as available in spring (from soil and mineral fertilizers) (Fig. 1). The lowest level of spring nitrogen fertilization (40 $kg \cdot ha^{-1}$), where the uptake was higher by 14–15 kg within all the rates of autumn fertilization, was an exception. Mineralization was likely to be the primary source of nitrogen. According to Grzebisz [14], the amount of nitrogen that is released in such a way from organic matter on medium soils is 40–50 $kg \cdot ha^{-1}$ per year. In the second year of harvesting, almost in all the treatments of spring and autumn fertilization a part of nitrogen was not used for the growth of generative organs. By contrast, vegetative shoots from spring tillering appeared, which were important beneficiaries of the available nitrogen. Weakening of vernalized autumn shoots after winter (freezing of leaves at a length of 5–9 cm and slow regrowth in spring) favoured their formation. Such a state of the plantation contributed to a fall in quality of the seed yield obtained in the second production year. According to Fairey and Lefkovitch [7], too large density of shoots, causing increasing competition

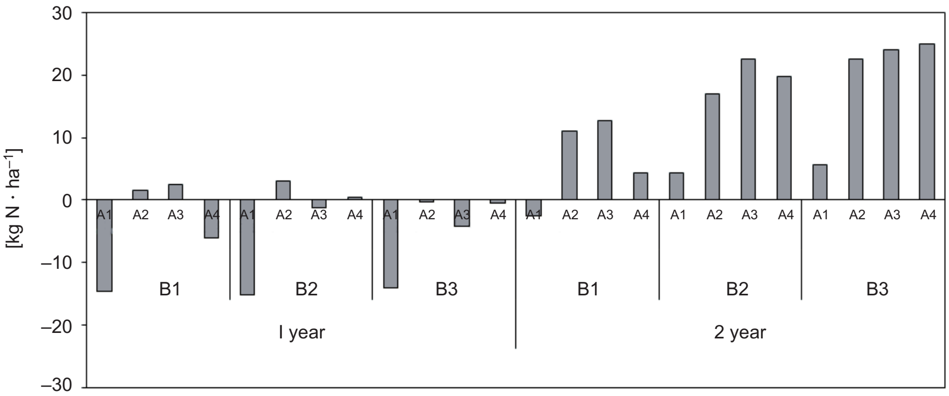

Fig. 1. Differences between amount of nitrogen available in spring (from soil and fertilizer) and taken up in seed and straw yield; A, B – nitrogen rates in autumn: 20 (B1), 40 (B2), 60 (B3) kg · ha^{-1} and in spring: 40 (A1), 60 (A2), 80 (A3), 40 + 40 (A4) kg · ha^{-1}

inside and between plants, affects a decrease in the thousand seed weight of red fescue seeds.

In the first and second year of harvesting, the proportion of normal seedlings in the preliminary assessment was similar in particular variants of spring nitrogen fertilization (Table 1). Only in the first year, in the second series (2006) a favourable effect of an autumn rate of 40 kg in relation to 60 kg N · ha^{-1} was indicated. The number of normal seedlings in that year was small, particularly in the second production year, which may have been a symptom of premature wilting of seeds in conditions of water deficit in June. The significant correlation of Sielianinow's coefficient in the period from May to June indicates a relation between hydrothermal conditions from stem formation to wax maturity and the number of normal seedlings (Table 4). Kozlowski and Kukulka [4] report that moderate temperatures and uniform precipitation during flowering and maturing positively affect the germination energy of red fescue. On average for two series of experiments the proportion of normal seedlings in the preliminary assessment in the second year was less almost by half than in the first year. Also the negative correlation coefficient indicates unfavourable influence of long utilization. Similar results were obtained in a study concerning red fescue whose seeds in the second year had a germination energy nearly 25 % less as compared with the first year [17].

The effect of nitrogen rate applied in autumn in the establishment year on the proportion of normal seedlings in the final assessment was significant only in the first year of the second series of investigation (2006) (Table 1). Similarly to the germination energy analysis, a positive effect of a rate of 40 kg in relation to 20 and 60 kg N · ha^{-1} was proved. The rate of autumn fertilization had no significant influence on this category of sowing material in the second year of seed harvesting. In the first production year, the amount and division of nitrogen rate applied in spring had no significant effect on the proportion of normally germinating seeds in the final assessment of the test. In the second year, the variant of two rates of spring nitrogen fertilization (40 kg · ha^{-1} at the start of growth and 40 kg · ha^{-1} at the beginning of stem

Table 1

Normal seedlings in preliminary and final assessment [%]

Dose of N [kg · ha^{-1}]	Preliminary assessment						Final assessment					
	Production year											
	I			II			I			II		
	2005	2006	average	2006	2007	average	2005	2006	average	2006	2007	average
Autumn												
20	83.9	44.3 ab	64.1	25.8	45.4	35.6	94.1	66.7 b	80.4	52.6	79.6	66.1
40	84.3	50.3 a	67.3	29.1	45.1	37.1	93.6	77.4 a	85.5	57.1	76.4	66.8
60	83.1	39.7 b	61.4	28.9	44.3	36.6	93.3	61.3 b	77.3	59.4	75.4	67.4
Spring												
40	84.3	47.5	65.9	25.8	48.5	37.2	93.5	68.4	80.9	54.6 ab	81.2 a	67.9 ab
60	84.6	41.3	63.0	28.3	47.2	37.7	93.8	65.8	79.8	60.6 a	78.0 ab	69.3 ab
80	81.1	47.0	64.1	31.8	43.2	37.5	93.4	72.6	83.0	63.2 a	76.6 ab	69.9 a
40 + 40	85.1	43.2	64.1	25.7	40.8	33.3	93.9	67.1	80.5	47.1 b	72.7 b	59.9 b
Average	83.8	44.8	64.3	27.9	44.9	36.4	93.7	68.5	81.1	56.4	77.1	66.7

a, b... – averages followed by the same letter constitute a homogenous group.

Table 2

Abnormal seedlings and hard seeds in final assessment [%]

Dose of N [kg · ha^{-1}]	Abnormal seedlings						Hard seeds					
	Production year											
	I			II			I			II		
	2005	2006	average	2006	2007	average	2005	2006	average	2006	2007	average
	Autumn											
20	1.81	4.38	3.09	5.15	1.91	3.53	0.25	3.01	1.63	3.53	2.24	2.88
40	1.81	4.89	3.35	4.14	1.28	2.71	0.25	1.64	0.95	1.88	2.64	2.26
60	2.25	3.38	2.81	3.65	2.20	2.92	0.56	2.88	1.72	4.79	2.96	3.87
	Spring											
40	1.67	4.18	2.93	3.04	1.53	2.29	0.67	3.18	1.93	3.89	2.20	3.04
60	2.00	4.67	3.33	6.18	1.88	4.03	0.25	1.83	1.04	2.17	2.82	2.50
80	2.17	3.84	3.00	3.17	1.71	2.44	0.25	2.35	1.30	2.34	3.27	2.81
40 + 40	2.00	4.17	3.08	4.86	2.08	3.47	0.25	2.67	1.46	5.19	2.16	3.67
Average	1.96	4.21	3.09	4.31	1.80	3.06	0.35	2.51	1.43	3.40	2.61	3.00

formation) proved to be significantly worse as compared with single rates of 60 and 80 kg · ha^{-1} in 2006, or only 40 kg N · ha^{-1} in 2007, applied early in spring. Synthesis of two series confirmed the negative effect of division of 80 kg · N rate on the number of normal seedlings. Nevertheless, although the differences were noticeable in relation to all the rates applied, they were significant only in relation to the largest. In 2006, a decrease in number of normally germinating seeds in the variant of divided rates was accompanied mostly by an increased (though not significantly) proportion of fresh seeds (Table 3). In 2007, in turn, an increase in proportion of dead seeds was observed, which might have been caused by heavy lodging, resulting in moisture growth after cutting at the bottom part of stand and latent germinating of a part of the seeds before threshing (the total precipitation from cutting to threshing was as large as 89.2 mm). The proportion of normal seedlings, as in the preliminary assessment, was the lowest in 2006, irrespective of the production year. Moreover, it was 14% less in the second year of seed harvesting than in the first. In a study by Fairey and Lefkovitch [7], red fescue showed the lowest germination capacity in the third year of seed harvesting.

The number of normal seedlings after 7 and 21 days of the test was higher for well filled seeds (significant correlation with thousand seed weight) (Table 4). Similar relations for red fescue were observed by Larsen and Andreasen [11]. Fairey and Lefkovitch [18], delaying nitrogen application by 3–4 weeks in relation to the early spring (end of March / beginning of April), indicated a significant increase in thousand seed weight in fescue. Nevertheless, germination capacity remained at a similar level. In the present study, an increase in the number of generative shoots and of seeds per spikelet had a negative effect on the proportion of this seed category. In the conditions which favoured productivity (at higher hydrothermal coefficient) the seeds had a high functional value (Table 4).

The proportion of abnormal seedlings was small and independent of rate, time of nitrogen fertilization, and year of production (Table 2). Such seedlings mostly did not form a radicle or coleoptile. Water shortage in May and June increased a number of such seeds in yield. There were few hard seeds too, irrespective of the level of nitrogen fertilization in autumn and spring (Table 2). In the second production year there were twice as many of them than in the first one.

The proportion of fresh seeds, which swelled but did not form any elements of seedling, had not significant relation to the level of nitrogen fertilization applied in spring in the first or second year or harvest (Table 3). Nitrogen applied in autumn at a dose of 40 kg · ha^{-1} resulted in a decrease in proportion of this category of seeds in the first production year of the second series (2006) relative to a dose of 20 kg; while the most such seeds were generated at a fertilization dose of 60 kg. In 2005, fresh seeds occurred sporadically, while in the dry 2006, they made up to 1/3 of yield. An increase in their proportion in 2006, along with the reduction in number of normally germinating seeds, may indicate a poor setting of the embryo due to premature wilting in conditions of water deficit and large proportion of vegetative shoots. Grzesiuk and Kulka [19] report that immature seeds can contain more germination inhibitors, and thus their dormancy is deeper than that of mature seeds. Fresh seeds, as hard ones, occurred in larger amounts at lower thousand seed weight and in the second production year.

Table 3

Fresh and dead seeds in final assessment [%]

Dose of N [kg · ha^{-1}]	Fresh seeds						Dead seeds					
	Production year											
	I			II			I			II		
	2005	2006	average	2006	2007	average	2005	2006	average	2006	2007	average
Autumn												
20	0.06	21.79 b	10.93	29.46	11.08	20.27	3.75	2.50	3.13	3.28	5.15	4.21 a
40	0.13	14.19 a	7.19	35.46	13.19	24.32	4.06	5.45	4.76	5.77	6.45	6.11 b
60	0.00	27.90 c	13.95	29.01	12.66	20.84	4.31	4.50	4.41	3.91	6.48	5.19 ab
Spring												
40	0.00	19.58	9.79	32.92	10.68	21.80	4.08	2.17	3.13	5.37	4.34 a	4.85
60	0.08	24.17	12.13	27.88	12.08	19.98	4.00	4.33	4.17	3.53	5.11 ab	4.32
80	0.17	19.38	9.77	28.79	12.60	20.70	4.33	1.68	3.01	3.18	5.76 ab	4.47
40 + 40	0.00	22.05	11.03	35.64	13.89	24.76	3.75	8.42	6.08	5.19	8.90 b	7.05
Average	0.06	21.29	10.68	31.31	12.31	21.81	4.04	4.15	4.10	4.32	6.03	5.17

a, b… – for explanations, see Table 1.

Table 4

Correlation coefficients

Specification	Year of production	TSW	Number of generative shoots	Number of spikelets in panicle	Number of seeds in spikelet	Seed yield	Sielianinow's coefficient V–VI
Normal seedlings in preliminary assessment	–0.63*	0.44*	–0.38*	0.16*	–0.32*	0.63*	0.25*
Normal seedlings in final assessment	–0.55*	0.29*	–0.19*	0.12	–0.15*	0.44*	0.52*
Abnormal seedlings	0.00	0.01	–0.14	0.08	–0.06	–0.22*	–0.33*
Hard seeds	0.29*	–0.25*	0.14	–0.12	0.06	–0.31*	–0.09
Fresh seeds	0.39*	–0.25*	0.13	–0.17*	0.20*	–0.56*	–0.47*
Dead seeds	0.12	–0.19*	0.14	0.01	0.21*	–0.02	0.15*

* – significant at $\alpha = 0.05$.

According to quality requirements for sowing material [1] swollen, but not germinating seeds are as germinating. Further detailed investigations are needed for this category of seeds, in order to fund physiological reasons for germination inhibition. The effectiveness of KNO_3 recommended by ISTA might be too small for breaking the dormancy of red fescue seeds. Salehi and Khosh-Khui [20] indicated that in red fescue very good results are obtained using sulphuric acid, which increased the germinating capacity from 42.5 to 84 %.

Autumn and spring nitrogen fertilization rates had a significant effect on the proportion of dead seeds (rotting and moulding) only in the second production year (Table 3). On average for two series, fewer such seeds were in the variant with the least autumn rate. Correlation coefficients indicate that an increase in the number of seeds per spikelet and reduction of thousand seed weight increase the proportion of this category of seeds in yield (Table 4). In 2007 spring nitrogen fertilization in the smallest amount of 40 kg contributed to a decrease in the proportion of dead seeds, but the difference was significant only in relation to the effect of a divided rate of 80 kg, half of which was applied at stem formation. The variant of delayed nitrogen fertilization favoured forming vegetative shoots, which enhanced lodging. In these conditions there is a higher risk of infection by pathogens, which can cause rotting and moulding of seeds.

Conclusions

1. Amount of nitrogen applied during autumn tillering of red fescue usually had no effect on the proportion of normal seedlings in seed yield in the first and second production years.

2. Nitrogen rates at the start of growth had no effect on the proportion of normal seedlings in seed yield in the first year. In the second year, the application of a half of 80 kg $N \cdot ha^{-1}$ at the beginning of stem formation resulted in a decrease in proportion of this category of seeds, as compared with a single application of full rate at the start of growth.

3. Number of hard and fresh seeds was only to a small extent determined by the method of autumn and spring nitrogen fertilization, both in the first and second production years. The proportion of these categories was higher at a smaller thousand seed weight.

4. Decrease in nitrogen fertilization rates applied after seed harvesting in the first production year from 40 to 20 kg $N \cdot ha^{-1}$ caused a reduction in the proportion of dead seeds in yield in the second year of harvesting.

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WPŁYW DAWEK I TERMINÓW NAWOŻENIA AZOTEM NA JAKOŚĆ PLONU NASION KOSTRZEWY CZERWONEJ UPRAWIANEJ NA NASIONA

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Abstrakt: Jesienią stosowano 20, 40 lub 60 kg N · ha^{-1}, natomiast wiosną w latach pełnego użytkowania 40, 60 oraz 80 kg N · ha^{-1} (jednorazowo lub w dwóch częściach: 40 kg · ha^{-1} w czasie początku wegetacji i 40 kg^{-1} na początku strzelania w źdźbło). W pierwszym roku zbioru nasion wiosenna dawka azotu nie miała wpływu na udział nasion normalnie kiełkujących, twardych, świeżych i martwych w ocenie wstępnej ani końcowej testu kiełkowania. W drugim roku wykorzystanie części azotu na wzrost wegetatywny, przy ograniczeniu tworzenia organów generatywnych przyczyniło się do pogorszenia jakości otrzymanego plonu nasion. Dzielenie dawki 80 kg · ha^{-1} azotu stosowanego wiosną w porównaniu do jednorazowej aplikacji spowodowało zmniejszenie udziału siewek normalnych z 69,9 do 59,9 %. W warunkach najmniejszej dawki nawożenia jesiennego ograniczeniu liczby nasion w kłoskach i zwiększeniu masy tysiąca nasion towarzyszyło zmniejszenie udziału nasion martwych w plonie.

Słowa kluczowe: kostrzewa czerwona, kiełkowanie nasion, nawożenie azotowe