Distribution of nitrogen in wheat plant in its late growth stages with regard to organic fertilisation and mineral nitrogen rate

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ABSTRACT

In Central Slovenia within a long term static experiment IOSDV we investigated the impact of mineral nitrogen (N) fertilisation (0, 65, 130, 195 kg/ha) on the N content and the N amount in winter wheat (larger roots, stems, spikes and leaves) in EC 81/82 and EC 90/91, employing three systems of management: farmyard manure ploughing in before forecrop maize, straw ploughing in and green manure, no organic fertilisation. At EC 81/82 the N content in larger roots was around twice as high as the N content in stems and around twice as low as the N content in spikes and leaves. There was 80% of the whole N amount in plant located in the spikes and leaves (33–168 kg/ha) in EC 81/82 and 90% in EC 90/91. Calculated N recovery from mineral fertiliser was 68–87%; it increased with the increasing N rates in the system with farmyard manure ploughing in and in the system with no organic fertilisation, but not in the system with straw ploughing in and green manure. Between EC 81/82 and EC 90/91 wheat gained from 4 to 34 kg N/ha, but there were more important translocations of N inside the plants, which were higher at higher mineral N rates. There was a significant impact of management system on the N uptake at the highest mineral N rate.

Keywords: wheat; nitrogen uptake; nitrogen content; management system; nitrogen recovery

Soil water availability, nitrogen (N) concentration at the root surface, the ability of plants to absorb N, N concentration in the plant tissues, and the potential of dry matter production of the cultivar or plant part are the most important factors that affect the N uptake and partitioning (Karrou and Maranville 1994). N uptake depends on the cultivar characteristics, soil properties, weather conditions and agrotechnique (Papakosta and Gagianas 1991).

Drought stress, abundant precipitation and low N concentration in soil water impact negatively on the N uptake (Karrou and Maranville 1994, Bashir et al. 1997), while increasing N rate and phosphorus and potassium fertilisation impact positively on the N content and the N amount in plant (Bronson et al. 1991, Karrou and Maranville 1994, Sowers et al. 1994, Benbi and Biswas 1997). There are also other factors influencing the N amount and the N content in wheat plant: forecrop (Jones et al. 1981, Powlson et al. 1992), soil tillage (Rasmussen and Rohde 1991), the time of ploughing, straw management (Carefoot and Janzen 1997), subsurface compaction (Oussible et al. 1993), time of N fertiliser application (Olson and Swallow 1984), the way of N application (Papakosta and Gagianas 1991, Sowers et al. 1994); however, the importance of soil depth could not be confirmed (Rasmussen and Rohde 1991). The N accumulation differs with regard to the growth stage and plant part as well (Bashir et al. 1997). In the experiment by Haberle (1991) N fertilisation caused more intensive growth of spring wheat, lower ratio of root: aboveground biomass and higher concentration of the total N in the dry matter of the aboveground parts.

Plants utilize both fertiliser and soil N. Growing fertiliser N rate increases the N uptake by the plant. At the same time fertiliser N and soil N quantity increase within the plant (Blankenau and Kuhlmann 2000). It is common in the temperate regions that the recovery of fertiliser N by the crop is seldom more than 50% (Rasmussen and Rohde 1991) [43–58% in the experiment by Haynes (1999) and Olson and Swallow (1984)], while in the experiment by Blankenau and Kuhlmann (2000) with manual harvesting procedure the N recovery by plant was 58–93%. Losses are caused by the N immobilisation in the soil (Blankenau and Kuhlmann 2000), but there are also plant N losses that take place mostly after heading and are higher at higher N rates (Francis et al. 1993, Sowers et al. 1994, Lees et al. 2000).

The cited articles prove that numerous investigations on the N uptake by wheat have been carried out, compared to experiments about the impact of the management system with organic matter on the

N uptake and N distribution within wheat plants. The objective of the study was to investigate how different systems of organic fertilisation and different mineral N intensity affect the uptake and distribution of N among parts of winter wheat plant (*Triticum aestivum* L.) in its late growth stages (EC 81/82 and EC 90/91).

MATERIAL AND METHODS

The study was done within the static long-term experiment IOSDV (Internationalen Organischen Stickstoff-Dauerdüngungsversuche) with a three-year field rotation of maize, wheat and barley in a way that all three crops were sown each year. The long-term experiment started in 1993 at Jable near Ljubljana (Central Slovenia). The soil is loamy silt (16.8% clay, 55.5% silt, 27.7% sand), classified as umbric Planosols (FAO 1988). The experiment design has already been precisely described (Tajnšek and Šantavec 1997). There are three different management systems with organic matter:

– the system with farmyard manure ploughing in to a forecrop maize (30 t/ha with approximately 0.4% N – 120 kg N/ha), all the straw of each crop is removed;
– the straw system: all the straw of each crop is ploughed in (data of N amount in straw is represented in Table 1), there is additional 60 kg/ha mineral N added for barley straw mineralisation, catch crop oilseed rape is ploughed in before maize;
– the system with no organic fertilisation.

And there are four mineral N rates (N0, N1, N2, N3) (Table 2); for winter wheat they are:

– N0 = no mineral N;
– N1 = 65 kg N/ha;
– N2 = 130 kg N/ha;
– N3 = 195 kg N/ha.

All together there were ten different fertilisation combinations; in the farmyard manure system and in the system with straw all four mineral N rates were included (N0, N1, N2, N3), in the system with no organic fertilisation two: N0 and N3. Each fertilisation combination had three replications; all the plots (30 m^2) were treated in the same way since the beginning of the experiment. Ploughing, cultivation, seeding rate, sowing method and phosphorus and potassium fertilisation rates (133 kg/ha K and 33 kg/ha P yearly) were the same for all plots, considering good agricultural practise. Weeds were controlled with a post-emergence herbicide. Plots were harvested with a small plot harvester. The straw and grain yields of each parcel of each crop were weighed and the N content and N yield were determined.

For the purpose of the presented research, samples of winter wheat were taken from each plot in the growing stages EC 81/82 and EC 90/91 in 2001 (cv. Reska) and in 2002 (cv. Eko-1) in the way that randomised blocs of selected wheat plants were pulled off the soil together with the main roots until there were at least ten stems in the sample. Soil was washed away; plants were divided into main roots (0–15 cm), stems, spikes and leaves. Samples were dried and ground. The N content in certain parts of the plant was determined by the Kjeldahl method (ISO 11261, 1995). The N amount (kg/ha) in certain parts of the plant per area unit was calculated by the data of the N content, dry matter and density (number of plants/m^2) of wheat plants.

Table 1. N amount in straw (kg N/ha) in the three year field crop rotation in IOSDV Jable considering investigated seasons 2001 and 2002 in the system with straw where straw of each crop is ploughed in at certain mineral nitrogen rates

	N0	N1	N2	N3
Rotation 1998–2000	nitrogen amount in straw ploughed in before 2001 (kg/ha)			
Wheat 1998	5	8	11	12
Barley 1999	5	5	9	17
Maize 2000	24	37	50	54
Rotation average	11	18	23	28
Rotation 1999–2001	nitrogen amount in straw ploughed in before 2002 (kg/ha)			
Wheat 1999	5	7	10	12
Barley 2000	10	13	17	23
Maize 2001	12	27	37	44
Rotation average	9	18	21	26

Table 2. Mineral N-fertilisation to different field crops in a three-year crop rotation in IOSDV Jable – Central Slovenia (1993–2004) considering growth stages

Crop	N0 rate (kg N/ha)	N1 rate (kg N/ha)	N2 rate (kg N/ha)	N3 rate (kg N/ha)
Maize	0	100 (Meier 00)	100 (Meier 00)	150 (Meier 00)
			100 (Meier 26)	150 (Meier 26)
Winter wheat	0	65 (EC 21/22)	75 (EC 21/22)	80 (EC 21/22)
			55 (EC 31/32)	80 (EC 31/32)
				35 (EC 45/50)
Winter barley or oats	0	55 EC 21/22	55 (EC 21/22)	70 (EC 21/22)
			55 (EC 31/32)	70 (EC 31/32)
				25 (EC 45/50)

All the data of the N content and the N amount were presented on the dry matter.

The autumn and winter in season 2000/01 were rainy and the winter was mild. In the next examined season there was colder winter and warmer spring, specially June with average temperature 19.2°C.

All data were analysed by the means of the analysis of variance for randomised blocs with the help of the PC programme Statgraphics plus for each year. Differences among main factors were detected by the ANOVA protected Duncan multiple test at $P \leq 0.05$.

RESULTS

Nitrogen content in main roots

In the main roots of winter wheat in growth stage EC 81/82 the N1 rate did not have a significant impact on the N content, while N2 and N3 caused its significant increase (Table 3). The most of all the N content was increased by mineral N fertilisation in the system with farmyard manure. The results agree with those of Karrou and Maranville (1994) who reported that the root N content increased when the soil N increased.

At the growth stage EC 90/91 the N content in larger roots stayed at the same level at N0 and N1 compared to EC 81/82, while in the treatments with higher mineral N rates (N2, N3) the N content decreased (Table 3).

There were no significant differences between management systems in the N content in the main roots, with the exception in N3 in EC 81/82, when it was significantly lower in the straw system compared to the system with farmyard manure ploughing in and the system with no organic fertilisation. As in the growth stage EC 81/82 also in EC 90/91 the N content tended to increase with mineral N rate increase.

Nitrogen content in stems

The N content in stems was around a half as low as the N content in larger roots in growth stage EC 81/82 (Table 3). In stems, as well as in roots, the highest N content was reached at N3 in the system with farmyard manure ploughing in (0.47%). The N content tended to increase with the mineral N rate increase; in some cases it was significant. There was no significant difference between N0 and N1.

There was no significant difference between management systems, with the exception of N3 rate, where the N content in stems was significantly higher in the system with farmyard manure ploughing in compared to the system with no organic fertilisation and the straw system.

The maximum N concentration in stems was observed early in spring and then it was decreasing continuously as the plant was approaching maturity in the experiment by Gregory et al. (1979). In two to three weeks from EC 81/82 to EC 90/91 in our experiment the N content in stems decreased at all variants. Also in EC 90/91 the N content in stems was by around 50% lower compared to the N content in larger roots (Table 3). Mineral N fertilisation did not have a significant impact on the N content in stems in EC 90/91 in the system with straw while in the farmyard manure system and in the system with no organic fertilisation the N content tended to increase with mineral N fertilisation increase.

There were no significant differences between management systems.

Table 3. N content (% dry matter) in larger roots, stems and spikes and leaves of winter wheat in growth stages EC 81/82 and EC 90/91 considering management system with organic matter (no organic fertilisation, animal manure ploughing in to a forecrop maize, straw system) and mineral nitrogen rate (N0, N1, N2, N3)

Organic fertilisation		EC 81/82			EC 90/91		
		roots (% N)	stems (% N)	spikes and leaves (% N)	roots (% N)	stems (% N)	spikes and leaves (% N)
–	N0	0.41 a	0.21 abc	1.03 a	0.42 ab	0.20 ab	1.18 a
	N3	0.77 cd	0.38 e	1.75 cd	0.61 e	0.31 de	1.68 c
Animal manure system	N0	0.38 a	0.19 ab	1.03 a	0.39 a	0.19 a	1.16 a
	N1	0.41 a	0.22 abc	1.11 a	0.44 abc	0.19 a	1.15 a
	N2	0.68 bc	0.28 cd	1.49 b	0.49 bc	0.25 bcd	1.45 b
	N3	0.81 d	0.47 f	1.83 d	0.62 e	0.32 e	1.77 c
Straw system	N0	0.45 a	0.19 a	1.03 a	0.42 ab	0.22 abc	1.14 a
	N1	0.40 a	0.17 a	1.05 a	0.41 a	0.19 a	1.13 a
	N2	0.62 b	0.26 bcd	1.46 b	0.51 cd	0.25 bcd	1.43 b
	N3	0.66 bc	0.32 de	1.64 c	0.58 de	0.28 cde	1.68 c
Year	1	0.56 a	0.27 a	1.29 a	0.47 a	0.24 a	1.22 a
	2	0.55 a	0.27 a	1.39 b	0.51 b	0.24 a	1.53 b

*the same letter in the column indicates that there is no significant difference between the treatments according to the Duncan test ($P \leq 0.05$)

Nitrogen content in spikes and leaves

The N content in spikes and leaves in growth stage EC 81/82 was 2- to 2.5-times higher than the N content in larger roots and 4- to 6-times higher than the N content in stems (Table 3). N1 rate did not have a significant impact on the N content in spikes and leaves, while N2 and N3 rates caused a significant increase of the N content in spikes and leaves. A management system had a significant impact on the N content in spikes and leaves at N3, where it was the highest in the system with farmyard manure ploughing in and the lowest in the straw system.

At EC 90/91 the N content in spikes and leaves showed similar characteristics to the N content in larger roots and stems (Table 3). If comparing EC 90/91 to EC 81/82 it can be seen that the N content at lower mineral N rates stayed on the same level, while at higher mineral N rates it decreased.

Nitrogen amount in larger roots

With regard to the fertilisation treatment the N amount in larger roots ranged between 1.8 kg N/ha (N0) and 7.3 kg N/ha (N3 in the system with farmyard manure) in EC 81/82 (Table 4). In the system with farmyard manure and in the system with no organic fertilisation the mineral N rate increase caused a significant increase of the amount of N, which was present in larger roots per hectare. In the system with straw the significant increase was only between N0 and N1. The factor of N uptake between N0 towards N3 was higher than 2.5, what points to the big difference between them with regard to the ability for N accumulation in larger roots. A management system did not have a significant impact on the N amount in larger roots, with the exception of N3 rate, where it was considerably lower in the straw system comparing to the system with no organic fertilisation and the system with farmyard manure.

Between EC 81/82 and EC 90/91, the N amount in larger roots decreased or stayed at the same level. Mineral N had a significantly positive impact in all management systems while management systems did not have a significant impact on the N amount in larger roots.

Nitrogen amount in stems

As the N amount in other parts of the plant also the N amount in stems is a product of the N content and the amount of dry matter. Due to

Table 4. N amount (kg N/ha) in larger roots, stems, spikes and leaves and in whole plants of winter wheat in growth stages EC 81/82 and EC 90/91 considering management system with organic matter (no organic fertilisation, animal manure ploughing in to a forecrop maize, straw system) and mineral nitrogen rate (N0, N1, N2, N3) with significant differences and the quantity of dry matter of individual plant part in kg/ha in brackets

Organic fertili-sation	N rate	EC 81/82								EC 90/91							
		roots (kg N/ha)		stems (kg N/ha)		spikes and leaves (kg N/ha)		whole plant (kg N/ha)		roots (kg N/ha)		stems (kg N/ha)		spikes and leaves (kg N/ha)		whole plant (kg N/ha)	
–	N0	1.8 a	(439)	4.0 ab	(1,905)	33 a	(3,204)	38 a	(5,548)	1.4 a	(333)	2.2 a	(1,100)	42 ab	(3,559)	45 a	(4,992)
	N3	5.7 cd	(740)	20.3 e	(5,342)	144 de	(8,229)	170 d	(14,311)	5.6 d	(918)	13.0d	(4,194)	177 cd	(10,536)	195 cd	(15,648)
Animal manure system	N0	1.8 a	(474)	4.2 ab	(2,210)	36 a	(3,495)	42 a	(6,179)	1.8 ab	(462)	2.5 a	(1,316)	49 ab	(4,224)	54 ab	(6,002)
	N1	3.7 ab	(902)	9.8 bc	(4,455)	76 b	(6,847)	90 b	(12,204)	3.1 bc	(705)	5.8 ab	(3,053)	90 b	(7,826)	99 b	(11,584)
	N2	5.0 bc	(735)	15.7 de	(5,607)	127 cd	(8,523)	148 cd	(14,865)	4.4 cd	(898)	9.1 bc	(3,640)	153 c	(10,552)	167 c	(15,090)
	N3	7.3 d	(901)	27.8 f	(5,915)	168 e	(9,180)	203 e	(15,996)	5.1 d	(823)	13.6 d	(4,250)	202 d	(11,412)	221 d	(16,485)
Straw system	N0	1.8 a	(400)	3.5 a	(1,842)	33 a	(3,204)	38 a	(5,446)	1.2 a	(286)	2.5 a	(1,136)	38 a	(3,333)	42 a	(4,755)
	N1	3.5 ab	(875)	7.6 ab	(4,471)	70 b	(6,667)	81 b	(12,013)	3.1 bc	(756)	5.1 a	(2,684)	80 ab	(7,080)	88 ab	(10,520)
	N2	5.0 bc	(806)	14.2 cd	(5,462)	108 c	(7,397)	127 c	(13,665)	3.9 cd	(765)	9.3 bc	(3,720)	142 c	(9,930)	155 c	(14,415)
	N3	4.4 bc	(667)	15.5 de	(4,844)	121 cd	(7,378)	141 cd	(12,889)	4.4 cd	(759)	10.3 cd	(3,679)	160 cd	(9,524)	175 cd	(13,962)
Year	1	4.4 a	(786)	12.8 a	(4,741)	76 a	(5,891)	94 a	(11,418)	2.9 a	(617)	6.0 a	(2,500)	89 a	(7,295)	98 a	(10,412)
	2	3.6 a	(655)	11.7 a	(4,333)	107 b	(7,698)	122 b	(12,686)	3.8 b	(745)	8.6 b	(3,583)	138 b	(9,020)	151 b	(13,348)

*the same letter in the column indicates that there is no significant difference between the treatments according to the Duncan test ($P \leq 0.05$)

the fact that the dry matter weight depends a lot on available N, mineral N rate has usually a higher impact on the N amount in plants per area unit than on the N content (concentration).

Mineral N fertilisation had a significant positive impact on the N amount in stems in all management systems in growth stage EC 81/82 (Table 4). Although in the system with straw the N amount in stems per area unit was lower than in the systems with farmyard manure and the system with no organic fertilisation, the difference between management systems was not significant, except at N3 rate. The N amount in stems was significantly higher in the system with farmyard manure compared to the system with straw and the system with no organic fertilisation at N3, namely.

The N amount in stems decreased considerably between EC 81/82 and EC 90/91; the most of all at N3 in the system with farmyard manure (for 14.2 kg N/ha) (Figure 1). This outcome agrees with the results of other authors who reported that between flag leaf emergence and maturity large N reductions occurred in stems accompanied by large N accumulation in spikes (Bashir et al. 1997). In EC 90/91 a management system did not have a significant impact on the N amount in stems per area unit. But there was a significant impact of mineral N fertilisation. In average in that growth stage there was between 1.5- and 2.8-times more N in stems per area unit compared to the N amount in larger roots.

Nitrogen amount in spikes and leaves

In spikes and leaves in EC 81/82 there was by 6- to 9.4-times more N than in stems (Table 4). The impact of mineral N fertilisation was significant. Systems of management did not have a significant impact on the N amount in spikes and leaves, except at N3 rate, where the N amount in spikes and leaves was significantly higher in the system with farmyard manure comparing to the straw system.

Between EC 81/82 and EC 90/91 the N amount in spikes and leaves notably increased, especially at lower mineral N rates (Table 4, Figure 1). Because the N amount in stems decreased between EC 81/82 and EC 90/91 and increased in spikes and leaves simultaneously, the difference between the N amount in spikes and leaves and the N amount in stems was higher in EC 90/91 than in EC 81/82. It is interesting that in all management systems the N amount at the highest mineral N rate (N3) was 4.2-times higher compared to the lowest mineral N rate (N0).

Nitrogen amount in whole plants

A management system and mineral N fertilisation had a significant impact on the N amount in whole plants in the growth stage EC 81/82. According to Grylls et al. (1997) the total crop uptake increased with increased fertiliser N in different climatic conditions. In the experiment by Kubát et al. (2003) organic and mineral fertilisation enhanced significantly the N uptake by winter wheat. In our experiment the N amount in whole plants increased with mineral N rate increasing in all management systems, most of all in the system with farmyard manure. Management system had a significant impact at N3 rate, where the N amount in whole plants was significantly higher in the system with farmyard manure comparing to the straw system and the system with no organic fertilisation.

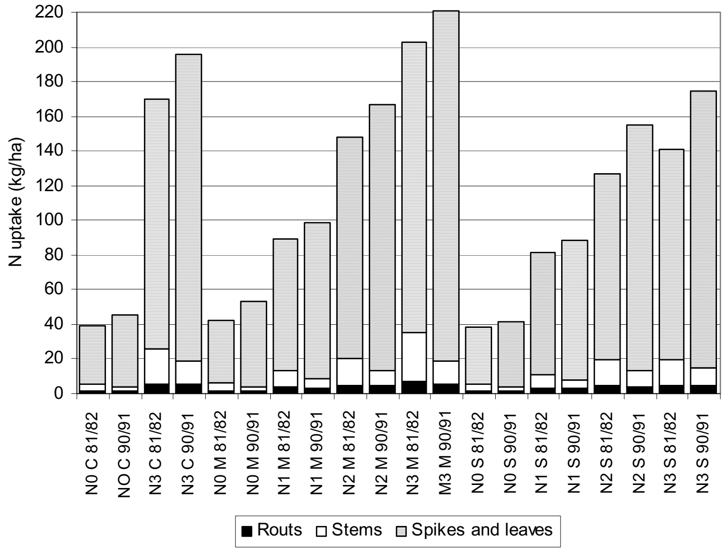

Figure 1. N uptake in kg N/ha by certain plant parts at EC 81/82 and EC 90/91 considering mineral N rate (N0, N1, N2, N3) and management system with organic matter (C – no organic fertilisation, M – animal manure system, S – straw system)

The N amount in whole plants increased between the examined growth stages. The exception was N3 in the system with farmyard manure (Table 4). Between EC 81/82 and EC 90/91 the N amount in whole plants was increasing linearly with mineral N rate increase. That agrees with the results of Bronson et al. (1991) and Sowers et al. (1994) who reported that the total N uptake in grain and straw linearly increased with the N rate. While according to Lees et al. (2000) wheat was found to accumulate 190 kg N/ha in the forage by flowering, in our experiment there was even 221 kg N/ha in whole wheat plants in EC 90/91 in N3 in the system with farmyard manure.

DISCUSSION

The analysis of N in larger roots, stems and spikes and leaves at winter wheat in growth stages EC 81/82 and EC 90/91 showed that a management system and the mineral N fertilisation have a significant impact on the N uptake and its incorporation into biomass.

At the early waxy maturity (EC 81/82) the effect of organic and mineral N fertilisation was already defined in the wheat plant. Although the plants still took up N and incorporated it into their biomass, the reciprocal proportions between the management systems and mineral N rates did not change any more. The results of the investigation showed that at maturity there was about 5% of the whole plant biomass N present in larger roots (1.2–5.6 kg N/ha). Although in the early waxy maturity (EC 81/82) the N content in main roots (0.38–0.81%) was approximately twice as high as the N content in stems (0.17–0.47%), it was about half the content of N in spikes and leaves (1.03–1.75%). In the early waxy maturity there was already around 80% of the whole plant N located in the spikes and leaves (33–168 kg/ha depending on N rate). Until the growth stage EC 90/91 the share increased to 90%. At the early waxy maturity the weight of spikes and leaves represents around 40–48% of the whole aboveground plant biomass. When the N content in larger roots in EC 81/82 exceeded 0.60%, it decreased afterwards until EC 90/91. The same trend was confirmed for the N content in stems when the N content exceeded 0.30% in EC 81/82.

According to Blankenau and Kuhlmann (2000) wheat plant still uptakes N in the time of grain filling and more if there is more available N in the soil solution and if there is enough available water. In our investigation it was discovered that in the time between early waxy maturity and the maturity the yield quantity was finally defined. Although wheat plant in that time still took up N, more important were the N translocations within the plant – from roots and stems to spikes. Spikes and leaves represented the highest percentage of plant biomass.

The investigation showed that the translocation of N was higher at higher mineral N rates. Higher mineral N rates caused higher N content in larger roots and stems. According to Bashir et al. (1997) at maturity the grain contain around 75% of the total plant N. In our experiment at maturity the N amount in spikes and leaves together represented around 90% of the whole plant biomass. As in that growth stage there is only a minor quantity present in leaves, it can be concluded that at maturity spikes, including grains, represented 85–90% of the whole N amount in wheat.

N uptake by wheat plant increased with increasing mineral N fertilisation. In both growth stages and in all management systems with organic matter higher impact on the N uptake increase by mineral N fertilisation had its positive impact on the biomass increase compared to its impact on the N content increase.

The share of the fertiliser N of all plant N can be estimated from the difference between the N amount at controls (N0) and the N amount at certain N rates. Considering the results in Table 4 it was calculated (as the index of efficiency by the difference method) that in the system with straw wheat took up 71% of fertiliser N at N1, 87% at N2 and 68% at N3. The values are the approximations but they can form the basis for the estimation of the efficiency of winter wheat for fertiliser N recovery. In the experiment by Kumar and Goh (2002) about 73% of the crop N originated from soil N and the rest came from the applied fertiliser, while at the same time the wheat crop took up 52% of the fertiliser applied N. In the experiment by Powlson et al. (1992) unlabelled N accounted for 20–50% of the total N content of fertilised crops at harvest.

Although there could be plant N losses that, according to Francis et al. (1993), Lees et al. (2000) and Sowers et al. (1994), occur mostly after anthesis and are higher at higher N rates, winter wheat in our experiment gained from 4–34 kg N/ha between EC 81/82 and EC 90/91. In the experiment of Blankenau and Kuhlmann (2000) the N uptake was between 19 and 36 kg N/ha during grain filling (from milk-ripe stage) for unfertilised crops and was higher for fertilised treatments. In the experiments of Blankenau and Kuhlmann (2000) and Jones et al. (1981) the fertiliser N recovered in crops increased with the increasing N rates. In our experiment the fertiliser N recovered in crops increased with the increasing N rates in the system with farmyard manure and in the system with no organic fertilisation, while not in the system with straw.

Straw incorporation relative to its removal reduced plant N with spring ploughing but not with fall ploughing in the experiment of Carefoot and Janzen (1997). In our experiment the uptake of N at the highest mineral rate in EC 81/82 was significantly higher in the system with farmyard manure comparing to the straw system and the system with no organic fertilisation. In EC 90/91 there were no significant differences between management systems. In the 22-year- long experiment by Benbi and Biswas (1997) the addition of farmyard manure resulted in highest N removal by wheat.

We can conclude that in the time between EC 81/82 and EC 90/91 wheat still absorbed N from the soil (from 4 to 34 kg/ha), but there were more important translocations of N inside the plants, which were higher at higher mineral N rates. Under the conditions of IOSDV Jable the investigation showed a significant impact of the farmyard manure on the N uptake by the wheat plant at the highest mineral N rate.

In the system with straw the quantity of N, which was ploughed in by the straw at N2 and N3 rates, amounted 21–28 kg N/ha in the annual average of field crop rotation. Together with the 60 kg mineral N/ha, which was fertilised before barley straw ploughing in, the quantity of additional N in the system with straw was 41–48 kg N/ha per year. This N quantity is comparable to 40 kg N/ha per year fertilised by farmyard manure in the system with farmyard manure. The fact that at higher mineral N rates (N2, N3) N uptake was higher in the system with farmyard manure comparing to the system with straw could be explained by the synergistic effects of others macro- (P, K) and micronutrients in the farmyard manure. Only when the sufficient quantity of these for wheat growth essential nutrients was present in the soil higher quantities of N in the farmyard manure system could be reflected in the trend of higher N uptake comparing to the system with straw.

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ABSTRAKT

Distribuce dusíku v plně vyvinutých rostlinách ozimé pšenice při hnojení organickými hnojivy a rozdílných dávkách minerálního dusíku

V dlouhodobém přesném polním pokusu ve středním Slovinsku, evidovaném v síti IOSDV, byl sledován vliv stupňovaných dávek minerálního dusíku (0, 65, 130 a 195 kg N/ha) a tří způsobů aplikace organické hmoty (zaorání hnoje k předplodině kukuřici, zaorání slámy se zeleným hnojením a bez organického hnojení) na obsah a množství N v jednotlivých částech ozimé pšenice (větší kořeny, stébla, klasy a listy) v růstových fázích EC 81/82 a EC 90/91. Ve fázi EC 81/82 byl obsah N v mohutnějších kořenech přibližně dvojnásobný v porovnání se stébly a poloviční ve srovnání s obsahem N v klasech a v listech. 80 % z celkového rostlinného N bylo v této fázi nalezeno v klasech a listech (33–168 kg N/ha) a 90 % ve fázi EC 90/91. Vypočtené využití N se pohybovalo v rozmezí 68–87 % a rostlo s rostoucí dávkou N při aplikaci hnoje, nikoli však při použití slámy a zeleného hnojení. U sledovaných růstových fází odebrala pšenice mezi 4–34 kg N/ha, významnější se ukázala translokace N v rostlině, která byla větší při vyšších dávkách N. Významný se ukázal též způsob aplikace organické hmoty při nejvyšší dávce N.

Klíčová slova: pšenice; příjem dusíku;, obsah dusíku; pěstební systém; využití dusíku

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