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Introduction

Application and utilisation of nitrogen (N) is important from both an agronomic and environmental point of view. Increased utilisation of applied N will increase seed yield and the amount of N removed in the harvested straw and seed and concomitantly lower the amount of N than can potentially leach to ground and surface water. From an agronomic viewpoint it is important to understand the relationship between higher N uptake and seed yield. We know from several field experiments that the current year has a large impact on the uptake and utilisation of applied N due to soil available water, temperature and precipitation. On the other hand we have only limited knowledge in the area of utilisation of seed yield potential in combination with utilisation of N. Aims of the current study were therefore to explain seed yield increase by nitrogen (N) use efficiency (NUE), N uptake efficiency (NUpE), N utilization efficiency (NUtE) and number of fertile tillers in two red fescue field experiments in 2004 and 2005.

Materials and Methods

Two red fescue (*Festuca rubra* var *rubra* L. cv. Pernille) field experiments were harvested in 2004 and 2005. The cover crop was spring barley. Nitrogen (N) was applied at 60, 90 or 120 kg/ha in the autumn (N autumn) before seed harvest, at initiation of spring growth (N spring early) at 0, 30 or 60 kg/ha and at start of May (N spring late) at 0 or 30 kg/ha which is just before stem elongation. The experimental design was a three factor design with four replicates. The three factors: N autumn, N spring early and N spring late were randomly distributed within each replicate giving a total of 72 plots each year. The numbers of fertile tillers were counted in a subsample (0.25 m^2) in each plot. The plots were harvested using a plot combiner and the seeds were dried to 12% moisture and cleaned to 100% pure seeds. A subsample of the seeds and straw from each plot were analysed for total N and the amount of N uptake (kg/ha) in seeds and straw was calculated. Based on these calculations and the applied N it was possible to calculate nitrogen uptake efficiency (NUpE) as total N in straw and seeds divided by total N applied. It was also possible to calculate nitrogen utilisation efficiency (NUtE) as total N uptake in seeds divided by total N uptake in seeds and straw. Data was analysed using a generalised linear model (PROC GLM) in Statistical Analysis System version 8, software package (SAS 1999).

Results and Discussion

Seed yields were significantly different between 2004 and 2005 with an average seed yield of 984 kg/ha in 2004 and 1691 kg/ha in 2005, respectively. Based on the fact that years were significantly different, and that the purpose was not to discuss the effect of years, the analysis was made on data from the two years individually. The effect of autumn, early and late spring N application on seed yield and NUpE were significant within the two years (Table 1). In the case of number of fertile tillers and NUtE there were only minor effects of the different N application rates (Table 1). The higher number of fertile tillers in 2005 compared with 2004 could not solely explain the large difference in seed yield between the two years.

Table 1. Seed yield (kg/ha), number of fertile tillers per m^2, nitrogen uptake efficiency (NUpE) and nitrogen utilisation efficiency (NUtE) in 2004 and 2005. Different letters within columns and within nitrogen (N) autumn, N spring early or N spring late indicate significance difference at 5% level.

		Seed yield		No. fertile tillers		NUpE		NUtE	
	kg/ha	2004	2005	2004	2005	2004	2005	2004	2005
N autumn	60	946 b	1620 b	4040 a	4305 a	0.79 a	1.18 a	0.36 a	0.16 a
	90	992 a	1706 a	3989 a	4549 a	0.65 b	1.00 b	0.36 a	0.17 a
	120	1015 a	1746 a	4184 a	4622 a	0.56 c	0.78 c	0.34 b	0.17 a
N spring early	0	945 b	1570 b	3791 b	4184 b	0.75 a	1.12 a	0.36 a	0.17 a
	30	997 a	1730 a	4166 a	4646 a	0.66 b	0.97 ab	0.35 a	0.17 a
	60	1011 a	1773 a	4257 a	4646 a	0.58 c	0.86 b	0.35 a	0.15 b
N spring late	0	993 a	1600 b	3975 a	4458 a	0.70 a	1.05 a	0.35 a	0.17 a
	30	976 a	1782 a	4167 a	4525 a	0.63 b	0.92 a	0.35 a	0.16 a

There was a large difference in NUpE between the two years while results within the two years clearly showed that increased N application rates will, not surprisingly, result in lower NUpE. In 2005 it was possible to have NUpE>1 which shows that more N than applied was taken up by the crop and therefore there must have been an extra N source as *e.g.* mineralised N. NUtE clearly shows that the seeds are a variable N sink, but also that the different N application strategies had no effect on NUtE.

Even though there was a large amount of N available in 2005 it was still possible to increase the average seed yield from 1600 kg/ha to 1782 kg/ha by a late N application. These results show that the seed yield potential, defined in this experiment as the number of fertile tillers, in combination with utilisation of the seed yield potential, defined in this paper as the uptake and utilisation of N, plays an important role in creation of the seed yield.

Conclusion

We conclude that:

- the very high NUpE in 2005 must have been due to an extra N source such as mineralised N; and,
- the higher seed yield and utilization of a late spring N application in 2005 compared to 2004 was due to a higher seed yield potential and a higher utilization of this yield potential in 2005 compared to 2004.