Has nitrogen use efficiency changed for barley in Finnish growing conditions?

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Abstract

Nitrogen is one of the most important nutrients in crop production, even thought crops can make use of only 30-50% of the applied nitrogen fertilizer. The loss of nitrogen causes environmental pollution as well as economic losses. Therefore, cereal cultivars with more efficient nitrogen use are of special interest in Finland as cereal production covers some 50% of the cultivated area. The objective of this study was to determine genotypic differences for traits characterizing nitrogen use efficiency (NUE). Three spring barley cultivars (landrace and two modern cultivars) were studied in MTT, Jokioinen in clay soil without (N0) and with 90 kg N ha^{-1} (N90) fertilizer. The plant samples were collected at four growth stages during the growing period and samples were divided to main shoots and tillers. The nitrogen content was analysed with Leco and calculations of NUE were made based on differences in fertilizers treatments (N0-N90). According to our results from three years there were no significant differences in NUE between modern varieties and landrace.

Key Words

Nitrogen utilization efficiency, nitrogen uptake efficiency, plant breeding, *Hordeum vulgare* L.

Introduction

Nitrogen is one of the most important nutrients in crop production, even thought crops can make use of only 30-50% of the applied nitrogen fertilizer. Improving efficient nitrogen use in cereal production is a current challenge for agronomical research in Finland since over 50% of arable land is used for cereal production. Increaseing the ability of the crop to use nitrogen more efficiently parallels reducing the availability of nitrogen for leaching.

Moll et al. (1982) defined nitrogen use efficiency as grain yield per unit of available nitrogen. This nitrogen use efficiency (NUE) can be divided into two components, the ability of the plant to extract the nitrogen from the soil, uptake efficiency (UPE), and the ability of the plant to convert the absorbed nitrogen into grain yield, utilization efficiency (UTE).

There have been results showing minimal correlation between total nitrogen uptake and year of release of the wheat cultivars (Austin et al. 1980, Slafer et al 1990). However, differences in nitrogen uptake have been found between varieties on barley (Gorny 2001) and on wheat (Le Gouis et al. 2000).These differences have been found between the varieties adapted in variable environments (Gorny 2001). Nitrogen uptake efficiency has been found to be a very important part of NUE especially in low N conditions (Ortiz-Monasterio et al. 1997). Nitrogen utilization efficiency on the other hand appears to have been affected by past plant breeding and is found to be an important part of NUE in high N conditions (Ortiz-Monasterio et al. 1997). Nitrogen partitioning is thought to be interrelated with dry matter partitioning (Simpson et al. 1983). Because of that, UTE can be divided into two parts, harvest index (HI) and biomass production efficiency (BPE). By plant breeding the HI has drastically ingreased on modern varieties (Austin et al. 1980) and affected also the improved UTE (Calderini et al. 1995).

The purpose of this research was to determine what is the average NUE of barley varieties in Finland, and the effect of plant breeding on the components of NUE.

Methods

The experiment was conducted during the growing seasons 2001 - 2003 on clay soil (Mukula and Rantanen 1987) on a site located at the MTT Agrifood Research Finland, Jokioinen, Finland (60?49'N, 23?30'E).The cultivars used in the experiment were Uurainen (old long strawed landrace released in Finland 1922), Inari (Finnish cultivar, 1994) and Scarlett (modern cultivar from Germany, 1998). The experiments were conducted in a split-plot arrangement of treatments in a randomised complete block design with four replications. The whole-plot treatment consisted two N fertilizer treatments, named as N0 and N90, 0 and 90 kg N ha $^{-1}$.The three genotypes were randomly assigned as the subplot of 12.5 m^2 (10 m x 1.25 m). The experiment was planted on 10 May 2001, 29 April 2002 and 13 May 2003 at seeding rate of 500 m^{-2}. Weeds and diseases were controlled by chemical treatments using the local standards. In 2001 and 2002 the plots were irrigated twice (2 x 15mm) during the vegetative growth, with in year 2003 no irrigation was needed. Plant sampling began at three-leaf stage. Twenty random plants per plot were cut at ground level and used for analysis. Each sample was divided into main stem and tillers and further divided into head, leaves and stem. Samples were dried in 60? C for two days and ground for Leco autoanalyzer measurement. Calculations for NUE were made from the samples collected right before the harvest. To calculate the parameters of NUE and nitrogen harvest index the following equations were used:

- Harvest index (HI) = 100*grain weight (g m^{-2})/ phytomass (g m^{-2})
- Biomass Production Efficiency (g g^{-1}) (BPE) = total plant phytomass (g m^{-2}) / total N in the plant (g m^{-2})
- Nitrogen Utilization Efficiency (g g^{-1})(UTE) = HI*BPE
- Nitrogen Uptake Efficiency (UPE) = [total N in the plant {= plant N (N90)-plant N (N0)}] / N supplied
- Nitrogen Use Efficiency (g g N^{-1}) (NUE) = UTE*UPE

Statistical analyses were carried out with SAS (PROC MIXED).

Results

The years differed from each other by the rainfall and temperature accumulation. The year 2002 had lowest precipitation during the study period. The years 2001 and 2003 had about the same precipitation, but the time of the rainfalls differed. The temperature accumulation during the growing season was highest on year 2003 and lowest on 2001.

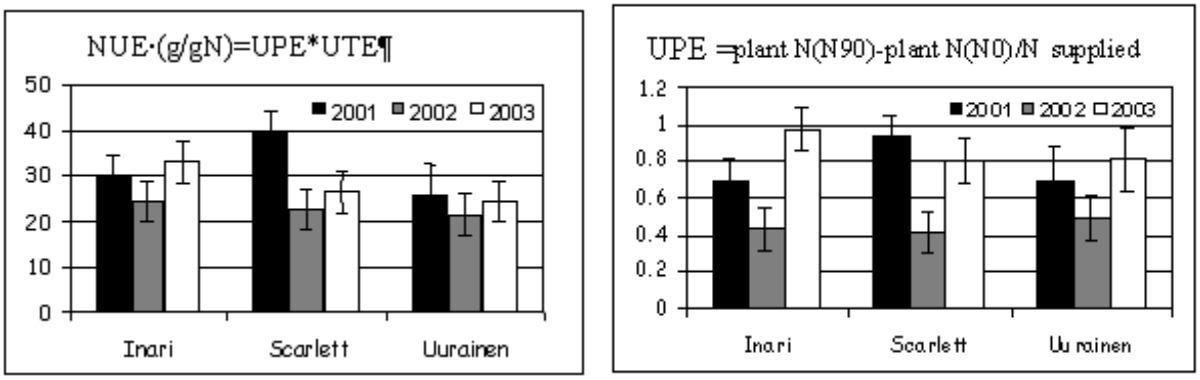

Figure 1. Nitrogen use efficiency (NUE) and nitrogen uptake efficiency (UPE) from three year on two modern varieties (Inari and Scarlett) and on landrace Uurainen.

The NUE was lowest on all varieties on year 2002. Scarlett and Inari had higher NUE than Uurainen. However, the NUE of Uurainen tended to be more stable. The differences between varieties and years on NUE were not statistically significant. These findings suggest that the NUE on two row barley cultivars varies between 25 g g^{-1} N and 30 g g^{-1} N in Finland and it indicates that the plant breeding has not much improved NUE.

Of the other components affecting NUE, the UPE was also lowest during the growing period 2002 on all varieties. The soil N content was also lowest in year 2002 (results not shown) as well as the N content of the plants. Based on the observations of Ortiz-Monasterio et al. (1997) the UPE results could implicate variety differences in N uptake efficiency. However, differences between the varieties in our experiments were not statistically significant.

The UTE was highest on all varieties on 2002. However, the UTE was lowest on Uurainen almost without exception. There were no significant differences in UTE between Inari and Scarlett in years 2001 and 2003. Accordingly plant breeding has affected UTE during the last 80 years. Observing the components of UTE, the BPE also changed between the years. On 0 and 90 kg N ha^{-1} nitrogen levels it was lowest on year 2003 and highest on 2002. Although the difference between the years was not significant. With out exception BPE was lowest on nitrogen level 90 kg N ha^{-1}. From the three varieties Scarlett had the lowest capacity to produce biomass per unit of nitrogen taken up.

The nitrogen level affected the HI. The HI was higher on 90 kg N ha^{-1} than on 0 fertilizer. From the varieties the Uurainen had, almost without exception, the lowest HI and Scarlett the highest. Even though the results suggest that the varieties do not differ in NUE under Finnish growing conditions, there seems to be some trend of better nitrogen utilization efficiency for modern varieties compared to landrace. This trend is mostly result of improved HI. Calderini et al. (1995) have reported similar results in wheat.

Table 1. Effect of nitrogen fertilizer level and variety on nitrogen utilization efficiency and it's components.

	UTE			BPE			HI		
Treatment	2001	2002	2003	2001	2002	2003	2001	2002	2003
Nitrogen (N) kg ha^{-1}									
0	48.8	57.2	39.5	96.1	114.1	80.6	50.8	50.1	49.0
90	41.9	51.9	30.3	87.0	105.7	66.5	48.3	49.1	45.8
	***	***	***	**	**	***	***	*	***
Variety (V)									
Inari	47.6	59.6	37.7	93.5	114.8	72.9	50.9	52.0	51.7
Scarlett	47.2	57.1	39.0	86.9	107.4	73.1	54.3	53.2	53.2
Uurainen	41.2	47.0	28.0	94.2	107.6	74.5	43.6	43.7	37.3
	**	***	***	**	**		***	*	**
N x V			*	*				*	o

UTE = nitrogen utilization efficiency, BPE = biomass production efficiency, HI = harvest index

*** = P<0.001, ** = P<0.01, * = P<0.05 ja o = P<0.10

Conclusion

According to this research with three cultivars, there has not been change in NUE on two row barley varieties in Finnish growing conditions during the 20th century.

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