Results and agro-environmental perspectives of the CULTAN method

Fluid injection fertilization (CULTAN) can increase N use efficiency and decrease environmental impact compared to broadcast fertilization.

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Introduction

Fluid injection fertilization is widely practiced in Canada, the USA and Australia (e.g. Holloway et al. 2001) and became known in Germany as "CULTAN" fertilization (***C***ontrolled ***U***ptake ***L***ong-***T***erm ***A***mmonium ***N***utrition, Sommer, 2000). The intention with the technique, as originally developed in Germany by Dr. Sommer, was to achieve the predominant nutrition of crops with ammonium instead of nitrate. While fluid injection fertilization is generally defined as the subsurface injection of any N containing fluids, the CULTAN technique applies ammonia or ammonium containing fluids with no or only a limited content of other N forms (urea, nitrate). We started research work to quantify agronomic and environmental benefits of the CULTAN strategy, motivated by the increasing negative environmental impacts of nitrate (e.g. NO_3^- leaching, N_2O release) and of broadcast fertilization (e.g. surface runoff) and encouraged by positive farmers experiences as well as the fact that NH_4^+ is favorable for crop physiology and growth (Marschner, 1999).

Materials and Methods

A long-term field experiment to assess the CULTAN technique was started in 2002 (loamy sand, Latin square, 3 replications, 2 N levels, broadcast application vs. fluid injection at 3 different growth stages, 2 cultivars per plot since 2009). Ammonium sulphate solution was injected either at beginning of vegetation, at mid or end of tillering. Nitrate leaching was monitored by passive seepage water sampels. In a lysimeter station (8 monolith lysimeters within equally treated field plots) fluid injection and broadcast fertilization were compared in ploughing and conservation tillage systems. Additionally, field experiments were carried out on commercial fields every year.

Results

Equivalent or higher grain yields can be achieved by fluid fertilizer injection in comparison to broadcast fertilization. However, yields varied with N fertilizer level and time of injection. Table 1 shows the cereal yields after fluid injection relative to those with broadcast solid fertilization (set to 100). With the officially recommended N application rate (represented by N-level N_2), we reached or even exceeded the broadcast fertilization yields by the CULTAN treatment in 5 of 6 years with at least one of the tested three injection dates. In average of all years, yield level by CULTAN fertilization was 101 resp. 99% when applied in the middle or at the end of the tillering period, but only 94% when injected too early (beginning of the growth period). At the lower N level (N_1 representing recommended N fertilization minus 25%) CULTAN fertilization produced equal or higher grain yields in all years, predominantly when injection was performed at mid-tillering (average 113%). For both N levels N_1 and N_2 we

Table 1. Grain yield of cereals by CULTAN fertilization relative to conventional broadcast (split in two resp. in three doses for wheat) fertilization with calcareous ammonium nitrate. Broadcast = 100. N_0 = yield with no N fertilization; N_1 = N fertilization as recommended – 25%; N_2 = N fertilization as recommended.

Year	Crop	Variety	N_0	Broadcast	Fluid injection: Early	Middle	Late
N-level N_2							
2006	W-Wheat	Dekan	45	100	88	98	102
2007	W-Barley	Theresa	47	100	77*-	96	107
2008	W-Rye	Visello	41	100	91	95	87
2009	S-Wheat	Kadrilj	53	100	84*-	90	115*
2009	S-Wheat	Taifun	64	100	85	95	98
2010	W-Barley	Finesse	20	100	97	98	(40)
2010	W-Barley	Fridericus	25	100	95	99	(51)
2011	W-Wheat	Dekan	29	100	98	103	96
2011	W-Wheat	Mulan	34	100	92	115*	101
2012	W-Wheat	Dekan	22	100	108	109*	90
2012	W-Wheat	Mulan	19	100	118**	112*	94
	Average		36	100	94	101	99
N-Level N_1							
2006	W-Wheat	Dekan	50	100	94	108	98
2007	W-Barley	Theresa	53	100	85	106	114*
2008	W-Rye	Visello	48	100	104	112	93
2009	S-Wheat	Kadrilj	68	100	107	122*	117*
2009	S-Wheat	Taifun	77	100	102	112*	100
2010	W-Barley	Finesse	24	100	108	106	(57)
2010	W-Barley	Fridericus	28	100	98	101	(63)
2011	W-Wheat	Dekan	35	100	110*	103	106
2011	W-Wheat	Mulan	38	100	107	113*	111
2012	W-Wheat	Dekan	29	100	140*	134*	107
2012	W-Wheat	Mulan	24	100	126*	130**	103
	Average		43	100	107	113	105

Numbers in brackets: Crop damage due to poor weather condition during late injection; excluded from average calculation; W = winter, S = spring; * significantly different p<0,05; **sign. P<0,01; ANOVA and Dunnett test by stat. program R

also recorded equal or higher grain protein contents by injection in the middle or at the end of tillering in all years. These results and other data from field and pot experiments (Walter, 2010; Richter, 2010; Schittenhelm and Menge-Hartmann, 2006; Kücke, 2003; Jacobs, 2012) indicate that in most cases N use efficiency is higher after fluid injection compared to broadcast fertilization. These yield and quality differences increase with decreasing N level and are particularly pronounced in years with drought periods in spring as well as in cropping systems with minimum tillage. We also found lower evapotranspiration per unit grain yield for cereals in our lysimeter research and a significant reduction of ammonia volatilization and N_2O release from fertilizer N (Deppe *et al.*, 2012) after CULTAN fertilization. Moreover, several further studies show that nitrate leaching can be reduced remarkably. For example, Walter (2010) found on average a reduction in nitrate leaching of 50% (p<0.00).

Summary and conclusions

Our results show that at a high N fertilization level CULTAN fertilization results in yields and qualities comparable to broadcast N application. However, in cases of reduced N level, field experimental data prove higher N use efficiency by the CULTAN strategy. Despite the fact that we have no official fertilization recommendation for the use of the CULTAN method, the interest of farmers in this technology is steadily increasing. However, a wider use of fluid

N injection is currently limited by i) the low production capacity for spoke wheel injectors in Europe, ii) occasionally limited local availability of fluid fertilizers, and iii) lack of contractors who offer this kind of fertilization. Based on our data and those from other research groups we conclude that N fertilizer consumption in cereal cultivation can be reduced by 15 to 20% without significant decrease in grain yield or quality. Similar results are reported for other crop species (e.g. vegetables, potatoes). With regard to the requirements of EU frameworks, the rules of good agricultural practice, the adaptation of fertilization to new climatic conditions and the adaptation of fertilization to minimum or non tillage soil cultivation, a subsurface placement of fertilizers like the CULTAN technique is in almost all situations superior to broadcast fertilizer application (not only for N, but also for P). Since less than 5% of the plough layer soil gets in contact with fertilizer nutrients, we assume further favorable effects on soil organic matter stability and soil biology/microbiology and will focus future research work on these aspects, as well as on crop health which has been reported by farmers to be improved by CULTAN fertilization.

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