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Nitrogen fertilization of winter wheat in spring in Finland: comparison of calcium ammonium nitrate and calcium nitrate, and the effect of split application

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Abstract. The effectiveness of calcium nitrate (CN) and calcium ammonium nitrate (CAN) as N sources for winter wheat in spring was studied in seven field trials in Southern Finland, in the province of Uusimaa. The experiments were carried out on clay soils in 1986—1989. Nitrogen dressings of 120—150 kg ha^{-1} were broadcasted either as a single application or split into two applications. The two applications were in most cases 30—40 and 90—110 kg ha^{-1}. The single or the first split application was given in the beginning of the growing season and the latter application at the end of tillering. The grain yields obtained by a single N application of 140—150 kg ha^{-1} ranged from 2 610 to 7 550 kg ha^{-1} and the protein content of grains from 9.4 to 14.5 %. The nitrogen form of the fertilizer had no significant effect on the grain yield and on the protein content of grains. Splitting the nitrogen increased the grain yield by 400 kg ha^{-1} and the protein content of grains by 0.8 percentage points.

Index words: Calcium ammonium nitrate, calcium nitrate, fertilization, nitrogen, split application, winter wheat

Introduction

Calcium ammonium nitrate (CAN) is the most commonly used straight nitrogen fertilizer in Finland. An amount of 79 000 tons of CAN was sold in Finland during the period July 1, 1988 to June 30, 1989 (Anon. 1989). Calcium nitrate (CN) is today of minor importance, 3 000 tons being used annually. The nitrogen of CN is in nitrate form, whereas CAN contains nitrogen in nitrate and in ammonium form in equal proportions.

There are only few papers comparing the effect of CN and CAN on the grain yield of winter cereals in Finland or other Scandinavian countries. Jaakkola (1978) compared five forms of fertilizer N in a five-year field experiment on winter wheat, winter rye and spring wheat; there was no difference in the effect of CN and CAN on the grain yield. The effect of CAN and CN on the grain yield of winter wheat has been compared also in

Sweden in a series of 97 trials; CN was found to be a more effective N source than CAN in the eastern and in the western part of Sweden, but not in the southern part (JONSSON 1971). The rate of nitrogen application in both trials (JAAKKOLA 1978, JONSSON 1971) was lower (75 and 60 N kg ha^{-1}, respectively) than used nowadays.

The N fertilizer dressing of winter cereals in spring is traditionally given in one application in Finland. Splitting the fertilizer dressing into two applications is a common practice in Sweden, where the climatic conditions and the length of the growing period are equal to those in Finland. A low application of N is given in the beginning of the growing season and the rest of the nitrogen at the tillering stage, if growth is exuberant. If the vegetation is scanty, the higher dose is given first.

The aim of this study was to compare CN and CAN in spring fertilization of winter wheat. The effect of a split fertilizer application was also investigated.

Materials and methods

The seven field experiments reported in this paper were carried out in 1986—1989 in Southern Finland, in the province of Uusimaa. The experimental crop in all trials was the winter wheat cultivar "Aura". The quantity of seeds sown was 220—250 kg ha^{-1}. Plant-available nutrient resources of the soils were determined before starting the trials by acid ammonium acetate extraction (VUORINEN and MÄKITIE 1955). At the time of sowing in September the experimental fields were given a NPK fertilizer application according to their fertility. The N application in autumn ranged from 48 to 110 kg ha^{-1}. Details of the experimental fields and their autumn fertilization are given in Table 1.

In spring the experimental fields were given a N dressing as calcium nitrate (15.5 % N) or calcium ammonium nitrate (27.5 % N). The nitrogen dressing was broadcasted on the field either as one application or split into two applications. The first application was given at the beginning of the growing period in late April or in early May. The second application was given at the end of the tillering stage in late May. The rates of fertilizer dressings (N kg ha^{-1}) were as follows:

	Beginning of growing season	End of tillering
Trial 1	150	—
	110	40
	40	110
Trials 2—7	120	—
	30	90
	140	—
	30	110

The field of trial 1 was divided into four blocks, each comprising six plots of 60 m^2. Trial 3 consisted of two blocks and trials 2, 4, 5, 6 and 7 of three blocks, each comprising 8 plots of 30 m^2.

After harvest the grain yields were weighed, the moisture content was determined and the grain yields per hectare were calculated at a moisture level of 15 %. The replicate samples

Table 1. Location, soil type and autumn fertilization of the experimental fields.

Trial	Year	Location	Soil type	Autumn fertilization	
				N-P-K (%)	kg ha^{-1}
1	1986	Kotkaniemi, Vihti	Loamy clay	16-7-13	500
2	1986	Sten Ståhls, Loviisa	Sandy clay	12-11-10	600
3	1987	Stor Sarvlax, Loviisa	Gyttja clay	12-11-10	400
4	1988	Västankvarn, Inkoo	Gyttja clay	16-7-13	300
5	1989	Stor Sarvlax, Loviisa	Gyttja clay	12-11-10	400
6	1989	Majuri, Vihti	Silty clay	20-4-8	550
7	1989	Västankvarn, Inkoo	Gyttja clay	16-7-13	400

were combined for protein analysis, and the analysis was carried out in duplicate. The grain yield results were tested statistically using the analysis of variance, which was made separately for each trial. The paired t-test was applied for the data of all trials to test the effect of the N form of the fertilizer, split application and rate of N dressing on the protein content of grains.

Results and discussion

The average yields of winter wheat when using CAN and CN were 5 480 kg ha^{-1} and 5 380 kg ha^{-1}, respectively (Table 3). The low yields of 1987 and 1988, ranging from 2 430 to 3 590 kg ha^{-1}, were mainly due to the low average temperature in 1987 and the dryness in 1988. The Summers of 1986 and 1989 were beneficial for winter wheat and the yields were relatively high, ranging from 4 630 to 8 210 kg ha^{-1}. The low protein contents were typical of high grain yields and vice versa. The protein content of grains ranged from 9.4 to 15.1 % (Table 2).

Raising the rate of N application from 120 to 140 kg ha^{-1} did not have any significant effect on the quantity of grain yields, although it decreased the average yield by 100 kg ha^{-1}. Increasing the N application by 20 kg ha^{-1} elevated the average protein content of grains by 0.5 percentage points ($t = 4.60^{***}$). The autumn fertilization showed no effect in any trial.

The grain yields obtained with CAN were in five trials slightly higher than those obtained with CN, but the difference was significant only in trial 7 ($F = 10{,}27^{**}$). The type of

Table 2. Grain yield (kg ha $^{-1}$) and protein content (%) of grains of winter wheat fertilized with CAN and CN.

Trial	Year	N kg ha^{-1}	Grain yield, kg ha $^{-1}$		Protein content of grains, %	
			CAN	CN	CAN	CN
1	1986	150	4930	4630	13.4	13.6
		110+40	5320	4900	13.3	14.6
		40+110	5000	4940	13.9	14.7
2	1986	120	6780	6860	12.2	12.5
		30+90	7290	7160	14.6	13.9
		140	6980	6550	13.7	14.1
		30+110	7370	7150	15.0	15.1
3	1987	120	2880	3120	14.7	14.4
		30+90	3300	3590	14.3	14.2
		140	2690	2730	14.5	14.5
		30+110	3070	3070	14.8	14.9
4	1988	120	2710	2620	12.2	12.0
		30+90	2910	2860	12.0	12.0
		140	2600	2610	12.1	12.1
		30+110	2560	2440	11.9	12.1
5	1989	120	7220	7430	9.8	9.4
		30+90	7710	7720	10.2	9.5
		140	7230	7550	9.9	9.4
		30+110	7880	8210	10.8	10.3
6	1989	120	6250	6300	10.6	11.3
		30+90	6740	6700	11.3	11.6
		140	6430	6170	12.2	11.8
		30+110	6410	6460	11.3	12.5
7	1989	120	5190	4680	9.4	9.9
		30+90	6470	5830	13.0	11.3
		140	5010	4720	10.1	10.8
		30+110	6170	5940	13.0	12.0

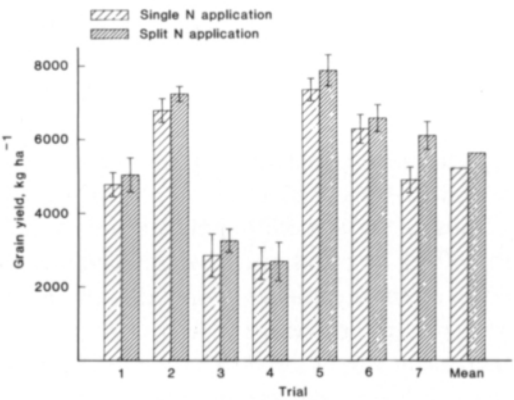

Fig. 1. Grain yields of winter wheat fertilized by single and split N dressing in seven (1—7) field trials.

N fertilizer did not affect the protein content of grains. The average protein content obtained with CN and CAN was 12.4 %. JAAKKOLA's (1978) results of a five-year field trial also indicated that there was no significant difference in the size of grain yield or in the protein content of grains when winter wheat and winter rye were fertilized with CN or CAN. According to ESALA (1989), CN and CAN were also equal N sources as the second N dressing for spring wheat. Because of the fast-acting nitrate (TISDALE et al. 1985), CN is claimed to be a useful fertilizer for winter cereals in spring. The present results do not, however, distinguish between the effectiveness of CN and CAN.

Splitting the fertilizer dressing into two ap-

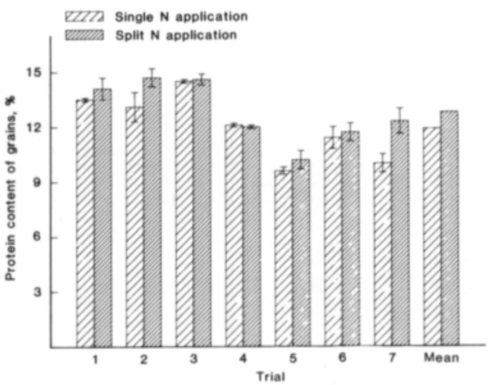

Fig. 2. Protein content of grains of winter wheat fertilized by single and split N dressing in seven (1—7) field trials.

plications increased the grain yields by 2—25 % (Fig. 1); the difference was 400 kg ha^{-1} on average. The split application affected similarly the yields obtained with CN and CAN. The increase of grain yield was statistically significant in trial 2 ($F = 15.85^{**}$), trial 5 ($F = 11.93^{**}$) and trial 7 ($F = 84.25^{***}$). Split application of N increased the protein content of grains in all trials except trial 3 (Fig. 2). The maximum increase of 2.3 percentage points was obtained in trial 7. The increase of the protein content was 0.8 percentage points on average ($t = 3.71^{**}$), which is noteworthy as the protein content of winter wheat is low, as compared to spring wheat.

Based on three field experiments, VARIS and JUUTI (1975) reported that splitting a N dressing of 100 kg ha^{-1} into two applications in spring increased both the quantity and protein content of grain yield of winter wheat. The present results, which are based on more extensive material, were in agreement with their observations. Inversely, RAININKO (1966) did not obtain higher yields by giving an additional N dressing of 25 or 50 kg ha^{-1} to wheat at the flowering stage. The grain yield of winter rye increased in a Danish field trial when a N application of 200 or 300 kg ha^{-1} was split in spring, while splitting a N application of 100 kg ha^{-1} had a negative effect (OLSEN 1986). Indeed, VARIS and JUUTI (1975) suggested that splitting the N application of winter cereals is beneficial only if relatively high amounts of nitrogen are used. A large amount of N in the beginning of the growing season increases the vegetative growth too much, which can disturb later growth by causing lodging, by shadowing the lower leaves and by spending the plant-available nutrient resources of the soil in too early a growth stage. These negative effects can be prevented by splitting the N dressing, which guarantees a more steady availability of N during the growing season.

All trials reported in this paper were carried out on clay soils. According to the results of Danish field experiments, winter wheat can benefit even more from splitting the N dressing when grown on coarse soil, because nitrogen is more readily leached from sandy soils than from clay soils (OLSEN and LARSEN 1984). Furthermore, GREGERSEN and HEJLESEN (1985) found that higher winter wheat yields can be obtained on sandy soils if the nitrogen dressing is split into three applications instead of two.

According to the present results, a N dressing of 120 kg ha^{-1} can be considered sufficient for winter wheat. Raising the amount of N by 20 kg ha^{-1} did not further increase the grain yield, even though the protein content increased by 0.5 percentage points. Splitting the N application into two parts was a more effective way of increasing the size and the protein content of the yield than was the use of an increased single application. There was no difference in the size of the yield and the protein content of grains whether CN or CAN was used. However, the use of CAN is more economical, because the N content of CN (15.5 %) is considerably lower than that of CAN (27.5 %), resulting in higher transportation, storage and broadcasting costs when using CN, as compared to CAN. Furthermore, CN is extremely hygroscopic and this property makes CN a less attractive fertilizer (TISDALE et al. 1985).

References

ANON. 1989. Lannoitteiden myynnin jakautuminen maatalouskeskusalueittain lannoitusvuonna 1988/89. 20 p. Kemira Oy, Helsinki.

ESALA, M. 1989. Kevätvehnän valkuaispitoisuuden lisääminen. Kylvömies 1/1989 p. 6—8.

GREGERSEN, A.K. & HEJLESEN E. 1985. Vand og kvaelstof til vinterhvede på sandjord. Summary: Irrigation and application of nitrogen to winter wheat on sandy soil. Tidsskr. Planteavl 89: 231—240.

JAAKKOLA, A. 1978. Nitrate, ammonium and urea nitrogen fertilizers for wheat and rye in a field experiment. J. Scient. Agric. Soc. Finl. 50: 346—360.

JONSSON, L. 1971. Urea som gödselmedel. Höstsäd. Lantbrukshögskolans meddelanden A 147. 28 p. Uppsala.

OLSEN, C.C. 1986. Optimeret udnyttelse af vinterruggens udbytteevne. Meddelelse nr. 1888. Statens Planteavlsforsoeg, Lyngby, Danmark. 4 p.

OLSEN, C.C. & LARSEN, K.E. 1984. Kvaelstof til vinterhvede, engangs- eller delt udbringing. Summary: Nitrogen application to winter wheat, single or split dressing. Tidsskr. Planteavl. 88: 243—255.

RAININKO, K. 1966. Myöhäisen typpilannoituksen vaikutus kevätvehnän satoon ja leivinominaisuuksiin. Summary: Influence of late nitrogen fertilization on the quality of wheat. J. Scient. Agric. Soc. Finl. 38: 140—149.

TISDALE, S.L., NELSON, W.L. & BEATON, J.D. 1985. Soil fertility and fertilizers. 754 p. 4th Ed. New York.

VARIS, E. & JUUTI, T. 1975. Syysvehnän typpilannoituksen ajoittamisesta. Summary: Timing of nitrogen application in winter wheat production. J. Scient. Agric. Soc. Finl. 47: 270—282.

VUORINEN, J. & MÄKITIE, O. 1955. The method of soil testing in use in Finland. Agrogeol. Publ. 63. 44 p. Helsinki.

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SELOSTUS

Syysvehnän kevätlannoitus: Kalkkisalpietarin ja oulunsalpietarin vertailu sekä jaetun typpilannoituksen vaikutus

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Kalkkisalpietarin ja oulunsalpietarin tehokkuutta syysvehnän kevättyppilannoituksessa tutkittiin 7 kenttäkokeen sarjassa Uudellamaalla vuosina 1986—1989. Koekenttien maalaji oli hiesu-, hieta-, hiue- tai liejusavea. Typpilannoite-erät, jotka sisälsivät typpeä 120—150 kg ha^{-1}, levitettiin koeruuduille joko kertalannoituksena kasvukauden alussa tai jaettuna kahteen osaan, joista ensimmäinen, (tavallisimmin 30—40 kg ha^{-1}) annettiin kasvukauden alussa ja jälkimmäinen (90—110 kg ha^{-1}) versomisvaiheen lopussa. Jyväsato vaihteli 2 610—7 550 kg ha^{-1} ja jyvien valkuaispitoisuus 9.4—14.5 % ruuduissa, joille oli annettu typpeä 140—150 kg ha^{-1} kertalannoituksena. Typpilannoitelaji ei vaikuttanut jyväsadon määrään tai valkuaispitoisuuteen. Jaettu typpilannoitus suurensi hehtaarisatoa keskimäärin 400 kg ja jyvien valkuaispitoisuutta 0.8 prosenttiyksikköä.