Effect of (2-Chloroethyl)trimethylammonium Chloride on Protein Content, Protein Yield, and Some Qualitative Indexes of Winter Wheat Grain

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Whole grain protein content, protein yield, and some qualitative indexes were determined for samples of grain coming from plants treated with (2-chloroethyl)trimethylammonium chloride (CCC) and nitrogen applied separately or in combination. All treatments involving CCC application decreased whole grain protein content compared with nitrogen treatments alone. With combined CCC and nitrogen treatments the decrease in protein content was less. Because of this and the considerable increase in grain yields caused by the application of CCC, protein yields were either unaffected when CCC was applied alone, or markedly increased when CCC and nitrogen were combined. Out of several undesirable changes in quality and baking test indexes as a result of CCC applied alone, only the volume of loaf was smaller after combined CCC and nitrogen treatment.

A number of authors have reported that (2-chloroethyl)trimethylammonium chloride (CCC, Cycocel) application not only prevents lodging in wheat but also increases grain yield (*8*, *9*, *11*, *13*). Since the complete reduction of losses caused by lodging may increase grain yield by 26% or sometimes more (*10*), application of CCC seems to be of importance for Poland, which imports considerable amounts of wheat every year. This report presents the results of one of the first studies conducted recently in our country on the effects of CCC application to wheat.

It is generally assumed that CCC increases the grain yield of wheat through reduction of culm length and increase of culm thickness, both resulting in higher or complete resistance to lodging. Michniewicz, Chromiński, and Belt (*9*) have suggested, however, that CCC may raise wheat yields for other reasons than positively affecting lodging resistance. They think that the increase of more than 50% in winter wheat grain yield which they obtained when CCC was applied in the soil and almost 100% when used as a foliar spray, may also be due to action of an unknown nature on the whole plant or/and its generative organs. Reports on the effect of CCC on the increase in weight of 1000 kernels (*1*, *6*, *9*, *13*) and the number of fertile spikelets in wheat ears (*3*) indicate that such a possibility exists.

Considering these observations, it seemed especially interesting to examine the effect of CCC on the quality indexes of wheat grain and baking test results in the case when CCC affects both yield and 1000-kernel weight.

Furthermore, the possibility of widespread application of CCC by wheat growers makes such studies desirable.

To evaluate the effects of CCC application more exactly, data are presented on its influence on grain yield, 1000-kernel weight, whole grain protein content, and protein yield.

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Material and Methods

Grain of the winter wheat of Leszczyńska Wczesna variety, having average to good quality under normal growth conditions, was harvested in 1965 in the field experiment of Michniewicz, Chromiński, and Belt (*9*) carried out at the Kopernik University Agricultural Experiment Station, Piwnice n. Toruń, in northwest-central Poland. Their experiment tested the effect of CCC applied in rates from 4 to 12 kg. per hectare (1 ha. = 2.471 acres; 1 kg. per ha. = 0.892 pound per acre) and of nitrogen applied in rates from 80 to 160 kg. per hectare, as well as the combined action of CCC and nitrogen. In the fall of 1964 all the plots received 16(36) and 33(40) kg. of P and K per hectare as superphosphate and 40% potassium salt, respectively. Nitrogen was applied in the form of ammonium nitrate as top dressing in two equal doses, on April 9, 1965, at about the beginning of the vegetation period, and on May 29, 1965, at the stage of shooting. On May 29, CCC was also applied in the soil, alone or mixed with ammonium nitrate.

The grain obtained from the experiment described was affected in both total grain yield and weight of 1000 kernels, both being increased by CCC application.

In the present work the grain samples from the extreme CCC and nitrogen treatments—i.e., from the highest and the lowest—as well as from their combinations, were tested for whole grain protein content by the micro-Kjeldahl method (*2*). The flour prepared from each sample on a Quadrumat Senior mill at 60% extraction was used for measuring the properties of dough on a Brabender-type farinograph and for baking tests.

Results and Discussion

Data on the effect of CCC and nitrogen on whole grain protein content and yield, grain yield, and 1000-kernel weight are presented in Table I. The results shown indicate that CCC applied alone markedly decreased the whole grain protein content. This effect was less when CCC was applied jointly with nitrogen. A statistical analysis of the data on whole grain protein content showed that the decreases in protein content caused by CCC applied alone were significant at the 1% level, compared with treatments with nitrogen alone. However, out of four combinations of joint CCC and nitrogen treatments only one significantly decreased whole grain protein content, as compared to nitrogen only—the higher CCC treatment of 12 kg. per hectare combined with the lower nitrogen treatment of 80 kg. per hectare.

Despite the decrease in the protein content of grain, protein yields from both treatments with CCC alone were unchanged as compared with the corresponding nitrogen treatments. The plants responded to CCC with such a great increase in grain yields that the CCC-depressing effect on protein content was completely neutralized and protein yields were not affected. For that reason and because of the increase in per cent protein content in wheat kernels caused by nitrogen application, joint CCC and nitrogen treatments produced considerably higher protein yields than nitrogen treatments alone. The data in Table I show that the differences between these two groups of treatments were significant at 5 or 1% levels.

The grain qualitative indexes are summarized in Table II, A, and some of the farinograms are presented in Figure 1. Both the data in Table II, A, and the farinograms indicate negative effects of CCC on the quality of grain. The most pronounced effect was that produced by doses of CCC applied alone on the dough-softening index, which can be clearly seen from the farinograms. Among the combined treatments with nitrogen and CCC, this negative effect was observed only when the higher CCC dose was applied jointly with the lower nitrogen one. The stability of dough tended to be somewhat lower with CCC treatment of 12 kg. per hectare and with combined treatment involving 12 kg. of CCC and 160 kg. of N.

The results of the baking tests given in Table II, B, show that only CCC applied alone resulted in a worse structure of bread and a considerable darkening of the crust color. The volume of the loaf tended to be smaller when samples from all treatments containing CCC were tested. The dark brown color of the crust in treatments with CCC alone was probably a result of an increase in the amount of carbohydrates caramelizing in the baking process; however, no measurements of reducing sugars content have been made to support this suggestion.

Comparison of the data from Tables I and II indicates that effects of CCC on the quality of wheat grain were

Table I. Effect of Nitrogen and CCC on Whole Grain Protein and Yield, Grain Yield, and 1000-Kernel Weight

(% protein = % N × 5.7, dry weight basis)

	Treatments, Kg./Ha.[a]								L.S.D., %	
	N 80	N 160	CCC 4	CCC 12	N 80 CCC 4	N 160 CCC 4	N 80 CCC 12	N 160 CCC 12	5	1
Protein content, %	11.66	12.40	8.55	8.25	10.45	11.35	10.20	11.43	1.36	1.82
Protein yield, ql./ha.[b]	3.22	3.39	3.33	3.38	3.57	3.63	4.58	4.43	0.15	0.20
Grain yield, ql./ha.[b]	27.6	27.3	39.0	41.0	34.2	32.0	44.9	38.8	5.0	6.7
1000-kernel weight, g.[c]	36.1	35.4	39.4	40.1	35.9	35.5	37.3	35.3	0.5	0.7

[a] Kilogram per hectare = 2.2 lb. per 2.471 acres = 0.892 per acre.
[b] Metric quintal per hectare = 220.46 lb. per 2.471 acres = 89.22 lb. per acre.
[c] Dry weight basis.

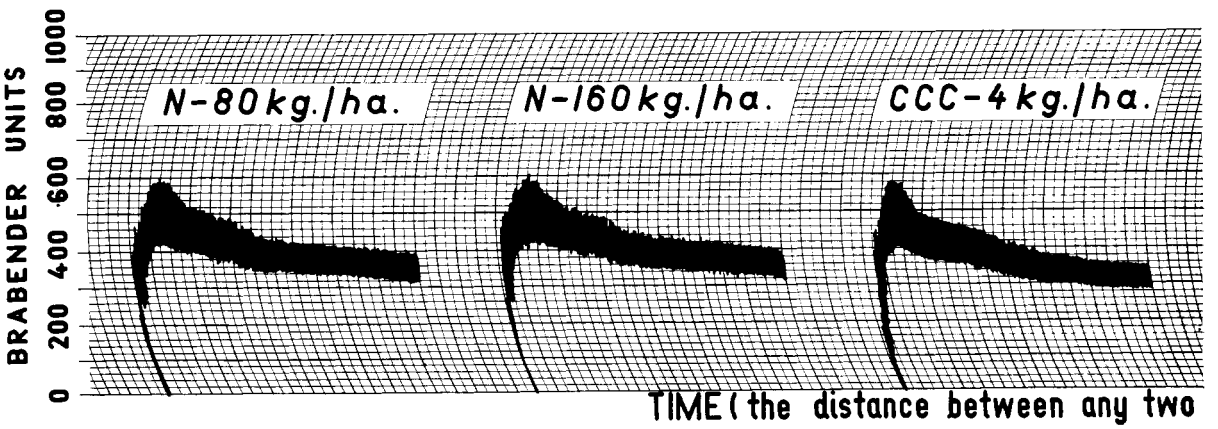


Figure 1. Effect of nitrogen and (2-chloroethyl)trimethylammonium

Table II. Effect of Nitrogen, CCC, and Joint Application on Quality Indexes and Baking Tests of Winter Wheat Grain

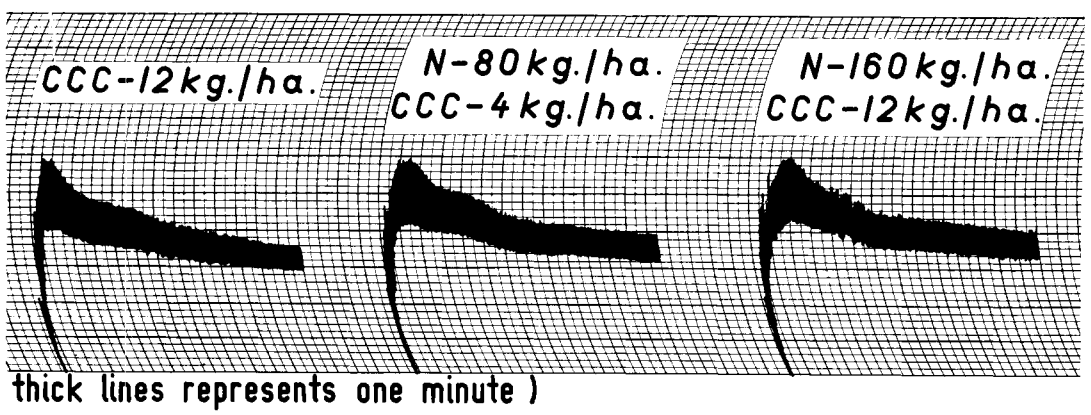
	Treatments, Kg./Ha.[a]							
	N 80	N 160	CCC 4	CCC 12	N 80 CCC 4	N 160 CCC 4	N 80 CCC 12	N 160 CCC 12
A. Quality indexes determined on farinograph								
Water absorption, %	60.2	60.0	60.0	59.0	59.0	59.4	59.0	60.2
Development of dough, sec.	72	78	78	54	60	90	72	90
Stability of dough, sec.	54	48	48	36	54	48	48	42
Elasticity of dough, Brabender units	160	150	150	160	160	160	155	150
Softening of dough, Brabender units	140	140	180	175	140	135	150	130
B. Baking test								
Water absorption of flour, %	62.4	62.4	61.6	60.8	61.6	61.6	61.2	63.2
Increase in weight of bread, %	53.2	52.0	50.0	48.0	50.4	50.0	49.2	51.2
Volume of loaf, cc.	444	460	404	412	412	400	404	408
Structure of bread according to Schnelle[b]	4	4	3	3	4	4	4	4
Color of crust	Light brown	Light brown	Dark brown	Dark brown	Light brown	Light brown	Brown	Light brown

[a] Kilogram per hectare = 2.2 lb. per 2.471 acres = 0.892 lb. per acre.
[b] Scale of 1 to 5, very poor to very good.

most pronounced with treatments which significantly decreased whole grain protein content. This points at the changes in protein content as responsible for the changes in the qualitative indexes of grain and in the results of the baking test.

Since in previous reports the effects of CCC on wheat were always studied when CCC was applied simultaneously with normal or high rates of nitrogen fertilizers, the results reported here for CCC applied alone cannot be compared directly with those previously published.

As regards the combined effect of CCC and nitrogen fertilizers, Sturm and Jung (*12*) reported no changes in protein content of spring and winter wheat grain, Zenishcheva and Bezdek (*13*) found the whole grain protein content of winter wheat of Fanal variety unaffected by CCC application when both CCC-treated and control plants remained nonlodged, and Humphries *et al.* (*3*) obtained an increase in grain protein content of spring wheat of the Phoebus variety. The most extensive studies conducted so far on the effects of CCC on spring and winter wheats grown under field conditions were carried out by Schröder and Rhode (*11*) in northwestern West Germany. Their studies showed that CCC applied jointly with nitrogen decreased grain protein content at the 5% significance level. This agrees with the tendency found in the present study for the per cent grain protein content to be always lower



chloride on quality of wheat grain as determined on a farinograph

with joint CCC and nitrogen treatments than nitrogen treatments alone.

The literature concerning the effects of CCC on quality of wheat is very scanty and only two reports on this subject are known to the author. Zenishcheva and Bezdek (*13*), on the ground of preliminary measurements which did not include baking tests, suggested that CCC had no direct effect on grain quality but its application could prevent undesirable quality changes resulting from lodging. Schröder and Rhode (*11*) found that the loaf volume was decreased by CCC application. The data presented in Table II, B, indicating decrease in volume of loaf in all treatments involving CCC application, are also in line with their results.

Out of two CCC treatments tested in the present study, only the lower—i.e., 4 kg. per hectare—is justified by agronomic practices. As many authors have reported (*4*, *5*, *7*, *9*, *12*), CCC treatments involving the application of 1.5 to 4.5 kg. per hectare cause lodging resistance in wheat even at high rates of nitrogen fertilizers application. At such doses of CCC applied jointly with nitrogen, undesirable changes in grain are not likely to affect quality significantly. On the other hand, since CCC permits the use of greater amounts of nitrogen fertilizer, it is possible to increase protein content in grain by skillfully applied nitrogen top dressings. This can increase yields without reducing grain quality.

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