EFFECT OF IRRIGATION AND MINERAL FERTILIZATION ON SPRING CEREALS CULTIVATED ON A SANDY SOIL.

Part II. ACTIVITY OF SOME PHYSIOLOGICAL PROCESSES AND CHEMICAL COMPOSITION OF GRAIN

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ABSTRACT

As effect of overhead irrigation and mineral fertilization the synthesis of chlorophyll and carotenoides was enhanced as well as the assimilation surface of the tested plant leaves. Moreover an increased activity of some enzymes in the flag-leaf and increased content on nitrates was found. The applied treatments had only a slight effect on the crop chemical composition but changed its biological value. High doses of mineral fertilizer caused a decrease of aminoacid content whereas irrigation increased that content, particularly of essential AA, basic AA and limiting AA. These indices were higher in grain obtained from irrigated plots, thus enhancing the biological value of the crop.

Key words: irrigation, NPK, wheat, triticale, barley, oat, enzymes, nutrients, grain quality.

INTRODUCTION

Extensive fertilization combined with supplemental irrigation intensifies the physiological processes in plants. Such are the findings of Karczmarczyk et al (1990), Machackova et al. (1975), Wojcieska et al. (1982), Zbiec et al. (1989). The positive influence of these measures explains the obtained yield increases. About modification of the crop quality caused by irrigation and fertilization inform papers of Dziezyc and Biskupski (1974), Karczmarczyk et al (1983), Koszanski et al (1994), Sienkiewicz and Ploszynski (1969). The described changes depend on the complex influence of environmental factors, as well as on the various response of the cultivated plant species and cultivars. Hence differences of the results obtained by various authors, and the need of more general conclusions make continuation of studies on this subject necessary.

The purpose of this study was to assess the impact of irrigation and mineral fertilization on chlorophyll and carotenoides content, and the activity of some enzymes in the flag leaves of the tested plants. Furthermore the mineral composition of the crop and the biological value of the protein was studied.

MATERIALS AND METHODS

The field experiment design has been described in the part I of this paper. The flag leaves for chemical analysis were sampled when the cereals were in the earing phase. The chlorophyll content was assessed by Arnon (1956) method, that of carotenoides by Sohnarrenberger and Mohr (1970) in dimethylformamide leaf extract. Nitrate content was measured with an ion-selective electrode. Nitrate reductase activity was assessed using NADH as hydrogen donor, activity of phosphatases and peroxidase - colorimetrically. The activity of photosynthesis was measured by Infralyt. Minerals content was assessed by methods commonly used in chemistry labs. The aminoacids were assessed in 6N HCI-hydrolyzate by an automatic AA analyzer (AAA-881) (Oser, 1951).

RESULTS AND DISCUSSIONS

Intensity of photosynthesis and thus biomass production is dependent on photosynthetic pigments, mineral, content, and enzyme activity.

It was shown that as effect of irrigation the chlorophyll content in wheat and triticale flag leaf rose by 20 and 25%, oat and barley by 5-7% respectively. High doses on mineral fertilizer caused an overall increase of chloro-

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Table 1. Effect of irrigation and NPK doses on pigment content and leaf area of spring wheat and triticale

Variants	Spring wheat			Spring triticale		
	Chlorophyll (μg/g)	Carotenoides (μg/g)	Leaf area (dm^2/1pl)	Chlorophyll (μg/g)	Carotenoides (μg/g)	Leaf area (dm^2/1pl)
O	2965	1220	15.9	2642	1140	40.3
W	3703	1312	28.8	3173	1208	66.7
O	2242	932	9.0	2004	1003	33.6
150 kg NPK	2551	960	10.6	2641	1095	45.2
300 kg NPK	3995	1571	32.9	3086	1263	60.0
450 kg NPK	4547	1602	36.9	3899	1336	75.8

O - not irrigated; W - irrigated

Table 2. Effect of irrigation and NPK doses on pigment content and leaf area of spring barley and oat

Variants	Spring wheat			Spring oat		
	Chlorophyll (μg/g)	Carotenoides (μg/g)	Leaf area (dm^2/1pl)	Chlorophyll (μg/g)	Carotenoides (μg/g)	Leaf area (dm^2/1pl)
O	2418	1209	14.0	3035	1185	40.3
W	2576	1193	22.8	3196	1237	66.7
O	1809	983	9.4	1700	903	33.6
150 kg NPK	2271	1099	14.2	2931	1031	45.2
300 kg NPK	2793	1299	21.6	3629	1311	60.0
450 kg NPK	3116	1422	28.6	4203	1599	75.8

O - not irrigated; W - irrigated

phyll, in case of oat by almost 150%. The carotenoides content in leaves from variants fertilized by 3-fold NPK doses, increased by 30-70%. The total leaf surface of plants has also a great influence on biomass synthesis. As shown in table 1, the leaf surface of irrigated plants exceeded that of nonirrigated by 60-80%, whereas triple NPK doses increased the surface of barley leaves by 204%, 310% of wheat, and over 120% of triticale and oat.

A positive effect of irrigation and fertilization on biomass production shows table 2. The photosynthesis of wheat was in irrigated variants by 16%, of triticale by 13% higher, and if the plants had been well fertilized the increases amounted to 47 and 38% respectively. The respiration was also increased, but to a much lesser degree.

The nutritional status of a plant can be expressed by nitrate content in the flag leaf (Tables 3 and 4). It was shown that the applied treatments caused an elevation of NO_3 content in the flag leaf. Irrigation caused an increase of NO_3 content in wheat by 81%, in oat by 66%, whereas fertilization increased the nitrate content in wheat four times, and doubled it in oats.

Table 3. Intensity of photosynthesis and respiration of spring wheat and spring triticale flag leaf (mg CO_2)

Variants		Photosynthesis		Respiration	
Irrigation	NPK(kg/ha)	(mg dm^2 h^{-1})	(mg g^{-1} h^{-1})	(mg $dm^2 h^{-1}$)	(mg g^{-1} h^{-1})
Spring wheat					
O	0	11.4	20.6	1.34	2.08
	450	16.8	29.4	1.76	2.82
Means		14.1	25.0	1.55	2.45
W	0	13.2	25.8	1.42	2.70
	450	19.4	37.6	2.06	3.10
Means		16.3	31.7	1.74	2.90
	0	12.3	23.2	1.38	2.39
	450	18.1	33.5	1.91	2.96
Spring triticale					
O	0	10.6	19.8	1.10	2.12
	450	14.9	27.4	1.52	2.42
Means		12.8	23.6	1.31	2.27
W	0	12.2	24.4	1.20	2.22
	450	16.5	28.6	1.50	2.62
Means		14.4	26.5	1.35	2.42
	0	11.4	22.1	1.15	2.17
	450	15.7	28.0	1.51	2.52

O - not irrigated; W - irrigated

Table 4. Effect of irrigation and mineral fertilization on the activity of some enzymes in spring wheat flag leaf

Variants		Peroxidase	Phosphatase		Nitrate	$N-NO_3$
Irrigation	NPK (kg/ha)	(unit)*	acid (mmol/kg)	alkaline (mmol/kg)	reductase (umol/g/h)	content (mg/kg)
	0	110	4.33	1.33	152	4.8
O	150	162	5.00	1.20	212	7.2
	300	198	6.33	1.20	262	23.3
	450	234	6.93	1.07	414	28.2
Means		176	5.65	1.20	260	15.9
	0	105	5.27	1.35	173	13.1
W	150	150	6.47	1.15	297	14.1
	300	170	7.20	1.10	384	42.5
	450	195	7.87	1.03	542	45.4
Means		155	6.70	1.16	349	28.8
	0	108	4.80	1.34	163	9.0
	150	156	5.74	1.18	255	10.6
	300	184	6.77	1.15	323	32.9
	450	215	7.40	1.05	478	36.9

O - not irrigated; W - irrigated; */ E/s 100 g

Table 5. Effect of irrigation and mineral fertilization on the activity of some enzymes in oat flag leaf

Variants	Peroxidase (unit)*	Phosphatase		Nitrate reductase (umol/g/h)	N-NO3 content (mg/kg)
		acid (mmol/kg)	alkaline (mmol/kg		
O	90	10.5	2.0	101	34.8
W	69	12.4	1.8	149	57.8
O	60	10.0	2.3	82	31.2
150 kg NPK	72	10.6	2.0	99	41.6
300 kg NPK	84	11.8	1.8	139	49.3
450 kg NPK	100	13.3	1.7	181	63.1

O - not irrigated; W - irrigated; */ E/s 100 g

As can be clearly seen from data of tables 4 and 5, irrigation and fertilization had an influence on the activity of some enzymes contained in flag leaf tissue. The activity of peroxydase diminished under the influence of irrigation by 14% in wheat, 30% in oat, and rose two-fold as effect of mineral fertilization. The alkaline phosphatase activity was lowered by up to 35%, on the other hand the acid phosphatase was by 18-54% more active in plants taken from irrigated and well fertilized plots.

There is no doubt that, big crops of high protein content can yield only plants distinguished by efficient photosynthesis and nitrogen incorporation.

According to Beeverst and Hageman (1960) and Erlich and Hageman (1973), a key role in the above mentioned aspect play enzymes, particularly nitrate reductase. Our study proved a connection between mineral fertilization, yield and nitrate reductase activity. The growth of irrigated and well fertilized plants was extended and photosynthesis more efficient. Thus the production of biomass was larger, and on the other hand, as stated by Joy and Hageman (1966) enhanced photosynthesis was a source of electrons needed by nitrate and nitrite reductases for nitrate reduction.

Nitrate reductase, according to Hageman and Flesher (1960) and Wojcieska et al. (1982) reacts to nitrate content in the soil and plants, that was confirmed in our study: there was a close relation between fertilization level and irrigation, and nitrate reductase activity in leaf tissue.

Also an increased peroxidase activity was found as effect of high doses of mineral fertilizer. This enzyme according to Machackowa (1975), protects endogenous growth regulators, hence is an important factor in plant phyiological processes. It should be stressed that, plants which gave a bigger yield were characterized by enhanced enzyme activity and photosynthesis.

The crop value is determined by nutrient and mineral content, particularly by protein and exogenous aminoacid levels. The production of protein can be risen by fertilization, yield increase, cultivation of more productive cultivars and plants, but the improvement of its quality is a harder task, because it depends mostly on the genetic traits, whereas the environment plays only a minor role in the quality modifications. Unfortunately, as Dziezyc and Biskupski (1974), Pisulewska (1995) and Wróbel and_Budzynski (1994) found, there exists a contrary relation between the crop quantity and the quality of the protein. The crop quality was assessed by analysis of oat and triticale grain, the results being presented in tables 6, 7, 8 and 9.

The grain of both plants from irrigated plots contained 10% less protein, fiber and lipids, but an increased level of carbohydrates and mineral compounds. On the other hand, increased fertilization enhanced the content of protein from 10% to 13%, also of mineral compounds and lipids, but decreased that of fiber and carbohydrates.

Only minor changes in the content of macro and microelements were found as effect of irrigation - a decreased level of total and nitrate nitrogen, which levels increased under the influence of high fertilizer doses.

The protein yield was related to the grain

Table 6. Nutrient content in spring triticale (means of 3 years in %)

Variants	Total protein	Fiber	Lipids	Ash	Carbohydrates
O	12.8	9.59	3.83	2.18	71.6
W	11.4	9.39	3.53	2.78	72.9
O NPK	10.5	9.72	3.26	2.12	74.4
150 kg NPK	10.8	9.60	3.62	2.31	73.7
300 kg NPK	11.3	9.43	3.87	2.60	72.9
450 kg NPK	13.7	9.21	3.97	2.86	70.3

O - not irrigated; W - irrigated

Table 7. Nutrient content in oats (means of 3 years in %)

Variants	Total protein	Fiber	Lipids	Ash	Carbohydrates
O	11.8	11.0	6.66	2.28	68.3
W	10.8	10.1	6.06	2.69	70.4
O NPK	9.6	11.4	6.12	2.28	70.6
150 kg NPK	10.5	10.6	6.32	2.39	70.2
300 kg NPK	12.0	10.4	6.46	2.56	68.6
450 kg NPK	13.1	9.8	6.52	2.72	67.9

O - not irrigated; W - irrigated

Table 8. Amount of macro and microelements in spring triticale grain

Variants	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (%)	Zn (%)	$N-NO_3$ (ppm)
O	2.07	0.42	0.59	0.04	0.12	92	36	72
W	1.81	0.40	0.62	0.03	0.12	83	36	64
O NPK	1.68	0.38	0.57	0.03	0.13	94	36	60
150 kg NPK	1.87	0.41	0.58	0.03	0.12	90	35	68
300 kg NPK	2.02	0.42	0.61	0.04	0.12	84	36	76
450 kg NPK	2.19	0.43	0.66	0.04	0.11	82	36	85

O - not irrigated; W – irrigated

Table 9. Amount of macro and microelements in oat grain

Variants	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (%)	Zn (%)	$N-NO_3$(ppm)
O	1.99	0.69	0.56	0.12	0.15	145	33	84
W	1.84	0.72	0.57	0.10	0.17	121	31	76
O NPK	1.47	0.64	0.51	0.09	0.15	146	28	65
150 kg NPK	1.89	0.70	0.57	0.11	0.16	144	31	71
300 kg NPK	2.07	0.74	0.58	0.11	0.16	127	34	85
450 kg NPK	2.22	0.76	0.61	0.12	0.18	116	35	98

O - not irrigated; W - irrigated

Table 10. Yield and charateristics of oat grain protein

Variants		Protein yield(kg/ha)	Crude protein(%)	Yield of Aminoacids (kg/ha)	Lys+Arg / Prol	EAAI	BAAI	CSI_{Lys}
Irrigation	NPK (kg/ha)							
	0	257	9.8	236	1.22	57.8	1.32	62
O	150	322	10.9	296	1.34	55.2	1.06	58
	300	406	12.5	277	1.31	39.4	0.94	46
	450	415	13.9	213	1.30	33.4	0.82	42
Means		350	11.8	256	1.29	46.5	1.04	52
	0	264	9.4	256	2.12	64.0	1.59	96
	150	570	10.1	569	2.31	51.0	1.46	92
W	300	784	11.4	674	1.94	46.2	1.28	81
	450	817	12.2	427	1.87	41.6	1.04	60
Means		609	10.8	482	2.06	52.2	1.34	82
O NPK		261	9.6	246	1.67	60.9	1.46	79
150 kg NPK		446	10.5	433	1.83	56.1	1.26	75
300 kg NPK		595	12.0	426	1.63	42.8	1.11	64
450 kg NPK		616	13.1	320	1.59	37.5	0.93	51

O - not irrigated; W – irrigated

Table 11. Yield and characteristics of spring triticale grain protein

Variants		Total protein (%)	Yield of protein (kg/ha)	Limiting amino acid index					Digestibility factor Lys+Arg / Prol
Irrigation	NPK (kg/ha)			EAAI	BAAI	CSI_{Lys}	CSI_{Leu}	CSI_{met}	
O	0	10.9	307	48	9.38	36	40	31	0.72
	450	14.7	466	48	7.97	40	51	31	1.08
Means		12.8	387	48	8.68	38	46	31	0.90
W	0	10.1	393	55	9.87	32	47	31	0.57
	450	12.6	1051	53	8.89	37	51	33	0.82
Mean		11.4	722	54	9.38	35	49	32	0.70
NPK	0	10.5	350	52	9.63	34	44	31	0.65
NPK	450	13.7	759	51	8.43	39	51	32	0.95

O - not irrigated; W – irrigated

yield, thus the decreased protein content as effect of irrigation did not diminish its yield. The aminoacids fraction of nitrogen content was lower in grain from well fertilized objects, but increased as effect of irrigation. The aminoacids yield was proportional to the protein yield. Similar data pertaining to negative impact of high fertilizer doses on exogenous aminoacids were described by Mackowiak (1973) and Mikos and Styka (1987).

Digestibility index, expressed by the lysine plus arginine to proline ratio, was not affected by NPK in oat grain, increased in triticale grain, and increased markedly as effect of irrigation, particularly in oat.

The essential aminoacids (EAAI), basic (BAAI) and limiting aminoacids indices increased in grain obtained from irrigated plots which indicated clearly that, exogenous aminoacid levels and biological value of the protein were enhanced (tables 10 and 11).

CONCLUSIONS

Mineral fertilization, and to a lesser extent irrigation caused a significant increase of photosynthetic pigment content, photosynthesis and leaf surface of the tested plants.

Irrigation decreased the activity of peroxydase and alkaline phosphatase. Mineral fertilization caused an increase of peroxydase, acid phosphatase, and most of all enhanced the nitrate reductase which level was proportional to the nitrate content in flag leaves.

The applied treatments had only limited effects on the chemical composition of the grain. Irrigation caused a decrease of nitrogen and protein contents, whereas fertilization enhanced the concentration of N in grain. A slight increase of P and K in the grain was also found.

Irrigation caused an increase of aminoacids, particularly exogenous in grain, fertilization had a negative effect. The digestibility index of the protein as well as essential and basic aminoacids indices were higher in grain from irrigated plots, hence the crop was of better biological quality.

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Table 1. Effect of irrigation and NPK doses on pigment content and leaf area of spring wheat and triticale.

Variants	Spring wheat			Spring triticale		
	Chlorophyll (ug/g)	Carotenoides (ug/g)	Leaf area (dm^2/1pl)	Chlorophyll (ug/g)	Carotenoides (ug/g)	Leaf area (dm^2/1pl)
O	2965	1220	15.9	2642	1140	40.3
W	3703	1312	28.8	3173	1208	66.7
O	2242	932	9.0	2004	1003	33.6
150kg NPK	2551	960	10.6	2641	1095	45.2
300kg NPK	3995	1571	32.9	3086	1263	60.0
450kg NPK	4547	1602	36.9	3899	1336	75.8

O - not irrigated; W - irrigated

Table 2. Effect of irrigation and NPK doses on pigment content and leaf area of spring barley and oat.

Variants	Spring wheat			Spring oat		
	Chlorophyll (ug/g)	Carotenoides (ug/g)	Leaf area (dm^2/1pl)	Chlorophyll (ug/g)	Carotenoides (ug/g)	Leaf area (dm^2/1pl)
O	2418	1209	14.0	3035	1185	40.3
W	2576	1193	22.8	3196	1237	66.7
O	1809	983	9.4	1700	903	33.6
150kg NPK	2271	1099	14.2	2931	1031	45.2
300kg NPK	2793	1299	21.6	3629	1311	60.0
450kg NPK	3116	1422	28.6	4203	1599	75.8

O - not irrigated; W - irrigated

Table 3. Intensity of photosynthesis and respiration of spring wheat and spring triticale flag leaf (mg Co_2).

Variants		Photosynthesis		Respiration	
Irrigation	NPK(kg/ha)	(mg dm^2 h^{-1})	(mg g^{-1} h^{-1}	(mg dm^2h^{-1})	(mg g^{-1} h^{-1}
Spring wheat					
O	0	11.4	20.6	1.34	2.08
	450	16.8	29.4	1.76	2.82
Means		14.1	25.0	1.55	2.45
W	0	13.2	25.8	1.42	2.70
	450	19.4	37.6	2.06	3.10
Means		16.3	31.7	1.74	2.90
	0	12.3	23.2	1.38	2.39
	450	18.1	33.5	1.91	2.96
Spring triticale					
O	0	10.6	19.8	1.10	2.12
	450	14.9	27.4	1.52	2.42
Means		12.8	23.6	1.31	2.27
W	0	12.2	24.4	1.20	2.22
	450	16.5	28.6	1.50	2.62
Means		14.4	26.5	1.35	2.42
	0	11.4	22.1	1.15	2.17
	450	15.7	28.0	1.51	2.52

O - not irrigated; W - irrigated

Table 4. Effect of irrigation and mineral fertilization on the activity of some enzymes in spring wheat flag leaf

Variants		Peroxidase	Phosphatase		Nitrate	$N-NO_3$
Irrigation	NPK (kg/ha)	(unit)*	acid (mmol/kg)	alkaline (mmol/kg)	reductase (umol/g/h)	content (mg/kg)
	0	110	4.33	1.33	152	4.8
O	150	162	5.00	1.20	212	7.2
	300	198	6.33	1.20	262	23.3
	450	234	6.93	1.07	414	28.2
Means		176	5.65	1.20	260	15.9
	0	105	5.27	1.35	173	13.1
W	150	150	6.47	1.15	297	14.1
	300	170	7.20	1.10	384	42.5
	450	195	7.87	1.03	542	45.4
Means		155	6.70	1.16	349	28.8
	0	108	4.80	1.34	163	9.0
	150	156	5.74	1.18	255	10.6
	300	184	6.77	1.15	323	32.9
	450	215	7.40	1.05	478	36.9

O - not irrigated; W - irrigated;

*/ E/s 100 g

Table 5. Effect of irrigation and mineral fertilization on the activity of some enzymes in oat flag leaf

Variants	Peroxidase (unit)*	Phosphatase		Nitrate reductase (umol/g/h)	N-NO3 content (mg/kg)
		acid (mmol/kg)	alkaline (mmol/kg		
O	90	10.5	2.0	101	34.8
W	69	12.4	1.8	149	57.8
O	60	10.0	2.3	82	31.2
150 kg NPK	72	10.6	2.0	99	41.6
300 kg NPK	84	11.8	1.8	139	49.3
450 kg NPK	100	13.3	1.7	181	63.1

O - not irrigated; W - irrigated;
*/ E/s 100 g

Table 6. Nutrient content in spring triticale (means of 3 years in %).

Variants	Total protein	Fiber	Lipids	Ash	Carbohy drates
O	12.8	9.59	3.83	2.18	71.6
W	11.4	9.39	3.53	2.78	72.9
O NPK	10.5	9.72	3.26	2.12	74.4
150 kg NPK	10.8	9.60	3.62	2.31	73.7
300 kg NPK	11.3	9.43	3.87	2.60	72.9
450 kg NPK	13.7	9.21	3.97	2.86	70.3

O - not irrigated; W - irrigated

Table 7. Nutrient content in oats (means of 3 years in %).

Variants	Total protein	Fiber	Lipids	Ash	Carbohy drates
O	11.8	11.0	6.66	2.28	68.3
W	10.8	10.1	6.06	2.69	70.4
O NPK	9.6	11.4	6.12	2.28	70.6
150 kg NPK	10.5	10.6	6.32	2.39	70.2
300 kg NPK	12.0	10.4	6.46	2.56	68.6
450 kg NPK	13.1	9.8	6.52	2.72	67.9

O - not irrigated; W - irrigated

Tabele 8. Amount of macro and microelements in spring triticale grain.

Variants	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (%)	Zn (%)	N-NO_3(ppm)
O	2.07	0.42	0.59	0.04	0.12	92	36	72
W	1.81	0.40	0.62	0.03	0.12	83	36	64
O NPK	1.68	0.38	0.57	0.03	0.13	94	36	60
150 kg NPK	1.87	0.41	0.58	0.03	0.12	90	35	68
300 kg NPK	2.02	0.42	0.61	0.04	0.12	84	36	76
450 kg NPK	2.19	0.43	0.66	0.04	0.11	82	36	85

O - not irrigated; W – irrigated

Table 9. Amount of macro and microelements in oat grain.

Variants	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (%)	Zn (%)	N-NO_3(ppm)
O	1.99	0.69	0.56	0.12	0.15	145	33	84
W	1.84	0.72	0.57	0.10	0.17	121	31	76
O NPK	1.47	0.64	0.51	0.09	0.15	146	28	65
150 kg NPK	1.89	0.70	0.57	0.11	0.16	144	31	71
300 kg NPK	2.07	0.74	0.58	0.11	0.16	127	34	85
450 kg NPK	2.22	0.76	0.61	0.12	0.18	116	35	98

O - not irrigated; W - irrigated

Table 10. Yield and charateristics of oat grain protein.

Variants: Irrigation	Variants: NPK (kg/ha)	Protein yield(kg/ha)	Crude protein(%)	Yield of aminoacids(kg/ha)	Lys+Arg prol	EAAI	BAAI	CSI_{Ly5}
	0	257	9.8	236	1.22	57.8	1.32	62
O	150	322	10.9	296	1.34	55.2	1.06	58
	300	406	12.5	277	1.31	39.4	0.94	46
	450	415	13.9	213	1.30	33.4	0.82	42
Means		350	11.8	256	1.29	46.5	1.04	52
	0	264	9.4	256	2.12	64.0	1.59	96
	150	570	10.1	569	2.31	51.0	1.46	92
W	300	784	11.4	674	1.94	46.2	1.28	81
	450	817	12.2	427	1.87	41.6	1.04	60
Means		609	10.8	482	2.06	52.2	1.34	82
O NPK		261	9.6	246	1.67	60.9	1.46	79
150 kg NPK		446	10.5	433	1.83	56.1	1.26	75
300 kg NPK		595	12.0	426	1.63	42.8	1.11	64
450 kg NPK		616	13.1	320	1.59	37.5	0,93	51

O - not irrigated; W - irrigated

Table 11. Yield and characteristics of spring triticale grain protein.

Variants: Irrigation	Variants: NPK (kg/ha)	Total protein (%)	Yield of protein (kg/ha)	Limiting amino acid index: EAAI	BAAI	CSL_{Lys}	CSI_{Leu}	CSImet	Digestibility factor Lys+Arg Prol
O	0	10.9	307	48	9.38	36	40	31	0.72
	450	14.7	466	48	7.97	40	51	31	1.08
Means		12.8	387	48	8.68	38	46	31	0.90
W	0	10.1	393	55	9.87	32	47	31	0.57
	450	12.6	1051	53	8.89	37	51	33	0.82
Mean		11.4	722	54	9.38	35	49	32	0.70
NPK	0	10.5	350	52	9.63	34	44	31	0.65
NPK	450	13.7	759	51	8.43	39	51	32	0.95

not irrigated; W - irrigated