EFFECT OF IRRIGATION AND MINERAL FERTILIZATION ON SPRING CEREALS CULTIVATED ON A SANDY SOIL
PART I. YIELD OF PLANTS

Stanislaw Karczmarczyk, Zdzislaw Koszanski, Cezary Podsiadlo and Adam Kocmit [1]

ABSTRACT

Spring wheat cv Hera, spring triticale cv Migo, spring barley cv Lot, oat cv Boryna were cultivated on a sandy soil in north-western Poland in the years 1992-1994. Because of insufficient rain in these years, doses of supplemental irrigation ranged from 160-200 mm. Overhead irrigation increased the yield of wheat by 168%, of triticale by 101%, of barley by 88% and oats by 86%. Application of irrigation combined with high doses of NPK caused yield increases of wheat, triticale, barley and oat by 239, 128, 114 132%, respectively. The productivity of irrigation was enhanced in variants treated with large fertilizer doses, and the effectiveness of NPK was manyfold higher on irrigated plots. The yield increases can be explained by better tillering, increased number of stalks and spikes per m^2, and increased weight of 1000 seeds.

Key words*:* irrigation, NPK, sandy soil wheat, triticale, barley, oat yield.

INTRODUCTION

Supplemental irrigation, even in moderate climate, is one of the crucial means which guarantee stable and reliable yields. Large area of sandy soils characterized by low water retention, introduction of extensive plant species and cultivars, as well as application of high doses of mineral fertilizers make the maintentance of optimal soil moisture a necessity. Yield failures can be also caused by uneven rainfall, or rain deficite, particularly during critical phases of plant growth.

Studies performed in Pomerania by Karczmarczyk et al. (1979), Podsiadlo and Koszanski (1995), in central and southern Poland by Grabarczyk et al. (1992), Zarski (1993), Dziezyc et al. (1978), Gruszka (1978), Panek (1976), Trybala (1968), have shown that irrigation of cereals is purposeful. As effect of irrigation the yields increased by 20-30%, but if combined with fertilizer doses - reached 70-80%.

In dry years the effects of irrigation and fertilization exceeded 100%. It should be stressed that, on medium soils these effects were much smaller, and there were none on heavy soils.

The purpose of this study was the assessment of irrigation and fertilization effects on spring wheat, spring triticale, spring barley and oat yield, assay of the water and fertilizer efficacy. Furthermore the content of pigments and enzyme activity in flag leaves was measured, chemical composition and biological value of the grain assayed and, also some chemical and physical soil properties were measured.

This paper pertains to the yield, and to water and fertilizer productivity.

MATERIALS AND METHODS

The field experiments were conducted in the years 1992-1994 on a sandy soil (humus content 1.3-1.5%, pH 5.2-5.6). In all the years there was a rain defficiency during vegetation, except 1993 year after a dry April and May, there was a rain surplus in June and July. Irrigation doses were: 180 - 200 mm for wheat and triticale, 160 - 180 for barley and oat. Only in 1993 the doses were lower (130 mm).

The experiment was a split-plot design in 4 replicates. Irrigated objects W, non-irrigated O; and 4 fertilizer variants: 0,150 (50+40+60), 300, 400 kg NPK per 1 ha. Four spring cereals were cultivated: wheat cv Hera, triticale cv Migo, barley cv Lot, oat cv Boryna. The forecrop was a root plant, the agrotechnique - proper for the plants. The plant's yield and the productivity of water and fertilizers was assessed. Results were evaluated statistically by Tukey's test.

[1] Agricultural University of Szczecin, Poland

RESULTS AND DISCUSSIONS

As is shown in table 1, the yield increases of both grain and straw obtained as effect of applied measures were significant.

Wheat reacted to irrigation the best, the grain yield increased by 168%, that of triticale was by 101% higher, barley by 88%, oat 86% as compared to not irrigated. The straw yield increases were similar.

Table 1. Yield of spring wheat, triticale, spring barley and oat (mean of 3 years t/ha)

Objects Irrigation	NPK kg/ha	Spring wheat		Triticale		Spring barley		Oat	
		grain	straw	grain	straw	grain	straw	grain	straw
0 (rainfed)	0	2.24	1.84	2.86	2.07	2.59	1.88	2.64	2.35
	150	2.55	2.44	3.65	2.79	3.13	2.29	2.96	2.65
	300	2.39	2.62	3.42	2.91	3.11	2.57	3.24	2.85
	450	2.56	3.17	3.17	3.28	2.94	2.88	2.99	2.90
Means		2.44	2.52	3.26	2.76	2.94	2.41	2.96	2.69
W (irrigated)	0	3.89	3.16	3.89	3.00	3.42	2.39	2.81	2.69
	150	5.89	4.67	6.24	5.36	5.36	4.02	5.63	6.02
	300	7.70	6.07	7.76	6.44	6.69	5.49	6.88	6.82
	450	8.64	7.30	8.34	7.01	6.63	6.12	6.68	7.09
Means		6.53	5.30	6.56	5.45	5.53	4.50	5.50	5.66
Irrespective of watering	0	3.07	2.50	3.38	2.54	3.01	2.14	2.73	2.52
	150	4.22	3.56	4.95	4.08	4.25	3.16	4.30	4.34
	300	5.05	4.35	5.59	4.68	4.90	4.03	5.06	4.84
	450	5.60	5.23	5.76	5.15	4.79	4.50	4.84	5
$LSD_{0.05}$:									
for irrigation (W)		0.25		0.34		0.30		0.21	
for fertilization (F)		0.30		0.38		0.36		0.29	
for interaction (WxF)		0.45		0.52		0.42		0.39	

High doses on mineral fertilizers also caused yield increases, but only in irrigated variants these effects were spectaular, for example wheat gave a yield by 286% higher. Mineral fertilization, irrispectively of irrigation, caused yield increases of 50-80% (grain) and 100-110% (straw). Again the best reaction had spring wheat (Table 2).

Table 2. Combined effect of watering and mineral fertilizing on the yield of spring cereals

Yield increase	Wheat		Triticale		Barley		Oat	
	grain	straw	grain	straw	grain	straw	grain	straw
(t/ha) compared to control	6.40	5.46	5.48	4.94	4.10	4.24	4.24	4.74
compared to 1 NPK	6.09	4.80	4.69	4.22	3.56	3.83	3.92	4.44
(%) compared to control	286	297	192	239	`158	226	161	202
compared to 1 NPK	239	199	128	151	114	167	132	168

The highest yields of wheat and triticale were harvested from plots which had been irrigated and well fertilized, those being 8.6 - 8.3 t per ha 450 kg NPK applied for barley and oat did not enhance their yiled on non-irrigated plots because of lack of water, whereas on watered plots because of logging and grain losses during harvest (Table 3).

Table 3. Productivity of NPK (kg of grain/ 1 kg NPK)

NPK (kg/ha)	Irrigation	Spring wheat	Triticale	Spring barley	Oat
150	O	2.10	5.50	3.60	1.70
	W	13.40	15.60	12.90	18.80
300	O	0.50	2.00	1.80	1.50
	W	12.70	12.90	10.90	13.50
450	O	0.70	0.80	0.80	0.80
	W	10.70	9.90	7.10	8.60
Means	O	1.10	2.80	2.10	1.30
	W	12.20	12.80	10.30	13.60

Interesting data are presented in table 4 which shows the combined effects of applied treatments.

Table 4. Effectiveness of water used (kg of grain/1 mm)

NPK (kg/ha)	Spring wheat	Triticale	Spring barley	Oat
0	9.4	6.3	5.1	3.8
150	20.1	15.3	13.5	17.0
300	32.0	24.9	22.9	22.8
450	35.7	29.7	23.6	22.9
Mean	24.3	19.1	18.8	16.6

The yield increase obtained from plots with irrigation and high fertilization, calculated in comparison to standard NPK dose (150 kg), exceeded 6 tons in case of wheat, 5 tons triticale, 4 tons oat and 3.5 tons of barley. If compared to the zero NPK variant, that increase was even larger.

Evaluation of the fertilizer productivity (Table 5) shows a decreasing effect of rising fertilizer dose, but it was anyway 10 times higher in watered variants (wheat and oat), 5 times higher in case of barley, and fourfold of triticale.

The results obtained resemble those from semi-arid zones, and exceed very much the averages obtained in temperate climate. It must be stressed though that, such big yield increases were acquired in extreemely dry years and from a poor sandy soil, of small water capacity and a very low ground water level. Similar results were reported by Grabarczyk et al. (1992), Trybala (1968), Zarski (1993), and

Table 5. Yield structure elements of spring cereals (means of 3 years)

Objects			Tillering				Weight of
Species	Irrigation/NPK (kg/ha)	Plants (No/m^2)	total	productive	Culms (No/m^2)	Spikes (No/m^2)	1000 grains (g)
Spring wheat	O	616	1.03	0.91	636	562	39.1
	W	619	1.06	0.96	655	598	41.3
	O	617	1.01	0.86	622	529	38.9
	1 NPK	618	1.04	0.93	643	576	40.0
	2 NPK	619	1.07	0.98	655	606	40.8
	3 NPK	618	1.08	0.98	654	611	41.3
Spring triticale	O	420	1.19	1.14	508	479	36.6
	W	419	1.27	1.26	532	496	40.8
	O	422	1.19	1.08	501	453	37.2
	1 NPK	419	1.24	1.16	517	485	38.8
	2 NPK	420	1.25	1.20	522	501	39.4
	3 NPK	419	1.27	1.23	530	511	39.5
Spring barley	O	348	2.41	1.46	836	508	40.8
	W	349	2.75	1.64	956	572	46.4
	O	351	1.95	1.31	680	459	42.2
	1 NPK	350	2.43	1.57	847	549	43.7
	2 NPK	346	2.94	1.66	1015	573	44.3
	3 NPK	346	3.02	1.67	1042	578	44.2
Oat	O	546	1.24	1.04	672	567	32.1
	W	545	1.34	1.11	732	604	33.3
	O	546	1.04	0.99	573	543	29.4
	1 NPK	545	1.21	1.03	657	583	33.1
	2 NPK	549	1.43	1.08	783	594	34.1
	3 NPK	544	1.47	1.15	794	623	34.3

O = rainfed; W = irrigated

they pertain to light and very light soils in central and Southern Poland.

Extremely dry years occur in our climatic zone every 4-6 years, and even in average years 10 - 15 days without any rain can happen, and should they coincide with the plant's critical period, the yield would be decreased.

As a factor which exerted such positive influence on the yield, a good soil moisture that grants a proper nutrition, leading to better growth must be considered. So the tillering improved, as well as the number of stalks and ears per area unit, also the weight of 1000 grains. For example, the number of barley stalks increased as a result of fertilization by 53%, that of spikes by 26%, tillering and 1000 grains weight were by 10-15% higher.

Undoubtedly, the applied measures caused an increase of the plant physiological processes, resulting in yield and the crop's quality increase. That will be described in the second part of this paper.

CONCLUSIONS

As effect of supplemental irrigation the yield of spring wheat was by 168%, of triticale by 101%, spring barley by 88% and oats by 86% higher.

Mineral fertilization caused yield increases by 82, 70, 63 and 85% respectively. Combined effect of both treatments yielded crops higher by 239% of wheat, 128% of triticale, 114% of barley, 132% of oat.

The productivity of irrigation increased in well fertilized variants, and the effects of NPK applied on watered plots exceeded several times those of nonirrigated.

The yield increases caused by the applied measures can be explained by a better development of the plants, which found an expression in enhanced tillering, number of stalks and spikes per area unit and weight of 1000 grains.

REFERENCES

Dziezyc, J., Dmowski, Z., Buniak, W., 1978. Reakcja pszenicy i jeczmienia na formy nawozów azotowych, potasowych I wap-

niowych w warunkach nawadniania. Zesz. Probl. Post. Nauk. Roln.: 199.

Grabarczyk, S., Panek, J., Rzekanowski, C., Zarski, J., 1992. Efekty deszczowania roslin uprawianych na glebach kompleksu zytniego slabego. Rocz.Akademii Rolniczej w Poznaniu, CCXXXIV: 75-82.

Gruszka, J., 1978. Reakcja pszenicy jarej I ozimej na deszczowanie I wzrastajace nawozenie mineralne na madzie sredniej. Zesz.Probl.Post>Nauk Roln., 199: 379-388.

Karczmarczyk, S., 1979. Wplyw deszczowania I nawozenia mineralnego na plonowanie bobiku, pszenicy ozimej I jeczmienia jarego uprawianych w ogniwie zmianowania oraz na zmiany niektórych wlasciwosci gleby lekkiej. Akademia Rolnicza w Szczecinie, Rozprawy Nr 60.

Panek, K., 1976. Zmiennosc cech morfologicznych I plonu pszenicy ozimej I jarej pod wplywem nawadniania oraz zróznicowanego nawozenia. Zesz.Probl.Post.Nauk Roln.: 181.

Podsiadlo, C., Koszanski, Z., 1995. Reakcja odmian pszenicy jarej na deszczowanie I nawozenie mineralne. Zesz.Nauk.Akademii Rolniczej w Szczecinie, 165: 105 - 110.

Trybala, M., 1968. Wplyw nawadniania I nawozenia mineralnego na plonowanie roslin uprawnych na glebie piaszczystej. Zesz.Probl.Post.Nauk Roln., 86: 117 -163.

Zarski, J., 1993. Reakcja zbóz jarych na deszczowanie I nawozenie azotowe w warunkach gleby bardzo lekkiej. Akademia Techniczno-Rolnicza w Bydgoszczy. Rozprawy Nr 59.

Table 1. Yield of spring wheat, triticale, spring barley and oat (mean of 3 years t/ha).

Objects Irrigation	NPK (kg/ha)	Spring wheat grain	straw	Tritical grain	straw	Spring barley grain	straw	Oat grain	straw
	0	2.24	1.84	2.86	2.07	2.59	1.88	2.64	2.35
	150	2.55	2.44	3.65	2.79	3.13	2.29	2.96	2.65
O (rainfed)	300	2.39	2.62	3.42	2.91	3.11	2.57	3.24	2.85
	450	2.56	3.17	3.17	3.28	2.94	2.88	2.99	2.90
Means		2.44	2.52	3.26	2.76	2.94	2.41	2.96	2.69
	0	3.89	3.16	3.89	3.00	3.42	2.39	2.81	2.69
	150	5.89	4.67	6.24	5.36	5.36	4.02	5.63	6.02
W (irrigated)	300	7.70	6.07	7.76	6.44	6.69	5.49	6.88	6.82
	450	8.64	7.30	8.34	7.01	6.63	6.12	6.68	7.09
Means		6.53	5.30	6.56	5.45	5.53	4.50	5.50	5.66
Irresoective of watering	0	3.07	2.50	3.38	2.54	3.01	2.14	2.73	2.52
	150	4.22	3.56	4.95	4.08	4.25	3.16	4.30	4.34
	300	5.05	4.35	5.59	4.68	4.90	4.03	5.06	4.84
$LSD_{0.05}$for irrigation (W)	450	5.60	5.23	5.76	5.15	4.79	4.50	4.84	5
for fertilization (F)		0.25		0.34		0.30		0.21	
for interaction(WxF)		0.3		0.38		0.36		0.29	
		0.45		0.52		0.42		0.39	

Table 2. Combined effect of watering and mineral fertilizing on the yield of spring cereals.

Yield increase	Wheat		Triticale		Barley		Oat	
	grain	straw	grain	straw	grain	straw	grain	straw
(t/ha)compared to control	6.40	5.46	5.48	4.94	4.10	4.24	4.24	4.74
compared to 1 NPK	6.09	4.80	4.69	4.22	3.56	3.83	3.92	4.44
(%) compared to control	286	297	192	239	158	226	161	202
compared to 1 NPK	239	199	128	151	114	167	132	168

Table 3. Productivity of NPK (kg of grain/ 1 kg NPK)

NPK (kg/ha)	Irriga-tion	Spring wheat	Triticale	Spring barley	Oat
150	O	2.10	5.50	3.60	1.70
	W	13.40	15.60	12.90	18.80
300	O	0.50	2.00	1.80	1.50
	W	12.70	12.90	10.90	13.50
450	O	0.70	0.80	0.80	0.80
	W	10.70	9.90	7.10	8.60
Means	O	1.10	2.80	2.10	1.30
	W	12.20	12.80	10.30	13.60

Table 4. Effectiveness of water used (kg of grain/1 mm)

NPK (kg/ha)	Spring wheat	Triticale	Spring barley	Oat
0	9.4	6.3	5.1	3.8
150	20.1	15.3	13.5	17.0
300	32.0	24.9	22.9	22.8
450	35.7	29.7	23.6	22.9
Mean	24.3	19.1	18.8	16.6

Table 5. Yield structure elements of spring cereals (means of 3 years)

Objects			Tillering				Weight of
Species	Irrigation/NPK (kg/ha)	Plants (No/m^2)	total	productive	Culms (No/m^2)	Spikes (No/m^2)	1000 grains (g)
Spring wheat	O	616	1.03	0.91	636	562	39.1
	W	619	1.06	0.96	655	598	41.3
	O	617	1.01	0.86	622	529	38.9
	1 NPK	618	1.04	0.93	643	576	40.0
	2 NPK	619	1.07	0.98	655	606	40.8
	3 NPK	618	1.08	0.98	654	611	41.3
Spring triticale	O	420	1.19	1.14	508	479	36.6
	W	419	1.27	1.26	532	496	40.8
	O	422	1.19	1.08	501	453	37.2
	1 NPK	419	1.24	1.16	517	485	38.8
	2 NPK	420	1.25	1.20	522	501	39.4
	3 NPK	419	1.27	1.23	530	511	39.5
Spring barley	O	348	2.41	1.46	836	508	40.8
	W	349	2.75	1.64	956	572	46.4
	O	351	1.95	1.31	680	459	42.2
	1 NPK	350	2.43	1.57	847	549	43.7
	2 NPK	346	2.94	1.66	1015	573	44.3
	3 NPK	346	3.02	1.67	1042	578	44.2
Oat	O	546	1.24	1.04	672	567	32.1
	W	545	1.34	1.11	732	604	33.3
	O	546	1.04	0.99	573	543	29.4
	1 NPK	545	1.21	1.03	657	583	33.1
	2 NPK	549	1.43	1.08	783	594	34.1
	3 NPK	544	1.47	1.15	794	623	34.3

O = rainfed
W = irrigated