ZESZYTY PROBLEMOWE POSTĘPÓW NAUK ROLNICZYCH 1994, z. 413, 315-320

THE INFLUENCE OF MINE WATER SPRINKLING ON POTATO YIELD AND QUALITY AND SOIL pH

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A b s t r a c t. In the years 1987-89 in Chełm Region, a field experiment was conducted on sprinkling potato with salty water coming from a coal mine in Bogdanka, with mine water diluted with drinking water (1:1) and finally with drinking water, compared to unirrigated object. Potato sprinkled with mine water gave a significantly lower crop as well as dry matter content and starch. This water type brought about increase in Na, K, P content and Ca, Mg decrese in tubers as againts the control. Mine water showed a high pH value in KCl (8-8.5) and it significantly affected (after 3 years, application) lowering of soil acidification in 20 cm layer and in 20-40 cm interval. In the first layer pH increased from 4.5 to 5.5 while in the other from 4.5 to 5.1.

K e y w o r d s: mine water, sprinkling, potato, soil pH

INTRODUCTION

The problem of salty water used for cultivated plants sprinkling has still been a questionable issue. The available literature offers rather scant information dealing with this problem [5,6,9]. Mine water salinity results mainly from Cl^- and Na^+ ions content that limits its practical use in plant production. According to the Polish regulations, water in which chloride contents exceed 400 and sodium 150 mg/1 can not be used to irrigation in agriculture (Government Gazette, 1991, No 116, entry 503).

However, chloride ions compared to sodium ones, undergo faster washing out of soil complex, yet, they cause unfavourable yielding of plants like cucumber, tomato, tobacco and potato [11].

Sodium is an essential macroelement in animal feeding. Na content in dry matter feed should range from 0.15 to 0.25 % [7,12]. Sprinkling with salty water of high amount of Na^+ can have a disadvantageous impact on soil processes. Higher sodium content in sorption complex deteriorates the physical properties of soil, incites its compactness due to crumb structure destruction resulting from dispergation of colloids that bind cloddy agregates [3,11].

In the Bogdanka mine about 3.154 mln m^3 salty water is obtained annually. Owing to precipitation deficiency during the vegetative season in this region, there were some researches undertaken on agricultural usuability of mine water. Their objective was to compare yielding and potato quality (*Solanum tuberosum* L.) under the conditions of sprinkling with water of various origin.

The investigations were carried out due to the commission of the Institute of Mining in Katowice.

METHODS

In the years 1987-89 in Zaróbka country, Chełm Region, there were investigations

performed on Norfolk four-cross rotation with the following plants: potato (San variety), spring barley (Ars variety), red clover (Hruszowska variety), winter wheat (Emika variety).

The experiment was set up after a randomized blocks method, in 4 replications, on a good wheat complex soils of the mentioned below mean values of nutrients available in 100 g of 20 cm layer: 16.5 mg P_2O_5; 15.1 K_2O; 1.8 Mg at pH 4.5 in KCl, while in 20-40 cm level: 5.6-P_2O_5; 6.3-K_2O and 1.5 Mg at pH 4.5 in KCl.

This experiment was performed on the plots of 32 m^2 each, with 6 m space isolation between the folowing sprinkling variants: A - class-mine water, B - class-mine water diluted with drinking water in 1:1 ratio (mixed water), C - drinking water (1st class of water purity), D - control variant (no sprinkling). At potato vegetative season there was applied from 60 to 90 mm water, depending on soil moisture (under 60 % of field water capacity) in one dose beneath 30 mm. Each sprinkling had been preceded by chemical analyses of water, after the experiment completion soil pH was estimated on the A, B, C, D objects (1990).

Potato cultivation and fertilization were conducted according to agrotechnical instructions [5]. Having crop estimated, some tuber samples were collected for chemical analyses and then a dry mass content was determined (according to dryer method); starch (Reimann-Parow's balance); nitrogen (Kjeldahl's method); P (photocolorimetric method); K, Ca, Mg, Na (AAS method).

Moreover, potato tubers were reported to be infected with the diseases: late blight (*Phytophtora infestans* Mont. de Barry), scab (*Streptomyces scabies* Thaxt) and rhizoctoniose (*Rizoctonia solani* Kuhn).

Tuber crops, macroelements content as well as soil pH were worked up statistically applying the analysis of variance and the least significant difference ($LSD_{0.05}$) after Tukey's test.

RESULTS

Mine water employed in sprinkling is characterized by a high content of Cl^- ions (822-936 mg/l) and Na^+ (669-785 mg/l). A chlorine content surpassed twice over the values of water admissible to irrigation while a sodium content reached fourth or fifth over that (Table 1). Mixed water contained 452-495 mg Cl^- and 367-426 mg Na^+ in 1 liter, whereas drinking water was entirely suitable for plant irrigation. It should be emphasized that mine water showed a basic reaction (pH 8.2-8.5), higher than drinking water one (pH 7.4-7.8).

The highest mean crops of potato were obtained in 1987, exceeding significantly the results of 1988 and 1989 (Table 2). Alike in 1989 when tuber yields were higher significantly, compared to crop in 1988. The weather conditions from March to September did not differentiate crops in a significant way on the unirrigated object in 1987-89 (Tables 2, 3). Hence, varied potato crop resulted from sprinkling with mine, mixed and drinking water.

The highest mean crops of tubers were acquired at sprinkling with drinking water

Table 1. Chemical composition of water used for sprinkling

Year	Water type	pH	Ions content in mg/l							
			total	Cl^-	SO_4^-	HCO_3^-	Na^+	K^+	Ca^{2+}	Mg^{2+}
	A	8.5	2348.1	927.5	39.4	538.5	771.2	19.9	19.3	13.3
1987	B	8.1	1517.4	490.2	15.3	514.1	415.3	8.2	51.1	19.7
	C	7.7	695.3	32.8	0.0	491.2	37.8	0.8	98.1	27.1
	A	8.2	2097.8	822.0	61.8	480.5	668.7	11.1	35.9	14.4
1988	B	7.9	1388.4	451.6	23.5	454.6	367.5	8.8	56.9	21.8
	C	7.4	630.1	39.7	1.6	435.5	18.9	6.3	90.2	33.6
	A	8.3	2426.2	935.6	64.3	583.8	785.2	15.0	48.8	17.8
1989	B	8.0	1592.6	494.7	30.5	553.8	425.7	7.2	48.0	29.5
	C	7.8	725.9	17.5	6.6	527.8	50.7	1.4	84.8	33.1

(35.5 t/ha). This crop surpassed significantly the corresponding results from A and D objects. However, no statistically based difference was recorded between a drinking water combination C, mixed B and mine water combination A, mixed B and control D.

Table 2. Potato yields and contents of dry mass and starch in tubers

Year	Water type	Yield (t/ha)	Dry mass (%)	Starch (%)
	A	38.6	21.3	13.8
	B	40.5	21.9	15.7
1987	C	39.7	22.0	17.2
	D	31.4	22.6	19.6
	$\bar{x}$	37.5	21.9	16.6
	A	21.9	16.8	12.5
	B	25.3	19.7	13.8
1988	C	31.4	20.3	15.1
	D	31.7	23.7	17.8
	$\bar{x}$	27.6	20.1	14.8
	A	28.7	17.4	11.1
	B	31.6	21.2	15.9
1989	C	35.4	21.1	16.8
	D	32.1	21.9	16.0
	$\bar{x}$	31.9	20.4	14.9
	A	29.7	18.5	12.5
$\bar{x}$	B	32.5	20.9	15.1
1987-1989	C	35.5	21.1	16.5
	D	31.7	22.7	17.8
	$\bar{x}$	32.3	20.8	15.4
$LSD_{0.05}$ between:				
water type		3.3	1.8	1.4
years		3.6	-	1.6
water type x years		6.1	-	2.5

Irrespective of water type, the greatest yield farming effects of sprinkling were obtained in 1987 and the poorest in 1988.

In the years 1988-89, mine and mixed water exerted a negative influence on potato crop as againts the control object. Probably these results are connected with a consequent negative reaction of mine and mixed water in field crop rotation.

The greatest content of dry mass and starch was determined in unirrigated potatoes (D). Therefore a significant decrease of the mentioned components arose from mine (A) and mixed water (B) sprinkling. Regarding (A) component, dry matter increased by 4.2 % and starch by 5.3 % while at (B) 1.8 and 2.7 %, respectively. From that statement it follows that mine water exerted a more negative influence on starch content than on dry mass.

Sprinkling brought about growth of phytophtora infection of tubers (Table 4). The utmost intensification of the disease was recorded in 1988 when in July deficiency of soil moisture accounted for sprinkling. Having performed that operation, in August high precipitation rate together with irrigation and adequate temperature (Table 3) concurred to late blight development and a substantial decline of yield. However, sprinkling limited putting tubers to scab that breeds better in dry conditions. Analyzing *Rizoctonia* infection of potato only a slight tendency of growth following sprinkling could be observed (Table 4).

Out of 6 macroelements determined in potato tubers, as many as 5 (P, K, Ca, Mg, Na) showed significant changeability induced by

Table 3. Precpitation and air temperature distribution from March to September in 1987-1989 (after the Meteorological Station in Piaseczno)

Specifications	Year	Months							Total
		III	IV	V	VI	VII	VIII	IX	
Sum of monthly precipitation (mm)	1987	42.1	35.3	47.2	57.3	58.4	44.4	39.4	324.1
	1988	34.9	35.0	39.8	75.4	48.4	93.6	47.0	364.1
	1989	23.6	20.4	32.5	90.2	37.5	100.7	34.4	339.3
Number of days with precipitation	1987	17	11	12	10	10	12	12	84
	1988	24	4	7	14	5	8	11	73
	1989	9	6	7	11	10	10	7	60
Monthly mean of air temperature (°C)	1987	-4.0	6.7	13.0	17.0	18.8	15.3	12.7	11.4
	1988	0.8	7.0	14.9	16.3	19.7	17.6	13.1	12.7
	1989	4.6	9.9	14.2	16.0	18.5	17.4	14.2	13.5

Table 4. Potato tubers infected with diseases

Year	Water type	Tubers infected with *Phytophthora infestans* (%)	Tubers infected with *Streptomyces scabies* (%)	Tubers infected with *Rizoctonia solani**
	A	1.0	35	8.4
	B	1.3	34	8.4
1987	C	0.0	32	8.4
	D	0.0	40	8.0
	$\bar{x}$	0.6	35	8.2
	A	22.0	35	8.9
	B	21.4	35	7.8
	C	20.2	37	6.8
1988	D	8.4	51	7.1
	$\bar{x}$	18.0	39	7.5
	A	5.1	32	5.5
	B	5.2	36	6.0
1989	C	5.0	38	7.0
	D	2.8	48	6.9
	$\bar{x}$	4.5	38	6.3
	A	9.4	34	7.6
$\bar{x}$	B	9.3	35	7.4
1987-1989	C	9.1	36	7.4
	D	3.7	46	7.3
	$\bar{x}$	7.9	38	7.4

*in 9-degree scale (1-strongly infected, 9-healthy).

sprinkling (Table 5). The highest percentage of phosphorus in tubers proved to appear in a mine water combination while significantly lower in C and D variants. Potassium concentration in potato depended on sprinkling, time and synergistic activity of the mentioned factors. The greatest K content was established on mine water objects whereas the lowest at the control. However, the highest amount of potassium in tubers was determined in 1988 when the poorest crop was recorded.

Mine water (A and B) increased significantly Ca concentration in tubers as against drinking water and they lessened it compared to control. Mg content was significantly higher in potatoes irrigated with drinking water and unsprinkled.

The sodium percentage in plants sprinkled with A and B water augmented regularly in the successive years. The 3-year data demonstrate that potato sprinkled with mine (A) and mixed (B) water showed a significantly higher concentration of sodium in comparison to other objects (C and D).

Sprinkling performed in the years 1987-89 brought some significant changes in soil pH (Table 6). The highest pH increments regarded the objects sprinkled with mine and mixed water. The water is characterized by higher, alkaline reaction than drinking water owing to a greater sum of cations. The pH changes revelated similar tendencies in both soil layers, i.e., 0-20 and 20-40 cm.

DISCUSSION

Mine water showed high sodium and chlorine content as against water admissible to agricultural plants irrigation (Gov. Gazette, No 116, entry 503). Mine water diluted with drinking water (1st purity class) in 1:1 ratio, has not purified it fully to be applied in sprinkling.

The crop of potato tubers sprinkled with mine water was significantly lower than that obtained for drinking water. Thus, a negative

Table 5. Macroelement content in potato tubers

Year	Water type	in % of dry mass					
		N	P	K	Ca	Mg	Na
1987	A	1.48	0.38	3.15	0.07	0.10	0.048
	B	1.54	0.37	3.04	0.07	0.10	0.035
	C	15.4	0.35	2.78	0.06	011	0.034
	D	1.62	0.36	2.96	0.08	0.12	0.035
	$\bar{x}$	1.54	0.36	2.98	0.07	0.11	0.038
1988	A	1.72	0.41	3.15	0.07	0.10	0.057
	B	15.8	0.38	3.61	0.06	0.11	0.046
	C	1.81	0.34	3.30	0.06	0.14	0.016
	D	1.55	0.34	2.87	0.09	0.13	0.018
	$\bar{x}$	1.66	0.37	3.23	0.07	0.12	0.034
1989	A	1.75	0.39	2.91	0.07	0.11	0.124
	B	1.59	0.32	2.39	0.07	0.10	0.110
	C	1.55	0.32	2.39	0.06	0.11	0.057
	D	1.56	0.32	2.22	0.08	0.11	0.047
	$\bar{x}$	1.66	0.34	2.48	0.07	0.11	0.084
$\bar{x}$ 1987-1989	A	1.65	0.39	3.07	0.07	0.10	0.076
	B	1.57	0.36	3.01	0.07	0.10	0.064
	C	1.63	0.34	2.82	0.06	0.12	0.036
	D	1.58	0.34	2.68	0.08	0.12	0.033
	$\bar{x}$	1.61	0.36	2.90	0.07	0.11	0.052
$LSD_{0.05}$ between:							
water type			0.04	0.28	0.008	0.01	0.005
years				0.33			0.007
water type x years				0.48			0.015

Table 6. Changes in soil pH caused by 3 years sprinkling

Soil pH	Soil level	
	0-20 cm	20-40 cm
Before sprinkling	4.3	4.5
After 3 years sprinkling		
A	5.5	5.1
B	5.4	5.3
C	5.2	4.9
D	4.6	4.5
$LSD_{0.05}$	0.45	0.38

impact of chlorine on yielding became evident and that was confirmed in other works [3,5,12].

Irrigation brought about reduction of plant dry mass and that statement was also proved by other authors [1-3,5,10]. In our experiment it was found out that mine and mixed water decreased dry matter content in a greater part in comparison with drinking water. Such dependence also appeared in case of potato starchiness but with higher intensity. The lowest significant starch content was determined in the tubers sprinkled with mine and mixed water beside drinking water. All the concerned types of water reduced starch concentration significantly as against the control. The above mentioned view was formulated by some authors [1,2,5].

The tubers from sprinkled combinations (irrespective of water type) got infected with phytophtora more severly, than with scab when sprinkled potatoes proved to be less affected. The quoted dependences were testified in the literature [4].

Mine and mixed water irrigation as opposed to drinking water application, caused a considerable increment of sodium, potassium and

phosphorus content in tubers. The lowest concentration of aforecited macroelements in potato referred to the unirrigated objects. These results are justifiable in the light of determined mineralization of water.

The sodium increase in tubers sprinkled with mine and mixed water in the successive years is indicative of sodium cumulative tendency in soil. It can be expected that owing to many years' application of mine water, excessive accumulation of Na^+ will occur in the absorbing complex. Such process can result in soil salinity and decrease in quality of some cultivated plants [3,5,10,11].

All the types of water employed in 3 years' sprinkling influenced the increment of soil pH. It should be noted that mine and mixed water demonstrated their higher efficiency in this respect.

CONCLUSIONS

1. Mine water sprinkling brought about a significant decrease in potato yielding, compared with drinking water.

2. The negative influence of mine and mixed water was manifested by a significant decline of starch and dry mass of tubers.

3. Mine water sprinkling caused a significant augment of Na, K, P content in potato tubers. Sodium concentration grew in the successive years.

4. Three years' sprinkling exerted a significant influence on soil pH, irrespective of water type. Soil pH was changed by mine and mixed water more effectively.

5. Mine water should not be applied in potato sprinkling.

REFERENCES

1. **Dzieżyc J. (Ed.)**: Potrzeby wodne roślin uprawnych. PWN, Warszawa 1989.
2. **Dzieżyc J. (Ed.)**: Czynniki plonotwórcze-plonowanie roślin.PWN, Warszawa-Wrocław, 1993.
3. **Fotyma M., Mercik S.**: Chemia rolna. PWN, Warszawa 1992.
4. **Gabriel W. (Ed.)**: Biologia ziemniaka. PWN, Warszawa, 1985.
5. **Gajda J., Wilczek M.**: Wstępne wyniki badań nad wykorzystaniem wód kopalnianych do nawodnień kultur rolniczych. Budownictwo Węglowe, Projekty-Problemy, 9(384), 19-23, 1989.
6. **Hryncewicz Z.** (Ed.): Uprawa roślin rolniczych. PWRiL, Warszawa, 1985.
7. **Kemp A.**: Die Mineralstoffversorgung von Milchküchen in der Weidezeit. Z. Tierphysial. Tieremährung Futtermittelkd, 23, 267-278, 1968.
8. **Majdowski F., Pruszyński C.**: Badania nad wpływem stężenia soli w wodzie używanej do nawodnień na rozwój traw. Rocz. Nauk Roln., F., 77(4), 649-664, 1970.
9. **Majdowski F., Pruszyński C.**: Nawadnianie wodami zasolonymi łąki na glebie lekkiej. Roczn. Nauk Roln., F., 79(2), 71-83, 1976.
10. **Stuczyńska J., Styczyński M., Jakubowski S.**: Reakcja czterech gatunków traw na nawożenie sodem przy zróżnicowanych dawkach potasu. Biul. IHAR, 162, 15-25, 1987.
11. **Uggla H.**: Gleboznawstwo rolnicze. PWN, Warszawa, 1983.
12. **Würtele K.H.**: Die Beeinflussung der P, Ca, Mg und Na-Gehaltes von Weidepflänzen durch Mineraldüngung. Landw. Forschung, 28/II, 182-189, 1973.

WPŁYW DESZCZOWANIA WODĄ KOPALNIANĄ NA PLON I JAKOŚĆ ZIEMNIAKA ORAZ pH GLEBY

W latach 1987-1989 prowadzono ścisłe doświadczenie polowe w woj. chełmskim z deszczowaniem ziemniaka wodą zasoloną, z kopalni w Bogdance, wodą kopalnianą rozcieńczoną wodą pitną (1:1) i wodą pitną, w porównaniu z obiektem nienawadnianym.

Ziemniak deszczowany wodą kopalnianą odznaczał się istotnie niższymi plonami i zawartością suchej masy oraz skrobi. Woda ta wpłynęła na wzrost zawartości Na, K i P oraz zmniejszenie Ca i Mg w bulwach, na tle kontroli. Woda kopalniana charakteryzowała się wysokim pH w KCl (8-8.5) i wpłynęła istotnie, po 3-letnim stosowaniu, na obniżenie zakwaszenia gleby, zarówno w warstwie do 20 cm, jak i w przedziale 20-40 cm. pH w pierwszej warstwie zwiększyło się z 4.3 do 5.5; natomiast w drugiej z 4.5 do 5.1.

S ł o w a k l u c z o w e: deszczowanie wodą kopalnianą, ziemniaki, pH gleby.