The Influence of Irrigation Water of High Sodium Carbonate Content on Soils

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The effect of irrigation waters on soils gains an ever growing importance in our days. With the development of irrigation farming and the increased extension of irrigated areas more and more frequently the necessity arises to utilize waters of more or less significant salt content for irrigation purposes. It is well known that the irrigation water and its salt content may exercise two different influences in irrigation farming. One of these influences is the immediate effect of salts on the plants while the other is the effect of the salt content of the irrigation water on the soil. As a rule, the first effect may become injurious when the irrigation water contains such a large amount of salt that the damaging influence is exercised in the form of increased osmotic pressure of the solution or large-scale accumulation of some substance, detrimental to plants. Such effect is caused as a rule by an excessive amount of dissolved salt and it appears already in the year of irrigation in damaging or even dying off of the vegetation. The other effect needs a longer time to influence the characters of the soil, changing by implication the physical, chemical and other soil features and as a result finally soil fertility itself. For the development of such an unfavourable effect on the characters of the soil, however, a comparatively lower amount of water soluble salts is sufficient.

It is well known that among salts disadvantageous for plant and soil mainly the sodium salts deserve attention. Among these, soda (sodium carbonate) occupies a particular place because it is not only injurious to plants in the same concentration as most of the other sodium salts but it has very detrimental effects also on soil characters.

It should be noted of course that in some cases it is unavoidable to use waters containing more or less soda for irrigation. This applies particularly to areas where the natural irrigation waters contain sodium carbonates. This is the case especially when irrigation is effected with ground waters or when drainage waters find their way into the irrigation system.

In the practice of irrigation in Hungary the presence of soda in the irrigation water was considered to be inadmissible. Even the present irrigation norms tolerate sodium carbonates only to a limit of 10 mg/l.

Considering, that in practical irrigation, waters are frequently used, the soda content of which is higher than the above mentioned limit, experiments were conducted for four years to study the use of waters of different sodium carbonate contents for irrigation.

The experiments were set up with rice culture and irrigation waters of different chemical composition were used for each plot.

The experimental design was as follows:

I. Rice flooded with water of natural composition.

II. Rice flooded once with irrigation water of 400 mg/l (i.e. 400 p. p. m.) sodium carbonate content.

III. Rice flooded once with irrigation water of 1000 p. p. m. sodium carbonate content.

IV. Rice flooded with water of natural composition.

V. Rice flooded twice with irrigation water of 200 p. p. m. sodium carbonate content.

Rice flooded twice with irrigation water of 500 p. p. m. sodium carbonate content.

Thus plots No. II. and III. received in one, while plots No. V. and VI. in two dosage rates the irrigation water of 400 p.p. m. and/or 1000 p. p. m. sodium carbonate content. Plots No. I. and IV. were irrigated with natural water and thus served as a control. The total amount of irrigation water applied to the plots during the vegetation period was 9200 cu. m. per hectare.

The experiments were conducted from 1959 to 1962 during four vegetation periods. Both the soil and the irrigation water were sampled in every experimental year to establish the changes that intervened as an effect of irrigation.

Between the irrigation water and the sodium carbonates incorporated in the soil, an interaction arose and thus even in the case of irrigation waters with which a significant amount of sodium carbonates was introduced, the sodium carbonate content subsequently diminished because an exchange reaction took place between the soil colloids and the irrigation water of sodium carbonate content according to the following equation:

$$R_2Ca + 2\,Na^+ + CO_3^{--} \rightleftarrows 2\,RNa + CaCO_3$$

As a matter of course, in basic media the reaction followed the direction of the upper arrow, since it was promoted by calcium and partly magnesium compounds precipitated in an insoluble form.

These analyses are illustrated by Table 1.

Table 1.

Analysis of Irrigation Waters after Flooding

Treatment	Total salt g/l	Ca^{2+}	Mg^{2+}	Na^+	HCO_3	Na_2CO_3
		p. p. m.				
Original irrigation water ...	0.22	1.58	1.15	1,04	2.20	—
Original irrigation water + + 1000 p. p. m. Na_2CO_3	0.97	1.07	0.56	15.20	13.50	1.24

In Table 1. a comparison is made between the original irrigation water and the water enriched with 1000 p. p. m. sodium carbonate after introduction in the soil. It clearly appears from the data of the Table that a considerable material — both as regards the total amount of salts and the sodium carbonates — came from the irrigation water into the soil. Parallel with the increase of the sodium carbonates in the water, the amount of calcium and sodium ions substantially diminished which also indicates the alkalization of the water.

It is a matter of course that beyond the data presented in the Table the changes in the chemical composition of the waters used for irrigation were

Table 2.

Analysis of the Soils of the Experimental Plot by 1 : 5 Aqueous Extracts

(1) Plot number, date and depth		pH	(2) Total salt percent	$NaHCO_3$	Total HCO_3	Na^+
				mg. equ.		
I.						
1959	1— 10	7.3	0.076	0.87	1.10	1.64
	80—100	7.1	0.127	0.47	0,84	0.74
1962	0— 10	7.6	0.155	1.47	1.53	0.34
	80—100	7.5	0.170	1.79	1.98	1.34
II.						
1959	0— 10	7.1	0.114	0.43	0.73	0.30
	80—100	7.4	0.225	2.39	2.48	3.24
1962	0— 10	7.4	0.190	1.24	1.36	0.41
	80—100	7.9	0.245	2.45	2.48	2.34
III.						
1959	0— 10	7.0	0.116	0.39	0.77	0.45
	80—100	7.8	0.281	2.36	2.38	4.14
1962	0— 10	7,9	0.165	1.47	1.53	1.13
	80—100	8.2	0.340	3.22	3.37	3.82
IV.						
1959	0— 10	6.7	0.123	0.48	0.60	0.32
	80—100	7.1	0.279	1.49	0.59	3.82
1962	0— 10	6.8	0.110	1.59	1.68	0.34
	80—100	8.1	0.250	2.72	3.63	3.82
V.						
1959	0— 10	7.2	0.198	0.46	1,07	0.87
	80—100	7.2	0.190	0.46	0.95	1.04
1962	0— 10	7.9	0.060	1.18	1.53	0.47
	80—100	8.4	0.260	3.28	3.46	3.65
VI.						
1959	0— 10	6.9	0,090	0.52	0.95	0.47
	80—100	7.2	0.350	0.66	0.99	3.92
1962	0— 10	7.8	0.110	1.12	1.27	0.73
	80—100	8.0	0.200	2.16	2.21	2.69

further analysed in due time and it was found that in the meantime the water became more concentrated to a certain extent in the period of evaporation and it was diluted after addition of pure irrigation water.

As to the changes occurring in the soil, sampling was also performed regularly and analyses were carried out. Some characteristic analyses are reported in Table 2, where the changes of the salt contents of the experimental plots are demonstrated by a comparison of the values found at the outset of the test with those obtained at the end of the period. Examination of the experimental data reveals that the salt content and the pH value increased to a more limited extent, also in those plots where irrigation water of natural composition, that is, of favourable effect was used.

This appears from the analytical data related to plots No. I. and IV. In those plots, however, where water of a certain sodium carbonate content was used the pH value and the alkalinity of the soils increased to a far greater extent. Thus in plots No. II. and III. a remarkable increase of the pH values can be observed and the same trend was recognized in connection with the change of the amount of sodium hydrocarbonate.

The increase of sodium ions, as measured in the aqueous soil extract, follows a similar trend.

Similar changes are displayed by the data of plots No. V. and VI. Though from Table 2 it appears that upon the effect of the soda-treated irrigation water, the amount of the soluble salts did not essentially increase on the plots involved, the alkalinity of the medium and the amount of the water soluble sodium salts were found to be definitely higher. From all this it may be concluded that the sodium carbonates added to the irrigation water in such a high concentration do not accumulate in the soil in the form of soluble salts but they get bound on the colloid particles of the soil in an exchangeable form. This finding is supported by determinations of the exchangeable cations of the soil. These determinations were equally carried out on all plots at the outset of the experiments and at its end after four years.

The results of the above mentioned analyses are condensed in Table 3 where the amount of the exchangeable sodium ions is reported as a per cent of the amount of the total exchangeable cations.

Table 3.

Exchangeable Sodium as a Percentage of the S Value

(1) Plot number	(2) Depth of horizon, cm	(3) At the outset of the experiment 1959	At the end of the experiment 1962
I.	0—10	2.26	2.02
	10—20	1.83	1.68
II.	0—10	1.86	2.76
	10—20	3.11	2.03
III.	0—10	2.09	4.00
	10—20	2.48	6.06
IV.	0—10	1.78	1.81
	10—20	3.92	4.53
V.	0—10	2.42	4.14
	10—20	1.82	5.33
VI.	0—10	1.55	3.88
	10—20	1.50	3.35

From the data of Table 3. it clearly appears that in plots No. I. and IV. which were given irrigation water of natural quality and served, so to say, as a control, the relative amount of the exchangeable sodium underwent substantial change in the course of the four experimental years. As a contrast, the per cent value of the exchangeable sodium remarkably increased in the upper horizon of all plots treated with water of sodium carbonate content. This increase is comparatively less in the case of plot No. II. and more in the case of plots No. III., V. and VI.

The data both of Table 2. and 3. unequivocally show that in all cases where the same amount of sodium carbonate was added with one operation to the irrigation water, the increase of the alkalinity of the soil was smaller as compared with the treatment where the same amount was added to the irrigation water in two portions. This appears also from the quantitative analysis of the amount of the exchangeable sodium as well as from the analysis of the hydrocarbonate and sodium ions of the soil. Hence it may be concluded that higher amounts of sodium carbonates can be tolerated in the irrigation water when they occur only periodically and do not form a constant component of the irrigation water.

Naturally, the data presented in Tables 2. and 3. demonstrate that the exchangeable sodium and/or soluble salt content of the soil did not reach such values as yet by virtue of which the soil could be termed as an alkali or saline soil. Since, however, the Tables clearly exhibit the increasing trend, there is no doubt that when irrigation is continued for a longer period with water of sodium carbonate content, the soil becomes alkaline or saline.

That this did not actually occur in the course of the four experimental years is partly due to the fact that irrigation with water of sodium carbonate content has been carried out only in a small portion of all cases as compared with the use of natural irrigation water of good quality.

Naturally, the chemical composition of the soil and the presence of soluble salts, particularly of calcium salts in the soil may largely influence the limit set to sodium carbonate contents in the irrigation water. When the soil contains soluble calcium salts to a more considerable extent, higher amounts of sodium carbonate can be tolerated in the irrigation water because these carbonates entering into reaction with the soluble calcium compounds of the soil give rise to neutralisation of the harmful effects of the sodium carbonates.

Regular soil analyses and regular analyses of the irrigation waters are absolutely necessary in order to establish the amount of sodium carbonates which can be tolerated regularly or periodically in the irrigation water in any well defined case.

Summary

The study of the problem of interaction between irrigation water containing sodium carbonate and soil is rather important. On one hand some irrigation waters — especially when ground waters are used continuously — contain a certain amount of sodium carbonate and on the other hand when irrigation is based on canals collecting periodically waters of drainage canals, too, periodical sodium carbonate alkalinity may arise.

Sodium carbonate getting into the soil by irrigation has an effect both on plant vegetation and on soil properties. Any detrimental action on the vegetation manifests itself already in the year of irrigation while disadvantageous effects on soil properties often develop only in the course of several years causing substantial damage. The essence of the latter action consists of in the alkalization of soils, of a disadvantageous influence on their physical and chemical properties namely of a decrease in the utilizable water capacity of soils and of their nutrients household as well.

As a result the soil fertility decreases rather strongly. It must be noted, however, that only high amounts of sodium carbonate in the irrigation water involve an immediate physiological influence on the crop. As a contrast, a comparatively lower amount of sodium carbonate may adversely influence the physico-chemical and subsequently the physical and chemical conditions of the soil, particularly if this influence lasts for a longer period.

The subject of the experiments was, starting from these practical tasks, to study the periodical influence of irrigation waters with various sodium carbonate contents on soil properties and to determine the limit of sodium carbonate content that may be tolerated in waters used for irrigation.

From the obtained data the following conclusions may be drawn:

1. Irrigation waters with sodium carbonate content increase soil alkalinity and develop rates of the absorption of sodium ions on soil colloids from the soil solution according to the following equation:

$$R_aCa + 2Na^{+} + CO_3^{--} \rightleftarrows 2RNa + CaCO_3$$

As the solubility of $CaCO_3$ in alkaline medium is very low, it is precipitating from the solution and is moving the reaction equilibrium in the direction of the upper arrow. This accounts for the fact that the sodium ion concentration of the irrigation water in all four years of the study presented on the plots a nearly identical value corresponding to an equilibrium.

Due to the conditions favourable for the absorption of sodium, during the comparatively short experimental period, a measurable increase in the exchangeable sodium content of the soil could be demonstrated.

2. The exchange equilibrium between soil and water with soda content is established in a short time, as indicated by the fact that in the irrigation water immediately after flooding a substantially lower sodium ion concentration was measured than could be expected theoretically by the amount of soda applied. This points also to the fact that sodium carbonate occurring periodically in the irrigation water is fixed in a short time. The rate of exchange depends on the chemical properties of both soil and water.

3. The increasing alkalinity of soils moves the above equation in the direction of the upper arrow and makes advantageous conditions for the further absorption of sodium ions. That is why the amount of the exchangeable sodium ion of the soil showed more increase when 400 mg/l sodium carbonate was applied on one occasion than in the case when the same total amount was incorporated into the irrigation water in two portions of 200 mg/l each.

4. From the preceeding it follows that if the irrigation water contains soda only periodically, the limit of the sodium carbonate concentration of the water can be higher than if soda is a constant chemical component of the water.

5. During the 4 year treatment the flooding water contained soda only periodically and the ratio of the natural water free of sodium carbonate to the water with soda content was 8.2 : 1 or 7.2 : 2, respectively. The increase in the amount of the exchangeable sodium of the soil was exactly measured but it was not so considerable as it could have been due to the morphological characters of alkali (Szik) soil. Consequently when the irrigation water contains soda only periodically, the process of alkalinization is a slow one and takes place only after a long period.

6. It may be also concluded that if there are water soluble calcium salts (e.g. gypsum) in the soil, the increase in the quantity of the sodium carbonate content of the irrigation water depends on their amount.

L'influence sur le sol des eaux d'irrigation à haute teneur en carbonate de sodium

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Résumé

L'étude du problème de l'interaction entre les eaux d'irrigation contenant du carbonate de sodium et les sols est bien important. Cette interaction peut avoir des conséquences graves, d'une part si des eaux souterraines, contenant une certaine quantité de carbonate de sodium sont employées continuellement, et, d'autre part, si l'irrigation se fait par des canaux amenant des eaux de surface salines ce qui peut causer la formation d'alcalinité de carbonate de sodium.

L'effet du carbonate de sodium parvenu dans le sol par irrigation peut être de deux sortes, une action détrimentale sur la végétation et des effets désavantageuses sur les propriétés des sols qui souvent se dévéloppent seulement en plusieurs années en causant

des dommages substantiels. L'essentiel de cette dernière action consiste dans l'alcalinisation des sols, produisant une détérioration de leurs propriétés physiques et chimiques, notamment une diminution de la capacité des sols pour eau utilisable et aussi des changements défavorables dans leur régime nutritif.

Comme résultat de ces changements la fertilité des sols diminue plutôt fortement. Mais il faut mentionner que seulement une haute teneur en carbonate de sodium peut avoir une influence physiologique immédiat sur le sol. Par contre, une teneur beaucoup plus faible de l'eau en carbonate de sodium peut avoir une influence désavantageuse sur les propriétés physico-chimiques et consécutivement sur les propriétés physiques et chimiques des sols, surtout si cette cause agit pendant un certain temps.

Le sujet des expériences a été, en partant de ces problèmes pratiques, d'étudier l'influence périodique sur le sol des eaux d'irrigation chargées de diverses quantités de carbonate de sodium et de déterminer la limite de tolérence de la teneur en carbonate de sodium dans les eaux d'irrigation.

L'on peut tirer les conclusions suivantes à partir des données obtenues.

1. Les eaux d'irrigation contenant du carbonate de sodium augmentent l'alcalinité des sols et font montrer la ration des ions sodium adsorbés par les colloïdes du sol en raison de l'équation suivante:

$$R_2Ca + 2\,Na^+ + CO_3^{--} \rightleftarrows 2\,RNa + CaCO_3$$

Comme la solubilité du $CaCO_3$ dans un milieu alcalin est faible, il se précipite de la solution et cela fait déplacer l'équilibre de la réaction dans la direction du trait supérieur. Cela tient compte du fait que dans les quatre années de l'expérience la concentration des ions de sodium de l'eau d'irrigation a présenté sur les parcelles une valeur presqu'identique correspondant à un équilibre.

A cause des conditions favorables pour l'adsorption du sodium, l'on peut démontrer à la fin de cette période expérimentale relativement courte une augmentation mesurable de la teneur en sodium échangeable des sols.

2. L'équilibre d'échange entre le sol et l'eau contenant du carbonate de sodium s'effectue dans un laps de temps court, ce qui est indiqué par le fait que la concentration des ions sodium dans l'eau d'irrigation est considérablement plus faible que cette à laquelle on pouvait s'attendre théoriquement en partant de la quantité de carbonate de sodium appliquée. Cela est aussi confirmé par le fait que le carbonate de sodium qui se trouve périodiquement dans les eaux d'irrigation est fixé rapidement. L'allure de l'échange dépend des propriétés chimiques du sol et de l'eau.

3. L'alcalinité croissante des sols fait déplacer l'équilibre dans l'équation mentionnée dans la direction du trait supérieur et rend les conditions favorables pour une adsorption ultérieure d'ions sodium. C'est pourquoi la quantité des ions sodium a augmenté plus considérablement lorsque l'on a appliqué à une seule occasion 400 mg/l de carbonate de sodium que lorsque la même quantité a été ajoutée à l'eau d'irrigation en deux doses de 200 mg/l chacune.

4. De ce qui précède il s'ensuit que si l'eau d'irrigation ne contient du carbonate de sodium que périodiquement la limite de la concentration du carbonate de sodium peut être plus élevée que si la soude est un composant constant de l'eau.

5. Pendant les quatre années du traitement l'eau d'irrigation ne contenait du carbonate de sodium que périodiquement et le rapport de l'eau fluviale exempte de soude avec l'eau en contenant a été 8,2 : 1 ou 7,2 : 2, respectivement. L'on a dosé exactement la quantité d'ions de sodium dans les sols mais celle-ci n'était pas d'ordre de produire les caractères morphologiques d'un sol à alcali (szik). Donc si l'eau d'irrigation ne contient de la soude que périodiquement le processus de l'alcalisation est lent et ne s'effectue qu'après une longue période.

6. L'on peut aussi conclure à ce que s'il y a dans le sol des sels de calcium solubles dans l'eau (p. ex. du gypse), l'accroissement de la quantité du carbonate de sodium dans l'eau d'irrigation dépend de leur quantité.

Tableau 1. Analyse des eaux d'irrigation après inondation. (1) Traitement. (2) Salinité totale g/l.

Tableau 2. Analyse de l'extrait aqueux 1 : 5 des sols des parcelles des expériences. (1) Numéro de la parcelle, date et profondeur. (2) Salinité totale %.

Tableau 3. Sodium échangeable en pour cent de la valeur S. (1) Numéro de la parcelle. (2) Profondeur de l'horizon, cm. (3) Au commencement et à la fin de l'expérience.

Der Einfluß des Bewässerungswassers mit hohem Natriumkarbonatgehalt auf Böden

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Zusammenfassung

Das Studium des Problems der Wechselwirkung zwischen sodahaltigem Bewässerungswasser und Boden ist von hoher Bedeutung. Einerseits enthalten einige Bewässesungswässer — besonderswenn Grundwässer dauernd verwendet werden — eine bestimmte Menge an Natriumkarbonat und anderseits, wenn die Bewässerung auf solche Kanäle begründet ist, die periodisch auch Wässer von Abzugsgräben sammeln, kann periodisch eine Natriumkarbonat-Alkalität auftreten.

Das durch Bewässerung in den Boden gelangende Natriumkarbonat hat eine zweifache Wirkung, da jeder schädliche Einfluß auf die Vegetation sich schon im Jahre der Bewässerung äußert, während ungünstige Einwirkungen auf die Bodeneigenschaften sich oft erst im Verlaufe von mehreren Jahren entwickeln, wobei sie wesentliche Schäden verursachen. Das Wesen der Einwirkung auf den Boden besteht in deren Alkalisierung, in einem ungünstigen Einfluß auf dessen physikalische und chemische Eigenschaften, namentlich in der Abnahme der verwertbaren Wasserkapazität der Böden und in der Verschlechterung ihres Nährstoffhaushaltes.

Infolge dieser Umstände nimmt die Produktivität des Bodens ziemlich bedeutend ab. Es soll jedoch bemerkt werden, daß nur größere Mengen von Natriumkarbonat im Bewässerungswasser einen unmittelbaren physiologischen Einfluß auf die Vegetation ausüben. Dagegen kann eine verhältnismäßig geringe Menge von Natriumkarbonat die physikalischen und chemischen Eigenschaften des Bodens ungünstig beeinflussen, insbesondere wenn dieser Einfluß während einer längeren Periode andauert.

Der Zweck der Versuche war, von diesen praktischen Aufgaben ausgehend, den periodischen Einfluß der Bewässerungswässer von verschiedenem Natriumkarbonatgehalt auf die Bodeneingeschaften zu studieren und die Grenze des Natriumkarbonatgehaltes zu bestimmen, welcher in den zur Bewässerung verwendeten Wässern noch toleriert werden kann.

Aus den erhaltenen Angaben können folgende Schlußfolgerungen gezogen werden:

1. Sodahaltige Bewässerungswässer erhöhen die Bodenalkalität und fördern den Umfang der Adsorption der Natriumionen an Bodenkolloiden aus der Bodenlösung gemäß der Gleichung:

$$R_2Ca + 2Na^- + CO_3^{--} \rightleftarrows 2RNa + CaCO_3.$$

Da die Löslichkeit von $CaCO_3$ in einem alkalischen Mittel sehr gering ist, wird es aus der Lösung ausgeflockt und verschiebt das Gleichgewicht der Reaktion in der Richtung des oberen Pfeils. Dies ist für die Tatsache verantwortlich, daß die Natriumionenkonzentration des Bewässerungswassers in allen vier Versuchsjahren auf den Versuchsparzellen einen beinahe identischen Wert aufwies, welcher einem Gleichgewicht entspricht.

Dank den für die Natriumadsorption günstigen Bedingungen konnte während der verhältnismäßig kurzen Versuchsperiode eine meßbare Zunahme im austauschbaren Natriumgehalt des Bodens nachgewiesen werden.

2. Das Austauschgleichgewicht zwischen Boden und sodahaltigem Wasser wird in kurzer Zeit hergestellt; hierfür spricht die Tatsache, daß im Bewässerungswasser unmittelbar nach der Berieselung eine wesentlich niedrigere Natriumionenkonzentration festgestellt wurde als es theoretisch, nach der Menge der verwendeten Soda, zu erwarten gewesen wäre. Dies weist auch auf die Tatsache hin, daß das im Bewässerungswasser periodisch vorkommende Natriumkarbonat in kurzer Zeit fixiert wird. Das Ausmaß des Austauches hängt von den chemischen Eigenschaften von Boden und Wasser ab.

3. Höhere Alkalität der Böden verschiebt die obige Gleichung in der Richtung des oberen Pfeils und schafft günstige Bedingungen für die weitere Adsorption von Natriumionen. Aus diesem Grunde zeigte die Menge der austauschbaren Natriumionen des Bodens eine größere Zunahme, wenn 400 mg/l Natriumkarbonat auf einmal zur Anwendung gelangte, als wenn die gleiche Gesamtmenge in zwei Anteilen zu je 200 mg/l Bewässerungswasser zugegeben wurde.

4. Aus diesen Ausführungen folgt, daß, wenn das Bewässerungswasser nur periodisch Soda enthält, die Grenze der Natriumkarbonatkonzentration des Wassers höher liegen kann als in jenem Falle, in welchem Soda einen ständigen chemischen Bestandteil des Wassers bildet.

5. Während der vierjährigen Behandlung hat das Berieselungswasser nur periodisch Soda enthalten und das Verhältnis des natürlichen, natriumkarbonatfreien Wassers zum Wasser mit Sodagehalt war 8,2 : 1 bzw. 7,2 : 2. Die Zunahme in der Menge des austauschbaren Natriumgehaltes der Böden wurde genau bestimmt, war aber nicht so bedeutend als es entsprechend den morphologischen Merkmalen des Alkali- (Szik) Bodens erwartet werden könnte. Infolgedessen ist der Prozeß der Alkalisierung, wenn das Berieselungswasser nur periodisch Soda enthält, ein langsamer, und tritt nur nach einer längeren Periode auf.

6. Es kann weiter gefolgert werden, daß wenn der Boden wasserlösliche Kalziumsalze (z. B. Gips) enthält, die Zunahme in der Menge des Natriumkarbonatgehaltes im Berieselungswasser von deren Menge abhängt.

Tabelle 1. Die Analyse der Bewässerungswässer nach Überflutung. (1) Behandlung. (2) Gesamtsalz g/l.

Tabelle 2. Analyse von 1 : 5 wässrigen Auszügen der Böden der Versuchsparzellen. (1) Parzellen Nr. Zeitpunkt und Tiefe. (2) Gesamtsalz %.

Tabelle 3. Austauschbares Natrium in Prozenten des S-Wertes. (1) Parzellen-Nr. (2) Horizonttiefe, cm. (3) Zu Beginn und Ende des Versuches.

Влияние на почву оросительных вод, содержащих соду

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Резюме

Часто оросительные воды содержат соду, поэтому изучение влияния этих вод на почву является очень важным вопросом. Особенно часто это происходит, если для орошения используются грунтовые воды или воды оросительных каналов, в которые стекают сбросные воды. В таких случаях щелочность воды увеличивается. Влияние оросительных вод, постоянно или временно содержащих соду на почвы и культурные растения двояко: временное влияние на растения проявляется уже в первый год орошения, а отрицательный эффект от орошения на почвы может проявиться через несколько лет, он выражается в засолении почвы, ухудшении водного питательного и воздушного режима, что ведет к значительному снижению урожая. Необходимо подчеркнуть, что для непосредственного отрицательного физиологического влияния на растения оросительной воды,в последней должно содержаться большое количество соды. Относительно небольшие количества соды в поливной воде так же могут отрицательно сказываться на физико-химические, а затем физические и химические свойства почвы, это наблюдается при длительном орошении, т. е. при длительном соприкосновении почвы с оросительной водой. Автор изучал в течение четырех лет влияние оросительных вод, содержащих различные количества соды, на свойства почвы, с тем что бы установить предел допускаемой концентрации соды в оросительных водах в условиях Центральной и Юго-Восточной Европы.

Результаты исследований позволили установить следующее:

1. Оросительная вода, содержащая соду, создает щелочную среду в жидкой фазе почвы, т. о. возникают благоприятные условия для связывания ионов натрия почвенными коллоидами, что ведет к увеличению осолонцевания почвы. В щелочной среде обмен катионов натрия с катионами кальция почвенных коллоидов происходит по следующему уравнению:

$$R_2Ca + 2\,Na^{\cdot} + CO_3^{--} \rightleftarrows 2\,RNa + CaCO_3$$

В результате обмена образуется карбонат кальция, растворимость которого в щелочной среде минимальная, поэтому он осаждается из раствора и равновесие реакции смещается в сторону верхней стрелки. Этим объясняется, что концентрации ионов натрия в оросительных водах за четыре года наблюдений показали примерно одинаковые величины, соответствующие состоянию равновесия. Благоприятные условия для связывания натрия

привели к увеличению обменного натрия в почве, за сравнительно короткий промежуток времени.

2. Между почвой и водой, содержащей соду, обменное равновесное состояние наступает довольно быстро, что доказывается более низкой концентрацией ионов натрия в оросительной воде при орошении затоплением, чем предполагалось на основе теоретических расчетов исходя из количества использованной соды. Сода, временно появляющаяся в оросительной воде, связывается за короткий промежуток времени соответственно химическим свойствам почвы и воды.

3. Увеличение ионов обменного натрия приводит к смещению реакции среды жидкой фазы почвы в сторону подщелачивания, создаются благоприятные условия для дальнейшего связывания ионов натрия. Этим объясняется тот факт, что при содержании 400 мг/литр. соды в оросительной воде обменного натрия в почве было меньше, чем при дробном внесении в оросительную воду того же количества соды (200—200 мг/литр)

4. При временном содержании соды в оросительной воде допускается её более. высокая концентрация, чем в случае когда сода в воде является её постоянным компонентом.

5. За четыре года опытов при орошении затоплением вода периодически содержала соду и отношение исходной воды к содово-засоленной было 8,2 : 1 и 7,2 : 2. В почве количество обменного натрия возрастало в измеримых величинах, но не до такой степени, что бы создавались свойства характерные засоленным почвам. Процесс засоления при временном содержании соды в оросительной воде проходит медленно и проявляется через большой промежуток времени.

6. Если в орошаемой почве находятся растворимые соли кальция, например $CaSO_4$, то чем больше их в почве, тем больше соды допускается в оросительных водах.

Табл. 1. Состав поливных вод после напуска. (1) Вариант. (2) Сумма солей в гр/литр.

Табл. 2. Состав водной вытяжки почв опытных делянок. (1) Номер делянки, время взятия образца и глубина. (2) Сумма солей в %.

Табл. 3. Обменный натрий в % от «0». (S) Номер делянки. (2) Глубина горизонта в см. (3) В начале и конце опыта.