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Study of the main hydromelioration parameters to increase the yield of topinambur (Tuberosus) on brackish soils of Alazani

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Abstract
The article assesses the physical and mechanical properties of brackish soils on the territory of the ameliorative experimental base of Tsotne Mirtskhulava Water Management Institute of Georgian Technical University (village Khornabuji, Sighnagi Region) and the main growth indicators of topinambur on such soils.
The results of field and laboratory studies were used to establish the irrigation indicators chemical composition and absorbed bases of the brakish soils and topinambur irrigation rates in village Khornabuji, Signagi Region.

Keywords: brackish soils, topinambur, irrigation rate, irrigation indicators, absorbed bases, groundwater.

Introduction

Brackish soils in Georgia are especially widespread in the Alazani Valley (in its eastern part). Other regions of Georgia with brackish soils are: partly in Gardabani, Marneuli, around Tbilisi (Soganlugi Valley), in a very small area in Tiriponi Valley (eastern part) and Mtkvari Valley (Kaspi, Doesi, etc.).

The saline area of the Alazani Valley offers a diverse picture. The area, which is mostly solonetz, contains quite great areas of brackish soils, sometimes occupying tens of hectares, and sometimes the most productive areas, almost free of the deficiencies of the above-mentioned soils, alternating between them. The amount of readily soluble salts varies greatly depending on individual horizons and locations. Table 1 below gives a clear idea of the intensity and type of salination.

Table 1 shows significant differences not only in the amounts, but also in the composition of salts. The two sections, located by about 250 m from one another, differ greatly in the content of sodium carbonate what greatly reduces the value of the soil. The area is also characterized by large amounts of SO_3 and resultant $CaSO_4$ (gypsum) what, undoubtedly, must be considered a positive value [1].

Table 1: Amount of salts, %

Section	Horizon, cm	Solid residue	HCO_3	NNa_2CO_3	Cl	SO_3	CaO	Mgo	$CaSo_4$
1	0÷10	2,9192	–	0,5680	0,3798	1,2040	0,0977	–	0,2372
	10÷20	4,6429	–	0,6720	0,4498	2,0482	0,3052	–	5,7410
	20÷40	5,0690	–	0,7043	0,4709	2,2865	0,2195	–	0,5329
	40÷60	5,4960	–	0,7675	0,5132	1,3723	0,2680	–	0,6507
	60÷80	6,3503	–	0,8667	0,5795	2,8659	0,3646	–	0,8852
	80÷100	5,2782	–	0,7044	0,4710	2,3767	0,3619	–	0,8787
	100÷120	3,3372	–	0,3039	0,2032	1,6601	0,3480	–	0,8449
	120÷140	2,2398	–	0,0909	0,0608	1,1984	0,3419	–	0,8301
2	0÷25	0,203	0,072	No	0,035	0,041	0,004	0,002	–
	25÷59	2,204	0,032	No	0,284	1,184	0.171	0,101	–
	59÷79	2,698	0,032	No	0,264	1,542	0,371	0,122	–
	79÷104	2,616	0,034	No	0,272	1,459	0,377	0,117	–
	104÷140	1,891	0,037	No	0,372	0,884	0,056	0,016	–

It is hard to name a cultivated plant with the best therapeutic properties of all, but it can be said that topinambur tops the list of the most useful foods [4]. Therefore, our goal is to study the areas of brackish soils in the territory surrounding the village of Khornabuji, Signagi Region, in order to start plantations of topinambur. Figure 1 shows the map of the study object in the GIS system.

Fig. 1: Map of the study area in Signagi Region.

We started the rehabilitation of the degraded soils of Georgia by conducting field studies of topinambur plants on the brackish soil of Alazani [2,4,5].

Topinambour cultivated plantations will contribute to the production of an ecologically clean, inexpensive, local food crop with high nutritional value and high inulin content. Fig. 2 shows measuring the height of topinambour plant in Alazani Valley during the flowering season and harvesting: the general view of topinambour bulbs.

Fig. 2: Flowering topinambur plant and general view of its bulbs.

2. Hydromeliorative study of brackish soils to increase the yield of topinambur in AlazaniValley

Presently, only the upper zone of Alazani Valley is irrigated, which is mainly covered with vineyards, as well as technical and vegetable crops. In a geomorphological respect, this strip, in particular, where the gentle slope turns into a plain, is a concave area [2]. Here, the ground waters outcrop to the surface as springs. So, historically, forest plant formation was spread in this strip, which by present, is substituted by field and meadow plant formations, as facilitated by the artificial deforestation.

A similar evolution is observed in the soil cover. Here, the varieties of forest chernozems with their cultural varieties and meadow-type soils with different variations are widespread [7-11].

For the purpose of scientific research on topinambur plant, soil field studies were conducted in 2022 at the Alazani research base of Tsotne Mirtskhulava Water Management Institute of Georgian Technical University (Signagi Municipality) [5, 12].

The soil profile of the Alazani Valley is complete and well expressed.

- Horizon A is 25-35 cm thick, with fine-grain and cloddy structure, with 3-4% of humus;
- Horizon B has a denser and heavy mechanical composition and is 30-40 cm thick; the carbonates are washed to 40-60 cm down the forest;
- Horizon C (80-120 cm) is well expressed with secondary coarse $CaCO_3$ concretions. This layer is very compacted and dense, and mostly water-proof.

The bedrocks are presented by deluvial-proluvial sediments of various grain sizes. These soils are mostly heavy loamy or clay.

Usually, the upper layers have heavy granulometric content. The soil mass from the depth of 130-150 cm gets lighter. In natural conditions, the physical properties of the area under the forest with the physical-chemical conditions favorable for the grassy plants to grow change depending on the duration of cultivation. Table 2 gives the numerical values of the hydrological and physical properties of Alazani brakish soils.

Table 2: Hydro- and physical properties of the soils in Alazani Valley.

Soil	Genetic horizon		Specific weight	Volumetric weight	Capillary moisture content	Total moisture content	Limit moisture content	Total porosity	Capillary porosity	Non-capillary porosity	% of total capillary porosity	% of total capillary porosity	Limit moisture content 80%	Irrigation rate (m) m^3/ha
	Index	Sampling depth												
Section1 Chernozem-type soil (sown with tobinambur)	A	0-20	2,60	O,9	41,89	47.42	45.01	62.09	41.89	20.20	67,47	32.53	36.01	619
	AB	20-40	2,76	8	42,12	43.56	41.57	58.81	42.12	13.69	75.47	24.53	33.26	652
	B	40-60	2,81	1,12	40.68	41.88	39.55	56.90	40.68	16.22	71.49	28.51	31.64	669
	C	60-80	2,87	1.21	37,27	38.64	37.04	55.99	37.27	18.23	66.56	33.44	29.64	653
	C	80-100	2.84	1,26	35.33	36.83	34.61	51.74	35.33	16,41	68.28	31.72	27.69	664
		100-120	2.75	1.37	31,45	32.55	31.39	50.91	31.45	19.48	61.75	38.25	25,12	593
				1.35										

Section 2 The soil covered with tobinambur and othet agricultural crops	A AB BC C	0-20 20-60 60-100 100-120	2,58 2,59 2,69 2,73	0,73 1.03 1,27 1,37	39,52 39,69 38,63 36,62	53,57 41.94 40.11 39,78	39,64 37,79 39.13 37.90	71.38 59.96 52.86 49,81	39,52 39,69 38,63 36,62	32,86 20.27 14,23 13.19	55.36 66.19 73.08 73.52	44.64 33.81 26.92 26.48	31.72 30.24 30.91 30,32	852 545 696 727
Section 3 Slightly bogged soil	A B BC C	0-40 40-60 60-80 80-100	2.65 2.67 2.73 2.75	1.09 1.27 1.39 1.43	53,46 51.95 47,06 45.49	64.17 52.87 48,55 49.91	51.02 51.06 46.58 44.49	58,77 52.28 48,83 46.21	53.46 51.95 47.06 45.41	5,31 0.33 1.77 0.80	99.96 99,37 96.37 98.27	9.04 0.63 3.63 1.73	40.82 40.85 37.27 35.60	

The irrigation rate of tobinambur (m) varies depending on the depth (the data are given in Table 2) and is calculated by the following formula [1,2] :

$$m = 100H\alpha(r_{Limit} - r_{Limit\ 80\%}), \quad m^3/ha; \quad (1)$$

where: H is the active soil layer (m), α *is the volumetric weight of brakish soil* (kg/m^3), and r_{Limit} is the limit moisture content of soil (%).

The physical properties of soil vary depending on the type of cultivation. The volumetric and specific weights in the lower profile layers of Section #1 (Photo 3) increase gradually. Particularly dense and compacted is the intermediate layer from the depth of 0,5 m. The variation of the volumetric weight in this area varies within 1300-1400 (kg/m^3), and approximates 1 in the upper layers. The same change is observed with capillary, total and limit moisture contents. Generally, the porosity even at the depth of 50-70 cm does not fall below 56%. Non-capillary porosity in the upper layers is high (22-32%).

The physical properties of the same soil, but sown with the crop (Section #2) (Photo 3) improve a lot. For instance, volumetric weight of the arable layer is 740 (kg/m^3), and it is no more than 1 at the depth of 0,5 m. Consequently, total porosity is high (60-71%). In the soil profile capillary and limit moisture content is reduced, and total moisture content is increased. All this leads to an increased non-capillary porosity or aeration, which varies within 20-30%, and is 34-45% of total porosity.

The same soil in section #3 (Photo 3), which uses bogged water due to its impaired regime, has much deteriorated physical properties, as seen by unusually increased capillary and limit moisture content. Due to this, capillary and total porosity get close to one another, while non-capillary porosity decreases to minimum. The processes occurring in the soil in the given case are unfavorable for biochemical and biological processes. As a result, the plant roots are infected and perish because of rot. Even a slight violation of the water use regime along Alazani Valley causes the rise of the ground waters and soil bogging processes.

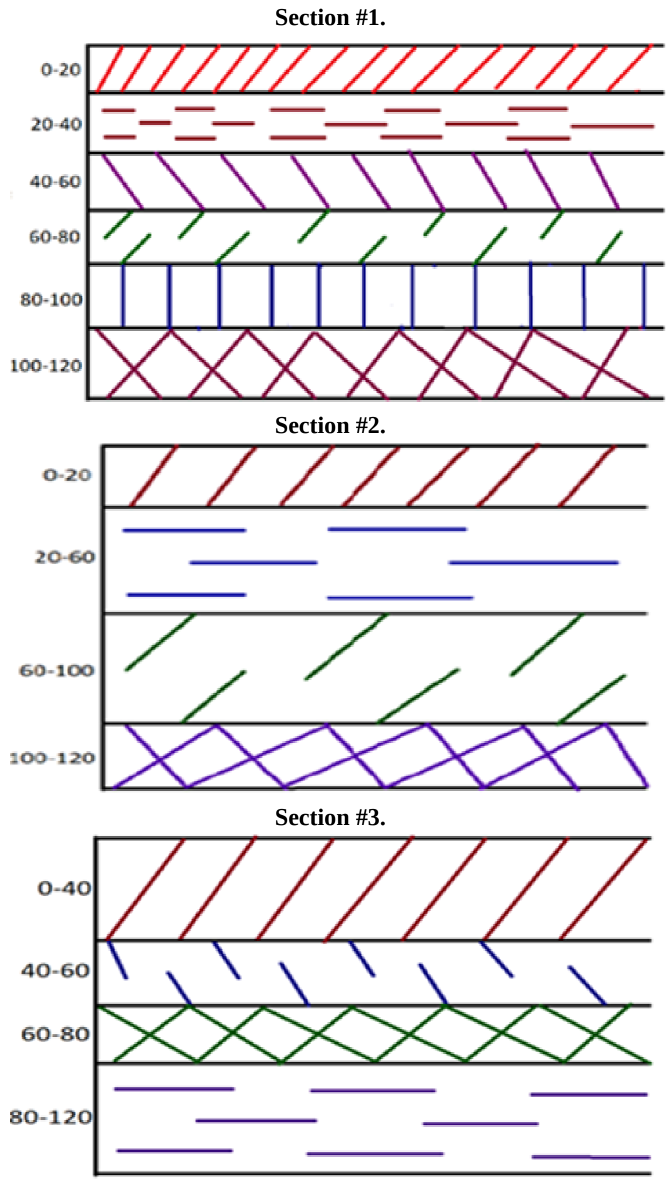

Fig. 3: Section of soils and grounds in Alazani Valley.

The water regime of the eastern part of Alazani Valley is of a solid compensatory or cyclic type. It is compensated by evaporation, and partly by transpiration. The genesis of the salinated soils of Alazani Valley is the result of the groundwater regime standing above the critical level for most of the year.

As already mentioned, in the central part of the right bank of Alazani Valley and its eastern part, brackish soils and solonetz are widely spread. These soils have heavy grain-size content (see Table #2).

One of the two soil sections is solonetz, salinated at depth, and another is of the brackish soil. Both profiles are typical to the central part of Alazani Valley, where the structure of ground is stratified, alluvial, lighter at depth and have sediments of average loams at some locations. In natural conditions, both the soil and the underlying layers have looser and lighter grain-size content, while the analysis demonstrates that it is of a heavy clay composition.

Profile of Section #1 is clay for almost 1 m deep and is followed by an average loamy layer, which is changed by the same clay layer near it.

The profile of Section #2 gas the same structure.to 120 cm depth, it is clay and is presented by loamy sediments deeper. The soils of Alazani Valley are rich in silt (<0,001 mm); its content varies within 50-60%, sometimes reaches even 70%, and falls to 30% at greater depths. Based on the given analysis, the clay-content coefficient of these soils is mostly high. As one can see, the salinated solonetz meadow soils in Alazani Valley in horizons A and B contain 2-5% humus, while brackish soils contain 1-3%. These soils are generally poor in nitrogen, and horizons A and B have higher absorption capacity to the depth of 30-50 cm. Deeper, the absorption capacity falls drastically; the content of absorbed *Mg* and *Na* is high in the soils in the central part of Alazani Valley and reaches 30-32% on the example of Section #3, demonstrating that it is solonetz brackish soil.

Table 3: Results of grain-size analysis of the soils in Alazani Valley.

Section #	Sampling depth (cm)	Grain-size composition of soils									
		1-0.25	0,25-0,05	0,05-0.01	0,001-0,005	0,005-0,001	<0,001	<0,01	>0,01	0,01-0,001	<0,01 /<0,001
1	0-16	0,43	1.0	6,56	15,11	17.13	59,77	92,01	7,99	32,24	1.54
	16-32	0,13	1,27	10,86	12,49	14.80	60,49	87,74	12,26	27,29	1,45
	32-48	0.10	0.80	11,56	13,26	14.89	59,39	87.54	12,46	28,15	1,47
	48-64		1,57	12,31	3,86	13,73	68,53	86,12	13,88	17,59	1,26
	64-80		3.08	31,78	17,21	20,05	27,88	64,15	34,86	37,26	2,34
	80-96		0.49	18,90	22,24	28,24	30,13	80,61	19,39	50,48	2,87
2	0-16	0.12	3,39	9,50	10,34	20,82	55.83	86.99	13.01	31.16	1.56
	16-32	0.21	3.83	4.63	25/83	21,32	44.18	91,33	8.67	47.15	2.07
	32-48		5.18	7.60	13.53	37.03	36.66	87.22	12.78	50,56	2.38
	48-64		1.02	8.80	6.06	11.22	72/90	90,18	9.82	17,28	1.26
	64-80		1.36	27.20	4,36	17.93	59.15	82.44	18.56	22.29	1.38
	80-96		0.37	7.48	12,86	34.59	44.70	92.15	7.85	47,45	2.06
	96-112		0.97	27.34	24.57	27.84	39.28	71.69	28.31	32.41	1.82
	112-128		1,95	19,12	16,17	18.71	44.05	78.93	21.07	34.88	1.79

Table 4: Chemical composition of solonetz and brackish soils from the central part of Alazani Valley and absorbed bases.

Section no.	Sampling depth, cm	Humus, %	C/N	Absorbed bases								$CaCO_3$ %	$CaS0_4$ %
				Mil.equiv.				% of absorption moisture content					
				Ca	Mg	Na	Sum	Ca	Mg	Na	Ca/ Mg		
1	0-16	5,04	14,79	28.79	10.00	2.83	41.53	69.11	24.08	6.81	2.87	5/55	2.91
	16-32	3,07	20.45	31.,15	11.18	3.65	45.98	67.75	24.31	7,91	279	6.04	3.98
	32-48	2.27	21.04	21.55	3.45	15.56	26.56	81/14	13.99	5.87	6.25	31.78	4.27
	48-64	1.74	23.19	11.50	2.55	0.52	14,57	78.93	17,50	3.57	4,51	17.79	44.34
	64-80	1.19	22.20	9.20	2.38	0.43	12.01	76.60	19.82	3.58	3.87	15,31	20.99
	80-96	-	-	-	-	-	-	-	-	-	-	8.25	16.43

2	0-16 16-32 32-48 48-64 64-80 80-96 96-112 112-128	2,86 1,89 0.97 - - - - -	17.00 14.59 20.65 - - - - -	21,34 29,79 24.80 21,45 20.40 13.55 14.15 14/40	6.74 7,15 9.54 11.26 9.45 7.32 4.60 4.27	12.48 18.04 11.30 12.48 12.91 10.90 8.00 5.26	40.57 54,89 45.64 45.19 42.76 31.77 26.75 23.93	52.63 54.11 54.35 47.47 47.71 42.65 52.89 60.17	16.61 13.03 20.90 24.92 22/10 23.04 17.19 17,84	30,67 32.86 24.75 27.61 30.19 24,31 29.92 21.99	3.17 4.15 2.60 1.90 2.16 1.85 3.08 3.37	15,41 16.79 25,61 27.20 20,78 21.43 10.84 14,27	9,87 6.95 7.78 8.56 5.80 6.24 2,61 3.20

Content of $CaCO_3$ is quite high in both types of soils and a shift is observed in the lower layers. The profile clearly shows the strips of $CaSO_4$ as a result of the periodic contact between the ground water and the soil.

Table 5: Dynamics of salination in the soils in the central part of Alazani Valley.

Area	Time of observation	Sampling depth, cm	Solid residue	Mil. equiv.						
				$C0_3$	HCO_3	Cl	$S0_4$	Ca	Mg	Na
Plot 1	Spring	0-16 16-32 32-48 48-64 64-80 80-96	1,30 1,32 2,20 2,19 1,88	0,33	0,28 1.21 0.64 0.33 0.31 0.31	1.04 1.07 5.22 6.57 6,29 5,19	1,10 1.46 15.40 26.40 23.34 21.99	0.60 0.40 4.34 15.52 14.87 12.82	0.16 0.08 1.32 1.73 1.56 1.32	0,66 3,59 15,60 16,05 10,41 13,35
	Summer	0-16 16-32 32-48 48-64 64-80 80-96	0,155 0,227 0,596 2.204 2,894 2,222	0,14 0.10 0.07	1.13 1.65 0,79 0,61 0,41 0.45	2.10 0.27 4.14 2.09 12,18 5.10	0-16 0.31 7.49 25.75 30.33 23.57	0.43 0.47 2.04 15.47 13.62 14.52	0.69 0.60 0.08 2.63 14/47 2.71	2.42 1.26 10.36 10.35 14/83 11.95
	Autumn	0-16 16-32 32-48 48-64 64-80 80-96	0,305 1.038 1,908 1,630 1,890 1.837	None	1.51 0.79 0.39 0.31 0.34 0.34	0.62 2.85 3.07 3.05 4.32 6.37	2.08 15,85 24,07 20,53 23.11 25,31	4.99 3.14 15.07 11.88 14.17 12.92	0.16 1.81 3.12 3.12 5.53 4.19	- 14.51 12.35 8.89 10.06 14.92

Data from Table #5 give an idea about the degree of salination and seasonal changes of the given soils. As one can see, migration of easily soluble salts occurs depending on the seasonal variation and salinity of ground water levels.

The reason is that the ground water level in the central part of Alazani Valley is above its critical level almost for the whole year.

By the end of summer, salination in the soil profile is mostly chloride-sulphate. An opposite picture is observed in solonetz soils in the upper layer. salination in the ground water is mostly chloride-sulphate, but often, there is an opposite picture observed [5,11,12].

In respect of melioration, Alazani Valley is a hard object. The salt and solonetz soils in its central part are diversified and complex. Pure solonetz soils are very rare and there is permanent seasonal migration of easily soluble salts across the entire soil profile.

At the same time, these soils have quite unfavorable physical properties. Their above-soil horizons in natural conditions are almost totally water-proof. In spring, when a certain amount of easily soluble salts is migrated to certain depths, the physical properties of the soil are deteriorated.

In summer and autumn, salination in the upper layers as a result of the salt migration reaches maximum values, and the physical characteristics of the profile are better. However, the upper horizons are still water-proof as evidenced by the data from Table #5.

As the experimental study makes it clear, the process of solonetz-formation as a result of de-salination of the given soils (by washing down the soil monoliths) is evident. The organic, mineral and colloid part of the soils gets intensely dispersed and mobile. The speed of the chlorines wash-out in the horizons with partial water filtration is high and in their content in the tenth liter is more milli-equivalent.

As the de-salination starts, total alkanility increases abruptly, and falls again in the last liters. Similar changes occur in the soil after the de-salination ends.

3. Conclusion

The article gives the assesment of the results of hydro-physical, chemical-laboratory studies of the brackish soils in Alazani Valley (village Khornabuji) and establishes as follows:

- Irrigation rate of tobinambur;
- Variation of clearly expressed physical properties of soil depending on the degree and type of cultivation;
- Migration of easily soluble salts through soil profile as a result of the seasonal variation of the ground water level and salinity;
- The process of solonetz-formation as a result of de-salination through wash-out is evident;

- Organic, mineral and colloid part of the soils become very disperse and mobile in the horizons, which are partially water-permeable. As for chlorines, they are washed out quite quickly;
- Ground water level in the central part of Alazani Valley is above its critical level and is maintained for almost whole year.

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