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Wheat production management in saline soils through the use of vinasse

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ABSTRACT

Background: In the context of global climate change, rising temperatures, water scarcity, and anthropogenic factors have accelerated land degradation processes. Salinization, a key driver of degradation, poses a significant threat to food security by drastically reducing crop productivity. Wheat, a staple crop crucial for food security, is highly susceptible to osmotic stress and ionic toxicity caused by salinization. Consequently, the desalination and dealkalinization of saline soils are crucial to support agricultural intensification.

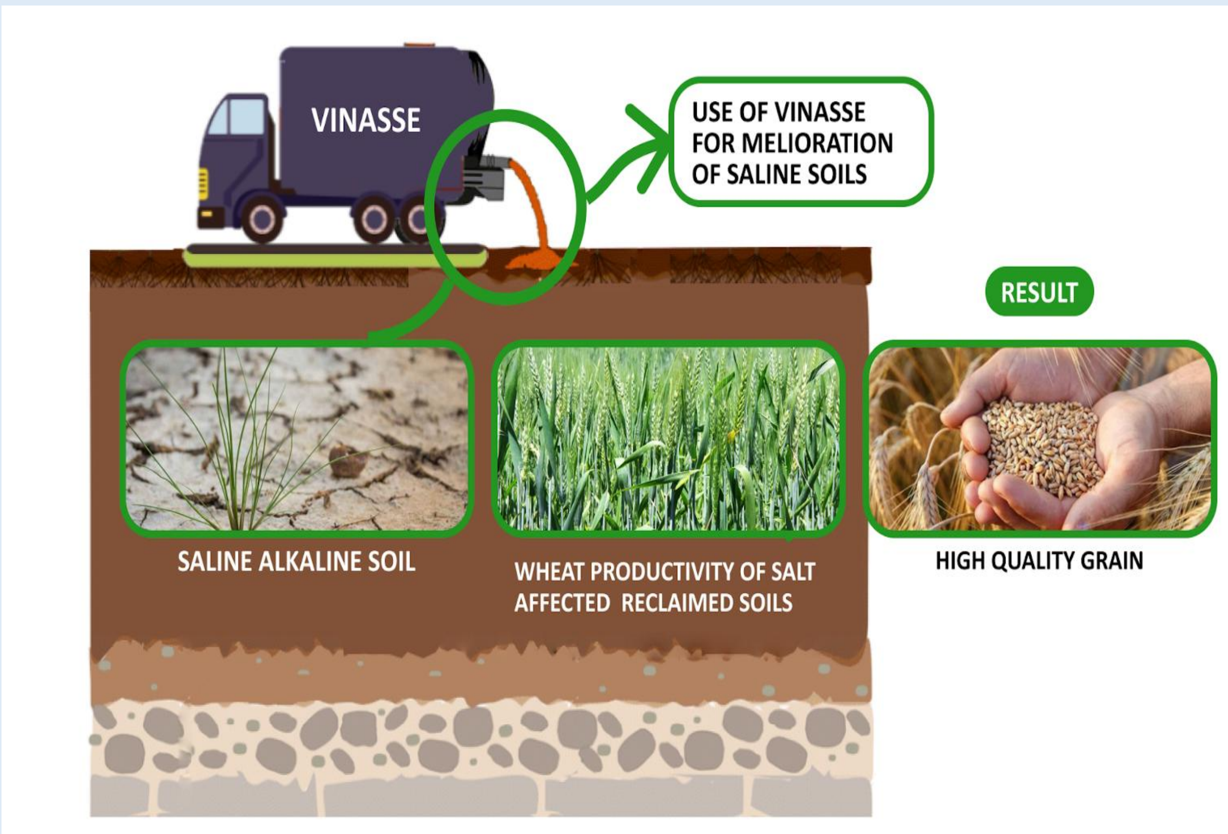
Objective: This study investigates the effectiveness of vinasse, a by-product of alcohol production, as a soil ameliorant for saline-alkaline soils and evaluates the qualitative and quantitative properties of wheat cultivated on reclaimed lands. Vinasse is a weak acid suspension containing organic matter and solid minerals.

Methods: The research was conducted in 2023–2024 under field conditions. Saline soils were treated with vinasse, followed by soil washing, and winter wheat was cultivated in the reclaimed soil.

Results: The application of vinasse neutralized the alkali reaction of the soil solution, displaced sodium from the soil's absorption complex, and resulted in the desalination and dealkalinization of the soil profile. Winter wheat cultivated on the improved soil yielded 3.4 t/ha. Chemical analysis of the wheat grains demonstrated high nutritional value and functionality, which are of significant importance.

Conclusion: Vinasse is an effective agent for the chemical improvement of saline-alkaline soils. The slow interaction between tartaric acid in vinasse and soil carbonates ensures the gradual neutralization of alkali reactions and enhances soil quality throughout the profile. Wheat grown in the reclaimed soil exhibited superior qualitative and functional properties, highlighting the potential of vinasse in agricultural applications.

Keywords: Vinasse, reclamation, functional food, winter wheat, desalination, dealkalinization.



INTRODUCTION

Climate change [1-3], land degradation [4-6], unplanned land use [7-9], intensive agricultural practices, and biodiversity loss [10-12] collectively pose significant threats to global food security. Among these challenges, salinization is recognized as one of the primary drivers of land degradation. Currently, over 1 billion hectares of land globally are affected by salinization, which represents 25% of irrigated land, with 50% of this area experiencing secondary salinization to varying extents [13, 14]. Salinization significantly reduces soil productivity [15]. As a result of various anthropogenic factors, vast areas of land have been removed from agricultural use [16, 17]. To mitigate this pressing global issue, which represents a significant threat to food security, it is crucial to rehabilitate lands impacted by salinization and alkalization and reintegrate them into agricultural cycles. Furthermore, efforts must be made to enhance the fertility of low-productive lands.

A variety of ameliorants have been used to improve saline soils [18-21], and a range of different approaches have been demonstrated [22, 23]. Wheat (*Triticum aestivum*) is the most widely consumed cereal crop globally [24, 25], playing a crucial role in food security due to its high content of proteins, carbohydrates, and vitamins—nutrients that are essential for human health [26, 27]. Agriculture plays a crucial role in supporting human health, as it provides products with high nutritional and functional value, which are essential for maintaining well-being. Producers are increasingly focused on developing innovative methods to enhance the content of biologically active substances in agricultural products (28-33).

However, soil salinization and alkalization pose significant challenges to wheat cultivation, as the crop is particularly vulnerable to osmotic stress and ion toxicity. Wheat yields are notably reduced under salinity stress, particularly when soil solution concentrations range from 4 mS/cm [34].

The impact of salinity is particularly pronounced during xerothermic conditions [35]. Salinity accelerates all phenological phases of plant growth and development [36], which in turn leads to a reduction in grain yield [37]. Seed germination is an important stage in plant development; however, under osmotic stress conditions, the germination process is disrupted, which impairs overall plant growth and development [38-40]. Under conditions of high soil solution concentration, osmotic potential decreases, leading to impaired enzyme function and, consequently, disrupted plant metabolism [41]. Additionally, osmotic stress reduces the number of productive shoots, spikelets, and grain weight, ultimately diminishing yield [42]. Water availability in the soil is crucial for normal plant development, as all vital physiological processes depend on accessible water. In saline soil, however, osmotic stress reduces the available water potential in plant cells [43].

Studies have demonstrated that high soil solution concentration has a significantly negative impact on wheat grain quality. In soils with an alkaline reaction nitrogen assimilation is disrupted, resulting in a decrease in the protein content of wheat grain [44].

The aim of this study is to investigate the ameliorative effectiveness of waste generated during alcohol production, specifically bran, in the reclamation of saline soils. Additionally, the study will evaluate the qualitative and quantitative characteristics of winter wheat cultivated on the ameliorated soils.

The brandy production process generates a significant amount of waste- vinasse, which contains 5.647 g/l of acids, including 3.89 g/l of tartaric acid, 1.452 g/l of malic acid, and 0.305 g/l of acetic acid. Additionally, vitamins are rich in nutrients, microelements, valuable vitamins, and enzymes. Due to its rich chemical composition, researchers have explored the potential of using vinasse to improve soil nutrition [45]. However, the disposal of vinasse into the environment poses significant risks to both aquatic and terrestrial animals, presenting a serious environmental issue [46].

MATERIALS AND METHODS

The research was conducted during the 2023-2024 period on a 0.18-hectare plot of land owned by a farmer in the semi-desert zone of the Republic of Armenia, specifically in the Yeraskhahun community of the Armavir region. For laboratory analysis, four soil samples were collected from the plot both before and after land reclamation. These samples were taken from the following soil layers: 0-25 cm, 25-50 cm, 50-75 cm, and 75-100 cm. Before reclamation, the land underwent tillage, leveling, and the construction of embankments, resulting in the creation of three 600 m² micro-plots. A total of 3,600 tons of vinasse (at a rate of 20,000 tons/ha) was applied to the land, which was transported from the brandy factory using an autocissor. Afterward, the land was washed with a total of 41,000 m³ of wash water.

Before reclamation, the chemical composition of the saline soil, the composition and ratio of exchangeable cations, and calcareousness were studied. The same laboratory analyses were conducted after reclamation. Following this, winter wheat (Nairi 68) was cultivated on both the reclaimed land (0.18 ha) and the irrigated meadow brown soils (0.15 ha). Sowing was done using row planting, with an inter-row distance of 15 cm and a planting depth of 5-6 cm. Irrigation was carried out through furrows, with three irrigation cycles, each delivering 1000 m³/ha. The wheat was fertilized with $N_{150}P_{120}K_{90}$. Phosphorus and potassium fertilizers were applied during the main tillage, while nitrogen fertilizer was applied both during tillage (60 kg) and nutrition process (60 kg). Plant height, spike length, 1000-grain weight were measured, and wheat yield was determined. All studies were performed using standard methods. The chemical composition of wheat grown in both irrigated meadow gray soils and ameliorated soils was also analyzed. Laboratory tests were conducted at the Republic of Armenia Standard Diologi Laboratory, where the content of carbohydrates, proteins, gluten, and dry matter in the wheat grain was determined.

RESULTS AND DISCUSSION

Before reclamation, the chemical composition of the saline soil was analyzed. The results indicated that the reaction of soluble salts in the soil solution was strongly alkaline. The content of soluble salts in the top meter of soil was 1.09%, primarily due to the high concentrations of sulfates, chlorides, and carbonates (Table 1).

Table 1. Chemical composition of soil solution of saline-alkaline soil before melioration

Type of soil	Layer of soil, cm	pH	EC, mS/cm	Total salts, %	Soluble ions, meq 100g of soil						
					CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	$Na^+ K^+$
Saline alkaline	0-25	9.6	8.5	1.34	3.20	4.0	6.60	8.90	0.60	0.10	19.45
	25-50	9.8	7.9	1.07	1.90	4.50	8.50	2.90	0.09	0.15	16.90
	50-75	9.5	8.0	1.13	1.11	3.10	4.50	8.50	0.21	0.16	16.94
	75-100	9.3	6.4	0.82	0.50	2.19	5.10	4.61	0.25	0.17	13.10
	0-100	9.5	7.6	1.09	1.60	3.44	6.10	6.22	0.28	0.14	16.59

After the introduction of vinasse into the soil, tartaric acid reacts with soil carbonate to form sodium, calcium, and magnesium tartrate. Sodium tartrate is water-soluble and is removed from the soil during the leaching process. Magnesium tartrate has low solubility, while calcium tartrate is insoluble in water. The interaction between tartaric acid and carbonates occurs very slowly, preventing the immediate neutralization of tartaric acid and maintaining an acidic reaction throughout the soil profile. Under these conditions, the solubility of the formed calcium tartrate increases, and soil carbonates are decomposed (Table 2). This leads to an increase in calcium concentration in the soil solution, which interacts with the sodium in the soil's adsorption complex. As a result, adsorbed sodium is displaced from the adsorption complex into the soil solution, where it reacts with tartaric acid to form sodium tartrate, a soluble compound that is removed through the drainage system during the washing process. Magnesium tartrate, unlike calcium tartrate, has relatively higher solubility, interacting with the adsorption complex and contributing to the alkalization process.

As a result of dealkalization, the filtration rate increases (10-12 cm/day). The process of improving saline-alkaline soil with the vinasse leads to both desalination and dealkalization.

Table 2. The amount of carbonates in saline alkaline, %

Soil layer, cm	$CaCO_3$	$MgCO_3$	$CaCO_3$	$MgCO_3$
	Before melioration		After melioration	
0-25	11.1	3.3	10.5	3.1
25-50	12.0	2.9	11.6	2.5
50-75	10.5	2.8	10.0	2.4
75-100	10.3	2.8	9.9	2.5

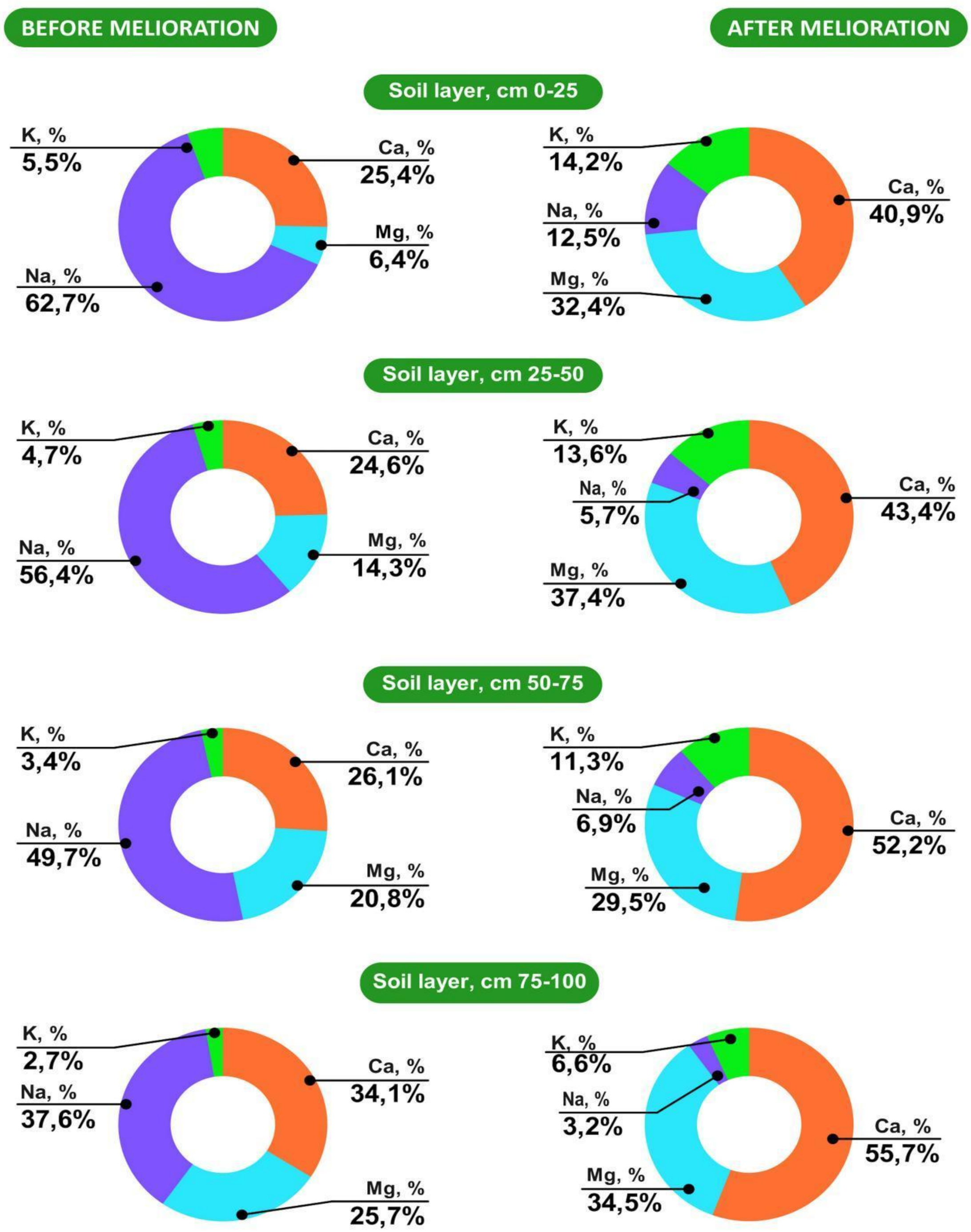
After reclamation, the strongly alkaline pH in the soil solution is neutralized, and the toxic CO_3^{2-} ion is eliminated. The electrical conductivity of the soil solution decreases to 2.0-2.4 mS/cm, and the pH stabilizes at 7.7-8.1 (Table 3).

Table 3. Chemical composition of soil solution of saline alkaline soil after melioration

Type of soil	Layer of soil, cm	pH	EC, mS/cm	Total salts, %	Soluble ions, meq of 100g soil						
					CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	$Na^+ K^+$
Meliorated soil	0-25	8.1	2.4	0.36	-	2.20	0.40	2.10	1.25	0.56	0.93
	25-50	8.0	2.2	0.26	-	1.50	0.35	0.90	0.95	0.64	0.88
	50-75	7.8	2.3	0.25	-	2.90	0.36	0.19	1.50	0.80	1.32
	75-100	7.7	2.0	0.28	-	3.60	0.30	0.04	0.90	0.90	3.12
	0-100	7.9	2,2	0.28	-	2.55	0.35	0.80	1.15	0.72	1.56

The composition and ratio of exchangeable cations also improved during the reclamation process (Figure 1). Before reclamation, sodium predominated in the CEC (Cations Exchange Capacity) of the saline soil, comprising 37.60-62.36%. During reclamation, sodium was displaced from the absorption complex, and the ESP in the reclaimed soil fell within the permissible limits. The amount of exchangeable calcium in the absorption complex increased. The significant rise in exchangeable magnesium is attributed to the relatively higher solubility of magnesium tartrate in the soil solution. The amount of absorbed potassium also increased, which can be explained by the interaction between tartaric potassium and absorbed sodium. As a result of the amelioration, the soil layer became dealkalized, however, the ratio of exchangeable cations remains unfavorable for crops, as the amount of exchangeable magnesium is high. The ideal ratio of exchangeable cations in the absorption complex for crops is as follows: Ca> 60%, Mg< 30%, Na<15%, K< 5%. To increase the amount of calcium in the absorption complex, the use of calcium-containing compounds is recommended.

Figure 1. The amount of exchangeable cations before and after melioration



Following the completion of the land reclamation process, winter wheat was cultivated on both the reclaimed lands and the irrigated meadow brown soil in the semi-desert zone. The chemical composition of the irrigated meadow brown soil is presented in Table 4. The content of soluble salts in this soil exceeds the permissible limit, which is set at < 0.2%.

Table 4. The chemical composition of irrigated meadow brown soil

Soil layer, cm	pH	EC, mS/cm	Total salts, %	Na, meq of 100g soil		Exchangeable cations, %			
				Soluble	Exchang.	Ca	Mg	Na	K
0-25	8.00	3.7	0.40	2.50	3.50	50.00	32.00	14.00	4.00
25-50	7.9	3.8	0.37	2.80	3.50	49.00	33.00	11.00	7.00

Table 5. The amount of available nutrients in the soil, mg/kg of 100g soil

Soil type	Soil layer, cm	N	P_2O_5	K_2O
Irrigated meadow brown soil	0-25	1.2	0.45	10.6
	25-50	1.5	0.36	7.1

The data on the nutrient content of the soils are provided in Table 5. The irrigated meadow brown soils are poorly supplied with available nutrients (Table 5). In the ameliorated soil, the plant height of winter wheat was 86.6 cm (Table 6), the spike length was 8.0 cm, and the 1000-grain weight was 54.370 g. In the irrigated meadow brown soil, the wheat plant height was 88.9 cm, the spike length was 8.1 cm, the 1000-grain weight was 52.100 g, and the grain yield was 3 t/ha. Based on the results of the study, it can be concluded that the 1000-grain weight of wheat grown in irrigated meadow brown soil was 2.27 g less, and the total yield was 0.4 t/ha $^{-1}$ lower.

Table 6. Productivity indicators and structural elements of winter wheat (Nairi 68)

Variants	Hight of the stem, cm	Length of the spike, cm	Weight of 1000 grains, g	Grain yield, t/ha^{-1}
Meliorated soil	86.6	8.0	54.370	3.4
Irrigated meadow brown soil	88.9	8.1	52.100	3.0

The content of proteins, gluten, carbohydrates, and dry matter was determined in the winter wheat grain cultivated in peat-amended soil as well as in irrigated meadow soil (Table 7).

Table 7. Chemical composition of wheat grains, %

Variants	Proteins	Gluten	Carbohydrates	Dry metter
Meliorated soil	13.1	30.0	60.1	91.5
Irrigated meadow brown soil	10.3	28.6	58.5	90.5

The results of the study indicated that the content of functional elements-proteins, gluten, carbohydrates, and dry matter was higher in the wheat grain cultivated in vinasse-amended soil compared to that of wheat grown in irrigated meadow brown soil. Based on these findings, it can be concluded that wheat cultivated in vinasse-amended soil not only yielded higher quantities but also exhibited superior qualitative properties compared to wheat grown in irrigated meadow brown soil.

CONCLUSIONS

The use of industrial waste, vinasse (at a rate of 10-20 thousand t/ha), in the chemical reclamation of saline-alkaline soils is effective. The slow interaction between tartaric acid and soil carbonates neutralizes the alkali reaction and promotes dealkalization and desalinization throughout the soil profile. Unlike other ameliorants, such as sulfuric acid and ferric iron, which exhibit low intensity due to the low solubility of gypsum accumulating on the soil surface, vinasse accelerates the reclamation process and improves the physical and chemical properties of the soil. Vinasse-treated soil creates favorable conditions for wheat growth and development. The resulting crop is both quantitatively and qualitatively superior to wheat grown in irrigated meadow brown soil.

Abbreviations: RA: Republic of Armenia, CEC: Cations Exchange Capacity.

Competing Interests: The authors declare that there are no competing interests.

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REFERENCES

1. Rosenzweig C, Strzepek KM, Major DC, Iglesias A, Yates DN, McCluskey A, et al. Water resources for agriculture in a changing climate. *Glob. Environ. Change*. 2004; 14(4): 345–360. DOI: https://doi.org/10.1016/j.gloenvcha.2004.09.003
2. Giraldo P, Benavente E, Manzano-Agugliaro F, and Gimenez E. Worldwide research trends on wheat and barley: a bibliometric comparative analysis. Agronomy. 2019; 9:352. DOI: https://doi.org/10.3390/agronomy9070352
3. Mirzabaev A, Kerr RB, Hasegawa T, Pradhan P, Wreford A, Pahlen MCT, Smith HG. Severe climate change risks food security and nutrition. Climate Risk Management. 2023; 39. DOI: https://doi.org/10.1016/j.crm.2022.100473
4. Amombo E, Ashilenje D, Hirich A. et al. Exploring the correlation between salt tolerance and yield: research advances and perspectives for salt-tolerant forage sorghum selection and genetic improvement. Planta. 2022; 255(710). DOI: https://doi.org/10.1007/s00425-022-03847-w
5. Netondo GW, Onyango JC, and Beck E. Sorghum and salinity: II. gas exchange and chlorophyll fluorescence of sorghum under salt stress. *Crop Sci.* 2004; 44: 806–811. DOI: https://doi.org/10.2135/cropsci2004.8060
6. Giraldo P, Benavente E, Manzano-Agugliaro F, and Gimenez E. Worldwide research trends on wheat and barley: a bibliometric comparative analysis. *Agronomy.* 2019; 9(352). DOI: https://doi.org/10.3390/agronomy9070352
7. Parven A, Pal I, Witayangkurn A, Pramanik M, Nagai M, Miyazaki H, Wuthisakkaroon Ch. Impacts of disaster and land-use change on food security and adaptation: Evidence from the delta community in Bangladesh. *International Journal of Disaster Risk Reduction*. 2022; 78. DOI: https://doi.org/10.1016/j.ijdrr.2022.103119
8. Ahmed Z, Ambinakudige S. Does land use change, waterlogging, and salinity impact the sustainability of agriculture and food security? Evidence from the southwestern coastal region of Bangladesh*. Environ Monit Assess*. 2023; 195, 74. DOI: https://doi.org/10.1007/s10661-022-10673-w
9. Jónsdóttir S, Gísladóttir G. Land use planning, sustainable food production and rural development: A literature analysis. Geography and Sustainability. 2023; 4(4): 391-403. DOI: https://doi.org/10.1016/j.geosus.2023.09.004
10. Chappell MJ, LaValle LA. Food security and biodiversity: can we have both? *Agroecological analysis. Agric Hum Values*. 2011; 28: 3–26. DOI: https://doi.org/10.1007/s10460-009-9251-4
11. Kalhoro NK, Raipar I, Kalharo SHA, Ali A, Raza S, Ahmed M, Kalharo FA, Ramzan M, Wahid F. Effect of Salt Stress on the Growth and Yield of Wheat (Triticum Aestivum). American

Journal of Plant Scieces. 2016; 7(15). DOI: https://doi.org/10.4236/ajps.2016.715199

12. Waha K, Accatino F, Godde C, Rigolot C, Bogard J, Domingues JP, Gotor E et al. The benefits and trade-offs of agricultural diversity for food security in low- and middle-income countries: A review of existing knowledge and evidence. *Global Food Security*. 2022; 33. DOI: https://doi.org/10.1016/j.gfs.2022.100645
13. Negacz K, Malek Ž, Vos A, Vellinga P. Saline soils worldwide: Identifying the most promising areas for saline agriculture. *Journal of Arid Environments*. 2022, 203. DOI: https://doi.org/10.1016/j.jaridenv.2022.104775
14. Ivushkin K, Bartholomeus H, Bregt AK, Pulatov A, Kempen B, Sousa D, Global L. Mapping of soil salinity changes. *Remote Sens Environ*. 2019; 231. DOI: https://doi.org/10.1016/j.rse.2019.111260
15. Muhammad M, Waheed A, Wahab A, Majeed M, Nazim M, Liu YH, Li L, et al. Soil salinity and drought tolerance: An evaluation of plant growth, productivity, microbial diversity, and amelioration strategies. *Plant Stress.* 2024; 11. DOI: https://doi.org/10.1016/j.stress.2023.100319
16. Dregne HE. Land degradation in the drylands. *Arid Land Res Manag* 2002, 16: 99–132. DOI: http://dx.doi.org/10.1080/153249802317304422
17. Tarolli P, Luo J, Park E, Barcaccia G, Masin R. Soil salinization in agriculture: Mitigation and adaptation strategies combining nature-based solutions and bioengineering. *iScience. 2024;* 27(2). DOI: https://doi.org/10.1016/j.isci.2024.108830
18. Chen J, Hu G, Wang H, Fu W. Leaching and migration characteristics of nitrogen during coastal saline soil remediation by combining humic acid with gypsum and bentonite*. Ann. Agric. Science*. 2023;68(1):1–11. DOI: https://doi.org/10.1016/j.aoas.2023.02.001
19. Gharaibeh MA, Eltaif NI, Shunnar OF. Leaching and reclamation of calcareous saline-sodic soil by moderately saline and moderate-SAR water using gypsum and calcium chloride. *Journal of Plant Nutrition and Soil Science*. 2009. DOI: https://doi.org/10.1002/jpln.200700327
20. Mace JE, Amrhein C, and Oster JD. Comparison of gypsum and sulfuric acid for sodic soil reclamation. *Arid Soil Research and Rehabilitation.* 1999; 13(2): 171–188. DOI: https://doi.org/10.1080/089030699263401
21. Zhao Y, Zhang Z, Li Z, Yang B, Li B, Tang X, Lai Y. Comprehensive study on saline-alkali soil amelioration with sediment of an irrigation area in northeast China. *Arabian Journal of Chemistry*. 2023; 16(4). DOI: https://doi.org/10.1016/j.arabjc.2023.104608
22. Aboelsoud HM, AbdelRahman MAE, Kheir AMS, Eid MSM, Ammar KA, Khalifa TH, Scopa A: Quantitative estimation of saline-soil amelioration using remote-sensing indices in arid land for better management. *Land* 2022; 11. DOI: https://doi.org/10.3390/land11071041
23. Sahakyan S, Yedoyan T. Application of acoustic oscillations for accelerating the leaching process of saline soils. *Journal of the Saudi Society of Agricultural Sciences.* 2024; 23(6): 442-450. DOI: https://doi.org/10.1016/j.jssas.2024.04.004
24. Giraldo P, Benavente E, Manzano-Agugliaro F, Gimenez E: Worldwide research trends on wheat and barley: a bibliometric comparative analysis. *Agronomy.* 2019; 9(352). DOI: https://doi.org/10.3390/agronomy9070352
25. Chandra T, Jagajjit J, Jaiswal S, Iquebal MA, Kumar D. Current research status and emerging trends in wheat: An integrated scientometric analysis based on ploidy uncovers hidden footprints in the scientific landscape. *Heliyon*. 2024; 10(16). DOI: https://doi.org/10.1016/j.heliyon.2024.e36375
26. Essa MM, Bishir M, Bhat A, et al. Functional foods and their impact on health. *J Food Sci Technol*. 2023; 60: 820–834. DOI: https://doi.org/10.1007/s13197-021-05193-3
27. Martirosyan D, Kanya H, Nadalet C. Can functional foods reduce the risk of disease? Advancement of functional food definition and steps to create functional food products. *Functional Foods in Health and Disease*. 2021; 11(5). DOI: https://doi.org/10.31989/ffhd.v11i5.788
28. Martirosyan DM, Lampert T, Lee MA. A comprehensive review on the role of food bioactive compounds in functional food science. *Functional Food Science* 2022, 3(2): 64-79. DOI: https://www.doi.org/10.31989/ffs.v2i3.906
29. Martirosyan DM, Stratton S. Quantum and tempus theories of function food science in practice. *Functional Food Science*, 2023; 3(5): 55-62. DOI: https://www.doi.org/10.31989/ffs.v3i5.1122
30. Martirosyan D, Stratton S. Advancing functional food regulation. *Bioactive Compounds in Health and Disease*. 2023; 6:166. DOI: https://doi.org/10.31989/bchd.v6i7.1178
31. Melyan G, Santrosyan G. In vitro propagation of stone fruit rootstock cultivar Evrica 99 and its influence on some phytochemical traits of fresh apricot fruit. *Functional Foods in Health and Disease.* 2024; 14:128–142.

DOI: https://doi.org/10.31989/ffhd.v14i2.1317

32. Martirosyan H, Galstyan M, Aloyan T, Gasparyan N, Terteryan Kh, Sahakyan N, Avagyan G. The impact of mineral and organic fertilizers on potato yield, qualitative and quantitative indicators, and functional value. *Functional Food Science*. 2024; 4(8): 309-324. DOI: https://doi.org/10.31989/ffs.v4i8.1400
33. Avagyan G, Daveyan S, Eloyan A, Sahakyan S, Asatryan A, Martirosyan H. Influence of water-absorbing polymers on grain crop yield, disease incidence, and end-use quality. *Functional Food Science*. 2024; 4(7): 261-276. DOI: https://www.doi.org/10.31989/ffs.v4i6.13
34. Kopittke PM, Menzies NW, Wang P, McKenna BA, Lombi E. Soil and the intensification of agriculture for global food security. *Environmental International*. 2019; 132. DOI: https://doi.org/10.1016/j.envint.2019.105078
35. Huang M, Chai L, Jiang D, Zhang M, Zhao Y, and Huang Y. Increasing aridity affects soil archaeal communities by mediating soil niches in semi-arid regions. *Sci. Total Environ*. 2019, 647: 699–707. DOI: https://doi.org/10.1016/j.scitotenv.2018.07.305
36. Seleiman MF, Aslam MT, Alhammad BA, Hassan MU, Maqbool R. et al. Salinity stress in wheat: effects, mechanisms and management strategies. *Phyton-International Journal of Experimental Botany.* 2022; 91(4): 667-694. DOI: https://doi.org/10.32604/phyton.2022.
37. Sorour SG, Aiad MA, Ahmed AA, Henash MIA, Metwaly EM, Alharby H, et al: Yield of wheat is increased through improving the chemical properties, nutrient availability, and water productivity of salt-affected soils in the north delta of Egypt. *Appl. Ecology and Environmental Research*. 2019; 17: 8291–8306. DOI: http://dx.doi.org/10.15666/aeer/1704_82918306
38. Feghenabi F, Hadi H, Khodaverdiloo H, Genuchten M. Seed priming alleviated salinity stress during germination and emergence of wheat (Triricum aestivum). *Agricultural Water Management*. 2020, 231. DOI: https://doi.org/10.1016/j.agwat.2020.106022
39. Shahid SA, Zaman M, Heng L. Introduction to soil salinity, sodicity and diagnostics techniques. Guideline for Salinity Assessment, Mitigation and Adaptation Using Nuclear and Related Techniques. 2018: 1–42. DOI: http://dx.doi.org/10.1007/978-3-319-96190-3_1
40. Mohammadi M, Pouryousef M, Farhang N. Study on germination and seedling growth of various ecotypes of fennel (Foeniculum vulgare Mill.) under salinity stress. *Journal of Applied Research on Medicinal and Aromatic Plants.* 2023; 34. DOI: https://doi.org/10.1016/j.jarmap.2023.100481
41. Hasanuzzaman M, Nahar K, Fujita M, Ahmad P, Chandna R, Ahmad P, Azooz MM, et al. Salt stress in plants. *Omics, Signaling, and Responses*; 2013. DOI: http://dx.doi.org/10.1007/978-1-4614-6108-1_6
42. Saddiq MS, Iqbal S, Hafeez MB, Ibrahim AM, Raza A. Effect of salinity stress on physiological changes in winter and spring wheat. *Agronomy*. 2021; 11(6). DOI: https://doi.org/10.3390/agronomy11061193
43. Nassar R, Kamel HA, Ghoniem AE, Alarcón JJ, Sekara A. Physiological and anatomical mechanisms in wheat to cope with salt stress induced by seawater. *Plants*. 2020; 9(237). DOI: https://doi.org/10.3390/plants9020237
44. Dissanayake BM, Staudinger Ch, Munns R, Taylor NL, Distinct MH. Salinity-induced changes in wheat metabolic machinery in different root tissue types. *Journal of Proteomics*. 2022; 256. DOI: https://doi.org/10.1016/j.jprot.2022.104502
45. Carpanez TG, Moreira VR, Assis IR, Amaral MCS. Sugarcane vinasse as organo-mineral fertilizers feedstock. Opportunities and environmental risks. *Science of The Total Environment.* 2022; 832. DOI: https://doi.org/10.1016/j.scitotenv.2022.154998
46. Christofoletti CA, Escher JP, Correia JE, Marinho JFU, Fontanetti CS. Sugarcane vinasse: Environmental implications of its use. *Waste Management.* 2013; 33: 2752-2761. DOI: https://doi.org/10.1016/j.wasman.2013.09.005