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ORIGINAL ARTICLE

Ultrasonic Characterization on Arginine with Saline Salts(K_2SO_4, Na_2SO_4, $MgSO_4$) Solutio n in View to Sustainable Farming

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Abstract

Background/Objective: In irrigated areas, accumulation of salt restricts plant growth, reduces or even stops seed germination, and encourages poor seedling establishment. When the soil's salinity drops, the plants can absorb water and nutrients. A reduction in the growth rate of plants is the initial indication of the plant's response to salinity, which is linked to several metabolic alterations identical to those induced by water stress in plants. This stress significantly impairs crop yield by restricting plant growth. **Method:** The ultrasonic velocity and density of Arginine in water and 0.2N solutions of Magnesium sulphate, Potassium sulphate, and Sodium sulphate have been measured as a function of concentration at temperatures of 313.15 K and 318.15 K. This fundamental data has been utilized to calculate various thermo-physical parameters of the specified systems. **Findings:** This study evaluated the impact of Arginine on saline salts, particularly sodium sulphate, magnesium sulphate, and potassium sulphate. The outcome validates the role of Arginine in saline solutions and introduces a novel strategy that improves synthesis through ultrasonic techniques. The degree of interaction is greater for Arginine with magnesium sulphate. It follows that Arginine has greater effectiveness with magnesium sulphate saline solution. It can improve the physical characteristics of saline soil. **Novelty:** The application of chemical fertilizers adversely affects the physical properties of soil. The application of amino acids in place of harmful fertilizers is sustainable. As a fundamental component of protein, it cannot disrupt the natural balance of soil. The ultrasonic approach is non-destructive, which allows it to determine the type of interaction with greater precision.

Keywords: Saline soil; Hydrogen bonding; Solute-solvent interaction; Amino acids; Ultrasonic velocity

1 Introduction

In the agricultural sector, soil salinity has garnered a lot of attention because of soil mineral deposition, which leads to poor drainage conditions. Both agricultural production and soil quality are significantly impacted by increased soil salinity.[1] In particular, longer growing seasons in agriculture are caused by higher soil salinity, which eventually affects crop yield. Salinization of the soil is also influenced by soil fertilization. Reducing the negative effects of fertilization on soil quality requires an organized investigation of fertilizer characteristics, application methods, and fertilization schedule. Organic farming has abruptly declined in many parts of the world, despite the fact that mineral fertilizers are more widely available and play a crucial role in increasing agricultural productivity to feed the growing population of the globe.[2] In irrigated areas, accumulation of salt restricts plant growth, reduces or even stops seed germination, and encourages poor seedling establishment. When the soil's salinity drops, the plants are able to take up water and nutrients.[3]A decrease in plant growth rate is the first sign of the plant salt reaction, which is associated with a number of metabolic changes identical to those caused by plant water stress. Because it restricts plant growth, this stress has a significant and detrimental effect on crop output.[4]

Amino fertilizers are becoming an effective and eco-friendly substitute for synthetic fertilizers as the globe shifts to more sustainable farming methods. They are key element of sustainable agricultural production due to their organic composition, capacity to improve soil health and minimize environmental pollution. Applying amino fertilizers may build a healthier and more sustainable planet along with to increasing crop quality and production.[5]

Arginine is utilized extensively to improve plant stress resistance since it is the primary precursor of nitric oxide and polyamine synthesis. Therefore, increasing the antioxidant system's activity could enhance the fruits' ability to store after being treated with arginine.[6] Despite this, high nitrogen-carbon ratio of Arginine has made it a crucial element in nitrogen transport and storage in plants. Treatment with arginine may enhance nitrogen nutrition since it is instantly absorbed by plants as an organic nitrogen source. At the same time, arginine is necessary for the metabolism of nitrogen, especially for plants that convert ammonia and create urea. However, very little research has examined how increasing nitrogen in plants treated with arginine enhances plant growth and production.[7]

Plant growth is often restricted by the availability of nutrients. The limiting required component is often nitrogen. Lack of nitrogen reduces agricultural productivity, Agricultural output suffers when there is a nitrogen shortage, yet excessive nitrogen fertilizer has detrimental effects on the economy and ecology. Enhancing the efficiency of nitrogen utilization is a major concern for agriculture, and it is becoming more and more crucial to look into the mechanisms of nitrogen uptake, storage, plant growth and stress tolerance.[8] Among the 21 proteinogenic amino acids, arginine possesses the highest nitrogen-to-carbon ratio and serves as a principal source of organic nitrogen storage and transport in plants. Furthermore, it serves as a precursor and an amino acid for protein synthesis.[9] In plant physiological functions, arginine is essential. As a plant develops, it serves as a pool for nitrogen absorption. Under stressful conditions, plants showed positive development when arginine was applied topically. In the vegetative sector, arginine is utilized as a bio-stimulant to improve food quality and productivity.[10]

Based on the evidence above, we determined effect of Arginine on saline salt such as sodium sulphate, magnesium sulphate and potassium sulphate. Our study confirms the functions of Arginine on saline salt and provides a novel strategy for improving production by ultrasonic method. The ultrasonic approach is non-destructive, which allows it to determine the type of interaction with greater precision.

2 Methodology

All chemicals used in experiment such as Arginine and sodium sulphate, potassium sulphate and magnesium sulphate are SR grade and AR grade with purity ≥99% were purchased from Himedia.

Name of compound	Molecular weight	Volume	Molality (Mole)
Arginine	174.20g.mol^{-1}	30ml	0-0.2
Potassium Sulphate	174.20g.mol^{-1}	350ml	0.2
Sodium Sulphate	142.04g.mol^{-1}	350ml	0.2
Magnesium Sulphate	246.47g.mol^{-1}	350ml	0.2

The Weight of chemical was determined by following formula.

Weight of substance $= \frac{Molecular\ Weigth\ \times Molality \times Volume}{1000}$

2.1 Preparation of Systems:

1. Arginine ($C_6H_{14}N_4O_2$)+ H_2O ‘
2. Arginine ($C_6H_{14}N_4O_2$)+ H2O+Potassium Sulphate(K_2SO_4)
3. Arginine ($C_6H_{14}N_4O_2$)+ H_2O+Sodium Sulphate(Na_2SO_4)
4. Arginine ($C_6H_{14}N_4O_2$)+ H_2O+Magnesium Sulphate($MgSO_4$)

2.2 Apparatus

1. Ultrasonic interferometer operating on $2MH_z$ along with water bath maintained at desired temperature.
2. A 10ml density bottle and a weighing scale were utilised for the determination of density. A 0.2 M aqueous saline salt stock solution (Na_2SO_4, K_2SO_4, $MgSO_4$) was made using double distilled water. It serves as a solvent for the formulation of the requisite experimental solution. The concentration of Arginine fluctuates between 0.02 and 0.2 M. The specific conductance of the twice distilled water utilised was below 18·10—6 Ω—1 cm—1. All the solutions were stored in sealed bottles to prevent dissipation and explosion upon exposure to air. An ultrasonic interferometer (Mittal-M-77, India) is measured at 2 MHz across changing temperatures. It is founded on the notion of varied paths. The final measured value of ultrasonic velocity is the average of 20 readings. The thermostat regulates the temperature of water running through the insulated brass enclosing the quartz crystal and cell. An ultrasonic interferometer and a thermostated water bath were employed to detect ultrasonic velocity. The equipment was maintained at experimental temperature for 30 minutes prior to recording. The densities of water and the experimental solution were measured using a 10 ml density bottle and an electronic balance. Electronic weighing balance with an accuracy of ± 0.01 g. The computed density of the solution was determined as the average of three density observations. All glassware and cells were cleaned with acetone before to the experiment, and the device was calibrated using double distilled water. The fluctuation in thermodynamic parameters offers essential insights into the intermolecular forces present in a solution. The measuring of ultrasonic velocity in a solution is an effective tool for elucidating its physico-chemical properties. The ultrasonic velocity and density values are utilized in the following parameter computations.

- Adiabatic compressibility (β) = $\frac{1}{\rho U^2}$ ———-. (M^2N^{-1})
- Acoustic impedance (Z)= ρU^2——-. (Kgm^2s^{-1})
- Wada Constant (W)=$V_m\ \beta^{\frac{-1}{7}}$ ———-(m^3mole^{-1})(ms^{-1})$^{-1/7}$
- Specific Heat Ratio (γ) = $\frac{17.1}{T^{\frac{4}{9}}\ \rho^{\frac{1}{3}}}$ ——-$(K^{\frac{4}{9}})^{-1}\left(Kg^{\frac{1}{3}}m^{-1}\right)^{-1}$
- Intermolecular Free length (L_f)= $K\beta^{\frac{1}{2}}$——-(m)
- Non-Linearity Parameter (B/A) = $\left\{2+\frac{0.98*10^4}{U}\right\}$———($m^{-1}s$)

3 Result and Discussion

3.1 Ultrasonic velocity (U)

Temperature has a substantial impact on the energy of molecules in liquids that are joined by hydrogen bonds. As the temperature rises, the number of hydrogen bonds in the liquid is expected to increase because thermal movements of the molecules raise activation energy.[(11)],[(12)] The ultrasonic velocity (U) concentration-dependent linear rise exhibits the cohesive forces increased as a result of strong molecular contact. However, as temperature (T) grew, so did these characteristics as cohesive forces do. The enhancement of cohesive forces was aided by an increase in ultrasonic velocity. Solute-solvent interactions are the main source of the tendency to form structures, while thermal fluctuations are the cause of the expansion of structures that have already been formed.[(13)],[(14)] From Figure 1 and Table 1, it has been noted that ultrasonic velocity rises as a concentration of $C_6H_{14}N_4O_2$ in Na_2SO_4, K_2SO_4, $MgSO_4$ suggest the association between molecules of Sodium sulphate, potassium sulphate, magnesium sulphate and amino acids. There is larger ion –dipole interaction between $C_6H_{14}N_4O_2$ +$MgSO_4$ than $C_6H_{14}N_4O_2$ +Na_2SO_4 and $C_6H_{14}N_4O_2$ +K_2SO_4. It conforms stronger interaction between $C_6H_{14}N_4O_2$ + $MgSO_4$. The order of interaction is $C_6H_{14}N_4O_2$ +$MgSO_4$> $C_6H_{14}N_4O_2$ +K_2SO4> $C_6H_{14}N_4O_2$ +Na_2SO_4.

3.2 Density (ρ)

Density with concentration is represented graphically in Figure 2 and Table 2. The density of solution rises with concentration of $C_6H_{14}N_4O_2$ in Na_2SO_4, K_2SO_4 and $MgSO_4$ whereas decreases with rise in temperature. Volume decreases with increasing

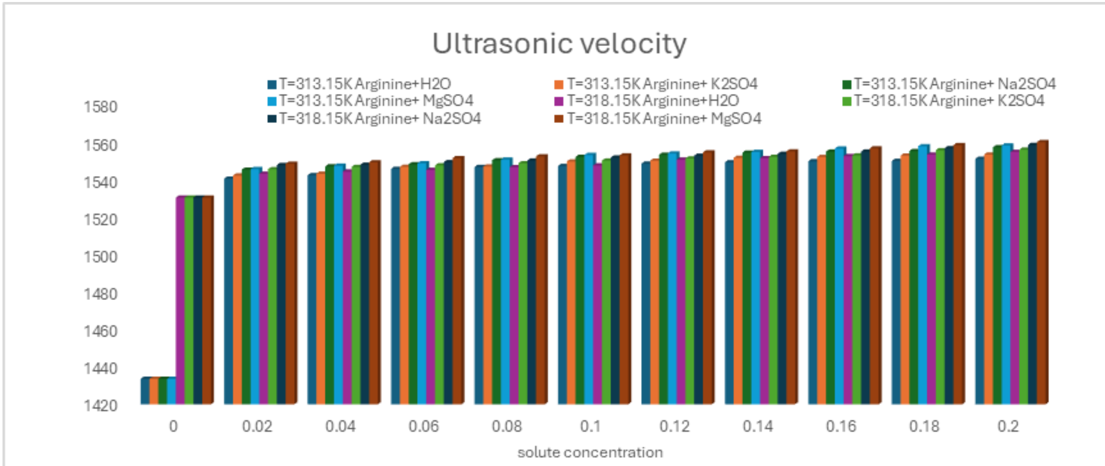

Fig 1. Variation in Ultrasonic velocity of Arginine saline salt solution of K_2SO_4, Na_2SO_4, $MgSO_4$

Table 1. Values of Ultrasonic velocity of Arginine with saline salt (Na_2SO_4, K_2SO_4, $MgSO_4$) at T=313.15K and T=318.15K

ULTRASONIC VELOCITY (U)(m/s)								
Concentration	**T=313.15K**				**T=318.15K**			
	Arginine + H_2O	**Arginine + K_2SO_4**	**Arginine + Na_2SO_4**	**Arginine + $MgSO_4$**	**Arginine + H_2O**	**Arginine + K $_2SO_4$**	**Arginine + Na_2SO_4**	**Arginine + $MgSO_4$**
0.00	1433.600	1433.600	1433.600	1433.600	1530.542	1530.542	1530.542	1530.542
0.02	1540.708	1542.354	1545.490	1545.818	1543.333	1545.732	1547.925	1548.671
0.04	1542.536	1543.304	1547.255	1547.588	1544.496	1546.946	1548.101	1549.448
0.06	1545.889	1546.998	1548.360	1548.893	1545.351	1547.818	1549.516	1551.690
0.08	1546.916	1547.205	1550.502	1550.907	1546.871	1548.926	1550.378	1552.622
0.1	1547.447	1549.893	1552.312	1553.343	1547.765	1550.345	1551.999	1553.089
0.12	1548.700	1550.320	1553.472	1554.162	1550.856	1551.470	1552.967	1554.761
0.14	1549.440	1551.803	1554.576	1554.962	1551.666	1552.334	1553.931	1555.251
0.16	1549.986	1552.265	1555.132	1556.772	1552.731	1553.095	1555.160	1556.861
0.18	1550.176	1553.033	1555.447	1557.998	1553.562	1555.896	1556.968	1558.580
0.2	1551.321	1553.540	1557.468	1558.436	1554.999	1556.190	1558.700	1560.221

density, suggesting that constituent molecules are associated. As a result of physical changes that show the molecules are closely packed together, the density increases. As a result, there is less compression in the liquid mixture.[15],[16],[17] The density (ρ) of the mixture drops as the temperature rises. When the temperature rises, the density (ρ) decreases. A higher temperature leads kinetic energy and volume expansion, which subsequently drives density to decrease. $C_6H_{14}N_4O_2$ +$MgSO_4$ molecules are more closely packed than $C_6H_{14}N_4O_2$ in Na_2SO_4, K_2SO_4. Therefore, the order of interaction is $C_6H_{14}N_4O_2$ +$MgSO_4$> $C_6H_{14}N_4O_2$ +Na_2SO_4 >$C_6H_{14}N_4O_2$ +K_2SO_4.

3.3 Acoustic impedance (Z)

The resistance a material offers to the transmission of ultrasonic waves is measured by its acoustic impedance (Z). As shown in Figure 3 and Table 3, the acoustic impedance values rise with Concentration of $C_6H_{14}N_4O_2$ in Na_2SO_4, K_2SO_4, $MgSO_4$ with rising temperature. Significant interaction between the component molecules is suggested by the rise in acoustic impedance with mixture composition. When sound pressure is present, sounds can pass through materials. A wave travels through a liquid due to an excess pressure because the atoms or molecules in the liquid are elastically bonded to one another. As the concentrations of $C_6H_{14}N_4O_2$ in saline salts rises, consequently increases the acoustic impedance. The lyophobic interaction between solute and solvent molecules occurs, which increases the intermolecular distance and creates a relatively larger gap between the molecules.[18] It is the basis for the rise in acoustic impedance with concentration. As compared to the other three systems,

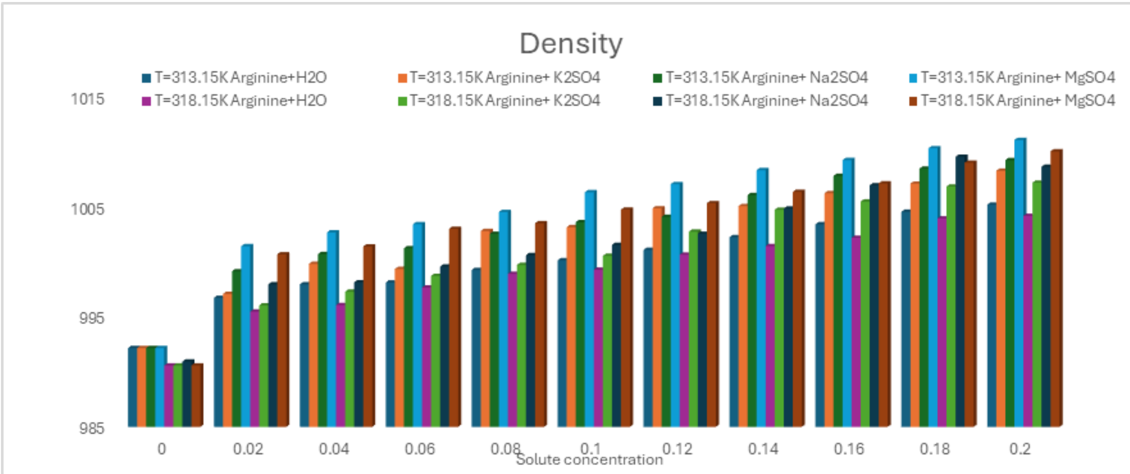

Fig 2. Variation in Density of Arginine saline salt solution of K_2SO_4, Na_2SO_4, $MgSO_4$

Table 2. Values of Density of Arginine with saline salt (Na_2SO_4, K_2SO_4, $MgSO_4$) at T=313.15K and T=318.15K

DENSITY (ρ)(kg/m^3)								
Concentration	**T=313.15K**				**T=318.15K**			
	Arginine + H_2O	**Arginine + K_2SO_4**	**Arginine + Na_2SO_4**	**Arginine + $MgSO_4$**	**Arginine + H_2O**	**Arginine + K_2SO_4**	**Arginine + Na_2SO_4**	**Arginine + $MgSO_4$**
0.00	992.150	992.150	992.150	992.150	990.573	990.573	990.932	990.573
0.02	996.708	997.060	999.121	1001.392	995.465	996.022	997.932	1000.657
0.04	997.936	999.795	1000.679	1002.643	996.054	997.263	998.115	1001.368
0.06	998.102	999.326	1001.203	1003.394	997.640	998.695	999.555	1002.973
0.08	999.234	1002.777	1002.516	1004.494	998.884	999.695	1000.578	1003.471
0.1	1000.120	1003.120	1003.576	1006.289	999.260	1000.519	1001.512	1004.715
0.12	1001.069	1004.833	1004.053	1007.029	1000.632	1002.712	1002.522	1005.297
0.14	1002.215	1005.036	1006.036	1008.301	1001.400	1004.703	1004.812	1006.329
0.16	1003.387	1006.202	1007.772	1009.217	1002.158	1005.447	1006.923	1007.092
0.18	1004.516	1007.069	1008.431	1010.282	1003.914	1006.811	1009.511	1008.973
0.2	1005.165	1008.238	1009.202	1011.032	1004.146	1007.157	1008.601	1010.002

the acoustic impedance of the $C_6H_{14}N_4O_2$ in $MgSO_4$ system is higher which suggests strong molecular association between solute-solvent molecules. Therefore, the order of association between solute-solvent is $C_6H_{14}N_4O_2$ +$MgSO_4$> $C_6H_{14}N_4O_2$ +Na_2SO_4 >$C_6H_{14}N_4O_2$ +K_2SO4.

3.4 Adiabatic Compressibility (β)

Adiabatic compressibility, essentially determines the orientation and intermolecular structure of constituent molecules, is crucial in the ultrasonic investigation of liquids and liquid mixtures. From Figure 4 and Table 4, The values of adiabatic compressibility reducing as the concentration of $C_6H_{14}N_4O_2$ in Na_2SO_4, K_2SO_4, and $MgSO_4$ increases, attributable to the electrostriction compression of the solute surrounding the molecule. When an ion enters the solvent environment, electrostrictive forces attract the bulk solvent towards the ion. Consequently, a reduced quantity of ions is accessible for the subsequent incoming ion, referred to as compression. Electrostrictive forces induce the dissociation of water molecules, hence diminishing compressibility and the compact arrangement of water molecules surrounding the solute. A reduction in adiabatic compressibility signifies significant solute-solvent interaction.[19],[11] the strong solute-solvent interaction is observed between $C_6H_{14}N_4O_2$ + $MgSO_4$ than $C_6H_{14}N_4O_2$+Na_2SO_4 and $C_6H_{14}N_4O_2$ +K_2SO_4. The solute-solvent interaction shows the order Therefore, the order of interaction is $C_6H_{14}N_4O_2$ +$MgSO_4$> $C_6H_{14}N_4O_2$ +Na_2SO_4 >$C_6H_{14}N_4O_2$ +K_2SO_4.

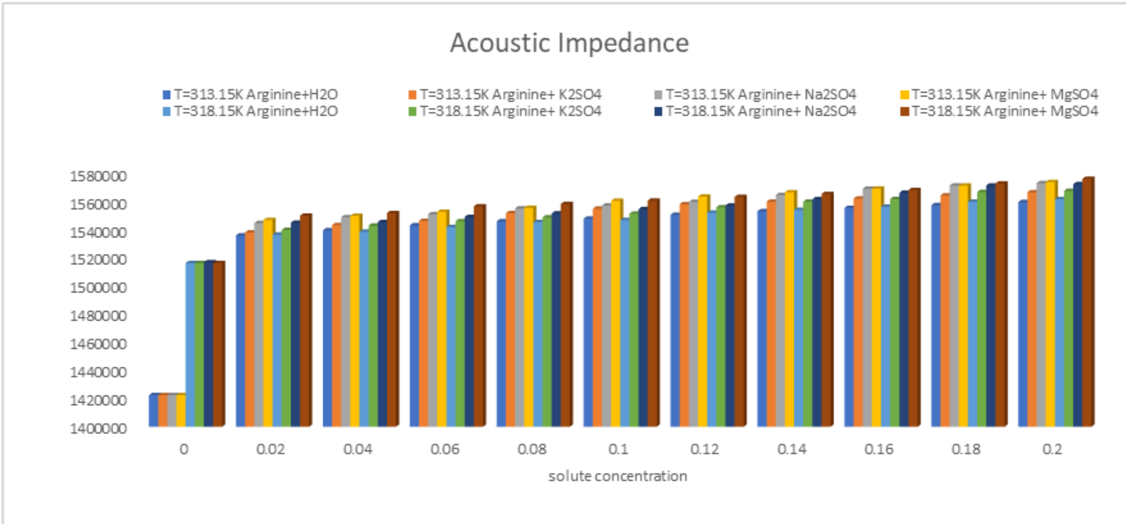

Fig 3. Variation in Acoustic Impedance of Arginine with saline salt solution of K_2SO_4, Na_2SO_4, $MgSO_4$

Table 3. Values of Acoustic impedance of Arginine with saline salt (Na_2SO_4, K_2SO_4, $MgSO_4$) at T=313.15K and T=318.15K

Acoustic impedance (Z)(Kgm^2s^{-1})								
Concentration	**T=313.15K**				**T=318.15K**			
	Arginine + H_2O	**Arginine + K_2SO_4**	**Arginine + Na_2SO_4**	**Arginine + $MgSO_4$**	**Arginine + H_2O**	**Arginine + K_2SO_4**	**Arginine + Na_2SO_4**	**Arginine + $MgSO_4$**
0.00	1422346	1422346	1422346	1422346	1516113	1516113	1516663	1516113
0.02	1535635	1537819	1544459	1546617	1536333	1539583	1544723	1549688
0.04	1539352	1542987	1548638	1549574	1538401	1542712	1545182	1551567
0.06	1542954	1545955	1550756	1552506	1541703	1545798	1548826	1556303
0.08	1545731	1551501	1554809	1555318	1545144	1548453	1551274	1558011
0.1	1547632	1554728	1556890	1560253	1546619	1551149	1554345	1560411
0.12	1550355	1557812	1559456	1563223	1551836	1555677	1556883	1562996
0.14	1552872	1559617	1564347	1566367	1553838	1559634	1561408	1565094
0.16	1555235	1561892	1568871	1568904	1556081	1561554	1565926	1567902
0.18	1557176	1564011	1571133	1571121	1559642	1566493	1571069	1572565
0.2	1559333	1566338	1572776	1573617	1561446	1567327	1572106	1575826

3.5 Molar Compressibility or Wada Constant (W)

Some percentage of free space always exists between liquid molecules since they are not densely packed. The Wada constant varies with temperature, as seen in Figure 5 and Table 5, which also indicates that as the temperature rises, the distance between solute solvent molecules decreases as they approach one another. This supports the strong solute-solvent interaction occurs in liquid solutions. It was reported that if the variation in Wada's Constant is linear, then it shows that there is an absence of complex formation in the mixture and so is found in the present investigation which means that there is no complex formation in the mixture.[(12)],[(20)] In Table 6 we observed that the Wada constant for $C_6H_{14}N_4O_2$ in Na_2SO_4, K_2SO_4, $MgSO_4$ systems is rises with solute concentration and temperature. The strong solute- solvent interaction is observed between $C_6H_{14}N_4O_2$ + $MgSO_4$ than $C_6H_{14}N_4O_2$ + Na_2SO_4 & $C_6H_{14}N_4O_2$ + K_2SO_4.

3.6 Non-linearity parameter (B/A)

Non-linear parameter (B/A) obtain by Hartmann-Balizer is related to the internal pressure, hardness, intermolecular potential, molecular structure and molecular interaction of liquid.[(21)]Figure 6 and Table 6 show the non-linearity parameter for both the systems as a function of concentration at 323.15K and 328.15K temperature. The decreasing trends of this parameter

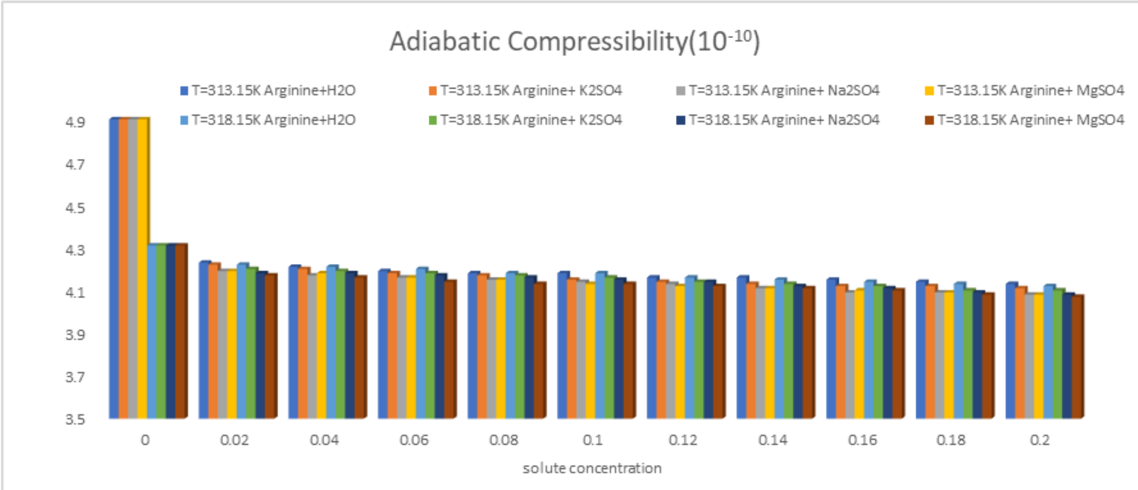

Fig 4. Variation in Adiabatic compressibility of Arginine with saline salt solution of K_2SO_4, Na_2SO_4, $MgSO_4$

Table 4. Values of Adiabatic Compressibility of Arginine with saline salt (Na_2SO_4, K_2SO_4, $MgSO_4$) at T=313.15K and T=318.15K

Adiabatic Compressibility (β)(M^2N^{-1})(E-10)								
Concentration	T=313.15K				T=318.15K			
	Arginine + H_2O	Arginine + K_2SO_4	Arginine + Na_2SO_4	Arginine + $MgSO_4$	Arginine + H_2O	Arginine + K_2SO_4	Arginine + Na_2SO_4	Arginine + $MgSO_4$
0.00	4.90	4.90	4.90	4.90	4.31	4.31	4.31	4.31
0.02	4.23	4.22	4.19	4.19	4.22	4.20	4.18	4.17
0.04	4.21	4.20	4.17	4.18	4.21	4.19	4.18	4.16
0.06	4.19	4.18	4.16	4.16	4.20	4.18	4.17	4.14
0.08	4.18	4.17	4.15	4.15	4.18	4.17	4.16	4.13
0.1	4.18	4.15	4.14	4.13	4.18	4.16	4.15	4.13
0.12	4.16	4.14	4.13	4.12	4.16	4.14	4.14	4.12
0.14	4.16	4.13	4.11	4.11	4.15	4.13	4.12	4.11
0.16	4.15	4.12	4.09	4.10	4.14	4.12	4.11	4.10
0.18	4.14	4.12	4.09	4.09	4.13	4.10	4.09	4.08
0.2	4.13	4.11	4.08	4.08	4.12	4.10	4.08	4.07

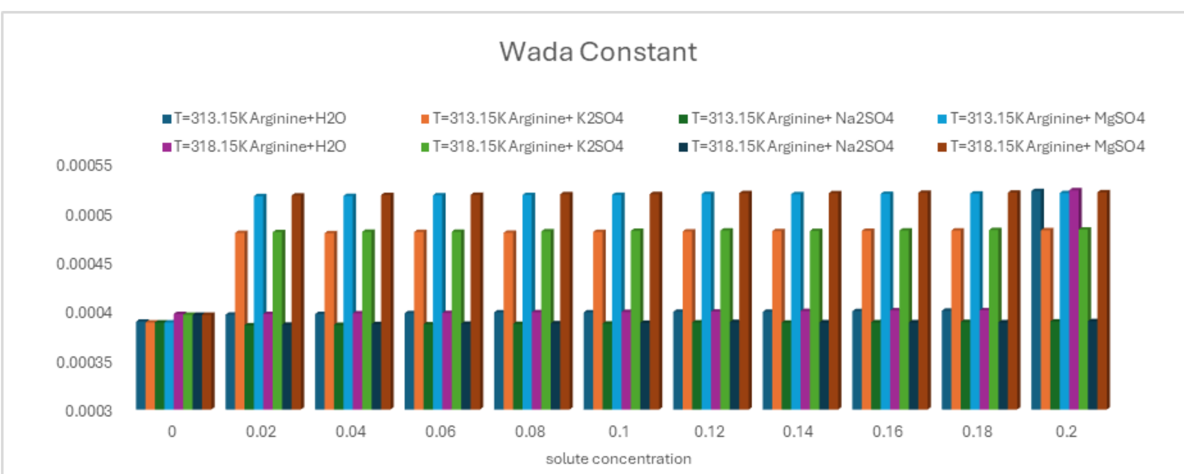

Fig 5. Variation in molar compressibility or wada constant of Arginine with saline salt solution of K_2SO_4, Na_2SO_4, $MgSO_4$

Table 5. Values of molar compressibility or Wada Constant of Arginine with saline salt (Na_2SO_4, K_2SO_4, $MgSO_4$) at T=313.15K and T=318.15K

Wada Constant (W)($m^3 mole^{-1}$)(ms^{-1})$^{-1/7}$								
Concentration	T=313.15K				T=318.15K			
	Arginine + H_2O	Arginine + K_2SO_4	Arginine + Na_2SO_4	Arginine + $MgSO_4$	Arginine + H_2O	Arginine + K_2SO_4	Arginine + Na_2SO_4	Arginine + $MgSO_4$
0.00	0.0003890	0.0003882	0.0003882	0.0003882	0.0003968	0.0003960	0.0003959	0.0003960
0.02	0.0003961	0.0004789	0.0003853	0.0005161	0.0003968	0.0004797	0.0003859	0.0005168
0.04	0.0003967	0.0004786	0.0003857	0.0005163	0.0003974	0.0004800	0.0003866	0.0005173
0.06	0.0003976	0.0004798	0.0003863	0.0005170	0.0003977	0.0004801	0.0003869	0.0005175
0.08	0.0003984	0.0004791	0.0003867	0.0005173	0.0003986	0.0004805	0.0003873	0.0005181
0.1	0.0003984	0.0004799	0.0003871	0.0005174	0.0003988	0.0004810	0.0003878	0.0005182
0.12	0.0003990	0.0004804	0.0003882	0.0005183	0.0003992	0.0004814	0.0003886	0.0005192
0.14	0.0003990	0.0004807	0.0003880	0.0005181	0.0003998	0.0004809	0.0003883	0.0005191
0.16	0.0003997	0.0004810	0.0003883	0.0005185	0.0004004	0.0004814	0.0003883	0.0005196
0.18	0.0004001	0.0004813	0.0003887	0.0005188	0.0004005	0.0004818	0.0003883	0.0005197
0.2	0.0005214	0.0004816	0.0003892	0.0005193	0.0005221	0.0004823	0.0003895	0.0005200

exhibits the interaction between the components of solute and solvent is stronger at higher concentration. The nonlinearity parameter for solutions decreases with increase in concentration of solute molecules of $C_6H_{14}N_4O_2$. Decrease in non-linearity parameter suggests solute solvent interaction occurs in constituent molecules. The strength of interaction is stronger in $C_6H_{14}N_4O_2$+$MgSO_4$ than $C_6H_{14}N_4O_2$ +Na_2SO_4 and $C_6H_{14}N_4O_2$+ K_2SO_4. The order for strength of interaction between constituent molecules is Therefore, the order of interaction is $C_6H_{14}N_4O_2$ +$MgSO_4$> $C_6H_{14}N_4O_2$ +Na_2SO_4 >$C_6H_{14}N_4O_2$ +K_2SO_4.

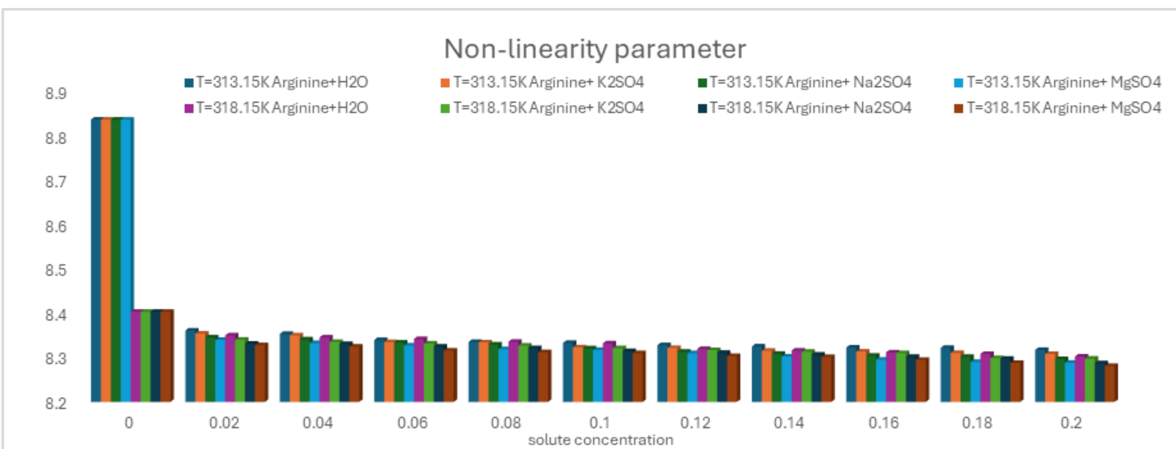

Fig 6. Variation in Non-linearity parameter of Arginine with saline salt solution of K_2SO_4, Na_2SO_4, $MgSO_4$

3.7 Specific Heat Ratio

The variation specific heat ratio of $C_6H_{14}N_4O_2$ +Na_2SO_4 and $C_6H_{14}N_4O_2$+Na_2SO_4 is shown in Figure 7 and Table 7. The specific heat ratio decreases with increase in solute ($C_6H_{14}N_4O_2$) concentration and temperature. Decrease in specific heat ratio lowers the transfer of heat hence thermal conductivity reduces.[22] The reduction in thermal conductivity is higher in $C_6H_{14}N_4O_2$+$MgSO_4$ than $C_6H_{14}N_4O_2$ +Na_2SO_4 than $C_6H_{14}N_4O_2$ +K_2SO_4.

Table 6. Values of non- linearity parameter of Arginine with saline salt (Na_2SO_4, K_2SO_4, $MgSO_4$) at T=313.15K and T=318.15K

Non-Linearity Parameter (B/A) ($m^{-1}s$)								
	T=313.15K				T=318.15K			
Concentration	Arginine + H_2O	Arginine + K_2SO_4	Arginine + Na_2SO_4	Arginine + $MgSO_4$	Arginine + H_2O	Arginine + K_2SO_4	Arginine + Na_2SO_4	Arginine + $MgSO_4$
0.00	8.8359375	8.8359375	8.8359375	8.8359375	8.4029605	8.4029605	8.4029605	8.4029605
0.02	8.3607121	8.3539239	8.3452272	8.3396855	8.3498934	8.3400382	8.3310561	8.3280064
0.04	8.3531743	8.3500127	8.3410310	8.3324347	8.3451119	8.3350628	8.3303363	8.3248331
0.06	8.3393944	8.3348498	8.3337976	8.3270994	8.3416014	8.3314938	8.3245555	8.3156945
0.08	8.3351856	8.3340023	8.3292774	8.3188831	8.3353699	8.3269646	8.3210391	8.3119033
0.1	8.3330117	8.3230171	8.3205336	8.3171072	8.3317106	8.3211737	8.3144371	8.3100054
0.12	8.3278879	8.3212756	8.3131638	8.3097088	8.3190909	8.3165901	8.3105011	8.3032196
0.14	8.3248658	8.3152346	8.3084497	8.3024048	8.3157922	8.3130744	8.3065863	8.3012337
0.16	8.3226378	8.3133551	8.3039697	8.2950772	8.3114603	8.3099810	8.3016024	8.2947174
0.18	8.3218628	8.3102329	8.3017159	8.2901236	8.3080843	8.2986215	8.2971159	8.2877748
0.2	8.3171968	8.3081736	8.2963917	8.2883558	8.3022549	8.2974315	8.2872907	8.2811615

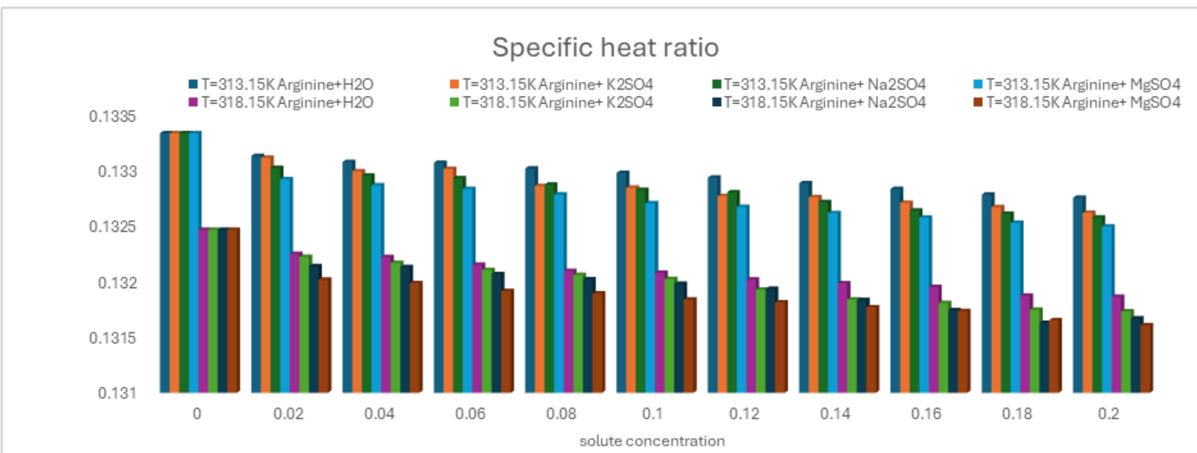

Fig 7. Variation in Specific heat ratio of Arginine with saline salt solution of K_2SO_4, Na_2SO_4, $MgSO_4$

Table 7. Values of Specific heat ratio of Arginine with saline salt (Na_2SO_4, K_2SO_4, $MgSO_4$) at T=313.15K and T=318.15K

Specific Heat Ratio (γ)$(K^{\frac{4}{9}})^{-1}\left(Kg^{\frac{1}{3}}m^{-1}\right)^{-1}$								
	T=313.15K				T=318.15K			
Concentration	Arginine + H_2O	Arginine + K_2SO_4	Arginine + Na_2SO_4	Arginine + $MgSO_4$	Arginine + H_2O	Arginine + K_2SO_4	Arginine + Na_2SO_4	Arginine + $MgSO_4$
0.00	0.1333256	0.1333256	0.1333256	0.1333256	0.1324605	0.1324605	0.1324605	0.1324605
0.02	0.1331221	0.1331064	0.1330148	0.1329142	0.1322431	0.1322185	0.1321341	0.1320140
0.04	0.1330674	0.1329849	0.1329457	0.1328589	0.1322171	0.1321636	0.1321260	0.1319828
0.06	0.1330600	0.1330057	0.1329225	0.1328257	0.1321469	0.1321004	0.1320625	0.1319123
0.08	0.1330098	0.1328529	0.1328645	0.1327772	0.1320921	0.1320563	0.1320175	0.1318905
0.1	0.1329705	0.1328378	0.1328177	0.1326982	0.1320755	0.1320201	0.1319764	0.1318360
0.12	0.1329285	0.1327623	0.1327966	0.1326657	0.1320151	0.1319238	0.1319321	0.1318106
0.14	0.1328778	0.1327533	0.1327093	0.1326099	0.1319813	0.1318366	0.1318318	0.1317655
0.16	0.1328260	0.1327020	0.1326331	0.1325698	0.1319481	0.1318040	0.1317396	0.1317322
0.18	0.1327762	0.1326639	0.1326042	0.1325232	0.1318711	0.1317445	0.1316269	0.1316503
0.2	0.1327477	0.1326127	0.1325704	0.1324904	0.1318609	0.1317294	0.1316665	0.1316056

3.8 Free length (L_f)

A vital physical characteristic of a liquid that relates the strength of interaction with density and sound speed is the intermolecular free length. It is the separation between the surfaces of molecules that are nearest to their neighbour in a liquid. The study of free length is useful to understand intermolecular interactions. Free length is depending upon adiabatic compressibility. When the value of free length is long then free volume is large and decreasing the free available space.[(23)],[(24)] from Figure 8 and Table 8, The decrease in free length with increasing solute ($C_6H_{14}N_4O_2$) concentration and temperature indicates significant intermolecular interactions among the constituent molecules. It facilitates structural behaviour, compact packing, and enhanced interaction among different molecules through hydrogen bonding. we conclude that the free length reductions with an increase in temperature and solute concentration ($C_6H_{14}N_4O_2$) indicative of close packing of molecules. The Free length for $C_6H_{14}N_4O_2$ is lower magnesium sulphate suggests stronger interaction between Arginine in saline salt solution. Therefore, the free length or separation in the surfaces of neighbour is in order of the order of interaction is $C_6H_{14}N_4O_2$ +$MgSO_4$> $C_6H_{14}N_4O_2$ +Na_2SO_4 >$C_6H_{14}N_4O_2$ +K_2SO_4.

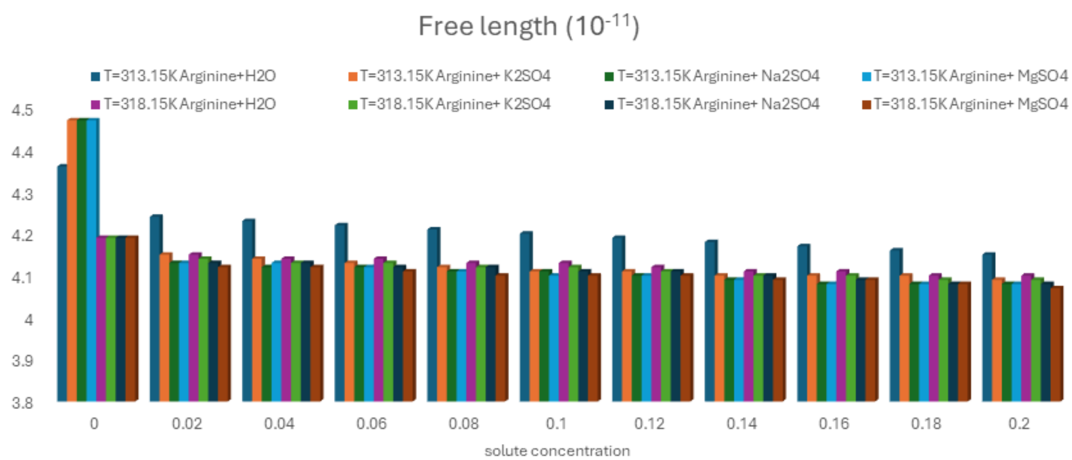

Fig 8. Variation in intermolecular free length of Arginine with saline salt solution of K_2SO_4, Na_2SO_4, $MgSO_4$

Table 8. Values of intermolecular free length of Arginine with saline salt (Na2SO4, K_2SO_4, $MgSO_4$) at T=313.15K and T=318.15K

Intermolecular Free length (E*-11)(L_f) (m)								
Concentration	T=313.15K				T=318.15K			
	Arginine + H_2O	Arginine + K_2SO_4	Arginine + Na_2SO_4	Arginine + $MgSO_4$	Arginine + H_2O	Arginine + K_2SO_4	Arginine + Na_2SO_4	Arginine + $MgSO_4$
0.00	4.36	4.47	4.47	4.47	4.19	4.19	4.19	4.19
0.02	4.24	4.15	4.13	4.13	4.15	4.14	4.13	4.12
0.04	4.23	4.14	4.12	4.13	4.14	4.13	4.13	4.12
0.06	4.22	4.13	4.12	4.12	4.14	4.13	4.12	4.11
0.08	4.21	4.12	4.11	4.11	4.13	4.12	4.12	4.10
0.1	4.20	4.11	4.11	4.10	4.13	4.12	4.11	4.10
0.12	4.19	4.11	4.10	4.10	4.12	4.11	4.11	4.10
0.14	4.18	4.10	4.09	4.09	4.11	4.10	4.10	4.09
0.16	4.17	4.10	4.08	4.08	4.11	4.10	4.09	4.09
0.18	4.16	4.10	4.08	4.08	4.10	4.09	4.08	4.08
0.2	4.15	4.09	4.08	4.08	4.10	4.09	4.08	4.07

4 Conclusion

- The rise in ultrasonic velocity suggests there is larger ion –dipole interaction between $C_6H_{14}N_4O_2$ +$MgSO_4$ than $C_6H_{14}N_4O_2$ +Na_2SO_4 and $C_6H_{14}N_4O_2$+K_2SO_4. It conforms stronger interaction between Arginine and magnesium sulphate. Volume decreases with increasing density, suggesting association between constituent molecules solution.

- The increasing trend of acoustic impedance indicates an effective molecular interaction between solute and solvent molecules. Higher values of n indicate a stronger influence of attractive forces over repulsive forces. The attractive force is greater for Arginine in a magnesium sulphate solution.
- The linear increase of the Wada constant indicates significant solute-solvent interactions in liquid solutions. It indicates there is no evidence of complex formation in the mixture.
- The reduction in the Non-linearity parameter indicates that the solute-solvent interaction intensity is greater in the Arginine and magnesium sulphate system.
- When the free length is extensive, the free volume is substantial, resulting in a reduction of the available space and adiabatic compressibility. The declining trend of free length and adiabatic compressibility reinforces structural enhancing behaviour, compact packing, and enhanced association among different molecules due to hydrogen bonding.
- The application of chemical fertilizers adversely affects the physical properties of soil. The application of amino acids in place of harmful fertilizers is sustainable. As a fundamental component of protein, it cannot disrupt the natural balance of soil. The ultrasonic approach is non-destructive, which allows it to determine the type of interaction with greater precision. The degree of interaction is higher for Arginine with magnesium sulphate. therefore, Arginine is more effective on magnesium sulphate saline salt. It may improve physical properties of saline soil.

References

1) Khasanov S, Kulmatov R, Fadong L, van AA, Bartholomeus H, Ilhomjon A, et al. Impact assessment of soil salinity on crop production in Uzbekistan and its global significance. *Agriculture, Ecosystems & Environment*. 2023;342:108262. https://doi.org/10.1016/j.agee.2022.108262.
2) Wang T, Liu Q, Wang N, Dai J, Lu Q, Jia X, et al. Foliar arginine application improves tomato plant growth, yield, and fruit quality via nitrogen accumulation. *Plant Growth Regulation*. 2021;95:421–428. http://dx.doi.org/10.21203/rs.3.rs-634304/v1.
3) Eisenhauer N, Bender SF, Calderón-Sanou I, de Vries FT, Lembrechts JJ, Thuiller W, et al. Frontiers in soil ecology—Insights from the World Biodiversity Forum. *Journal of Sustainable Agriculture and Environment*. 2022;1(4):245–261. https://doi.org/10.1002/sae2.12031.
4) Khalid M, Rehman HM, Nisar A, Sehar N, Saleem F, Ahmad S, et al. Using Exogenous Melatonin, Glutathione, Proline, and Glycine Betaine Treatments to Combat Abiotic Stresses in Crops. *International Journal of Molecular Sciences*. 2022;23(21). https://doi.org/10.3390/ijms232112913.
5) Guo N, Zhang S, Gu M, Xu G. Function, transport, and regulation of amino acids: What is missing in rice? *The Crop Journal*. 2021;9(3):530–542. https://doi.org/10.1016/j.cj.2021.04.002.
6) Trovato M, Funck D, Forlani G, Okumoto S, Amir R. Editorial: Amino Acids in Plants: Regulation and Functions in Development and Stress Defense. *Frontiers in Plant Science*. 2021;12:772810. https://doi.org/10.3389/fpls.2021.772810.
7) Kawade K, Tabeta H, Ferjani MYHA. The Roles of Functional Amino Acids in Plant Growth and Development. *Plant and Cell Physiology*. 2023;64(12). https://doi.org/10.1093/pcp/pcad071.
8) Freitas IS, Trennepohl BI, Acioly TMS, Conceição VJ, Mello SC, Neto DD, et al. Exogenous Application of L-Arginine Improves Protein Content and Increases Yield of Pereskia aculeata Mill. Grown in Soilless Media Container. *Horticulturae*. 2022;8:142. https://doi.org/10.3390/horticulturae8020142.
9) Kensuke K, Gorou H, Yuu H, Akira O, Masami YH, Kazuki S, et al. Metabolic Control of Gametophore Shoot Formation through Arginine in the Moss Physcomitrium patens. *Cell Reports*. 2020;32(10):108127. https://doi.org/10.1016/j.celrep.2020.108127.
10) Medan RA, Al-Douri EFS. Effect of Foliar Application of Sitofex, Potassium and Arginine on Vegetative Growth of "Zaghinia" Apricot Trees. *IOP Conference Series: Earth and Environmental Science*. 2021;761:012053. http://dx.doi.org/10.1088/1755-1315/761/1/012053.
11) Stepanov VP. Ultrasonic Study of the Adiabatic Compressibility of Binary Molten Mixtures of Cesium Halides. *Russian Journal of Physical Chemistry A*. 2019;93:799–803. http://dx.doi.org/10.1134/S0036024419050297.
12) Lamba M, Bhakri K, Chakraborty N, Juglan K. Ultrasonic and volumetric investigation of aqueous disodium EDTA with PEG 400 and PEG 4000 at different temperatures. *Physica Scripta*. 2024. http://dx.doi.org/10.1088/1402-4896/ad73bc.
13) Naveen A. Prediction of molecular interactions based on theoretical evaluation of ultrasonic velocity and excess acoustical parameters from 288.15–318.15K. *International Journal of Engineering Applied Sciences and Technology*. 2022;7. Available from: https://www.researchgate.net/publication/363841993.
14) Geetha R, Padmavathy R, Muhamed RR. Molecular interactions in ternary system of K-contin and (2-Aminoacetamido)acetic acid at various temperatures – ultrasonic and viscometric analysis. *SN Applied Sciences*. 2023;5:383. http://dx.doi.org/10.1007/s42452-023-05597-0.
15) Hema, Bhatt T. Comparative thermo-acoustic study of ternary mixture of polar and nonpolar solvents with benzene and ethanol system. *SN Applied Sciences*. 2020;2(1). http://dx.doi.org/10.1007/s42452-019-1777-5.
16) Juglan KC, Kumar H, Chakraborty N. Study of thermodynamic and acoustic properties of niacin in aqueous hexylene glycol and propylene glycol at different temperatures. *ACS Omega*. 2020;5(50):32357–32365. https://doi.org/10.1021/acsomega.0c04292.
17) Kumari L, Hussain A, Agarwal H, Mishra A, Gautam R, Singh R, et al. A Thermoacoustical and DFT Exploration of Physio-Chemical Properties for N, N-dimethylacetamide (DMA) with Water. *Oriental Journal Of Chemistry*. 2023;40(2). http://dx.doi.org//10.13005/ojc/400209.
18) Juglan KC, Kumar H, Chakraborty N. Study of thermodynamic and acoustic properties of niacin in aqueous hexylene glycol and propylene glycol at different temperatures. *ACS Omega*. 2020;5(50):32357–32365. https://doi.org/10.1021/acsomega.0c04292.

19) Arya P, Bhatt T, Arya HC, C, Rana M. Study of Molecular Interaction in Ternary Liquid Mixture of Toluene + 1,4-Dioxane + 1-Propanol. *Chemistry Africa*. 2023;7. http://dx.doi.org/10.1007/s42250-023-00779-0.
20) Mishra PL, Ajay B, Lad AB, Manik UP. A Volumetric and Acoustical Study to Explore Interactions between Saline Salts and Fertilizer in View to Control the Salinity of Soil. *Journal of Scientific Research*. 2021;65(6). http://dx.doi.org/10.37398/JSR.2021.650610.
21) Dubey GP, Seema R. Thermodynamic, acoustic and spectroscopic studies in binary liquid mixtures containing amine and alcohol. *Physics and Chemistry of Liquids*. 2021;59(2). https://doi.org/10.1080/00319104.2020.1731810.
22) Hepat SV, Manik UP. The salinity management of saline soil by ultrasonic characterization of Arginine with saline salt. *Materials Today: Proceedings*. 2023. https://doi.org/10.1016/j.matpr.2023.11.110.
23) Sharma DK, Agarwal S, Khan A. Intermolecular Free Length and Molar Volume of Binary Liquid Mixtures of Ethyl Acetate with 1-Alkanol At 303.15K. *Der Pharma Chemica*. 2022;14(10):1–9. https://doi.org/10.4172/0975-413X.14.10.1-9.
24) Dwivedi S. Study of Acoustical and Physico-chemical Properties for the Ternary Mixture of (Toluene + Chlorobenzene + Cyclohexane) at 298.15 K Temperature. *Journal of Ultra Chemistry*. 2021;17(2):9–15. http://dx.doi.org/10.22147/juc/170201.