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Research Article

Comparative effect of sucrose, fructose and glucose concentrations on the survival rate of tomato (*Solanum lycopersicum l.*) in tissue culture

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Abstract: Tomato (*Solanum lycopersicum L.*) is a globally important horticultural crop. Its efficient micro-propagation is critical for sustainable production, especially in tropical regions prone to biotic and abiotic stresses. This study investigated the influence of three exogenous sugars; sucrose, glucose and fructose applied at varying concentrations (0, 10, 20, 30 and 40 g/L) on the survival and developmental performance of two tomato varieties (Rio Grande and UC-82B) under in vitro conditions. Seeds were cultured on Murashige and Skoog medium supplemented with each sugar type and data on seedling survival, shoot number, shoot length, leaf count, node formation and root development were recorded over a 40–60 period. Results indicated that low concentrations (0–10 g/L) of sucrose and glucose significantly improved survival and shoot proliferation, with Rio Grande exhibiting superior performance across all treatments. However, high concentrations (≥30 g/L) significantly reduced survival rates and morphological vigor, suggesting the onset of osmotic or metabolic stress. Fructose-treated seedlings consistently showed the lowest survival responses in all concentrations. The best results came from low sucrose concentrations, particularly in the Rio Grande variety, supporting propagation use. These findings contribute to refining tomato micro-propagation protocols and provide a foundation for advancing crop regeneration technologies in Africa.

Keywords: Tomato micro-propagation, sugar concentration, genotype response, in vitro culture

1. Introduction

Tomato (*Solanum lycopersicum l.*) remains a crop of paramount importance across global agricultural landscapes, appreciated for both its economic value and rich nutritional profile. In tropical regions, it is one of the top three most cultivated vegetable crops globally (Junaid et al., 2020). Tomato is a key dietary component, contributing essential micronutrients such as lycopene, vitamin C, folate and potassium, with fruit phenotypes varying from red to orange, yellow, green and purple, depending on genotype and maturity stage (Moghimi et al., 2023). However, tomato productivity is often constrained by biotic stresses, particularly bacterial diseases, while fungal pathogens receive comparatively less research attention (Aliyu et al., 2021). In the pursuit of improved regeneration and crop enhancement, plant tissue culture techniques have become invaluable, especially in species like tomato that offer both commercial and genetic amenability. Since its earliest development, in vitro propagation has evolved to include callus induction, shoot organogenesis and somatic embryogenesis. Recent studies have demonstrated successful regeneration from diverse explants including hypocotyls, leaves, cotyledons and inflorescence tissues, with efficiency influenced by cultivar, explant source and media composition (Yadav et al., 2019; Mohammadi et al., 2020).

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The type of carbohydrate incorporated into the culture medium plays a critical role in influencing in vitro plant growth and development. In conditions where photosynthesis is limited or inhibited, sugars serve as vital sources of energy and structural carbon. Sucrose has traditionally been the preferred choice due to its physiological relevance and metabolizable nature. However, newer findings have shown that glucose and fructose can also support tissue development, though responses may vary across species and genotypes (Oyekale & Adegbite, 2016; Teymouri et al., 2023). The concentration of sugar is critical; low levels may inhibit energy supply, while excessive concentrations risk osmotic stress and metabolic imbalance. Optimal ranges are commonly reported between 20–30 g/L, though genotype-dependent variability exists (Hamed et al., 2021).

Given the high energy demand associated with shoot and root formation, understanding the role of different sugars and concentration in tomato tissue culture is essential for optimizing propagation protocols. While sucrose has been widely used, its ideal concentration for specific cultivars remains unclear. Moreover, comparative evaluation of glucose and fructose may reveal alternative carbohydrate strategies to enhance regeneration. Therefore, this study investigates the effects of sucrose, glucose, and fructose at varying concentrations on the in vitro performance of two tomato varieties. The goal is to determine which sugar type is most efficiently utilized during early growth and to establish the optimal concentration for promoting survival, shoot proliferation, and root development.

2. Materials and methods

2.1. Study area

The research was conducted at the Biotechnology Laboratory of the Department of Agronomy, University of Ibadan, located at approximately 7.3912° N latitude and 3.9167° E longitude in Ibadan, Oyo State, Nigeria.

2.2. Collection of seed

Seeds of two different tomato varieties (Rio Grande and UC-82B) were obtained from an Agro-allied store in the Bodija district of Ibadan, Oyo State, South-Western Nigeria, for the study. The disease-free seeds are suitable for use in both the field and the laboratory.

2.3. Materials for study

These include the laboratory coat, hand gloves, aluminum foil paper, cotton wool, distilled water, ethanol, permanent markers, measuring cylinder, Myo-inositol, syringe, electric weighing balance, microwave oven, weighing boats, spatula, magnetic stirrer, autoclave, laminar airflow hood, growth room and cupboards, pH meter, pipettes, light bulbs, laboratory trolley, beakers, measuring cylinder, sterile scalpel, sterile surgical blades, scissors, alcohol lamp, forceps, scalpel holder, spray bottle, paper tape, detergent, test tubes, masking tape, agar, sucrose, fructose, glucose, Murashige and Skoog(MS).

2.4. Germination test

The seeds of tomato were tested for germination to determine their viability level. This was done by placing the seeds on a cotton wool soaked with purified water inside a sterilized Petri dish.

2.5. Growth room conditions

The explants of tomato were cultured in a growth room with a temperature of $25^{o}C \pm 2^{o}C$ and maintained at 85% relative humidity under 16 hours light /8 hours dark photoperiod and a light intensity of 25umols-1m-1 provided by white fluorescent bulbs.

2.6. In Vitro culture technique

2.6.1. Sterilization of Equipment and Glass wares

All operations concerning in vitro cultures were carried out inside a laminar air flow cabinet under aseptic conditions. All equipment; glass materials and chemicals were sterilized before use. A horizontal laminar flow cabinet with High Efficiency Particulate Arrestance (HEPA) filter was used for the in vitro culture operations. The cabinet surface was wiped clean with a paper towel and soaked with 70% ethanol. All the surgical instruments, glass wares and other smaller tools were sterilized in an autoclave at 121°C and 15 psi for 30 minutes and dried in the oven. Surgical instruments such as scalpel, forceps and scissors were frequently sterilized during operations by dipping in the sterilizer and allowed to cool prior to use.

2.6.2. Preparation of culture media and stock solution

The culture media consist of Murashige and Skoog (MS) (Murashige and Skoog, 1962) inorganic salts, organic supplement such as sucrose, Myo-inositol and agar, stock solution of kinetin(1mg/L) were prepared by weighing 0.1g of kinetin and dissolving in 1M KOH before bringing to final volume (100 ml) with distilled water and stored in refrigerator after use. The pH of the culture media was adjusted after preparation to 5.7± 0.1 before sterilization in the autoclave at 121°C and 15 psi for 15 minutes.

2.7. Experimental design

The experiment followed a 2 × 5 factorial arrangement in a Completely Randomized Design (CRD), consisting of two tomato varieties (UC-82B and Rio Grande) and five sugar concentration levels (0, 10, 20, 30, and 40 g/L) for each sugar type—sucrose, fructose, and glucose—with three replications per treatment.

2.8. Data collection

Data collected include the percentage number of plants that survive, number of shoots, shoot length, number of roots, number of leaves, and number of nodes. All data were collected after 40 - 60 days of culture.

2.9. Data analysis

The experimental data obtained from tomato explants subjected to varying concentration were organized and analyzed using descriptive and inferential statistics methods data from the experiment and were subjected to the analysis of variance (ANOVA) using GENSTAT statistical package.

3. Results and discussion

Figure 1 shows that both Rio Grande and UC-82B cultivars exhibited comparable survival rates two weeks after planting. Although Rio Grande recorded a slightly higher percentage, the difference was not significant. This implies that genotypic variation did not influence seedling establishment under the prevailing conditions. Environmental factors are often more influential than genetic differences in early seedling survival, as reported by Osei et al. (2016). Similarly, Balraj et al. (2013) reported that minor differences in seedling vigor among tomato varieties may not necessarily lead to significant survival advantages during the initial growth stage.

As shown in Figure 2, the impact of sucrose, glucose and fructose on the survival of tomato seedlings two weeks after planting. Seedlings treated with sucrose had the highest survival rate of 22%, demonstrating better effectiveness than those treated with glucose 15% and fructose 14%. The pronounced effect of sucrose suggests its potential to enhance early seedling vigor and stress resilience, possibly due to its dual role in energy metabolism and osmotic regulation during early growth. These results align with earlier findings that recognize sucrose as a key signal molecule in plant development and stress response (Ruan et al., 2010). Additionally, its role in promoting root growth and seedling establishment under variable environmental conditions has been emphasized in studies on sugar-mediated physiological processes (Smeekens et al., 2010).

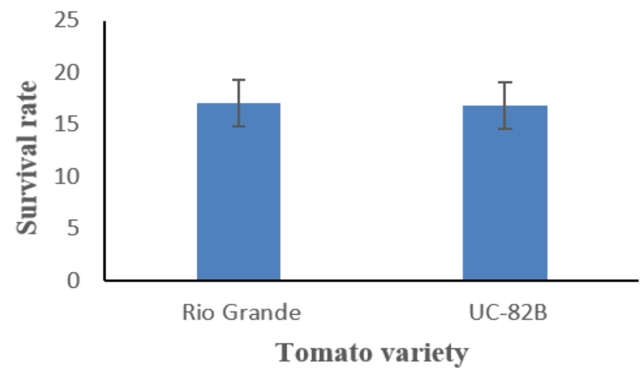


Fig. 1: Survival rate of tomato variety at 2 weeks after planting

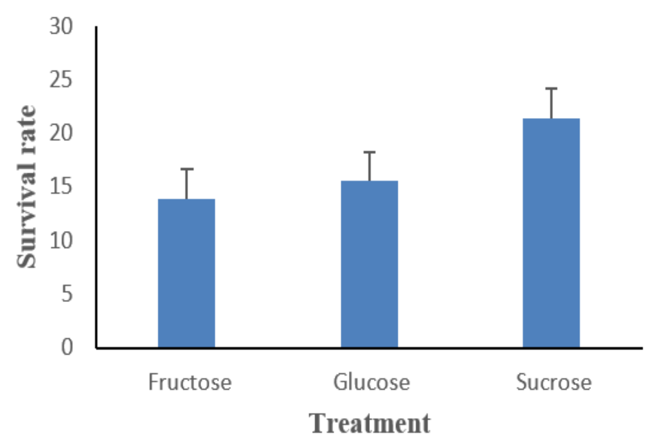
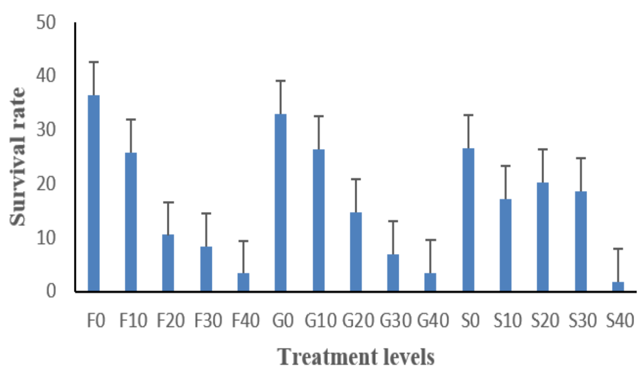


Fig. 2: Effect of treatment on survival rate of tomato at 2 weeks after planting

Figure 3 shows the survival of *Solanum lycopersicum L* (tomato) seedlings in response to increasing concentrations (0%, 10%, 20%, 30% and 40%) of fructose, glucose and sucrose measured two weeks after planting. Across all sugar types, the untreated controls (0%) had the highest survival rate consistently above 30% and significantly higher ($p < 0.01$) than seedlings exposed to higher sugar concentrations. Treatments with 40% fructose and 40% sucrose resulted in near-zero survival and significantly lower ($p < 0.001$) than all other concentrations, indicating that higher sugar levels may exert phytotoxic effects or induce osmotic stress detrimental to seedling viability.

This aligns with findings from Ogunsola and Ogunsola (2021), who reported that abiotic stressors such as osmotic imbalance and excessive solute accumulation significantly impair tomato seedling establishment in West African climates. Similarly, Esan et al. (2020) demonstrated that salt-induced osmotic stress in Nigerian tomato genotypes led to reduced photosynthetic pigments and increased oxidative damage, showing the sensitivity of tomato seedlings to solute-induced stress.



F: Fructose; G: Glucose; S: Sucrose

Fig. 3: Effect of different treatment levels on survival rate of tomato at 2 weeks after planting

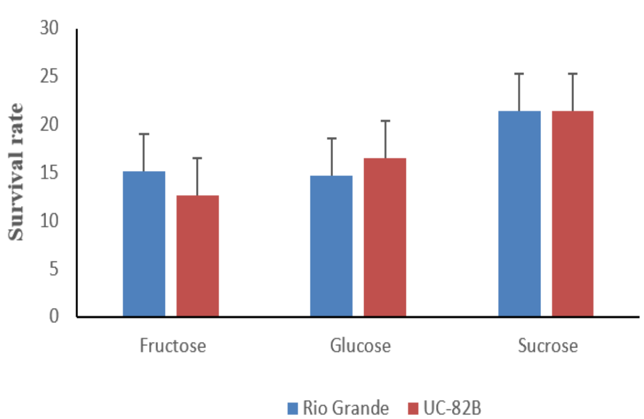
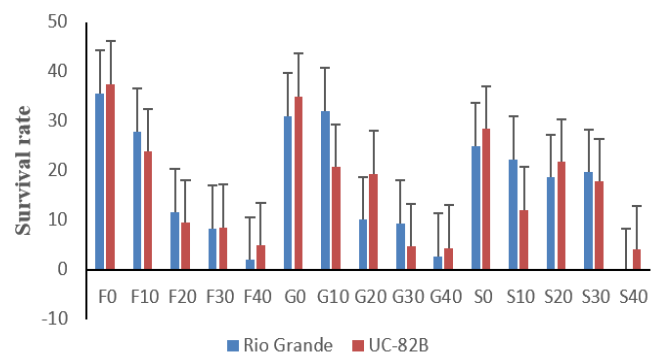


Fig. 4: Effect of different treatment on the survival rate of two tomato variety at 2 weeks after planting

As presented in Figure 4, the survival rates of Rio Grande and UC-82B tomato varieties under three sugar treatments: fructose, glucose and sucrose. Across all treatments, sucrose consistently yielded the highest survival rates, followed by glucose and fructose. It is noted that both varieties exhibited similar responses to each sugar type, with no significant differences observed between treatments. This uniformity suggests that the beneficial effect of sucrose on seedling survival is not variety-dependent but rather a broadly applicable physiological response. These findings align with the work of Madina et al. (2024), who reported that nutrient-mediated physiological responses in tomato seedlings were consistent across varieties when exposed to controlled treatments. Similarly, Ajenifujah-Solebo et al. (2025) emphasized that varietal differences in tomato survival are often overshadowed by the influence of external inputs such as sugar type and concentration, especially under uniform environmental conditions.



F: Fructose; G: Glucose; S: Sucrose

Fig. 5: Effect of different treatment levels on the survival rate of two tomato variety at 2 weeks after planting

Interaction between tomato variety and treatment levels on seedling survival. It is illustrated in Figure 5 that the interactive effects of sugar concentration and tomato variety on seedling survival two weeks post-planting that both Rio Grande and UC-82B varieties exhibited their highest survival rates under the 0% sugar treatments (F0, G0, S0), with values exceeding 35%. As concentration increased across fructose, glucose and sucrose treatments, a consistent decline in survival was observed, culminating in the lowest rates, below 10% at the 40% concentration level (F40, G40, S40). Glucose and sucrose at 0% and 10% concentrations supported relatively better survival outcomes compared to fructose. This suggests that low or no sugar supplementation enhances seedling viability. The detrimental effects observed at higher concentrations may be attributed to solute-induced physiological stress, which impairs membrane stability and metabolic function (Makinde & Adekoga, 2025). Both tomato varieties responded similarly across treatments, indicating that the influence of concentration on survival is largely independent of genotype. However, Rio Grande consistently showed marginally higher survival rates under lower glucose and sucrose treatments, giving a slight varietal advantage in stress tolerance under mild sugar exposure. This observation aligns with findings by Madina et al. (2024), who reported that varietal performance under nutrient modulation in Nigerian-grown tomatoes was more influenced by external inputs than genetic difference.

Figure 6 shows the survival rates of Rio Grande and UC-82B tomato varieties at four weeks post-planting. Both cultivars demonstrated similar survival performance, with Rio Grande having a slightly higher rate of 23% than UC-82B of 21%. However, this difference was not significant, as indicated by overlapping error margins. These results suggest that varietal influence on seedling survival remained stable under the prevailing environmental conditions, with no clear advantage observed for either variety. This conforms to the finding reported by Ajenifujah-Solebo et al. (2025), who noted limited genotype impact on early tomato vigor under uniform agro-ecological conditions. Similarly, research by Olayiwola et al. (2023) emphasized that early seedling survival is predominantly shaped by extrinsic factors such as soil fertility, irrigation practices and microbial interactions, rather than inherent varietal traits.

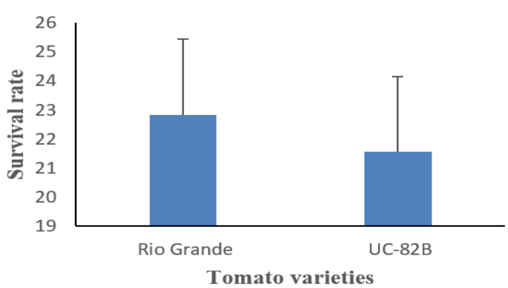


Fig. 6: Survival rate of tomato variety at 4 weeks after planting

Figure 7 shows the survival outcomes of tomato seedlings subjected to three treatments; fructose, glucose, and sucrose at four weeks after planting. Among the treatments, sucrose consistently produced the highest survival rate (27%), while fructose and glucose yielded similar but lower survival rates (19%). This sustained advantage of sucrose over the others shows its superior physiological role in promoting long-term seedling viability.

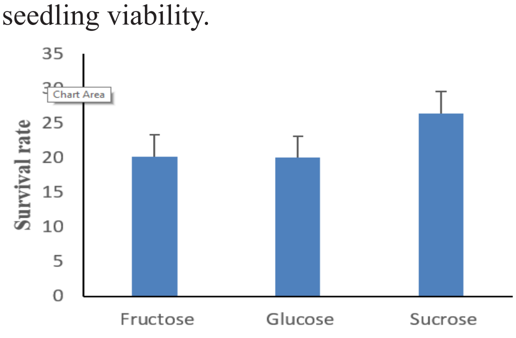
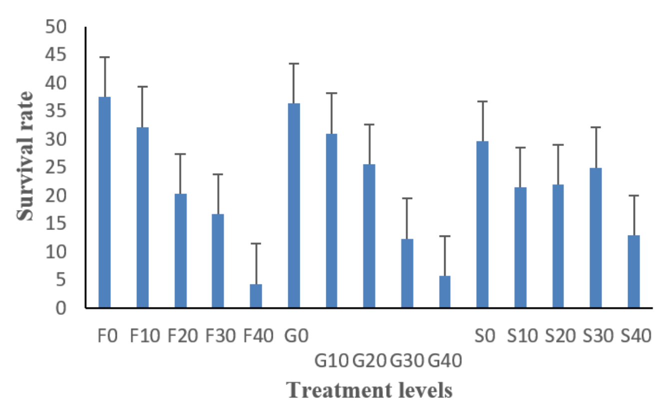


Fig. 7: Effect of treatment on survival rate of tomato at 4 weeks after planting

These findings align with those of Ogunsola and Ogunsola (2021), who emphasized the importance of carbohydrate-mediated stress mitigation in tomato seedlings under African climatic conditions. Furthermore, Esan et al. (2020) demonstrated that exogenous sugar treatments, particularly sucrose, improved seedling resilience by enhancing antioxidant activity and stabilizing membrane function under abiotic stress.

Figure 8 illustrates the survival rates of tomato seedlings treated with varying concentrations (0, 10, 20, 30, and 40 mM) of fructose (F), glucose (G) and sucrose (S) four weeks after planting. The highest survival rates were recorded at 0 mM concentrations (F0, G0, S0), consistently above 30%, indicating that tomato seedlings performed optimally without external supplementation. Increasing sugar concentrations led to a decline in survival, with the steepest drops observed at 40 mM, especially in fructose and glucose treatments. Sucrose displayed a comparatively moderated decline, suggesting differential osmotic tolerance among sugar types. These findings align with the study of Lemoine et al., (2013) indicating that elevated sugar concentrations can impose osmotic stress, thereby impairing plant viability.



F: Fructose; G: Glucose; S: Sucrose

Fig. 8: Effect of different treatment levels on survival rate of tomato at 4 weeks after planting

As presented in Figure 9, the survival outcomes of Rio Grande and UC-82B tomato seedlings subjected to three sugar treatments; fructose, glucose and sucrose at 4 weeks after planting. Across both varieties, sucrose consistently yielded the highest survival rates of 27%, showing higher outcome than fructose and glucose treatments, which recorded 20–22%. The response patterns were uniform between the two varieties, indicating negligible varietal influence at this developmental stage. These results suggest that sucrose enhances seedling resilience more effectively than the other sugars, potentially due to its higher phloem mobility and role in stress mitigation during early growth phases (Ruan, 2014).

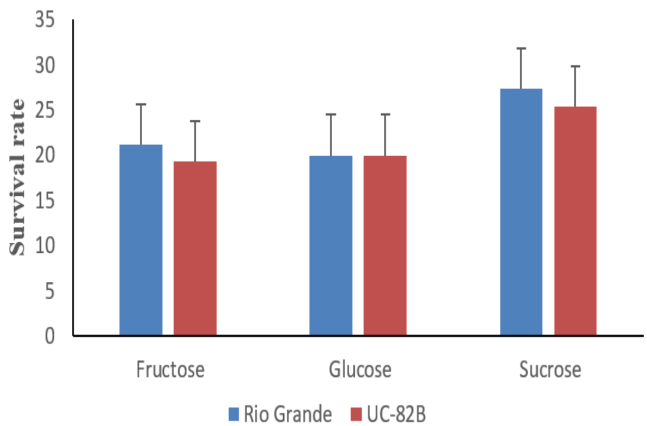
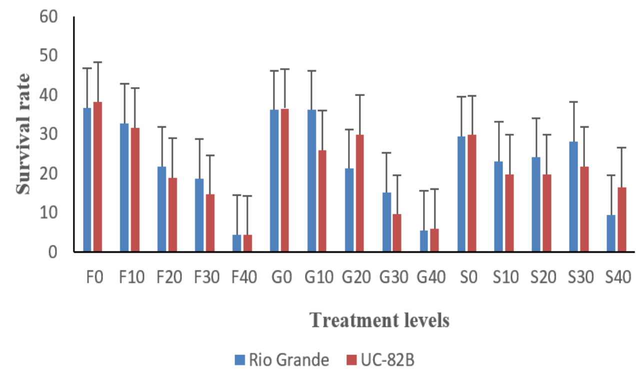


Fig. 9: Effect of different treatment on the survival rate of two tomato variety at 4 weeks after planting

Figure 10 evaluates the survival response of Rio Grande and UC-82B tomato seedlings to increasing concentrations (10, 20, 30, and 40 mM) of fructose, glucose and sucrose at four weeks after planting. Low to moderate concentrations (e.g., F10, G10, S10) consistently enhanced survival rates, indicating a favorable physiological response to sugar supplementation at these levels. However, higher concentrations (F40, G40, S40) resulted in a pronounced decline in survival, suggesting that elevated sugar levels may induce osmotic stress or metabolic toxicity detrimental to seedling viability. The survival trend was uniform across treatments, Rio Grande exhibiting slightly greater tolerance at higher concentrations compared to UC-82B. These findings are consistent with the work of Madina et al. (2024), who reported that nutrient modulation influenced tomato seedling performance more significantly higher than varietal traits under Nigerian field conditions. Also, Akinboye et al. (2018) demonstrated that sugar composition and concentration directly affect physiological integrity and shelf-life in Nigerian tomato varieties, reinforcing the importance of concentration thresholds in treatment efficacy.

Figure 11 shows a consistent survival advantage of Rio Grande over UC-82B, suggesting superior physiological resilience or adaptive capacity under the tested conditions. This result aligns with earlier observations at four weeks, showing Rio Grande's potential as a more stress-tolerant genotype. Previous studies by Aliero et al. (2019) in Nigeria have shown that Rio Grande exhibits distinct protein expression profiles under salt stress, including upregulation of protective proteins such as 38 kDa and 45 kDa bands, which may contribute to its enhanced tolerance.



F: Fructose; G: Glucose; S: Sucrose

Fig. 10: Effect of different treatment levels on the survival rate of two tomato variety at 4 weeks after planting

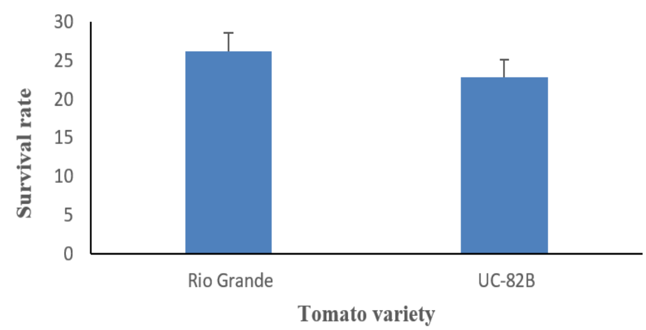


Fig. 11: Survival rate of tomato variety at 6 weeks after planting

Figure 12 shows the survival outcomes of seedlings treated with fructose, glucose and sucrose. While all sugar types supported survival to varying degrees, sucrose consistently resulted in the highest survival rate. This suggests that sucrose may offer superior osmo-protective and metabolic benefits during early seedling development. Supporting this, Gómez-Cabezas and España (2024) demonstrated that exogenous sucrose enhanced dry matter accumulation, chlorophyll content and net assimilation rate in tomato seedlings under suboptimal light conditions.

Figure 13 presents results of the survival response of tomato seedlings to increasing concentrations (0, 10, 20, 30, 40 g/L) of fructose, glucose and sucrose. Survival was highest at lower concentrations, particularly at G0 and G10, with a decline observed as concentrations increased. The lowest survival rates were observed at F40, G40 and S40, suggesting that elevated sugar levels may induce osmotic stress or metabolic toxicity, impairing seedling viability. These finding aligns with the work of Setiaji et al. (2020), who reported that tomato callus biomass increased with sucrose concentration up to a threshold, beyond which growth was inhibited.

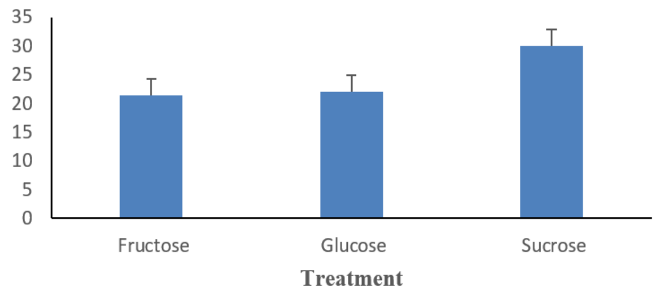
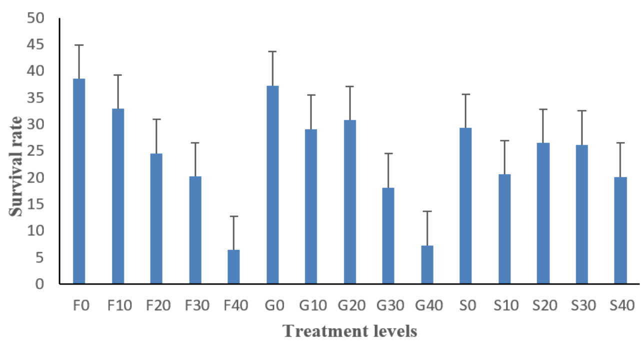


Fig. 12: Effect of treatment on survival rate of tomato at 6 weeks after planting



F: Fructose; G: Glucose; S: Sucrose

Fig. 13: Effect of different treatment levels on survival rate of tomato at 6 weeks after planting

Figure 14 shows the survival outcomes of Rio Grande and UC-82B under fructose, glucose and sucrose treatments. Sucrose consistently produced the highest survival rates, especially in Rio Grande, followed by glucose and fructose. The superior performance of Rio Grande across all treatments suggests a genetic advantage in stress resilience. This varietal difference is supported by the findings of Aliero (2019), who found that Rio Grande exhibited upregulation of protective proteins (e.g., 38 kDa and 45 kDa bands) under salt stress, indicating enhanced tolerance mechanisms.

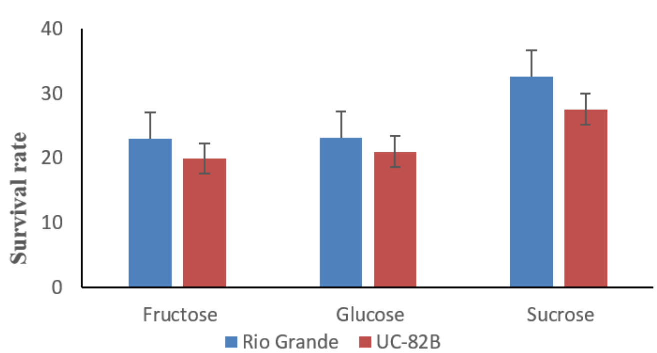
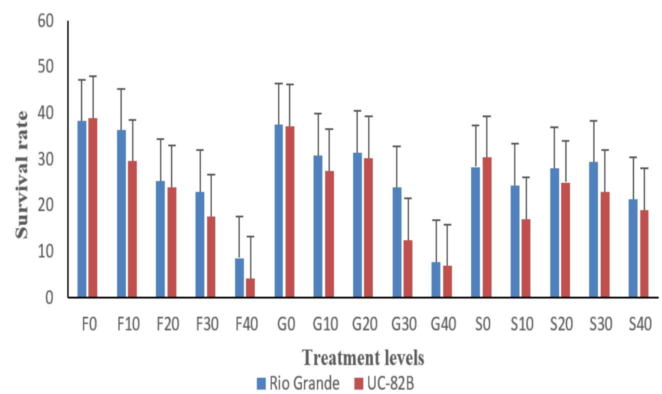


Fig. 14: Effect of different treatment on the survival rate of two tomato variety at 6 weeks after planting

As presented in Figure 15, the survival response of Rio Grande and UC-82B tomato seedlings to increasing concentrations (0–40 g/L) of fructose, glucose and sucrose. The highest survival rates were observed at 0 and 10 g/L concentrations (F0, G0, G10, S0, S10), with a progressive decline as concentrations increased. The lowest survival rates occurred at 40 g/L treatments (F40, G40, S40), indicating impaired seedling viability. This was more pronounced in UC-82B, which exhibited greater sensitivity to high sugar concentrations, while Rio Grande maintained relatively higher survival across treatments. Among the treatments, glucose and sucrose at low concentrations (G0–G10, S0–S10) were most effective in supporting survival, while fructose treatments showed lower overall efficacy. This aligns with the work of Qi et al. (2011), who reported that sucrose phosphate synthase activity increases under stress, enhancing carbohydrate metabolism and seedling vigor.



F: Fructose; G: Glucose; S: Sucrose

Fig. 15: Effect of different treatment levels on the survival rate of two tomato variety at 6 weeks after planting

4. Conclusion

This study provides compelling evidence that sugar supplementation plays a critical role in the in vitro survival and early development of tomato seedlings. Low to moderate concentrations of glucose and sucrose (0–10 g/L) significantly enhanced seedling survival across both Rio Grande and UC-82B varieties, with Rio Grande demonstrating superior tolerance to sugar-amended conditions. Survival rates declined markedly at higher concentrations (≥30–40 g/L), likely due to osmotic or metabolic stress induced by sugar toxicity.

Among the three sugar types evaluated, sucrose emerged as the most effective in promoting seedling vigor, particularly in Rio Grande, followed closely by glucose. Fructose treatments consistently produced lower survival outcomes across all concentrations.

Ultimately, the data support sucrose at low concentrations as the preferred carbon source for in vitro culture of tomato explants, especially when paired with responsive genotypes such as Rio Grande. Future studies should explore the underlying molecular mechanisms of sugar metabolism and genotype-specific stress tolerance to further enhance regeneration efficiency and guide commercial propagation strategies.

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