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Synergistic Effects of KCl, KNO_3 and SA in Improvement of Germination of Watermelon Under Salinity Stress

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ABSTRACT

Salinity is a major constraint on global food security because it suppresses crop productivity as demand continues to rise each year. High salt levels depress germination in many crops by limiting water uptake, which ultimately reduces yield. To address this, we tested potassium chloride (KCl), potassium nitrate (KNO_3), and salicylic acid (SA) for their ability to improve germination and early seedling growth of salt-stressed watermelon var. 168. Seeds were primed with 200 mM NaCl for four days, then germinated on Petri dishes containing selected concentrations of KCl, KNO_3, or SA. Germination was recorded daily through day 8, and performance was evaluated using germination percentage, germination rate, seed vigor index, seedling length, hypocotyl length, radicle length, and seedling biomass. The most effective single concentrations were 10.0 mM KCl, 7.5 mM KNO_3, and 1.0 mM SA. Notably, the combination of 7.5 mM KNO_3 and 10.0 mM KCl reduced salt toxicity and markedly improved performance, increasing germination percentage by about 100%, doubling the germination rate, and raising the seed vigor index roughly tenfold compared with the NaCl control.

Keywords: Salinity Stress; Watermelon var. 168; Germination Traits; Germination Enhancer

Introduction

Soil salinization is a serious global threat to agricultural productivity and food security, with the greatest impacts in arid and semi-arid regions (Hossain, 2019). Current estimates indicate that more than 1.3 billion hectares are affected by salinization and alkalization, roughly one-tenth of Earth's land surface, and up to half of all arable land could be degraded by 2050 if present trends continue (Atta et al. [1,2]). Plants are susceptible to salinity throughout their life cycle but are especially vulnerable during germination and early seedling growth. Many crops exhibit marked sensitivity when soil electrical conductivity exceeds about 4 dS/m, leading to osmotic stress and ion toxicity that suppress growth (Paul [3]). Most vegetables have even lower salinity thresholds, about 1 to 2.5 dS/m in saturated paste extract (Machado et al. [4]). High salinity reduces germination percentage and speed, seedling dry mass, and root and shoot length in species such as cucumber (Baghbani [5]), primarily through reductions in osmotic potential, specific ion toxicity, and nutrient imbalance (Greenway & Munns, 1980; Askari-Khorasgani et al., 2021; Lu et al., 2023). Disruption at the germination stage can cascade into substantial production losses in many crops, including watermelon. At the physiological level, salinity interferes with photosynthesis, nutrient uptake, and cellular metabolism, and it can depress antioxidant enzyme activities, collectively stunting growth (Jia et al., 2020; Kesawat et al., 2023; Zeng et al., 2015). Globally there are more than 500 melon varieties and about 150 watermelon varieties. In Malaysia, watermelon, rockmelon, and honeydew are the principal cultivated types (Rosmuna & Nik Rozana, 2016). *Citrullus lanatus* var. 168, also marketed as Super Sweet Black Angel 168, is a mini watermelon that typically weighs 1.0 to 1.5 kg and was introduced by the Agriculture, Fisheries and Conservation Department with germplasm from Taiwan, Australia, and Thailand ([6]). Watermelon is valued as a convenient, nutrient-rich snack, with phytochemicals such as lycopene, vitamin C, β-carotene, and polyphenols contributing to its health profile (Maoto, Beswa, & Jideani, 2019).

Multiple strategies have been proposed to manage salinity in crop production. These include grafting, deploying salt-tolerant cultivars, and agronomic management such as irrigation, drainage, and fertilization. Grafted seedlings can better tolerate biotic stresses including

salinity and soil-borne pathogens (Yetisir & Uygur, 2009). Introducing salt-tolerant crops is often effective, and the germination stage remains the most sensitive to salinity (Dadashpour [7]). However, these approaches may be time-consuming and costly for farmers working degraded lands. By contrast, supplementing germination media with liquid enhancers can be a practical, lower-cost option to boost establishment under saline conditions.Recent work highlights the potential of chemical treatments such as potassium nitrate (KNO_3), potassium chloride (KCl), and phytohormones like salicylic acid (SA) to modulate plant physiology and improve adaptation under salinity stress (Khan [8]). Potassium is a core macronutrient, essential for growth and protein synthesis. KCl has improved germination and growth under salt stress in rice (Afzal et al. [9]) and maize, where 50 mmol L^{-1} KCl priming increased germination index, germination percentage, seed vigor index, and the coefficient of germination in salt-stressed seeds (Badar-uz-Zaman et al. [10]). KNO_3 is widely applied during the growing season and through irrigation. Halopriming with KNO_3 enhanced seedling dry weight, emergence, and carbohydrate metabolism in corn, with maximum emergence at 40 to 60 mM (Farhoudi [11]). Under saline conditions, low-dose KNO_3 increased germination percentage and mitigated salinity effects in *Silybum marianum* L., although higher concentrations could depress germination (Zavariyan [12]). Exogenous KNO_3 can also trigger nitric oxide release, which promotes germination and reduces damage from environmental stresses (Oliviera [13]).

Salicylic acid likewise contributes to salinity tolerance by regulating biochemical and physiological processes and by elevating antioxidant enzymes. SA can promote catalase activity, lowering hydrogen peroxide and improving germination (Ayyub et al. [14]). In salt-stressed watermelon, SA increased chlorophyll, nitrogen, potassium, and protein contents, with the strongest responses around 5 mmol L^{-1} followed by 2.5, 1.0, and 0.5 mmol L^{-1}. Beyond single compounds, combined applications of macronutrients and growth regulators can alleviate stress injury. Examples include $CaCl_2$, GA_3, and SA reducing chilling injury in peaches (Gang et al. [15]) KCl, KNO_3, GA, and SA improving rice germination under salinity (Nurfatiha et al. [16]), and KCl, thiourea, GA_3, and SA mitigating drought stress during rice germination (Mahadi et al. [17]). Building on this evidence, the present study aimed to evaluate the synergistic effects of KCl, KNO_3, and SA on watermelon germination under salt stress.

Materials and Methods

Seed Materials and Seed Sterilization

Super Sweet Black Angel var. 168 seeds were obtained from D'syira Enterprise, Serdang, Selangor, Malaysia. Following Wang et al. [18], seeds were surface-sterilized in 5% (w/v) sodium hypochlorite (NaOCl) for 5 minutes, rinsed four times with sterile water, and air-dried on sterile filter paper.

Salt-Stress Induction

Seed halopriming with NaCl was used to induce salt stress (Gebreegziabher [19]). Seeds were incubated in 200 mM NaCl at approximately 25 °C for 4 days.

Determination of Ideal Concentrations of KCl, KNO_3 and SA

Salt-stressed seeds were placed in 9 cm Petri dishes lined with Whatman No. 1 filter paper and moistened with 5 mL of the test solution: KCl at 10, 20, 30, 40, or 50 mM; KNO_3 at 1.0, 2.5, 5.0, 7.5, or 10 mM; and SA at 0.25, 0.50, 0.75, 1.0, or 2.0 mM. Deionized water served as the control for each series. Dishes were sealed with Parafilm to limit evaporation (Ghanad et al. [20]) and arranged in a completely randomized design at ~25 °C under a 16/8-hour light/dark cycle using Philips fluorescent lighting. Germination was monitored daily for 8 days.

Determination of the Optimal Combination of KCl, KNO_3, and SA

Using the same procedures as above, combination treatments were prepared from the concentrations identified as optimal for each compound. The treatment combinations are listed in Table 1.

Table 1: The combination treatments of ideal concentration of KCl , KNO3 and SA.

Number	Combination Treatment
1	**Control (deionized water)**
2	KNO_3 + SA
3	KNO_3 + KCl
4	KCl + SA
5	KNO_3 +KCl + SA

Measurement of Seed germination Performance

Germination percentage, germination rate, seed vigor index, seedling biomass, hypocotyl length, radicle length and seedling length were the parameters used to determine seed germination performance after 8 days.

Germination Percentage (GP): After 8 days, germination percentage was calculated by using formula proposed by Kandil et al. [21]:

$$Germination\ Percentage = \frac{Number\ of\ Germinated\ Seeds \times 100}{Total\ Number\ of\ Seeds\ Tested}$$

Germination Rate (GR): Priming will increase germination rate under saline conditions and the best treatment will show low germination rate. According to Awasthi et al. [22], germination rate was calculated using following equation:

$$GR = \frac{Number\ of\ Germination\ seeds}{Day\ of\ First\ Count} + \cdots\cdots\cdots + \frac{Number\ of\ Germination\ seeds}{Day\ of\ final\ count}$$

Seed Vigor Index (SV1): Seed vigor index evaluates how well germinated seeds can establish into normal seedlings. Salt stress responses are evident in root and shoot growth, so both lengths are informative (Jamil [23]). Following Elouaer [24], we calculated:

$$Seeds\ vigor\ index = \frac{Germination\ Percentage(\%) \times Seedinglength}{100}$$

Where seedling length = length of hypocotyl + length of radicle

These indices integrate emergence and early growth into a single measure of vigor.

Seedling Biomass: Seedling biomass was quantified as dry weight. After gently rinsing seedlings under running tap water, they were blotted dry and oven-dried at 60 °C for 24 hours. The dried seedlings were then weighed for each treatment to determine biomass Awasthi et al. [22].

Hypocotyl, Radicle and Seedling Length: Hypocotyl and radicle lengths were measured for each germinated seed. Hypocotyl length was recorded in centimeters from the base of the cotyledons to the junction with the radicle, and radicle length was recorded from the hypocotyl–radicle junction downward to the root tip, as illustrated in Figu Hypocotyl and radicle lengths were measured for each germinated seed. Hypocotyl length was recorded in centimeters from the base of the cotyledons to the junction with the radicle, and radicle length was recorded from the hypocotyl–radicle junction downward to the root tip, as illustrated in Figure 1 (Elouaer [24]).

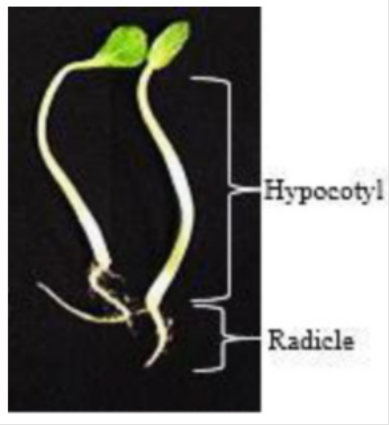

Figure 1: Hypocotyl length and Radicle length of watermelon seedlings.

Statistical Analysis

The collected data were analyzed using SPSS window version 23. One-way ANOVA at p ≤ 0.05 was conducted to test for siginificant difference between different treatment solutions followed by Duncan's Multiple Range Test with p ≤ 0.05 if ANOVA was significant (Kalhori, et al. [25]).

Results and Discussion

Determination of the Ideal Concentration Solution for KCl

Table 2 shows that germination percentage not significantly increased (ANOVA, p≤0.05). However, germination rate two times higher and five-fold for seed vigor index morehigher than control in 10.0mM KCl. shows that seedling growth traits except biomassionare significantly increased in 10.0 mM of KCl (ANOVA, p≤0.05). Both seedling and radicle length significantly increased by five times higher while hypocotyl length increased by nine times more higher than control. Thus, the ideal concentration of KCl treatment is 10.0mM KCl andhas been chosen as an ideal concentration based on its highest total results (9.35) Values are mean and standard errors of measurement made on three replicates. Superscripts within the means of each column (a-b) with different letters indicate significant differences among the means (Duncan's Multiple Range Test, p<0.05)

Table 2: Germination percentage (GP), germination rate (GR) and seed vigor index (SVI) of salt-stressed watermelon seeds in different concentration of KCl.

Concentration (mM)	GP (%)	GR	SVI	Total
0	100.0±0.0^{b}	1.72±0.28^{a}	0.93±0.64^{a}	102.65
10.0	100.0±0.0^{b}	3.01±0.56^{b}	4.66±0.26^{b}	107.67
20.0	46.7±24.0^{a}	0.60±0.33^{a}	0.43±0.31^{a}	47.73
30.0	80.0±11.5^{ab}	1.29±0.25^{a}	1.06±0.64^{a}	82.35
40.0	60.0±0.0^{ab}	1.31±0.45^{a}	0.65±0.30^{a}	61.96
50.0	73.3±13.3^{ab}	1.35±0.10^{a}	0.70±0.33^{a}	75.35

Note: Values are mean and standard errors of measurement made on three replicates. Superscripts within the means of each column (a-b) with different letters indicate significant differences among the means (Duncan's Multiple Range Test, p<0.05).

Determination of the Ideal Concentration Solution for KNO_3

Results show that germination rate of salt-stressed watermelon seeds treated 7.5 mM KNO_3 significantly increased (ANOVA, p≤0.05) by two-fold higher than control. Meanwhile, Table 3 shows that seedling growth traits higher in 2.5 -10.0 mM KNO3 (ANOVA, p≥0.05) with the highest in 7.5 mM. Thus, 7.5 mM has been chosen as an ideal concentration (Table 4). Values are mean and standard errors of measurement made on three replicates. Superscripts within the means of each column (a-b) with different letters indicate significant differences among the means (Duncan's Multiple Range Test, p<0.05)

Table 3: Seedling length (SL), hypocotyl length (HL), radicle length (RL) and biomass of salt stressed watermelon seedlings in different concentration of KCl.

Concentration (mM)	SL (cm)	HL (cm)	RL (cm)	Biomass (g)	Total
0	0.93±0.64^{a}	0.23±0.19^{a}	0.70±0.45^{a}	0.037±0.0033^{a}	1.90
10.0	4.66±0.26^{b}	2.13±0.49^{b}	2.53±0.36^{b}	0.033±0.0088^{a}	9.35
20.0	0.57±0.38^{c}	0.39±0.33^{a}	0.51±0.37^{a}	0.027±0.0015^{a}	1.50
30.0	1.40±0.79^{a}	0.48±0.24^{a}	0.72±0.41^{a}	0.030±0.0000^{a}	2.63
40.0	1.08±0.49^{a}	0.28±0.28^{a}	0.80±0.21^{a}	0.033±0.0067^{a}	2.19
50.0	0.86±0.29^{a}	0.49±0.29^{a}	0.38±0.05^{a}	0.033±0.0033^{a}	1.76

Note: Values are mean and standard errors of measurement made on three replicates. Superscripts within the means of each column (a-b) with different letters indicate significant differences among the means (Duncan's Multiple Range Test, p<0.05).

Table 4: Seedling length (SL), hypocotyl length (HL), radicle length (RL) and biomass of salt stressed watermelon seedlings in different concentration of KNO_3.

Concentration (mM)	SL (cm)	HL (cm)	RL (cm)	Biomass (g)	Total
0	1.20±0.54^{a}	0.54±0.27^{a}	0.58±0.25^{a}	0.028±0.009^{a}	2.35
1.0	1.37±0.66^{a}	0.82±0.56^{a}	0.56±0.25^{a}	0.019±0.0007^{a}	2.77
2.5	3.47±1.57^{ab}	2.05±1.11^{a}	1.42±0.60^{ab}	0.024±0.0056^{a}	6.96
5.0	3.63±0.98^{b}	2.18±0.80^{a}	1.45±0.24^{ab}	0.027±0.0033^{a}	7.29
7.5	5.80±1.45^{b}	3.40±1.10^{a}	2.40±0.45^{b}	0.029±0.0058^{a}	11.63
10.0	3.20±1.83^{ab}	2.05±1.35^{a}	1.15±0.53^{ab}	0.021±0.00521^{a}	6.42

Note: Values are mean and standard errors of measurement made on three replicates. Superscripts within the means of each column (a-b) with different letters indicate significant differences among the means (Duncan's Multiple Range Test, p<0.05).

Determination of the Ideal Concentration Solution for SA

This study found that GP, GR, and SV not significant (ANOVA, p≥0.05) in SA treatments (Table 5). The ideal concentration in 1.0 mM A as it shows the highest total results (100.77). Meanwhile, Table 6 presents that seedling length of salt-stressed watermelon seeds treated with 7.5 mM SA is significantly increased (ANOVA, p≤0.05) by sixteen times higher than control. However, hypocotyl length, radicle length and seedling biomass treated with SA are not significant (ANOVA, p≥0.05). Therefore, 1.0 mM has been chosen as an ideal concentration it shows the highest total results (11.76).

Table 5: Germination percentage (GP), germination rate (GR) and seed vigor index (SVI) of salt-stressed watermelon seeds in different concentration of KNO_3.

Concentration (mM)	GP (%)	GR	SVI	Total
0.0	80.0±11.5^a	1.87±0.45^a	1.07±0.51^a	82.94
1.0	80.0±20.0^a	1.54±0.44^a	1.34±0.69^a	82.88
2.5	80.0±11.5^a	2.40±0.35^a	2.82±1.46^{ab}	85.22
5.0	73.3±6.7^a	1.99±0.26^a	2.77±0.90^{ab}	78.06
7.5	100.0±0.0^a	3.5±0.29^b	5.80±1.45^b	109.3
10.0	86.7±6.7^a	1.77±0.17^a	2.99±1.86^{ab}	91.46

Table 6: Germination percentage (GP), germination rate (GR) and seed vigor index (SVI) of salt-stressed watermelon seeds in different concentration of SA.

Concentration (mM)	GP (%)	GR	SVI	Total
0.00	86.7±6.7^a	1.64±0.46^a	0.32±0.05^a	88.66
0.25	93.3±6.7^a	2.43±0.43^a	1.58±1.14^{ab}	97.31
0.50	93.3±6.7^a	2.76±0.51^a	1.22±0.64^{ab}	97.28
0.75	86.7±6.7^a	2.37±0.20^a	0.69±0.28^a	89.76
1.00	93.3±6.7^a	2.61±0.35^a	4.86±2.44b	100.77
2.00	93.3±6.7^a	1.67±0.35^a	0.95±0.63^a	95.92

Note: Values are mean and standard errors of measurement made on three replicates. Superscripts within the means of each column (a-b) with different letters indicate significant differences among the means (Duncan's Multiple Range Test, $p<0.05$)

Determination of Ideal Combination Solution from KCl, KNO_3 and SA

Table 7 shows that germination traits are significantly increased (ANOVA, $p\leq0.05$) in combination 7.5 mM KNO_3 and 10.0 mM KCl which is two-fold higher in GR and ten-fold increased in SV as compared to control. Therefore, 7.5 mM KNO_3 and 10.0 mM KCl as the ideal combination as show the highest total results (106.04). presents that seedling growth traits are significantly increased (ANOVA, $p\geq0.05$) in combination treatment. Combination 7.5 mM KNO_3 and 10.0 mM KCl shows the total highest results (4.63).

Table 7: Seedling length (SL), hypocotyl length (HL), radicle length (RL) and biomass of salt stressed watermelon seedlings in different concentration of SA.

Concentration (mM)	SL (cm)	HL (cm)	RL (cm)	Biomass (g)	Total
0.00	0.35±0.04^a	0.00±0.00^a	0.35±0.04^a	0.035±0.0024^a	0.74
0.25	1.61±1.12^a	0.33±0.33^a	1.28±0.79^a	0.037±0.0044^a	3.26
0.50	1.27±0.62^a	0.52±0.40^a	0.76±0.22^a	0.032±0.0035^a	2.58
0.75	0.83±0.37^a	0.29±0.29^a	0.54±0.08^a	0.035±0.0009^a	1.70
1.00	5.88±2.30^b	2.15±1.01^b	3.70±1.60^b	0.029±0.0022^a	11.76
2.00	0.97±0.61^a	0.37±0.37^a	0.61±0.25^a	0.036±0.0035^a	1.99

Note: Values are mean and standard errors of measurement made on three replicates. Superscripts within the means of each column (a-b) with different letters indicate significant differences among the means (Duncan's Multiple Range Test, $p<0.05$)

Discussion

Under salt stress the ionic balance of plant cells is disrupted, membranes experience osmotic stress, reactive oxygen species accumulate, redox homeostasis is disturbed, and membrane integrity becomes difficult to maintain (Feng et al. [26]). High salinity reduces both yield quality and quantity because it perturbs processes at cellular and whole-plant scales, including water potential regulation and ion transport (Patade et al. [27]). To alleviate these constraints in watermelon var. 168, we evaluated potassium chloride, potassium nitrate, and salicylic acid as seed and germination treatments. Different treatments produced distinct effects on germination, and the addition of exogenous compounds helped protect redox balance and membrane stability.

Potassium supplied as KCl is widely used in crops because K^+ is an essential macronutrient and Cl^- is a beneficial micronutrient for normal growth (Badar-uz-Zaman et al. [10]). Under abiotic stress, plant survival and productivity depend strongly on K^+, which supports enzyme activation, osmoregulation, protein synthesis, energy transfer, photosynthesis, stomatal movement, phloem transport, and cation–anion balance (Marschner [28]). In saline media, however, K^+ effectiveness declines because Na^+ competes for uptake and transport sites. Salt stress inhibits K^+ movement from roots to shoots and lowers total nutrient uptake, creating K^+ deficiency. This deficiency arises from three factors: high external Na^+ that suppresses K^+ transport activity, direct competition between Na^+ and K^+ at plasma membrane transporters, and K^+ loss through membrane depolarization and leakage due to impaired membrane integrity (Coskun [29]).

Elevated reactive oxygen species can then trigger programmed cell death and other injuries, further limiting growth and yield (Gong et al. [30]). A higher cytosolic K^+ to Na^+ ratio is therefore central to salt tolerance because it restricts Na^+ influx and sustains K^+ retention. In our study, adding K^+ as KCl to salt-stressed seeds increased tolerance and early growth by raising tissue K^+ and lowering Na^+, thereby helping to maintain a favorable K^+ to Na^+ ratio. Consistent with this mechanism, K^+ salts can accelerate water imbibition and increase germination rate, and adequate K^+ availability also supports photosynthesis, leaf area, and leaf number (Farooq et al. [30]). Potassium nitrate alleviated salinity inhibition by improving germination traits and seedling growth, in agreement with reports that KNO_3 enhances germination under saline conditions (Zavariyan et al. [12]). KNO_3 supplies both K and N, supporting protein formation and enzyme and hormone synthesis that sustain early development (Serrano [31]). Exogenous KNO_3 can also promote the generation of nitric oxide, which stimulates germination and improves membrane function under stress (Oliveira [13]). Several studies show that shoot growth is often more sensitive to salt than root growth in cucumber, making shoot traits a useful stress indicator (Wang et al. [31]). In our work, KNO_3 enhanced hypocotyl length in salt-stressed watermelon, consistent with mitigation of ionic and osmotic stress and restoration of a more favorable K^+ to Na^+ ratio required for turgor maintenance, membrane potential, osmoregulation, protein synthesis, and enzyme activation (Shabala et al. [32]).

(Table 8) Salicylic acid is an endogenous phenolic hormone involved in plant development and in adaptation to multiple abiotic stresses, including salinity, osmotic stress, heat, and drought (Lee, et al. [33]). SA has been reported to improve carbohydrate metabolism, protein content, and photosynthetic performance under salinity, for example in maize (Bagher [34]). It can also help restore membrane potential through stimulation of H^+-ATPase activity and Na^+/H^+ antiport at the tonoplast (Jayakannan et al. [35]). The effect of SA is concentration dependent. In watermelon cv. Charleston Gray, the highest dry mass and leaf number were observed at 5.0 mM, the highest fresh mass at 2.5 mM, and the maximum root length at 1.0 mM, which aligns with our finding that 1.0 mM favored root elongation (Ayyub [14]). SA has enhanced germination across a range of salinity levels by promoting nutrient uptake and cell expansion where these are otherwise suppressed (Dolatabadian et al. [36]). Its benefits have been demonstrated in beans, tomato, and maize through improved membrane stability (Jini [37]). (Table 9) In cucumber, SA treatment alleviated salt stress by activating defense pathways and improving osmotic adjustment (Dong [38]). Together these mechanisms explain the improvements we observed with SA and support the combined use of KCl, KNO_3, and SA to stabilize ion homeostasis, protect membranes, and strengthen early seedling performance under salinity.

Table 8: Germination percentage (GP), germination rate (GR) and seed vigor index (SVI) of salt-stressed watermelon seeds in different combination of KCl, KNO_3 and SA.

Combination	GP (%)	GR	SVI	Total
Control	**73.3±6.7^b**	**1.61±0.11^a**	**0.21±0.01^a**	**75.1**
7.5 mM KNO_3 +.1.0 mM SA	73.3±6.7^{ab}	2.99±0.51^{bc}	0.75±0.42^a	77.0
7.5 mM KNO_3 + 10.0 mM KCI	100.0±0.0^c	3.89±0.15^c	2.15±0.77^b	106.0
10.0 mM KCI + 1.0 mM SA	60.0±0.0^a	1.94±0.11^{ab}	0.61±0.22^a	62.6
7.5 mM KNO3 + 10.0 mM KCI + 1.0 mM SA	86.7±13.3^{bc}	2.64±0.65^{abc}	0.41±0.11^a	89.9

Note: Values are the mean and standard errors of measurement made on three replicates. Superscripts within the means of each column (a-c) with different letters indicate significant differences among the means (Duncan's Multiple Range Test, $p<0.05$).

Table 9: Seedling length (SL), hypocotyl length (HL), radicle length (RL), and biomass of salt-stressed watermelon seedlings in different combination of KCl, KNO_3 and SA.

Combination	SL (cm)	HL (cm)	RL (cm)	Biomass (g)	Total
Control	**0.29±0.04^a**	**0.00±0.00^a**	**0.29±0.04^a**	**0.033±0.0033^a**	**0.61**
7.5 mM KNO_3 +1.0 mM SA	0.97±0.51^{ab}	0.42±0.42^{ab}	0.55±0.10^{ab}	0.030±0.0000^a	1.97
7.5 mM KNO_3 +10.0 mM KCl	2.15±0.77^b	1.07±0.33^b	1.07±0.43^b	0.037±0.0033^a	4.33
10.0 mM KCl +1.0 mM SA	0.83±0.27^{ab}	0.42±0.26^{ab}	0.40±0.01^{ab}	0.037±0.0033^a	1.69
7.5 mM KNO_3 +10.0 mM KCl	0.46±0.27^a	0.00±0.00^a	0.46±0.07^{ab}	0.037±0.0033^a	0.96

Note: Values are the mean and standard errors of measurement made on three replicates. Superscripts within the means of each column (a-b) with different letters indicate significant differences among the means (Duncan's Multiple Range test, $p<0.05$)

Conclusion

In conclusion, [39-44] treating salt-stressed watermelon var. 168 seeds with 7.5 mM KNO_3 and 10.0 mM KCl delivered the most effective mitigation of salinity effects, outperforming all single-salt and salicylic acid treatments. Over eight days this combination increased germination percentage, approximately doubled the germination rate, and raised the seed vigor index by about tenfold relative to the NaCl control, alongside clear gains in seedling, hypocotyl, and radicle lengths and in biomass. These findings indicate that applying moderate KNO_3 and KCl together can counter osmotic constraints imposed by salinity and promote rapid, uniform establishment, offering a practical route to safeguard early growth and eventual yield under saline conditions..

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