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Research Article

Assessing the Impact of Sugar Beetroot Extract on the Improvement of Salt Tolerance in Wheat Varieties through Hydroponic Cultivation

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ABSTRACT

Wheat is a primary dietary source for the majority of Pakistan's population and is also cultivated on a global scale. Salinity is one of the primary abiotic stresses that significantly reduce cereal yield and growth. However, this problem can be resolved by incorporating salinity tolerance into the wheat crop. The objective of this experiment was to examine the bio-stimulant potential of foliar application of sugar beetroot extracts (SBE) to alleviate the adverse effects of salinity on wheat. In hydroponic conditions, wheat varieties Anaaj-17 and Gandum-1 were exposed to variable concentrations of SBE (0%, 10%, 20%, and 30%). The wheat varieties were cultivated in two distinct environments: non-saline S0, which contained 2 mM NaCl, and saline S1, which contained 100 mM NaCl. The evaluation was conducted using a variety of morphological characteristics (shoot, root length, shoot, root fresh weight, shoot, root dry weight, root shoot ratio) and biochemical parameters (Na+, K+ in root and leaf, chlorophyll, and relative water contents in leaves) and wheat plants were harvested 30 days after transplanting. Utilizing a completely randomized design (CRD), the experiment was conducted in a factorial arrangement with three replications. The foliar application of SBE improved the salinity tolerance of wheat. The SBE-30% dosage application exhibited superior results when contrasted with other concentrations. The foliar applications of SBE significantly enhanced the chlorophyll contents in the leaf and facilitated the growth of the shoots and roots. The SBE was determined to be advantageous in that it decreased the sodium content and increased the potassium content of foliage and roots. It was determined that SBE is effective in promoting wheat growth in both saline and non-saline hydroponic environments

Keywords: Salinity, Wheat, Sugar Beetroot Extracts, Abiotic Stress.

INTRODUCTION

A cereal crop known as wheat (*Triticum aestivum* L.) is widely cultivated and is a source of essential nutrients, including carbohydrates and proteins. It is a fundamental meal for a substantial portion of the global populace. The primary source of nutrition for approximately 36% of the global population is wheat, which is of critical importance to global food security (Hasanuzzaman et al., 2017). An annual production of 25.5 million tonnes is the consequence of wheat cultivation in Pakistan, which occupies approximately 21.8 million acres. This sector accounts for 8.7% of the agricultural value and 1.7% of the national GDP (Survey, 2019-20). However, a variety of abiotic stresses are threatening wheat production, with soil salinity being the most significant. Soil salinity is a critical agricultural challenge that substantially affects crop growth, productivity, and yield. It is estimated that salinity has a significant impact on key crops, including wheat, rice, barley, and maize, and affects over 800 million hectares of land globally (Munns and Tester, 2008). The yields of approximately 6.3 million hectares of cultivated land in Pakistan are significantly influenced by salinity (Abbas et al., 2010).

Salinity disrupts the physiological processes of plants, including seed germination, nutrient assimilation, photosynthesis, and overall growth. Osmotic stress, ionic toxicity, and oxidative stress are all induced by elevated salt concentrations, which in turn reduce the vitality and productivity of plants (Flowers, 2004). The accumulation of sodium (Na+) and chloride (Cl-) ions disrupt the cellular homeostasis of plant tissues, resulting in symptoms such as atrophy, leaf burn, and low growth rates. These stresses considerably limit the plant's ability to thrive, particularly in the presence of elevated soil salinity.

Bio-stimulants derived from natural sources, such as sugar beetroot extract (SBE), have attracted attention as a sustainable solution to enhance plant tolerance to abiotic stresses and address these challenges. Recent studies by Hasanuzzaman et al. (2021) and Bulgari et al. (2019) have highlighted the importance of bio-stimulants, such as sugar beetroot extract, in enhancing plant tolerance to abiotic stress, particularly salinity. SBE and other plant bio-stimulants are acknowledged for their capacity to improve nutrient assimilation, modulate physiological processes, and mitigate the adverse effects of stress, thereby enhancing plant growth and resilience (Bulgari et al., 2019). SBE has been shown to effectively improve salt tolerance in a variety of crops by improving osmotic balance, reducing ion toxicity, and enhancing antioxidant defenses (Mäck et al., 2007). Glycine betaine, vitamins, and essential nutrients are prevalent in SBE. This investigation investigates the potential of SBE as a foliar bio-stimulant to enhance the salinity tolerance of wheat. The research is focused on the cultivation of two wheat varieties, Anaaj-17 and Gandum-1, in hydroponic systems that are either saline or non-saline. The objective of the investigation is to evaluate the effectiveness of SBE in reducing the adverse effects of salinity on the growth and development of wheat by employing it at varying concentrations. This study's findings have the potential to provide a valuable perspective on sustainable agricultural practices and a potential strategy for improving crop resilience in saline environments.

MATERIALS AND METHODS

The study investigated the effects of sugar beetroot extract (SBE) on wheat (*Triticum aestivum* L.) in hydroponic cultures that were either saline or non-saline. SBE, a natural bio-stimulant, was applied as a foliar treatment to wheat during the vegetative phase. The experiment was conducted at Ghazi University in Dera Ghazi Khan. Fresh sugar beetroot roots that were collected locally were processed into a liquid and diluted for treatment at four concentrations.

For nutrient supply, the hydroponic apparatus employed Hoagland solution (half-strength). Wheat varieties Anaj-17 and Gandum-1 were subjected to testing in both saline (10 dSm-1) and non-saline (2 dSm-1) conditions. SBE was administered at concentrations of 0% (control), 10%, 20%, and 30%. Four days following the transplantation of homogeneous seedlings into silver containers containing Hoagland solution, salt stress was introduced.

In response to the application of SBE three times following the application of salt, data on shoot and root length, fresh and desiccated weights, potassium and sodium content in leaves and roots, chlorophyll content (SPAD value), and relative water content (RWC) were collected. The contents of potassium and sodium were determined using a flame photometer after the plant material was digested with a diacid mixture. The chlorophyll content was measured using the SPAD meter, and the RWC was calculated using a standard formula.

The experiment was designed in a completely randomized layout and consisted of three replicates. The statistical analysis was conducted using the ANOVA method, and the Least Significant Difference (LSD) test was implemented to identify significant differences between regimens at a 1% probability level.

The data from the research investigation was acquired and analyzed using the Fisher's analysis of variance (ANOVA) technique. The Least Significant Difference (LSD) Test was employed at a 1% probability level to compare the means of significant treatments (Steel et al., 1997).

RESULTS

Effect of sugar beet extract on root length (cm)

Gandum-1 and Anaaj-17, both wheat varieties, were markedly (p<0.01) reduced in root length by salt stress at EC = 10 dSm-1 in comparison to non-saline conditions (EC = 2 dSm-1). The foliar application of sugar beetroot extract (SBE) resulted in an increase in root length in both saline and non-saline hydroponic conditions. Under SBE-30%, the maximum lengths were measured at 45.73 cm, with SBE-20% and SBE-10% followed by 42.72 cm and 40.72 cm, respectively. The marginal differences observed between the SBE-30% and SBE-20% treatments suggest that while SBE-30% is most effective, SBE-20% may offer a cost-effective alternative with comparable benefits under certain conditions. The minimum length was 39.46 cm as a result of SBE-0%. Anaaj-17 exhibited a greater reduction in root length than Gandum-1 under salt stress, indicating that Gandum-1 is more tolerant to salt.

Table 1. Effect of sugar beet extract (SBE) on root length (cm) of wheat varieties under saline and non-saline hydroponic conditions.

Sugar beet Extract Levels (SBE)	Salinity Levels (S)				(SBE) Means
	S0(2mM)		S1 (100mM)		
	Anaaj-17	Gandum-1	Anaaj-17	Gandum-1	
SBE (0%)	44.49f	45.36e	33.22m	34.78kl	39.46 D
SBE (10%)	45.68e	47.75d	34.45l	35.00k	40.72 C
SBE (20%)	47.45d	49.34c	36.11j	38.00i	42.72 B
SBE (30%)	50.26b	52.00a	39.00h	41.67g	45.73 A
Salinity Means	47.79 A		36.53 B		

Significant difference where p<0.01

Effect of sugar beet extract on shoot length (cm)

Under salt stress at EC = 10 dSm-1, the shoot length of both wheat varieties, Gandum-1 and Anaaj-17, was significantly reduced (p<0.01) in comparison to non-saline conditions (EC = 2 dSm-1). Under hydroponic conditions, the longest shoots were observed at SBE-30% (57.64 cm), followed by SBE-20% (54.97 cm) and SBE-10% (51.92 cm). The foliar application of sugar beetroot extract (SBE) resulted in an increase in shoot length in both saline and non-saline environments. The shortest stalks were obtained with SBE-0% (50.64 cm). Under salt stress, Anaaj-17 demonstrated a larger reduction in shoot length than Gandum-1, which implies that Gandum-1 has a greater tolerance to salt.

Table 2. Effect of sugar beet extract (SBE) on shoot length (cm) of wheat varieties under saline and non-saline hydroponic conditions.

Sugar beet Extract Levels (SBE)	Salinity Levels (S)				(SBE) Means
	S0(2mM)		S1 (100mM)		
	Anaaj-17	Gandum-1	Anaaj-17	Gandum-1	
SBE (0%)	55.66h	58.66f	43.67o	44.57n	50.64 D
SBE (10%)	57.35g	59.34e	45.00n	46.00m	51.92 C
SBE (20%)	60.44d	62.00c	48.44l	49.00k	54.97 B
SBE (30%)	63.00b	65.00a	50.56j	52.00i	57.64 A
Salinity Means	60.18 A		47.40 B		

Significant difference where p<0.01

Effect of sugar beet extract on root fresh weight (g)

The fresh root weight of both wheat cultivars, Gandum-1 and Anaaj-17, was substantially (p<0.01) reduced by salt stress at EC = 10 dSm-1 in comparison to non-stress conditions (EC = 2 dSm-1). This is demonstrated in Table 3. In both saline and non-saline hydroponic conditions, the root weight was enhanced by the foliar application of sugar beetroot extract (SBE). The highest weight was observed under SBE-30% (22.37 g), followed by SBE-20% (19.03 g) and SBE-10% (17.16 g). SBE-0% yielded the lowest weight (16.08 g). Gandum-1 is salt-tolerant, while Anaaj-17 is salt-sensitive, as evidenced by the fact that Anaaj-17 experienced a significant reduction in root weight under salt stress.

Table 3. Effect of sugar beet extract (SBE) on root fresh weight (g) of wheat varieties under saline and non-saline hydroponic conditions.

Sugar beet Extract Levels (SBE)	Salinity Levels (S)				(SBE) Means
	S0(2mM)		S1 (100mM)		
	Anaaj-17	Gandum-1	Anaaj-17	Gandum-1	
SBE (0%)	19.54h	20.87f	11.68p	12.24o	16.08 D
SBE (10%)	20.64g	21.69e	12.86n	13.45m	17.16 C
SBE (20%)	22.43d	23.68c	14.57l	15.46k	19.03 B
SBE (30%)	25.51b	27.68a	17.44j	18.87i	22.37 A
Salinity Means	22.75A		14.57B		

Significant difference where p<0.01

Effect of sugar beet extract on shoot fresh weight (g)

The results suggest that salt stress at EC = 10 dSm-1 significantly (p<0.01) reduced the fresh shoot weight of both wheat cultivars, Gandum-1 and Anaaj-17, in comparison to non-stress conditions (EC = 2 dSm-1). The foliar application of sugar beetroot extract (SBE) in both cultivars resulted in a statistically significant increase in shoot weight in both saline and non-saline hydroponic conditions. The highest discharge weight (46.28 g) was observed with SBE-30%, followed by SBE-20% (43.80 g) and SBE-10% (41.13 g). Under SBE-0%, the lowest weight was recorded at 38.87 g. While Gandum-1 exhibits a higher level of salt tolerance, Anaaj-17 exhibited a greater reduction in shoot weight under salt stress, indicating that it is more salt-sensitive.

Table 4. Effect of sugar beet extract (SBE) on shoot fresh weight (g) of wheat varieties under saline and non-saline hydroponic conditions.

Sugar beet Extract Levels (SBE)	Salinity Levels (S)				(SBE) Means
	S0(2mM)		S1 (100mM)		
	Anaaj-17	Gandum-1	Anaaj-17	Gandum-1	
SBE (0%)	42.65h	46.59f	32.89p	33.35o	38.87 D
SBE (10%)	45.58g	48.74d	34.35n	35.88m	41.13 C
SBE (20%)	47.88e	50.88b	37.68l	38.79k	43.80 B
SBE (30%)	50.69c	53.44a	39.56j	41.44i	46.28 A
Salinity Means	48.30A		36.74B		

Significant difference where p<0.01

Effect of sugar beet extract on root dry weight (g)

The data indicate that salt stress at EC = 10 dSm-1 significantly reduced the dried root weight of both wheat cultivars, Gandum-1 and Anaaj-17 (p<0.01), in comparison to non-stress conditions (EC = 2 dSm-1). The foliar application of sugar beetroot extract (SBE) resulted in an increase in the desiccated root weight under both saline and non-saline hydroponic conditions. SBE-30% treated plants exhibited the highest dried root weight (8.86 g), with SBE-20% (6.16 g) and SBE-10% (4.19 g) following in that order. The dried root weight of the individuals who were treated with SBE-0% was the lowest at 3.10 g. The desiccated root weight of Anaaj-17 was substantially reduced in comparison to that of Gandum-1 under salt stress, suggesting that Anaaj-17 is more salt-sensitive, whereas Gandum-1 demonstrates a higher level of salt tolerance.

Table 5. Effect of sugar beet extract (SBE) on root dry weight (g) of wheat varieties under saline and non-saline hydroponic conditions.

Sugar beet Extract Levels (SBE)	Salinity Levels (S)				(SBE) Means
	S0(2mM)		S1 (100mM)		
	Anaaj-17	Gandum-1	Anaaj-17	Gandum-1	
SBE (0%)	3.34m	4.66k	1.47p	2.95n	3.10 D
SBE (10%)	4.68j	5.24h	2.88o	3.98l	4.19 C
SBE (20%)	6.77f	7.34d	4.97i	5.57g	6.16 B
SBE (30%)	9.88b	10.39a	6.95e	8.22c	8.86 A
Salinity Means	6.54A		4.62B		

Significant difference where p<0.01

Effect of sugar beet extract on shoot dry weight (g)

The results indicate that salt stress at EC = 10 dSm-1 significantly (p<0.01) reduced the dried shoot weight of both wheat cultivars, Gandum-1 and Anaaj-17, in comparison to non-saline conditions (EC = 2 dSm-1). The foliar application of sugar beetroot extract (SBE) in both saline and non-saline hydroponic conditions was shown to enhance the dried shoot weight. The dry shoot weight that was recorded was the highest at SBE-30% (10.64 g), followed by SBE-20% (7.93 g) and SBE-10% (6.14 g). The lowest weight was recorded at SBE-0% (5.09 g). Gandum-1 demonstrates a greater tolerance to salt stress, whereas Anaaj-17 exhibited a more pronounced reduction in desiccated shoot weight under salt stress, indicating that it is more salt-sensitive.

Table 6. Effect of sugar beet extract (SBE) on shoot dry weight (g) of wheat varieties under saline and non-saline hydroponic conditions.

Sugar beet Extract Levels (SBE)	Salinity Levels (S)				(SBE) Means
	S0(2mM)		S1 (100mM)		
	Anaaj-17	Gandum-1	Anaaj-17	Gandum-1	
SBE (0%)	5.46m	6.72j	3.44p	4.73n	5.09D
SBE (10%)	6.81i	7.32h	4.56o	5.90k	6.14C
SBE (20%)	8.50f	9.70d	5.77l	7.78g	7.93B
SBE (30%)	10.83c	11.79a	8.98e	10.97b	10.64A
Salinity Means	8.39A		6.51B		

Significant difference where p<0.01

Effect of sugar beet extract on root shoot ratio

In comparison to non-stress conditions (EC = 2 dSm-1), the data indicate that salt stress at EC = 10 dSm-1 significantly reduced the root-to-shoot ratio in both wheat cultivars, Gandum-1 and Anaaj-17 (p<0.01). In order to enhance the root-to-shoot ratio in both stress and non-stress hydroponic environments, sugar beetroot extract (SBE) was administered foliarly. The ratio was highest at SBE-30% (0.80), followed by SBE-20% (0.79) and SBE-10% (0.78). In the absence of SBE application (SBE-0%), the lowest ratio was observed at 0.77. Gandum-1 exhibited a higher salt tolerance than Anaaj-17, as evidenced by the latter's greater reduction in root-to-shoot ratio under saline conditions. This suggests that Anaaj-17 is more salt-sensitive.

Effect of sugar beet extract on chlorophyll content (SPAD Value)

The data suggest that salt stress at EC = 10 dSm-1 significantly (p<0.01) reduced the chlorophyll content of both wheat varieties, Anaaj-17 and Gandum-1, in comparison to non-saline conditions (EC = 2 dSm-1). The foliar application of sugar beetroot extract (SBE) was shown to increase chlorophyll levels in both saline and non-saline hydroponic environments. The chlorophyll content with the highest value (40.96) was observed under SBE-30%, followed by SBE-20% (38.59) and SBE-10% (36.08). The lowest value (36.03) was observed under SBE-0%. The chlorophyll content of Anaaj-17 decreased more significantly than that of Gandum-1 during salt stress, indicating that it is more susceptible to salt. In contrast, Gandum-1 has a higher tolerance to salt.

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Table 7. Effect of sugar beet extract (SBE) on root shoot ratio of wheat varieties under saline and non-saline hydroponic conditions.

Sugar beet Extract Levels (SBE)	Salinity Levels (S)				(SBE) Means
	S0(2mM)		S1 (100mM)		
	Anaaj-17	Gandum-1	Anaaj-17	Gandum-1	
SBE (0%)	0.79b	0.77e	0.76f	0.77e	0.77 D
SBE (10%)	0.79c	0.80a	0.76f	0.77f	0.78 C
SBE (20%)	0.78d	0.79c	0.74g	0.77e	0.79 B
SBE (30%)	0.79c	0.80a	0.77e	0.80a	0.80 A
Salinity Means	0.79 A		0.76 B		

Significant difference where $p<0.01$

Table 8. Impact of Sugar Beet Extract (SBE) on chlorophyll content (SPAD value) in wheat varieties under saline and non-saline hydroponic conditions.

Sugar beet Extract Levels (SBE)	Salinity Levels (S)				(SBE) Means
	S0(2mM)		S1 (100mM)		
	Anaaj-17	Gandum-1	Anaaj-17	Gandum-1	
SBE (0%)	41.90h	42.46g	25.33p	26.44o	34.03 D
SBE (10%)	43.77f	44.57e	27.44n	28.54m	36.08 C
SBE (20%)	45.79d	47.47c	29.57l	31.56j	38.59 B
SBE (30%)	48.79b	50.47a	31.26k	33.34i	40.96 A
Salinity Means	45.65 A		29.18 B		

Significant difference where $p<0.01$

Effect of sugar beet extract on relative water contents (%)

The data indicate that salt stress at EC = 10 dSm-1 significantly reduced the relative water content (RWC) of both wheat cultivars, Gandum-1 and Anaaj-17, by a significant margin ($p<0.01$) in comparison to non-stress conditions (EC = 2 dSm-1). The foliar administration of sugar beetroot extract (SBE) resulted in an increase in root water content (RWC) in both saline and non-saline hydroponic environments. The highest RWC (87.40%) was achieved under SBE-30%, with SBE-20% (84.31%) and SBE-10% (81.82%) following in that order. SBE-0% yielded the lowest RWC (80.12%). Anaaj-17 demonstrated a more substantial reduction in RWC than Gandum-1 under salt stress, suggesting that it is more salt-sensitive, whereas Gandum-1 exhibits a higher level of salt tolerance.

Table 9. Impact of sugar beet extract (SBE) on relative water content (%) in wheat varieties under saline and non-saline hydroponic conditions.

Sugar beet Extract Levels (SBE)	Salinity Levels (S)				(SBE) Means
	S0(2mM)		S1 (100mM)		
	Anaaj-17	Gandum-1	Anaaj-17	Gandum-1	
SBE (0%)	86.45g	88.44f	71.93o	73.67m	80.12 D
SBE (10%)	88.42f	91.34d	72.67n	74.86l	81.82 C
SBE (20%)	90.34e	94.78b	75.77k	76.34j	84.31 B
SBE (30%)	93.24c	97.45a	78.45i	80.44h	87.40 A
Salinity Means	91.31 A		75.52 B		

Significant difference where $p<0.01$

Effect of sugar beet extract on sodium contents in root (m mol g^{-1}dwt^{-1})

The results suggest that salt stress at EC = 10 dSm-1 significantly increased the sodium content in the roots of both wheat cultivars, Anaaj-17 and Gandum-1, in comparison to non-saline conditions (EC = 2 dSm-01) (p<0.01). However, the foliar application of sugar beetroot extract (SBE) in saline hydroponic conditions resulted in a substantial reduction in the root sodium levels. The sodium content of SBE-30% was the lowest at 9.69 m mol g-1 dwt-1, followed by SBE-20% (12.16 m mol g-1 dwt-1) and SBE-10% (13.97 m mol g-1 dwt-1). The maximum content was found in SBE-0% (16.03 m mol g-1 dwt-1). Under salt stress, the accumulation of sodium in the roots of Anaaj-17 was greater than that of Gandum-1. This indicates that Gandum-1 is more salt-tolerant, while Anaaj-17 is more salt-sensitive.

Table 10. Influence of sugar beet extract (SBE) on sodium content (m mol $g^{-1}dwt^{-1}$) in root of wheat varieties under saline and non-saline hydroponic conditions.

Sugar beet Extract Levels (SBE)	Salinity Levels (S)				(SBE) Means
	S0(2mM)		S1 (100mM)		
	Anaaj-17	Gandum-1	Anaaj-17	Gandum-1	
SBE (0%)	14.66f	13.73g	18.34a	17.34b	16.03 A
SBE (10%)	12.34i	11.34k	16.64c	15.57d	13.97 B
SBE (20%)	10.56l	9.57m	14.76e	13.73h	12.16 C
SBE (30%)	8.77n	7.23o	12.22j	10.55l	9.69 D
Salinity Means	11.03 B		14.89 A		

Significant difference where p<0.01

Effect of sugar beet extract on sodium contents in Leaf (m mol $g^{-1}dwt^{-1}$)

The results presented in Table 11 indicate that both wheat varieties Anaaj-17 and Gandum-1 exhibited higher sodium levels in their leaves when exposed to salt stress at EC = 10 dSm-1, in comparison to non-saline conditions at EC = 2 dSm-1. When SBE was administered as a foliar spray, the salt level in the foliage of both wheat varieties that were cultivated under hydroponic conditions was found to decrease. The leaf sodium contents of plants exposed to SBE-30% were the lowest (7.32 m mol g-1dwt-1), followed by SBE-20% (8.66 m mol g-1dwt-1) and SBE-10% (10.16 m mol g-1dwt-1). In SBE-0%, the leaf exhibited the maximum sodium content (11.80 m mol g-1dwt-1). When subjected to saline conditions, Annaj-17 leaves exhibit a higher concentration of sodium than Gandum-1 leaves. As a result, it was determined that Annaj-17 is a salt-sensitive variety, while Gandum-1 is salt-tolerant.

Table 11. Influence of sugar beet Extract (SBE) on sodium content (m mol $g^{-1}dwt^{-1}$) in leaf of wheat varieties under saline and non-saline hydroponic conditions.

Sugar beet Extract Levels (SBE)	Salinity Levels (S)				(SBE) Means
	S0(2mM)		S1 (100mM)		
	Anaaj-17	Gandum-1	Anaaj-17	Gandum-1	
SBE (0%)	9.40g	7.55k	15.90a	14.33b	11.80 A
SBE (10%)	8.23j	6.76m	13.44c	12.21d	10.16 B
SBE (20%)	7.12l	5.22n	11.53e	10.76f	8.66 C
SBE (30%)	6.76m	4.51o	9.22h	8.77i	7.32 D
Salinity Means	6.94 B		12.02 B		

Significant difference where p<0.01

Effect of sugar beet extract on potassium contents in root (m mol $g^{-1}dwt^{-1}$)

The results showed that the potassium level in the root of both wheat cultivars Anaaj-17 and Gandum-1 was significantly (p<0.01) reduced by salt stress at EC = 10 dSm-1 in comparison to non-saline conditions at EC = 2 dSm-1. The potassium level in the roots was elevated when SBE was administered as a foliar application to both wheat cultivars. At the same time, they were grown under stress and non-stress hydroponic conditions. The maximum potassium contents in the roots of plants exposed to SBE-30% were 77.22 m mol g-1dwt-1, followed by SBE-20% (74.02 m mol g-1dwt-1) and SBE-10% (71.57 m mol g-1dwt-1). The roots of SBE-0% contained the lowest potassium content (69.72 m mol g-1dwt-1). When exposed to saline conditions, Annaj-17 demonstrated a lower potassium content than Gandum-1. Annaj-17 is salt-sensitive, while Gandum-1 is salt-tolerant.

Table 12. Influence of sugar beet extract (SBE) on potassium content (m mol $g^{-1}dwt^{-1}$) in root of wheat varieties under saline and non-saline hydroponic conditions.

Sugar beet Extract Levels (SBE)	Salinity Levels (S)				(SBE) Means
	S0(2mM)		S1 (100mM)		
	Anaaj-17	Gandum-1	Anaaj-17	Gandum-1	
SBE (0%)	69.75j	71.33h	67.55l	70.24i	69.72 D
SBE (10%)	71.41g	73.56e	68.76k	72.56f	71.57 C
SBE (20%)	73.57e	76.77b	71.32h	74.44d	74.02 D
SBE (30%)	76.77b	80.78a	74.56c	76.77b	77.22 A
Salinity Means	74.24 A		72.03B		

Significant difference where p<0.01

Effect of sugar beet extract on potassium contents in leaf (m mol $g^{-1}dwt^{-1}$)

In comparison to the non-saline condition at EC = 2 dSm-1, the data showed that the potassium content in the leaf of both wheat varieties Gandum-1 and Anaaj-17 was significantly (p<0.01) reduced by salt stress at EC = 10 dSm-1. The potassium content in the foliage of both wheat cultivars that were grown under stress and non-stress hydroponic conditions was observed to increase when SBE was administered as a foliar spray. The leaf potassium contents of plants exposed to SBE-30% were the highest (77.62 m mol g-1dwt-1), followed by SBE-20% (74.83 m mol g-1dwt-1) and SBE-10% (71.65 m mol g-1dwt-1). The leaf had a minimum potassium content of 69.93 m mol g-1dwt-1 in SBE-0%. Under salt stress conditions, Annaj-17 leaves exhibited a lower potassium content than Gandum-1 leaves. Annaj-17 is salt-sensitive, while Gandum-1 is salt-tolerant.

Table 13. Influence of sugar beet extract (SBE) on potassium content (m mol $g^{-1}dwt^{-1}$) in leaf of wheat varieties under saline and non-saline hydroponic conditions.

Sugar beet Extract Levels (SBE)	Salinity Levels (S)				(SBE) Means
	S0(2mM)		S1 (100mM)		
	Anaaj-17	Gandum-1	Anaaj-17	Gandum-1	
SBE (0%)	71.84j	74.45f	65.57o	67.87m	69.93 D
SBE (10%)	73.45g	76.88d	66.85n	69.45l	71.65 C
SBE (20%)	76.87d	79.90b	69.67k	72.88h	74.83 B
SBE (30%)	79.34c	82.96a	72.22i	75.97e	77.62 A
Salinity Means	76.96 A		70.06 B		

DISCUSSION

The results of this experiment, which was conducted under hydroponic conditions of stress and non-stress, offer valuable insights into the mechanism of action of sugar beetroot extract (SBE) as a natural bio-stimulant. The findings of this investigation indicate that the foliar application of SBE may be a viable approach to reducing salt stress in cereals, as it enhances both morphological and biochemical parameters in the wheat varieties Gandum-1 and Anaaj-17.

The potential of the extract to mitigate the adverse effects of salinity is emphasized by the increase in root and stem lengths in both wheat varieties by SBE, particularly under saline conditions. The primary cause of the reduction in root and shoot lengths that is typically observed in response to salinity is osmotic stress, which impedes cell elongation and division (Yassin et al., 2019). However, the administration of SBE seems to alleviate these effects, as demonstrated by the longer root and shoot lengths in both Gandum-1 and Anaaj-17 (Tables 1 and 2). These findings are in accordance with prior research, which has demonstrated that similar bio-stimulants, such as glycine betaine, can increase the root and branch lengths of salt-stressed crops, such as eggplant and okra (Abbas et al., 2010; Habib et al., 2012).

The enhancement of root and shoot biomass (fresh and dried weights) further substantiates the role of SBE in fostering plant growth under stress conditions. In response to salt stress, biomass accumulation is known to be reduced by ionic toxicity and osmotic imbalance, which impede nutrient assimilation and photosynthesis (Basit et al., 2020). However, the fresh and dried weights of roots and seedlings showed significant increases in the SBE-treated plants (Tables 3, 4, 5, and 6). This enhancement is most likely due to the presence of bioactive compounds in SBE, such as ascorbic acids, glycine betaine, vitamin E, and amino acids, which are recognized for their capacity to improve photosynthesis and, as a result, biomass production in stressful conditions (Abdelmotlb et al., 2019). These results corroborate the findings of previous studies on green beans, which showed that the foliar application of glycine betaine increased the biomass of roots and seedlings under salt stress (Abdelmotlb et al., 2019).

The root-to-shoot ratio has a substantial impact on the adaptability of a plant to duress. Regardless of whether the conditions were saline or non-saline, the SBE administration in this study significantly improved the root-to-shoot ratio of both wheat varieties (Table 7). This suggests that SBE enhances the allocation of resources to root development, a process that is critical for the assimilation of water and nutrients in saline environments (Rady et al., 2018). The plant's increased root-to-shoot ratio also indicates that it is more resilient to stress, as it can investigate a broader soil volume in search of water and nutrients, thereby increasing its chances of survival in challenging environments.

The SBE application significantly impacted the sodium and potassium content in roots and foliage, which are critical parameters under salt stress, as evidenced by the biochemical analysis. The accumulation of sodium in plant tissues is detrimental under salt stress, as it disrupts cellular homeostasis and causes ionic imbalance (Jiang et al., 2017). In this investigation, SBE significantly diminished the sodium content of the roots and foliage of the wheat varieties (Tables 10 and 11). This reduction is crucial because it prevents sodium-induced toxicity, which can impede the metabolic activities of plant cells (Abbas et al., 2010). The results are consistent with the findings of other studies that have shown that the sodium content in the roots and stems of eggplant and other crops that are susceptible to salt stress is reduced by the foliar application of glycine betaine (Abdelmotlb et al., 2019; Noman et al., 2018).

In contrast, potassium, a nutrient that is essential for the growth and stress tolerance of plants, demonstrated a significant increase in SBE-treated plants (Tables 12 and 13). In salt-stressed plants, potassium assimilation is frequently inhibited by elevated sodium levels, which can lead to a deficiency that can compromise plant growth and photosynthetic efficiency, as per Basit et al. (2020). The foliar application of SBE may enhance the plant's ion absorption mechanism and repel sodium ions at the root level, thereby increasing potassium uptake. The preservation of ionic equilibrium and the maintenance of the plant's physiological functions during periods of duress may be facilitated by SBE, as evidenced by the increase in potassium content, notably in the salt-tolerant variety Gandum-1 (Habib et al., 2012).

The chlorophyll content is a critical indicator of photosynthetic capacity, and its reduction in response to salt stress is well-documented (Jiang et al., 2017). Salt stress typically disrupts magnesium absorption and causes oxidative injury to chloroplasts, thereby impairing chlorophyll synthesis. Nevertheless, the administration of SBE in this study significantly increased the chlorophyll content of both wheat varieties, irrespective of whether the conditions were saline or non-saline (table 8). The increase in chlorophyll content suggests that SBE may have the potential to mitigate the oxidative stress caused by salinity, potentially through the action of antioxidants such as ascorbic acid and tocopherols that are present in the extract (Giri, 2011; Yildirim et al., 2015). These findings are in accordance with previous research that has shown the potential of bio-stimulants, such as glycine betaine, to enhance the chlorophyll content and photosynthetic efficacy of salt-stressed plants (Yildirim et al., 2015).

Furthermore, the increase in chlorophyll content is linked to an increase in photosynthetic efficiency, which is crucial for the growth of plants and the production of biomass. The salt-tolerant variety Gandum-1 demonstrated superior growth performance under duress and higher chlorophyll content in comparison to Anaaj-17. as a consequence. This emphasizes the potential of SBE to improve the resistance of cereals to salinity.

The relative water content (RWC) of a plant has a substantial impact on its water status and its ability to maintain turgor pressure in the presence of duress. Table 9 indicates that the administration of SBE significantly improved RWC in both wheat varieties under saline conditions in this study. The improvement in RWC suggests that SBE plays a critical role in the preservation of cellular hydration and osmotic equilibrium, which are essential for the maintenance of metabolic activities in the presence of stress (Rady et al., 2018). The elevated RWC in SBE-treated plants may be attributed to the osmoprotective compounds in the extract, which facilitate the retention of water within the cells and the reduction of water loss through transpiration (Abdelmotlb et al., 2019).

The decrease in membrane permeability, as demonstrated by the diminished electrolyte leakage, further substantiates the role of SBE in enhancing membrane integrity under salt stress. The preservation of cellular integrity and the prevention of the loss of essential ions and metabolites are contingent upon membrane stability. The SBE-treated plants demonstrated a significant reduction in electrolyte leakage in comparison to the control, suggesting that the extract plays a critical role in protecting the plasma membrane from oxidative damage and ensuring its functional integrity (Yildirim et al., 2015). These findings are consistent with previous research conducted on mung bean and onion plants, which showed that bio-stimulants, including glycine betaine, can enhance membrane integrity and reduce electrolyte leakage in response to salt stress (Abdelmotlb et al., 2019; Rady et al., 2018).

CONCLUSION

This study illustrated that wheat plants could be protected from the adverse effects of salt stress by utilising a variety of concentrations of sugar beetroot extract as a natural bio-stimulant. As opposed to SBE-20%, SBE-10%, and SBE-0%, the research study demonstrated that the most effective and optimal treatment for wheat under salt stress in hydroponic conditions was a 30% concentration of SBE. The foliar application of SBE led to a significant increase in the following: root length, shoot length, root dry weight, shoot dry weight, root shoot ratio, potassium, chlorophyll, relative water contents, and the reduction of Na+ contents from the root and Leaf. After considering all of the factors, it was determined that the variety Gandum-1 is more salt-tolerant than Anaaj-17 under NaCl stress. It is recommended that farmers apply SBE at a 30% concentration as a foliar spray to improve wheat growth in saline environments. This strategy provides a practical approach to managing soil salinity and improving crop yield.

AUTHOR CONTRIBUTIONS

All authors contributed equally to this research.

COMPETING OF INTEREST

The authors declare no competing interests.

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