Middle East Journal of Agriculture Research
Volume: 12 | Issue: 04| Oct. – Dec. | 2023

EISSN: 2706-7955 ISSN: 2077-4605
DOI: 10.36632/mejar/2023.12.4.45
Journal homepage: www.curresweb.com
Pages: 676-683

Improving the growth, yield and quality of beetroot (*Beta vulgaris* L.) by applying a potassium-solubilizing bacteria and foliar spray of seaweed extract

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Received: 05 Oct. 2023 **Accepted:** 10 Nov. 2023 **Published:** 15 Nov. 2023

ABSTRACT

Potassium dissolving Bacteria possess the ability to solubilize insoluble forms of potassium present in the soil, converting them into a soluble form that plants can easily uptake and utilize. As well as seaweed extract contains a wide range of nutrients such as nitrogen, potassium, phosphorus, magnesium, and trace elements like iron, zinc, manganese, and copper. These nutrients are essential for plant growth and are often easily absorbed by plants. The experiment was carried out during the two seasons of 2021 and 2022 to study the effect of using microbial potassium solubilizers (Potasiomag) which contains *Bacillus circulans* mixed with seeds at a rate (0, 600g, 900g/ seeds) and foliar application of seaweed extract (Kelpak) at a rate of (0, 2 and 4 cm^3/L) on plant growth, total yield, and its components, as well as the root quality of beetroot compared with control. The results indicated that the higher rate of Potasiomag 900g/seeds with Kelpak at a rate 4cm^3/L as a foliar application gave a strong beetroot plant and with a good quality roots.

Keywords: Beetroot, *Beta vulgaris* L, growth, yield, potassium-solubilizing bacteria (Potasiomag), seaweed extract (Kalpak),

1. Introduction

Beetroot is one of the major root vegetables grown throughout the world and is mainly consumed as a salad vegetable, though the leaves can also be eaten as spinach (Lock *et al.* 2004). Beetroots are biennials although they are usually grown as annuals producing green tops and swollen roots during the first growing season. Beetroots are vegetables with worldwide distribution, and their production reaches 269 million tonnes. The beetroot (*Beta vulgaris* L.), locally known as Shamandar, is a vegetable plant and belongs to family Amaranthaceae (Thompson, 2001). Beetroot is a good source of minerals, carbohydrates, protein and it has high levels of vitamin B1 and micro nutrients (Cerne & Vrhovnik, 1999). Considered as a vegetable, beetroot may have many positive influences on human health (Cerne & Vrhovnik, 1999). Beetroot juice is today advocated as a stimulant for the immune system, as well as a cancer preventative and it has long been considered beneficial to the blood, heart and the digestive system (Nottingham, 2004).

Red beetroots are becoming more and more important vegetable nowadays due to their many positive nutritional and physiological properties. In addition to its significant potassium and magnesium content, it is associated with low sodium concentrations, which have a beneficial effect on the ionic balance of the human body. The betacyanins in it reduce oxidative stress and the harmful effects of free radicals, have antibacterial and antiviral properties, inhibit the proliferation of cancer cells, and are involved in the prevention of cardiovascular disease. The plant itself can occur almost anywhere, as it is easy to grow and requires no additional care other than hoeing or thinning (Ceclu and Nistor 2020)

Potassium solubilizing Bacteria *(Bacillus circulans)*, these bacteria facilitate its absorption by plant roots. This increases the efficiency of potassium uptake, ensuring that plants have an adequate

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supply of this essential nutrient. Moreover, Biofertilizer competence scours the environment and promotes the profitable capability of land by reducing chemical fertilizer consumption (Pham, 2004, Osman, 2007). In order to minimize environmental contamination from chemical fertilizer enforcement and avoid plant-to-root disease, biofertilizer enforcement was also required (Rizk and Shafeek, 2000).

Potassium plays an important role in the advancement of enzyme performance and promotes the translocation of absorbance and protein structure. Singh *et al.* (1989) indicated that the vegetative growth of vegetables plant and minerals uptake was increased with growing the level of N, P and K fertilizers.

The inoculation with potassium dissolving bacteria led to improved plant growth and yield. (Abou El-Magd *et al.,* 2014) as well as potassium-dissolving bacteria recorded higher numbers in the root zone when the plants were sprayed with bio-fertilizers. On the other hand, potassium-solubilizing bacteria have the benefit of assisting in increasing the number of soil microorganisms, particularly in the root rhizosphere's surface stratum, which provides materials for plant growth. This enhances the availability of potassium to plants, which is vital for their growth and development (Awad, 2002). Also, they added that, Bacteria that dissolve potassium assemble the necessary elements to extract insoluble potassium in soluble forms. Furthermore, Abo-Sedera *et al.,* (2012) found that utilized bio-fertilizers increased macro mineral in plants. Also, bio fertilizers combined with mineral fertilizer at recommended dose acquired the highest amounts of plant growth as well as total yield advantage.

Hassan, (2015) reported that application of bio-enriched treatments increased vegetative growth of garlic plants i.e. plant length, number of leaves per plant, fresh and dry weight of whole plant as well as chemical composition and yield of plants.

Many investigators indicated that application of potassium dissolving bacteria with combine minerals or organic fertilizers led to get better vegetables growth, yield and quality of several economic vegetables (Abou El-Magd, *et al.,* 2012 and 2014, Pratap, *et al.,* 2012; Abdel-Razzak, *et al.,* 2013 and Shafeek, *et al.,* 2016), Onion (Shafeek, *et al.,* 2012 and Banjare, *et al.,* 2015), Potato (Osman, 2007) and Legumes (Shafeek, *et al.,* 2004 and 2014) and beet root (Abdel - Lateef, 2018; Ferweez and Abd El-Monem 2018 and Shafeek, *et al.,* 2019).

Seaweed extracts using as foliar sprays for several crops because the extract contains growth promoting hormones (IAA and IBA), cytokinins, trace elements (Fe, Cu, Zn, Co, Mo, Mn and Ni) as well as vitamins and amino acids (Zodape *et al.* 2011). Abdel-Mawgoud *et al.* (2010) found that applying seaweed extract increased different growth parameters and yield on watermelon. In the same respect, Shehata *et al.,* (2011) on Celeriac plants, Fawzy *et al.,* (2012) on Chinese garlic and Hernández *et al.,* (2013) reported that foliar spraying of seaweed extract gave the highest values of vegetative growth, yield and its quality. In addition, Shabana *et al.,* (2015) indicated that foliar spraying of seaweed extract resulted in the highest values of vegetative growth, yield, and fruit quality. However, Ghurbat (2013) on sweet pepper plants reported that spraying seaweed extract led to positive significant difference in plant height(cm), leaves chlorophyll content and total yield as well as fruit diameter, fruit length, fruit dry weight, TSS %, Vitamin C, fruit weight, yield per plant and total yield as compared to untreated plants. Whereas, foliar application with sprayed concentrations especially 0.75 and 1.00 ml seaweed extract / L induced significant promoting effects on vegetative growth and yield characters as well as induced favorable changes in seed quality and profile of protein pattern of chickpea plants (Boghdady, *et al.,* 2016).

The main objective of this study was to improve the growth, yield and quality response of beetroot by using a potassium-solubilizing bacteria and foliar spray of seaweed extract.

2. Materials and Methods

Two field experiments were carried out at a privet farm in Monofeya Governorate, Egypt, during the two growing seasons of 2021 and 2022 in order to study the effect of mixing seeds of beetroot with potassium-solubilizing bacteria (Potasiomag) contain contain *Basillus circulans* with foliar application of different levels of seaweed extract (Kelpak) on plant growth, total yield, and its components, as well as the root quality of beetroot plants.

The experimental trails were conducted in clay loam soil using a drip irrigation system. The chemical analysis and physical properties of the experimental soil are shown in Table 1.

Table 1: The physical and chemical properties of the experimental soil.

Physical properties											
Course Sand %		**Fine sand %**		**Silt %**			**Clay %**		**Soil Texture**		
8.6		24.4		23.9			43.1		Clay loam		
Chemical analysis											
Ec dSm^{-1}	**pH 1:2.5**	**$CaCO_3$ (%)**	**OM (%)**	**Soluble cations meq/100gm soil**				**Soluble anions meq/100 gm soil**			
				Na	**K**	**Ca**	**Mg**	**CO_3**	**HCO_3**	**Cl**	**SO_4**
0.58	7.88	3.30	0.04	3.53	0.22	0.80	1.25	0.0	1.75	2.50	1.55
Total macro-nutrients											
N				**P**					**K**		
1.54				0.22					1.25		

Seeds of beetroot cv. AlShamah hybrid F1 were sown on November 24th and 26th in 2021 and 2022, respectively. The applying of Potasiomag to the seeds of beetroot was prepared as the written instructions on the bag as follows: A gum solution is prepared by dissolving 50 grams of Arabic gum in 400 ml of hot water, then leaving it to cool slightly, then mixing the components of the bag well with the seeds, and then planting is done directly. Potasiomag was used at a rate of 0, 600g and 900g/seeds and seaweed extract (Kelpak) at a rate of (0, 2 and 4 cm^3/l) were sprayed after 20 days from sowing date, every 15 days intervals for two times.

Phosphorus in the form of superphosphate (15.5% P_2O_5) and Potassium in the form of potassium sulfate (48% K_2O) were added before planting at the rate of 150 and 100 kg/fed., respectively. Nitrogen fertilizer in the form pf Ammonium sulphate, 20.6% N was added at a rate of 100 kg N /fed. in two equal portions 40 and 60 days from sowing.

The normal agriculture practices for beetroot production under drip irrigation systems were followed according to the recommendations of the Ministry of Agriculture.

The experimental design was split plot design with three replications, where the potassium-solubilizing bacteria (Potasiomag) treatments were assigned in the main plots and seaweed extract (Kelpak) were sprayed randomly within the subplots. The area of experimental plot was 10.5 m^2. Every plot consisted of 5 dripper lines 3m in length and 0.7m in width.

At the vegetative growth stage, random samples of five plants from each plot were taken 60 days from sowing for determination of plant length (cm), number of leaves per plant as well as, fresh and dry weight (g) of leaves /plant. Also, some physical properties of root (diameter, length and weight) were measured.

The Kjeldahl method was used to measure total nitrogen (Jackson *et al.*, 1973). Additionally, phosphorus was determined according Chapman and Pratt (1978). Whereas, the content of potassium was measured (Brown and Lilland, 1946). TSS % was determined according to AOAC (1975).

All obtained data were subjected to the statistical analysis and means were compared according to LSD at 5% level test described by Gomez and Gomez (1984).

3. Results and Discussion

3.1. Plant growth characters

Data in Table (2) shows the effect of using potassium-solubilizing bacteria (Potasiomag) with different levels as a foliar application of seaweed extract on the vegetative growth of beetroot plants.

The highest rate of (Potasiomag) mixed with seeds had a positive effect on all parameters of vegetative growth, such as plant length (cm), number of leaves, and fresh and dry weight of leaves per plant in both seasons. This may be due to KSB facilitate the solubilization of other nutrients such as phosphorus and micronutrients present in the soil. This improves overall nutrient availability to plants, ensuring better growth and development. These results were harmony with obtained by Leaungvutiviroj, (2010); Abo-Sedera, *et al.* (2012) and Shafeek, *et al*. (2016).

Table (2) showed that spraying with high levels of seaweed extract (4 cm/L) significantly increased the most plant growth parameters expressed as plant height, number of leaves, fresh and dry weight of beetroot plants compared to low level (2 cm/L) and control treatment in both seasons.

It could be concluded that the increase in vegetative growth characteristics caused by seaweed extracts may be due to the fact that seaweed extract contains natural plant growth regulators like auxins,

cytokinins, and gibberellins. These hormones aid in cell division, elongation, flowering, and fruiting, promoting overall plant growth and development. These results agreed with those obtained by El-Moniem and Abd-Allah (2008), Jensen (2004), and Khan *et al.*, 2009).

Concerning the interaction influence, there were insignificant effects on beetroot plant growth characteristics such as plant length, number of leaves per plant, fresh weight, and dry weight of leaves in both seasons (Table 2). The highest amount of these characters were recorded by applying (900 g/seed) with seaweed extract at (4 cm\L.). in both experimental seasons.

Table 2: Effect of potassium-solubilizing bacteria (Potasiomag) with foliar application of seaweed extract (Kelpak) on growth characters of beetroot during 2021 and 2022 seasons.

Potassium-solubilizing bacteria (Potasiomag)	Seaweed foliar spray (cm/L) (Kelpak)	2021 season				2022 season			
		Plant length (cm)	N. of leaves/plant	Weight (g)		Plant length (cm)	N. of leaves/plant	Weight (g)	
				fresh	dry			Fresh	Dry
Without	0	46.67	6.33	64.00	3.63	49.33	5.67	51.67	2.83
	2	52.33	7.67	70.00	3.97	57.00	6.33	55.33	3.50
	4	54.67	8.00	77.33	4.43	64.00	6.33	66.00	4.37
Mean		**51.22**	**7.33**	**70.44**	**4.01**	**56.78**	**6.11**	**57.67**	**3.57**
600g/seeds	0	57.33	7.33	81.00	4.47	54.33	7.33	62.33	2.93
	2	61.67	9.00	93.33	5.33	61.33	7.00	60.33	3.93
	4	63.67	9.33	106.00	6.47	66.67	8.33	70.67	5.57
Mean		**60.89**	**8.56**	**93.44**	**5.42**	**60.78**	**7.56**	**64.44**	**4.14**
900g/seeds	0	60.33	8.33	93.33	5.87	56.00	8.67	71.00	3.60
	2	64.00	9.67	102.00	7.30	64.67	8.33	72.67	4.67
	4	68.33	10.67	115.67	7.93	71.67	10.00	94.00	6.33
Mean		**64.22**	**9.56**	**103.67**	**7.03**	**64.11**	**9.00**	**79.22**	**4.87**
Average	0	54.78	7.33	79.44	4.66	53.22	7.22	61.67	3.12
	2	59.33	8.78	88.44	5.53	61.00	7.22	62.78	4.03
	4	62.22	9.33	99.67	6.28	67.44	8.22	76.89	5.42
LSD 5% levels	Potassium	**3.24**	**0.28**	**4.22**	**0.43**	**2.75**	**1.15**	**2.01**	**0.29**
	Seaweed	**1.39**	**0.46**	**4.71**	**0.30**	**2.05**	**0.58**	**3.01**	**0.27**
	Interaction	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

3.2. Total yield and its components

Table (3) recorded that the applying (Potasiomag) mixed with seeds had highest significant stimulating effects on total yield and its component of beetroot compared with non inoculation seeds (control).

Application of potassium-solubilizing bacteria (Potasiomag) gave the highest total root yield (ton/fed) as well as improved the root characteristics (length, diameter, and weight) in the two studied seasons.

However, the inoculation of seeds with the highest concentration (Potasiomag) at 900g/seeds significantly increased total yield and its component compared low level (600g/seeds) in the first and second seasons, respectively. Generally, KSB help solubilize insoluble potassium in the soil, making it available in a form that plants can easily absorb and utilize. This improves the potassium uptake by the plants, promoting healthy growth. (Abou El-Magd 1979). In addition, improving nutrient uptake, KSB contribute to enhanced plant growth parameters such as shoot and root development, biomass production, and overall vigor. This often results in healthier and more robust plants (El-Sheekh, 1997) on onion and El-Basyouny (2002) and Shafeek, *et al.,* 2016) on garlic plant.

Concerning to the effects of foliar application of seaweed extract (Kelpak) on the total yield of beetroot plant (Table 3), the resulted data showed that all concentration of seaweed extract had an enhancement in total root yield and its components if compared with that plant no sprayed (control).

The presented data revealed that, foliar application of the high level of seaweed extract (4 cm/L) resulted the heaviest root yield (18.86 and 15.93. %**)** in 1st and 2 seasons respectively. The response of root length, diameter and weight to foliar application of seaweed extract nearly followed the same pattern of change which mentioned before. Seaweeds have gained importance as foliar sprays for

several crops because the extract contains growth promoting hormones (IAA and IBA), cytokines, trace elements (Fe, Cu, Zn, Co, Mo, Mn and Ni) as well as vitamins and amino acids (Zodape *et al.* 2011). Also, vitamin C is a product of D-glucose metabolism which affects some nutritional cycle's activity in higher plants and plays an important role in the electron transport system El-Kobisy *et al.,* (2005).

However, seaweed extract intercept free radicals and protect cells from the oxidative damage that leads to aging and disease (Karadeniz *et al*., 2005).

The inoculations seeds by potassium-solubilizing bacteria (Potasiomag) and foliar application of seaweed is offered in (Table 3). However, no significant interaction was obtained on total yield and its component in both seasons of studies. Usually, the inoculations of seeds by highest level of potassium-solubilizing bacteria (Potasiomag) and high concentration of foliar spraying seaweed extract (4 cm/L) generated the biggest total roots yield and its characteristics of beetroot plants.

Potassium-solubilizing bacteria (Potasiomag) play a significant role in enhancing plant growth, nutrient uptake, and overall crop yield and compounds in seaweed extract encourage the development of a healthy root system. Stronger roots enable plants to access more nutrients and water from the soil, leading to better overall growth which reflect on total yield.

Table 3: Effect of potassium-solubilizing bacteria (Potasiomag) with foliar application of seaweed extract (Kelpak) on total yield and its continent of beetroot plant during 2022 and 2023 seasons.

Potassium-solubilizing bacteria (Potasiomag)	Seaweed foliar spray (cm/L) (Kelpak)	2021 season				2022 season			
		Total yield (ton/fed.)	Root weight (g)	Root (cm)		Total yield (ton/fed.)	Root weight (g)	Root (cm)	
				Length	Width			Length	Width
Without	0	2.15	89.93	6.00	4.83	2.14	53.33	5.10	3.77
	2	2.28	102.70	6.67	5.60	2.32	60.00	6.00	4.83
	4	2.46	109.33	7.17	5.83	2.42	70.33	6.67	5.17
Mean		**2.29**	**100.66**	**6.61**	**5.42**	**2.14**	**61.22**	**5.92**	**4.59**
600g/seeds	0	2.17	93.33	6.97	5.43	2.15	64.67	5.93	4.57
	2	2.35	103.00	7.50	6.00	2.35	78.67	7.00	5.63
	4	2.56	107.00	8.17	6.43	2.44	89.00	7.50	6.00
Mean		**2.36**	**102.22**	**7.54**	**5.96**	**2.31**	**77.44**	**6.81**	**5.40**
900g/seeds	0	2.18	103.00	7.57	5.83	2.16	70.67	6.93	5.13
	2	2.54	113.00	8.00	6.20	2.46	84.67	8.00	6.00
	4	2.69	123.00	8.67	7.17	2.62	103.33	8.83	6.80
Mean		**2.48**	**113.00**	**8.08**	**6.40**	**2.41**	**86.22**	**7.92**	**5.98**
Average	0	2.16	95.42	6.84	5.37	2.15	62.89	5.99	4.49
	2	2.39	106.23	7.39	5.93	2.38	74.44	7.00	5.49
	4	2.57	114.22	8.00	6.48	2.49	87.56	7.67	5.99
LSD 5% levels	Potassium	**0.03**	**6.99**	**0.35**	**0.21**	**0.06**	**5.91**	**0.48**	**0.14**
	Seaweed	**0.06**	**3.76**	**0.25**	**0.23**	**0.03**	**3.00**	**0.19**	**0.20**
	Interaction	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

3.3. Chemical root quality

All inoculation of seeds by potassium-solubilizing bacteria (Potasiomag) as shown in (Table 4) had positive effect on increasing of nutritional amounts of dry beetroot compared with control.

It could be concluded that, the inoculation by potassium-solubilizing bacteria (Potasiomag) improving soil health by enhancing nutrient availability. They break down complex compounds, releasing potassium and other nutrients trapped in the soil, making them more accessible to plants. (Tinker, 1984).

However, the potassium-solubilizing bacteria (Potasiomag) may be due to the action aiding potassium uptake, these bacteria can also indirectly promote plant growth by producing growth-promoting substances like phytohormones, siderophores, and organic acids. These substances can stimulate root growth, improve nutrient absorption, and enhance plant resilience against stressors. conclusion are harmonize with those of (Mandhare, *et al.,* 1998; Ali, *et al.,* 2001 and Shafeek, *et al.,* 2016).

The foliar application of seaweed extract (Kelpak) on beetroot found that all concentrations of seaweed extract presented in Table (4) resulted more nutritional values of the percentage of chemical root quality i.e., TSS, N, P and K if compared with control. Moreover, the high concentrations of seaweed extract (4 cm/L) produced elevation roots quality on tissues of beetroot comparison with that plant received the untreated (control).

These results were similar in the two experiments of 2021 and 2022. It could be concluded that this might be attributed to seaweed extract contains a wide range of nutrients such as nitrogen, potassium, phosphorus, magnesium, and trace elements like iron, zinc, manganese, and copper. These nutrients are essential for plant growth and are often easily absorbed by plants (Shehata, *et al.,* 2011; Hernández *et al.,* 2013 and Shabana *et al.,* 2015).

The interaction between potassium-solubilizing bacteria (Potasiomag) and several levels of seaweed extract presented as shown in Table (4) were not significant in both seasons.

Table 4: Effect of potassium-solubilizing bacteria (Potasiomag) with foliar application of seaweed extract (Kelpak) on chemical quality of beetroot during 2022 and 2023 seasons.

Potassium-solubilizing bacteria (Potasiomag)	Seaweed foliar spray (cm/L) (Kelpak)	2021 season %				2022 season %			
		N	P	K	TSS	N	P	K	TSS
Without	0	3.53	0.20	1.17	2.27	3.73	0.13	0.93	2.17
	2	3.76	0.22	1.30	3.33	3.94	0.15	1.02	3.53
	4	3.95	0.28	1.55	3.77	4.10	0.18	1.14	3.80
Mean		**3.75**	**0.23**	**1.34**	**3.12**	**3.93**	**0.15**	**1.03**	**3.17**
600g/seeds	0	4.00	0.25	1.22	2.37	3.79	0.14	1.14	2.30
	2	4.20	0.34	1.58	3.43	4.40	0.16	1.18	3.87
	4	4.38	0.31	1.78	3.83	4.68	0.19	1.23	4.27
Mean		**4.19**	**0.30**	**1.53**	**3.21**	**4.29**	**0.16**	**1.19**	**3.48**
900g/seeds	0	4.28	0.25	1.36	3.00	4.36	0.17	1.18	3.00
	2	4.81	0.31	1.74	4.00	4.69	0.22	1.29	3.93
	4	5.04	0.37	1.91	4.50	4.82	0.26	1.30	4.57
Mean		**4.71**	**0.31**	**1.67**	**3.83**	**4.62**	**0.22**	**1.26**	**3.83**
Average	0	3.94	0.24	1.25	2.54	3.96	0.15	1.08	2.49
	2	4.26	0.29	1.54	3.59	4.34	0.18	1.17	3.78
	4	4.46	0.32	1.75	4.03	4.53	0.21	1.22	4.21
LSD 5% levels	Potassium	**0.39**	**0.02**	**0.11**	**0.28**	**0.17**	**0.01**	**0.06**	**0.11**
	Seaweed	**0.14**	**0.04**	**0.08**	**0.22**	**0.26**	**0.01**	**0.03**	**0.23**
	Interaction	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

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