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Optimization of Onion Seed Production Using a Combination of Molasses, Lithovit Fertilizer, and Plant Growth Regulators

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A FIELD experiment was conducted during the two winter growing seasons of 2019/2020 and 2020/2021 in Sanhour El-Madina village (31°07' N, 30°43' E), Desouk, Kafr El-Sheikh Governorate, Egypt, to investigate the effects of molasses application methods (soil, foliar spraying, and control), Lithovit fertilizer (0, 0.5, and 0.75 g l^{-1}), and plant growth regulators (GA_3 gibberellic acid, GA_3+CK cytokinin, and control) on seed production of onion (*Allium cepa*, L.) cultivar Giza Red. Soil application of molasses generally outperformed foliar application and control in earlier flowering, extended bolting period, increased umbel scapes, umbel diameter, seed setting, 1000-seed weight, and seed yield. Foliar application was significantly better than the control in the previous traits. The percentage of seed germination was markedly increased by foliar or soil application of molasses in favour of foliar application compared with control. Lithovit application (0.5 g l^{-1}) improved most parameters, including earlier umbel emergence, extended bolting, increased umbel scapes, seed set, 1000-seed weight, yield, and germination, than control. Foliar spraying with the lithovit 0.75 g l^{-1} led to intermediate effects between the control and 0.5 g l^{-1} for the mentioned parameters. Both growth regulators GA_3 and GA_3+CK accelerated umbel emergence, enhanced umbel characteristics, increased 1000-seed weight, onion seed yield, and improved germination compared to the control, with GA_3+CK showing superior effects. Interactions among treatments were significant for several parameters. The combination of soil molasses, 0.5 g/l Lithovit, and GA_3+CK yielded the best results for most traits. These findings suggest integrated management practices incorporating molasses, Lithovit fertilizer, and plant growth regulators can enhance onion seed production.

Keywords: Allium cepa, molasses, Lithovit, Gibberellic acid, Cytokinin, seed production.

1.Introduction

Onion (*Allium cepa* L.) is a significant crop in Egypt for local consumption and export, providing substantial economic returns. It is a biennial plant, producing bulbs in the first growing season and seeds in the second from the initial bulbs. While Egypt is a major onion producer, relying primarily on bulb production, there is an increasing recognition of the importance of domestic onion seed production. Egypt depends on high-quality seeds to maintain high productivity and its competitive edge in export markets. To boost onion seed production, researchers are exploring innovative, non-traditional approaches. These include the application of agricultural waste (such as molasses) as organic fertilizers and soil amendments, calcium carbonate fertilizer with trace elements for more efficient nutrient delivery and plant growth regulators to enhance seed yield and quality. As a fertilizer, molasses provides plants with energy, promotes beneficial microorganisms, enhances soil organic matter, nitrogen, and potassium, reduces soil pH, and increases yield **(Pyakurel et al. 2019; Wynne and Meyer, 2002)**.

Crop production relies on nutrients and organic matter in molasses, such as N, P, K, Ca, S and micronutrients, which can partially replace chemical fertilizers **(Srivastava et al. 2012).** Molasses improves the availability of nutrients in the soil and boosts crop productivity compared to chemical fertilizers. It also benefits crop yield, physical soil composition, and biological activity of beneficial microbes **(Jiang et al. 2012).** Adding molasses at 0.05 g/l during the seedling stage increases plant biomass, root vigour, and enzyme activity, resulting in up to 20% higher seed yield than artificial fertilizers **(Li et al. 2020).** Plants treated with molasses show higher levels of photosynthetic pigments, vegetative growth, yield, and bulb quality **(Chandraju et al. 2008).** A foliar molasses spray mixed with whey and yeast enhances vegetative growth, photosynthetic pigments, yield, and bulb quality in onions **(Mahmoud et al. 2020). Sorour et al. (2021)** found that molasses application, whether through foliar spray or soil addition, improved sugar beet growth, yield, and quality. The soil addition of molasses (24 l ha^{-1}) significantly increased the physiological and biochemical characteristics of wheat **(Khedr et al (2022).**

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Applying organic soil amendments such as compost was the most effective in promoting onion growth under well-watered and water-stressed conditions (**El-Ghamry et al. 2024). EL-Ramady et al. (2021)** shows that nano-nutrients enhance plant enzyme activity, improve seed germination, increase plant tolerance to negative conditions, enhance carbon absorption and nitrogen fixation, and improve photosynthesis and respiration processes. As a result, plant biomass and nutritional status are significantly improved, leading to increased crop productivity. Nanotechnology also helps improve soil fertility and enhance carbon sequestration, contributing to sustainable agriculture and combating climate change.There's a global trend to decrease mineral nitrogen fertilizers in agriculture, seeking alternatives to boost crop productivity for plants like rice **(El-Habet and Elsadany, 2020; Manda and Ghosh 2021)**, cotton **(Yanni et al. 2020)**, sugar beet **(Sorour et al. 2021),** onion **(Geries and Elsadany, 2021),** wheat (**Ghazi et al. 2022**), and eggplant (**Mahmoud et al. 2023**). lithovit, through slow nutrient release and increased nutrient use efficiency, also enhance abiotic stress tolerance **(Naderi and Shahraki, 2013; Zulfiqar et al. 2019)**. Lithovit, a fertilizer, dolomite and limestone-based foliar carbon dioxide fertilizer with particles, significantly enhances photosynthesis by providing plants with high CO2 concentrations **(Hamed, 2018).** The plant cell wall, with pores ranging from 5 to 20 nm in diameter, acts as a selective barrier that allows only particles smaller than these pores to easily pass through and reach the plasma membrane **(Fleischer et al. 1999; Moore, 2006).** Customized particles can expand existing pores or create new ones, improving uptake **(Fernandez and Eichert, 2009)**. Lithovit is made from natural limestone deposits, consists of 100% calcium carbonate with trace elements, and is approved for organic farming. It has been shown to improve various growth parameters, including the number of umbels per plant, umbel diameter, 1000-seed weight, seed germination percentage, and bolting period, when used as a foliar spray at 0.50 g/l **(Abdelghafar et al. 2016).**

Gibberellic acid (GA_3) at 100 ppm significantly enhances onion scape length, umbel diameter, seed yield, and seed quality **(Ali et al. 2015; Helaly et al. 2016).** GA_3 also improves germination, root surface area, root length, and root diameter **(Macias-Leon & Leskovar, 2017).** Synthetic cytokinin, N6-benzyladenine (6-BAP), promotes growth, delays senescence, and improves post-harvest life of vegetables **(Werner et al. 2001; An et al. 2006; Yu et al. 2016; Van Staden et al. 2008)**. However, BA can cause plant morphological issues **(Valero-Aracama et al. 2010)**. GA_3 at 100 ppm increases seed germination by 13%, while NAA increases it by 16% **(Geetharani et al. 2008)**. GA_3 at 50 ppm shortens the time for floral stem emergence and increases uniformity and yield **(Naamni et al. 1980).** Combining vernalization at 5°C for 14 days with 100 ppm GA_3 significantly enhances growth and yield parameters and higher concentrations of GA_3 (200 ppm) produced the same result in the same work. (**Khatun et al. 2020**). These findings collectively underscore the potential of integrated approaches, combining organic amendments, lithovit fertilizer, and plant growth regulators to optimize onion production and quality.

2. Materials and Methods

2.1. Experimental location and soil properties

A field experiment was conducted during the two winter growing seasons of 2019-2020 and 2020-2021 in Sanhour El-Madina village (31°07' N, 30°43' E), Desouk, Kafr El-Sheikh Governorate, Egypt. The objective of this study was to investigate the influence of molasses application methods, Lithovit fertilizer and plant growth regulators on flowering, seed yield, and seed quality of onion cultivar Giza Red. Soil analysis conducted prior planting according to **Jackson (1967**), revealed a clay-textured soil with the following properties: pH 7.9, EC 1.75 dS m^{-1}, organic matter content 1.81 mg g^{-1}, and available nitrogen, phosphorus, and potassium levels of 27.15, 16.90, and 280 ppm, respectively. This soil is cultivated annually with vegetable crops and fertilized with large quantities of organic and phosphorus fertilizers every sowing season, which led to raising its content of organic matter and phosphorus.

2.2. Content of molasses and Lithovit

The source of molasses was Delta Sugar Company Factors, El-Hamol, Kafr El-Sheikh Governorate, Egypt. Molasses of Sugar beet, with a pH of 7.3, include a Brix value of 81%, a total sugar content of 47%, and a purity level of 58%. It contains 0.43% unfermentable sugar, specific gravity of 1.42 g cm^{-3} and ash 10.56%. Regarding mineral content, the molasses has 1.3% nitrogen, 0.25% phosphorus, 3.2% potassium, 0.6% calcium, 0.19% magnesium, 1.3% sodium, and 0.4% sulfur. Delta Sugar Company conducted this analysis. Lithovit is a natural calcium carbonate (Ca CO_3) foliar fertilizer supplemented with 12 different minerals that deliver fine particles (< 10 μm) that can be easily adsorbed directly through the stomata of plant leaves. Lithovit® Standard (Carbon dioxide) contains 79.19 % calcium carbonate, 11.41% silica, 4.62% magnesium carbonate, 1.31% iron, 0.97% alumina, 0.55% sodium oxide, 0.33% sulphate, 0.21% potassium oxide, 0.06% nitrogen, 0.01% phosphate, 0.014% manganese, 0.005% zinc, 0.002% copper. The source is Agrolink Agricultural Co., Egypt, manufactured in Germany by **(Tribodyn, 2020).**

2.3. Experimental treatment

The molasses treatments involved applying 50 l ha^{-1} in three equal portions with irrigation water during the first three irrigations, sprayed foliar at 10 cm³ l^{-1} three times every 20 days starting at 18 DAS with total volume of 1 cm³ m^{-1} (10 l ha^{-1}), and omitted as a control. Lithovit solution was used as a foliar spray with concentrations of 0, 0.5, and 0.75 g l^{-1} three times (19, 39 & 59 DAS). Gibberellic (GA_3) acid and cytokinin (CK) were used as a foliar spray with the rate of 100 ppm three times (20, 40 & 60 DAS). Foliar spray with water was used as a control treatment for lithovit and growth regulator treatments.

2.4. Experimental Design

The experimental design was a strip split-plot design with three replicates. The horizontal plots were assigned to application methods of molasses, the vertical plots to Lithovit fertilizer and sub-plots to growth regulators. The plot size was 21 m^2 (6 m x 3.5 m). Each plot included 6 beds, 1 m wide and 3.5 m long.

2.5. Agriculture practices

Phosphorus fertilizer was applied during soil preparation as calcium superphosphate (15.5 % P2O5) at a rate of 55.4 kg P_2O_5 ha^{-1}. Mother bulbs (4–7 cm diameter) of onion cultivar "Giza red" were planted individually at 25 cm distance on both sides of the bed alternately on the 15th and 18th of December in the 2019 and 2020 seasons. respectively. Potassium sulphate (48% K_2O) fertilizer was added to all sub-plots at 115 kg K_2O ha^{-1} before the initial irrigation. Subplots were fertilized at 286 kg N ha^{-1} as ammonium nitrate (33.5 % N) in two equal doses. The first dose was added before the first irrigation, while the second dose was applied before the second irrigation. Other cultural practices were recommended for conventional onion production in the local production district.

2.6. Parameters

Parameters of Phenological, seed yield, yield attributes and germination were recorded according to the standard procedure on the date of the first umbel scape, bolting period, number of umbel scape per plant, umbel diameter, seed setting %, 1000-seed weight and seed yield of onion. Onion seeds were stored at room temperature for 4 months after harvesting. Then, germination percentages were recorded using the method described by **Scott et al (1984).**

2.7. Statistical analysis:

All collected data were statistically analyzed using analysis of variance (ANOVA) according to the standard procedure of **Snedecor and Cochran (1982)**. The means were compared to Duncan's at a 5% significance level. All statistical analyses were performed with the software package Costat ® Statistical Software. 6.311 **(Co Stat Software, 2005)**; a product of Cohort Software, Monterey, California.

3. Results

3.1 Phenological parameter

Data in Table 1 show the effect of molasses application methods, -fertilizer (Lithovit) concentrations, and plant growth regulators on several phenological parameters of onion plants in the 2019/20 and 2020/21 seasons. Soil application of molasses led to earlier flowering (the first umbel scape), a longer bolting period, more umbel scapes per plant, and larger umbel diameter compared to foliar application and control treatment in both seasons. For most parameters, foliar application led to intermediate effects between control and soil application. Foliar spraying with Lithovit resulted in a significant decrease in the date of the first umbel scape emergence, a prolonged bolting period, and an increase in the number of umbel scapes per plant compared with control in both seasons (Table 1). Umbel diameter substantially increased with Lithovit application, up to 0.5 g l^{-1} higher than 0.75 g l^{-1} and the control. The 0.5 g l^{-1} rate provided generally optimal phenological parameters of onion. Foliar spraying with growth regulators (GA_3 and especially GA_3+Ck) accelerated the date of the first umbel (flower) scape emergence, prolonged the bolting period, increased the number of umbel scapes per plant, and increased umbel diameter compared to the control. The combination treatment of GA_3+Ck was better than GA_3 alone in the mentioned traits. The interaction of molasses application and lithovit significantly affected the date of the first umbel scape in both seasons, the number of umbel scapes in the first season and the umbel diameter in the second season (Table 1). Figure 1 illustrates that applying molasses with Lithovit accelerated the first umbel scape date than the control treatment (without molasses and Lithovit) in both seasons. Soil application of molasses with 0.5 g l^{-1} Lithovit produced the earliest umbel scape emergence in the two seasons. Figure 2 illustrates that the number of umbel scapes per plant was markedly increased by increasing the concentration of Lithovit from 0 to 0.5 g l^{-1} and then slightly decreased at 0.75 g l^{-1} at any application methods of molasses. The greatest number of umbel scape per plant was obtained at the combination of soil molasses and 0.5 g l^{-1} lithovit. Figure 3 shows that foliar spraying with Lithovit increased umbel diameter compared with control treatment at any application methods of molasses. Applying molasses as soil or foliar addition leads to an increase in umbel diameter during any lithovit treatment. Soil molasses with 0.5 g l^{-1} lithovit produced the thickness umbel diameter.

Table 1. Date of the first umbel scape, bolting period, number of umbel scape per plant and umbel diameter of onion asaffected by methods of molasses application, lithovit, and plant growth regulators in 2019/20 and 2020/21 seasons.

Factor	First umbel scape (day)		Bolting period (day)		Umbel scape (no/plant)		Umbel diameter (cm)	
	2019/20	2020/21	2019/20	2020/21	2019/20	2020/21	2019/20	2020/21
Molasses (M):								
Control	78.98 a	81.74 a	48.43 c	41.00 c	4.84 c	5.52 c	7.31 c	7.50 b
Foliar	76.28 b	78.89 b	57.82 b	49.89 b	7.63 b	8.28 b	8.33 b	8.33 ab
Soil	71.80 c	74.44 c	64.78 a	57.28 a	8.10 a	8.98 a	9.67 a	8.76 a
F test	**	**	**	**	***	**	**	*
Lithovit, g l^{-1} (L):								
0	78.04 a	80.19 a	53.54 c	45.98 c	5.33 c	6.93 c	8.05 b	7.24 b
0.5	73.04 c	76.04 b	60.76 a	53.00 a	7.84 a	8.22 a	8.95 a	9.09 a
0.75	75.98 b	78.85 a	56.72 b	49.19 b	7.39 b	7.62 b	8.32 b	8.26 b
F-test	**	*	**	**	***	**	*	**
Regulator (R):								
Control	78.20 a	80.33 a	50.76 c	44.00 c	5.70 c	6.62 c	7.30 c	7.03 c
GA3	76.24 b	78.83a	57.54 b	49.54 b	6.58 b	7.81 b	8.34 b	8.50 b
GA3+Ck	72.61 c	75.91 b	62.72 a	54.63 a	8.28 a	8.34 a	9.67 a	9.06 a
F-test	**	**	**	**	**	**	**	**
Interaction:								
M x L	*	*	NS	NS	**	NS	NS	**
M x R	**	**	NS	NS	*	NS	*	NS
L x R	NS	NS	NS	NS	NS	NS	*	*
M x L x R	**	*	NS	NS	NS	NS	NS	NS

*, **, and NS represent $P < 0.05$, $P < 0.01$, and insignificant, respectively. Based on Duncan's Multiple Range Test, the means within each factor that share the same letter do not differ significantly at the 5% level.

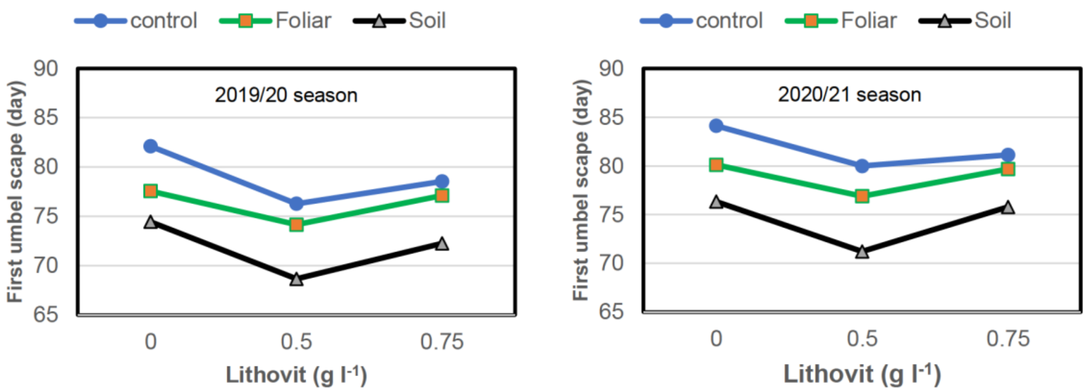


Figure 1: The first umbel scape date as affected by the interaction between molasses application and lithovit concentration in the 2019/20 and 2020/21 seasons.

The interaction of molasses application and growth regulators significantly affected the date of the first umbel scape in both seasons and the number of umbel scape and umbel diameter in the first season (Table 1). Foliar spraying with growth regulators (GA_3 and especially GA_3+Ck) accelerated the date of the first umbel scape emergence (Fig. 4), and also increased the number of umbel scape per plant (Fig. 5) and their diameter (Fig. 6) compared to the control at any application methods of molasses. The combination of GA_3+Ck had higher effect than GA_3 alone using the same molasses application method. Soil molasses and GA_3+Ck recorded the lowest number of days needed for the first umbel scape emergence and the highest values of umbel scape numbers per plant and their diameter. Umbel diameter was significantly influenced by the interaction between lithovit and growth regulator in both seasons (Table 1). Figure 7 illustrates that umbel diameter was markedly increased by increasing the concentration of Lithovit from 0 to 0.5 g l^{-1} and then slightly decreased at 0.75 g l^{-1} at any growth regulator treatment. The umbel diameter's thickness was obtained by applying lithovit (0.5 g l^{-1}) with GA_3+Ck in both seasons.

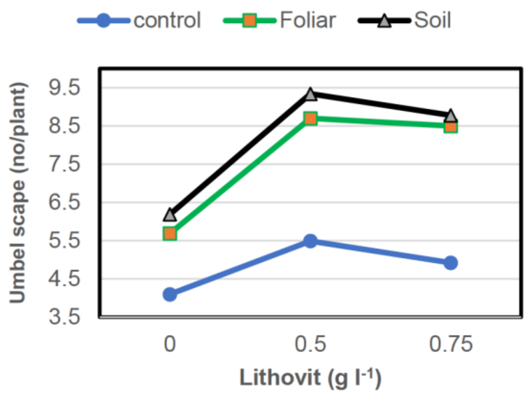


Figure 2: Number of umbel scape as affected by the interaction between molasses application and lithovit concentration in the 2019/20 season.

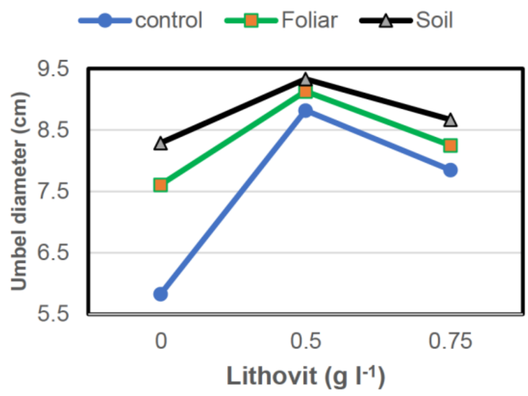


Figure 3: Umbel diameter (cm) as affected by the interaction between molasses application and lithovit concentration in the 2020/21 season.

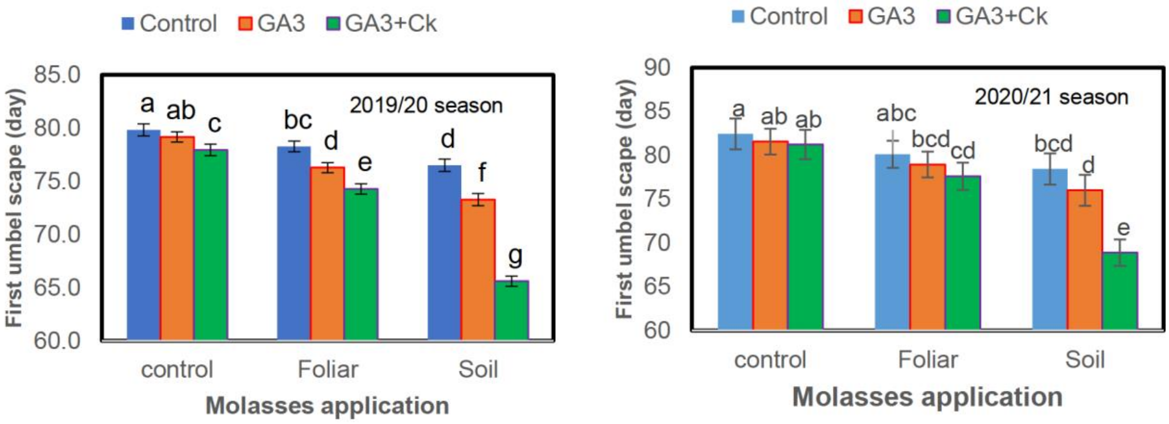
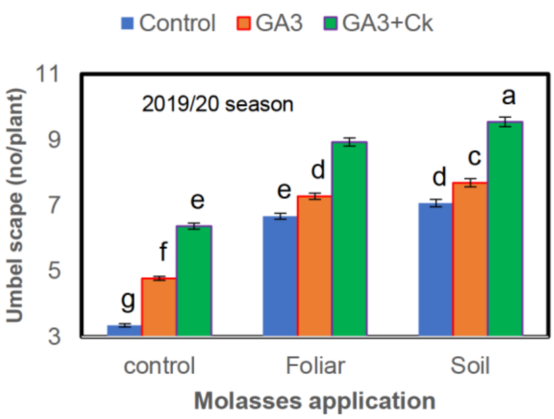


Figure 4: Date of the first umbel scape as affected by the interaction between molasses application and growth regulator in the 2019/20 and 2020/21 seasons.



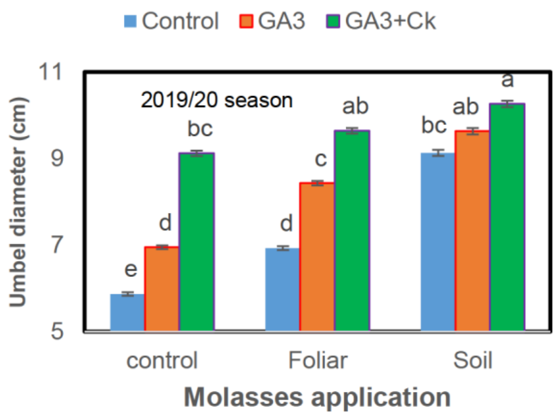


Figure 5: Number of umbel scape affected by the interaction between molasses application and growth regulator in the 2019/20 season.

Figure 6: Umbel diameter (cm) as affected by the interaction between molasses application and growth regulator in the 2019/20 season

The second-order interaction (M x L x R) significantly affected the date of the first umbel scape in both seasons. Data in Table 2 show that the first umbel scape's earliest emergence was obtained from applying soil molasses, 0.5 g l^{-1} lithovit, and GA_3+CK, while the latest one was obtained from the control (without treatment).

3.2 Seed yield and its attributes

The data presented in Table 3 show that seed setting percentage, 1000-seed weight, seed yield, and seed germination saw the highest values with soil application of molasses, followed by foliar application and then the control treatment in both seasons. However, foliar by molasses increased seed germination better than soil application.

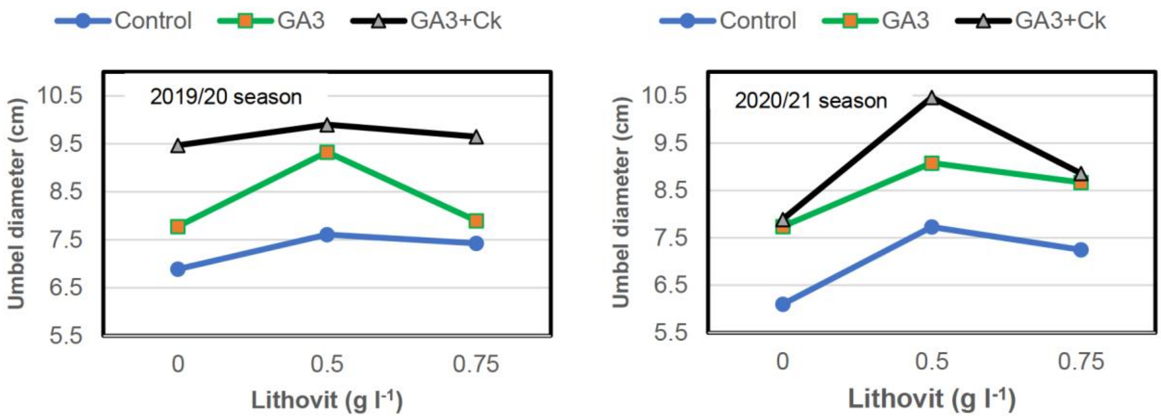


Figure 7: Umbel diameter (cm) as affected by the interaction between Lithovit and growth regulator in 2019/20 and 2020/21 seasons.

Table 2. Date of the first umbel scape (day) of onion as affected by the interaction of molasses application, lithovit and plant growth regulators in 2019/20 and 2020/21 seasons.

Molasses	Lithovit ($g\ l^{-1}$)	2019/20 season			2020/21 season		
		Growth regulator			Growth regulator		
		Control	GA_3	GA_3+CK	Control	GA_3	GA_3+CK
control	0	83.33 a	82.33 a	80.67 b	85.67 a	85.00 ab	81.67 b-e
	0.50	76.50 fg	76.50 fg	75.83 fgh	79.00 c-g	79.00 c-g	82.00 bcd
	0.75	79.67 bc	78.67 cde	77.33 efg	82.67 abc	80.67 c-f	80.00 c-f
Foliar	0	80.00 bc	76.67 fg	76.00 fgh	81.67 b-e	79.33 c-f	79.33 c-f
	0.50	75.50 gh	74.50 h	72.50 i	78.00 efg	77.17 fg	75.50 gh
	0.75	79.33 bcd	77.67 def	74.33 h	80.67 c-f	80.33 c-f	78.00 efg
Soil	0	77.67 def	76.33 fg	69.33 j	78.00 efg	78.67 d-g	72.33 hi
	0.50	74.50 h	69.00 j	62.50 l	77.33 fg	71.33 i	65.00 j
	0.75	77.33 efg	74.50 h	65.00 k	80.00 c-f	78.00 efg	69.33 i

Means in each season designated by the same letter are not significantly different at the 5% level using Duncan's Multiple Range Test.Foliar spraying with the lowest concentration of lithovit (0.5 $g\ l^{-1}$) significantly increased seed setting percentage, 1000-seed weight, and seed yield compared to the highest concentration (0.75 $g\ l^{-1}$) and the control in both seasons (Table 3). Foliar spraying with the highest concentration of lithovit (0.75 $g\ l^{-1}$) led to intermediate effects between control and the lowest concentration (0. 5 $g\ l^{-1}$) for the mentioned parameters, indicating it provides benefits over control but less than foliar application at the rate of (0. 5 $g\ l^{-1}$). Data in Table 3 show that the application of GA_3, either alone and in combination with CK significantly increased the seed setting percentage, 1000-seed weight, and seed yield per hectare as well as seed germination compared to the control, with superiority for the combination treatment that exhibited the highest values of these parameters in both seasons. The interaction of molasses application and lithovit significantly affected seed setting % in the first season (Table 3). Figure 8 illustrates the application of molasses and lithovit increased that seed setting %. Seed setting % was gradually increased by increasing the concentration of lithovit from 0 to 0.5 $g\ l^{-1}$ and then slightly decreased at 0.75 $g\ l^{-1}$ at any application methods of molasses. The highest seed setting was obtained using soil molasses and 0.5 $g\ l^{-1}$ lithovit. The interaction of lithovit and growth regulators significantly affected seed setting % in the second season (Table 3). Figure 9 illustrates the application of growth regulator and lithovit increased seed setting %. Seed setting % was gradually increased by increasing the concentration of Lithovit from 0 to 0.5 $g\ l^{-1}$ and then slightly decreased at 0.75 $g\ l^{-1}$ at any growth regulator treatment. The highest seed setting percentage was obtained at the combination of GA_3+Ck and 0.5 $g\ l^{-1}$ lithovit.

Table 3. Seed setting %, 1000-seed weight, seed yield and seed germination % of onion as affected by methods of molasses application, lithovit, and plant growth regulators in 2019/20 and 2020/21 seasons.

Factor	Seed setting (%)		1000-seed weight(g)		seed yield (kg ha^{-1})		seed germination (%)	
	2019/20	2020/21	2019/20	2020/21	2019/20	2020/21	2019/20	2020/21
Molasses (M):								
Control	68.53 c	68.04 c	4.97 b	3.45 c	800 c	907 c	87.67 c	88.07 c
Foliar	73.41 b	72.24 b	5.33 a	4.32 b	1100 b	1209 b	95.37 a	94.70 a
Soil	76.63 a	76.11 a	5.60 a	5.13 a	1307 a	1356 a	92.59 b	91.96 b
F test	**	**	*	**	**	**	**	**
Lithovit, g l^{-1} (L):								
0	69.96 c	69.56 c	4.98 c	3.96 c	1030 c	1026 c	89.81 b	89.85 b
0.5	75.48 a	74.32 a	5.61 a	4.65 a	1111 a	1276 a	94.81 a	92.96 a
0.75	73.13 b	72.50 b	5.30 b	4.28 b	1067 b	1170 b	90.93 b	91.93 ab
F-test	*	**	*	**	**	**	**	*
Regulator (R):								
Control	66.17 c	68.84 c	4.55 c	3.88 c	983 c	1111 c	86.26 c	87.52 c
GA3	73.04 b	71.59 b	5.43 b	4.36 b	1066 b	1147 b	93.22 b	92.44 b
GA3+Ck	79.36 a	75.95 a	5.91 a	4.66 a	1159 a	1214 a	96.07 a	94.78 a
F-test	**	**	**	**	**	**	**	**
Interaction:								
M x L	**	NS	NS	NS	**	**	NS	NS
M x R	NS	NS	NS	NS	**	*	**	*
L x R	NS	**	NS	NS	*	*	NS	NS
M x L x R	NS	NS	NS	NS	*	*	NS	NS

*, **, and NS represent P < 0.05, P < 0.01, and insignificant, respectively. Based on Duncan's Multiple Range Test, the means within each factor that share the same letter do not differ significantly at the 5% level.

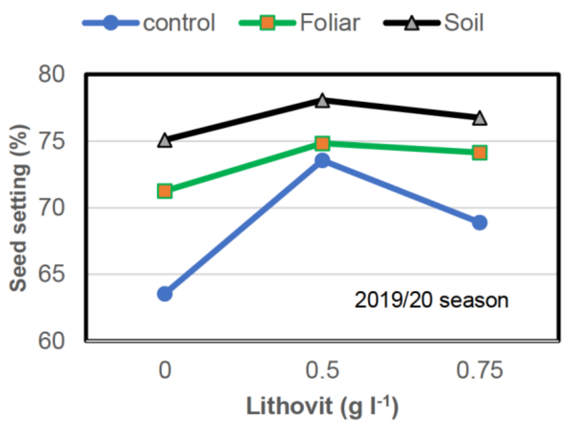


Figure 8: Seed setting (%)as affected by the interaction between molasses application and lithovit concentration in 2019/20 season.

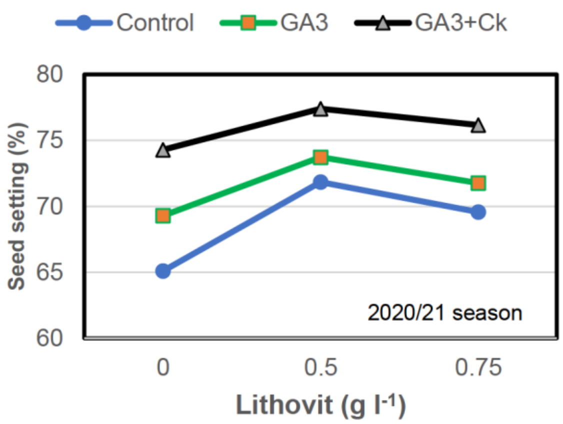


Figure 9: Seed setting (%)as affected by the interaction between molasses application and growth regulator in 2020/21 season

The interaction of molasses application and lithovit significantly affected seed yield in both seasons (Table 3). Figure 10 illustrates that applying molasses and lithovit increased seed yield. Seed yield gradually increased by increasing the concentration of Lithovit from 0 to 0.5 g l-1, and then it slightly decreased to 0.75 g l-1 using any molasses application method. The highest seed yield was obtained at the combination of soil molasses and 0.5 g l^{-1} lithovit, while the lowest one was obtained at control treatment (without molasses and lithovit).

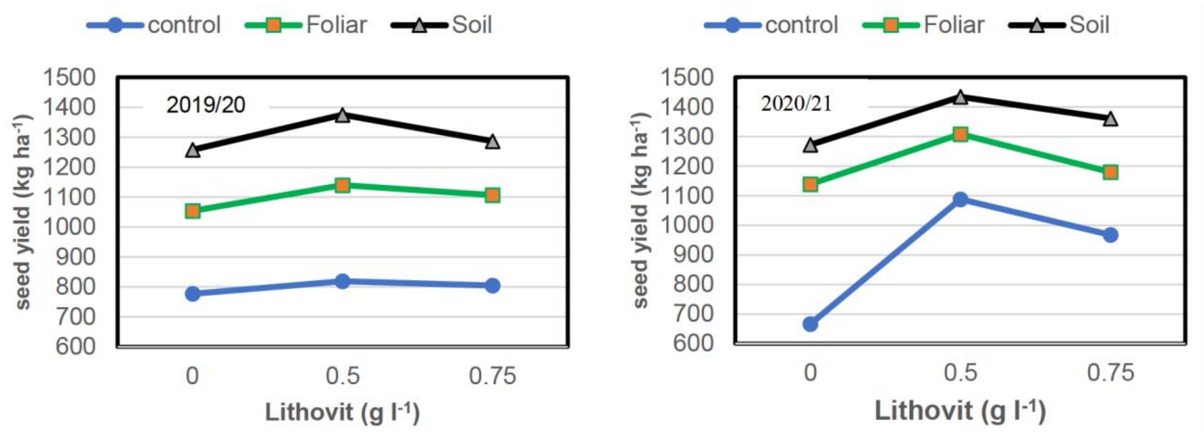


Figure 10: Seed yield (kg ha^{-1}) as affected by the interaction between molasses application and lithovit concentration in the 2019/20 and 2020/21 seasons.

The interaction between lithovit and growth regulator significantly influenced seed yield in the two seasons (Table 3). Figure 11 illustrates that seed yield were markedly increased by increasing the concentration of Lithovit from 0 to 0.5 g l^{-1} and then slightly decreased at 0.75 g l^{-1} at any growth regulator treatment. Applying lithovit (0.5 g l^{-1}) with GA_3+Ck produced the highest seed yield in both seasons.

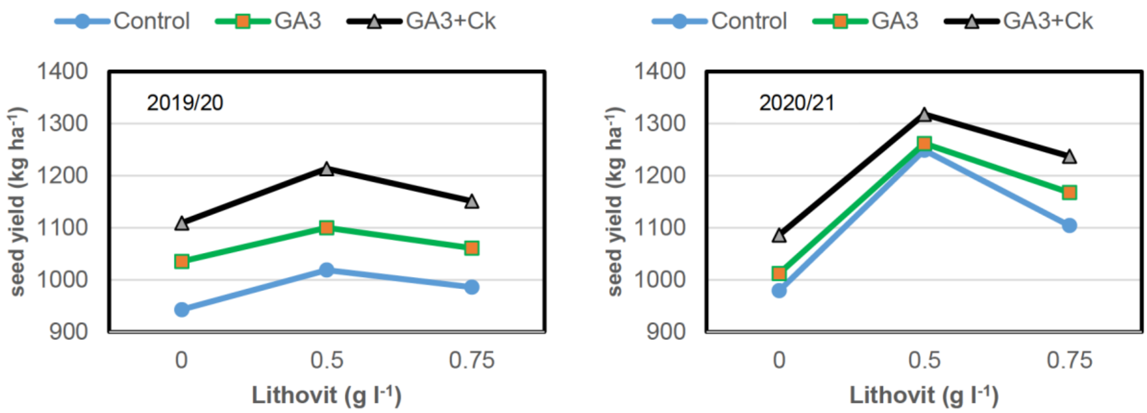


Figure 11: Seed yield as affected by the interaction between molasses application growth regulator in the 2019/20 and 2020/21 seasons.

The interaction between molasses application and growth regulator significantly affected seed yield in both seasons (Table 3). Generally, applying molasses or growth regulators increased seed yield in both seasons (Figure 12). The highest seed yield was obtained from soil application of molasses along with GA_3+CK .

The second-order interaction (M x L x R) only significantly affected seed yield in both seasons (Table 3). Data in Table 4 shows that application of soil molasses, 0.5 g l^{-1} lithovit, and GA_3+CK significantly outyielded the other combination in seed yield. The application of soil molasses, 0.5 g l-1 lithovit, and GA3+CK produced the highest seed yield, while the control treatment produced the lowest.

3.3 Seed germination (%)

This parameter measures the viability of seeds and their potential to develop into healthy plants. Foliar application of molasses led to a significant increase in seed germination percentage compared to soil application and control in both seasons (Table 3). Soil application led to higher germination % than control treatment. The application of lithovit appears to positively affect seed germination, with the highest percentage observed at the 0.5 g l^{-1} concentration, followed by the 0.75 g l^{-1} concentration and control in both seasons (Table 3).

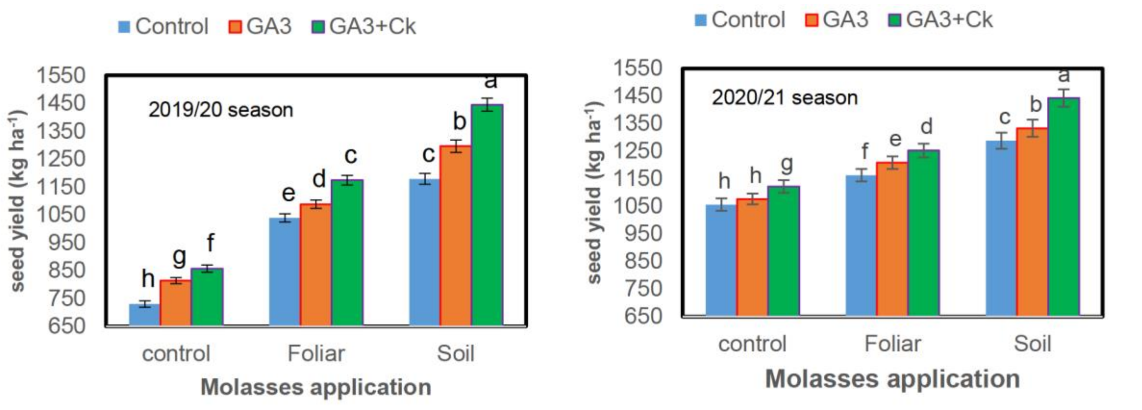


Figure 12: seed yield (kg ha^{-1}) as affected by the interaction between molasses application and growth regulator in 2019/20 and 2020/21 seasons.

Table 4. Seed yield (kg ha^{-1}) of onion as affected by the interaction of molasses application, lithovit and plant growth regulators in the 2019/20 and 2020/21 seasons.

Molasses	Lithovit (g l^{-1})	2019/20 season			2020/21 season		
		Growth regulator			Growth regulator		
		Control	GA_3	GA_3+CK	Control	GA_3	GA_3+CK
Control	0	707 o	801 m	824 m	657 i	658 i	683 i
	0.5	738 no	804 m	874 i	1061 ij	1084 hi	1118 h
	0.75	746 n	837 lm	873 i	918 k	954 k	1032 j
Foliar	0	990 k	1050 j	1122 hi	1095 hi	1105 hi	1218 g
	0.5	1041 j	1096 hi	1185 g	1294 ef	1310 def	1319 def
	0.75	1087 i	1118 hi	1216 fg	1104 hi	1213 g	1223 g
Soil	0	1133 h	1257 de	1383 b	1186 g	1273 f	1358 cd
	0.50	1225 ef	1346 c	1554 a	1392 c	1391 c	1518 a
	0.75	1180 g	1285 d	1397 b	1289 ef	1338 de	1455 b

The combined application of GA_3 and cytokinin (GA_3+Ck) consistently showed the highest seed germination % across both seasons, followed by GA_3 alone and then the control (Table 3).
None of the interactions significantly affected seed germination, except the M x R interaction in both seasons (Table 3). Figure 13 shows that foliar spraying with growth regulators (GA_3 and especially GA_3+Ck) increased seed germination compared to the control at any application method of molasses. The combination of GA_3+Ck had the most excellent effect on seed germination compared to GA_3 alone using the same molasses application method. Soil molasses and GA_3+Ck produced the highest seed germination %.

4. Discussssion

The statement suggests that soil application of molasses has significant positive effects on phenological parameters, seed yield, and its attributes, as well as seed germination of onion, compared to foliar application and control treatment. Foliar application of molasses showed intermediate improvements, outperforming the control. Molasses resulted in early flowering (date of the first umbel scape), extended bolting period, increased number of umbel scape, larger umbel diameters, seed setting %, 1000-seed weight, seed yield and seed germination of onion, **(Abdelghafar *et al*, 2016)**. Molasses, a byproduct of sugar production, is rich in carbohydrates (stimulating beneficial soil microbes and potentially altering plant hormone balance) and minerals (calcium, potassium and magnesium), vitamins, and micronutrients (iron and copper), which are vital for enzyme function and plant metabolism. Calcium is one of the components of molasses and lithovit, It is considered an important consistent of plant tissues and has a vital role in maintain and modulating various cell functions reduced senescence and retardation of softening in fruits **(Biggs *et al*. 1997; Gerasopoulos and Drogoudi, 2005; Hepler, 2005).**Molasses contains on organic matter, proteins, and amino acids that can directly or indirectly influenced the physiological activities of the plants**(Raad, 2011,El-Shabase *et al*., 2005, Awad *et al*.,2007; Al-Said and Kamal, 2008; Abd El-Aal *et al*., 2010 ; Karazija *et al*. 2015 and Datir *et al.* 2012).** These factors can collectively contribute to early flowering, an extended bolting period, an increased number of umbel scapes, an enlarged umbel diameter, an increased seed setting%, 1000-seed weight, seed yield and seed germination of onion. These results are consistent with findings of **Gerasopoulos and Drogoudi (2005)** and **Hepler (2005)**. They concluded that Ca is vital in maintaining and modulating various cell functions to reduce senescence in other plants. Molasses contains organic matter, vitamins, minerals, proteins, and amino acids that can directly or indirectly influence the physiological activities of plants **(El-Shabase *et al*, 2005; Awad *et al*,2007; Al-Said and Kamal, 2008; Abd El-Aal *et al*, 2010; Karazija *et al*, 2015 and Datir *et al*, 2012).** In this connection, **Schenck (2001) and Chikhoune *et al* (2014)** reported that molasses alters the C: N ratio, affecting soil microbial ecology and providing other favourable environments for better plant growth.

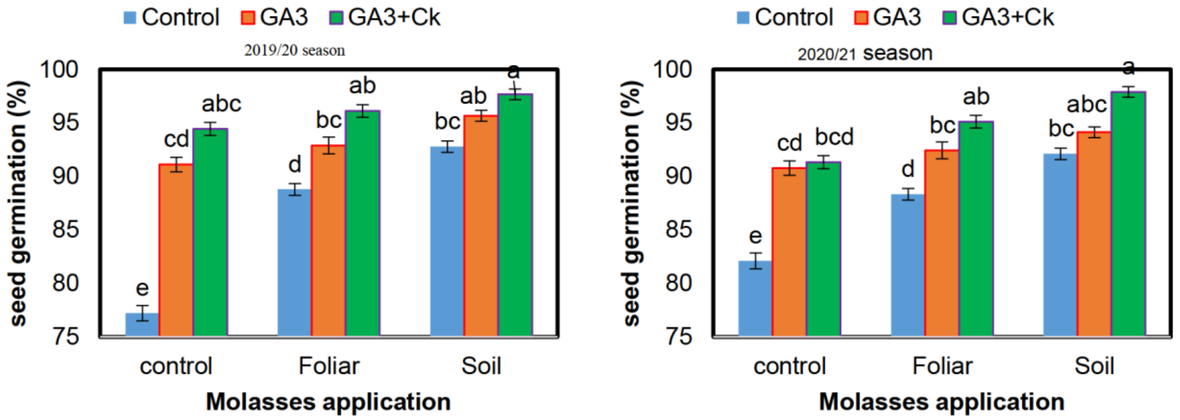


Figure 13: Seed germination (%) affected by the interaction between molasses application and growth regulator in the 2019/20 and 2020/21 seasons.

Foliar spraying with the solution of Lithovit at 0.5 g/l rate resulted in a significant decrease in the date of the first umbel scape emergence, a prolonged bolting period, and an increase in the number of umbel scapes per plant compared with control in both seasons. The carbonates of the Lithovit, which enter the leaf directly through the stomata get converted into CO2, water, calcium- and magnesium ions and increase the concentration of CO2 in the leaf, resulting in a higher photosynthesis rate and an improved plant growth. Also, these may be due to feeding onion plant leaves with CO2 gas from inside the leaves at a rate much higher than in the air (**Nassef and Nabeel, 2012 and Bilal, 2010)**. Lithovit improved the basic process of photosynthesis. These prompted assimilates accumulation, which is required for constructing protoplasm and protein, as well as inducing cell division, which led to an increase in cell number and size with an overall increase in the vegetative growth that had an impact on the flowering parameters **(Abdelghafar et al, 2016 and Ibrahim et al, 2016).** Using lithovit increased the number of umbel scapes per plant and umbel diameter. These may be attributed to lithovit particles degrading and releasing CO_2 in the leaves, increasing the CO_2 concentration in the photosynthesis-active region and promoting a more robust natural growth. It can be claimed that the presence of magnesium in the Lithovit complex, the key component for chlorophyll production, may be responsible for the rise in pigments used for photosynthesis (**Kumar *et al*. 2016**). Adding micronutrients from the Lithovit compound may increase enzyme activity that contributes to photosynthesis increases **(Hamoda *et al*, 2016).**

A higher seed yield from spraying lithovit at 0.50 gm/l may directly result from the increased bolting period, the number of umbels scapes per plant, umbel diameter, seed setting and 1000-seed weight. When the sun is out, the temperature gradually rises, water evaporates, and (Ca, Mg) (HCO3)2 is converted back into Lithovit, which produces high concentrations of CO_2 on the surface of the leaves. **(Nassef and Nabeel, 2012; Bilal, 2010; Maswada and Abd El-Rahman, 2014; Hamed, 2018; Ibrahim et al, 2016 and Carmen et al, 2014)** noted a similar result and added that Plant nutrition by lithovit boosts photosynthesis and promotes plant growth, lower photorespiration, and increases carbon uptake for plant growth and development. In the same trend, **Fernandez and Eichert (2009)** noted that Upon interaction with designed particles, there is potentially a possibility for pore enlargement or the production of new cell wall pores, which would, therefore, improve the uptake of the particles. **Moore (2006)** added that the only particles that could easily pass through and reach the plasma membrane were those whose diameter was less than the pore diameter of the cell wall. The increase in total yield as the weight from the treated plants with Lithovit may be why the Lithovit fertilizer particles are so tiny, that plant leaves can directly absorb them (**Ibrahim et al, 2016)** or correlated with increased scape length, umbel diameter scape, and umbel diameter **(Kumar et al 2016).**

Using growth regulators as gibberellic acid (GA_3) led to improvement parameters, where decreased the days that needed to appear the first umbel scape, longed the bolting period, increased the number of umbel scapes and led to an increased umbel diameter, seed setting, 1000- seed weight and seed yield as well as seed germination but addition cytokines (CK) as a mixture with (GA_3) the results become the best compared by control or gibberellic acid only. The reason was the rapid increment and expansion of plant cells for proper plant growth, which induces plant defence against pathogens infection, stimulates plant growth and improves the number of scapes and umbel diameter. These results agree with the findings of **(Ali *et al* 2015 and Khatun *et al* 2020).** The combined application of GA_3 and cytokinin (GA_3+CK) consistently showed the highest seed germination percentage across both seasons. The increased germination by 6BA might be due to the strong neutralizing effect of cytokinin on the inhibitors present in the seed **(Patil *et al* 2021). Geetharani *et al* (2008)** found that GA_3 at 100 ppm increased seed germination by 13%. The first and second order had a significant effect on the most of studied parameters. According to the findings of the current investigation, molasses as a soil application and 0.50 g Lithovit/L with PGRs (GA_3 + CK as combined) had better impacts on the onion plants than the other treatments. Last but not least, nutrient materials are a cutting-edge technology that is practically used in every facet of our lives, particularly in agriculture. This study has demonstrated the effectiveness of CO2-fertilizer in the form of Lithovit on onion blooming parameters, the yield of seeds production, and quantity and quality.

4. Conclusions

This study reveals the significant benefits of integrating molasses application, lithovit and growth regulators on onion seed production. Soil-applied molasses, Lithovit at 0.5 g/l, and the combination of GA_3+CK proved most effective in improving flowering characteristics, seed yield, and quality. The synergistic effects of these treatments offer promising opportunities for enhancing onion seed production systems.

Conflicts of interest: Authors have declared that no competing interests exist.

Author contribution: Sobhy Gh. R. Sorour and Labib S. M.Geries are contributed in this article as supervision committee of Mohamed A. EL-Sabaawy (Ph.D. student). All authors have read and agreed to the published version of the manuscript.

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