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Foliar application of kaolin can improve quality attributes of deficit irrigated green bean (*Phaseolus vulgaris* L.) during cold storage

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ABSTRACT

Two similar cold storage experiments were conducted to investigate the main and interaction effects of kaolin foliar application (Kao) and deficit irrigation (DI) at different physiological stages on quality attributes of green beans pods (*Phaseolus vulgaris* L) Paulista cv., during cold storage (7 ±1 °C). DI has been applied by skipping one irrigation at different physiological stages (DI-Vegetative growth, DI- Flowering and DI-Ripen) plus normal watering, as a comparison treatment. Kaolin clay (Kao-C) foliar spray has been applied with different concentrations (without kaolin, Kao-1= 12.5 g / L and Kao-2 = 25 g / L) weekly after the first irrigation till the ripening time (a total of five times). Skipping one irrigation either DI-Vegetative or DI-Vegetative combined with Kao-1 or Kao-2 had a noticeable positive effect on N, total soluble solids (TSS), and dry matter, in addition to reducing the percentage of weight loss after 14 days of cold storage. Based on the obtained results, Implementing one irrigation skip either during the vegetative growth stage or during the maturity and harvesting stage, in conjunction with kaolin treatment, to conserve about 25% of irrigation water, while preserving the quality characteristics of green bean pods.

1. Introduction

Green beans are young, unripe fruits of various cultivars of the common bean (Phaseolus vulgaris L.) dicotyledonous plants, a member of the Fabaceae (Leguminosae) family that contains many of the world's most popular garden and cash crops such as peas, broad bean and cowpea. Most of the common bean cultivars are grown for the production of green pods and/or dry seeds yield. The green pods and dry seeds play a vital role in human nutrition as a cheap source of protein, carbohydrates, dietary fiber, vitamins and minerals, It's also digestible, low in calories and ideal for health conscious weight watchers [1]–[5].

Green bean is normally harvested seasonally and stored at room-temperatures with short shelf-life of about seven days, therefore extending its shelf-life is an important issue. For this reason, demand for fresh refrigerated fruit and vegetable has increased significantly [6]. Green bean pods are highly perishable with limited shelf-life due to their high respiration rate. During postharvest, green beans are susceptible to mechanical damage, shriveling, chlorophyll pigment degradation, and increased fiber content. These biochemical changes reduce the quality and consumption of green bean pods and decrease their economic and nutritional values. The moisture loss and respiration rate of minimally processed (Such as peeling, coring, cutting, and packing) vegetables are much higher during refrigerated storage compared to non-processed vegetables [7]–[12].

The paleness of the color of the pods is an important characteristic because it is an indicator of a significant loss in quality, in addition, structural relaxation and formation of a stretchable structure are important characteristics of quality because they are an indicator of odor loss, chlorophyll loss and water loss. Wherefore, the change in these properties changes depending on the conditions (temperature, humidity, etc.) of the environment in which the beans are stored, especially after harvest. Many studies have indicated that green beans can only be stored for 8 - 12 days at a temperature of 5 - 7.5 °C and 95% relative humidity conditions. It has been determined that yellowing, loss of firmness, formation of elastic structure, leathery appearance, and weight loss will appear in beans stored above these temperature values, and at lower temperatures will appear cold damage in the form of black dots in the capsule [13]–[18].

Trail et al. [19] reported that chlorophyll content of beans stored at 5°C was not influenced by storage period. Pods stored at 10 °C showed significant increase in chlorophyll after 4 days storage followed by a decline as time of storage increased. Weight loss and seed percentage were higher in pods

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stored at 10 °C than in those stored at 5 °C. Storage temperature and period had no influence on texture or soluble solids content. A study about extending the shelf-life of fresh-cut green bean pods showed that TSS of green beans samples decreased at the beginning of storage in all samples and then slightly increased in controls at the end of storage, there was no major difference among all treatments. A reduction in firmness was observed for all the samples with increasing storage period. Chlorophyll content decreased with an increase in storage time [20].

The problem of freshwater shortage in the world is increasing at a rapid pace, considering the pace at which the population is growing and the rise in water use per capita as the economy induces a raised demand. Research on deficit irrigation has become needed to improve water productivity, although a high soil water potential throughout the growing season is necessary to maintain unimpaired crop growth and high economic yield, the imposition of some stress by longer irrigation intervals, higher moisture depletion or skipping irrigation during the early vegetative or during maturation could still attain similar economic yields [21]–[29].

Kaolin clay (Aluminum Silicate) is considered as one of the cheapest materials that may be used in the agricultural field as an anti-transpiration, a controller of heat, salinity stress and water use competence besides to protect plants from insect infections and many diseases. Because of their unparalleled nature, they have been joined for using in farming with a pre-harvest interlude of zero days [30]. Deficit irrigation and the application of kaolin could mitigate climate change/drought impact and save water in agriculture [31]–[35]. Kaolin clay foliar application increased the marketable yield to 93% of the unstressed-unsprayed plants, while conserving 25% of irrigation water [36].

Accordingly, the present investigation was proposed to study the effect of deficit irrigation through preventing one irrigation at different physiological stages (to conserve about 25% of irrigation water) and/or Kaolin clay foliar application on pods quality attributes of green beans (*Phaseolus vulgaris* L) Paulista cv.during cold storage.

2. Materials and Methods

2.1. Experimental layout and treatments

Soil samples to 25 cm depth, preceding the initiation of each field experiment, were collected to identify some physical and chemical properties of the experimental site (Table 1). Soil samples were analyzed at Soil Testing Laboratory, College of Agriculture, Fayoum University, according to the standard published procedures [37]–[39].

Table 1. Some important physical and chemical properties of the experimental site in 2018 (SI) 2019 (SII) seasons.

Physical characteristics	Value	
	2018	2019
Silt (%)	46.3	46.1
Clay (%)	43.7	44.2
Fine sand (%)	4.3	4.1
Coarse sand (%)	5.7	5.6
Soil texture	Silty Clay	Silty Clay
Chemical characteristics		
pH [at a soil: water (w/v) ratio of 1:2.5]	7.556	7.615
ECe (ds/m; soil – paste extract)	2.37	2.33
Organic matter (%)	1.42	1.45
Nitrate (NO3) (mg/kg)	255	260
Available (P) (mg/kg)	49.4	49.1
Available (K) (mg/kg)	370	382
Ca (mg/100g soil)	12.1	13.02
Mg (mg/100g soil)	6.1	4.9
CaCO3 (%)	3.6	4

Deficit irrigation (DI) has been applied by skipping one irrigation at different physiological stages (DI-vegetative growth, DI- Flow., DI-ripen, and normal watering as a control). Total amounts of irrigation water after sowing the seeds until the end of harvest fed-1 (four irrigations in ordinary irrigation [valued at 554.76 m^3 of water] and three irrigations [valued at 416.07 m^3 of water] in deficit irrigation). Suspension of kaolin clay (Kao-C) as a foliar application have been applied at different concentrations (without kaolin, Kao-1= 12.5 g / L, and Kao-2 = 25 g / L) weekly beginning from a week after the first irrigation (approximately three weeks after sowing) to time of ripening (a total of five times). Storage experiments (post-harvest treatments) consists of two identical cold storage experiments conducted immediately after field experiments in 2018 and 2019 seasons. Green pods from each experimental unit, were picked a week after preventing of irrigation on ripening stage (DI-ripen). A collective sample (1kg) of green pods per treatment was mixed and divided into two equal batches. The 1st and 2nd batches were allocated to determine green pods quality at the beginning (zero day) and termination (14 days) of cold storage, respectively. Green bean pods packed in cardboard boxes and placed in storage refrigerator at temperature of 7 ±1 °C and relative humidity of 95 ±2%. The experimental layout of storage experiments was split-split-plot system in a Randomized Complete Blocks design with 3 replications. Storage periods occupied the main plots, deficit irrigation (water stress) was allocated at the sub-plots, and kaolin foliar application was allocated at the sub-sub-plots. Number of treatments of storage experiment was 24 treatments (2 storage periods × 4 deficit irrigation × 3 kaolin application). Estimation of the percentage of weight loss was done by Split-plot system in a Randomized Complete Blocks design with 3 replications. Deficit irrigation (water stress) occupied the main plot and kaolin was at the sub-plots.

2.2. Data recorded

At the beginning and at the end of the storage period, pods weight (g), pods dry matter (%), N, P, and K content (%), crispness (index), firmness (kg cm^{-2}) and TSS were assayed by the following ways:

Pods N content was determined according to [40]. An Orange-G dye solution was prepared by dissolving 1.0 g of 96% (w/w) assay-dye in 1 l of distilled water, with 21.0 g citric acid which acted as a buffer to maintain the correct pH, and 2.5 ml 10% (v/v) thymol in 10% (v/v) ethanol as an inhibitor of microbial growth. Ground plant material (0.2 g pod tissue from each plot) was placed in a centrifuge tube and 20 ml of the dye reagent solution was added. The contents of each tube were shaken for 15 min, then filtered using Whatman No. 1 filter paper. The solution was diluted 100-fold with distilled water and its absorbance was measured at 482 nm. N contents were calculated using the formulae:

$$N (\%) = 0.39 + 0.954 \times \text{Dye absorbed (g /100 g) and dye absorbed (g /100 g)} = (a - b / a) (cfv / w) \times 100$$

where, a is the absorbance of the dye reagent solution at 482 nm without plant material (the blank), b is the absorbance of the dye reagent solution at 482 nm with plant material, c is the concentration of the dye reagent (1.0 g l-1 distilled water), f is the purity factor of the dye reagent (96%), v is the volume of the dye reagent solution used per sample (20 ml), and w is the weight of ground dry material in g (0.2).

Pods P content was determined according to [41]. The molybdenum-reduced molybdophosphoric blue colour method, in sulphuric acid (with reduction to exclude arsenate), was used to determine P contents (in mg g-1 DW). Sulphomolybdic acid (molybdenum blue), diluted sulphomolybdic acid, and 8% (w/v) sodium bisulphite-H_2SO_4 solution were used as reagents.

Pods K content was assessed using a Perkin-Elmer Model 52-A Flame Photometer (Glenbrook, Stamford, CT, USA) as outlined by [39].

Total soluble solids (TSS) content were determined in 0.2 g of dried pods samples as described by [42]. Samples were homogenized in 5 ml of 96% (v/v) ethanol, and then washed with 5 ml 70% (v/v) ethanol. The extracts were centrifuged at 3500 × g for 10 min, and the supernatants were stored at 4°C prior to determination. The reaction mixture of 0.1 ml of the ethanolic extract and 3 ml of freshly-prepared anthrone reagent [150 mg anthrone plus 100 ml of 72% (v/v) sulphuric acid] was placed in a boiling water bath for 10 min, and was then cooled. The absorbance of the mixture was recorded at 625 nm using a Bausch and Lomb-2000 Spectronic Spectrophotometer.

Dry matter in fresh pods (%) was calculated according to the following formula:

$$\% \text{ Dry Matter in Fresh Pods} = [(\text{dry pods weight}) / (\text{fresh pods weight})] \times 100$$

Pods Crispness (index) was evaluated by a team of six volunteers, each one of them gives a score from zero to five to the same sample and a certain number of repetitions for crispness of pods, so that the degree is 5 for the highest pod crispness, an average of those scores is made for each iteration. Pods Firmness (kg cm^{-2}) was measured using a fruit firmness tester with a 3 mm diameter plunger fruit penetrometer Model 53200, range till 13 kg (T. R. Turoni srl, Via Copernico 26, 47122 Forlì, Italy). Percentage of weight loss was estimated and expressed as the difference between initial weight of green bean pods sample at the beginning of the storage period and the final weight of green bean pods at the end of storage period divided by the initial weight of green bean pods sample at the beginning of storage and multiply by 100 as the following formula:

$$\% \text{ weight loss} = [(\text{fresh pods weight} - \text{pods weight after storage}) / (\text{fresh pods weight})] \times 100$$

2.3. Statistical analysis

Data were subjected to an analysis of variance (ANOVA) procedures in Genstat statistical package (version 11) (VSN International Ltd, Oxford, UK). Difference between means was compared using Duncan's multiple range test [43], [44].

3. Results

3.1. Pods dry matter content

Regarding the main effects of the studied factors, namely storage period, DI, and Kao-C foliar application, there was a noticeable increase in the percentage of pods dry matter after cold storage. Specifically, there was a 7.56% increase in SI and a 9.24% increase in SII. On the other hand, it is noteworthy that the highest mean values for pods dry matter were observed in the DI-Ripen treatment. This treatment showed a significant increase of 24.12% in SI and 13.71% in SII compared to the normal watering treatment, which exhibited the lowest mean values in SI. Furthermore, Kao-2 treatment resulted in the lowest mean values of pods dry matter, showing a decrease of -4.56% in SI and -2.18% in SII compared to the control treatment without kaolin (distilled water). Conversely, the control treatment without kaolin (distilled water) in SI and the Kao-1 treatment in SII exhibited the highest mean values.

Regarding the first-order interactions between the experimental factors, significant interactions were observed between the storage periods and irrigation treatments in both seasons. After 14 days of cold storage, the highest mean values of dry matter content were obtained with DI-Ripen, resulting in an increase of 39.52% in SI and 22.51% in SII compared to the control treatments, which had the lowest mean values. Similarly, significant interactions were found between the storage periods and Kao-C foliar application. After 14 days of cold storage, the highest mean values were observed in the control treatment without kaolin (Control), showing an increase of 11.43% in SI and 8.66% in SII compared to the control treatments. Furthermore, significant interactions were observed between the irrigation treatments and Kao-C foliar application. In SI, the highest mean values were obtained with DI-Ripen without Kao-C (Control), resulting in a significant increase of 48.19% compared to the control treatments. In SII, both DI-Ripen with Kao-2 and without Kao-C (Control) treatments exhibited the highest mean values, showing an increase of 20.36% and 20.18% respectively, compared to the control treatments.

Considering the second-order interaction among the experimental factors, the highest mean values of pods dry matter were observed in the interaction between 14 days of cold storage and DI-Ripen without Kao-C treatment. This combination resulted in a substantial increase of 70.61% in SI and 31.85% in SII compared to the control treatments. In contrast, the lowest mean values were obtained from the interaction between zero days of cold storage and normal watering without Kao-C treatment in SI, and the interaction between zero days of cold storage and DI-Veg. with Kao-2 treatment in SII, resulting in a decrease of -19.13% compared to the control treatment in SII.

Table 2. Main and interaction effects of cold storage periods, deficit irrigation (DI) treatments and foliar application of Kaolin clay (Kao-C) on pods dry matter content (%) of common bean during 2018 (SI) 2019 (SII) seasons.

Storage periods	Seasons / Irrigation treatments	SI Kaolin conc. Control	SI Kao-1	SI Kao-2	SI Mean	SII Kaolin conc. Control	SII Kao-1	SII Kao-2	SII Mean
0 Day	Normal Watering	9.90 p*	11.35 o	12.23 n	11.16 f	10.77 f	10.90 ef	12.04 c-f	11.24 c
	DI-Veg.	14.07 h	15.10 d	14.22 g	14.46 c	10.98 ef	11.90 def	8.71 g	10.53 c
	DI-Flow.	14.07 h	14.83 e	13.79 i	14.23 d	12.54 a-e	13.44 a-d	12.29 b-f	12.76 b
	DI-Ripen	15.83 c	13.60 j	13.06 l	14.16 d	12.85 a-d	13.17 a-d	13.33 a-d	13.12 ab
14 Days	Normal Watering	12.17 n	12.7 m	13.42 k	12.79 e	11.72 def	13.64 abc	11.83 def	12.40 b
	DI-Veg.	14.45 f	14.38 f	14.47 f	14.43 c	12.25 b-f	13.94 ab	11.80 def	12.66 b
	DI-Flow.	16.55 b	15.77 c	13.49 jk	15.27 b	13.75 ab	12.73 a-d	13.16 a-d	13.21 ab
	DI-Ripen	16.89 a	15.77 c	14.06 h	15.57 a	14.20 a	13.36 a-d	13.74 ab	13.77 a
0 Day		13.47 e	13.72 d	13.33 f	13.50	11.79 cd	12.35 bc	11.59 d	11.91
14 Days		15.01 a	14.68 b	13.86 c	14.52	12.98 ab	13.42 a	12.63 b	13.01
	Normal Watering	11.04 h	12.07 g	12.82 f	11.98 D	11.25 de	12.27 bcd	11.93 cd	11.60 B
	DI-Veg.	14.26 d	14.74 c	14.35 d	14.45 C	11.61 d	12.9 abc	10.26 e	11.82 B
	DI-Flow.	15.31 b	15.30 b	13.64 e	14.75 B	13.15 ab	13.08 ab	12.73 abc	12.99 A
	DI-Ripen	16.36 a	14.68 c	13.56 e	14.87 A	13.52 a	13.26 ab	13.54 a	13.44 A
	Mean	14.24 A	14.20 A	13.59 B		12.38 B	12.88 A	12.11 A	

*Values marked with the same letter(s) within the main and interaction impacts are statistically similar using Duncan's multiple range test. Uppercase letter(s) refers to differences within the main effects and lowercase letter(s) refers to differences within the interaction effects. DI-Veg. = Single water stress at vegetative stage, DI-Flow. = Single water stress at flowering, DI-Ripen = Single water stress at ripening, Kao-1= 12.5 g/L, Kao-2 = 25 g/L

3.2. Pods crispness (index)

Regarding the main effects of the studied factors, namely storage period, DI, and Kao-C foliar application, after cold storage, there was a significant decrease in pods' crispness, with a reduction of -50% in SI and -25% in SII compared to the initial values. On the other hand, the highest mean values were observed in the normal watering treatment in SI, exhibiting a significant increase of 32.61% compared to the DI-Ripen treatment, which exhibited the lowest mean values. However, no significant differences were observed among the irrigation treatments in SII. Similarly, no significant differences were observed in both seasons with respect to the Kao-C foliar application.

Regarding the first-order interactions between experiment factors, in both seasons, the interaction between storage periods and irrigation treatments showed a significant effect on pods crispness. Specifically, the zero-day storage combined with DI-Veg. resulted in the highest average values with an increase of 2.70% and 10.15% compared to the control treatments. Moreover, the interaction between storage periods and Kao-C also exhibited significance differences, with all Kao-C treatments at zero-day storage showed significant superiority over other treatment combinations in both seasons. Additionally, the interaction between irrigation treatments and Kao-C had a notable impact. In SI, normal watering without Kao-C and with Kao-1 recorded the highest mean values, while in SII, normal watering with Kao-2 achieved the highest mean values with a 13.53% increase compared to the control treatment.

Considering the second-order interaction among the experimental factors, zero-day storage + DI-Flow., without Kao-C, exhibited the highest mean values of pods crispness, showing a 3.85% increase compared to the control treatment in SI. However, in SII, it showed similar mean values to the control treatment, as well as the combination of zero-day storage with DI-Veg. and Kao-1.

Table 3. Main and interaction effects of cold storage periods, deficit irrigation (DI) treatments and foliar application of Kaolin clay (Kao-C) on pods crispness (index) of common bean during 2018 (SI) 2019 (SII) seasons.

Storage periods	Seasons / Irrigation treatments	SI Kaolin conc. Control	SI Kao-1	SI Kao-2	SI Mean	SII Kaolin conc. Control	SII Kao-1	SII Kao-2	SII Mean
0 Day	Normal Watering	4.33 ab*	4.17 a-d	3.80 a-f	4.11 a	4.33 a	4.00 ab	3.17 a-f	3.83 ab
	DI-Veg.	4.17 a-e	4.33 ab	4.17 abc	4.22 a	4.17 ab	4.33 a	4.17 ab	4.22 a
	DI-Flow.	4.50 a	4.17 abc	3.50 b-f	4.06 a	4.33 a	4.00 ab	3.33 a-e	3.89 ab
	DI-Ripen	3.33 c-f	3.33 c-f	3.33 c-f	3.33 b	2.67 c-g	3.33 a-e	3.17 a-f	3.06 cd
14 Days	Normal Watering	2.33 g	2.50 g	2.50 g	2.44 c	1.83 g	2.67 c-g	3.83 abc	2.78 cde
	DI-Veg.	2.00 ghi	2.17 gh	2.00 ghi	2.06 cd	2.17 efg	1.83 g	2.67 c-g	2.22 e
	DI-Flow.	1.83 ghi	1.33 hi	1.83 ghi	1.67 d	3.00 b-g	2.00 fg	3.00 b-g	2.67 de
	DI-Ripen	1.17 i	2.00 gh	1.67 ghi	1.61 d	2.50 d-g	4.00 ab	3.67 a-d	3.39 bc
0 day		4.08 a	4.00 a	3.71 a	4.00	3.88 a	3.92 a	3.46 ab	4.00
14 Days		1.83 b	2.00 b	2.00 b	2.00	2.38 c	2.63 c	3.29 b	3.00
	Normal Watering	3.33 a	3.00 a	3.17 ab	3.28 A	3.08 ab	3.33 ab	3.50 a	3.31 A
	DI-Veg.	3.08 abc	3.25 ab	3.08 a-d	3.14 AB	3.17 ab	3.09 ab	3.42 ab	3.22 A
	DI-Flow.	3.17 ab	2.75 a-e	2.67 b-e	2.861 B	3.67 a	3.00 ab	3.17 ab	3.28 A
	DI-Ripen	2.25 e	2.67 b-e	2.50 cde	2.472 C	2.58 b	3.67 a	3.42 ab	3.22 A
	Mean	2.96 A	3.00 A	2.85 A	3.00	3.13 A	3.27 A	3.38 A	3.00

*Values marked with the same letter(s) within the main and interaction impacts are statistically similar using Duncan's multiple range test. Uppercase letter(s) refers to differences within the main effects and lowercase letter(s) refers to differences within the interaction effects. DI-Veg. = Single water stress at vegetative stage, DI-Flow. = Single water stress at flowering, DI-Ripen = Single water stress at ripening, Kao-1= 12.5 g/L, Kao-2 = 25 g/L.

3.3. Pods firmness

Regarding the main effects of the studied factors, namely storage period, DI, and Kao-C foliar application, pods firmness after cold storage decreased by -30 % in SI and -13.79 % in SII. On the other hand, the DI also had a significant effect, where DI-Ripen recorded the lowest mean value of pods firmness in SI with a decreased of -16.14 % compared to the control treatment, whereas the same treatment produced the highest mean value in SII, with an increase of 20.82 % compared to the control treatment, which exhibited the lowest mean value. Furthermore, Kao-C foliar application did not result in any significant differences in SI. However, in SII, Kao-2 treatment stood out with the highest mean value, showing a notable increase of 9.68% compared to the control treatment.

When considering the first-order interactions between the experimental factors, the interaction between storage periods and DI was found to be significant in both seasons. In SI, the highest average value of pods firmness was observed in zero-day storage period, specifically with normal watering and DI-Flow. Similarly, in SII, the highest average value was obtained from the zero-day storage period, with DI-Veg. and DI-Ripen treatments. Notably, the 14-day cold storage period with DI-Ripen also resulted in significantly higher average value compared to the control treatment, with increases of 9.34%, 13.48%, and 10.16% respectively. The interaction between storage periods and Kao-C was found to be significant. The lowest average value of pods firmness was observed in 14-day cold storage period when all Kao-C treatments were applied in both seasons. Furthermore, the interaction between irrigation treatments and Kao-C spraying had a significant effect. In SI, the lowest mean value of pods firmness was obtained from DI-Ripen treatment without kaolin (Control), resulting in a decrease of -14.25% compared to the control treatment. However, in SII, the highest mean value of pods firmness was observed under DI-Ripen treatment + Kao-2, showing an increase of 30.54% compared to the control treatment.

Regarding the second-order interaction between the experimental factors, the interaction between zero-day storage, normal watering, and DI-Flow, combined with Kao-2, resulted in the highest average value of pods firmness. In SI, this combination led to an increase of 25.14%, while in SII, it led to an increase of 24.51% compared to the control treatment. Additionally, in SII, the highest mean value of pods firmness was obtained from the interaction between zero-day storage, DI-Veg., and Kao-2, resulting in a significant increase of 22.50% compared to the control treatment.

Table 4. Main and interaction effects of cold storage periods, deficit irrigation (DI) treatments and foliar application of Kaolin clay (Kao-C) of pods firmness (kg cm-2) of common bean during 2018 (SI) 2019 (SII) seasons.

Storage periods	Seasons Irrigation treatments	SI Control	SI Kaolin conc. Kao-1	SI Kao-2	SI Mean	SII Control	SII Kaolin conc. Kao-1	SII Kao-2	SII Mean
0 Day	Normal Watering	2.72 $^{c-i*}$	3.25 ^{ab}	3.40 ^{a}	3.12 ^{a}	2.67 ^{cd}	2.60 ^{cde}	2.77 ^{bcd}	2.68 ^{bc}
	DI-Veg.	3.20 $^{a-d}$	2.80 $^{b-h}$	2.93 $^{a-g}$	2.98 ^{ab}	2.78 ^{bcd}	2.73 ^{bcd}	3.27 ^{a}	2.93 ^{a}
	DI-Flow.	2.98 $^{a-f}$	3.23 ^{abc}	3.38 ^{a}	3.20 ^{a}	2.90 $^{a-d}$	2.80 $^{a-d}$	2.73 ^{bcd}	2.81 ^{ab}
	DI-Ripen	3.17 $^{a-e}$	2.70 $^{d-i}$	2.65 $^{e-j}$	2.84 ^{b}	3.02 $^{a-d}$	2.92 $^{a-d}$	3.18 ^{ab}	3.04 ^{a}
14 Days	Normal Watering	2.43 $^{g-j}$	2.38 ^{hij}	2.25 ^{ijk}	2.36 ^{c}	2.13 ^{fg}	2.10 ^{g}	2.60 ^{cde}	2.28 ^{e}
	DI-Veg.	2.12 ^{jkl}	2.48 $^{f-j}$	2.23 ^{ijk}	2.28 ^{c}	2.17 ^{efg}	2.53 $^{d-g}$	2.92 $^{a-d}$	2.54 ^{cd}
	DI-Flow.	2.25 ^{ijk}	2.12 ^{jkl}	1.67 ^{lm}	2.01 ^{d}	2.62 ^{cde}	2.10 ^{g}	2.57 ^{def}	2.43 ^{de}
	DI-Ripen	1.25 ^{m}	2.22 ^{ijk}	1.80 ^{kl}	1.76 ^{d}	2.80 $^{a-d}$	2.97 $^{a-d}$	3.08 ^{abc}	2.95 ^{a}
0 day		3.02 ^{a}	3.00 ^{a}	3.09 ^{a}	3.00	2.84 ^{ab}	2.76 ^{b}	2.99 ^{a}	2.90
14 Days		2.01 ^{c}	2.30 ^{b}	1.99 ^{c}	2.10	2.43 ^{c}	2.43 ^{c}	2.79 ^{ab}	2.50
	Normal Watering	2.58 ^{ab}	2.82 ^{a}	2.83 ^{a}	2.74 ^{A}	2.40 ^{de}	2.35 ^{e}	2.68 ^{bcd}	2.48 ^{C}
	DI-Veg.	2.66 ^{a}	2.64 ^{a}	2.58 ^{ab}	2.63 ^{A}	2.48 ^{cde}	2.63 $^{b-e}$	3.09 ^{a}	2.73 ^{B}
	DI-Flow.	2.62 ^{a}	2.68 ^{a}	2.53 ^{abc}	2.61 ^{A}	2.76 ^{bc}	2.45 ^{cde}	2.65 $^{b-e}$	2.62 ^{BC}
	DI-Ripen	2.21 ^{c}	2.46 ^{abc}	2.23 ^{bc}	2.30 ^{B}	2.91 ^{ab}	2.94 ^{ab}	3.13 ^{a}	2.99 ^{A}
	Mean	2.52 ^{A}	2.65 ^{A}	2.54 ^{A}		2.64 ^{B}	2.59 ^{B}	2.89 ^{A}	

*Values marked with the same letter(s) within the main and interaction impacts are statistically similar using Duncan's multiple range test. Uppercase letter(s) refers to differences within the main effects and lowercase letter(s) refers to differences within the interaction effects. DI-Veg. = Single water stress at vegetative stage, DI-Flow. = Single water stress at flowering, DI-Ripen = Single water stress at ripening, Kao-1= 12.5 g/L, Kao-2 = 25 g/L

3.4. Pods N content

Regarding the main effects of the three treatment factors; pods N content after cold storage decreased by -12.70 % in SI and -18.19 % in SII. The irrigation treatments had a significant effect on pods N content in SI, where DI-Ripen recorded the highest mean values of pods N content in SI with an increase of 7.30 % compared to the control treatment. While, in SII, the irrigation treatments did not produce any significant differences. Also Kao-C spraying treatments did not result any significant differences in SI, as for SII, Kao-2 recorded the highest mean value with an increase of 1.18 %. The lowest mean value was obtained from Kao-1 with a decreased of -4.07 % compared to the control treatment.

Regarding the first-order interactions between experiment factors; the interaction between storage periods and irrigation treatments was a significant effect in both seasons, where the highest mean averages of pods N content were obtained from zero day with DI-Ripen or DI-Flow., with an increase of 15.88 % and 14.14 % in SI, 4.24 % and 4.65 % in SII, compared to the control treatments, respectively. The interaction between storage periods and Kao-C was also significant. The lowest average value was obtained from 14 days of cold storage with all Kao-C treatments, in both seasons. The interaction between irrigation treatments and Kao-C spraying appeared significant, where the highest average values of pods N content were obtained from DI-Flow., without kaolin (Control) or with Kao-1 in SI, with an increase of 7.40 % and 7.04 % compared to the control treatment, respectively, but, in SII, the highest mean value was obtained from DI-Ripen with Kao-2, which is almost equal to the control treatment, with an increase of 17.08 % compared to DI-Veg., with Kao-1, which produced the lowest mean value.

Regarding the second-order interaction between the three treatment factors; the highest mean value of pods N content was obtained from the interaction between zero day with DI-Veg., combined with Kao-1 with an increase of 17.06 % in SI, while the highest mean value, in SII, was obtained from zero day with DI-Ripen and Kao-2 with an increase of 2.73 % compared to the control treatment.

Table 5. Main and interaction effects of cold storage periods, deficit irrigation (DI) treatments and foliar application of Kaolin clay (Kao-C) on pods N content (mg g^{-1} D. W.) of common bean during 2018 (SI) 2019 (SII) seasons.

Storage periods	Seasons	SI				SII			
	Irrigation	Kaolin conc.			Mean	Kaolin conc.			Mean
	treatments	Control	Kao-1	Kao-2		Control	Kao-1	Kao-2	
0 Day	Normal Watering	8.43^{b-g*}	7.68 $^{e-i}$	8.07 $^{c-i}$	8.06 ^{cd}	9.09 ^{ab}	7.85 $^{c-f}$	7.64 $^{c-g}$	8.19 ^{ab}
	DI-Veg.	8.34 $^{b-h}$	9.87 ^{a}	7.70 $^{e-i}$	8.64 ^{bc}	7.59 $^{c-g}$	7.87 $^{c-f}$	8.23 $^{a-d}$	7.90 ^{b}
	DI-Flow.	9.08 $^{a-d}$	9.57 ^{ab}	8.95 $^{a-e}$	9.20 ^{ab}	8.53 $^{a-c}$	8.58 $^{a-c}$	8.61 $^{a-c}$	8.57 ^{a}
	DI-Ripen	9.32 $^{a-c}$	9.43 ^{ab}	9.30 $^{a-d}$	9.34 ^{a}	7.99 $^{b-e}$	8.29 $^{a-d}$	9.34 ^{a}	8.54 ^{a}
14 Days	Normal Watering	8.05 $^{c-i}$	8.30 $^{b-h}$	7.70 $^{e-i}$	8.10 ^{cde}	7.13 $^{d-h}$	6.83 $^{e-h}$	7.71 $^{c-g}$	7.22 ^{c}
	DI-Veg.	7.01 ^{i}	7.12 ^{hi}	8.03 $^{d-i}$	7.40 ^{df}	7.21 $^{d-h}$	6.04 ^{h}	6.72 $^{f-h}$	6.65 ^{cd}
	DI-Flow.	8.63 $^{a-f}$	8.10 $^{c-i}$	7.47 $^{f-i}$	8.06 ^{cde}	6.69 $^{f-h}$	6.22 ^{h}	6.47 ^{gh}	6.46 ^{d}
	DI-Ripen	7.33 $^{g-i}$	7.22 $^{g-i}$	7.34 $^{f-i}$	7.30 ^{f}	6.76^{e-h}	6.80 $^{e-h}$	6.95 $^{e-h}$	6.83 ^{cd}
0 day		8.79 ^{ab}	9.14 ^{a}	8.50 ^{b}	8.81	8.30 ^{a}	8.15 ^{a}	8.46 ^{a}	8.30
14 Days		7.754 ^{c}	7.69 ^{c}	7.63 ^{c}	7.69	6.95 ^{b}	6.47 ^{b}	6.96 ^{b}	6.79
	Normal Watering	8.24 ^{ab}	8.00 ^{ab}	7.88 ^{b}	8.04 ^{B}	8.11 ^{a}	7.34 ^{ab}	7.67 ^{ab}	7.71 ^{A}
	DI-Veg.	7.68 ^{b}	8.50 ^{ab}	7.86 ^{b}	8.01 ^{B}	7.40 ^{ab}	7.00 ^{b}	7.47 ^{ab}	7.27 ^{A}
	DI-Flow.	8.85 ^{a}	8.82 ^{a}	8.21 ^{ab}	8.63 ^{A}	7.61 ^{ab}	7.40 ^{ab}	7.55 ^{ab}	7.52 ^{A}
	DI-Ripen	8.32 ^{ab}	8.33 ^{ab}	8.30 ^{ab}	8.32 ^{AB}	7.38 ^{ab}	7.54 ^{ab}	8.14 ^{a}	7.69 ^{A}
	Mean	8.27 ^{A}	8.41 ^{A}	8.06 ^{A}		7.62 ^{AB}	7.31 ^{B}	7.71 ^{A}	

*Values marked with the same letter(s) within the main and interaction impacts are statistically similar using Duncan's multiple range test. Uppercase letter(s) refers to differences within the main effects and lowercase letter(s) refers to differences within the interaction effects. DI-Veg. = Single water stress at vegetative stage, DI-Flow. = Single water stress at flowering, DI-Ripen = Single water stress at ripening, Kao-1= 12.5 g/L, Kao-2 = 25 g/L

3.5. Pods P content

Regarding the main effects of the three studied factors; pods P content after cold storage increased by 135.79 % in SI and 27.72 % in SII. Normal watering and DI-Ripen recorded the highest significant mean values of pods P content in SI, while the irrigation treatments did not produce any significant differences in SII. Also, Kao-C spraying treatments did not show any significant differences in SII. However, in SI, control without Kao-C (distilled water) recorded the highest mean value of pods P content.

Regarding the first-order interactions between experiment factors; the interaction between storage periods and irrigation treatments was a significant in both seasons, the highest mean value of pods P content was obtained from 14 days of cold storage with normal watering with an increase of 195.80 % and 109.25 %, compared to the control treatments, in both seasons, respectively. The interaction between storage periods and Kao-C was also significant, where the lowest averages value was obtained from zero day with all Kao-C treatments approximately, in both seasons. The interaction between irrigation treatments and Kao-C spraying exhibited significant effect, where the highest mean value of pods P content was obtained from normal watering without kaolin (Control) in SI, but, in SII, the highest mean value was resulted from DI-Ripen with Kao-2, with an increase of 3.57 % compared to the control treatment.

Regarding the second-order interaction between the three treatment factors; The highest mean value of pods P content was obtained from the interaction between 14 days of cold storage with normal watering without kaolin (Control) with an increase of 154.29 % in SI, while the highest mean value in SII was obtained from the interaction between 14 days of cold storage and normal watering with Kao-1 with an increase of 87.27 % compared to the control treatment.

Table 6. Main and interaction effects of cold storage periods, deficit irrigation (DI) treatments and foliar application of Kaolin clay (Kao-C) on pods P content (mg g^{-1} D. W.) of common bean during 2018 (SI) 2019 (SII) seasons.

Storage periods	Seasons	SI				SII			
	Irrigation	Kaolin conc.			Mean	Kaolin conc.			Mean
	treatments	Control	Kao-1	Kao-2		Control	Kao-1	Kao-2	
0 Day	Normal Watering	1.142 ^{e*}	0.464 ^{g}	0.964 ^{ef}	0.857 ^{d}	1.398 $^{f-h}$	0.952 ^{i}	1.250 $^{g-i}$	1.200 ^{d}
	DI-Veg.	0.881 $^{e-g}$	0.678 ^{fg}	0.857 $^{e-g}$	0.805 ^{d}	1.035 ^{hi}	1.541 $^{e-g}$	1.601 $^{d-g}$	1.392 ^{d}
	DI-Flow.	0.928 ^{ef}	0.821 $^{e-g}$	0.940 ^{ef}	0.896 ^{d}	1.827 $^{c-e}$	1.946 $^{c-e}$	1.880 $^{c-e}$	1.884 ^{bc}
	DI-Ripen	0.785 $^{e-g}$	1.154 ^{e}	1.119 ^{e}	1.019 ^{d}	1.565 $^{e-g}$	2.231^{bc}	1.952 $^{c-e}$	1.916^{bc}
14 Days	Normal Watering	2.904 ^{a}	2.529 ^{b}	2.172 ^{bc}	2.535 ^{a}	2.416 ^{ab}	2.618 ^{a}	2.499 ^{ab}	2.511 ^{a}
	DI-Veg.	2.386 ^{b}	1.797 ^{cd}	1.964 ^{cd}	2.049 ^{b}	2.666 ^{a}	1.730 $^{d-f}$	1.845 $^{c-e}$	2.079 ^{b}
	DI-Flow.	1.690 ^{d}	1.583 ^{d}	1.833 ^{cd}	1.702 ^{c}	1.678 $^{d-f}$	1.710 $^{d-f}$	1.833^{c-e}	1.737 ^{c}
	DI-Ripen	2.118 ^{bc}	2.124 ^{bc}	2.196 ^{bc}	2.146 ^{b}	1.928 $^{c-e}$	1.583 $^{d-g}$	1.999 ^{cd}	1.837 ^{c}
0 day		0.934 ^{c}	0.779 ^{c}	0.970 ^{c}	0.894	1.456 ^{d}	1.667 ^{c}	1.670 ^{c}	1.598
14 Days		2.274 ^{a}	2.008 ^{b}	2.041 ^{b}	2.108	2.172 ^{a}	1.907 ^{b}	2.044 ^{ab}	2.041
	Normal Watering	2.023 ^{a}	1.496 $^{b-d}$	1.568 ^{bc}	1.696 ^{A}	1.907 ^{ab}	1.785^{ab}	1.874 ^{ab}	1.855 ^{A}
	DI-Veg.	1.633 ^{b}	1.238 ^{d}	1.410 $^{b-d}$	1.427 ^{B}	1.850 ^{ab}	1.633 ^{b}	1.723 ^{ab}	1.735 ^{A}
	DI-Flow.	1.309 ^{cd}	1.202 ^{d}	1.386 $^{b-d}$	1.299 ^{B}	1.752 ^{ab}	1.824^{ab}	1.856 ^{ab}	1.811 ^{A}
	DI-Ripen	1.452 $^{b-d}$	1.639 ^{b}	1.657 ^{b}	1.583 ^{A}	1.746 ^{ab}	1.907 ^{ab}	1.975 ^{a}	1.876 ^{A}
	Mean	1.604 ^{A}	1.394 ^{B}	1.510 ^{AB}		1.814 ^{A}	1.787 ^{A}	1.857 ^{A}	

*Values marked with the same letter(s) within the main and interaction impacts are statistically similar using Duncan's multiple range test. Uppercase letter(s) refers to differences within the main effects and lowercase letter(s) refers to differences within the interaction effects. DI-Veg. = Single water stress at vegetative stage, DI-Flow. = Single water stress at flowering, DI-Ripen = Single water stress at ripening, Kao-1= 12.5 g/L, Kao-2 = 25 g/L.

3.6. Pods K content

Regarding the main effects of the three treatment factors; the results did not differ much before and after cold storage, and there were no significant differences between the two periods in SII, pods K content after cold storage decreased by -5.84 % in SI and -0.38 %, in SII. The irrigation treatments had a significant effect in both seasons, DI-Ripen in SI with an increase of 2.94 % compared to the control treatment and normal watering in SII, recorded the highest mean value of pods K content. Also Kao-C spraying treatments exhibited a significant effect, in both seasons, where Kao-1 recorded the highest mean value of pods K content with an increase of 2.85 % in SI, while, in SII, the highest averages values were obtained from Kao-1 and Kao-2 without any significant differences between them, with an increase of 6.46 % and 5.43 % compared to the control treatments, respectively.

Table 7. Main and interaction effects of cold storage periods, deficit irrigation (DI) treatments and foliar application of Kaolin clay (Kao-C) on pods K content (mg g^{-1} D. W.) of common bean during 2018 (SI) 2019 (SII) seasons.

Storage periods	Seasons Irrigation treatments	SI Kaolin conc. Control	SI Kaolin conc. Kao-1	SI Kao-2	SI Mean	SII Kaolin conc. Control	SII Kaolin conc. Kao-1	SII Kao-2	SII Mean
0 Day	Normal Watering	8.32 ^{bcd*}	9.05 ^{a}	8.32 ^{bcd}	8.56 ^{ab}	7.93 $^{a-e}$	8.204^{ab}	7.76 $^{a-e}$	7.97 ^{a}
	DI-Veg.	8.53 ^{abc}	8.52 ^{abc}	7.87 $^{d-g}$	8.31 ^{b}	7.59 $^{b-f}$	8.032 $^{a-d}$	8.23 ^{ab}	7.95 ^{a}
	DI-Flow.	7.64 ^{fg}	7.60^{fgh}	7.76 ^{efg}	7.67 ^{d}	7.36 $^{d-h}$	7.36 $^{d-h}$	7.24 $^{e-i}$	7.32 ^{bc}
	DI-Ripen	8.30 ^{bcd}	8.97 ^{a}	8.81 ^{ab}	8.70 ^{a}	6.84 ^{ghi}	7.44 $^{c-h}$	6.94 $^{f-i}$	7.07 ^{c}
14 Days	Normal Watering	8.19 ^{cde}	8.36 ^{bcd}	7.51 ^{fgh}	8.02 ^{c}	6.75 ^{hi}	7.90 $^{a-e}$	8.32 ^{a}	7.66 ^{ab}
	DI-Veg.	7.47 ^{gh}	7.43 ^{gh}	7.44 ^{gh}	7.45 ^{d}	6.61 ^{i}	7.40 $^{c-h}$	7.24 $^{e-i}$	7.08 ^{c}
	DI-Flow.	7.49 ^{gh}	7.07 ^{h}	7.83 $^{d-g}$	7.46 ^{d}	8.13 ^{abc}	8.12 ^{abc}	7.54 $^{b-g}$	7.93 ^{a}
	DI-Ripen	8.05 $^{c-f}$	8.85 ^{ab}	8.22 ^{cde}	8.37 ^{b}	6.98 $^{f-i}$	7.50 $^{b-g}$	8.08 $^{a-d}$	7.52 ^{b}
0 day		8.21 ^{b}	8.53 ^{a}	8.19 ^{b}	8.31	7.43 ^{b}	7.76^{ab}	7.54 ^{ab}	7.57
14 Days		7.80 ^{c}	7.93 ^{c}	7.75 ^{c}	7.83	7.12 ^{c}	7.73^{ab}	7.80 ^{a}	7.55
	Normal Watering	8.25 ^{cd}	8.71 ^{ab}	7.92 ^{def}	8.29 ^{B}	7.34 ^{bcd}	8.05 ^{a}	8.04 ^{a}	7.81 ^{A}
	DI-Veg.	8.00 ^{de}	7.97 ^{de}	7.66 ^{efg}	7.88 ^{C}	7.10 ^{cd}	7.77^{ab}	7.74 ^{ab}	7.52 ^{BC}
	DI-Flow.	7.57 ^{fg}	7.34 ^{g}	7.80 ^{ef}	7.57 ^{D}	7.74 ^{ab}	7.74^{ab}	7.39 ^{bc}	7.63 ^{AB}
	DI-Ripen	8.19 ^{cd}	8.91 ^{a}	8.51 ^{bc}	8.54 ^{A}	6.91 ^{d}	7.47 ^{bc}	7.51 ^{bc}	7.30 ^{C}
	Mean	8.00 ^{B}	8.23 ^{A}	7.97 ^{B}		7.27 ^{B}	7.74 ^{A}	7.67 ^{A}	

*Values marked with the same letter(s) within the main and interaction impacts are statistically similar using Duncan's multiple range test. Uppercase letter(s) refers to differences within the main effects and lowercase letter(s) refers to differences within the interaction effects. DI-Veg. = Single water stress at vegetative stage, DI-Flow. = Single water stress at flowering, DI-Ripen = Single water stress at ripening, Kao-1= 12.5 g/L, Kao-2 = 25 g/L

Regarding the first-order interactions between experiment factors; the interaction between storage periods and irrigation treatments showed significant difference, in both seasons, where the highest mean value of pods K content was obtained from zero day with DI-Ripen in SI, with an increase of 1.66 % and from zero day with normal watering and DI-Veg., 14 days of cold storage with DI-Flow., in SII, without any significant differences between them. The interaction between storage periods and Kao-C was also a significant, where the lowest averages values were obtained from 14 days of cold storage with all Kao-C treatments in SI, and from 14 days of cold storage without kaolin (Control) in SII. But the highest mean value was obtained from 14 days of cold storage with Kao-2, with an increase of 4.94 % compared to the control treatment in SII. The interaction between irrigation treatments and Kao-C spraying reflected a significant effect. The highest mean value of pods K content was obtained from DI-Ripen with Kao-1 in SI with an increase of 7.92 %, but in SII the highest averages values were obtained from normal watering with Kao-1 and Kao-2 with an increase of 9.71 % and 9.52 % compared to the control treatment, respectively.

Regarding the second-order interaction between the three treatment factors; the highest averages values of pods K content were obtained from the interaction between zero day with normal watering or with DI-Ripen (both) with Kao-1, with an increase of 8.80 % and 7.76 % in SI, respectively. While the highest mean value, in SII, was obtained from the interaction between 14 days of cold storage + normal watering with Kao-2 with an increase of 4.89 % compared to the control treatment.

3.7. Pods TSS content

Regarding the main effects of the three treatment factors; pods TSS content after cold storage decreased by -3.74 % in SI and -13.21 % in SII. Irrigation treatments had a significant effect in both seasons, where normal watering and DI-Ripen in SI recorded the highest mean values, without any significant differences between them. However, DI-Ripen in SII, recorded the highest mean value of pods TSS content with an increase of 19.78 %. Also, Kao-C spraying treatments had a significant effect, in both seasons, where control (without kaolin) achieved the highest significant mean value of pods TSS content in SI. While the highest mean value, in SII, was obtained from Kao-1 with an increase of 12.51 % compared to the control treatment.

Regarding the first-order interactions between experiment factors; the interaction between storage periods and irrigation treatments was a significant in both seasons, where the highest average values of pods TSS content were obtained from zero day with DI-Ripen and 14 days of cold storage combined with normal watering (both), with an increase of 17.30 % and 16.05 % in SI, respectively. In SII, 14 days cold storage + DI-Ripen treatment exhibited the highest mean value, with an increase of 24.42% compared to the control treatment. The interaction between storage periods and Kao-C showed significant differences, in general, the lowest averages values were obtained from 14 days of cold storage with all Kao-C treatments, in both seasons. While the highest mean value was obtained from zero day without kaolin (Control) in SI and zero day with Kao-1 in SII with an increase of 13.55 % compared to the control treatment. The interaction between irrigation treatments and Kao-C spraying reflected significant differences, where the highest mean value of pods TSS content was obtained from normal watering without kaolin (Control) in SI, but in SII the highest average values were resulted from normal watering + Kao-1 and DI-Ripen + Kao-2 with an increase of 45.29 % and 46.28 % compared to the control treatments, respectively.

Regarding the second-order interaction between the three treatment factors; the highest mean value of pods TSS content was obtained from the interaction between 14 days of cold storage with normal watering without kaolin (Control) in SI with an increase of 3.04 %. While in SII, the highest mean value was obtained from the interaction between zero day with DI-Veg., and Kao-1 with an increase of 51.06 % compared to the control treatment.

Table 8. Main and interaction effects of cold storage periods, deficit irrigation (DI) treatments and foliar application of Kaolin clay (Kao-C) of pods TSS content (mg g^{-1} D. W.) of common bean during 2018 (SI) 2019 (SII) seasons.

Storage periods	Seasons	SI				SII			
	Irrigation treatments	Kaolin conc. Control	Kao-1	Kao-2	Mean	Kaolin conc. Control	Kao-1	Kao-2	Mean
0 Day	Normal Watering	4.770 ^{ab*}	3.229 $^{c-e}$	3.047 $^{c-e}$	3.682 ^{ab}	3.913 $^{d-i}$	4.381 $^{c-g}$	4.077 $^{c-h}$	4.124 ^{bcd}
	DI-Veg.	3.986 $^{a-d}$	2.326 ^{e}	2.921 $^{c-e}$	3.078 ^{bc}	4.694 $^{b-e}$	5.911 ^{a}	3.515 $^{f-j}$	4.707 ^{ab}
	DI-Flow.	3.411 $^{b-e}$	2.439 ^{e}	3.255 $^{c-e}$	3.035 ^{bc}	4.259 $^{c-g}$	4.891 $^{a-d}$	4.618 $^{b-f}$	4.589 ^{ab}
	DI-Ripen	4.685 ^{ab}	4.020 $^{a-d}$	4.255 $^{a-c}$	4.319 ^{a}	4.084 $^{c-h}$	4.062 $^{c-h}$	5.024 $^{a-d}$	4.390 ^{bc}
14 Days	Normal Watering	4.915 ^{a}	3.602 $^{a-e}$	4.301 $^{a-c}$	4.273 ^{a}	2.96 $^{h-k}$	5.610 ^{ab}	2.899 $^{i-k}$	3.824 ^{cd}
	DI-Veg.	3.544 $^{a-e}$	3.147 $^{c-e}$	2.969 $^{c-e}$	3.22 ^{bc}	3.507 $^{f-j}$	2.331 ^{k}	2.641 ^{jk}	2.826 ^{e}
	DI-Flow.	2.383 ^{e}	3.045 $^{c-e}$	2.767 ^{de}	2.730 ^{c}	3.368 $^{g-k}$	3.507 $^{e-j}$	4.145 $^{c-g}$	3.673 ^{d}
	DI-Ripen	3.210 $^{c-e}$	3.258 $^{c-e}$	3.622 $^{a-e}$	3.364 ^{bc}	5.135 $^{a-c}$	5.223 $^{a-c}$	5.034 $^{a-d}$	5.131 ^{a}
0 day		4.214 ^{a}	3.003 ^{b}	3.369 ^{b}	3.529	4.237 ^{bc}	4.811 ^{a}	4.309 ^{b}	4.452 ^{bc}
14 Days		3.513 ^{b}	3.263 ^{b}	3.414 ^{b}	3.397	3.743 ^{cd}	4.167 ^{bcd}	3.680 ^{d}	3.864 ^{cd}
	Normal Watering	4.843 ^{a}	3.47 ^{bcd}	3.674 ^{bcd}	3.978 ^{A}	3.438 ^{de}	4.995 ^{a}	3.488 ^{de}	3.974 ^{B}
	DI-Veg.	3.765 ^{bc}	2.736 ^{d}	2.945 ^{cd}	3.149 ^{B}	4.10 ^{bcd}	4.12 ^{bcd}	3.078 ^{e}	3.766 ^{B}
	DI-Flow.	2.897 ^{cd}	2.742 ^{d}	3.01 ^{bcd}	2.883 ^{B}	3.813 ^{cde}	4.199 ^{bcd}	4.380 ^{abc}	4.131 ^{B}
	DI-Ripen	3.948 ^{b}	3.64 ^{bcd}	3.939 ^{b}	3.841 ^{A}	4.610 ^{abc}	4.643 ^{ab}	5.029 ^{a}	4.760 ^{A}
	Mean	3.863 ^{A}	3.130 ^{B}	3.392 ^{B}		3.990 ^{B}	4.489 ^{A}	3.994 ^{B}	

*Values marked with the same letter(s) within the main and interaction impacts are statistically similar using Duncan's multiple range test. Uppercase letter(s) refers to differences within the main effects and lowercase letter(s) refers to differences within the interaction effects. DI-Veg. = Single water stress at vegetative stage, DI-Flow. = Single water stress at flowering, DI-Ripen = Single water stress at ripening, Kao-1= 12.5 g/L Kao-2 = 25 g/L

3.8. Pods weight loss

Regarding the main effects of DI and Kao-C foliar application on percentage of pods weight loss, after cold storage; Although the lowest averages values were resulted from DI-Flow., and DI-Veg., irrigation treatments, and from Kao-2 foliar spraying treatments in both seasons (which is considered a positive point for those treatments), the statistical analysis showed no significant differences as a main effect for both factors in both seasons.

As for the interaction effect between the two study factors; the interaction between all irrigation treatments with Kao-2 achieved the lowest average value on pods weight loss after cold storage in both seasons. The lowest averages values were resulted from the interaction between normal watering and DI-Flow., both with Kao-2 with a decreased by -52.82 % and -51.69 % in SI, -52.78 % and -51.68 % in SII, respectively.

Table 9. Main and interaction effects of DI and Kao-C on pods weight loss of common bean during 2018 (SI) 2019 (SII) seasons.

Irrigation treatments	Kaolin conc.	Pods weight loss (%) SI	SII
Normal Watering		3.296 ^{A}	2.943 ^{A}
DI-Veg.		2.301 ^{A}	2.054 ^{A}
DI-Flow.		1.86 ^{A}	1.685 ^{A}
DI-Ripen		2.68 ^{A}	2.410 ^{A}
	Control	2.71 ^{A}	2.440 ^{A}
	Kao-1	2.80 ^{A}	2.525 ^{A}
	Kao-2	2.05 ^{A}	1.855 ^{A}
	Control	3.459 ^{ab}	3.092 ^{ab}
Normal Watering	Kao-1	4.76 ^{a}	4.277 ^{a}
	Kao-2	1.632 ^{b}	1.460 ^{b}
	Control	1.976 ^{b}	1.770 ^{b}
DI-Veg.	Kao-1	3.075 ^{ab}	2.748 ^{ab}
	Kao-2	1.839 ^{b}	1.644 ^{b}
	Control	2.17 ^{ab}	1.947 ^{ab}
DI-Flow.	Kao-1	1.806 ^{b}	1.615 ^{b}
	Kao-2	1.671 ^{b}	1.494 ^{b}
	Control	3.303 ^{ab}	2.950 ^{ab}
DI-Ripen	Kao-1	3.021 ^{ab}	2.699 ^{ab}
	Kao-2	1.767 ^{b}	1.580 ^{b}

*Values marked with the same letter(s) within the main and interaction impacts are statistically similar using Duncan's multiple range test. Uppercase letter(s) refers to differences within the main effects and lowercase letter(s) refers to differences within the interaction effects. DI-Veg. = Single water stress at vegetative stage, DI-Flow. = Single water stress at flowering, DI-Ripen = Single water stress at ripening, Kao-1= 12.5 g/L Kao-2 = 25 g/L.

4. Discussion

Drought and Salinity are of the most limiting abiotic stresses in agricultural productivity [1–3]. It is clear from the above explained data that in general that the studied factors had a significant effect on the quality characteristics of green bean pods, whether individually as main effects, or as a result of a first-order interaction between two factors, or the second degree among the three studied factors.

It is evident that the percentage of dry matter and P content increased in the pods after cold storage. This can be explained by the fact that despite the quantitative stability of the above-mentioned compounds, or the slight decrease (much less than the lack of water content), the loss of part of the moisture and water, which carrying of these compounds, will lead to an increase in concentration of these compounds, although their quantities do not differ, or even slightly deficient. Also, the pods content of N, K and TSS decreased after cold storage, but it seems that the cold storage conditions and the short storage period (14 days) prevented this from happening significantly. This is logical due to the respiration of the beans and the consequent deterioration and loss of moisture, during the storage period. These effects were more pronounced, especially in the qualities of crispness and firmness, which were greatly reduced after refrigerated storage. These findings might be related to the respiration process and the biochemical changes such as the breakdown and decomposition of part of the protein and a number of other plant compounds. The general decrease in the weight of the pods is observed after cold storage, despite the different percentages of this decrease according to the other factors of the study. This is very logical due to the high respiration rate of the beans and the consequent deterioration and loss of moisture, leading to weight loss during the storage period. It is very clear that the highest percentages of weight loss were resulted from complete irrigation treatments without kaolin spraying, which supports the importance of implementing one irrigation skip in conjunction with spraying kaolin to reduce the rate of pods weight loss after storage.

The obtained results from this study are in agreement with many previous studies that mentioned that green beans are susceptible to mechanical damage, shriveling, weight loss and increased fiber content during storage period [4]. The change in these properties depending on the conditions of the environment (temperature, humidity, storage period, etc.) in which the pods of green beans are stored. Total soluble solids (TSS) of green beans samples decreased at the beginning of storage in all samples, there was no major difference among all treatments. A reduction in firmness was observed for all the samples with increasing storage period. Weight loss values increase with increasing storage period [5–20].

5. Conclusions

The results suggest that the application of kaolin clay under different levels of water stress, can maintain quality attributes of green bean bods (*Phaseolus vulgaris* L.) and reduce their deterioration during cold storage. However, the magnitude of the effect varies depending on the severity of water stress and the concentration of kaolin clay applied. The authors recommend implementing one irrigation skip either during the vegetative growth stage or the maturity and harvesting stage, in conjunction with kaolin treatment, to conserve about 25% of irrigation water, while preserving the quality characteristics of green bean pods.

Author Contributions

Conceptualization, W.M.S. (Wael M. Semida), A.E.E. (Ahmed E. Emara), I.M.G. (Ibrahim M. Ghoneim), and M.A.B. (Mohammed A. Barakat); investigation, A.E.E. (Ahmed E. Emara), and W.M.S. (Wael M. Semida) ; data curation, A.E.E. (Ahmed E. Emara), and W.M.S. (Wael M. Semida) ; formal analysis, A.E.E. (Ahmed E. Emara), and W.M.S. (Wael M. Semida) ; methodology, A.E.E. (Ahmed E. Emara), and W.M.S. (Wael M. Semida) ; resources, W.M.S. (Wael M. Semida), A.E.E. (Ahmed E. Emara), I.M.G. (Ibrahim M. Ghoneim), and M.A.B. (Mohammed A. Barakat) ; software, A.E.E. (Ahmed E. Emara), and W.M.S. (Wael M. Semida); writing—original draft, A.E.E. (Ahmed E. Emara), and W.M.S. (Wael M. Semida) writing—review and editing, A.E.E. (Ahmed E. Emara), and W.M.S. (Wael M. Semida). All authors have read and agreed to the published version of the manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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