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Mitigating High Temperature Effects on Dry Bean Plants Using Some Foliar Substances

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ABSTRACT

Two field experiments were carried out during the two successive summer seasons of 2019 and 2020 at a private farm located in Mit Taher village, Minyet El-Naser city, Dakahlia Governorate, Egypt to evaluate the effects of sowing dates, some foliar substances (trehalose at 25 and 50 ppm and nitric oxide at 30 and 60 ppm) and their interactions on vegetative growth, chemical constituents of leaves, setting percentage as well as seed yield and quality of common bean plants cv. Nebrasca. The obtained results indicated that most studied parameters differed significantly due to different sowing dates and applied foliar substances in both growing seasons. Sowing in early date (March 1st) recorded the highest values of all studied characteristics except for prolin content in plant leaves. Also, foliar application with either nitric oxide or trehalose proved superiority as compared with the control in most studied parameters. Plants in the absence of foliar applications recorded the highest values of prolin content in plant leaves. Plants sown in the early date (March 1st) and sprayed with nitric oxide at 60 ppm recorded the best values of vegetative growth, chemical composition, setting percentage, seed yield and germination in both growing seasons. Thus, this treatment could be recommended to improve common bean plants performance under similar conditions of this study. Additionally, foliar application with nitric oxide at 60 ppm in the intermediate sowing date recorded higher yield nearly equal the control treatment in the early sowing date in both seasons.

Keywords: common bean – sowing dates – nitric oxide - trehalose

INTRODUCTION

Common or snap bean (*Phaseolus vulgaris* L.) is grown as a cash crop at a huge range by smallholder farmers. It is one of the important legume vegetable crops cultivated in the arid regions for both immature green pods and dry seeds. It considered as a good source of proteins, calories, dietary fibers, vitamins and minerals for millions of people in both developing and developed countries worldwide. In Egypt, it is an imperative crop for either local consumption or exportation. Dry bean cultivated area in 2020 summer season was nearly 126404 fed producing about 136046 tons with an average yield 1.076 ton/fed in Egypt according to the Ministry of Agricultural (Agriculture Extension services).

In the future, the ambient temperature is predicted to rise because of several reasons associated with global climate changes. High temperature can result in heat stress which threats crop production. Heat stress which express as different sowing dates imposes challenges for dry bean and has various effects on physiology, morphology as well as reproductive stage of plants (Omae *et al.* 2012). At the reproductive stage, high temperature stress which resulted from delay sowing is becoming a severe limitation for production of seed legumes. Delaying resulted in pollen and ovule infertility, flowers abortion, impaired fertilization, reduced seed filling leading to smaller seeds and poor yield (Sita *et al.* 2017). So an optimum time of sowing enhances the efficiency of dry bean by exploiting growth factors in an effective manner.

Foliar application with anti-stressors as trehalose and nitric oxide is a potential method that may decrease the harmful effects of high temperature on plants. Trehalose (α-D-glucopyranosyl-1,1-α-D-glucopyranoside) is a non-reducing glucose disaccharide composed of two glucose units attached through their 1-carbons that is produced by a variety of organisms including plants. It acts as an osmoprotectant, a carbon storage (Wang *et al.*, 2020) and as a cytoprotective agent under unfavorable environmental conditions (Fichtner and Lunn, 2021). The beneficial role of trehalose in ameliorating stress related to its ability to improve cellular redox balance, promoting photosynthesis and enhancing antioxidant systems (Lin *et al.*, 2020). Nitric oxide is a bioactive molecule that plays an important role in plant biomass and yield production by transporting its significant role in water relations in plant cells through controlling cellular osmotic adjustment. It also plays an important role in plant disease resistance in response to several abiotic stresses (Shan *et al.*, 2015).

Therefore, this investigation aimed to study the role of foliar application of trehalose and nitric oxide in improving growth and seed yield of common bean under late growing conditions of Delta region, Dakahlia Governorate, Egypt.

MATERIALS AND METHODS

Two field experiments were carried out at a private farm located in Mit Taher village, Minyet El-Naser city, Dakahlia Governorate, Egypt during the two successive summer seasons of 2019 and 2020 to evaluate the effects of three sowing dates (March 1st, March 15th and April 1st),

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some foliar substances (trehalose and nitric oxide) and their interactions on vegetative growth, chemical constituents of leaves, setting percentage as well as seed yield and quality parameters of common bean (*Phaseolus vulgaris* L.) under climate changes conditions of Delta region.

The experimental layout was split-plot system in a randomized complete block design with three replicates. The main-plots were used for sowing dates, while foliar application treatments were randomly distributed in the sub-plots. Each experimental unit included 3 ridges, each of 75 cm width and 10.0 m long, which resulting an area of 22.5 m^2. This study included fifteen treatments were the combination between three sowing dates were early sowing (March 1st), intermediate sowing (March 15th) and late sowing (April 1st) and five foliar application treatments including the control, trehalose (25 and 50 ppm) and nitric oxide (30 and 60 ppm). All foliar spraying solutions were applied three times within fifteen days intervals starting after thirty days from sowing in both growing seasons.

Dry seeds of cv. Nebraska were obtained from Horticulture Research Institute, Agricultural Research Center, Egypt. The dry seeds were sown immediately in the moderately moist soil in the previous mentioned three dates in both seasons of study. The seeds were sown on one side of the ridge at 10 cm apart, four to five seeds were sown then the grown plants were thin to only two plants after three weeks.

Cattle manure was added at 20m^3/fed and calcium superphosphate (15.5% P_2O_5) were added at 200 kg/fed during experimental field preparation. Growing plants were fertilized with ammonium sulphate (20.5% N) at 200 kg/fed and potassium sulphate (48% K_2O) at 50 kg/fed. These chemical fertilizers (nitrogen and potassium fertilizers) were added in two equal portions, the first one was before first irrigation and the second one was before flowering. Other inter-cultural practices including weed and pest control were done as instructed by the Ministry of Agriculture and Land Reclamation.

Mechanical and chemical analysis of soil:

Soil samples were taken at random from the experimental field area at a depth of 15 - 30 cm from soil surface before soil preparation during the two growing seasons to measure some physical and chemical soil properties according to Page (1982) and results were shown in Table 1.

Table 1. Some physical and chemical soil properties at the experimental sites during the two growing seasons of 2019 and 2020.

Soil properties	Seasons 2019	2020
Mechanical analyses		
Sand %	36.1	38.3
Silt %	31.6	30.0
Clay %	32.3	31.7
Textural class	Clay-loam	Clay-loam
Chemical analyses		
EC dSm^{-1*}	0.60	0.66
pH**	7.94	7. 41
$CaCO_3$ %	2.62	2.43
O.M %	2.51	2.32
Hydro physical analyses		
F.C %	38.42	38.82
W.P %	16.30	16.38
S.P %	78.42	78.60

Meteorological data:

Meteorological data (weekly temperature ºC and relative humidity %) of Minyet El-Naser city, Dakahlia Governorate, Egypt, during 2019 and 2020 seasons were obtained from The Central Lab. for Agricultural Climate, Agricultural Research Center as shown in Table 2.

Table 2. Average air temperature (ºC) and relative humidity (%) at the experimental site during 2019 and 2020 seasons.

Months	Average air temperature (°C) 2019	2020	Average relative humidity (%) 2019	2020
March	15.9	17.47	55.61	55.35
April	19.51	19.79	47.91	54.96
May	25.7	25.67	35.96	39.89
June	29.17	27.99	42.34	41.45
July	30.30	30.03	42.02	43.77

Recorded data:

Vegetative growth characteristics: Five plants were randomly taken from each treatment after 70 days from sowing to measure plant height, number of leaves and branches per plant, fresh and dry weight of plant and leaf area per plant.

Chemical constituents in leaves: All studied chemical constituents parameters in leaves were determined after 70 days from sowing. Nitrogen and Phosphorus were determined according to AOAC (1992). Potassium was measured according to Chapman and Pratt (1971). Chlorophylls a and b were determined according to the methods of Moran and Porath (1982) and Prolin was determined according to the method of Bates *et al.* (1973).

Setting percentage: Five plants were labeled to determine number of flowers (from the first flower to the end of flowering) then setting percentage was calculated as followed:

$$\textbf{Setting percentage} = \frac{\textbf{Number of pods/plant}}{\textbf{Number of flowers}} \times \mathbf{100}$$

Yield and its components: Dry pods of plants from each plot were harvested after 90 days from sowing at the maturity stage, counted, weighed and number of pods per plant, number of seeds per plant, weight of seeds per plant, 100-seed weight (seed index), total seed yield were estimated.

Germination and seedlings parameters: Random sample of 100 seeds for each treatment after the end of field experiments were allowed to germinate under the conditions of Laboratory for Seed Testing in Vegetables and Floriculture Department, Faculty of Agriculture, Mansoura University, Egypt as the rules of International Seed Testing Association (ISTA, 2018).

The following parameters were recorded: germination percentage (%) according to the equation described by ISTA (2018), mean germination time according to the equation described by Ellis and Roberts (1981), seedling length and seedling vigor index according to AbdulBaki and Anderson (1973).

Statistical analysis:

All obtained data were statistically analyzed according to the technique of analysis of variance (ANOVA) for the split-plot design as published by Gomez and Gomez (1984) by using "MSTAT-C" computer software package. Least significant difference (LSD) method was used to compaired the differences between treatment means at 5% level of probability as described by Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

Results

Vegetative growth characteristics:

Effects of sowing dates:

Data presented in Tables 3 and 4 show growth performance of common bean plants in response to the different three sowing dates in the two growing seasons after 70 days from planting. The obtained results show that all growth attributes (plant height, number of leaves and branches, total fresh and dry weights and leaf area) differed significantly due to sowing dates. Sowing in early date (March 1st) in the first and second seasons significantly recorded the highest values of all studied characteristics. On the other hand, the lowest values of all studied vegetative parameters were obtained as a result of late sowing date (April 1st) in both seasons.

Effects of foliar applications:

Comparing the effect of applied foliar substances (trehalose and nitric oxide) on vegetative growth characteristics, all vegetative growth parameters significantly increased in response to both applied foliar substances in the two growing seasons as compared to the check treatment. Data in Tables 3 and 4 clearly show that the highest significant values of all studied parameters were recorded with spraying nitric oxide at 60 ppm followed by trehalose at 50 ppm in both seasons respectively. The untreated plants recorded the lowest values of the mentioned vegetative parameters.

Effects of the interaction between sowing dates and foliar applications:

Plants sown early (March 1st) and sprayed with nitric oxide at 60 ppm in the first and second seasons recorded the best values of most studied parameters. No significant differences were recorded when plants sown on March1st and sprayed with trehalose at 25 ppm and sowing on March 15 and spraying with nitric oxide at 60 ppm in all studied parameters in both seasons except for total leaf area. In contrast, late sowing on April 1st in the absence of foliar substances produced the lowest values of the mentioned vegetative growth parameters in both seasons.

Chemical constituents of leaves:

Effects of sowing dates:

Data presented in Tables 5 and 6 show chemical constituents of common bean leaves in response to different three sowing dates in the two growing seasons after 70 days from planting. The obtained results show that N, P, K, chlorophylls a, b and prolin contents differed significantly due to sowing dates. Sowing on March 1st (early sowing date) in both seasons significantly recorded the highest values of all studied characteristics except for prolin content. Prolin content recorded the highest values in common bean leaves in late sowing date in both seasons. On the other hand, the lowest values of other studied chemical constituents were obtained as a result of late sowing date.

Effects of foliar applications:

Most studied chemical parameters significantly increased in response to both applied foliar substances in the two growing seasons as compared to control treatment. Data in Tables 5 and 6 clearly show that the highest significant values of N, P, K, chlorophylls a and b contents were recorded with spraying nitric oxide at 60 ppm in both growing seasons. On the other hand, plants sprayed with nitric oxide at 60 ppm recorded the lowest values of prolin content, while the control recorded the highest ones in both seasons.

Effects of the interaction between sowing dates and foliar applications:

The obtained results illustrate that the highest value of most chemical constituents resulted from early sowing and foliar spraying with nitric oxide at 60 ppm in both seasons. The second best interaction treatment was early sowing and foliar spraying with trehalose at 50 ppm in both seasons in all studied parameters except for chlorophyll b and prolin contents. Intermediate sowing date and foliar application with nitric oxide at 60 ppm came in the second order followed by early sowing and foliar application with trehalose at 50 ppm in chlorophyll a content in both seasons without significant differences. On contrary, late sowing on April 1st without foliar spraying produced the lowest value of all chemical constituents in snap bean leaves in the first and second seasons.

Table 3. Plant height, number of leaves and branches of common bean as affected by sowing dates and foliar applications as well as their interactions during 2019 and 2020 seasons after 70 days from sowing.

Characters		Plant height (cm)		Number of leaves/plant		Number of branches/plant	
Treatments		2019	2020	2019	2020	2019	2020
A- Sowing dates:							
March 1st		44.83	44.96	24.06	23.93	10.06	9.86
March 15th		41.36	41.46	22.26	22.20	9.00	8.86
April 1st		37.63	37.80	21.46	21.40	8.40	8.46
LSD 5 %		1.61	1.64	1.30	1.32	0.86	0.80
B- Foliar applications:							
Control		38.22	38.55	21.00	21.00	7.66	7.44
Trehalose at 25 ppm		40.38	40.77	22.00	21.88	8.44	8.11
Trehalose at 50 ppm		42.61	42.55	23.55	23.55	10.00	10.00
Nitric oxide at 30 ppm		41.44	41.55	22.44	22.33	9.11	8.77
Nitric oxide at 60 ppm		43.72	43.61	24.00	23.77	10.55	11.00
LSD 5 %		1.39	1.33	1.36	1.28	0.73	0.76
C- Interaction:							
March1st	Control	40.16	40.33	22.33	22.33	8.66	8.66
	Trehalose at 25 ppm	43.66	44.00	23.66	23.66	9.33	9.00
	Trehalose at 50 ppm	46.83	47.00	25.33	25.33	11.00	11.00
	Nitric oxide at 30 ppm	45.16	45.33	23.00	23.00	10.00	9.66
	Nitric oxide at 60 ppm	48.33	48.16	26.00	25.33	11.33	11.33
March15th	Control	38.66	39.33	20.66	20.66	7.66	7.66
	Trehalose at 25 ppm	40.33	40.33	21.33	21.33	8.33	7.66
	Trehalose at 50 ppm	42.66	42.33	23.00	23.00	9.66	9.66
	Nitric oxide at 30 ppm	41.83	42.00	22.66	22.33	9.00	8.66
	Nitric oxide at 60 ppm	43.33	43.33	23.66	23.66	10.33	10.66
April 1st	Control	35.83	36.00	20.00	20.00	6.66	6.00
	Trehalose at 25 ppm	37.16	38.00	21.00	20.66	7.66	7.66
	Trehalose at 50 ppm	38.33	38.33	22.33	22.33	9.33	9.33
	Nitric oxide at 30 ppm	37.33	37.33	21.66	21.66	8.33	8.00
	Nitric oxide at 60 ppm	39.50	39.33	22.33	22.33	10.00	10.33
LSD 5 %		1.95	2.03	NS	NS	NS	NS

Table 4. Fresh and dry weights and leaf area per plant of common bean as affected by sowing dates and foliar applications as well as their interactions during 2019 and 2020 seasons after 70 days from sowing.

Characters		Fresh weight (g/plant)		Dry weight (g/plant)		Leaf area (cm^2/plant)	
Treatments		2019	2020	2019	2020	2019	2020
		A- Sowing dates:					
March 1st		126.54	135.54	26.25	21.62	426.5	469.5
March 15th		96.70	93.69	18.79	16.48	370.3	426.5
April 1st		67.99	51.54	14.14	9.76	299.1	390.3
LSD 5 %		3.11	3.20	1.56	1.63	45.5	42.8
		B- Foliar applications:					
Control		81.50	74.82	14.63	11.97	306.5	354.3
Trehalose at 25 ppm		91.71	83.18	16.57	14.73	324.6	358.7
Trehalose at 50 ppm		103.14	104.11	22.46	17.57	407.4	463.0
Nitric oxide at 30 ppm		97.15	90.70	20.26	16.21	337.3	409.7
Nitric oxide at 60 ppm		111.88	115.15	24.70	19.30	450.6	558.1
LSD 5 %		4.40	4.57	2.58	1.52	33.7	32.3
		C- Interaction:					
March1st	Control	109.83	107.16	21.03	16.66	330.6	441.7
	Trehalose at 25 ppm	124.10	121.60	22.53	19.60	428.1	416.3
	Trehalose at 50 ppm	133.60	150.70	29.30	23.30	453.3	505.1
	Nitric oxide at 30 ppm	130.00	133.70	26.83	21.80	350.6	408.0
	Nitric oxide at 60 ppm	135.20	164.56	31.56	26.76	574.6	594.6
March15th	Control	83.33	74.13	14.80	13.70	296.0	304.0
	Trehalose at 25 ppm	87.16	80.83	14.50	15.16	304.0	330.6
	Trehalose at 50 ppm	103.26	106.06	22.26	18.23	405.1	453.3
	Nitric oxide at 30 ppm	94.00	86.63	19.53	16.50	393.0	393.0
	Nitric oxide at 60 ppm	115.73	120.80	22.86	18.83	448.8	487.0
April 1st	Control	51.33	43.16	8.06	5.56	292.9	296.0
	Trehalose at 25 ppm	63.86	47.13	12.70	9.43	241.8	350.6
	Trehalose at 50 ppm	72.56	55.56	15.83	11.20	320.2	448.8
	Nitric oxide at 30 ppm	67.46	51.76	14.43	10.33	268.5	428.1
	Nitric oxide at 60 ppm	84.73	60.10	19.66	12.30	372.1	574.6
LSD 5 %		7.63	7.79	2.74	2.64	53.0	48.7

Table 5. N, P and K percentages in common bean leaves as affected by sowing dates and foliar applications as well as their interactions during 2019 and 2020 seasons after 70 days from sowing.

Characters		N (%)		P (%)		K (%)	
Treatments		2019	2020	2019	2020	2019	2020
		A- Sowing dates:					
March 1st		4.76	4.72	0.376	0.373	3.42	3.42
March 15th		3.69	3.69	0.350	0.344	3.08	3.08
April 1st		3.51	3.50	0.306	0.300	3.04	2.99
LSD 5 %		0.15	0.12	0.002	0.002	0.02	0.02
		B- Foliar applications:					
Control		3.21	3.14	0.281	0.272	2.81	2.79
Trehalose at 25 ppm		3.72	3.73	0.333	0.334	3.05	2.98
Trehalose at 50 ppm		4.31	4.33	0.376	0.373	3.34	3.33
Nitric oxide at 30 ppm		4.05	4.01	0.343	0.334	3.19	3.19
Nitric oxide at 60 ppm		4.65	4.65	0.387	0.384	3.52	3.52
LSD 5 %		0.11	0.09	0.002	0.003	0.05	0.03
		C- Interaction:					
March1st	Control	3.92	3.76	0.298	0.293	3.04	3.02
	Trehalose at 25 ppm	4.48	4.50	0.362	0.360	3.26	3.26
	Trehalose at 50 ppm	5.09	5.07	0.418	0.416	3.59	3.59
	Nitric oxide at 30 ppm	4.84	4.85	0.375	0.375	3.45	3.44
	Nitric oxide at 60 ppm	5.48	5.44	0.425	0.423	3.78	3.78
March15th	Control	2.94	2.89	0.280	0.265	2.71	2.67
	Trehalose at 25 ppm	3.33	3.34	0.331	0.340	2.97	2.96
	Trehalose at 50 ppm	4.08	4.16	0.390	0.390	3.19	3.19
	Nitric oxide at 30 ppm	3.78	3.75	0.345	0.323	3.11	3.11
	Nitric oxide at 60 ppm	4.31	4.35	0.405	0.402	3.44	3.48
April 1st	Control	2.77	2.77	0.264	0.256	2.69	2.67
	Trehalose at 25 ppm	3.36	3.35	0.305	0.300	2.92	2.73
	Trehalose at 50 ppm	3.75	3.77	0.320	0.314	3.24	3.22
	Nitric oxide at 30 ppm	3.53	3.45	0.310	0.304	3.02	3.01
	Nitric oxide at 60 ppm	4.17	4.18	0.330	0.327	3.33	3.32
LSD 5 %		0.15	0.13	0.004	0.005	0.05	0.04

Setting percentage:

Effects of sowing dates:

Results in Table 7 show that sowing dates of common bean had a significant effect on setting percentage in both seasons. The highest setting values of common bean were markedly resulted from early sowing (March 1st) in both seasons (74.73 and 74.82 %). On the other hand, the lowest setting values were obtained as a result of late sowing date in the two seasons.

Table 6. Chlorophylls a, b and proline content in common bean leaves as affected by sowing dates and foliar applications as well as their interactions during 2019 and 2020 seasons after 70 days from sowing.

Characters Treatments		Chl. a (mg g^{-1} FW) 2019	Chl. a 2020	Chl. B (mg g^{-1} FW) 2019	Chl. B 2020	Proline (%) 2019	Proline 2020
A- Sowing dates:							
March 1st		0.694	0.692	0.252	0.251	8.65	8.77
March 15th		0.684	0.679	0.245	0.242	9.13	8.99
April 1st		0.677	0.669	0.234	0.228	10.28	10.29
LSD 5 %		0.007	0.005	0.002	0.002	0.06	0.05
B- Foliar applications:							
Control		0.604	0.595	0.200	0.195	10.76	10.77
Trehalose at 25 ppm		0.652	0.648	0.237	0.233	9.67	9.65
Trehalose at 50 ppm		0.718	0.715	0.262	0.261	8.51	8.49
Nitric oxide at 30 ppm		0.689	0.685	0.251	0.247	9.50	9.51
Nitric oxide at 60 ppm		0.761	0.757	0.269	0.266	8.33	8.33
LSD 5 %		0.006	0.004	0.003	0.002	0.05	0.03
C- Interaction:							
March1st	Control	0.604	0.600	0.210	0.210	10.21	10.80
	Trehalose at 25 ppm	0.666	0.665	0.245	0.245	9.06	9.01
	Trehalose at 50 ppm	0.728	0.728	0.268	0.267	7.59	7.59
	Nitric oxide at 30 ppm	0.697	0.697	0.259	0.256	8.94	8.95
	Nitric oxide at 60 ppm	0.774	0.770	0.277	0.275	7.48	7.49
March15th	Control	0.607	0.595	0.195	0.189	10.82	10.23
	Trehalose at 25 ppm	0.646	0.639	0.242	0.241	9.47	9.47
	Trehalose at 50 ppm	0.718	0.717	0.265	0.264	8.07	8.00
	Nitric oxide at 30 ppm	0.691	0.687	0.255	0.250	9.33	9.33
	Nitric oxide at 60 ppm	0.759	0.757	0.270	0.267	7.95	7.94
April 1st	Control	0.601	0.590	0.194	0.186	11.24	11.29
	Trehalose at 25 ppm	0.645	0.640	0.224	0.213	10.50	10.48
	Trehalose at 50 ppm	0.708	0.700	0.253	0.252	9.89	9.87
	Nitric oxide at 30 ppm	0.679	0.670	0.239	0.235	10.24	10.26
	Nitric oxide at 60 ppm	0.751	0.745	0.216	0.255	9.56	9.57
LSD 5 %		0.009	0.007	0.005	0.004	0.08	0.06

Table 7. Setting percentage, number of pods and seeds per plant of common bean as affected by sowing dates and foliar applications as well as their interactions during 2019 and 2020 seasons.

Characters Treatments		Setting (%) 2019	Setting (%) 2020	Number of pods/plant 2019	Number of pods/plant 2020	Number of seeds/plant 2019	Number of seeds/plant 2020
A- Sowing dates:							
March1st		74.73	74.82	22.53	23.14	76.26	77.53
March 15th		63.11	62.80	20.00	20.29	67.33	65.63
April 1st		53.92	53.66	15.80	15.79	54.66	54.68
LSD 5 %		1.36	1.28	0.36	0.33	1.66	1.75
B- Foliar applications:							
Control		59.12	59.21	17.77	18.18	60.88	60.08
Trehalose at 25 ppm		61.25	61.33	19.00	19.16	64.55	64.60
Trehalose at 50 ppm		64.96	64.80	20.11	20.44	68.66	68.42
Nitric oxide at 30 ppm		62.73	62.45	19.22	19.68	66.55	66.28
Nitric oxide at 60 ppm		71.53	71.01	21.11	21.23	69.77	70.35
LSD 5 %		1.82	1.91	0.41	0.44	2.63	2.68
C- Interaction:							
March1st	Control	68.20	68.20	21.00	21.86	72.00	72.33
	Trehalose at 25 ppm	69.56	69.53	22.00	22.33	73.33	73.30
	Trehalose at 50 ppm	74.20	74.20	22.66	23.66	79.66	80.60
	Nitric oxide at 30 ppm	71.23	71.33	22.00	22.76	76.33	74.66
	Nitric oxide at 60 ppm	90.46	90.83	25.00	25.10	80.00	86.76
March15th	Control	59.70	59.66	18.00	18.76	58.66	56.33
	Trehalose at 25 ppm	61.90	61.70	20.00	20.00	66.66	67.66
	Trehalose at 50 ppm	64.06	64.50	21.00	21.00	70.00	70.00
	Nitric oxide at 30 ppm	63.36	62.93	20.00	20.66	68.66	69.50
	Nitric oxide at 60 ppm	66.53	65.20	21.00	21.03	72.66	64.66
April 1st	Control	49.46	49.76	14.33	13.93	52.00	51.60
	Trehalose at 25 ppm	52.30	52.76	15.00	15.16	53.66	52.83
	Trehalose at 50 ppm	56.63	55.70	16.66	16.66	56.00	54.66
	Nitric oxide at 30 ppm	53.60	53.10	15.66	15.63	54.66	54.70
	Nitric oxide at 60 ppm	57.60	57.00	17.33	17.56	57.00	59.63
LSD 5 %		3.15	3.28	0.72	0.77	3.25	3.37

Effects of foliar applications:

Results presented in Table 7 show that the applied foliar substances significantly affected setting percentage as compared with the control treatment in both seasons. Foliar application with nitric oxide at 60 ppm exceeded other treatments and produced the highest setting percentages (71.53 and 71.01 %) in the first and second seasons, respectively. Plants sprayed with trehalose at 50 ppm came in the second order followed by nitric oxide at 30 ppm then trehalose at 25 ppm in both seasons, whereas the lowest setting percentages (59.12 and 59.21 %) were resulted in the absence of foliar substances in 2019 and 2020 seasons, respectively.

Effects of the interaction between sowing dates and foliar applications:

The obtained results from this study exhibited that the highest setting percentages (90.46 and 90.83 %) were resulted from the interaction between early sowing (March 1st) and nitric oxide at 60 ppm in the first and second seasons. In contrast, late sowing without foliar spraying produced the lowest setting percentages of common bean (49.46 and 49.76 %) in both growing seasons.

Yield and its components:

Effects of sowing dates:

Concerning the impact of different sowing dates on yield and its components, data in Tables 7 and 8 illustrate significant differences among treatments in both seasons. Plants sown earlier recorded the best average for number of pods per plant, weight of seeds per plant, 100-seed weight as well as total seed yield/fed in both seasons of study. On the other hand, the late sowing resulted in the lowest values of the previous parameters in both seasons.

Table 8. Weight of seeds per plant, 100-seed weight and total seed yield/fed of common bean as affected by sowing dates and foliar applications as well as their interactions during 2019 and 2020 seasons.

Characters		Weight of seeds (g/plant)		100-seed weight (g)		Total seed yield (t/fed)	
Treatments		2019	2020	2019	2020	2019	2020
A- Sowing dates:							
March 1st		31.10	31.01	54.88	53.57	1.742	1.737
March 15th		25.51	24.88	49.14	48.08	1.429	1.393
April 1st		19.07	19.82	47.39	46.38	1.068	1.110
LSD 5 %		0.52	0.43	0.74	0.78	0.040	0.035
B- Foliar applications:							
Control		22.61	22.31	49.33	48.82	1.266	1.249
Trehalose at 25 ppm		23.75	23.57	50.11	49.26	1.330	1.320
Trehalose at 50 ppm		25.40	25.46	50.13	48.10	1.422	1.426
Nitric oxide at 30 ppm		24.54	24.41	50.76	50.23	1.374	1.367
Nitric oxide at 60 ppm		29.83	30.43	52.01	50.31	1.671	1.704
LSD 5 %		0.60	0.56	0.53	0.61	0.038	0.032
C- Interaction:							
March1st	Control	27.96	26.86	53.36	52.63	1.566	1.505
	Trehalose at 25 ppm	28.20	27.56	54.13	53.13	1.579	1.544
	Trehalose at 50 ppm	29.93	29.63	55.60	51.63	1.676	1.659
	Nitric oxide at 30 ppm	28.73	28.10	54.86	54.50	1.609	1.574
	Nitric oxide at 60 ppm	40.66	42.90	56.43	55.96	2.277	2.402
March15th	Control	23.60	23.46	48.93	48.33	1.322	1.314
	Trehalose at 25 ppm	24.86	24.16	49.50	49.03	1.393	1.353
	Trehalose at 50 ppm	26.00	25.56	46.46	45.33	1.456	1.432
	Nitric oxide at 30 ppm	25.56	25.03	49.86	49.46	1.432	1.402
	Nitric oxide at 60 ppm	27.53	26.16	50.93	48.26	1.542	1.465
April 1st	Control	16.26	16.60	45.70	45.50	0.911	0.930
	Trehalose at 25 ppm	18.20	19.00	46.70	45.63	1.019	1.064
	Trehalose at 50 ppm	20.26	21.20	48.33	47.33	1.135	1.187
	Nitric oxide at 30 ppm	19.33	20.10	47.56	46.73	1.083	1.126
	Nitric oxide at 60 ppm	21.30	22.23	48.66	46.70	1.193	1.245
LSD 5 %		1.08	0.97	0.92	1.06	0.060	0.055

Effects of foliar applications:

Results in Tables 7 and 8 confirm positive respond of yield and its components to both applied foliar substances as compared with the check treatment. Foliar application of nitric oxide at 60 ppm is the superior in enhancing number of pods per plant, number of seeds per plant, weight of seeds per plant, 100-seed weight as well as total seed yield/fed of snap bean plants. On the other hand, control treatment gave less values of all the aforementioned parameters.

Effects of the interaction between sowing dates and foliar applications:

Generally, higher values of all the aforementioned characters were recorded by plants sown earlier and sprayed with all applied substances in both seasons of study. The best combination was sowing on March 1st and foliar application with nitric oxide at 60 ppm in both growing seasons. On the other hand, the lowest values were obtained with late sowing on April 1st and in the absence of foliar substances. Concerning total seed yield, in either intermediate or late sowing date, all applied foliar substance with their different concentrations exceeded the control treatment. Foliar application with nitric oxide at 60 ppm in the intermediate date recorded higher yield nearly equal the control treatment in the early sowing date, hence the role of these foliar applications was clear in mitigating the effect of high temperature stress during the late sowing date.

Germination and seedling parameters:

Effects of sowing dates:

Data presented in Tables 9 and 10 show germination and seedling parameters of common bean plants in response to the different three sowing dates in the two growing seasons. The obtained results show that all the mentioned germination and seedling parameters attributes differed significantly due to sowing dates. Sowing on March 1st (early sowing date) in the first and second seasons significantly recorded the highest values of all studied characteristics. On the other hand, the lowest values of all studied germination and seedling parameters were obtained as a result of sowing common bean on April 1st (late sowing date) in both seasons.

Effects of foliar applications:

All germination and seedling parameters (germination percentage, mean germination time, seedling length and seedling vigor index) significantly increased in response to both applied foliar substances in the two growing seasons as compared to the check treatment. Data in Tables 9 and 10 clearly show that the highest significant values of germination percentage, mean germination time, seedling length and seedling vigor index were recorded with spraying nitric oxide at 60 ppm. The untreated plants recorded the lowest values of germination and seedling parameters.

Effects of the interaction between sowing dates and foliar applications:

Results of this study illustrated that the highest values of germination and seedling parameters of snap bean were resulted from early sowing and foliar application with nitric oxide at 60 ppm in both second seasons. However, late sowing without applied foliar substances produced the lowest values of germination and seedling parameters of common bean in the two growing seasons, respectively.

Table 9. Germination percentage and mean germination time of common bean seeds as affected by sowing dates and foliar applications as well as their interactions during 2019 and 2020 seasons.

Characters		Germination (%)		Mean germination time (days)	
Treatments		2019	2020	2019	2020
A- Sowing dates:					
March 1st		88.62	87.50	2.70	2.88
March 15th		87.53	85.07	3.08	3.01
April 1st		86.93	85.00	3.19	3.12
LSD 5 %		0.49	0.52	0.16	0.19
B- Foliar applications:					
Control		79.91	77.87	3.85	3.84
Trehalose at 25 ppm		88.07	86.33	3.01	3.04
Trehalose at 50 ppm		90.58	88.41	2.67	2.72
Nitric oxide at 30 ppm		88.68	86.67	2.83	2.78
Nitric oxide at 60 ppm		91.21	90.00	2.58	2.64
LSD 5 %		0.61	0.55	0.15	0.15
C- Interaction:					
March1st	Control	80.83	79.63	3.46	3.60
	Trehalose at 25 ppm	88.70	87.93	2.67	2.88
	Trehalose at 50 ppm	91.66	90.00	2.65	2.61
	Nitric oxide at 30 ppm	89.83	88.50	2.46	2.75
	Nitric oxide at 60 ppm	92.06	91.46	2.27	2.55
March15th	Control	79.83	77.63	3.95	3.87
	Trehalose at 25 ppm	88.06	85.83	3.05	2.99
	Trehalose at 50 ppm	90.33	87.86	2.96	2.91
	Nitric oxide at 30 ppm	88.36	85.70	2.55	2.50
	Nitric oxide at 60 ppm	91.06	88.33	2.87	2.81
April 1st	Control	79.06	76.36	4.15	4.07
	Trehalose at 25 ppm	87.46	85.23	3.32	3.25
	Trehalose at 50 ppm	89.76	87.36	2.88	2.83
	Nitric oxide at 30 ppm	87.86	85.83	2.99	2.93
	Nitric oxide at 60 ppm	90.50	90.20	2.60	2.55
LSD 5 %		0.92	0.96	0.28	0.26

Table 10. Seedling length and seedling vigor index (SVI) of common bean seeds as affected by sowing dates and foliar applications as well as their interactions during 2019 and 2020 seasons.

Characters		Seedling length (cm)		Seedling vigor index (SVI)	
Treatments		2019	2020	2019	2020
A- Sowing dates:					
March 1st		11.04	10.83	9.81	9.51
March 15th		10.94	10.72	9.60	9.14
April 1st		10.88	10.66	9.49	9.09
LSD 5 %		0.06	0.07	0.20	0.19
B- Foliar applications:					
Control		9.84	9.54	7.86	7.43
Trehalose at 25 ppm		10.62	10.44	9.35	9.01
Trehalose at 50 ppm		11.59	11.37	10.50	10.05
Nitric oxide at 30 ppm		10.90	10.74	9.66	9.31
Nitric oxide at 60 ppm		11.81	11.62	10.77	10.46
LSD 5 %		0.07	0.10	0.10	0.12
C- Interaction:					
March1st	Control	9.93	9.63	8.03	7.49
	Trehalose at 25 ppm	10.67	10.54	9.46	9.27
	Trehalose at 50 ppm	11.77	11.53	10.72	10.35
	Nitric oxide at 30 ppm	11.01	10.96	9.89	9.70
	Nitric oxide at 60 ppm	11.95	11.85	11.00	10.84
March15th	Control	9.82	9.57	7.84	7.47
	Trehalose at 25 ppm	10.60	10.39	9.33	8.91
	Trehalose at 50 ppm	11.61	11.37	10.49	9.99
	Nitric oxide at 30 ppm	10.90	10.68	9.63	9.16
	Nitric oxide at 60 ppm	11.64	11.41	10.67	10.27
April 1st	Control	9.77	9.41	7.73	7.31
	Trehalose at 25 ppm	10.60	10.39	9.27	8.85
	Trehalose at 50 ppm	11.54	11.31	10.36	9.89
	Nitric oxide at 30 ppm	10.78	10.57	9.48	9.07
	Nitric oxide at 60 ppm	11.71	11.48	10.60	10.18
LSD 5 %		0.28	0.24	0.18	0.21

Discussion

This increment in vegetative growth performance in response to early sowing might be due to the suitable environmental conditions specially air temperature and relative humidity as shown in Table 2 during growth stages period causing not only maximum but also suitable growth that enable efficient photosynthesis which play a vital role in activating establishment and growth of plants. These favorable conditions reflected positively on more photosynthesis products formation causing better growth, improving nutritional status of plant and increasing chemical constituents leaves as well as setting percentage. In addition, the increases in yield and its components caused by early sowing could be attributed to the previous mentioned enhanced vegetative growth, chemical composition and setting percentage. These results are in compatible with those stated by Mashiqa *et al.* (2019) and Singh *et al.* (2020).

In contrast, in late sowing, plants are considered under heat stress conditions. These conditions restrict plant growth, while prolin is one of the component that produced in plants as a reaction of stress. Also, increased temperature in the reproductive growth stage, flower abortion, pollen and ovule infertility, impaired fertilization and reduced seed filling, leading to smaller seeds and poor yields (Sita *et al*., 2017). These results are in agreement with Suzuki *et al*. (2001) on green bean, Amer *et al*. (2002) on French bean and Amer (2004) on bean plants.

The desirable effects of spraying plants with either nitric oxide or trehalose may be attributed to their roles in resist multiple stress. Nitric oxide has a favorable role in enhancing plant nutritional status and also is effective in improving physiological, metabolic and physiological processes which intern enhanced plant growth, development and seed germination (Desikan *et al*., 2004; Tran *et al*., 2011; Corpas and Palma, 2018 and Nabia, 2019).

In addition, foliar application with trehalose plays a great role in remediated physiological and biochemical parameters and plant growth (Zulfiqar *et al.*, 2021). Also, its an energy source and has unique physicochemical properties since it efficiently stabilizes dehydrated enzymes, proteins and lipid membranes (Fernandez *et al.*, 2010), carbon metabolism, linking growth and development (Meitzel *et al.*, 2020), These results are in partial compatible with those recorded by Sadak (2016); Khater *et al.* (2018) and Zaky *et al.* (2021).

The increment in yield and its components achieved in our study as influenced by both applied foliar substances is a good reflection of the previous mentioned enhanced vegetative growth parameters (Tables 3 and 4), chemical composition (Tables 5 and 6), photosynthetic pigments and setting percentage (Table 7).

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تخفيف تاثير درجات الحرارة العالية علي نباتات الفاصوليا الجافه باستخدام بعض مواد الرش الورقى

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أجريت تجربتان حقليتان خلال العروة الصيفية لموسمي 2019 و 2020 بقرية ميت طاهر مركز منية النصر محافظة الدقهلية - مصر لدراسة تأثير مواعيد للزراعة وبعض مواد الرش (التريهالوز وأكسيد النيتريك) والتفاعل بينهم على النمو الخضري والمحتوى الكيماوي للأوراق ونسبة العقد وكذلك المحصول ومكوناته والانبات وصفات البادرات لنباتات الفاصوليا الجافة صنف نبراسكا. أوضحت النتائج المتحصل عليها أن هناك فروق معنوية في معظم الصفات محل الدراسة استجابة لمواعيد الزراعة المختلفة وكذلك مواد الرش والتفاعل بينهم في كلا الموسمين. سجلت الزراعة في الميعاد المبكر (الأول من مارس) أعلى النتائج لكل الصفات المدروسة فيماعدا محتوى الأوراق من البرولين. كذلك أثبتت مادتي الرش (التريهالوز وأكسيد النيتريك) تفوقهما على معاملة الكنترول في معظم الصفات محل الدراسة بينما سجلت نباتات الكنترول أعلى القيم بالنسبة لمحتوى الأوراق من البرولين. سجلت النباتات التي تمت زراعتها في الأول من مارس مع الرش بأكسيدالنيتريك بتركيز 60 جزء في المليون أعلى قيم لصفات النمو الخضري والمحتوى الكيماوي للأوراق ونسبة العقد وكذلك الانتاجية والانبات وصفات البادرات في كلا موسمي الدراسة وبالتالي يمكن التوصية بهذه المعاملة لتحسين أداء نباتات الفاصوليا الجافة تحت الظروف المشابهة لظروف التجربة.

الكلمات الدالة: الفاصوليا الجافة – مواعيد الزراعة – أكسيدالنيتريك – التريهالوز.