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Partial Exchange of Mineral N Fertilizer for Common Bean Plants by Organic N Fertilizer in the Presence of Salicylic Acid as Foliar Application

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Abstract

Common beans are very significant for poor countries, because they provide high nutritional value, especially in terms of protein, calories, and trace nutrients, to people who cannot afford more expensive forms of nourishment. The current experiment was performed to investigate the influence of four different levels of organic fertilizer (compost) in the presence of mineral N fertilizer, i.e., T_1: 25% M-RDN +75% O-RDN; T_2: 50% M-RDN +50% O-RDN; T_3: 75% M-RDN +25% O-RDN; and T_4 (control): 100% M-RDN (O-RDN, M-RDN = recommended dose of N in organic and mineral forms, respectively; RDN: 60 kg N/fed.) and foliar spray with salicylic acid (SA) at 0, 50, 100, and 150 ppm, as well as of their interaction, on vegetative growth, productivity, and seed quality of common bean (*Phaseolus vulgaris* L.) cv. Nebraska. Obtained results showed that the tallest plants, the highest number of branches per plant, and the heaviest leaf fresh and dry weight per plant were scored using the combined treatment comprising T_4 (100% M-RDN) and SA at 150 ppm in the two seasons. T_4-fertilized and 150 ppm SA-sprayed plants induced the highest values of leaf N, P, K, and total carbohydrates (%). The highest seed yield per plant and hectare as well as the highest average weight of 100 seeds were achieved by plants fertilized with T_4 or T_3 treatments (75% of M-RDN +25% O-RDN) and sprayed with 150 ppm SA in the two seasons. The combined treatment of T_4 and SA at 150 ppm caused the statistically highest values of seed N%, P%, total protein (%), K%, and total carbohydrate (%). In addition, the lowest values of seed nitrate content were achieved by plants fertilized with the T_1 treatment (25% M-RDN +75% O-RDN) and receiving 150 ppm SA foliar spray. In conclusion, for enhanced growth, productivity, and quality of common bean plants, it could be safe to fertilize with 75% M-RDN +25% M-RDN and spray these plants with SA at 150 ppm.

Keywords *Phaseolus vulgaris* L. · Nitrogen · Sustainable production · Yield · Seed quality

Common bean (*Phaseolus vulgaris* L.) is a major legume vegetable crop farmed in Egypt for human consumption and export (Saleh et al. 2018). It is rich in protein (22–27%) and high in amino acids, dietary fibers, minerals (P, Ca, K, Fe, and Mg), and vitamins (A, B1, B6, and B12). It is deemed a good source of protein for human consumption and is cultivated in crop alternation to improve soil properties (Ma et al. 2007). During the 2018/2019 growing season, the total yield was 27,593 t of dry seeds produced from 18,086 ha, according to statistics from the Ministry of Agriculture, Egypt, for the year 2020.

Chemical fertilizer alone enhances crop productivity in the first year but harms long-term sustainability. Chemical fertilizer prices are also rising daily. Thus, in modern agriculture, reducing reliance on chemical fertilizers while also ensuring sustainable production are critical issues that can be addressed through integrated plant nutrient supply such as farmyard manure (FYM), poultry manure, and compost, all of which are inexpensive and readily available under local conditions (Saleh et al. 2010). The use of both NPK fertilizers and organic manures has an impact on the physical and chemical qualities of soil and on biological activity. It is also positively correlated with soil porosity and enzy-

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matic activity (Band et al. 2007). The correct management of soil nutrients requires a mix of organic and inorganic fertilizer applications (Triwulaningrum 2009; Saleh et al. 2010; Alzamel et al. 2022; Ghosh et al. 2022). This is because both organic and inorganic fertilizers contribute many advantages to each other. Organic matter is made up of organic manure, which can make it efficient in terms of the soil's physical, chemical, and biological properties. Green bean yields can be increased by using organic and inorganic fertilizers (Duaja 2015).

Mineral and organic fertilizer application is an important part of plant administration. Increased agricultural yields, improved nutrient concentration in the plant, and improved soil fertility are all benefits of using adequate fertilizers. Chemical fertilizers are costly and have negative environmental consequences (Adediran et al. 2004; Chandini et al. 2019). Furthermore, the use of nitrogen-rich mineral fertilizers to maintain crop output is responsible for 60% of global anthropogenic N_2O emissions (Meng and Ding 2005; Ma et al. 2021; Hassan et al. 2022); hence, organic matter (compost) should be used instead of chemical fertilizers (Murphy 2014). Organic fertilizers effectively improve soil properties and increase root growth and soil microbe activity (Sanwal et al. 2007). However, due to attempts to conserve agriculture, the application of organic fertilizer has gained more relevance globally in recent years. Organic fertilizers have been found to aid in the protection of natural resources and limitation of ecosystem damage (Francis and Daniel 2004; Saleh et al. 2010; Ma et al. 2022). Organic farming has evolved into a system that promotes use of natural organic materials like plant leftovers, manure, mulch, and compost (Shannon and Sen 2002). In response to these concerns, some researchers have found that applying organic manure enhanced pod production and N, P, Ca, Ma, Zn, and Cu concentrations in common beans, as well as their uptake (Santosa et al. 2017).

Salicylic acid (SA) is a hormone-like molecule that is related to physiological operation and defensive responses in plants (Shi and Zhu 2008; Lefevere et al. 2020; Mollah et al. 2021). It has the potential to improve cell proliferation, senescence gene expression, and fruit output (Klessig et al. 2009; Kazem et al. 2020; Rao et al. 2021). Salicylic acid is crucial for enhancing environmental stress resistance (Raskin 1992; Liu et al. 2022) such as salinity tolerance (Jam et al. 2012; Farhangi-Abriz and Ghassemi-Golezani 2018; Hongna et al. 2021; Hamayun et al. 2022; Kumar et al. 2022), water-deficit tolerance (Bezaukova et al. 2001; Lee et al. 2019; Abbaszadeh et al. 2020; Ahmad et al. 2021; Khalvandi et al. 2021; Safari et al. 2021; Shemi et al. 2021), and low and high temperature tolerance (Khan et al. 2010; Ignatenko et al. 2019; Afzal et al. 2020; Wassie et al. 2020; Yang et al. 2022). Similarly, SA plays a role in plant physiological activities such as stomatal control, food uptake, chlorophyll and protein synthesis, ethylene biosynthesis inhibition, and photosynthesis (Raskin 1992; Cheng et al. 2016; Jahan et al. 2019). SA is implicated in disease-curing pathways after pathogen attack (Alvarez 2000; Liu et al. 2020). During the early phases of nodulation, node factors released by rhizobia in response to flavonoids produced by legumes impact the SA content of the plant. At a concentration of 50 ppm, SA improved plant growth and development, increased resilience to abiotic stressors in many plants (Azooz et al. 2011Safari et al. 2021; Rao et al. 2021; Liu et al. 2022), and protected plants from oxidative injury (Moosavi 2012; Kaya et al. 2022). Plant growth factors such as plant height, dry matter, chlorophyll, carbohydrate content, and yield characteristics were increased by SA foliar spray (Khan et al. 2010; Mohamed et al. 2021).

Therefore, the purpose of this work is to investigate the effects of partial substitution of mineral nitrogen fertilizer with organic fertilizer (compost), foliar spray with salicylic acid (SA), and their interactions on vegetative growth parameters, chemical constituents, total seed yield, and seed quality of common bean cv. Nebraska.

Materials and Methods

The field experiment was performed in sandy soil at a private sector farm during the summer seasons of 2020 and

Table 1 Physical and chemical analyses of the experimental soil

Physical analysis		Chemical analysis			
		Cations (meq/l)		Anions (meq/l)	
Coarse sand	19.6%	Ca^{++}	8.44	CO_3^-	Zero
Fine sand	40.5%	Mg^{++}	3.32	HCO_3^-	4.46
Silt	25.8%	Na^+	2.27	Cl^-	3.45
Clay	14.1%	K^+	1.31	SO_4^-	7.43
Texture class: Sandy loam					
Soil pH	7.7	Available N: 32.4 mg/kg			
Electrical conductivity (dS/m)	1.53	Available P: 12.9 mg/kg			
Organic matter	0.78%	Available K: 152 mg/kg			

2021 in El-Khatatba village, Monufia Governorate, Egypt (30°31′05″N and 30°07′34″E), to investigate the effects of different levels of organic fertilizers (compost) in the presence of mineral fertilizer and foliar spray with salicylic acid (SA) on the growth, productivity, and seed quality of common bean (*Phaseolus vulgaris L.*) cv. Nebraska. Table 1 shows the physical and chemical characteristics of the experimental soil as an average of both seasons. Chemical analysis was performed according to Black et al. (1982), while physical analysis was according to Jackson (1973).

Experiment Procedures

In both seasons, common bean seeds were planted mid-March. The experimental plot was 14 m^2 and comprised one row with a length of 20 m and a width of 0.7 m. On one side of the irrigation line, the planting space between hills was 10 cm. Plants were thinned after complete germination, leaving two plants per hill. According to the Egyptian Ministry of Agriculture's instructions, all replicates received similar agricultural practices such as irrigation management and disease and pest control measures. Fertigation was accomplished using a drip irrigation system with nozzles spaced 20 cm apart. This experiment included 16 treatments, which were combined between four fertilization treatments and four SA foliar sprays as follows:

Nitrogen Fertilizer Treatments

1. T_1: 25% M-RDN (45 kg N/fed. [4200 m^2]) + 75% of O-RDN (3.75 and 3.38 tons/fed. the first and second seasons, respectively).
2. T_2: 50% M-RDN (90 kg N/fed.) + 50% of O-RDN (2.5 and 2.25 tons/fed. in the first and second seasons, respectively).
3. T_3: 75% M-RDN (135 kg N/fed.) + 25% of O-RDN (1.25 and 1.30 tons/fed. in the first and second seasons, respectively).
4. T_4: 100% M-RDN (180 kg/fed.).

Table 2 Analysis of the compost used in the two seasons of study

Items	2020	2021
N%	1.20	1.33
P%	0.71	0.74
K%	1.61	1.58
C:N ratio	18:1	19:1
Organic matter %	32.47	33.92
PH	6.78	6.89
Electrical conductivity (dS/m)	3.14	3.42
1 m^3 =	681 kg	673 kg

Here, M-RDN and O-RDN mean the recommended dose of N fertilizer in mineral and organic forms, respectively.

The recommended dose of mineral N fertilizer (M-RDN), i.e., 60 kg N/fed. in the form of ammonium nitrate (NH_4NO_3, 33.5%; 180 kg/fed.) was used. Nitrogen was used as recommended by the Ministry of Agriculture of Egypt. Organic manure (compost) was added during soil preparation in both seasons. The chemical properties of the used compost are shown in Table 2.

Foliar Spray Treatments

1. control treatment (spray with tap water,)
2. SA at 50 ppm.
3. SA at 100 ppm.
4. SA at 150 ppm (the SA used is a commercial product from Leili Agrochemistry Co. Ltd., Beijing, China).

Common bean plants were sprayed with SA five times. Spraying was started after 30 days from seed sowing and repeated every 10 days at intervals throughout the growing season.

Agrarian practices such as irrigation, insect, and disease control were performed according to the recommendations of the Ministry of Agriculture.

Experimental Layout

The design of this experiment was a factorial experiment in a completely randomized block design with 16 treatments representing the combinations between four fertilization treatments and four SA foliar spray treatments (four N fertilization treatments × four SA foliar spray rates) replicated three times.

Recorded Data

Vegetative Growth Characteristics

After 60 days from seed sowing, five plants from each experimental plot were randomly selected for measuring plant height (PH), branch number (BN) per plant, leaf fresh weight (LFW) per plant, and leaf dry weight (DW) per plant.

Chemical Constituents Determination

Leaf total nitrogen (N; Pregl 1945), phosphorus (P; John 1970), potassium (K; Brown and Lilleland 1946), and total carbohydrates % (CARB; Herbert et al. 1971) were estimated in the dry matter of leaves.

Seed Yield and Components

At harvest, i.e., 110 days after sowing, dry pods of each plot were harvested at maturity then weighted in each harvest, seeds were extracted, and the following parameters were calculated: seeds yield/plant (SYp), total seeds yield/ha (SYh), and weight of 100 seeds (W100S).

Seed Chemical Composition

The dry seeds at harvest were oven-dried at 70 °C until constant weight to determine total N, total protein (PROT), P, K, and CARB according to the methods mentioned above for chemical analysis of leaves. In addition, seed total nitrate (NIT) was estimated according to Lufei and Yong (2017).

Statistical Analysis

The data obtained in both seasons were subjected to analysis of variance (ANOVA) and the least significant difference (LSD) method was used to differentiate between means (Snedecor and Cocharn 1991).

Results

The data in Table 3 show that fertilizing common bean plants with T_4 (100% M-RDN) was detected to be the most influential for obtaining the highest values of the studied vegetative growth parameters of common bean plants (PH, BN per plant, LFW per plant, and DW per plant), followed in descending order by those supplemented with T_3 (75% M-RDN +25% O-RDN).

On the contrary, the lowest values of vegetative growth parameters resulted from fertilizing the plants with T_1 (25% M-RDN +75% O-RDN), followed in ascending order by those fertilized with the T_2 treatment (50% M-RDN +50% O-RDN) in the two seasons. As for the effect of SA, the data in Table 3 reveal that all studied concentrations of SA (50, 100, and 150 ppm) statistically increased PH, BN, LFW, and DW, with superiority for the highest concentration (150 ppm) in the two seasons. Regarding the interaction effect between fertilization treatments and SA concentration, the obtained results demonstrate that combination with the T_4 treatment achieved the statistically highest values of vegetative growth parameters, followed by combination with the T_3 treatment, especially in plants sprayed with the high concentration of SA in the two growing seasons. In a nutshell, the tallest plants (63.8 and 61.4 cm), the highest branch number per plant (5.37 and 5.52), and the heaviest leaf fresh weight per plant (73.5 and 79.2 g) and leaf dry weight per plant (11.68 and 13.43 g) were scored using the combined treatment of T_4 and SA at 150 ppm in the first and second seasons, respectively.

Leaf Chemical Constituents Parameters

Table 4 illustrates that leaf N, P, K, and CARB% were highly influenced by all studied N fertilization treatments, with superiority of the T_4 treatment in the 2020 and 2021 seasons. The T_3 treatment also gave high, significant increases in these parameters in the 2020 and 2021 seasons. The differences between T_4 and T_3 treatments were not significant in most cases in the two study seasons. The lowest values of these parameters were elicited by the T_1 treatment, followed in ascending order by plants that received T_2 in the 2020 and 2021 seasons.

Regarding the effect of foliar spray with SA, the data in Table 4 show that leaf N, P, K, and CARB% were increased as the concentration of SA increased. Consequently, 150 ppm SA-sprayed plants showed the highest values of these parameters in the 2020 and 2021 seasons of study.

As for the interaction effect between fertilization and SA foliar spray treatments, data in Table 4 reveal that the combination with T_4 was the most effective for inducing the greatest leaf N, P, K, and CARB%, followed in descending order by the combination with T_3 in the 2020 and 2021 seasons. Generally, T_4 fertilization combined with 150 ppm SA spraying induced the highest values of these parameters in the two seasons. On the contrary, the lowest values of these parameters were achieved by plants enriched with T_1 and receiving no SA foliar spray in the two seasons. The remaining treatments occupied an intermediate position in the 2020 and 2021 seasons.

Yield Parameters

The data presented in Table 5 show that the highest seed yield per plant (SYp; 17.1 and 17.7 g), seed yield (ton/ha.; SYh; 2.45 and 2.53 tons), and average weight of 100 seeds (W100S; 35.6 and 36.1 g) were scored using the T_4 treatment in the first and second seasons, respectively, followed by those fertilized with the T_3 treatment. The differences between the abovementioned two treatments were not significant in the two seasons. The lowest values of yield parameters were gained by supplementation with the T_1 treatment, followed in ascending order by plants that received the T_2 treatment, without significant differences between them in the two seasons. Furthermore, there was a positive relationship between the seed yield parameters and SA concentrations, where the seed yield parameters were increased gradually with increasing concentration of SA. Therefore, 150 ppm SA-sprayed plants resulted in the highest SYp, SYh, and W100S in the two seasons. Referring to the interaction effect between the two studied factors,

Table 3 Effect of N fertilization and foliar spray with salicylic acid and their interaction on vegetative growth characteristics of common bean during the 2020 and 2021 seasons

Treatment		2020				2021			
Organic fertilizer	Foliar spray	Plant height (cm)	No. of branches/plant	Leaves fresh weight (g/plant)	Leaves dry weight (g/plant)	Plant Height (cm)	No. of branches/plant	Leaves fresh weight (g/plant)	Leaves dry weight (g/plant)
T1: 25% M-RDN +75% M-RDN	–	49.6	4.04	55.7	8.84	47.5	4.17	61.5	10.37
T2: 50% M-RDN +50% M-RDN	–	51.8	4.23	58.1	9.24	49.8	4.68	64.4	10.88
T3: 75% M-RDN +25% M-RDN	–	59.6	4.87	67.5	10.72	56.9	5.17	69.5	12.19
T4: 100% M-RDN	–	61.3	5.22	70.6	11.24	59.2	5.33	75.1	12.70
$LSD_{0.05}$		*4.1*	*0.13*	*2.1*	*0.37*	*3.1*	*0.14*	*2.3*	*0.43*
–	Control	52.5	4.50	60.8	9.64	50.4	4.59	64.8	10.96
–	SA at 50 ppm	53.9	4.39	62.3	9.92	52.3	4.72	67.2	11.34
–	SA at 100 ppm	57.3	4.71	63.6	10.16	54.8	4.95	68.7	11.60
–	SA at 150 ppm	58.5	4.78	65.1	10.32	56.0	5.08	72.3	12.24
$LSD_{0.05}$		*4.1*	*0.13*	*2.1*	*0.37*	*3.1*	*0.14*	*2.3*	*0.43*
T1: 25% M-RDN +75% M-RDN	Control	46.2	3.86	52.8	8.32	43.8	3.92	58.1	9.86
	SA at 50 ppm	47.2	3.94	54.1	8.64	45.1	4.11	59.8	10.03
	SA at 100 ppm	51.2	4.12	57.1	9.12	49.4	4.29	63.4	10.71
	SA at 150 ppm	53.8	4.24	58.7	9.28	51.6	4.36	64.6	10.88
T2: 50% M-RDN +50% M-RDN	Control	49.8	4.14	56.2	8.96	47.0	4.20	61.8	10.37
	SA at 50 ppm	49.7	4.19	58.7	9.28	49.2	4.61	61.4	10.39
	SA at 100 ppm	53.4	4.29	58.1	9.28	51.3	4.82	65.2	11.05
	SA at 150 ppm	54.2	4.31	59.2	9.44	51.8	5.08	69.2	11.73
T3: 75% M-RDN +25% M-RDN	Control	56.3	4.92	65.8	10.40	54.1	5.08	69.3	11.73
	SA at 50 ppm	58.2	4.26	67.1	10.72	56.1	4.93	73.2	12.41
	SA at 100 ppm	61.8	5.13	68.0	10.81	58.5	5.31	69.4	11.73
	SA at 150 ppm	62.1	5.18	68.9	10.88	59.0	5.34	76.1	12.92
T4: 100% M-RDN	Control	58.2	5.06	68.2	10.86	56.7	5.16	70.0	11.90
	SA at 50 ppm	60.4	5.16	69.2	11.04	58.9	5.26	74.2	12.58
	SA at 100 ppm	62.6	5.29	71.3	11.36	59.8	5.39	76.8	12.92
	SA at 150 ppm	63.8	5.37	73.5	11.68	61.4	5.52	79.2	13.43
$LSD_{0.05}$		*8.2*	*0.27*	*4.3*	*0.74*	*6.1*	*0.28*	*4.5*	*0.86*

Means between treatments in the same column followed by the LSD differ according to 0.05

Table 4 Effect of N fertilization and foliar spray with salicylic acid and their interaction on plant foliage chemical constituents of the common bean during the 2020 and 2021 seasons

Treatment		2020				2021			
Organic fertilizer	Foliar spray	N%	P%	K%	Total CARB%	N%	P%	K%	Total CARB%
T1: 25% M-RDN +75% M-RDN	–	2.16	0.157	1.47	13.9	2.27	0.149	1.43	14.8
T2: 50% M-RDN +50% M-RDN	–	2.23	0.165	1.55	15.0	2.34	0.155	1.49	16.1
T3: 75% M-RDN +25% M-RDN	–	2.35	0.176	1.62	18.1	2.40	0.163	1.64	18.6
T4: 100% M-RDN	–	2.44	0.183	1.71	19.4	2.49	0.175	1.72	20.2
LSD0.05		*0.11*	*0.009*	*0.13*	*1.1*	*0.09*	*0.008*	*0.16*	*1.2*
–	Control	2.21	0.161	1.47	15.6	2.30	0.154	1.48	16.2
–	SA at 50 ppm	2.26	0.168	1.56	16.3	2.33	0.154	1.54	16.9
–	SA at 100 ppm	2.33	0.174	1.62	17.0	2.41	0.164	1.61	18.1
–	SA at 150 ppm	2.38	0.178	1.69	17.5	2.46	0.169	1.66	18.5
LSD0.05		*0.11*	*0.009*	*0.13*	*1.1*	*0.09*	*0.008*	*0.16*	*1.2*
T1: 25% M-RDN +75% M-RDN	Control	2.08	0.146	1.34	12.3	2.14	0.138	1.30	13.1
	SA at 50 ppm	2.11	0.152	1.41	13.4	2.22	0.146	1.38	14.6
	SA at 100 ppm	2.19	0.161	1.52	14.7	2.31	0.152	1.47	15.8
	SA at 150 ppm	2.27	0.168	1.59	15.1	2.39	0.159	1.56	15.6
T2: 50% M-RDN +50% M-RDN	Control	2.17	0.157	1.41	14.6	2.26	0.149	1.42	15.2
	SA at 50 ppm	2.16	0.161	1.51	14.9	2.30	0.148	1.47	15.1
	SA at 100 ppm	2.28	0.168	1.61	15.3	2.38	0.157	1.52	16.9
	SA at 150 ppm	2.32	0.172	1.68	15.0	2.40	0.164	1.53	17.3
T3: 75% M-RDN +25% M-RDN	Control	2.26	0.169	1.53	17.1	2.37	0.162	1.58	17.9
	SA at 50 ppm	2.36	0.176	1.62	17.8	2.36	0.152	1.61	18.2
	SA at 100 ppm	2.35	0.179	1.60	18.2	2.41	0.167	1.67	18.7
	SA at 150 ppm	2.41	0.181	1.71	19.3	2.46	0.169	1.73	19.6
T4: 100% M-RDN	Control	2.34	0.172	1.61	18.2	2.41	0.168	1.63	18.7
	SA at 50 ppm	2.41	0.181	1.69	19.1	2.45	0.170	1.68	19.7
	SA at 100 ppm	2.49	0.187	1.74	19.8	2.52	0.179	1.76	20.8
	SA at 150 ppm	2.53	0.192	1.79	20.5	2.57	0.182	1.82	21.4
LSD0.05		*0.22*	*0.018*	*0.26*	*2.2*	*0.18*	*0.016*	*0.31*	*2.5*

Means between treatments in the same column followed by the LSD differ according to 0.05

the data in Table 5 reveal that the combination with T_4 is the most influential for producing the highest records of seed yield parameters, followed by the combination with the T_3 treatment in the two seasons. In a nutshell, the highest SYp (18.4 and 18.89 g), SYp (1104 and 1128 kg), and the W100S (35.9 and 36.79 g) were achieved by plants fertilized with T_4 and sprayed with 150 ppm SA, followed by those enriched with T_4 and foliar sprayed with 100 ppm SA in the two seasons. Besides this, the combined treatment of T_3 and SA at 150 ppm gave high increments in these parameters in the two seasons. The differences among the three mentioned treatments did not reach the level of significance in the two seasons. In contrast, the lowest values of seed yield were scored by the combination with T_1, especially in plants which received no SA treatment in the two seasons.

Table 5 Effect of N fertilization and foliar spray with salicylic acid and their interaction on seed yield and its components of the common bean during the 2020 and 2021 seasons

Treatment		2020			2021		
Organic fertilizer	Foliar spray	Seed yield/ plant (g)	Seed yield: tons/feddan ($4200\,m^2$)	Weight of 100 seeds (g)	Seed yield/ plant (g)	Seed yield/ic. (ton)	Weight of 100 seeds (g)
T1: 25% M-RDN +75% M-RDN	–	13.5	1.93	32.1	13.8	1.97	32.2
T2: 50% M-RDN +50% M-RDN	–	14.4	2.06	32.7	14.5	2.08	32.4
T3: 75% M-RDN +25% M-RDN	–	16.2	2.31	34.3	16.2	2.32	34.1
T4: 100% M-RDN	–	17.1	2.45	35.6	17.7	2.53	36.1
$LSD_{0.05}$		*1.3*	*0.22*	*56.17*	*1.1*	*0.25*	*0.25*
–	Control	13.9	1.99	33.1	14.1	2.02	33.4
–	SA at 50 ppm	14.7	2.10	33.5	15.1	2.16	33.5
–	SA at 100 ppm	16.0	2.28	33.9	16.3	2.32	33.8
–	SA at 150 ppm	16.7	2.38	34.1	16.8	2.40	34.1
$LSD_{0.05}$		*1.3*	*0.25*	*0.24*	*1.1*	*0.21*	*0.20*
T1: 25% M-RDN +75% M-RDN	Control	12.3	1.76	31.7	11.9	1.70	31.9
	SA at 50 ppm	12.9	1.85	31.9	13.2	1.88	32.1
	SA at 100 ppm	14.1	2.02	32.3	14.8	2.11	32.4
	SA at 150 ppm	14.7	2.10	32.4	15.3	2.19	32.4
T2: 50% M-RDN +50% M-RDN	Control	12.9	1.85	32.1	12.7	1.82	32.3
	SA at 50 ppm	13.6	1.94	32.5	14.1	2.02	32.3
	SA at 100 ppm	15.2	2.17	32.9	15.3	2.19	32.5
	SA at 150 ppm	15.9	2.28	33.1	15.9	2.27	32.6
T3: 75% M-RDN +25% M-RDN	Control	14.8	2.11	33.7	15.1	2.16	33.9
	SA at 50 ppm	15.6	2.23	34.1	15.9	2.27	33.8
	SA at 100 ppm	16.9	2.42	34.8	16.8	2.40	34.1
	SA at 150 ppm	17.6	2.51	34.9	17.3	2.48	34.6
T4: 100% M-RDN	Control	15.6	2.23	35.2	16.8	2.40	35.6
	SA at 50 ppm	16.7	2.39	35.6	17.2	2.46	35.9
	SA at 100 ppm	17.8	2.54	35.7	18.1	2.59	36.4
	SA at 150 ppm	18.4	2.63	35.9	18.8	2.68	36.7
$LSD_{0.05}$		*2.6*	*0.18*	*0.30*	*2.3*	*0.10*	*4.2*

Means between treatments in the same column followed by the LSD differ at 0.05

Table 6 Effect of N fertilization and foliar spray with salicylic acid and their interaction on seed chemical constituents of the common bean during the 2020 and 2021 seasons

Treatment		2020						2021					
Organic fertilizer	Foliar spray	N%	P%	K%	Total carbohydrate (%)	Total protein (%)	Nitrate (mg/kg)	N%	P%	K%	Total carbohydrate (%)	Total protein (%)	Nitrate (mg/kg)
T1: 25% M-RDN +75% M-RDN	–	3.25	0.424	1.90	51.4	20.27	982	3.19	0.419	2.02	49.8	19.90	961
T2: 50% M-RDN +50% M-RDN	–	3.33	0.428	2.02	54.1	20.77	1070	3.24	0.423	2.15	51.3	20.23	1078
T3: 75% M-RDN +25% M-RDN	–	3.41	0.441	2.17	55.8	21.27	1247	3.32	0.435	2.29	54.2	20.73	1224
T4: 100% M-RDN	–	3.50	0.445	2.27	56.6	21.87	1317	3.37	0.442	2.37	55.5	21.07	1357
LSD0.05		*0.12*	*0.009*	*0.16*	*2.1*	*1.14*	*52*	*0.15*	*0.008*	*0.24*	*1.9*	*1.12*	*49*
–	Control	3.25	0.424	1.91	52.8	20.31	1102	3.16	0.422	2.05	51.1	19.76	1095
–	SA at 50 ppm	3.33	0.430	2.05	53.9	20.81	1126	3.24	0.425	2.16	52.4	20.21	1110
–	SA at 100 ppm	3.43	0.439	2.17	54.9	21.44	1173	3.33	0.435	2.27	53.1	20.77	1173
–	SA at 150 ppm	3.46	0.445	2.23	56.2	21.63	1216	3.39	0.438	2.34	54.4	21.18	1242
LSD0.05		*0.12*	*0.009*	*0.16*	*2.1*	*1.14*	*52*	*0.15*	*0.008*	*0.24*	*1.9*	*1.12*	*49*
T1: 25% M-RDN +75% M-RDN	Control	3.14	0.413	1.76	49.3	19.62	1082	3.06	0.407	1.83	48.1	19.12	1014
	SA at 50 ppm	3.21	0.419	1.83	51.2	20.06	986	3.15	0.412	1.92	49.2	19.68	991
	SA at 100 ppm	3.29	0.428	1.96	52.3	20.56	943	3.22	0.426	2.13	50.2	20.12	932
	SA at 150 ppm	3.34	0.434	2.04	52.9	20.87	917	3.31	0.431	2.19	51.6	20.68	908
T2: 50% M-RDN +50% M-RDN	Control	3.21	0.417	1.81	52.8	20.06	1146	3.11	0.412	1.98	49.6	19.43	1209
	SA at 50 ppm	3.29	0.426	1.98	53.6	20.56	1107	3.19	0.418	2.11	51.7	19.93	1108
	SA at 100 ppm	3.39	0.431	2.12	54.1	21.18	1043	3.29	0.431	2.19	51.6	20.56	1007
	SA at 150 ppm	3.41	0.438	2.18	56.0	21.31	992	3.36	0.431	2.31	52.3	21.0	989
T3: 75% M-RDN +25% M-RDN	Control	3.29	0.431	1.96	54.3	20.56	1298	3.21	0.432	2.17	52.7	20.06	1327
	SA at 50 ppm	3.37	0.439	2.14	55.0	21.06	1269	3.28	0.430	2.26	53.8	20.50	1204
	SA at 100 ppm	3.47	0.446	2.26	56.2	21.68	1217	3.37	0.437	2.34	54.3	21.06	1187
	SA at 150 ppm	3.49	0.449	2.31	57.6	21.81	1205	3.41	0.442	2.38	56.1	21.31	1181
T4: 100% M-RDN	Control	3.36	0.436	2.11	54.9	21.0	1341	3.27	0.435	2.25	53.8	20.43	1419
	SA at 50 ppm	3.45	0.435	2.25	55.8	21.56	1332	3.32	0.439	2.34	54.9	20.75	1329
	SA at 100 ppm	3.58	0.45	2.34	57.1	22.37	1304	3.42	0.446	2.42	55.7	21.37	1317
	SA at 150 ppm	3.61	0.458	2.39	58.4	22.56	1294	3.48	0.449	2.47	57.4	21.75	1303
LSD0.05		*0.24*	*0.018*	*0.31*	*4.3*	*2.27*	*104*	*0.29*	*0.015*	*0.47*	*3.8*	*2.25*	*98*

Means between treatments in the same column followed by the LSD differ according to 0.05

The other treatments ranked between the aforementioned treatments in the 2020 and 2021 seasons.

Seed Chemical Constituents Parameters

Seed N, PROT, P, K, CARB, and NIT contents of common beans were highly influenced by the fertilization treatments in the 2020 and 2021 seasons (Table 6). In this regard, the highest values of seed N, PROT, P, K, and CARB content were recorded by using the T_4 treatment, followed in descending order by plants that received the T_3 treatment, without significant differences between them in the 2020 and 2021 seasons. In addition, the T_1 and T_2 treatments resulted in the lowest seed NIT content, with significant differences between them in the two seasons. The highest seed NIT content was achieved by plants fertilized with the full mineral N recommended dose (T_4), followed in descending order by the T_3 treatment, with significant differences between them in the 2020 and 2021 seasons.

Further, all tested concentrations of SA improved the values of seed chemical constituents parameters in the 2020 and 2021 seasons. In this regard, the increment in seed N, PROT, P, K, and CARB values was parallel to the applied concentration of SA, so the highest concentration of SA significantly scored the highest values of these parameters when compared with the control in the 2020 and 2021 seasons. However, all studied SA concentrations succeeded in decreasing seed NIT content, particularly the high concentration in the two seasons.

Regarding the interaction effect between fertilization and SA treatments, the data in Tables 4 and 5 show that combination with the T_4 treatment was the most promising for giving the best results of seed chemical constituents parameters, followed by combination with the T_3 treatment in the 2020 and 2021 seasons. In general, the combined treatment between T_4 and SA at 150 ppm statistically caused the highest values of seed N% (3.61 and 3.48), P% (0.458 and 449), PROT% (22.56 and 21.75), K% (2.39 and 2.47), and CARB% (58.4 and 57.4) in the first and second seasons, respectively. Also, the combined treatment between T_4 and SA at 100 ppm and the combined treatment between T_3 and SA at 150 ppm caused a high, significant increment in these parameters in the two seasons. The differences between the abovementioned three combined treatments were not significant in the 2020 and 2021 seasons. Additionally, the lowest values of seed NIT content were achieved by plants fertilized with the T_1 treatment and receiving 150 ppm SA foliar spray, as they scored 917 and 908 mg/kg dry seeds in the first and second seasons, respectively. The highest values of seed NIT content were achieved by combination with the T_4 treatment, especially in plants that received no SA treatment in the 2020 and 2021 seasons.

Discussion

The increase in plant development caused by supplementing mineral nitrogen with organic nitrogen could be explained by the fact that organic fertilizers release nitrogen slowly, whereas mineral fertilizers can compensate for the essential nitrogen. Furthermore, organic fertilizers aid in improving soil physical characteristics and lowering pH, which affect the availability of soil nutrients for plant uptake and, as a result, improve plant development. When organic and mineral N fertilizers are used simultaneously, uptake of NPK elements may be increased. Also, an increase in photosynthetic pigments and determined macronutrient content (Table 4) reflect a significant increase in dry matter contents and, consequently, plant growth parameters. The obtained results follow the same trend as those reported by AL-Deen Al-Leela et al. (2019), Mahmoud and Gad (2020), Rurangwa et al. (2020), Seif El-Yazal (2020), and Sánchez-Navarro et al. (2021). The role of salicylic acid may be due to its positive affects the activity and viability of plant cells, leading to the increase in plant growth. It also affects plant physiological processes as well as having anti-disease functions, and hence promotes plant growth (Raskin 1992). The increase in vegetative growth upon SA treatment may be due to its role in increasing the cytokinins, which play a role in reproducible cell division (Khan et al. 2010), and in raising the efficiency of photosynthesis by increasing CO_2 absorption in plastids, thus providing the materials needed for budding (Khan et al. 2010). The obtained results correspond to those mentioned by Abdelaal (2015), Refat et al. (2017), Azoz and El-Taher (2018), and Rasheed (2018). In this regard, the increase in NPK nutrients may be linked to the impact of organic fertilizer on soil pH, soil microbial biomass, and humate, all of which affect the breakdown and availability of such nutrients, resulting in increased uptake by plant roots. In this respect, Sánchez-Navarro et al. (2021) and Refat et al. (2017) observed that manure increases soil organic matter, NPK availability, and Mg, Mn, and Zn exchange, all of which impact the chemical components of the leaves. The current results follow those reported by (Hegazi and El-Shraiy (2007), Manivannan *et al.* (2009), Islam et al. (2016), Kamble et al. (2016), and Sharma et al. (2017). Consequently, 150 ppm SA-sprayed plants had the highest values of these parameters in the 2020 and 2021 seasons of study. This increment in these elements may be due to SA playing a role in plant physiological activities such as stomatal control, nutrient uptake, chlorophyll and protein synthesis, ethylene biosynthesis inhibition, transpiration, and photosynthesis (Raskin 1992; Abdelaal 2015; Refat et al. 2017; Azoz and El-Taher 2018, and Rasheed 2018). Compost application improved the physical conditions of the soil, which supported better aeration of plant roots, drainage of water, facilitation of N^+, P^+, and K^+ exchange, and thus prolonged the availability of nutrients, resulting in better growth (Table 3). The 50% compost +50% mineral N treatment provides more macro- and micronutrients to the soil and plants in an accessible form, resulting in improved growth and bean yield and quality (Manivannan et al. 2009). The current results parallel those reported by Seif El-Yazal (2020), Sánchez-Navarro et al. (2021), Islam et al. (2016), Kamble et al. (2016), and Sharma et al. 2017).

The increase in seed yield parameters due to SA treatments may be attributed to their role in increasing the number of branches per plant (Table 3). Also, SA plays a role in reducing the impact of abscisic acid (ABA) and increasing the production of growth-promoting plant hormones such as auxin and gibberellin (Bezaukova et al. 2001). Moreover, a role in the reduction of competition between flowers and vegetative growth for photosynthesis products may be attributed this substance, besides its role in increasing nutrients in the leaves (Table 4) and then mobilizing seeds and, thus, increasing yield parameters. Rasheed (2018) revealed that treating broad bean plants with SA at 100 mg/L led to significant increases in pods weight, number of seeds per pod, seed weight, weight of 100 seeds, seed yield per plant, and total seed yield per donum. The obtained results could be due to the fact that adding the compost and allowing it to decompose over time increased the concentration and availability of macroelements in the roots zone, allowing for greater absorption and uptake by the plant and, as a result, increasing their accumulation in plant tissues, increasing the assimilation rate, and thus increasing carbohydrate content. The obtained results are in agreement with those reported by Mahmoud and Gad (2020), Rurangwa et al. (2020), Seif El-Yazal (2020), and Sánchez-Navarro et al. (2021). However, all studied SA concentrations succeeded in decreasing seed NIT content, particularly the high concentration in the two seasons. Such increments in chemical fruit-quality agents due to the effect of SA are connected to the increase in photosynthetic pigments and micronutrients, which, in turn, affect the rate of organic compound assimilation and consequently increased the assayed organic constituents. The obtained results are in the same direction as those recorded by Mahmoud and Gad (2020), Refat et al. (2017), Azoz and El-Taher (2018), and Rasheed (2018).

Conclusion

Foliar application of SA at a high rate (150 ppm) combined with the fertilizer treatment of 75% chemical N fertilizer +25% organic fertilizer could play an important role in improving growth, yield, and chemical constituents of common bean plants. Therefore, the present study strongly advises the use of such treatment to provide good and high exportation characteristics due to its safety for human health.

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