The Pharma Innovation Journal 2023; 12(2): 1582-1589

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(2): 1582-1589

www.thepharmajournal.com
Received: 08-11-2022
Accepted: 16-01-2023

Neha Sharma
Division of Vegetable Science, Indian Agricultural Research Institute, New Delhi, India

M Mudasir Magray
Faculty of Agriculture, Wadura, SKUAT-K, Jammu and Kashmir, India

Sumati Narayan
Division of Vegetable Science, FoH, SKUAST-K, Shalimar, Srinagar, Jammu and Kashmir, India

Sajad A Bhat
Division of Basic Science and Humanities, FoH, SKUAST-K, Shalimar, Srinagar, Jammu and Kashmir, India

Corresponding Author:
Neha Sharma
Division of Vegetable Science, Indian Agricultural Research Institute, New Delhi, India

Effect of foliar application of varying doses of salicylic acid at different growth stages on growth, quality and nutrient uptake efficiency of French bean (*Phaseolus vulgaris* L.)

Neha Sharma, M Mudasir Magray, Sumati Narayan and Sajad A Bhat

DOI: https://doi.org/10.22271/tpi.2023.v12.i2s.18618

Abstract
Background: The ubiquitous presence of salicylic (SA) acid in plant systems has been confirmed by many scientists. Salicylic acid is widely distributed throughout the plant and is proposed to affect a number of phyto-physiological activities. As an endogenous plant growth factor or a hormone SA has number of functions including florigenic and thermogenic role, part in plant-pathogen interaction, signal transduction, etc.
Method: The present investigation was conducted at the Experimental Farm of the Division of Vegetable Science, SKUAST-K, during *Kharif* 2020 to find out the effect of foliar spray of varying doses of salicylic acid (SA) applied at different plant growth stages on growth and quality attributes of French bean var. Shalimar French Bean-1. The experiment was laid out in split plot design with twelve treatment combinations and three replications.
Result: The investigation revealed that the treatment combination T_1D_2 (250ppm of SA applied at plant emergence stage) recorded minimum values for days taken to 50 per cent flowering and days taken to pod formation. Moreover, the same treatment combination T_1D_2 also recorded maximum values for plant height, number of primary branches plant^{-1}, number of leaves plant^{-1} *et al*., leaf area and shoot dry weight plant^{-1}. It was further revealed that in the treatment combination T_1D_2 maximum values of vitamin C content, TSS, protein content, leaf chlorophyll content and pod dry matter content were also recorded, while pod anthocyanin content was maximum in the treatment combination T_2D_2 (250ppm of SA applied at vegetative stage). The treatment combination T_1D_2 also significantly enhanced nutrient uptake efficiency of the plants and resulted in lowest values for the available nitrogen, phosphorus and potassium, soil EC and maximum values for organic carbon as compared absolute control. than absolute control D_0.

Keywords: French bean, purple pod, salicylic acid, growth stage, foliar application, quality, growth, nutrient uptake

Introduction
French bean (*Phaseolus vulgaris* L.) is one of the most important food legumes cultivated extensively throughout the world. It can be raised as a vegetable crop or as a pulse. Common bean is cultivated prodigiously as a pulse crop but in some pockets, it is especially cultivated for its delicious tender fresh pods as well as dry pods. Beans are one of the delights of vegetarians for their wholesome nutritional properties but in the valley region the cultivation of beans for fresh pods is restricted to a limited area with quite less productivity (1.45 t ha^{-1}) as compared to rest of the country (2.83 t ha^{-1}) (Anonymous, 2018) [1]. Being a nutritionally important legume and a short duration crop French bean can be taken up by the famers in the valley for vegetable purpose to obtain good economic returns in less period of time. Besides following the recommended package of practices for the cultivation of beans, foliar application of different doses of salicylic acid at various plant growth stages will augment the growth development along with supplementing to the pod quality. Salicylic acid promotes plant growth and development along with increasing the efficiency of photosynthesis and flowering (Hayat *et al*., 2007) [10]. Other physiological roles of salicylic acid include increasing uptake of mineral nutrients from the soil, induction of tolerance against abiotic as well as biotic stresses in the plants, enhancing nitrogen metabolism thereby increasing the protein content and

interfering in ethylene production as a result of which delayed senescence is observed in the plants treated with salicylic acid. All these factors together contribute towards a rampant increase in the yield trends of the plants treated in cause of the application of salicylic acid. Manipulating the levels of salicylic acid in plant through exogenous application may have positive impacts on the productivity as well as the nutritional content of the bean pods.

Materials and Methods

The field of experiment was situated at the main SKUAST-K campus in Shalimar, Srinagar, which is located on the foothills of the Mahadev hill, 15 kilometres from Srinagar city, at an elevation of 1615 metres above mean sea level and is 34 degrees north latitude and 74 degrees east longitude. The experiment was laid out with 12 treatment combinations and three replications in split plot design as shown in Table A. The recommended dose of fertilizers FYM- 25 t ha^{-1} and NPK (30:60:60 kg ha^{-1}) was added to the experimental field through DAP, urea and MOP at the time of land preparation. Basal application of entire FYM, P, K and half N is done. Rest of the N is applied after 30 DAS. The flat seed beds were prepared by thoroughly working the soil into fine tilth. The seeds of French bean variety Shalimar French Bean-1 were used for sowing. The seeds were sown on flat beds with a spacing of 30 cm × 10 cm between and within rows thus accommodating approx. 100 seeds per plot (3 m^2). Seeds were soaked in water for 24 hrs prior to sowing so as to soften the hard seed coat and hasten germination. After sowing, the field was immediately irrigated. 10 healthy plants were selected at random from each replication to study observations on different growth and yield traits and tagged for recording the observations. Mean values were worked out for all the characters.

The height of ten tagged plants was measured in centimetres from the ground level to the tip of the plant at the time of last picking and the average was worked out.

At the end of flowering, branches emerging from the main stem, total number of compound leaves present on the whole plant were counted and leaf area of the fully developed 3 leaves was estimated using leaf area meter from ten selected plants and the average was worked out.

At the 50 per cent flowering stage, ten healthy plants were chosen for the calculation of dry shoot weight. The plants were uprooted, the underground root portion was cut and the clean shoot part was placed for 72 hours in an oven at 65℃. The weight was estimated after the required time and then the mean value was expressed in grams.

The days to the 50 per cent flowering appearance set on each tagged plant was recorded from the date of sowing of seeds and the average was worked out.

The days to the full pod set development on each tagged plant was recorded from the date of sowing of seeds and the average was worked out.

The selected fruits were crushed and juice was passed through a double layer of mesh cloth, collected in a tube, shaken well for about 2 minutes and then TSS was determined with the help of hand refractometer and presented as ˚Brix

The total soluble protein was estimated as per the method described by Lowry *et al*. (1951) [18].

Ascorbic acid content was determined by the method described by Ranganna (1986) [24].

Chlorophyll estimation was done using acetone method (Arnon, 1949) [2].

The pH differential spectrophotometric method described by Lapornik *et al*. (2005) [17] based on the principle of the transformation of the anthocyanin to the flavylium cation at the pH of extract decreasing to values between 0.5 and 0.8 was used to measure the anthocyanin content of the samples.

From each plot, 100 g of randomly selected pods (from each tagged plant) was placed in the hot air oven at 60-65 ℃ for 72 hrs and using the final weight after drying, the pod dry matter percentage was worked out.

`The soil samples were converted into soil water suspension of ratio 1: 2.5 and the pH of these suspensions was estimated by a glass electrode digital pH metre.

The Walkley and Black's method (1934) [28] was used to determine the soil organic carbon content.

The SOLU-bridge conductivity meter was used to estimate soil electrical conductivity (Jackson, 1973) [11].

To determine the available phosphorus content of the soil Olsen method (1954) was employed by using $NaHCO_3$ and estimation was done by using spectrophotometer.

One normal ammonium acetate was used as extractant and the available potassium content was determined by feeding the extract to flame photometer (Jackson, 1973) [11].

The experimental data was subjected to statistical analysis to test the significance of the findings. Significance of difference in treatment stage, dose and stage-dose interaction was tested at 5% level of significance and CD (critical difference) was worked out.

Results and Discussion

1. **Growth Parameters:** The experimental results depicted that foliar application of different concentrations of SA at different growth stages had a significant influence on the growth of French bean plants. Among all the treatment combinations, the treatment combination T_1D_2 i.e., application of 250ppm of SA at plant emergence stage resulted in significantly superior values for most of the growth attributes as compared to control treatment. From the data in tables 1.1 to 1.7 it is comprehensible that foliar spray of 250ppm of SA significantly increased the plant height, no. of branches per plant, no. of leaves per plant, leaf area and dry shoot weight per plant when applied at plant emergence stage. The intensity of growth processes of plants treated with SA was noticeably higher than in control. This may be attributed to the growth stimulating effect of SA. Application of SA promotes the accumulation of auxin and cytokinin which consequently increases the mitotic index of the apical meristems. The increase in the mitotic activity subsequently leads to enhanced growth (Hayat *et al*., 2007) [10]. These results were in agreement with the findings of Kumar *et al*. (1997) in *Pisum sativum*; Khatun *et al*. (2016) [15] in *Glycine max*; Yadav *et al*. (2019) [30] in *Vigna unguiculata* and Saha *et al*. (2020) [27] in *Phaseolus vulgaris*. Days taken to 50 per cent flowering and days taken to pod formation *-were also found to be significantly reduced with the application of SA. Application of SA hastened the floral bud emergence by 2-5 days due to its florigenic role. SA promotes the movement of solutes to the growing buds which causes better development of the buds and precocious flowering (Watanabe *et al*., 1981) [29].
2. **Quality Parameters:** Phenolic compounds like SA are acknowledged to have a significant influence on the

quality attributes like total soluble solids (TSS), protein content, ascorbic acid content, pod dry matter and pigments like chlorophyll and anthocyanins. From studying the experimental findings in tables 2.1 to 2.5, it was found that application of 250 ppm of SA at both plant emergence or vegetative growth stage significantly enhanced the bio-chemical attributes as compared to rest of the treatment combinations. The promotive effect of the foliar spray on chlorophyll content may be attributed to increased N uptake from the soil which is a principal component of the chlorophyll structure. Similar results were observed by, Khan *et al*. (2003) [14] in soybean and Khan *et al*. (2012) in wheat. Due to increased chlorophyll content; leaf area and no. of leaves per plant, subsequently the photosynthetic efficiency of the plant will be increased and higher amounts photosynthates will be produced which may contribute towards increased TSS and pod dry matter content. The increase in level of proteins is presumably because of better resistance mechanism possessed by the application of SA, since most of the pathogenesis related proteins residing in the leaf intercellular fluids are responsible to provide resistance to the plants against diseases (Chandra *et al*., 2007) [3]. These results coincided with the findings of Maity and Bera *et al*. (2009) [19] in *Vigna mungo*; Javaheri *et al*. (2012) [12] in tomato, Chaudhary (2019) [5] in pea and Chattoo *et al*. (2020) [4] in onion. Application of SA enhanced the ascorbic acid content in the pods. Increase in ascorbic acid content with the application of SA might been reported to be due to indirect activation of ascorbic acid biosynthesis from carbohydrates such as sucrose and glucose, as reported by Pérez-Balibrea *et al*. (2011) [23] in broccoli sprouts and inhibited ascorbic acid oxidase (AAO) enzyme activity, which is responsible for ascorbic acid oxidation as suggested by Rao *et al*. (2011) in sweet pepper. Anthocyanin content was markedly increased with the application of 250 ppm SA at vegetative stage. Anthocyanins and ascorbic acid contents are main components of fruit antioxidant activity and SA is an established natural plant signalling molecule that may stimulate the antioxidant activity of fruit by enhancing total phenolics, flavonoids, anthocyanins and ascorbic acid contents. Dokhanieh *et al*. (2013) [7] demonstrated that SA might be a potential molecule for activating phenylpropanoid–flavonoids pathways in the cherry fruit which stimulates the accumulation of phenolics, flavonoids and anthocyanins by activating their biosynthetic pathways. Anthocyanins have shown to be potent antioxidant and ROS scavengers (Hassanpour *et al*., 2011) [9] and SA in also known to have a significant role in promoting anti-oxidant activity. Razmi *et al*. (2013) [26] also reported that treatment of soybean with SA enhanced the total pigment content.

3. **Nutrient Uptake:** The efficiency of plants to absorb available nutrients from the soil depends on the physiological health of the plant. The healthier the plant, better will be its root system and higher will be it efficiency to absorb nutrients from the soil. As a result of this higher plant biomass will be produced and inflated yield will be achieved. This would ultimately exhaust the soil reservoir. Application of SA increase the nutrient uptake efficiency of the plant by improving the source and sink relationship, due to which higher amounts of nutrients will be absorbed from the roots and moved to the sink i.e., leaves and pods (Hayat *et al*., 2007) [10]. Ultimately, a result of this is that there is decline in soil nutrient status. The data in tables 3.1 to 3.6 shows that application of 250 ppm of SA at plant emergence and vegetative growth stage resulted in a significant decrease in the values of soil pH, soil EC, available soil N, P and K. This can be correlated to increased uptake of nutrients from the soil with the foliar spray of SA. Due to better establishment of roots at younger stages with the application of SA the nutrient uptake the plant is increased, consequently the amounts of mineral salts in the soil will be decreased. This might be the reason behind the lower values recorded for available nitrogen, phosphorous and potassium in the soil reservoir. The same treatment combination resulted in a significant increase in the organic carbon content in the soil. The increase in organic carbon content may be attributed to better development of root biomass which increases the organic matter content in the soil. This increase in organic matter might also be responsible for the corresponding decline in soil pH as well as EC. These findings can be supported through the investigations of Gunes *et al*. (2007) [8] in maize, Khan *et al*. (2010) [13] in mung bean (*Vigna radiata* L.), Nazar *et al*. (2011) [21] in mung bean, Dawa *et al*. (2015) [6] common bean (Bronco cultivar) and Metwaly and El-Shatoury (2017) [20] in potato cv. Spunta.

Tables

Table A: Treatment details

Factors	Levels
A. Treatment Stages (Major Factor)	T_1 – Plant Emergence (2-4 leaf stage) (15 DAS) T_2 – Vegetative Stage (30 DAS) T_3 – Flowering Stage (45DAS)
B. Doses of Salicylic Acid (Minor Factor)	D_0 – Control (No Spray) D_1 – 200 ppm D_2 – 250 ppm D_3 – 300 ppm

Table 1.1: Effect of salicylic acid application on final plant height (cm)

Stage Dose		Control (D_0)		200 ppm (D_1)	250 ppm (D_2)	300 ppm (D_3)	Mean
Plant Emergence(T_1)		45.88		48.92	51.21	47.59	48.40
Vegetative (T_2)		45.87		47.47	48.93	47.72	47.50
Flowering (T_3)		45.59		46.77	47.79	46.41	46.64
Mean		45.78		47.72	49.31	47.24	
C.D. ($p \leq 0.05$)							
	Stage	:	1.34				
	Dose	:	0.53				
	Stage × Dose	:	0.77				

Table 1.2: Effect of salicylic acid application on number of branches plant^{-1}

Dose \ Stage	Control (D_0)	200 ppm (D_1)	250 ppm (D_2)	300 ppm (D_3)	Mean
Plant Emergence(T_1)	2.600	3.133	3.733	2.800	3.067
Vegetative (T_2)	2.533	2.800	2.867	2.733	2.733
Flowering (T_3)	2.667	2.600	2.667	2.600	2.633
Mean	2.600	2.844	3.089	2.711	
C.D. ($p \leq 0.05$)					
	Stage	:	0.389		
	Dose	:	0.142		
	Stage × Dose	:	0.207		

Table 1.3: Effect of salicylic acid application on number of leaves plant^{-1}

Dose \ Stage	Control (D_0)	200 ppm (D_1)	250 ppm (D_2)	300 ppm (D_3)	Mean
Plant Emergence (T_1)	38.33	42.53	45.6	41.87	42.08
Vegetative (T_2)	38.2	41.53	43.93	40.07	40.93
Flowering (T_3)	39.07	40.27	41.67	39.27	40.07
Mean	38.53	41.44	43.73	40.40	
C.D. ($p \leq 0.05$)					
	Stage	:	0.66		
	Dose	:	0.78		
	Stage × Dose	:	1.13		

Table 1.4: Effect of salicylic acid application on leaf area (cm^2)

Dose \ Stage	Control (D_0)	200 ppm (D_1)	250 ppm (D_2)	300 ppm (D_3)	Mean
Plant Emergence (T_1)	34.64	38.08	39.31	36.63	37.17
Vegetative (T_2)	34.13	36.79	37.39	35.00	35.83
Flowering (T_3)	34.57	35.12	35.86	34.14	34.92
Mean	34.45	36.66	37.52	35.26	
C.D. ($p \leq 0.05$)					
	Stage	:	1.05		
	Dose	:	0.64		
	Stage × Dose	:	0.94		

Table 1.5: Effect of salicylic acid application on shoot dry weight (g)

Dose \ Stage	Control (D_0)	200 ppm (D_1)	250 ppm (D_2)	300 ppm (D_3)	Mean
Plant Emergence(T_1)	7.439	9.983	11.843	8.294	9.39
Vegetative (T_2)	7.869	9.704	11.132	8.259	9.241
Flowering (T_3)	8.037	9.163	9.645	8.095	8.735
Mean	7.782	9.617	10.874	8.216	
C.D. ($p \leq 0.05$)					
	Stage	:	0.056		
	Dose	:	0.064		
	Stage × Dose	:	0.094		

Table 1.6: Effect of salicylic acid application on days taken to 50 per cent flowering

Dose \ Stage	Control (D_0)	200 ppm (D_1)	250 ppm (D_2)	300 ppm (D_3)	Mean
Plant Emergence(T_1)	45.4	40.93	40.33	42.20	42.22
Vegetative (T_2)	46.13	43.47	42.87	43.93	44.10
Flowering (T_3)	46.33	46.13	46.00	46.27	46.18
Mean	45.96	43.51	43.07	44.13	
C.D. ($p \leq 0.05$)					
	Stage	:	0.70		
	Dose	:	0.24		
	Stage × Dose	:	0.35		

Table 1.7: Effect of salicylic acid application on days taken to pod formation

Dose \ Stage	Control (D_0)	200 ppm (D_1)	250 ppm (D_2)	300 ppm (D_3)	Mean
Plant Emergence(T_1)	53.20	48.53	47.13	50.00	49.72
Vegetative (T_2)	54.13	49.87	49.07	50.53	50.9
Flowering (T_3)	54.27	52.73	53	53.87	53.47
Mean	53.87	50.38	49.73	51.47	
C.D. ($p \leq 0.05$)					
	Stage	:	0.67		
	Dose	:	0.21		
	Stage × Dose	:	0.31		

Table 2.1: Effect of salicylic acid application on pod TSS (^{o}Brix)

Dose \ Stage	Control (D_0)	200 ppm (D_1)	250 ppm (D_2)	300 ppm (D_3)	Mean
Plant Emergence(T_1)	8.16	8.45	8.79	8.51	**8.48**
Vegetative (T_2)	8.02	8.40	8.74	8.30	8.37
Flowering (T_3)	8.13	8.36	8.63	8.22	8.34 ±
Mean	8.10	8.4	8.72	8.34	
C.D. ($p \leq 0.05$)					
	Stage	:	0.22		
	Dose	:	0.12		
	Stage × Dose	:	0.17		

Table 2.2: Effect of salicylic acid application on pod protein content (%)

Dose \ Stage	Control (D_0)	200 ppm (D_1)	250 ppm (D_2)	300 ppm (D_3)	Mean
Plant Emergence(T_1)	1.693	1.873	2.333	1.867	1.942
Vegetative (T_2)	1.677	1.86	2.197	1.790	1.881

Flowering (T_3)	1.733	1.843	2.017	1.757	1.838
Mean	1.701	1.859	2.182	1.804	

C.D. ($p \leq 0.05$)

Stage : 0.098
Dose : 0.054
Stage × Dose : 0.079

Table 2.3: Effect of salicylic acid application on pod vitamin C content (mg $100g^{-1}$)

Stage / Dose	Control (D_0)	200 ppm (D_1)	250 ppm (D_2)	300 ppm (D_3)	Mean
Plant Emergence(T_1)	13.51	14.37	15.16	13.71	14.19
Vegetative (T_2)	13.36	14.79	14.86	13.69	14.18
Flowering (T_3)	13.17	13.98	14.53	13.75	13.86
Mean	13.35	14.38	14.85	13.72	

C.D. ($p \leq 0.05$)			
	Stage	:	0.62
	Dose	:	0.34
	Stage × Dose	:	0.49

Table 2.4: Effect of salicylic acid application on leaf chlorophyll content (mg g^{-1})

Stage / Dose	Control (D_0)	200 ppm (D_1)	250 ppm (D_2)	300 ppm (D_3)	Mean
Plant Emergence(T_1)	0.993	1.210	1.590	1.140	1.233
Vegetative (T_2)	0.980	1.220	1.483	1.063	1.187
Flowering (T_3)	0.913	1.153	1.323	1.007	1.099
Mean	0.962	1.194	1.466	1.070	

C.D. ($p \leq 0.05$)			
	Stage	:	0.088
	Dose	:	0.066
	Stage × Dose	:	0.096

Table 2.5: Effect of salicylic acid application on pod anthocyanin content (µg g^{-1})

Stage / Dose	Control (D_0)	200 ppm (D_1)	250 ppm (D_2)	300 ppm (D_3)	Mean
Plant Emergence(T_1)	13.890	15.563	16.303	14.773	15.133
Vegetative (T_2)	13.480	15.867	17.307	14.683	15.334
Flowering (T_3)	13.337	15.08	15.960	14.393	14.693
Mean	13.569	15.503	16.523	14.617	

C.D. ($p \leq 0.05$)			
	Stage	:	0.029
	Dose	:	0.023
	Stage × Dose	:	0.034

Table 2.6: Effect of salicylic acid application on pod dry matter content (%)

Stage / Dose	Control (D_0)	200 ppm (D_1)	250 ppm (D_2)	300 ppm (D_3)	Mean
Plant Emergence(T_1)	9.860	11.580	13.157	10.167	11.191
Vegetative (T_2)	9.797	10.983	13.053	10.087	10.980
Flowering (T_3)	9.637	10.687	12.963	9.900	10.797
Mean	9.764	11.083	13.058	10.051	

C.D. ($p \leq 0.05$)			
	Stage	:	0.100
	Dose	:	0.026
	Stage × Dose	:	0.038

Table 3.1: Effect of salicylic acid application on soil pH after crop harvest

Stage / Dose	Control (D_0)	200 ppm (D_1)	250 ppm (D_2)	300 ppm (D_3)	Mean
Plant Emergence(T_1)	7.243 (2.871)	7.127 (2.851)	7.103 (2.847)	7.140 (2.853)	7.153 (2.855)
Vegetative (T_2)	7.217 (2.866)	7.113 (2.848)	7.113 (2.848)	7.197 (2.863)	7.160 (2.857)
Flowering (T_3)	7.257 (2.873)	7.227 (2.868)	7.220 (2.867)	7.237 (2.87)	7.235 (2.87)
Mean	7.239 (2.87)	7.156 (2.856)	7.146 (2.854)	7.191 (2.862)	

C.D. ($p \leq 0.05$)			
	Stage	:	0.037
	Dose	:	0.041
	Stage × Dose	:	0.060

Data within parenthesis are square root transformed values.
Initial soil pH = 7.27

Table 3.2: Effect of salicylic acid application on soil organic carbon (%) after crop harvest

Stage / Dose	Control (D_0)	200 ppm (D_1)	250 ppm (D_2)	300 ppm (D_3)	Mean
Plant Emergence(T_1)	0.879 (0.938)	0.899 (0.948)	0.938 (0.969)	0.884 (0.940)	0.900 (0.949)
Vegetative (T_2)	0.845 (0.919)	0.879 (0.938)	0.922 (0.960)	0.881 (0.939)	0.882 (0.939)
Flowering (T_3)	0.819 (0.905)	0.87 (0.933)	0.919 (0.959)	0.859 (0.927)	0.867 (0.931)
Mean	0.848 (0.921)	0.883 (0.940)	0.927 (0.963)	0.875 (0.935)	
C.D. ($p \leq 0.05$)					
	Stage	:	0.021		
	Dose	:	0.008		
	Stage × Dose	:	0.011		

Data within parenthesis are square root transformed values.
Initial soil OC = 0.910%

Table 3.3: Effect of salicylic acid application on EC (dS m^{-1}) after crop harvest

Stage / Dose	Control (D_0)	200 ppm (D_1)	250 ppm (D_2)	300 ppm (D_3)	Mean
Plant Emergence(T_1)	0.226 (0.475)	0.193 (0.439)	0.190 (0.436)	0.197 (0.444)	0.202 (0.449)
Vegetative (T_2)	0.224 (0.473)	0.197 (0.444)	0.190 (0.436)	0.212 (0.46)	0.206 (0.454)
Flowering (T_3)	0.221 (0.47)	0.206 (0.454)	0.192 (0.438)	0.217 (0.466)	0.209 (0.457)
Mean	0.224 (0.473)	0.199 (0.446)	0.191 (0.437)	0.209 (0.457)	
C.D. ($p \leq 0.05$)					
	Stage	:	0.019		
	Dose	:	0.009		
	Stage × Dose	:	0.014		

Data within parenthesis are square root transformed values.
Initial soil EC = 0.239 dS m^{-1}

Table 3.4: Effect of salicylic acid application on available N (kg ha^{-1}) in soil after crop harvest

Stage / Dose	Control (D_0)	200 ppm (D_1)	250 ppm (D_2)	300 ppm (D_3)	Mean
Plant Emergence(T_1)	274.77 (16.58)	270.80 (16.46)	268.17 (16.38)	271.13 (16.47)	271.22 (16.47)
Vegetative (T_2)	279.87 (16.73)	271.54 (16.48)	271.72 (16.48)	272.77 (16.52)	273.98 (16.55)
Flowering (T_3)	277.69 (16.66)	274.26 (16.56)	273.07 (16.52)	275.99 (16.61)	275.25 (16.59)
Mean	277.45 (16.66)	272.2 (16.5)	270.99 (16.46)	273.3 (16.53)	
C.D. ($p \leq 0.05$)					
	Stage	:	2.74		
	Dose	:	1.91		
	Stage × Dose	:	2.78		

Data within parenthesis are square root transformed values.
Initial soil available N = 281.96 kg ha^{-1}

Table 3.5: Effect of salicylic acid application on available P (kg ha^{-1}) in soil after crop harvest

Stage / Dose	Control (D_0)	200 ppm (D_1)	250 ppm (D_2)	300 ppm (D_3)	Mean
Plant Emergence(T_1)	21.79 (4.67)	19.91 (4.46)	19.50 (4.42)	20.68 (4.55)	20.47 (4.52)
Vegetative (T_2)	23.08 (4.80)	21.23 (4.61)	20.03 (4.48)	22.04 (4.69)	21.59 (4.65)
Flowering (T_3)	22.66 (4.76)	22.11 (4.70)	21.52 (4.64)	22.58 (4.75)	22.22 (4.71)
Mean	22.51 (4.74)	21.08 (4.59)	20.35 (4.51)	21.77 (4.67)	
C.D. ($p \leq 0.05$)					
	Stage	:	1.60		
	Dose	:	0.61		
	Stage × Dose	:	0.89		

Data within parenthesis are square root transformed values.
Initial soil available P = 23.89 kg ha^{-1}

Table 3.6: Effect of salicylic acid at different growth stages on available K (kg ha^{-1}) in soil after crop harvest

Stage / Dose	Control (D_0)	200 ppm (D_1)	250 ppm (D_2)	300 ppm (D_3)	Mean
Plant Emergence(T_1)	190.69 (13.81)	186.58 (13.66)	185.49 (13.62)	189.85 (13.78)	**188.15 (13.72)**
Vegetative (T_2)	192.95 (13.89)	188.55 (13.73)	187.57 (13.70)	190.94 (13.82)	**190.00 (13.78)**
Flowering (T_3)	191.22 (13.83)	190.09 (13.79)	189.18 (13.75)	192.33 (13.87)	**190.71 (13.81)**
Mean	191.62 (13.84)	188.41 (13.73)	187.41 (13.69)	191.04 (13.82)	

C.D. ($p \leq 0.05$)				
	Stage	:	1.18	
	Dose	:	0.93	
	Stage × Dose	:	1.36	

Data within parenthesis are square root transformed values.
Initial soil available K =194.79 kg ha^{-1}

Conclusion

Application of varying doses of SA at different growth stages had a significant influence on the plant growth and quality attributes of French bean. However, the treatment combination T_1D_2 (foliar spray of 250 ppm of SA at plant emergence stage) resulted in the superior values for majority of the parameters. The treatment combination T_1D_2 (foliar spray of 250 ppm of SA at plant emergence stage) increased the nutrient uptake efficiency of the plant which resulted in excellent growth and consequently lead to increased yield of French bean. Therefore, a spray of 250 ppm at plant emergence stage can be done to achieve virtuous plant growth and pod quality.

References

1. Anonymous. Area and Production of Beans in India for the year 2018, FAOSTAT, 2018.
2. Arnon D. Copper enzymes in isolated chloroplasts polyphenoloxidase in Beta Vulgaris. Plant Physiology. 1949;24(1):1-15.
3. Chandra A, Anand A, Dubey A. Effect of salicylic acid on morphological and biochemical attributes in cowpea. Journal of Environmental Biology. 2007;28(2):193-196.
4. Chattoo MA, Magray M, Shah M, Malik AA, Mushtaq F. Influence of salicylic acid on growth, yield and quality attributes of onion under temperate conditions. International Journal of Chemical Studies. 2020;8:2486-2489.
5. Chaudhary R. Effects of foliar application of NAA, GA_3 and salicylic acid on growth, yield and quality of garden pea (*Pisum sativum* L. subsp. *hortense*) cv. Azad Pea. M. Sc. Thesis, BHU, Varanasi, 2019.
6. Dawa K, Ahmed H, Fekry MH. Vegetative growth, yield and some chemical constituents in leaves and pods of common bean as affected by salicylic acid and potassium foliar application under different irrigation intervals. Journal of Plant Production. 2015;6(1):57-72.
7. Dokhanieh AY, Aghdam MS, Rezapour Fard J, Hassanpour H. Post-harvest salicylic acid treatment enhances antioxidant potential of cornelian cherry fruit. Scientia Horticulture. 2013;154:31-36.
8. Gunes A, Inal A, Alpaslan M, Eraslan F, Bagci EG, Cicek N. Salicylic acid induced changes on some physiological parameters symptomatic for oxidative stress and mineral nutrition in maize (*Zea mays* L.) grown under salinity. Journal of Plant Physiology. 2007;164:728-736.
9. Hassanpour H, Hamidoghli Y, Hajilo J, Adlipour M. Antioxidant capacity and phytochemical properties of cornelian cherry (*Cornus mas* L.) genotypes in Iran. Scientia Horticulture. 2011;129:459–463.
10. Hayat S, Ali B, Ahmad A. Salicylic Acid: Biosynthesis, metabolism and physiological role in plants. In: S. Hayat and A. Ahmad: Salicylic acid: A Plant Hormone. Springer, Netherlands, 2007, pp. 1-14.
11. Jackson ML. Soil Chemical Analysis. Prentice Hall of India Private Limited, New Delhi, 1973, pp. 1-492.
12. Javaheri M, Mashayekhi K, Dadkhah A, Tavallaee FZ. Effects of salicylic acid on yield and quality characters of tomato fruit (*Lycopersicum esculentum* Mill.). International Journal of Agriculture and Crop Sciences (IJACS). 2012;4(16):1184-1187.
13. Khan N, Syeed S, Masood A, Nazar R, Iqbal N. Application of salicylic acid increases contents of nutrients and antioxidative metabolism in mungbean and alleviates adverse effects of salinity stress. International Journal of Plant Biology. 2010;1(1):e1.
14. Khan W, Prithiviraj B, Smith DL. Photosynthetic responses of corn and soybean to foliar application of salicylates. Journal of Plant Physiology. 2003;160:485 – 492.
15. Khatun S, Roy TS, Haque MDN, Alamgir B. Role of plant growth regulators on growth and yield of soybean at different stages of application. Scientia Agriculture. 2016;15(3):380-386.
16. Kumar B, Sarlach RS. Forage cowpea (*Vigna unguiculata*) seed yield and seed quality response to foliar application of bio-regulators. International Journal of Agriculture, Environment and Biotechnology. 2015;8(4):891.
17. Lapornik B, Prosek M, Wondra A. Comparison of extracts prepared from plant by-products using different solvents and extraction time. Journal of Food Engineering. 2005;71:214-222.
18. Lowry OH, Rose Brough J, Farrland AL, Randall RJ. Protein measurement with Folin-Phenol reagent. Journal of Biological Chemistry. 1951;193:265-275.
19. Maity U, Bera AK. Effect of exogenous application of brassinolide and salicylic acid on certain physiological and bio-chemical aspects of green gram (*Vigna mungo* L.). Indian Journal of Agricultural Research. 2009;43(3):194.
20. Metwaly EE, El-Shatoury RS. Impact of foliar application with salicylic acid on growth and yield of potato (*Solanum tuberosum* L.) under different irrigation water quantity. Journal of Plant Production. 2017;8(10):969-977.
21. Nazar R, Iqbal N, Syeed S, Khan NA. Salicylic acid alleviates decreases in photosynthesis under salt stress by enhancing nitrogen and sulfur assimilation and antioxidant metabolism differentially in two mung-bean cultivars. Journal of Plant Physiology. 2011;168(8):807-815.
22. Olsen SR, Cole VC, Watamable FS, Dean LA. Estimation of available phosphorous in soil by extraction with $NaHCO_3$. Circular, United States Department of Agriculture. 1954;18:939.
23. Pérez-Balibrea S, Moreno DA, García-Viguera C. Improving the phytochemical composition of broccoli sprouts by elicitation. Food Chemistry. 2011;129:35–44.
24. Ranganna S. Handbook of analysis and quality control for fruit and vegetable products. Tata McGraw-Hill Pub Co., New Delhi, 1986.
25. Rao TVR, Gol NB, Shah KK. Effect of postharvest

treatments and storage temperatures on the quality and shelf life of sweet pepper (*Capsicum annum* L.). Sci. Hortic. 2011;132:18–26.
26. Razmi N, Ebadi A, Daneshian J, Jahanbakhsh S. Salicylic acid induced changes on antioxidant capacity, pigments and grain yield of soybean genotypes in water deficit condition. Journal of Plant Interactions. 2017;12(1):457-464
27. Saha A, Chakraborty L, Das K. Effect of foliar application of acetyl salicylic acid, ascorbic acid and riboflavin on growth, yield and yield component of French bean (*Phaseolus vulgaris* L. cv. Arka Arjun). International Journal of Chemical Studies. 2020;8(2):1802-1806.
28. Walkley A, Black IA. Estimation of soil organic carbon by the chromic acid titration method. Soil Science. 1934;37:29-38.
29. Watanabe K, Fujita T, Takimoto A. Relationship between structure and flower inducing activity of benzoic acid derivatives in *Lemma paucicostata* 151. Plant Cell Physiology. 1981;20:847-850.
30. Yadav SC, Choudhary MR, Ujjainiya P, Yadav BL. Influence of Plant Growth Substances and Bio-Fertilizers on Physiological Parameters of Vegetable Cowpea (*Vigna unguiculata* (L.) Walp). International Journal of Current Microbiology and Applied Sciences. 2019;8(8):812-818.