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Distribution of Nutrients in Snap Bean Plant Organs as Affected by N, P and K Fertilizer Levels

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ABSTRACT

A pot experiment was planted at the experiments Farm at Mansoura University Faculty of Agriculture, during the summer season of 2015 to monitor the effect of various levels of nitrogen (N), phosphorus (P) and potassium (K) fertilizers treatments on plant vegetative parameters, yield and NPK % in organs (root, stem, leaves and grains) of snap bean plant. The trial was hold out in a complete randomized block design (CRBD) with three replicates. The results revealed that application of different levels of NP and K fertilizers have a significant effect on growth parameters, yield components, chlorophyll a, b and total and concentration of N, P, K, iron, copper and zinc in different organs (root, stem, leaves and grains) of snap bean plants. All studied parameters increased by increasing the application rates of N, P and K fertilizers from zero to 150% from the recommended dose. Concentration of NPK in the leaves and grains of snap bean plant were significantly increased with increasing the NPK levels. On the different of this tendency; the mean means of NPK concentration were significantly decreased with increasing NPK levels in the roots and stems of snap bean plants. Also, the values of all the investigated micronutrients were significantly increased with increasing the NPK levels up to the level of 100% from recommended doses. More addition of NPK at the rate of 150% from recommended doses of NPK significantly decreased the average values of these micronutrient under those obtained from the plants treated with 100% from recommended doses of NPK. The distribution of macro- and micro-nutrients in the snap bean plant can be arranged in following order stems < roots < grains < leaves.

Keywords: *Phaseolus vulgaris* L., Nitrogen, Phosphorus, potassium, Yield, Yield components, Nutrients

INTRODUCTION

Snap bean (*Phaseolus vulgaris* L.) is an important leguminous crop of greater nutritional status to poor communities in African countries. It is grown twice a year, once in March, and second in August. Sudden beans are one of the important vegetable crops grown in the arid zones of green pods and dry seeds. Green pods are cooked as vegetables, being a good source of protein, vitamins, calcium and iron. In 2014 season the total planted area of snap bean was about 59665 fed with total production of 253110 tons with an average of 4.242 ton fed^{-1} as reported by Food and Agriculture Organization (FAO, 2017).

More attention has been paid to secure high yield and good quality of snap bean through improvement of the factors affecting its productivity. Environmental factors such as low soil content of nitrogen and phosphorus are important limits for bean production in most of the bean grown areas (Graham *et al*., 2003). In bean, symbiotic N-fixation rates, seed protein level and tolerance to P deficiency are low in comparison to other legumes (Broughton *et al*., 2003).

Fertilizing with an appropriate level of nitrogen has played a major role in improving the growth and yield of snap bean plants. Nitrogen is a vital component of all proteins (Salisbury and Ross, 1991). Many reports indicated a decrease in the growth of snap bean plants as well as better yields will not be given under the low N ratio available in the soil (Salinas *et al*., 2011). Whereas, excessive amounts of nitrogen fertilizer may led to unfavorite effect on the growth and yield of snap bean plants and will lead to increase the losses of nitrogen fertilizer. So, the adequate amounts of nitrogen fertilization led to improve growth, yield and quality of pods. Ivanove *et al.* (1987) reported that, the pod yield of French bean was increased with the increase N levels up to 150 kg per hectare. Sharma (2001) recorded that greatest height of plant, No. of branches per plant and pod yield of French bean were obtained as a result of using 120 kg N ha^{-1}. Projapoti *et al*., (2004) recorded higher pod yield of French bean from 120 kg N ha^{-1}.

Phosphorus is an essential mineral nutrient most commonly restricted the growth of crops and is an essential element required for plant growth and development. Phosphorus contributes to the metabolic process of energy transfer, signal transduction, macromolecular biosynthesis, photosynthesis and respiration chain reactions (Shenoy and Kalagudi, 2005). Large areas of agricultural soils are poor in phosphorus content, so phosphorus deficiency may be appeared on cultivated plants (Banerjee *et al.* 2010). Therefore, adequate application of phosphorus rate is serious for ornamental output and abundance of snap bean (Liu *et al.* 2015).

Chandra *et al.* (1987) found that increasing rates of nitrogen and phosphorus increased growth and yield of French bean. Sharma (2001) revealed that greatest height of plant and No. of branches per plant were recorded by adding 60 kg P/ha. The highest yield of pod was obtained by adding 120 kg N + 60 kg P/ha. Singh (2000) get utmost length of pod from the submission of 125 kg N/ha. Singh and Singh (2000) reported that yield of French beans improved with increasing N rates, but were commonly higher with 80 kg P/ha.

Potassium is one of the key ingredients needed for natural plant growth. Its role is well documented in photosynthesis, carbohydrates and starch formation, allowing crop yields to develop tolerance to drought conditions and to enhance the plant's ability to resist pest and disease attacks. Sangakkra (1996) found that vegetative growth and most yield components of French beans significantly increased up to 100 kg K_2O/ha. Srinivas and Nick (1990) reported that nitrogen and phosphorus fertilization of French beans led to increased yield pod. Islam (2004) showed that application of potassium has a beneficial effect on the characteristics of plant growth and also on the crop of bushes.

Fertilization with macronutrients is an important factor that affect on growth, yield and quality of any crop. Thus, adding the correct level of macronutrient is one of the important factors for increasing snap bean productivity and its quality. Therefore, this study was carried out to investigate the effect of macronutrient fertilization on growth parameters and yield of snap bean. As well, study the distribution of nutrients in snap bean plant organs as affected by N, P and K fertilizer levels.

MATERIALS AND METHODS

A pot experiment was planted at the experiments Farm at Mansoura University Faculty of Agriculture, during the summer season of 2015 to study the growth parameters, productive characteristics and distribution of nutrients of snap bean (*Phaseolus vulgaris* L.) plants as affected by different levels of mineral fertilizer. The trial was hold out in a complete randomized block design (CRBD) with three replicates and the treatments were as follows:

1- Control: does not contain N, P and K fertilizer.
2- (N50 / P_{50} / $K_{50)}$: 50 % from (RD) of N, P and K fertilizer (25 kg N + 30 kg P_2O_5 + 24 K_2O fed^{-1}).
3- (N_{100} / P_{100} / K_{100}): 100 % from (RD) of N, P and K fertilizer (50 kg N + 60 kg P_2O_5 + 48 K_2O fed^{-1}).
4- (N_{150} / P_{150} / K_{150}): 150 % from (RD) of N, P and K fertilizer (75 kg N + 90 kg P_2O_5 + 72 K_2O fed^{-1}).

The recommended doses were applied according to the Minister of Agriculture and Soil Reclamation, Egypt.

The source of nitrogen and potassium fertilizer levels were ammonium sulphate (20.5% N) and potassium sulphate (48% K2O), respectively. Both of them was added to the experimental soil in two equal doses, one after 21 days from date of sowing and the second two weeks later; calcium super phosphate (15.5 % P2O5) as a source of P- fertilizer levels was added in one dose to the pots before sowing. The trial contained 12 plastic pots with 25cm diameter, 35 cm height and the weight of each pot is 10 kg representing the fraction of 30 cm from the Farm of faculty of Agriculture. The physical and chemical propert.ies of the soil show in Table (1)

Table 1. Some physico-chemical analyses of the trial soil before the cultivation of summer 2015 season

Soil properties		Values
The size of distribution Particle (%)	Coarse sand	2.66
	Fine sand	18.21
	Silt	58.78
	Clay	20.35
	Soil texture	Silt loam
Some physical and chemical properties	Saturation (%)	57.5
	Calcium carbonate, Ca CO_3 (%)	3.93
	O.M. (%)	1.18
	pH (1:2.5)	8.09
	EC (dSm^{-1}) soil paste	0.87
Available nutrients (mg kg^{-1})	N	53.6
	P	5.72
	K	179.4
	Fe	3.12
	Cu	0.39
	Zn	0.68

Ten seeds of Snap bean (cv. Bronco) were sown on 1st March 2015 In each pot. Snap bean was thinned to the most suitable 5 plants per pot after 21 days from sowing. Pots were watering every 7 days to reach field capacity of each pot. All the other agriculture practices were done as recommended by the Minister of Agriculture and Soil Reclamation, Egypt for snap bean plant.

Sampling dates:

60 days after planting of snap bean seeds; 2 plants were taken randomly from each pot and plant growth parameters (height of plant, plant fresh and plant dry weight) were measured. Samples of plant estranged into leaves, stem and roots. The separated parts of plant samples were weighed and oven dried at 700 c constant weight. Then, dry matter of plant was calculated. The dried plant organs were thoroughly ground and stored for chemical analysis.

At green maturity stage (70-80 days from sowing) representative samples were collected from each treatment and the following data was recorded: average number o pods per plant, average pod weight (g) and total yield g/plant. Also, seeds of each sample were collected, oven dried and stored for chemical composition.

Soil analysis:

Analysis	Method of analysis	Author
Size of distribution Particle	The international pipette	Piper 1950
Soil pH	pH meter	Jackson 1967
Soil saturation percent	U.S. Salinity Laboratory Staff	U.S. Salinity Laboratory Staff 1954
Soil salinity	Electrical conductivity meter	Jackson 1967
Organic matter	Walkley and Black method	Black 1965
Calcium carbonate	Collin's calcimeter	Piper 1950
Available N	The conventional method of Kjeldahl	Bremner and Mulvany 1982
Available phosphorus	Spectrophotometer	Olsen and Sommers 1982
Available potassium	Flame photometer	Black 1965
Available Fe, Cu and Zn	DTPA method	Lindsay and Norvel 1978

Yield components:

90 days after (harvest stage), 2 plants were taken randomly from each pot to measure the following growth parameters:

- Height of plant (cm).
- Plant fresh weight (g).
- Plant dry weight (g).
- Number of pods $plant^{-1}$.
- Pod weight (g $plant^{-1}$).
- Fresh pod yield (g $plant^{-1}$).

Nutritional analysis of plant samples:

The oven-dried at 70°C snap bean plant sample after 50 days (vegetative growth stage) and 90 days (harvest stage) from planting was digested by using a sulfuric-perchloric acids (Peterburgski 1968). The total NPK were determined in different parts of snap bean plant (root, stem, leaves and grain) using the following methods: Total nitrogen (%) using micro-Kjeldahl, phosphorus (%) was determined calorimetrically and potassium (%) using a flame photometer by Pregle (1945), Black (1965) and Jackson (1967), respectively.

Statistical analysis

The results obtained for statistical analysis were analyzed according to the technique of ANOVA for factorial experiment in complete randomized block design (CRBD) by Gomez and Gomez (1984). LSD method was used (Snedecor and Cochran 1980).

RESULTS AND DISCUSSION

The Effect of NPK fertilizers on growth parameters of snap bean plant

The effect of NPK-fertilization levels on plant growth parameters (height of plant (cm) and weight (fresh and dry) in g of snap bean plants is presented in Table 2. It can be observed that; the average values of height of plant, fresh and dry weight of plant were significantly increased when the level of NPK was increased. The highest values (43.25 cm and 85.45 g plant-1 for height of plant and fresh weight, respectively) were recorded for the plants treated with 150% from the recommended doses of NPK, while the lowest one was connected with the untreated plants. On the other hand, the mean values of dry weight per plant of snap bean plants were significantly increased when the level of NPK was increased till the rate of 100% from the recommended doses. Increasing rate of NPK addition from 100% to 150% from the recommended doses considerably decreased the averages value of dry weight for snap bean.

While, data indicated that average pod weight (g), number of pods per plant and yield per plant were considerably increased when the level of NPK fertilization was increased till the rate of 100% from the recommended doses. More application of NPK fertilizers till the rate of 150% from the recommended doses significantly decreased the mean values of all the traits to be less than those obtained from the plants treated with 100% from the recommended doses of NPK. Comparing with the control treatment an increase was accounted to be 47.2, 57.5 and 49.1 % for the treatment of 50%, 100% and 150% from the recommended doses of NPK, respectively. These results can be attributed to the fact that snap beans can respond well to improved doses of fertilizer. These increases in yield components may be the result of a better use of Nick resulting in a biochemical increase of photosynths and ultimately yield.

These results are in conformity with the results of Mahmoud *et al*. (2010) and Lad *et al*. (2014), they note that all growth measurements of snap bean were increased significantly with adding higher levels of nitrogen fertilizers. This due to snap bean is low in the fixation of atmospheric N conversely to other bean (Feleafel and Mirdad 2014). The same trend was observed with P and K applications as reported by Lad *et al*. (2014), Fooladivanda *et al*. (2014), Liu *et al*. (2015) and Buriro *et al*. (2015), they found that application of P and K fertilizers significantly increased growth and yield parameters of bean plant. It could be concluded that snap beans plants could not achieve a higher yield when the application of NPK more than excess of recommended rates.

Table 2. Growth parameters of snap bean plant as affected by NPK mineral fertilization

Characters Treatments	Plant fresh Weight (g)	Plant dry weight (g)	Height of plant (cm)	Average pod weight/ g	No of pods / plant	Yield g/plant
$N_0P_0K_0$	78.29	9.79	34.91	8.09	11.53	97.23
$N_{50}P_{50}K_{50}$	81.70	11.09	38.67	8.81	16.47	143.14
$N_{100}P_{100}K_{100}$	84.90	11.36	42.54	8.88	17.60	153.09
$N_{150}P_{150}K_{150}$	85.45	11.13	43.25	8.77	16.60	144.93
F. test	*	*	*	*	*	*
LSD at 5 %	0.083	0.048	0.777	0.098	0.845	0.795

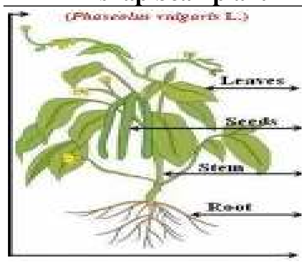
Effect of NPK-fertilizers on distribution of N, P and K in snap bean plant parts

Different comparisons among the mean values of N, P and K content in snap bean plant organs are presented in Table (3). It could be noticed that, within the different levels of NPK fertilization the highest concentrations of N, P and K in snap bean plant organs were realized in the leaves followed in descending order by grains, roots and lately stems and such effect was the same at any levels; data of the same Table detected that the average values of NPK concentration in the leaves and grains of snap bean plant were significantly increased as the level of NPK was increased. On the contrary of this trend; the mean values of NPK concentration were significantly decreased as level of NPK was increased in the roots and stems of snap bean plant. On other words; the highest values of N, P and K % were realized in the leaves and grains of snap bean for the plants treated with 150% from the recommended doses from NPK fertilizers, while such effect in the roots and stems was happened for the untreated plants.

Effect of NPK-fertilizers on distribution of Fe, Cu and Zn (%) in different parts of snap bean plant

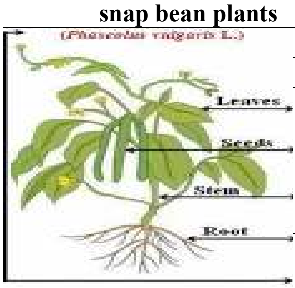
The effect of NPK fertilization levels on iron, zinc and copper (mg kg^{-1}) in snap bean plants organs is presented in Table 4. Data indicated that, the highest mean values of microelements studied have been recorded for the leaves following by grains, roots, whereas the lowest one was recorded for the stems of snap bean plant. Data in the same Table also detected that, increasing the NPK-fertilization level up to the level of 150% from the recommended doses significantly increased the mean of all the aforementioned traits. In addition, the differences between the mean values of all parameters for the plants treated with 100% and those treated with 150% did not reach to the level of significance such effect was the same for zinc and copper in the leaves and grains of snap bean plant. Concerning the effect of NPK level on the concentrations of iron, zinc and copper in the roots and stems of snap bean plant, data of Table 4 illustrated that the average values of all the investigated micronutrients were significantly increased when the level of NPK was increased up to the level of 100% from recommended doses. More addition of NPK at the rate of 150% from recommended doses from NPK significantly decreased the average values of these micronutrients under those obtained from the plants treated with 100% from recommended doses from NPK.

Table 3. Effect of different NPK-fertilizer rates on distribution of N, P and K content (%) in different parts of snap bean plant



Nitrogen (%)			Phosphorus (%)				Potassium (%)					Plant
Zero	50%	100%	Zero	50%	100%	Zero	50%	100%	Zero	50%	100%	Parts
2.10	2.54	2.81	2.88	0.25	0.28	0.37	0.38	1.83	2.27	2.56	2.65	Leaf
1.87	2.29	2.58	2.69	0.23	0.32	0.35	0.36	1.63	2.08	2.32	2.45	Seed
1.18	0.97	0.86	0.82	0.11	0.06	0.04	0.04	0.93	0.78	0.69	0.65	Stem
1.97	1.67	1.50	1.43	0.18	0.11	0.09	0.08	1.72	1.47	1.29	1.26	Root
*	*	*	*	*	*	*	*	*	*	*	*	F. test
0.08	0.07	0.10	0.07	0.007	0.06	0.005	0.008	0.04	0.05	0.08	0.04	LSD at 5 %

Table 4. Effect of different NPK-fertilizer rates on distribution of Fe, Cu and Zn (%) in different parts of snap bean plants



Iron (%)			Cupper (%)				Zinc (%)					Plant
Zero	50%	100%	Zero	50%	100%	Zero	50%	100%	Zero	50%	100%	Parts
49.61	51.41	51.96	52.60	7.48	7.71	8.26	8.44	21.93	23.07	22.82	22.47	Leaf
43.60	45.37	45.96	46.51	19.07	20.27	19.96	19.63	5.19	5.33	5.74	5.94	Seed
12.86	12.37	12.19	12.04	3.47	3.36	3.08	2.97	7.79	7.24	7.40	7.52	Stem
23.44	22.80	22.57	22.35	5.94	5.71	5.27	5.13	12.36	11.62	11.79	11.97	Root
*	*	*	*	*	*	*	*	*	*	*	*	F. test
0.298	0.264	0.197	0.170	0.167	0.110	0.152	0.106	0.172	0.158	0.171	0.147	LSD at 5 %

There is an activation relationship between the applied NPK-fertilizers and the increased levels of micronutrients (e.g., Cu, Fe and Zn) in plants. Actually, there are basically two kinds of interactions between nutrients i.e., antagonism and synergism. These interactions could occur with plant nutrients in the soil or at the root zone. Many chemical reactions occur at the rhizosphere, where some of them are benefit for the plants, while some may be detrimental to plant nutrition. These chemical interactions can enhance or interfere with the uptake of some nutrients based on the concentration of other elements. Synergy effect is positive achieve between nutrients and hosthhility is a negative effect between nutrients. The excess of one nutrient limit the absorption of another nutrient called physiological antagonism. These interactions may also depend on soil type, physical properties, pH, temperatures and the proportion of nutrients involved.

There is a high selective control process implicated in nutrient uptake of plants and this is why the plant does not contain the same proportion of nutrients within the plant as found in the soil. It includes nutrient management concepts based on crop type, soil type and plant growth stage (Malvi 2011).

Distribution of nutrients in snap bean plant organs as affected by NPK fertilizer levels

It could be summarized the distribution of nutrients either macro- or micro- nutrients in snap bean plant organs as affected by NPK-fertilizer levels as shown in Fig. (1).

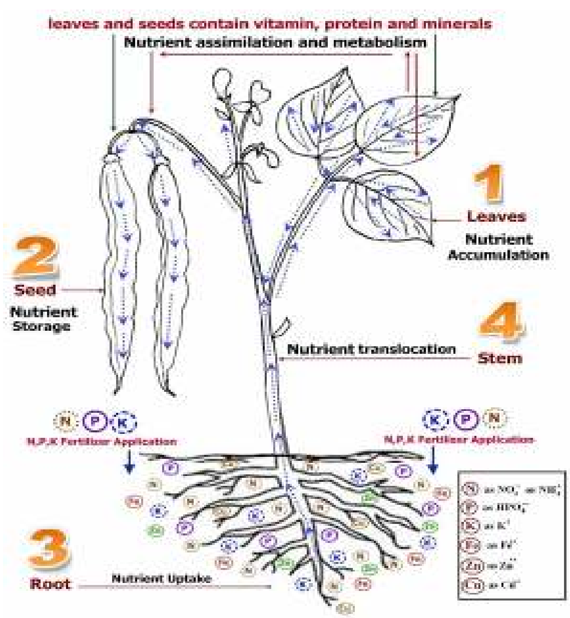


Fig. 1. Distribution of nutrients in snap bean plant organs as affected by N, P and K fertilizer levels

The results of Fig (1) can be attributed to the fact that the distribution of elements within the plant starts from the roots, where the roots are the organ competent to uptake of the nutrients. The elements in the plant can then pass through the stem, moving to the leaves, where all the vital processes and metabolism take place in leaves. Leaves, in turn, transmit metabolic products to grains, whether in the form of proteins, vitamins, minerals or other components. From the movement of elements within the bean plant, it was observed that the lowest nutrient content exists in the stems as it represents only a receptacle between the root and leaves. While, the highest content of these elements within the beans was observed in the leaves, that represent the place where all the vital processes and metabolism in plant. The distribution of elements in the bean plant can be arranged in the follow order: stems < roots < grains < leaves. This also explains why the scientists of soil fertility and plant nutrition agree that plant leaves are the main organ of plant analysis. It also explains why the edible part of this plant is the grains. These results are in consonance with the findings of Edelman and Colt (2016).

CONCLUSION

It can be concluded that, the growth parameters and yield components of snap bean plants were significantly increased when the levels of NPK fertilizers were increased. More addition of NPK fertilizers till the rate of 150% from the recommended doses significantly decreased the mean values of all the traits to be less than those obtained from the plants treated with 100% from the recommended doses from NPK. The distribution of macro- and micro-nutrients in the snap bean plants can be arranged in the follow order: stems < roots < grains < leaves.

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تأثير مستويات التسميد النيتروجيني والفوسفاتي والبوتاسي على توزيع العناصر الغذائية بأجزاء نبات الفاصوليا

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أجريت تجربة أصص بالمزرعة البحثية بكلية الزراعة جامعة المنصورة خلال الموسم الصيفي لعام 2015 لدراسة تأثير إضافة مستويات مختلفة من معاملات الأسمدة الأزوتية و الفوسفاتية و البوتاسية على ارتفاع النبات (سم) والوزن الطازج والجاف للنبات (جم)، متوسط وزن القرون (جم) و عدد القرون / النبات، محصول النبات بالـ (جم) ، و نسبة NPK (%) في أجزاء النبات (الجذر، الساق، الأوراق والحبوب) . أجريت التجربة في تصميم كامل العشوائية بثلاثة مكررات. أظهرت النتائج أن إضافة مستويات مختلفة من الأسمدة النيتروجينية والفوسفاتية والبوتاسية له تأثير معنوي على صفات النمو ومكونات المحصول وتركيز النيتروجين والفوسفور والبوتاسيوم والحديد والنحاس والزنك في (الجذور، السيقان، الأوراق والحبوب) في نبات الفاصوليا. وقد لوحظ تزايد جميع الصفات المدروسة بزيادة معدلات إضافة أسمدة N و P و K من صفر إلى 150٪. وقد لوحظ زيادة تركيز النيتروجين والفوسفور والبوتاسيوم في أوراق وحبوب نبات الفاصوليا بشكل ملحوظ مع زيادة مستوى إضافة العناصر الكبرى. والعكس صحيح ؛ فقد انخفض تركيز هذه العناصر بشكل ملحوظ مع زيادة مستوى إضافة أسمدة العناصر الكبرى في جذور وسيقان نبات الفاصوليا. كما ازدادت قيم جميع العناصر الصغرى تحت الدراسة مع زيادة مستوى إضافة أسمدة العناصر الكبرى إلى مستوى 100٪ من الجرعات الموصى بها لكن إضافة المستوى 150٪ من الجرعات الموصى بها من أدى إلى خفض متوسط قيم العناصر الصغرى (حديد، زنك ، نحاس). كما لوحظ أن توزيع العناصر الغذائية الكبرى والصغرى في نبات الفاصوليا يمكن ترتيبه في الأجزاء المختلفة للنبات كما يلي: السيقان< الجذور < الحبوب < الأوراق.