Journal of Horticultural Science & Ornamental Plants 11 (3): 214-221, 2019
ISSN 2079-2158

DOI: 10.5829/idosi.jhsop.2019.214.221

Minimizing NPK Fertilizers by Using Starter Fertilizers and Humic Acid Through Enhancing the Growth, Productivity and Nutritional Quality of Potato

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Abstract: Two field experiments were conducted at the Agricultural Experimental Station, Alexandria University, at Abis during the two growing seasons of 2015-2016 and 2016-2017. The objective of these experiments was giving a boost to the growth of potato plants in the first stage through soil application of starter fertilizers and foliar application of humic acid as well as exploring its effect on the growth, yield and chemical components. Each experiment included 12 treatments, which were the combinations of four starter fertilizers (SF); SF_0: control, SF_1: 190-570-190, SF_2: 380-760-380 and SF_3: 760-1140-760 mg l^{-1} of N– P2O5–K2O and three rates of humic acids (0, 0.5 and 1 g l^{-1}). The results showed that soil application of SF_2 or SF_3 increased the vegetative growth characters (plant height, the number of branches and leaves and plant fresh weight) and total tuber yield of potato plant. Moreover, SF_0 or SF_1 achieved the highest value of small tuber, in the two growing seasons. However, SF_1 or SF_2 gave the highest value of nutritional quality characters of tubers. The results also, showed that foliar application of humic acid did not reflect any effect on tubers characters and total yield of potato plants. However, foliar application of humic acid at rate 0.5 or 1.0 g l^{-1} lead to improve some tuber quality character, in the two growing seasons.

Key words: Potato · Starter fertilizers · Humic acid · Growth · Yield · Tuber quality

INTRODUCTION

In Egypt, potato (*Solanum tuberosum* L.) production concentrated in the newly reclaimed soil and Nile River delta. The annual tuber yield of potato was rising from 1.6 to 4.3 million tons in 1999 and 2017, respectively, making Egypt the first potato producer in Africa [1]. Egypt also ranks among the world's top potato exporters, where was exported more than 800 000 tons of fresh potatoes destined mainly for markets in Europe, in 2017.

The potato plant development is rapid especially the root system and shoots, where it is after seeds planting and once the potato plant emergence above the soil surface, the growth of root system and vegetative of the potato plants are completed through the 30-35 day. Consequently, the primary goal through the first growth stage of potato plant is the formation of a rich and robust root system, which will supply the plant with nutrients and water as well as meet the high NPK requirements of potato plant.

In arid and semi-arid regions such as Egypt, the most important problems that facing the potato producers are a restriction of the root system spread as a result of the lack of available P; that due to high alkaline soil (pH over 7) and adding phosphoric fertilizers during the soil preparation. Knowing that P is a key nutrient essential that playing a vital role in biochemical and physiological functions, especially in development of the roots and branches in a plant [2]. Baligar *et al.* [3] stated that P increased the root weight of dry bean and cowpea in a quadratic fashion with increasing P rate from 0 to 200 mg kg^{-1} of soil. Addition, Fageria [4] found that the improvement in root length in various crop species was achieved by improved P nutrition. Moreover, higher P level lead to roots had more fine hairs, i.e., increasing root surface area, compared to lower P level. Marschner [5] and Mengel *et al.* [6] reported that mineral nutrition has tremendous effects on root growth, development and function and, subsequently, the ability of roots to absorb and translocate nutrients.

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Therefore, improve the agricultural practices of potato production are of great economic interest. This may be achieved by applying simple applicable fertilization technologies such as the use of starter fertilizers (SF) and humic acid (HA) that contributes in providing potato plants by available NPK in low concentrations, especially during the first growth stage that will contribute to increasing the availability and uptake of P, hence formation strong roots.

Starter fertilizers (SF) are compound fertilizers, rich in phosphorus (P), add at small doses, where P helps to develop a strong root, which contribute to the increase the plant's capacity to absorb more nutrients from the soil [7-11]. Whereas, SF are an innovative technology to reduce using fertilizers, simultaneously increase productivity, increase nutrients available to plants and reducing pollution of the plant [12]. AVRDC [13] pointed out that the use of SF Led to accelerate root development, hence increasing the plant's ability to absorb more nutrients from the soil. Moreover, Stone [14] illustrated that applying small quantities of P and N fertilizers at planting under the seed level led to improved early growth and yield of bulb onion, salad onion, leek, crisp lettuce and forage maize crops. Furthermore, injection of SF significantly boosted early growth and the overall yield of cabbage, cherry tomato, sweet pepper, chili pepper and Chinese cabbage [15, 7, 16].

Humic acid (HA) is a very huge molecule, which can use as supplement fertilizer. The uptake of HA in plant tissue results in increased cell energy balance and intensification of metabolism. This leads to various biochemical effects through development of a powerful root system, increasing content of the sugar as well as preserving vitamins, amino acids in plant tissues, thus stimulates the growth whole plant [17]. Many investigators showed several valuable effects of HA such as increasing cell membrane permeability, chlorophyll content, oxygen uptake and photosynthesis, NPK uptake and root elongation [18-23, 11]. Moreover, HA has an indirect effect on plant growth through their strong ability to chelate nutrients, hence greatly increase the efficiency utilize nutrients by plants from the soil.

The current study was conducted to investigate response the growth, productivity and nutritional quality characteristics of potato to concentrations of starter fertilizers and humic acid.

MATERIALS AND METHODS

Two field experiments were carried out during the autumn seasons of 2016 and 2017, at the Experimental Station Farm of the Faculty of Agriculture, at Abies, Alexandria University, Egypt, to investigate the effects of four starter fertilizers (SF); SF_1: 190-540-190, SF_2: 380-760-380 and SF_3: 760-1140-760 mg l^{-1} of N– P_2O5–K_2O and SF_0: (control) without addition of starter fertilizer, three concentrations of humic acid (0.5 and 1.0 g l^{-1}) as well as their interactions on the performance characters of potato plants (Valor cv.). The potato tuber seed of Valor cv. that used in the two experiments obtained from Agro Food Co.

Preceding the initiation of each experiment, soil samples of 30 cm depth were collected and analyzed according to the published procedures [24] and the results of some soil physical and chemical properties are presented in Table 1.

The potato tuber seeds were planted, on 15th of September in both seasons, in ridges 4 m length and 0.7 m width at an interrow spacing 25 cm. The experimental layout was split-plot system in a randomized complete blocks design with three replications. Each replicate included 12 treatments, which were the combinations of four starter fertilizers (SF) and three humic acid rates. The starter fertilizers (SF) were randomly arranged in the main plots, while humic acid rates were, randomly, distributed in the sub-plots. Each sub-plot consisted of 3 ridges, the experimental area was 8.4 m^2.

Starter fertilizer was used as a drench to the plant root area, three weeks after planting, at rate 0.2 l plant 1. However, the potato plants that in the control treatment were treated by tap water. HA as potassium humate at concentrations 0, 500 and 1000 mg l^{-1} was applied at four times: first one was done after three weeks of planting with starter fertilizer as soil application, while the other three applications were added as foliar. The foliar applications of HA were executed three times in the 4, 6 and 8 weeks after planting. The control plants were treated with tap water.

The soil of each experiment was received 60 kg fed^{-1} calcium super phosphate (15.5%P_2O_5) as one dose at soil preparation. Ammonium nitrate (33.5% N) at 300 kg fed^{-1} was added at three times after 4, 7 and 10 weeks after planting, but potassium sulphate (48% K_2O) at 80 kg was added at two times, i.e., after 7, 10 weeks from planting. Other recommended agricultural practices were followed as commonly used in the commercial production of potato plant and according to the outlined of Ministry of Agriculture and Reclamation of Egypt.

Data Recorded: Vegetative growth characters; a random sample of five potato plants was taken from the first ridge of each sub-plot, after 80 days of planting to measure plant height, leaves number $plant^{-1}$, number of main stems, plant fresh weight and leaf's total chlorophyll content.

Table 1: Soil physical and chemical properties of the experimental sites in the two growing seasons of 2016 and 2017

	Seasons	
Properties	2016	2017
pH	7.91	8.00
E.C. ($dS.m^{-1}$)	3.02	3.01
Sand %	33.50	33.70
Silt %	23.50	23.80
Clay %	43.00	42.50
Soil texture	Clay loam	Clay loam
Soluble cations (m.eq l^{-1})		
Ca^{++}	2.70	3.80
Mg^{++}	2.37	2.60
Na^{+}	3.01	3.44
K^{+}	0.52	0.35
Soluble anions (m.eq l^{-1})		
CO_3^{-}	2.20	2.57
HCO_3^{-}	1.20	1.48
Cl^{-}	1.48	2.18
SO_4^{-}	3.20	3.61
Available P (ppm)	0.28	0.30

Mineral contents of leaves; random samples of the youngest expanded mature leaves of potato plants, were randomly collected from each sub-plot, then washed with distilled water, weighed, then oven dried at 70°C till constant weight. The dried leaf materials were grinding and homogenized, wet digested; using concentrated sulfuric acid and H_2O_2 and the total nitrogen and phosphorus on leaves of potato were determined calorimetrically; using spectrophotometer at 662 and 650 nanometers; according to Evenhuis, [25] and Murphy and Riley [26] respectively. Potassium was determined by flam photometer as described by Cottenie [27] of the leaves and of potato plant.

Tubers yield and quality characters; harvesting potato plants was performed at 120 days after planting 15th of January. The harvested tubers from the 2nd and 3rd ridges of each experimental unit were weighed then graded into three sizes according to their diameter; small (< 30 mm), medium (30- 60mm) and large (> 60mm). Total tuber yield $fed.^{-1}$ was calculated.

Tuber nutritional quality; tuber sample from each sub-plot was saved, to determine tuber dry matter content, NPK contents, total sugar, reducing and non-reducing sugar (mg. g^{-1}.d.w) according to Malik and Singh [28] and starch percentage as described by A.O.A.C, [29] methods. Moreover, the total phenols measurement of total, free and conjugated phenols were determining according to Snell and Snell, [30] method.

Statistical Analysis: Statistical analysis was performed using analysis of variance (ANOVA). Differences among means were considered significant at $p<0.05$ multiple range of post hoc comparisons were performed using the least significant difference (LSD) to resolve the differences among the means of replication according to of Duncan using SPSS [31].

RESULTS AND DISCUSSION

Vegetative Growth Characters: The results presented in Table 2 clarified the presence of significant gradual increments in all the studied vegetative growth characters of potato plant i.e., plant height, number of leaves and branches and plant fresh weight with each increase in starter fertilizer (SF) concentration, in both seasons. Data in Table 2 shows that the soil application of SF_2: 380-760-380 and SF_3: 760-1140-760 mg l^{-1} of $N–P_2O_5–K_2O$ treatments gave the highest value of plant height, number of both leaves and branches and plant fresh weight compared to control treatment. This can be clarified based on starter fertilizers (rich in NPK) may be accelerate root development and boosting plant growth, hence increasing the plant's ability to absorb more nutrients and water from the soil. Thus, the availability of these elements in the early growth stage of potato plants may be able to encourage the vegetative growth, increasing the meristematic activity and building protein molecules [5, 7, 10, 14]. Result in Table 2 indicated that the foliar application of humic acid (HA) on potato plants had a positive significantly effect on all previously mentioned characters of the vegetative growth, in the two growing seasons, except, the number of both leaves and branches, in the first season, were not significantly affected by the different rates of humic acids. Generally, foliar application of HA up to 1 g l^{-1} resulted in the highest plant height, number of leaves and branches and plant fresh weight compared to the control treatment. The encouraging effects of HA on the potato vegetative growth characters could be related to foliar application of HA and its uptake into the plant tissue resulting in various biochemical effects through increase nutrient uptake and maintaining vitamins and amino acids level in plant tissues thus promote the growth of roots and whole plant [17].

The interaction effects between SF and the different rates of HA on the vegetative growth characters of potato plants were found to be significant, but with different magnitudes, in both growing seasons, Table 2. The results illustrated that the potato plants that received the SF_3 treatment (760-1140-760 mg l^{-1} of $N– P_2O_5–K_2O$)

Table 2: Influence of starter fertilizers, humic acid concentrations and their interactions on the vegetative growth characters of potato plants, during the autumn seasons of 2016 and 2017

Treatments		Plant height (cm)		Number of branches		Number of leaves		Plant fresh weight (g)	
Starter Fertilizers (SF)	Humic acid concentrations (g l^{-1})	2016	2017	2016	2017	2016	2017	2016	2017
SF_0 *		69.17 D**	75.15 D	3.03 B	3.38C	40.41 C	41.75 C	342.22D	324.44C
SF_1		71.40 C	76.42 C	3.96 A	4.53B	43.40 BC	43.53 B	397.33C	418.44A
SF_2		74.16 B	78.37 B	3.58 A	5.05A	44.82 AB	44.68 AB	407.77B	424.77A
SF_3		75.93 A	79.76 A	3.55 AB	5.16A	47.38 A	45.24A	429.33A	393.33B
	Control	71.47 B	76.40 B	3.42A	4.23C	43.61A	43.12B	369.66C	382.50C
	0.5	72.92 A	77.61 A	3.55A	4.50B	43.88A	43.80AB	400.50B	387.33B
	1	73.60 A	78.27 A	3.63A	4.87 A	44.51A	44.48A	412.33A	400.91A
SF_0	Control	68.10 e	75.13 e	2.90 e	3.00 e	40.00 d	41.06 d	318.33 h	313.33 g
	0.5	69.50 e	75.16 e	3.00 de	3.33 de	40.16 cd	43.16 cd	346.66 g	330.00 f
	1	69.93 e	75.16 e	3.20 cde	3.83 cd	41.06 bcd	41.03 d	361.66 f	330.00 f
SF_1	Control	70.30 de	74.40 e	3.70 abcd	4.10 c	42.66 abcd	43.80 c	375.00 ef	436.66 ab
	0.5	70.00 e	76.86 d	4.03 ab	4.66 ab	44.20 abcd	43.63 cd	404.33 d	405.00 e
	1	73.90 bc	78.00 cd	4.16 a	4.83 ab	43.33 abcd	43.16 cd	412.66 cd	413.66 d
SF_2	Control	72.83 cd	77.60 cd	3.76 abc	5.16 ab	43.40 abcd	43.50 cd	382.33 e	443.33 a
	0.5	74.66 bc	78.76 bc	3.66 abcd	4.83 ab	43.73 abcd	43.53 cd	416.00 cd	406.00 e
	1	75.00 abc	78.76 bc	3.33 bcde	5.16 ab	47.33 ab	47.03 a	425.00 bc	425.00 c
SF_3	Control	74.66 bc	78.46 bc	3.33 bcde	4.66 ab	48.40 a	44.13 bc	403.00 d	336.66 f
	0.5	77.53 a	79.66 b	3.50 abcde	5.16 ab	47.43 a	44.90 abc	435.00 b	408.33 de
	1	75.60 ab	81.16 a	3.83 abc	5.66 a	46.33 abc	46.70 ab	450.00 a	435.00 b

* SF_1: 190-540-190, SF_2: 380-760-380 and SF_3: 760-1140-760 mg l^{-1} of N– P2O5–K_2O and SF_0 control treatment (water only).

**Values followed by the same alphabetical letter(s) in common, within a particular group of means in each character, do not significantly differ, using Revised L.S.D test at 0.05 level of probability.

Table 3: Influence of starter fertilizers, humic acid and their interactions on tuber total yield and percentage of large, medium, small tubers of potato plants, during the autumn seasons of 2016 and 2017

Treatments		Total yield (kg fed^{-1})		Total yield distribution: Large tubers %		Medium tubers %		Small tubers %	
Starter Fertilizers (SF)	Humic acid concentrations (g l^{-1})	2016	2017	2016	2017	2016	2017	2016	2017
SF_0 *		13.93 B**	13.25 B	36.47	36.45	29.72	30.04	33.81	33.51
SF_1		12.48 B	14.67 AB	32.86	35.79	33.33	33.06	33.81	31.15
SF_2		15.31 A	15.33 A	37.95	40.05	32.46	31.31	29.59	28.64
SF_3		14.62 A	14.18 B	39.26	42.10	32.28	30.68	28.46	27.22
	Control	12.90 B	13.49 B	31.86	30.17	30.46	30.24	37.68	39.59
	0.5	14.41 A	14.55 A	34.56	40.34	33.73	32.86	31.71	26.80
	1	14.95 A	15.03 A	43.21	44.58	31.44	30.74	25.35	24.68
SF_0	Control	13.43 cd	13.51 c	28.82	29.68	25.46	29.53	45.72	40.79
	0.5	13.49 c	11.59 d	40.55	34.60	30.24	33.39	29.21	32.01
	1	14.88 b	14.66 b	39.58	44.13	33.06	27.83	27.36	28.04
SF_1	Control	11.51 e	14.68 b	22.67	29.43	37.36	29.29	39.97	41.28
	0.5	12.66 d	14.93 b	27.88	36.64	33.10	37.31	39.02	26.05
	1	13.27 cd	14.41 bc	46.49	41.36	30.07	32.48	23.44	26.16
SF_2	Control	13.71 c	14.20 bc	40.99	29.37	32.89	29.29	26.12	41.34
	0.5	16.81 a	16.22 a	30.34	43.83	35.34	33.54	34.32	22.63
	1	15.43 b	15.57 ab	43.55	45.79	28.84	30.83	27.61	23.38
SF_3	Control	12.96 cd	11.54 d	33.49	32.75	26.93	33.45	39.58	33.80
	0.5	14.68 b	15.50 ab	39.64	44.39	35.69	27.49	24.67	28.12
	1	16.22 ab	15.49 ab	43.59	46.74	33.41	31.83	23.00	21.43

* SF_1: 190-540-190, SF_2: 380-760-380 and SF_3: 760-1140-760 mg l^{-1} of N– P2O5–K_2O and SF_0 control treatment (water only).

**Values followed by the same alphabetical letter(s) in common, within a particular group of means in each character, do not significantly differ, using Revised L.S.D test at 0.05 level of probability and sprayed with HA at 0.5 or 1 g l^{-1} achieved the significant highest vales of plant height, in both seasons. In addition, the results reported that soil application of SF1 and SF_3 treatments combined with spraying HA at rate 1.0 g l^{-1} rate gave the significant highest mean values of both the number of branches, in both growing seasons, respectively. Moreover, the treatments combination that included SF_3+HA at rate 0.5 g l^{-1} and SF_2+HA at rate 1.0 g l^{-1} attained the significant highest mean value of number of leaves, in the two seasons, respectively. Data in Table 2, also, shows that the treatments combination of SF_3 + HA at rate 1.0 g l^{-1} and SF_2+ 0.0 g l^{-1} of HA reflected the significant highest mean value of plant fresh weight, in the two seasons, respectively.

Total Yield: The results in Table 3 revealed that all soil application of SF treatments resulted in highly significant increases in tuber total yield fed^{-1} and percentage of large tuber yield of potato plants compared to the control treatment. Whereas, potato plants that received SF_2 and SF_3 treatments (380-760-380 and 760-1140-760 mg l^{-1} of $N–P_2O_5–K_2O$) gave the highest mean values of total yield fed^{-1} and percentage of large tuber yield compared with other treatments, in both growing seasons. However, effects of soil application of SF on percentage of medium and small tuber yield were not found to be significant Table 3. The enhancing effect of soil application of starter fertilizers on increasing the tuber total yield of potato may be attributed to a good response to the establishment, early growth of potato plants and often increased tuber yield. These results are in line with those reported by Stone [32].

The results in Table 3 showed that foliar application of humic acid at rates 0.5 and 1.0 g l^{-1} lead to attained the highest significant value of tuber total yield fed^{-1} and percentage of large and medium tuber yield, as well as lowest value of small tuber yield percentage, in the two growing seasons. Perhaps this is due to that HA has hormone-like activity that enhances plant growth and the nutrient uptake, as well as an increase phosphate uptake, root elongation and whole potato plant, which was reflected on the tuber yield [33-35, 17, 36, 37]. Similar results were reported that application of HA increased the growth and yields of various vegetable crops [38, 39].

The different comparisons among the means of the different treatment combinations between SF and HA on the tuber yield characters of potato plants illustrated presence of pronounced interaction effects as appears in Table 3. The comparisons, generally, showed that application of HA up to rate 1.0 g l^{-1} with any rates of SF, significantly increased tuber total yield and percentage of large and medium tuber yield, in both seasons, except for the total tuber yield fed^{-1} in second season and percentage of medium tuber yield, in the first season. On the other hand, potato plants that received any rate of SF and sprayed with HA up to 1.0 g l^{-1} showed significantly decrease the percentage of small tuber yield, which was not the case in SF_2, in the first season.

Leaves Chemical Characters: The results presented in Table 4 showed that soil application of SF treatments achieved highly significant increases in leaves chemical characters of potato plants (total chlorophyll and the mineral contents of potato leaves), in both seasons. Where, potato leaves contents from chlorophyll, N, P and K significantly increased as the SF rates increased up to 760-1140-760 mg l^{-1} of $N–P_2O_5–K_2O$, in both seasons. This could be due to the positive effect of starter fertilizers (rich in NPK) may be accelerate root development and boosting plant growth, which leads to increasing the plant's ability to absorb more nutrients and water from the soil [5, 14, 32, 13, 7, 10].

The effect of foliar application of HA on the leaves chemical characters of potato plants (total chlorophyll and the mineral contents of potato leaves), was significant Table 4. Comparisons among different HA rates, clearly demonstrated that, increasing HA rate up to 1.0 g l^{-1} increased the total chlorophyll and the mineral percentages (N, P, K) of potato leaves of compared with control, in both seasons. This can be explained based on the fact that spraying HA on the leaves of potato plant works as a musk that causing a dark color of potato leaves, which reflected on the increase of leaf content of chlorophyll of potato leaves as a result to reduces the effect of the light intensity on plant leaves. Moreover, HA has hormone-like activity, which leads to enhance the plant growth and the nutrient uptake [33-35].

The interaction effects between the SF and the different rates of HA on the leaves chemical characters of potato plants (total chlorophyll and the mineral contents of potato leaves), was significant, in both seasons, Table 4. The results illustrated that soil application to SF_3 (760-1140-760 mg l^{-1} of $N–P_2O_5–K_2O$) treatment combined with using HA as foliar application at rate 1.0 gl^{-1} achieved the significant highest vales of total chlorophyll and the mineral percentages (N, P, K) of potato leaves, in both growing seasons.

Table 4: Influence of starter fertilizers, humic acid and their interactions on the leaves chemical characters of potato plants, during the autumn seasons of 2016 and 2017

Treatments		Total chlorophyll (mg. g^{-1} f.w)		K (%)		N (%)		P (%)	
Starter Fertilizers (SF)	Humic acid concentrations (g l^{-1})	2016	2017	2016	2017	2016	2017	2016	2017
SF_0 *		39.25 D**	39.47 C	2.23 D	2.24 C	1.32 D	1.33 D	0.331 D	0.324 D
SF_1		40.20 C	40.52 B	2.48 C	2.27 C	1.45 C	1.44 C	0.365 C	0.364 C
SF_2		40.76 B	40.73 B	2.68 B	2.61 B	1.59 B	1.58 B	0.423 B	0.436 B
SF_3		41.81 A	42.04 A	3.30 A	3.25 A	1.85 A	1.85 A	0.463 A	0.475 A
	Control	39.75 B	39.92 B	2.55 C	2.45 B	1.50 C	1.50 B	0.376 C	0.390B
	0.5	40.78 A	40.91 A	2.65 B	2.65 A	1.57 B	1.58 A	0.395 B	0.398AB
	1	40.99 A	41.24 A	2.80 A	2.68 A	1.59 A	1.58 A	0.415A	0.411A
SF_0	Control	39.00 f	39.26 f	2.11 j	2.06 e	1.28 i	1.28 g	0.323 i	0.330 gh
	0.5	39.43 ef	39.53 ef	2.24 i	2.26 de	1.34 h	1.35 f	0.333 i	0.333 gh
	1	39.33 ef	39.63 ef	2.33 h	2.40 cd	1.36 h	1.35 f	0.336 hi	0.310 h
SF_1	Control	39.76 def	40.03 def	2.39 gh	2.20 de	1.40 g	1.39 f	0.350 gh	0.346 fg
	0.5	40.26 cdef	40.50 bcde	2.41 g	2.25 de	1.49 f	1.49 de	0.363 g	0.366 ef
	1	40.57 cde	41.05 bc	2.63 e	2.37 cd	1.48 f	1.45 e	0.383 f	0.380 e
SF_2	Control	40.16 cdef	40.20 cdef	2.54 f	2.44 bcd	1.53 e	1.54 d	0.403 e	0.433 cd
	0.5	40.80 cd	40.76 bcd	2.70 e	2.73 b	1.60 d	1.61 c	0.320 d	0.420 d
	1	41.33 bc	41.23 b	2.80 d	2.65 bc	1.64 c	1.61 c	0.446 c	0.456 bc
SF_3	Control	40.06 cdef	40.20 cdef	3.17 c	3.09 a	1.79 b	1.78 b	0.430 d	0.453 bc
	0.5	42.63 ab	42.86 a	3.27 b	3.36 a	1.86 a	1.87 a	0.466 b	0.473 ab
	1	42.73 a	43.06 a	3.45 a	3.3 a	1.89 a	1.91 a	0.493 a	0.500 a

* SF_1: 190-540-190, SF_2: 380-760-380 and SF_3: 760-1140-760 mg l^{-1} of N– P2O5–K_2O and SF_0 control treatment (water only).

**Values followed by the same alphabetical letter(s) in common, within a particular group of means in each character, do not significantly differ, using Revised L.S.D test at 0.05 level of probability

Table 5: Influence of starter fertilizers, humic acid and their interactions on potato tuber nutritional quality, during the autumn seasons of 2016 and 2017

Treatments		Tuber dry matter (%)		Total phenol (µg.g^{-1}f.w)		Total sugar (µg.100g^{-1}f.w)		Starch (%)		N (%)		P (%)	
Starter Fertilizers (SF)	Humic acid concentrations (g l^{-1})	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
SF_0 *		16.20C**	16.43D	0.469D	0.472D	13.53A	13.56A	14.11 C	14.07 C	1.88 D	1.91 D	0.327 D	0.334 D
SF_1		18.16 B	18.26 C	0.562C	0.553C	12.10B	12.20B	15.20 B	15.23 B	2.04 C	2.14 C	0.383 C	0.397 C
SF_2		21.06 A	20.91 B	0.689B	0.688B	10.90D	10.95D	16.45 A	16.52 A	2.30 B	2.31 B	0.433 B	0.450 B
SF_3		21.70 A	21.78 A	0.888A	0.888A	11.50C	11.57C	16.58 A	16.57 A	2.48 A	2.55 A	0.486 A	0.497 A
	Control	18.03 C	18.22 C	0.614C	0.605C	12.25A	12.33A	15.24 B	15.31 B	2.06 C	2.13 C	0.401 C	0.401B
	0.5	18.90 B	19.03 B	0.661B	0.663B	11.95B	12.07B	15.64 A	15.64 A	2.21 B	2.23 B	0.415 B	0.415B
	1	20.91 A	20.79 A	0.681A	0.682A	11.81B	11.80C	15.87 A	15.84 A	2.26 A	02.32 A	0. 430A	0.442A
SF_0	Control	15.46 h	15.83 h	0.464h	0.462 g	13.83 a	13.95e	13.93 f	289.33 f	1.85 f	1.85 g	0.323 g	0.340 e
	0.5	16.10 gh	16.33gh	0.465h	0.473 g	13.50ab	14.13 e	14.16 f	292.66 f	1.87 f	1.92 g	0.326 g	0.320 e
	1	17.03 fg	17.13 fg	0.479h	0.482 g	13.26 b	14.13 e	14.25 f	316.00 c	1.93 ef	1.97 fg	0.333 g	0.343 e
SF_1	Control	17.96 ef	18.15 ef	0.540 g	0.517 f	12.23 c	14.93 d	14.93 e	305.00 e	2.03 de	2.16 de	0.383 f	0.393 d
	0.5	18.06 def	18.33def	0.566 f	0.565 e	12.13 c	15.36 d	15.23 de	307.66 de	2.03 de	2.10 ef	0.383f	0.400 d
	1	18.46cdef	18.30def	0.581 f	0.578de	11.93cd	15.40cd	15.43 cd	316.33 bc	2.06 d	2.16 de	0.383f	0.400 d
SF_2	Control	19.20cde	19.40cde	0.609 e	0.602 d	11.43 e	16.02bc	15.82 c	312.33 cd	2.10 d	2.13 def	0.403 e	0.433 c
	0.5	19.86 c	19.63 c	0.713d	0.717 c	10.63 f	16.63ab	16.56ab	308.33 de	2.33 c	2.30 cd	0.420 de	0.433 c
	1	24.13 a	23.70 a	0.746 c	0.745 c	10.63 f	16.90 a	16.96a	319.0b	2.46 b	2.50 ab	0.476 c	0.483b
SF_3	Control	19.50 cd	19.50 cd	0.845b	0.841 b	11.53 de	16.36 ab	16.28 b	314.3bc	2.60 a	2.36 bc	0. 430 d	0.440c
	0.5	21.56 b	21.83 b	0.901a	0.897 a	11.53de	16.42ab	16.6ab	319.6b	2.60 a	2.63 a	0.500b	0.510 b
	1	24.03 a	24.03 a	0.918a	0.924 a	11.43 e	16.92 a	16.86a	326.3a	2.26 c	2.66 a	0.530 a	0.543 a

* SF_1: 190-540-190, SF_2: 380-760-380 and SF_3: 760-1140-760 mg l^{-1} of N– P_2O5–K_2O and SF_0control treatment (water only).

**Values followed by the same alphabetical letter(s) in common, within a particular group of means in each character, do not significantly differ, using Revised L.S.D test at 0.05 level of probability

Tuber Nutritional Quality: Concerning the effect of the SF on the tuber nutritional quality characters (percentages of dry matter, starch, N and K and total contents of phenol and sugar), the results in Table 5 demonstrated that the comparison among mean values were significant, in both growing seasons. Where, the results showed that the soil application of SF_3 attained the highest values of all tubers nutritional quality characters, with the exception of total sugars content, compared with control treatment, in both seasons. May be this is due to that the availability of NPK elements through soil application of SF in the early growth stage could, accelerate the photosynthetic rate, increasing the meristematic activity and building protein molecules [5, 14, 7, 10].

Regarding the main effects of the HA on the tuber nutritional quality characters (percentages of dry matter, starch, N and K and total contents of phenol and sugar) during the two growing seasons are presented in Table 5. The results indicated that foliar application of HA at rate 1.0 g l^{-1} attained the highest mean values of percentages of dry matter, starch, N and K and total content of phenol and lowest total content of sugars, in both growing seasons.

The comparisons among the various combined treatments, showed some significant interactive effect between SF and HA treatments on the tuber nutritional quality characters (percentages of dry matter, starch, N and K and total contents of phenol and sugar). The soil application of SF_3 (760-1140-760 mg l^{-1} of $N–P_2O_5–K_2O$) with HA at 1.0 g l^{-1} seems the best treatment combination for all potato tuber nutritional quality characters, in both seasons, with the exception of total sugars and N%, in the first season.

CONCLUSION

It is concluded that soil application of starter fertilizers and foliar application of humic acid through the first growth stage of potato plant, was leading to increase the tuber yield and improve the physical and chemical qualities of potato plant. Therefore, the combination of starter fertilizer (SF_1: 190-570-190 or SF_2: 380-760-380 of $N–P_2O_5–K_2O$) and HA at 1.0 g l^{-1} have the potential to be used to increase the productivity and quality of potato, as a low input, safe, environmentally friendly agricultural practices.

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