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OPTIMAL REQUIREMENTS OF NITROGEN AND PHOSPHORUS FERTILIZATION RATES FOR STRAWBERRY NURSERIES

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Metwally[1], A.A.; M.E. Ragab[1]; S.M. El-Miniawy[1]; S.M. Youssef[1] and Manal Mubarak[2]

1- Horticulture Dept., Fac. of Agric., Ain Shams Univ., Cairo, Egypt
2- Soil Sciences Dept., Fac. of Agric., Ain Shams Univ., Cairo, Egypt

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ABSTRACT

Due to the expansion of strawberry nursery cultivation, transplant production has become an important industry in Egypt. Nitrogen and phosphorus are the most important nutrients affecting the number and quality of strawberry transplants. However, no empirical research exists addressing the optimal requirements of nitrogen and phosphorus fertilization rates for strawberry nurseries in Egypt, until now. This study was conducted at a private farm in Abo Ghalib, Giza Governorate, Egypt during the two successive summer seasons of 2015 and 2016 to determine the optimal requirements of nitrogen and phosphorus fertilizations for Festival strawberry cultivar nurseries *via* evaluating the influence of four nitrogen rates (83, 100, 117 or 134 kg N/feddan) and five phosphorus rates (38, 62, 74, 86 or 98 kg P_2O_5/feddan) in a factorial experiment. Results revealed that increasing the rates of nitrogen and phosphorus fertilizations increased the number of main runners/mother plant and number of marketable transplants/m^2, and enhanced all vegetative growth parameters, leaf SPAD readings, leaf relative water content, crown diameter, crown carbohydrates, and leaf mineral content in both growing seasons. On the contrary, both elements had an inverse effect on leaf total soluble phenols. Thus, the study recommends to the nurserymen of Festival strawberry cultivar to apply 117 or 134 kg N with 98 kg P_2O_5 per feddan under pure sandy soil condition which gave the highest number of transplants with high quality and subsequent high quality crop in the field.

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INTRODUCTION

Strawberry (*Fragaria x ananassa Duch*.) is an important small fruit of great nutritional and medicinal value **(Maas et al 1991)** which belongs to the *Rosaceae* family. In Egypt, strawberry cultivated area was 6509 ha with an average yield of 43.55 tons ha^{-1} and a total production of 283471 tons **(FAOSTAT, 2014)** for local consumption and exportation. This area of strawberry is cultivated with locally produced transplants. Recently, strawberry nurseries have been expanded and the licensed strawberry nurseries area was about 163 feddans in 2016 (Central Administration of Horticulture, Ministry of Agriculture and Land Reclamation, Egypt). Due to the expansion of strawberry nursery cultivation, transplant production has become an important industry in Egypt. Nitrogen and phosphorus are the most important nutrients affecting the number and quality of strawberry transplants. However, no empirical research exists addressing the optimal requirements of nitrogen and phosphorus fertilization rates for strawberry nurseries in Egypt until now.

Nitrogen is one of the important essential nutrients to the plants. It has many important functions that play roles in plant metabolic processes, development and growth of the plants. Nitrogen biologically combined with carbon, hydrogen, oxygen, and sulphur to create amino acids, which are the building units of proteins and enzymes **(Epstein and Bloom, 2004)**. Nitrogen also is important for the chlorophyll formation which is necessary for the photosynthesis process in the plants **(Uchida, 2000, Epstein and Bloom, 2004**). Moreover, nitrogen encourages the uptake of other nutrients such as potassium and phosphorus (**Bloom, 2015)**. An insufficient nitrogen supply reduces plant growth and leaf area and induces a decrease in the rate of photosynthesis and leaf N content **(Deng and Woodward, 1998)**. On the other hand, at the excess and surplus of the nitrogen, the growth is exaggerated, with excess of leaves, causing in the susceptibility to pathogens, poor performance and low survival percentage after transplanting **(Kirschbaum et al 2010).**

Phosphorus also is an essential element for plant growth **(Epstein and Bloom, 2004)**, and is an important nutrient for crop propagation, health and vigor of strawberry plants **(Li et al 2010)**. Plants need the phosphorus for the accumulation and release of energy associated with cellular metabolism since phosphorus plays a major role in energy storage and transfer *via* the molecules of ADP and ATP which are the sources of the energy that drives many chemical reactions within the plants **(Marschner, 2012)**. Also, phosphorus acts as a structural element of nucleic acids (DNA and RNA molecules) **(Uchida, 2000, Marschner, 2012)**. The deficiency of phosphorus reduces both respiration and photosynthesis and also decreases protein and nucleic acid synthesis leading to the delaying of cell growth and subsequently decrements in plant growth **(Marschner, 2012)**. On the other hand, excess amounts of phosphorus compete with other micronutrients like iron, manganese, and zinc resulting in leaf chlorosis and decreased plant growth **(Choi and lee, 2012, Choi et al 2013)**

Therefore, the current study was designed to determine the optimal requirements of nitrogen and phosphorus fertilizations for Festival strawberry cultivar nurseries *via* evaluating the influence of four nitrogen rates (83, 100, 117 or 134 kg N/feddan) and five phosphorus rates (38, 62, 74, 86 or 98 kg P_2O_5/feddan) in a factorial experiment.

MATERIALS AND METHODS

Experimental site and cultivar

This study was conducted at a private farm in Abo Ghalib, Giza Governorate, Egypt, during the two successive seasons of 2015 and 2016. The aim of this study was to determine the optimal requirements of nitrogen and phosphorus fertilizations for Festival strawberry cultivar nurseries, since it is an important cultivar which planted widely in Egypt for exportation as fresh or frozen fruits. The soil type was a virgin sandy soil with pH of 7.6 and EC of 0.8 mmhos/cm. The electrical conductivity was determined in the extract of saturated soil paste according to the method mentioned by **Jackson (1973)**. The pH values were measured in soil suspension (1:2.5) using pH meter according to the method mentioned by **Black et al (1965).**

Fertilization treatments and cultivation

Chicken manure at 30 m^3/feddan with the initial calcium superphosphate at 250 kg/feddan (approximately 38 kg P_2O_5/feddan) were added, three weeks before cultivation. Nursery mother transplants (Super Elite plants) were taken out from the cold storage then dipped in 0.2% Rhizolex solution for 20 minutes and planted as plugs on the 1st and 4th of May in the first and second season, respectively. The transplants were spaced at 1.5 m between plants and 1.75 m between rows. Flowers were continuously removed from mother plants during the first month after transplanting. Drip irrigation system in the first two months was used then the micro sprinkler irrigation system (4 m x 5 m) was used.

Four nitrogen fertilization rates (83, 100, 117 or 134 kg N/feddan) were added as ammonium nitrate fertilizer, while commercial phosphoric acid at rates of 0, 40, 60, 80 or 100 l/feddan to make five phosphorus fertilization rates (38, 62, 74, 86 or 98 kg P_2O_5/feddan) were used. A constant rate of potassium sulfate (96 kg K_2O/feddan) was added. The fertilizers were added through the drip-irrigation system three times a week during the nursery period.

All other agricultural practices such as runner fixation, and pest and diseases control were performed as recommended for strawberry nurseries.

Experimental design

The experiment was a factorial designed as randomized complete blocks with three replicates. Each experimental plot contained two rows each of 1.75 m wide and 5 m long (plot area = 17.5 m^2).

Data recorded

Number of runners and transplants

Representative samples of nine mother plants with their runners and daughter plants for each experimental treatment were dug out on 1st of October in both seasons to record the number of main runners/mother plant and number of marketable daughter transplants/m^2.

Vegetative growth characteristics

The fresh transplants of strawberry were carefully dug out with a garden trowel to avoid the root damage. Root and plant lengths were measured. Number of leaves/plant was counted. Average leaf area was calculated as relation between area unit and fresh weight of leaves **(Koller, 1972)** using the following equation:

$$Leaf\ area = \frac{Disk\ area\ x\ No.of\ disks\ x\ fresh\ weight\ of\ leaves}{Fresh\ weight\ of\ disks}$$

In the laboratory, the plants were washed then root and vegetative growth fresh weights were recorded. They were dried in an oven at 70°C until constant weight to record the root and vegetative growth dry weights.

SPAD Readings

The leaf greenness of the obtained transplants was measured by a portable chlorophyll meter (SPAD-502, Konica Minolta Sensing, Inc., Japan). The SPAD measurements were taken at four locations on each leaf; two on each side of the midrib on the youngest fully expanded leaves of randomly selected five plants per plot and then averaged **(Khan et al 2003)**.

Total soluble phenols

Total soluble phenol content was determined spectrophotometrically, according to the Folin-Ciocalteu method as described by **López-Arnaldos et al (2001)**, using gallic acid (0–1000 µM) as the standard. The absorbance at 765 nm of reaction media was determined using a Multiskan™ GO Microplate Spectrophotometer after a 3 hour-incubation period at room temperature in the dark. Analysis was done in triplicate for each sample. Total soluble phenol content was expressed as gallic acid equivalents (GAE) per gram dry weight.

Leaf relative water content (RWC)

Leaf relative water content (RWC) was measured on fully expanded leaves according to the method of **Barrs and Weatherley (1962)**. Fresh weight (FW) was immediately recorded, and then leaves were immediately soaked for 4 hours in distilled water at room temperature under a constant light and saturated humidity to record turgid weight (TW). The samples were then dried for 24 hours at 80 ºC for recording dry weight (DW). Relative water content (RWC) was calculated by the following formula:

$$RWC\ (\%) = \frac{FW-DW}{TW-DW} \times 100$$

Leaf membrane stability index (LMSI)

Leaf membrane stability index (LMSI) was determined by the method of **Sairam et al (1997)**. Leaf disks (200 mg) were taken in two sets of test tubes containing 10 ml of distilled water. One set was kept at 40ºC in a water bath for 30 minutes and electrical conductivity (C1) was measured. The second set was incubated at 100ºC for 15 minutes and electrical conductivity (C2) was measured. The MSI was calculated according to the following formula:

$$MSI\ (\%) = (1- \frac{C1}{C2}) \times 100$$

Crown diameter and crown carbohydrate determination

Average diameter of crowns was measured using caliper. Total carbohydrates of crowns were determined using phenol sulphuric acid method **(DuBois et al 1956)**.

Mineral analysis of leaves

Leaf samples were dried at 70 C˚ in an oven until constant weight then pulverized to pass a 1 mm sieve. Dry samples of 0.1 g were taken and digested using the wet digestion method by using a mixture of sulphuric acid 98% and hydrogen peroxide 30% as described by **Thomas et al (1967)**.

All the studied elements were assayed in the digest extract of the plant samples. Kjeldahl method was used to determine total nitrogen as described by **Chapman and Pratt (1961)**. Spectrophotometer was used to measure phosphorus content using the ascorbic acid method **(AOAC, 2005)**. Flame photometer was used to measure potassium as described by **Page et al (1982)**. Calcium and magnesium were measured by the Versenate (EDTA) method as mentioned by **Cheng and Bray (1951).**

Statistical analysis

The statistical analysis was conducted using the CoStat package program (Version 6.303; Co-Hort Software, USA). Data were subjected to analysis of variance (ANOVA). The differences among means of data were compared by Duncan's Multiple Range Test **(Waller and Duncan, 1969)**. All statistical determinations were made at $P \leq 0.05$.

RESULTS AND DISCUSSION

Number of runners and transplants

Data in **Table (1)** clearly show that the applications of 117 or 134 kg N/feddan gave the highest significant number of main runners/mother plant and number of marketable transplants/m^2 in both growing seasons. On the contrary, the application of 83 Kg N/feddan gave the lowest significant ones. These results are in a good agreement with the previous studies which reported that the high rates of nitrogen fertilization increased the number of runners and daughter plants of strawberry **(Blatt and Crouse, 1970, Rodgers et al 1985, Li et al 2010)**. Similarly, increasing the nitrogen concentration in the nutrient solution augmented the number of runners produced in *Fragaria chiloensis* **(Alpert, 1991, Tworkoski et al 2001)**. These findings may be attributed to the increments in the endogenous hormones as mentioned by **Jang et al (2008)** who reported that the elevated nitrogen fertilization rates increased GAs contents which enhanced the growth and development of the rice plants. The increases in the endogenous hormones especially GAs led to increases in the number of runners produced from mother plants and consequently increased the number of daughter plants in the strawberry nursery. In this connection, exogenous GA3 spraying on strawberry plants in the nurseries increased the number of transplants produced and enhanced the transplant quality **(Ragab, 1996)**. Moreover, the increments in number of runners and number of daughter plants may be imputed to the role of nitrogen in the chlorophyll formation which improved the photosynthesis process **(Uchida, 2000, Leghari et al 2016)** and consequently increased the total carbohydrates which accumulated in the crown and roots of the mother plant. Also, nitrogen is essential for amino acids such as tryptophan which is an important component for biosynthesis of auxins **(Zhao, 2012, Wang et al 2015)** which regulate nearly all aspects of plant growth and development. In addition, nitrogen encourages the uptake and utilization of other nutrients including potassium and phosphorous and controls overall growth of plant **(Bloom, 2015).**

Concerning the phosphorus fertilization, the applications of 86 or 98 kg P_2O_5/feddan gave the highest significant numbers of main runners and number of transplants, while the application of 38 kg P_2O_5/feddan gave the lowest ones in both seasons. Previous studies reported that high phosphorus rates increased the number of runners and daughter plants, while the excessive phosphorus nutrition could harm the nursery productivity since it reduced the numbers of runners and daughter plants, and increased the number of dead runners; suggesting that too much soil phosphorus may prohibit nursery plant vegetative propagation and macronutrient acquisition **(Li et al 2009, 2010, 2014)**. These increments in the numbers of runners and daughter plants may be attributed to the roles of phosphorus in storing and transfer of energy during photosynthesis process **(Marschner, 2012).** Also, phosphorus acts as a structural element of nucleic acids (DNA and RNA molecules) **(Uchida, 2000, Marschner, 2012)**.

The interactive effects of the applications of nitrogen and phosphorus fertilizations were non-significant on the number of main runners/mother in both growing seasons. On the contrary, high rates of nitrogen with high rates of phosphorus fertilizations exhibited significant increases in number of marketable transplants/m^2. The applications of 117 kg N with 86 or 98 kg P_2O_5/feddan, and 134 kg N with 74, 86 or 98 kg P_2O_5/ feddan were the most effective applications. These increments in the number of transplants may be attributed to the synergistic functions of both elements upon the physiological and biochemical processes in the plants.

Vegetative growth of plants

Increasing the rates of nitrogen fertilization increased all vegetative growth parameters of strawberry transplants **(Tables 2 and 3)**. The applications of 117 or 134 kg N/feddan gave the highest values of all recorded vegetative growth parameters, i.e. root and plant lengths, number of leaves/plant, average leaf area **(Table 2)** and fresh and dry weights of roots and vegetative growth **(Table 3)** in both growing seasons. The fertilization at 134 kg N/feddan gave the highest significant values of all aforementioned recorded data. On the other hand, the 83 kg N/feddan application gave the lowest ones in both seasons.

Table 1. Effect of nitrogen and phosphorus fertilization rates on number of main runners/mother plant and number of marketable transplants/m^2 of strawberry cv. Festival in 2015 and 2016 seasons

Fertilization rates		Number of main runners/mother plant		Number of marketable transplants/m^2	
		1st season	2nd season	1st season	2nd season
Nitrogen fertilization					
83 kg N/feddan		10.67 c	9.13 c	125.87 c	127.73 c
100 kg N/feddan		12.40 b	11.47 b	136.73 b	150.27 b
117 kg N/feddan		14.27 a	12.93 a	150.13 a	163.07 a
134 kg N/feddan		14.67 a	13.50 a	152.47 a	165.07 a
Phosphorus fertilization					
38 kg P_2O_5/feddan		11.92 d	10.46 c	131.83 d	145.00 d
62 kg P_2O_5/feddan		12.50 cd	11.04 c	137.58 c	149.67 c
74 kg P_2O_5/feddan		13.00 bc	11.88 b	142.92 b	152.58 bc
86 kg P_2O_5/feddan		13.50 ab	12.54 ab	145.83 ab	153.67 ab
98 kg P_2O_5/feddan		14.08 a	12.88 a	148.33 a	156.75 a
Nitrogen fertilization X phosphorus fertilization interactions					
83 kg N/feddan	38 kg P_2O_5/feddan	9.67 a	7.33 a	113.00 h	120.00 i
	62 kg P_2O_5/feddan	10.00 a	8.00 a	124.67 g	124.33 hi
	74 kg P_2O_5/feddan	10.67 a	9.33 a	127.33 fg	131.00 f-h
	86 kg P_2O_5/feddan	11.33 a	10.33 a	131.33 fg	129.67 gh
	98 kg P_2O_5/feddan	11.67 a	10.67 a	133.00 f	133.67 fg
100 kg N/feddan	38 kg P_2O_5/feddan	11.00 a	10.33 a	125.00 g	138.67 ef
	62 kg P_2O_5/feddan	11.67 a	10.67 a	130.00 fg	149.67 cd
	74 kg P_2O_5/feddan	12.33 a	11.67 a	140.33 e	145.67 de
	86 kg P_2O_5/feddan	13.33 a	12.00 a	142.00 de	154.33 bc
	98 kg P_2O_5/feddan	13.67 a	12.67 a	146.33 c-e	163.00 a
117 kg N/feddan	38 kg P_2O_5/feddan	13.33 a	11.67 a	140.67 e	160.00 ab
	62 kg P_2O_5/feddan	14.00 a	12.33 a	144.00 de	161.00 ab
	74 kg P_2O_5/feddan	14.33 a	13.33 a	151.33 bc	166.00 a
	86 kg P_2O_5/feddan	14.67 a	14.00 a	155.67 ab	164.67 a
	98 kg P_2O_5/feddan	15.00 a	13.33 a	159.00 a	163.67 a
134 kg N/feddan	38 kg P_2O_5/feddan	13.67 a	12.50 a	148.67 b-d	161.33 ab
	62 kg P_2O_5/feddan	14.33 a	13.17 a	151.67 bc	163.67 a
	74 kg P_2O_5/feddan	14.67 a	13.17 a	152.67 a-c	167.67 a
	86 kg P_2O_5/feddan	14.67 a	13.83 a	154.33 ab	166.00 a
	98 kg P_2O_5/feddan	16.00 a	14.83 a	155.00 ab	166.67 a

Means into every group within a column for the same factor followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan' s multiple range test.

Table 2. Effect of nitrogen and phosphorus fertilization rates on some vegetative growth characters of strawberry cv. Festival plants in 2015 and 2016 seasons

Fertilization rates		Root length (cm)		Plant length (cm)		Number of leaves/plant		Average leaf area (cm^2)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Nitrogen fertilization									
83 kg N/feddan		10.04 c	11.76 a	16.58 c	16.99 c	6.77 c	6.44 d	48.25 c	52.90 c
100 kg N/feddan		10.65 b	12.25 a	17.40 b	17.91 b	7.55 b	7.29 c	51.37 b	55.80 b
117 kg N/feddan		10.74 b	12.09 a	18.28 a	18.69 a	7.81 ab	8.04 b	53.53 a	57.76 a
134 kg N/feddan		11.28 a	12.34 a	18.03ab	18.67 a	8.16 a	8.65 a	54.35 a	58.43 a
Phosphorus fertilization									
38 kg P_2O_5/feddan		9.43 d	10.90 d	16.29 b	17.03 b	7.13 c	7.18 c	50.11 c	54.25 c
62 kg P_2O_5/feddan		9.77 d	11.17 d	17.59 a	17.58 b	7.38 bc	7.33 bc	51.41 b	55.86 b
74 kg P_2O_5/feddan		10.83 c	11.86 c	17.78 a	18.36 a	7.55 bc	7.70a-c	52.03ab	56.52ab
86 kg P_2O_5/feddan		11.40 b	13.02 b	17.95 a	18.44 a	7.80ab	7.80ab	52.61ab	56.91ab
98 kg P_2O_5/feddan		11.95 a	13.62 a	18.25 a	18.91 a	8.00 a	8.02 a	53.23 a	57.58 a
Nitrogen fertilization X phosphorus fertilization interactions									
83 kg N/feddan	**38 kg P_2O_5/feddan**	8.96 a	11.27e-h	15.22 a	15.50 a	6.47 a	5.93 a	46.33 a	50.43 a
	62 kg P_2O_5/feddan	9.28 a	11.00 gh	16.23 a	16.53 a	6.87 a	6.13 a	47.67 a	52.20 a
	74 kg P_2O_5/feddan	10.45 a	12.07d-g	16.13 a	17.27 a	6.53 a	6.67 a	48.20 a	53.43 a
	86 kg P_2O_5/feddan	10.67 a	12.20d-g	17.27 a	17.50 a	6.87 a	6.67 a	49.37 a	53.87 a
	98 kg P_2O_5/feddan	10.83 a	12.27 c-f	18.07 a	18.13 a	7.13 a	6.80 a	49.67 a	54.57 a
100 kg N/feddan	**38 kg P_2O_5/feddan**	9.71 a	11.13 f-h	16.15 a	17.20 a	7.13 a	7.00 a	49.63 a	54.13 a
	62 kg P_2O_5/feddan	10.03 a	12.40c-e	17.87 a	16.70 a	7.27 a	7.07 a	50.77 a	54.90 a
	74 kg P_2O_5/feddan	10.83 a	11.47d-h	17.37 a	18.30 a	7.53 a	7.33 a	51.57 a	56.10 a
	86 kg P_2O_5/feddan	10.88 a	12.60b-d	17.37 a	17.90 a	7.87 a	7.47 a	52.33 a	56.60 a
	98 kg P_2O_5/feddan	11.79 a	13.67 ab	18.23 a	19.43 a	7.93 a	7.60 a	52.56 a	57.29 a
117 kg N/feddan	**38 kg P_2O_5/feddan**	9.33 a	10.40 h	17.48 a	17.60 a	7.27 a	7.47 a	51.53 a	55.47 a
	62 kg P_2O_5/feddan	9.55 a	10.47 h	18.00 a	18.57 a	7.67 a	7.73 a	53.77 a	57.97 a
	74 kg P_2O_5/feddan	10.67 a	12.33 c-f	19.23 a	19.00 a	7.87 a	8.13 a	53.83 a	58.20 a
	86 kg P_2O_5/feddan	11.84 a	13.47 bc	19.03 a	19.13 a	8.07 a	8.40 a	53.87 a	58.27 a
	98 kg P_2O_5/feddan	12.32 a	13.80 ab	17.63 a	19.13 a	8.20 a	8.47 a	54.67 a	58.90 a
134 kg N/feddan	**38 kg P_2O_5/feddan**	9.71 a	10.80 h	16.32 a	17.80 a	7.67 a	8.33 a	52.93 a	56.97 a
	62 kg P_2O_5/feddan	10.24 a	10.80 h	18.27 a	18.53 a	7.73 a	8.40 a	53.43 a	58.37 a
	74 kg P_2O_5/feddan	11.39 a	11.57d-h	18.37 a	18.87 a	8.27 a	8.67 a	54.50 a	58.33 a
	86 kg P_2O_5/feddan	12.21 a	13.80 ab	18.13 a	19.23 a	8.40 a	8.67 a	54.87 a	58.90 a
	98 kg P_2O_5/feddan	12.85 a	14.73 a	19.07 a	18.93 a	8.73 a	9.20 a	56.03 a	59.57 a

Means into every group within a column for the same factor followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan' s multiple range test.

Table 3. Effect of nitrogen and phosphorus fertilization rates on root and vegetative growth weights of strawberry cv. Festival plants in 2015 and 2016 seasons

Fertilization rates		Root fresh weight (g)		Root dry weight (g)		Vegetative growth fresh weight (g)		Vegetative growth dry weight (g)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Nitrogen fertilization									
83 kg N/feddan		0.86 c	0.82 c	0.282 b	0.237 c	9.47 d	9.08 c	3.52 c	3.39 d
100 kg N/feddan		0.99 b	1.13 b	0.324ab	0.308 b	12.98 c	12.36 b	4.07 b	3.91 c
117 kg N/feddan		1.15 a	1.41 a	0.337 a	0.400 a	14.88 b	14.76 a	4.26 b	4.15 b
134 kg N/feddan		1.19 a	1.47 a	0.363 a	0.399 a	16.23 a	15.10 a	4.69 a	4.50 a
Phosphorus fertilization									
38 kg P_2O_5/feddan		0.88 c	1.02 d	0.279 c	0.270 d	12.38 c	11.99 c	3.88 d	3.64 d
62 kg P_2O_5/feddan		0.93 c	1.10 c	0.285 c	0.295 cd	12.71 c	12.22 c	3.96 cd	3.87 c
74 kg P_2O_5/feddan		1.07 b	1.16 c	0.328bc	0.317 c	13.39 b	13.00 b	4.15 bc	3.99 bc
86 kg P_2O_5/feddan		1.13 ab	1.27 b	0.351ab	0.365b	13.80 b	13.36ab	4.24 ab	4.13 ab
98 kg P_2O_5/feddan		1.21 a	1.47 a	0.389 a	0.434 a	14.67 a	13.57 a	4.43 a	4.30 a
Nitrogen fertilization X phosphorus fertilization interactions									
83 kg N/feddan	38 kg P_2O_5/feddan	0.83 a	0.78 h	0.270 a	0.197 h	8.13 a	8.19 a	3.23 a	3.04 a
	62 kg P_2O_5/feddan	0.76 a	0.81 h	0.229 a	0.226 gh	9.02 a	8.07 a	3.35 a	3.21 a
	74 kg P_2O_5/feddan	0.88 a	0.75 h	0.297 a	0.224 gh	9.53 a	9.40 a	3.47 a	3.36 a
	86 kg P_2O_5/feddan	0.86 a	0.83 h	0.284 a	0.267 fg	10.04 a	9.78 a	3.75 a	3.64 a
	98 kg P_2O_5/feddan	0.95 a	0.91 gh	0.328 a	0.273 fg	10.63 a	9.96 a	3.79 a	3.68 a
100 kg N/feddan	38 kg P_2O_5/feddan	0.84 a	1.05 fg	0.277 a	0.272 fg	12.15 a	11.38 a	3.73 a	3.51 a
	62 kg P_2O_5/feddan	0.91 a	1.16 d-f	0.313 a	0.302 ef	12.30 a	12.30 a	4.00 a	3.94 a
	74 kg P_2O_5/feddan	1.03 a	1.09 ef	0.319 a	0.285 fg	12.72 a	12.28 a	4.24 a	3.98 a
	86 kg P_2O_5/feddan	1.05 a	1.11 ef	0.344 a	0.326 d-f	13.26 a	13.04 a	4.21 a	4.07 a
	98 kg P_2O_5/feddan	1.11 a	1.23 de	0.368 a	0.356c-e	14.48 a	12.81 a	4.17 a	4.04 a
117 kg N/feddan	38 kg P_2O_5/feddan	0.99 a	1.03 fg	0.285 a	0.293 ef	13.96 a	13.72 a	4.12 a	3.69 a
	62 kg P_2O_5/feddan	1.02 a	1.17 d-f	0.293 a	0.322 d-f	14.17 a	14.08 a	4.11 a	4.08 a
	74 kg P_2O_5/feddan	1.14 a	1.33 cd	0.340 a	0.395 bc	15.15 a	15.21 a	4.04 a	4.04 a
	86 kg P_2O_5/feddan	1.23 a	1.56 b	0.352 a	0.438 b	15.22 a	15.20 a	4.31 a	4.27 a
	98 kg P_2O_5/feddan	1.35 a	1.93 a	0.412 a	0.553 a	15.90 a	15.60 a	4.72 a	4.65 a
134 kg N/feddan	38 kg P_2O_5/feddan	0.85 a	1.23 de	0.281 a	0.318 d-f	15.30 a	14.66 a	4.43 a	4.31 a
	62 kg P_2O_5/feddan	1.03 a	1.25 de	0.304 a	0.330 d-f	15.36 a	14.44 a	4.38 a	4.23 a
	74 kg P_2O_5/feddan	1.24 a	1.46 bc	0.356 a	0.365 cd	16.14 a	15.11 a	4.86 a	4.59 a
	86 kg P_2O_5/feddan	1.37 a	1.59 b	0.426 a	0.428 b	16.68 a	15.41 a	4.70 a	4.54 a
	98 kg P_2O_5/feddan	1.44 a	1.82 a	0.447 a	0.553 a	17.68 a	15.89 a	5.06 a	4.82 a

Means into every group within a column for the same factor followed by the same letter are not significantly different ($P \le 0.05$) according to Duncan' s multiple range test.

These results coincide with the previous studies which reported that the number of leaves/plant **(Janisch et al 2012)**, and plant dry mass **(Kirschbaum et al 2010)** of strawberry were linearly increased with increasing the nitrogen rates. Similarly, increasing the nitrogen fertilization rate led to increases in leaf area of tomato **(Melton & Dufault, 1991 and Basoccu & Nicola, 1995)**, bell pepper **(Dufault and Schultheis, 1994)**, and broccoli **(Zhang et al 2017)** transplants. Moreover, increases in the weight of the shoots and roots were recorded in pepper (**Aloni et al 1991)**, tomato **(Melton and Dufault, 1991, Liptay et al 1992)** and lettuce **(Karchi et al 1992)** transplants fertilized with high rates of nitrogen. These increments in plant growth parameters of strawberry transplants may be due to the roles of nitrogen in the chlorophyll formation **(Uchida, 2000, Leghari et al 2016)**, biosynthesis of auxins **(Zhao, 2012, Wang et al 2015)**, the uptake and utilization of other nutrients including potassium and phosphorous **(Bloom, 2015)**, and leaf net assimilation rate **(Leghari et al 2016)**, which all together encourage overall plant growth and development.

As for the effect of phosphorus fertilization on strawberry transplants in the nursery, the results in **Tables (2 and 3)** revealed that phosphorus fertilization at high rates (74, 86 or 98 kg P_2O_5/feddan) gradually gave the highest values of growth parameters of strawberry transplants in both seasons. On the contrary, strawberry plants fertilized with 38 kg P_2O_5/feddan exhibited the lowest values. These results are in a good accordance with those obtained by **Li et al (2009)** who found that high phosphorus rates augmented plant height, number of leaves and leaf area of strawberry. The stimulatory effects of high phosphorus rates on the vegetative growth parameters could be attributed to the role of phosphorus in plants since phosphorus promotes root growth and development and consequently improves the uptake of nutrients including phosphorus which encourages the root elongation and all vegetative growth parameters of plants **(Hill et al 2006)**. Moreover, the increased supply of phosphorus might have stimulated the rate of various physiological processes in the plant and led to increased growth parameters which resulted in increased number of runners and number of transplants. In this connection, data in **Tables (2 and 3)** are well correlated with data in **Table (1)**.

Except for the root parameters (length, and fresh and dry weights of roots) in the second season, the combination between nitrogen and phosphorus fertilizations had no significant effects on all growth parameters of strawberry transplants. However, high rates of nitrogen (117 or 134 kg N/feddan) with the highest rate of phosphorus (98 kg P_2O_5/feddan) generally gave the highest values of growth parameters. The obtained results coincide with those obtained by **Nam et al (2006)** who found that **t**he dry weight of the strawberry plants cv. Nyoho cultivated under a hydroponics system increased with elevated concentrations of nitrogen and phosphorus in the fertilizer solutions. Similarly, high nitrogen rates with high rates of phosphorus increased the weights of shoots and roots and improved the transplant quality in pepper **(Aloni et al 1991)**, tomato **(Melton and Dufault, 1991)**, and lettuce **(Karchi et al 1992).** The increments in the vegetative growth characters in **Tables (2 and 3)** may be attributed to the synergistic functions of both elements upon the physiological and biochemical processes which improve overall the growth and development of the plants. In this connection, nitrogen is an essential element of all the amino acids in plant structures which are the building blocks of plant proteins **(Epstein and Bloom, 2004)**. Furthermore, it is important in the chlorophyll formation which is necessary for the photosynthesis process in the plant **(Uchida, 2000, Leghari et al 2016)**. In addition, phosphorus plays major roles in photosynthesis and respiration processes, since phosphorus plays a major role in energy storage and transfer **(Marschner, 2012)**. Also, phosphorus acts as a structural element of nucleic acids (DNA and RNA molecules) **(Uchida, 2000, Marschner, 2012)**.

SPAD readings and total soluble phenols

The applications of 117 and 134 kg N/feddan gave the highest significant SPAD readings, while the 83 kg N/feddan application gave the lowest significant ones in both growing seasons **(Table 4)**. These results concur with those reported by **García-Méndez et al (2009)** who found that increasing nitrogen rates enhanced strawberry leaf chlorophyll content. The enhancement of SPAD readings may be attributed to the fact that nitrogen is a part of the enzymes associated with chlorophyll synthesis **(Chapman and Barreto, 1997)**. On the contrary, the nitrogen fertilization showed an inverse effect on total soluble phenols. The obtained results revealed that total soluble phenols were decreased as the nitrogen fertilization increased. Similar reductions in total phenolic compounds of many plants were decreased by nitrogen fertilization **(Grevesen et al 2008, Mandal et al 2008,**

Nguyen and Niemeyer, 2008, Sousa et al 2008, De Long et al 2016). These decreases in total phenolic compounds could be explained by the growth-differentiation balance (GDB) **(Herms and Mattson, 1992)** and carbon-nutrient balance (CNB) **(Koricheva, 2002)** hypotheses which suppose that when nitrogen limits plant growth, carbohydrates will accumulate in plant tissues. This increased concentration of carbohydrates will lead to an increased synthesis of carbon-based secondary metabolites such as phenolics **(Massad et al 2012)**. Moreover, **Jones and Hartley (1999)** presented a protein competition model (PCM) for predicting total phenolic allocation and concentration in leaves of terrestrial higher plants in which is supposed that the accumulation of phenolics compounds is controlled by the competition between proteins and phenolics biosynthesis pathway, and thus protein and phenolic allocation are inversely correlated **(Heil and Baldwin, 2002)**.

As for the phosphorus fertilization, the applications of 86 or 98 kg P_2O_5/feddan gave the highest significant SPAD readings in the first season, while the phosphorus fertilization did not significantly affect SPAD readings in the second season. On the contrary, as the phosphorus rates increased, total soluble phenols in strawberry leaves decreased. However, the differences were not significant in both seasons. These findings agree with the previous studies which demonstrated that phosphorus application reduced the polyphenols including the total phenolic compounds **(De Long et al 2016)**.

In addition, the interactive effect of nitrogen and phosphorus fertilization had no significant effects neither on SPAD readings nor on total soluble phenols in strawberry leaves in both seasons.

Leaf relative water content and membrane stability index

Data in **Table (5)** reveal that increasing the nitrogen fertilization rates from 83 to 134 kg N/feddan increased leaf relative water content values in both seasons. However, the differences were not significant. On the contrary, increasing the nitrogen rates gradually decreased leaf membrane stability index in both seasons. In this connection, previous studies showed conflicting results on the impact of nitrogen rates on both leaf relative water content and leaf membrane stability. **Lu et al (2004)** found that high rates of nitrogen fertilizer increased the relative water content, while **Namvar and Khandan (2015)** reported that both relative water content and cell membrane stability were decreased with the high rates of nitrogen application.

Concerning the phosphorus effect, data in **Table (5)** show that increasing the phosphorus rates from 38 to 98 kg P_2O_5/feddan resulted in increases in relative water content and membrane stability of strawberry leaves in both seasons. However, the differences were not significant for both parameters in both growing seasons. The obtained results are consistent with the earlier studies which reported that the phosphorus fertilization levels did not affect significantly the leaf relative water content and the membrane stability index in cotton **(Singh et al 2006)**, and maize **(Naghashzadeh, 2014**).

Furthermore, the interaction between nitrogen and phosphorus fertilizations did not affect both tested parameters, indicating that both factors acted independently for the two characters.

Crown diameter and crown carbohydrate content

Results in **Table (6)** revealed that crown diameter accompanied with accumulation of carbohydrates in strawberry transplants were increased with increasing the nitrogen rates. The applications of 117 or 134 kg N/feddan gave the highest significant values of crown diameter and crown carbohydrate content, while the 83 kg N/feddan application gave the lowest significant values for both parameters in both seasons. It is well known that starch (non-soluble-nonstructural carbohydrate), glucose, fructose and sucrose (soluble nonstructural carbohydrates) are the predominant carbohydrates in the crowns of strawberry plants **(Macías-Rodríguez et al 2002)** which are affected by the nitrogen supply. In this connection, previous studies showed conflicting results on the impact of nitrogen rates on the accumulation of carbohydrates in strawberry crowns. **Carrillo-Mendoza et al (2005)** found that the N foliar application to strawberry plants in nurseries increased the content of total reducing sugars in the crowns, while the accumulation of starch reserves and the photosynthetic rate did not affected by the treatment. However, **Verpont (2003)** showed that the nitrogen fertilization didn’t affect the total nonstructural carbohydrates. On the contrary, high rates of nitrogen decreased the total nonstructural carbohydrates in crowns **(Acuña-Maldonado and Pritts, 2008, Kirschbaum et al 2010, Kirschbaum et al 2015)**.

Table 4. Effect of nitrogen and phosphorus fertilization rates on SPAD readings and total soluble phenols of strawberry cv. Festival leaves in 2015 and 2016 seasons

Fertilization rates		SPAD readings		Total soluble phenols (µmol eq. gallic acid /g dry weight)	
		1st season	2nd season	1st season	2nd season
Nitrogen fertilization					
83 kg N/feddan		34.58 c	35.34 b	94.00 a	93.57 a
100 kg N/feddan		35.80 b	35.84 b	86.24 b	86.61 b
117 kg N/feddan		37.69 a	36.99 a	83.31 b	81.75 b
134 kg N/feddan		38.33 a	37.75 a	78.95 c	73.65 c
Phosphorus fertilization					
38 kg P_2O_5/feddan		35.20 c	35.82 a	88.74 a	86.78 a
62 kg P_2O_5/feddan		36.05 bc	35.87 a	86.42 a	86.20 a
74 kg P_2O_5/feddan		36.60 bc	36.90 a	85.15 a	83.23 a
86 kg P_2O_5/feddan		37.13 ab	36.58 a	84.92 a	83.10 a
98 kg P_2O_5/feddan		38.02 a	37.23 a	82.90 a	80.18 a
Nitrogen fertilization X phosphorus fertilization interactions					
83 kg N/feddan	38 kg P_2O_5/feddan	32.93 a	34.35 a	97.32 a	96.37 a
	62 kg P_2O_5/feddan	33.90 a	34.05 a	95.66 a	98.50 a
	74 kg P_2O_5/feddan	35.20 a	36.65 a	91.87 a	93.12 a
	86 kg P_2O_5/feddan	35.03 a	35.52 a	92.33 a	91.75 a
	98 kg P_2O_5/feddan	35.83 a	36.15 a	92.83 a	88.12 a
100 kg N/feddan	38 kg P_2O_5/feddan	34.30 a	36.33 a	87.74 a	88.50 a
	62 kg P_2O_5/feddan	35.37 a	35.93 a	88.33 a	90.41 a
	74 kg P_2O_5/feddan	35.67 a	36.33 a	84.58 a	86.50 a
	86 kg P_2O_5/feddan	36.60 a	35.30 a	88.20 a	87.95 a
	98 kg P_2O_5/feddan	37.07 a	35.30 a	82.37 a	79.70 a
117 kg N/feddan	38 kg P_2O_5/feddan	36.73 a	36.57 a	86.49 a	84.45 a
	62 kg P_2O_5/feddan	36.83 a	36.00 a	83.16 a	88.91 a
	74 kg P_2O_5/feddan	37.20 a	36.53 a	87.75 a	76.25 a
	86 kg P_2O_5/feddan	38.07 a	37.27 a	81.66 a	84.50 a
	98 kg P_2O_5/feddan	39.60 a	38.57 a	77.50 a	74.66 a
134 kg N/feddan	38 kg P_2O_5/feddan	36.83 a	36.03 a	83.40 a	77.79 a
	62 kg P_2O_5/feddan	38.10 a	37.50 a	78.54 a	67.00 a
	74 kg P_2O_5/feddan	38.33 a	38.10 a	76.41 a	77.04 a
	86 kg P_2O_5/feddan	38.80 a	38.23 a	77.50 a	68.20 a
	98 kg P_2O_5/feddan	39.57 a	38.90 a	78.91 a	78.25 a

Means into every group within a column for the same factor followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan' s multiple range test.

Table 5. Effect of nitrogen and phosphorus fertilization rates on relative water content and membrane stability index of strawberry cv. Festival leaves in 2015 and 2016 seasons

Fertilization rates		Leaf relative water content (%)		Membrane stability index (%)	
		1st season	2nd season	1st season	2nd season
Nitrogen fertilization					
83 kg N/feddan		63.83 a	64.69 a	74.34 a	74.22 a
100 kg N/feddan		65.24 a	67.75 a	70.12 b	70.95 b
117 kg N/feddan		65.93 a	68.03 a	66.83 b	68.32 b
134 kg N/feddan		68.24 a	69.81 a	63.15 c	65.11 c
Phosphorus fertilization					
38 kg P_2O_5/feddan		62.82 a	65.61 a	65.19 a	68.59 a
62 kg P_2O_5/feddan		64.05 a	65.91 a	67.97 a	69.02 a
74 kg P_2O_5/feddan		65.59 a	66.70 a	69.32 a	69.08 a
86 kg P_2O_5/feddan		67.40 a	68.31 a	69.38 a	69.87 a
98 kg P_2O_5/feddan		69.20 a	71.32 a	71.19 a	71.69 a
Nitrogen fertilization X phosphorus fertilization interactions					
83 kg N/feddan	38 kg P_2O_5/feddan	64.20 a	60.11 a	71.52 a	73.52 a
	62 kg P_2O_5/feddan	62.68 a	62.21 a	76.34 a	74.22 a
	74 kg P_2O_5/feddan	62.31 a	65.99 a	75.49 a	74.25 a
	86 kg P_2O_5/feddan	64.67 a	67.21 a	75.00 a	74.28 a
	98 kg P_2O_5/feddan	65.30 a	67.94 a	73.33 a	74.84 a
100 kg N/feddan	38 kg P_2O_5/feddan	60.39 a	68.06 a	68.95 a	72.19 a
	62 kg P_2O_5/feddan	63.45 a	67.84 a	68.85 a	71.26 a
	74 kg P_2O_5/feddan	65.98 a	67.03 a	71.05 a	70.35 a
	86 kg P_2O_5/feddan	67.74 a	67.86 a	70.40 a	70.48 a
	98 kg P_2O_5/feddan	68.65 a	67.96 a	71.33 a	70.48 a
117 kg N/feddan	38 kg P_2O_5/feddan	64.43 a	66.42 a	59.58 a	64.47 a
	62 kg P_2O_5/feddan	63.60 a	65.16 a	65.26 a	66.91 a
	74 kg P_2O_5/feddan	65.04 a	65.02 a	69.58 a	68.98 a
	86 kg P_2O_5/feddan	66.80 a	69.27 a	69.94 a	69.77 a
	98 kg P_2O_5/feddan	69.76 a	74.30 a	69.79 a	71.47 a
134 kg N/feddan	38 kg P_2O_5/feddan	62.24 a	67.85 a	60.72 a	64.19 a
	62 kg P_2O_5/feddan	66.46 a	68.44 a	61.41 a	63.69 a
	74 kg P_2O_5/feddan	69.04 a	68.75 a	61.15 a	62.72 a
	86 kg P_2O_5/feddan	70.40 a	68.91 a	62.17 a	64.96 a
	98 kg P_2O_5/feddan	73.08 a	75.09 a	70.31 a	69.98 a

Means into every group within a column for the same factor followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan' s multiple range test.

Table 6. Effect of nitrogen and phosphorus fertilization rates on crown diameter and crown carbohydrates of strawberry cv. Festival in 2015 and 2016 seasons

Fertilization rates		Crown diameter (cm)		Crown carbohydrates (mg/ g dry weight)	
		1st season	2nd season	1st season	2nd season
Nitrogen fertilization					
83 kg N/feddan		0.92 c	0.96 c	174.18 c	176.13 c
100 kg N/feddan		0.99 b	1.04 b	194.89 b	185.78 b
117 kg N/feddan		1.01 ab	1.11 a	206.62 a	192.53 a
134 kg N/feddan		1.04 a	1.10 a	210.21 a	194.76 a
Phosphorus fertilization					
38 kg P_2O_5/feddan		0.90 c	0.95 d	191.12 c	181.22 c
62 kg P_2O_5/feddan		0.94 c	1.02 c	195.78 b	185.95 b
74 kg P_2O_5/feddan		0.94 c	1.04 c	196.28 ab	188.22 ab
86 kg P_2O_5/feddan		1.01 b	1.10 b	198.83 ab	189.61 a
98 kg P_2O_5/feddan		1.16 a	1.16 a	200.38 a	191.50 a
Nitrogen fertilization X phosphorus fertilization interactions					
83 kg N/feddan	38 kg P_2O_5/feddan	0.85 a	0.89 h	165.81 a	168.11 a
	62 kg P_2O_5/feddan	0.89 a	0.95 gh	167.89 a	173.00 a
	74 kg P_2O_5/feddan	0.90 a	0.98 fg	175.21 a	178.11 a
	86 kg P_2O_5/feddan	0.92 a	0.99 e-g	180.44 a	179.56 a
	98 kg P_2O_5/feddan	1.05 a	1.00 e-g	181.56 a	181.89 a
100 kg N/feddan	38 kg P_2O_5/feddan	0.91 a	0.96 gh	187.22 a	182.00 a
	62 kg P_2O_5/feddan	0.93 a	1.03 d-g	199.78 a	183.03 a
	74 kg P_2O_5/feddan	0.92 a	0.99 e-g	193.67 a	186.33 a
	86 kg P_2O_5/feddan	0.99 a	1.08 b-e	195.56 a	188.33 a
	98 kg P_2O_5/feddan	1.18 a	1.13 bc	198.22 a	189.22 a
117 kg N/feddan	38 kg P_2O_5/feddan	0.90 a	0.99 e-g	204.89 a	184.89 a
	62 kg P_2O_5/feddan	0.94 a	1.07 c-f	206.89 a	193.22 a
	74 kg P_2O_5/feddan	0.98 a	1.08 b-e	206.78 a	194.00 a
	86 kg P_2O_5/feddan	1.02 a	1.17 b	206.44 a	194.22 a
	98 kg P_2O_5/feddan	1.19 a	1.26 a	208.11 a	196.33 a
134 kg N/feddan	38 kg P_2O_5/feddan	0.93 a	0.95 gh	206.56 a	189.89 a
	62 kg P_2O_5/feddan	0.99 a	1.04 d-g	208.56 a	194.56 a
	74 kg P_2O_5/feddan	0.97 a	1.10 b-d	209.44 a	194.44 a
	86 kg P_2O_5/feddan	1.11 a	1.17 b	212.89 a	196.33 a
	98 kg P_2O_5/feddan	1.21 a	1.26 a	213.61 a	198.56 a

Means into every group within a column for the same factor followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan' s multiple range test.

These conflicting results may be attributed to the fact that the accumulation of carbohydrates is highly specific for individual carbohydrates and different plant tissues, and further depend on other environmental factors **(Druege et al 2004)**.

As for the effect of phosphorus fertilization, the highest rate of phosphorus (98 kg P_2O_5/feddan) gave the highest values of crown diameters in both growing seasons, while the high rates of phosphorus applications (74, 86 or 98 kg P_2O_5/feddan) gave the highest values of crown carbohydrates without significant differences among them. On the other hand, the lowest rate of phosphorus application (38 kg P_2O_5/feddan) gave the lowest values of both characteristics in both seasons. These findings are in agreements with those obtained by **Hermans et al (2006)** who stated that under phosphorus deficiency, starch and soluble carbohydrates are expected to accumulate in the source organ (leaves) and diminish in the sink organs (in our case, crowns).

Although the interactive effects of nitrogen and phosphorus fertilizations were not significant on crown diameter in the first season and crown carbohydrates in both seasons, the applications of 117 or 134 kg N/ feddan with 98 kg P_2O_5/ feddan gave the highest values in both seasons. The increments in strawberry crowns resulted from fertilization with nitrogen and phosphorus are well related with the increments in the growth parameters **Tables (2 and 3)**, since carbohydrate is important in energy production which is necessary for cell activities.

Leaf mineral analysis

Data in **Table (7)** show that the 117 and 134 kg N/feddan applications gave the highest percentages of nitrogen, phosphorus, potassium and magnesium in leaves, and the lowest calcium percentage in both seasons. However, the 83 kg N/feddan gave the highest calcium percentage in leaves; but it gave the lowest percentages of nitrogen, phosphorus, potassium and magnesium in both seasons. These results agree with those reported by **Verpont (2003), García-Méndez et al (2009), Kirschbaum et al (2010),** and **Kirschbaum et al (2015)** that the increase of nitrogen rates increased nitrogen concentration in leaves, roots and crowns. Potassium, calcium and magnesium compete with each other in the uptake by the plants **(Evangelou et al 1994).** Nitrogen fertilization had inconsistent effect on potassium and calcium concentrations in the plant, but generally increases magnesium concentration in the plant **(Barker and Pilbeam, 2015).** When supplies of cations are plentiful and nitrogen is taken up mainly as nitrate, the plant mineral concentrations may increase owing to the synergistic effect between nitrate and other cation uptake **(Whitehead, 2000).** The decrement in calcium percentage may be attributed to the increment in potassium owing to the antagonistic effect between each other concentration in the leaves of the plants.

Concerning the phosphorus fertilization rates, the 86 and 98 kg P_2O_5/feddan application gave the highest percentages of nitrogen, phosphorus, potassium, calcium and magnesium in both seasons, while the 38 and 62 kg P_2O_5/feddan application gave the lowest percentages of nitrogen, phosphorus, potassium, calcium and magnesium in both seasons. These results are consistent with **Li (2009)** on Festival strawberry cultivar that the plant phosphorus accumulation could increase with linear and quadratical effects of plant nitrogen accumulation. The deficiency of phosphorus leads to a lack of energy supply, which can result in limitation in the active uptake of nutrients such as potassium **(Barker and Pilbeam, 2015).** If phosphorus was applied in conjunction with ammonium, a beneficial interaction occurs. This interaction enhances the plant uptake of both minerals owing to the increase in phosphorus solubility, shoot and root growth **(Sumner and Farina, 1986, Bundy et al 2005).** Also, positive interactions between P and Mg are expected since Mg is an activator of kinase enzymes and activates most reactions involving phosphate transfer **(Hawkesford et al 2012).** In addition, phosphorus has antagonistic interaction with calcium in soil due to chemical bonding with phosphorus, for which precipitates are not very soluble, especially in alkaline soils. These precipitates can also occur within roots and other plant tissues, but the acidic biological environment allows for solubilization more readily than with soil **(Barker and Pilbeam, 2015).**

In addition, the interactive effect of nitrogen and phosphorus fertilization rates on percentages of phosphorus, potassium, calcium and magnesium in leaves were non-significant in both seasons, however it was significant on nitrogen percentage. The treatments which gave the highest nitrogen percentage in leaves were 100 kg N/feddan with 86 kg P_2O_5/feddan, 117 kg N/feddan with 74 and 86 kg P_2O_5/feddan, and 134 kg N/feddan with 38, 62 and 86 kg P_2O_5/feddan.

Table 7. Effect of nitrogen and phosphorus fertilization rates on macronutrient concentrations of strawberry cv. Festival leaves in 2015 and 2016 seasons

Fertilization rates		N (%)		P (%)		K (%)		Ca (%)		Mg (%)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Nitrogen fertilization											
83 kg N/feddan		1.78c	1.89 c	0.305 c	0.315 b	1.63 c	1.48 b	2.16 a	2.23 a	0.442 c	0.525 c
100 kg N/feddan		1.95b	1.99 b	0.331b	0.315 b	1.66 b	1.50 b	2.14 a	2.16 a	0.519 b	0.535 bc
117 kg N/feddan		2.00a	2.02 ab	0.351 ab	0.333 ab	1.71 a	1.60 a	2.08 a	2.12 a	0.554 a	0.552 ab
134 kg N/feddan		2.05a	2.08 a	0.368 a	0.350 a	1.74 a	1.62 a	2.03 a	2.10 a	0.579 a	0.558 a
Phosphorus fertilization											
38 kg P_2O_5/feddan		1.85c	1.94 b	0.311 d	0.302 b	1.58 c	1.40 d	1.97 c	2.03 c	0.497 c	0.523 c
62 kg P_2O_5/feddan		1.93b	1.97 b	0.321 cd	0.322 ab	1.66 b	1.51 c	2.01 bc	2.10 bc	0.501 bc	0.526 bc
74 kg P_2O_5/feddan		1.96ab	1.99 ab	0.339 bc	0.331 ab	1.70 b	1.56 b	2.06 bc	2.12 bc	0.514 bc	0.544 bc
86 kg P_2O_5/feddan		1.98ab	2.06 a	0.354 ab	0.342 a	1.74 a	1.61 a	2.17 ab	2.22 ab	0.540ab	0.549 ab
98 kg P_2O_5/feddan		2.00a	2.01 ab	0.369 a	0.346 a	1.73 a	1.64 a	2.29 a	2.29 a	0.566 a	0.569 a
Nitrogen fertilization X phosphorus fertilization interactions											
83 kg N/feddan	**38 kg P_2O_5/feddan**	1.62g	1.75h	0.273a	0.285a	1.54a	1.36a	2.02a	2.09a	0.423a	0.510a
	62 kg P_2O_5/feddan	1.86c-f	1.99d-g	0.279a	0.309a	1.56a	1.42a	2.09a	2.20a	0.438a	0.514a
	74 kg P_2O_5/feddan	1.74fg	1.85gh	0.299a	0.313a	1.62a	1.48a	2.13a	2.24a	0.444a	0.529a
	86 kg P_2O_5/feddan	1.82ef	1.75h	0.328a	0.333a	1.70a	1.54a	2.21a	2.29a	0.449a	0.534a
	98 kg P_2O_5/feddan	1.86c-f	2.09a-e	0.345a	0.337a	1.72a	1.60a	2.33a	2.31a	0.455a	0.538a
100 kg N/feddan	**38 kg P_2O_5/feddan**	1.84d-f	1.87gh	0.325a	0.296a	1.58a	1.34a	2.01a	2.04a	0.494a	0.504a
	62 kg P_2O_5/feddan	1.89b-e	1.98d-g	0.321a	0.311a	1.64a	1.46a	2.02a	2.04a	0.478a	0.518a
	74 kg P_2O_5/feddan	2.06a	2.02b-g	0.331a	0.314a	1.68a	1.50a	2.13a	2.09a	0.483a	0.525a
	86 kg P_2O_5/feddan	1.94a-e	2.11a-e	0.338a	0.322a	1.72a	1.58a	2.24a	2.22a	0.539a	0.562a
	98 kg P_2O_5/feddan	2.01ab	1.95e-g	0.339a	0.333a	1.70a	1.60a	2.27a	2.40a	0.600a	0.564a
117 kg N/feddan	**38 kg P_2O_5/feddan**	1.91b-e	1.96e-g	0.313a	0.316a	1.60a	1.42a	1.91a	1.93a	0.524a	0.534a
	62 kg P_2O_5/feddan	1.97a-d	1.84gh	0.326a	0.323a	1.72a	1.58a	1.93a	2.07a	0.526a	0.538a
	74 kg P_2O_5/feddan	1.99a-c	2.17a-c	0.358a	0.336a	1.74a	1.66a	1.98a	2.07a	0.553a	0.546a
	86 kg P_2O_5/feddan	2.08a	2.15a-d	0.365a	0.349a	1.74a	1.66a	2.16a	2.24a	0.581a	0.536a
	98 kg P_2O_5/feddan	2.06a	1.97d-g	0.394a	0.344a	1.74a	1.66a	2.40a	2.29a	0.587a	0.603a
134 kg N/feddan	**38 kg P_2O_5/feddan**	2.05a	2.19ab	0.331a	0.311a	1.60a	1.48a	1.93a	2.07a	0.546a	0.544a
	62 kg P_2O_5/feddan	2.00a-c	2.06a-f	0.356a	0.345a	1.74a	1.60a	1.98a	2.08a	0.562a	0.534a
	74 kg P_2O_5/feddan	2.07a	1.91f-h	0.368a	0.360a	1.76a	1.62a	2.00a	2.10a	0.573a	0.577a
	86 kg P_2O_5/feddan	2.07a	2.22a	0.386a	0.364a	1.80a	1.68a	2.09a	2.11a	0.593a	0.565a
	98 kg P_2O_5/feddan	2.06a	2.02c-g	0.397a	0.371a	1.78a	1.70a	2.16a	2.14a	0.623a	0.570a

Means into every group within a column for the same factor followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan' s multiple range test.

Increasing the fertilization rates of nitrogen and phosphorus increased the mineral contents in leaves of strawberry plants. This may be attributed to the transplant vigor and the increase of the vegetative growth, i.e. root length, plant length, number of leaves/plant, average leaf area, fresh and dry weights of roots and vegetative growth, as mentioned in **Tables (2 and 3),** also the increase in the crown diameter and crown total carbohydrates and SPAD reading as mentioned in **Tables (4 and 6)**.

CONCLUSION

Nitrogen and phosphorus are the main nutrients that affect the number and quality of strawberry transplants in the nurseries. It is the first scientific research addressing the optimal requirements of both elements for strawberry nurseries in Egypt. The current study demonstrated that increasing the rates of nitrogen and phosphorus fertilizations increased the number of main runners/mother plant, number of marketable transplants/m^2, and all quality parameters of the produced transplants, recommending to the nurserymen of Festival strawberry cultivar to apply 117 or 134 kg N with 98 kg P_2O_5 per feddan in pure sandy soil which gave the highest number of transplants with high quality and subsequent high quality crop in the field.

Conflict of interest

The authors declare that they have no conflict of interest.

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951
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