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Response of artichoke productivity to different proportions of Nitrogen and Potassium fertilizers

[1]Saleh S.A., [2]M.F. Zaki [2]A.S. Tantawy and [3]Y.A.M. Salama

[1]Horticultural Crops Technology Dept., National Research Centre, Dokki, Cairo, Egypt.
[2]Vegetable Research Dept., National Research Centre, Dokki, Cairo, Egypt.
[3]Plant Adaptation Unit, Genetic Resources Dept., Desert Research Centre, Egypt.

Abstract: The application mode of fertilizers affects plant growth of artichoke and its head production. The aim of our work was to follow the response of artichoke productivity to different proportions and application time of nitrogen and potassium fertilizers to identify the optimum doses of N and K for optimum yield and product characters. During the growing seasons of 2012/2013 and 2013/2014, the local vegetatively propagated cultivar 'Balady' in Egypt was fertilized by several proportions of N and K. Five combinations between two doses of nitrogen (100 and 150 kg) N/feddan (4200 m^2) and two doses of potassium (50 and 100 kg) K/feddan were applied in five equal constant doses (control) or dynamic doses (variable doses with plant growth cycle). Vegetative growth characters, head yield and its quality were recorded.
Results showed that the dynamic application doses of nitrogen (start by high nitrogen dose at the beginning then decreasing application doses during plant growth cycle) and potassium (start by less potassium dose at the beginning then increasing application doses during plant growth cycle) increased vegetative growth characters of artichoke plants and improved quantity and quality of artichoke heads compared to constant applications. The dynamic mode combination between doses of 150 kg N/feddan and 100 kg K/feddan led to increase all vegetative growth characters of artichokes (the height of plant, leaf numbers, leaf fresh & leaf dry weights and leaf area as well as chlorophyll content and increased head yield, and even more enhanced earliness and head quality. The lowest values of vegetative plant growth and head yield were obtained by either constant application doses of the same amounts, i.e., 150 kg N and 100 kg K/feddan (as a control) or dynamic mode combination between doses of 100 kg N/feddan and 50 kg K/feddan (as lower doses of dynamic mode application).
Keywords: Artichokes, Fertilization, N, K, Constant & Dynamic Applications, Yield, Quality.

Introduction

The appropriate supply of nutrient fertilizers is very necessary to obtain optimum growth and head yield of artichokes and to improve quality of the edible product. Among the major nutrients, nitrogen is required in the largest amount by plants and has an essential role for plant productivity because it is main part of essential active compounds, i.e., chlorophylls, proteins, nucleic acids and enzymes. N has important role in many active processes such as cell division and photosynthesis and accumulation of organic matter in plant tissues [1]. Next to N, potassium is required in the largest nutrient amount by all cultivated plants. The role of K is maintenance of electrochemical equilibrium in plant cells and cell compartments and enzyme activities regulation [2]. K has

important role for translocation and storage of assimilates and maintenance of tissue water relation [1]. K is the key for quantity and quality of the product due to its role in stimulating root growth and improving the size of fruits. The formations of carbohydrates and sugars translocation in plant depend on potassium [3].

The application mode of N & K (doses, proportions and time) is very important for the adequate nutrients uptake and optimum plant growth resulting maximum yield with good quality. Whereas, nitrogen results in the highest vegetative growth characters and increases head yield. Potassium enhances the earliness and improves product quality and head characters [4]. The excess nutrient fertilizers are not recommended due to economic and environmental issues. Also, the little application of nutrient fertilizers will not be enough to satisfy plant requirements in the long run during plant growth cycle. Thus, all nutrients should be applied in correct doses, proportions and time for the entire cultivation cycle of globe artichoke according to soil fertility. Whereas, many previous studies reported strong correlations between the amount of N and K and their effects on artichoke productivity [4,5,6,7,8].

Nitrogen is side-dressed at 100 kg N/feddan (4200 m^2) in three to five equal constant doses during artichoke growing season based on the recommendations of Egyptian Ministry of Agriculture. The recommended dose for potassium is 60 kg K/feddan, applied during plants enter the generative period. In France, the application doses of 120 to 140 kg N and 400 to 500 kg K/hectare (10000 m^2) are recommended for artichokes in autumn season, in addition to one or two further split N applications during spring season [9]. Artichoke growers apply nutrient fertilizers at the doses of 170 to 335 kg N/hectare and 35 to 110 kg K/hectare in Californian for each growing cycle [10]. All potassium doses and most nitrogen doses are applied in the first fertilizer application during new-planted artichokes have been completely established and/or re-growth from cut-back old plants has been started. The initial fertilization usually consists of side-dress application of dry fertilizers or injection of liquid fertilizers into irrigation system for established plants. Other two or three applications from nitrogen are still required [10]. In Spain, no positive effect was recorded for nitrogen doses above 200 kg N/hectare on head yield [11]. Whereas, little increase was recorded when artichokes fertilized by 400 kg N/hectare [11]. Potassium application doses did not affect head yield because there was high availability of K reached to 282 ppm in cultivated lands, which had been already enough for the optimum vegetative growth of artichoke and its productivity [11]. The variation in nutrient requirements of nitrogen and potassium for maximum artichokes productivity may due to the availability of these nutrients in cultivated soil. In Germany, the dynamic application of N doses at 300 kg/hectare in combination with K at 400 kg K/hectare was recommended for increasing plant growth and head yield and enhancing earliness and bud quality of seed-grown cultivar 'Green Globe' [4].

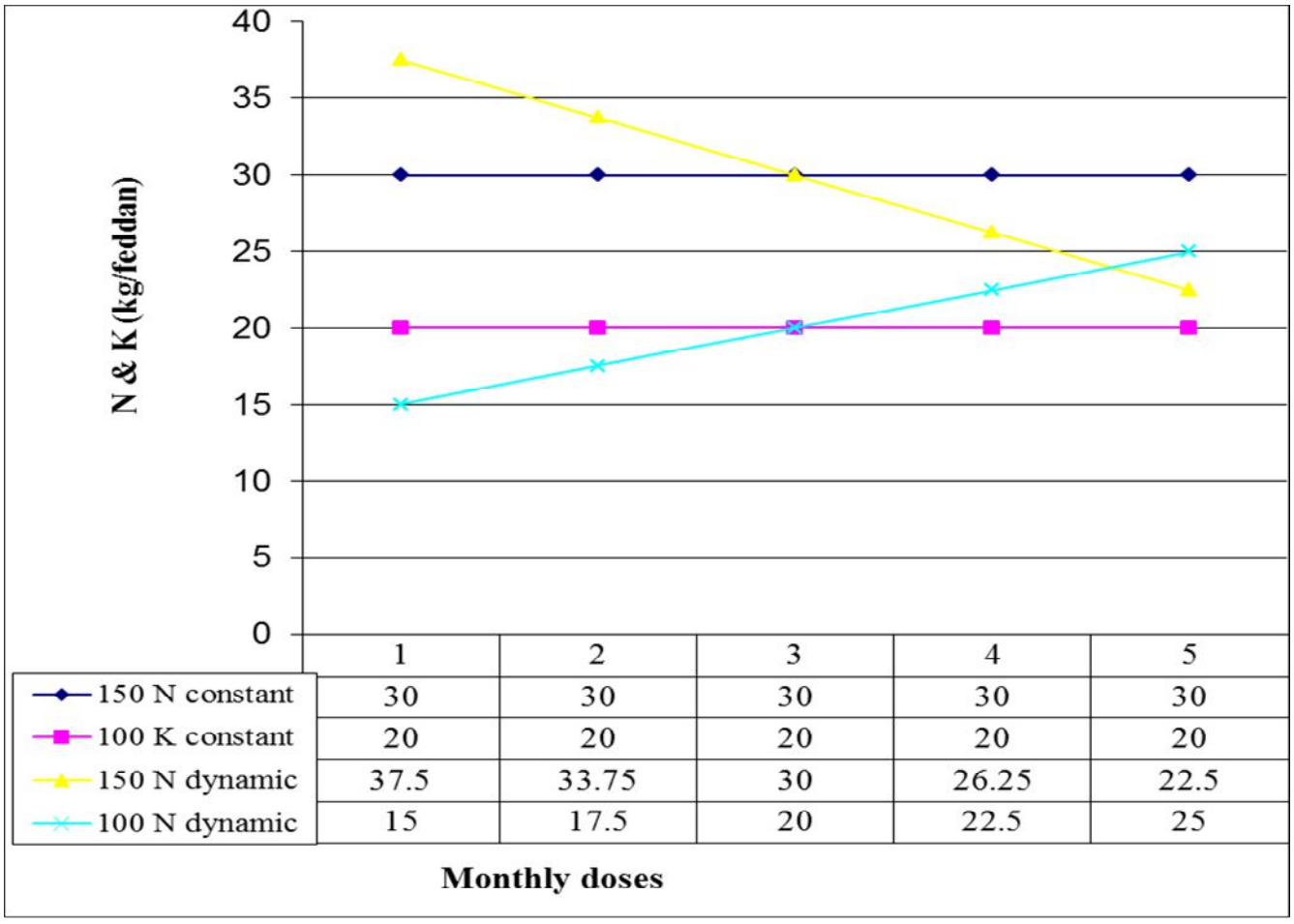
In despite of the knowledge that has been gained through previous studies on fertilizer management for artichoke plants, i.e., methods, amounts, regimes and intervals, essential studies are still needed to determine the optimum doses proportion and dynamic application time for artichoke production according to plant growth cycle. Whereas, the combination doses between nitrogen and potassium and their application time positively affected artichokes productivity. Thus, the present experiment was conducted to identify the optimum mode of N and K (doses proportion and application time) for maximum artichoke productivity and best product quality for local cultivar 'Balady' in Egypt.

Materials and Methods

Two Field experiments were conducted in a private farm located in Delta region, El-Menoufia Governorate, Egypt during the successive cropping seasons of 2012/2013 and 2013/2014 aiming to investigate the effect of different N and K application doses with varying N:K ratios on artichoke productivity. Five different proportions of N and K in the range of 100 to 150 kg N/feddan (4200 m^2) and 50 to 100 kg K/feddan were used as monthly constant or dynamic applications. The combined treatments are specified as follows:

1. 150 kg N/feddan with 100 kg K/feddan as monthly constant applications (control).
2. 150 kg N/feddan with 100 kg K/feddan as monthly dynamic applications.
3. 150 kg N/feddan with 50 kg K/feddan as monthly dynamic applications.
4. 100 kg N/feddan with 50 kg K/feddan as monthly dynamic applications.
5. 100 kg N/feddan with 100 kg K/feddan as monthly dynamic applications.

The local vegetative propagated cultivar 'Balady' in Egypt was grown on the end of August and fertilized by several proportions of N and K (see the different treatments were mentioned above). Ammonium nitrate (33% N) as nitrogen source and potassium sulphate (48% K_2O) as a source of potassium were applied (broadcast) in five doses, at one-month intervals, starting on the first of October and terminated on the first of February. As a control, the amounts of 150 kg N/feddan combined with 100 kg K/feddan were applied monthly at five constant doses (20% for each). The first one was applied after the complete offshoots establishment. The second one was applied during growth and before bud formation, and the third was applied while bud formation before harvest. The fourth and fifth were applied during harvesting period. The dynamic application treatments occurred monthly too but starting with higher N dose and subsequently decreasing doses application of N (25, 22.5, 20, 17.5 and 15%) and starting with lower K dose and subsequently increasing doses application of K (15, 17.5, 20, 22.5 and 25%) according to plant growth cycle (growth stage and generative stage). The different between the monthly constant application doses of 150 kg N and 100 kg K compared to the dynamic application doses are shown in Figure (1).



	1	2	3	4	5
150 N constant	30	30	30	30	30
100 K constant	20	20	20	20	20
150 N dynamic	37.5	33.75	30	26.25	22.5
100 N dynamic	15	17.5	20	22.5	25

Figure (1): Comparison between monthly doses of 150 kg N and 100 kg K_2O in constant and dynamic applications.

Calcium super phosphate (15.5% P_2O_5) was soil-incorporated before planting as a source of phosphorus at a rate of 60 P_2O_5 units/feddan. Other agricultural practices such as irrigation, weed control, pest management and gibberellic acid (GA_3) were followed according to the recommendation of the Ministry of Agriculture, Egypt.

The experiment was designed in a randomized complete block design (RCBD), five treatments with four replications. The plot area was 20 m^2 (20 m length x 1 m width) containing 20 plants with 1 m apart among plants in both seasons.

The soil of the experimental field is a silty-clay with 47% clay, 51% silt and 2% sand. The chemical properties of the experimental soil are shown in Table (1).

Table (1): Chemical properties of the experimental soil.

pH	EC ($dS\ m^{-1}$)	Organic matter (%)	N (%)	NO_3 ($mg\ kg^{-1}$)	K ($mg\ kg^{-1}$)
7.2	1.3	2.4	1.2	9.5	138

Growth characters such as plant height (cm), number of leaves per plant and representative samples from fourth leaf (120 days after planting) for measuring leaf area (cm^2), leaf fresh weight (g), leaf dry weight (g) and leaf chlorophyll content (SPAD) were evaluated.

The first harvest of heads started in January and continued until the end of May in both growing seasons. Yield and yield components were evaluated. Early yield was determined as weight and number of heads/plant from starting of harvest until the end of February, but total yield of heads was recorded as weight and number of heads per plant from the beginning of harvest until the end of growing season. Representative samples from heads were taken and evaluated. The weight, length and diameter of each head as well as the weight of edible part (receptacle) were evaluated in February. In representative samples of the edible parts the following chemical analyses were determined:

1. Total nitrogen was determined in edible parts of heads according to a modified method of Kjeldahl [12].
2. The rate of crude protein in edible parts of heads was calculated from the total N-content corrected with an appropriate conversion factor according to the correlation: % Crude protein = % N x 6.25 according to the method of [13].
3. Phosphorus was determined according to the method of [14].
4. Potassium was determined according to the method of [15].

The obtained data were statistically analyzed using CoStat software package [16]. The treatment effects were evaluated by analysis of variances. The mean values were compared using LSD test at $P < 5\%$ as reported by [17].

Results and Discussion

Vegetative growth characters

The dynamic application doses of nitrogen (start by high nitrogen dose at the beginning then decreasing dose applications during plant growth cycle, as descending order) and potassium (start by less potassium dose at the beginning then increasing dose applications during plant growth cycle, as ascending order) resulted in highest values of all vegetative growth characters of globe artichokes compared to the equal constant application doses (Table, 2). The highest dynamic application doses of 150 kg N/feddan combined with 100 kg K/feddan generally achieved superiority in all characters of plant growth expressed by height of plant (cm), number of leaves/plant, leaf fresh and dry weights and leaf area as well as chlorophyll content comparing with control plants fertilized by constant application doses of N and K in both seasons of 2012-2013 and 2013-2014 (Table, 2). May be this finding based on the fact that artichoke plants which received most of the nitrogen doses at the early period of growth after completely plant establishment, then the best indices of plant growth is expected.

It is well known that globe artichokes produce huge vegetative biomass according to their long growing season from September to May next year. So, nutrients amounts and their combinations have important role in

artichokes production. Concerning the effect of nutrients amounts of N and K, Table (2) showed increases in all characters of plant growth by increasing application doses of N and K fertilizers to 150 kg N and 100 kg K/feddan (4200 m^2). This may be related to sufficient availability of N and K under highest rate of N (150 kg) and K (100 kg)/feddan. Therefore, this result can confirm the sufficient of this proportion and its suitability for optimum globe artichokes growth. Our results are matching with many previous studies [4,6,18]. Enhancement role for highest N & K doses on characters of vegetative growth may be due to the predominant role of those nutrients for cell expansion and expansive growth control [2]. On the other hand, the dynamic combination of lower doses application (100 kg N combined with 50 kg K/feddan) or constant application doses as control treatment resulted in the lower values of all vegetative growth characters (Table, 2). In certain way, these results agree with previous results of [19], who found that the best characters for artichoke seedlings were resulted by application of 130 mg N and 250 mg K/litter nutrient solution. In clay soil, 60 kg N and 100 kg K/feddan produced the highest values of artichoke vegetative growth characters [5]. In calcareous soil, biomass reduction of artichokes was correlated with the reduction of N amounts [20]. In an organic soil described as 'Houghton muck', there was no significant effect for K fertilizer on biomass production of artichokes [21]. The differences in availability levels of N and K in cultivated lands may interpret the variation responses among several previous studies according to the different yield responses to N and K fertilizers.

Table (2): Effect of different combination rates of N and K as monthly constant or dynamic applications on vegetative growth characters of artichoke plants during the two growing seasons of 2012/2013 and 2013/2014.

$N + K_2O$ (Kg/feddan)	Height of plant, (cm)	Leaf No. /plant	Leaf fresh weight, (g)	Leaf dry weight, (g)	Leaf area (cm^2)	Chlorophyll (SPAD)
2012/2013						
Control	70.3	50.5	98.8	12.3	485.3	49.8
150 + 100	76.0	52.8	121.0	15.8	551.5	52.0
150 + 50	72.5	51.5	112.3	13.4	524.5	49.5
100 + 50	69.8	49.8	104.5	12.7	499.3	48.8
100 + 100	74.3	52.3	116.5	14.5	533.5	51.3
LSD at 5%	*2.7*	*2.3*	*14.6*	*1.9*	*47.0*	*N.S.*
2013/2014						
Control	71.8	51.3	104.5	12.6	502.8	51.5
150 + 100	77.3	53.8	122.3	15.3	562.3	54.3
150 + 50	72.8	52.5	111.8	13.5	530.0	50.8
100 + 50	72.5	51.8	110.0	13.8	510.8	48.5
100 + 100	74.0	52.0	118.3	14.8	538.3	52.5
LSD at 5%	*3.1*	*N.S.*	*10.7*	*N.S.*	*51.0*	*2.7*

Head yield

The dynamic application doses of 150 kg N and 100 kg K/feddan produced higher yield of early heads and total heads as numbers and weights than constant application doses of the same N and K amounts, which produced lower yield of both early heads and total heads. This results can be explained based on the fact of artichoke plants were received most of the nitrogen doses at the early period of growth after completely plant establishment, then the best indices of plant growth and subsequently, those plants produced higher head yield and this positive effects was expected (Table, 3). Also, dynamic application of potassium (start by less potassium dose at the beginning then increasing dose applications during plant growth cycle, as ascending order) resulted in highest values of head yield with a good quality of heads (Table, 3).

Concerning the effect of application amounts, the early head yield was higher with higher N fertilizer doses (150 kg N/feddan) combined with the higher doses of K (100 kg K/feddan). Potassium enhances the

earliness and improves product quality and head characters [4,18]. Also, the obtained results showed that the higher amounts of N (150 kg N/feddan) and K (100 kg K/feddan) produced the higher head yield in both seasons due to those plants developed the best characters of vegetative growth can also achieve the highest head yield. In both seasons, head yield components of those plants were fertilized by the lower doses of N (100 kg N/feddan) and K (50 kg K/feddan) was decreased as general trend. This emphasizes the role of N fertilizer as a vital factor for artichoke productivity as reported by previous authors [4,8]. The results in current study are in harmony with the findings of previous studies [20,23], where they found that the application amount of 300-320 kg N/hectare produced highest head yield. The application of 120 kg N/feddan enhanced the earliness of head yield [6]. The available NO_3-N in the cultivated soil of [6] was 10 mg nitrate per kg soil is the same level and similar to our cultivated land may be the reason of the comparable optimum nitrogen doses. Due to high level of available nitrogen in cultivated land (117 mg nitrate/kg soil), the reduction of N application from 500 to 300 kg N/hectare was recommended by [20]. In organic soil, nitrogen doses at 200 kg N/hectare increased head earliness, although K amounts had no significant effect [21]. In alluvial silty-clay soil rich in nitrogen, the amount of 150 kg N/hectare was enough and sufficient for increasing head yield as numbers and weights [24]. There was no positive effect for doses of 300 kg N/hectare [24]. In clay soil, the doses of 60 kg N/feddan combined with 100 kg K/feddan were suitable doses for the optimum head earliness and total yield [5]. No positive effects on earliness and head yield due to N doses higher than 200 kg/hectare [11,18]. The soil contained 22 mg nitrate/kg soil (higher than double of available N in cultivated land of current study) may explain the lower N requirement comparing with current investigation. The high availability of potassium reached 266 mg available K/kg soil was enough for optimum growth and head yield for artichokes [11]. So, soil fertility is very important and the previous soil analysis can expected the nutrients requirements in correct doses and at same time can explain the discrepant results among several studies.

Table (3): Effect of different combination rates of N and K as monthly constant or dynamic applications on head yield of artichoke plants during the two growing seasons of 2012/2013 and 2013/2014.

$N + K_2O$	Early yield		Total yield	
(Kg/feddan)	(head no./plant)	(kg/plant)	(head no./plant)	(kg/plant)
2012/2013				
Control	2.75	0.830	9.85	2.758
150 + 100	3.24	0.931	12.50	3.447
150 + 50	2.66	0.783	11.75	3.168
100 + 50	2.50	0.746	10.23	2.982
100 + 100	3.23	0.924	12.25	3.271
LSD at 5%	*0.28*	*0.088*	*1.34*	*0.295*
2012/2013				
Control	2.63	0.783	10.15	2.864
150 + 100	3.18	0.945	12.73	3.550
150 + 50	2.80	0.843	11.66	3.243
100 + 50	2.74	0.828	11.05	3.088
100 + 100	2.95	0.915	12.17	3.379
LSD at 5%	*0.32*	*0.096*	*0.94*	*0.247*

Head properties

Generally, dynamic application of N at 150 kg combined with 100 kg K/feddan was the best for head properties (weight, length and diameter) and the weight of edible part (Table, 4). The obtained results showed little influences of different doses proportions of nitrogen and potassium on physical properties of heads due to the narrow range of N and K (only 50 units/feddan for each) and environmental condition of our cultivated soil, which corroborates with the findings on head physical characters of previous studies [4,7]. In organic soil, the head weight was not response to change doses of N and K applications [21]. Application doses at 320 kg N/hectare

produced the highest marketable yield according to [23] and 150 kg N/hectare improved head weight according to results of [24]. The combination addition of 60 kg N/feddan with 100 kg K/feddan enhanced the weight of edible parts (receptacle) and increased head weight and other physical characters [5]. Improvement of head characters, i.e., weight and length of heads and their edible parts (receptacle) were noticed when N doses were applied more than 40 kg N/feddan as reported by [6], while the increases in N doses to 160 kg N/feddan did not add further improvements on all physical characters of heads. Head diameter and receptacle thickness did not record any change due to different nitrogen doses [6]. The variability of responses to fertilizer doses can be accepted and may be explained by soil fertility of the experimental field and intervals between studied fertilizer doses as discussed before. For example, the researchers who compared several fertilizer doses having high ranges to non-fertilized control mostly found positive response for fertilizer mounts, while, there is no considerable response for the narrow intervals among nutrient doses, which is expected and logic.

Table (4): Effect of different combination rates of N and K as monthly constant or dynamic applications on head properties of artichoke during the two growing seasons of 2012/2013 and 2013/2014.

$N + K_2O$ (Kg/feddan)	Weight (g)	Length (mm)	Diameter (mm)	Edible part (g)
2012/2013				
Control	249.6	88.3	81.3	48.8
150 + 100	271.3	93.5	85.8	52.3
150 + 50	266.5	92.0	83.5	50.9
100 + 50	258.7	89.2	81.8	49.5
100 + 100	262.4	91.4	82.7	51.3
LSD at 5%	*17.1*	*N.S.*	*N.S.*	*2.3*
2012/2013				
Control	255.5	87.5	83.6	50.3
150 + 100	268.8	91.3	87.1	52.5
150 + 50	263.3	92.3	82.8	49.7
100 + 50	254.8	88.5	83.4	49.3
100 + 100	265.5	89.7	85.5	52.1
LSD at 5%	*9.2*	*N.S.*	*N.S.*	*N.S.*

Chemical composition

Generally, Table (5) recorded little responses for chemical composition of edible parts (receptacle) to different fertilization mode, i.e., doses proportion and application time. The highest nitrogen contents and crude protein were attributed to dynamic application doses of higher N rate (150 kg/feddan) combined with higher K rate (100 kg K/feddan). While, either constant application doses of the same N and K amounts (150 kg N combined with 100 kg K/feddan) or reduced dynamic application rate of N to 100 kg and K to 50 kg/feddan decreased N content and crude protein in the edible parts (receptacle). It means that, there was a close relationship between supplied nutrients fertilizers and nutrients composition in plant tissues. Generally, chemical analysis of the edible parts (receptacle) revealed that all fertilization mode, i.e., doses proportion and application time did not record sufficient variation to be significant concerning their effects on contents of both P and K. Little increase in potassium contents in the edible parts (receptacle) was recorded by the dynamic application of N at 150 kg/feddan combined with K at 100 kg/feddan compared to other treatments in the first season. This low variation of plant chemical composition among N and K rates may be due to the narrow range (50 kg/feddan for each) of the studied fertilizer rates, which corresponded with the findings of [4,5,11]. Our obtained results did not match with reported results of [6], where its result recorded increases in the contents of N and K as well as P concentrations in the leaves and edible parts due to the gradual increases in applied doses from 40 to 160 kg/feddan. This may be because the experiment of [6] was conducted in a sandy soil and fertilization treatments were applied as soil dressing in three equal doses at 30, 45 and 60 days after planting. Also, the content of N was decreased in shoots by decreasing nitrogen doses, while the content of N in the edible parts was not changed [20]. To produce high level

of dry matter, artichokes consumed much amounts of nutrients leading to remove much nutrients amounts per time unit [25]. So fertilizers must apply in adequate doses to be suitable for uptake curves for N and K, which behaved similarly to growth curve of artichokes [9].

The variation in the content of N and K among several previous studies was due to the applied doses of fertilizers according to the soil texture and its fertility. For example, the content of N and K in both leaves and edible parts was lower under sandy soil conditions of [6] compared to silty-loam soil of [4] and silty-clay soil of our experiment. In addition to the soil types, sampling time among previous researches may explain the discrepancies in the contents of N and K in leaves and edible parts (receptacle).

Table (5): Effect of different combination rates of N and K as monthly constant or dynamic applications on contents of N, P, K and crude protein edible part of artichoke head during the two growing seasons of 2012/2013 and 2013/2014.

$N + K_2O$ (Kg/feddan)	N (%)	P (%)	K (%)	Crude protein (%)
2012/2013				
Control	2.87	0.41	3.39	17.9
150 + 100	3.21	0.52	3.61	20.1
150 + 50	3.02	0.47	3.46	18.9
100 + 50	2.93	0.40	3.37	18.3
100 + 100	3.14	0.44	3.53	19.6
LSD at 5%	*0.24*	*N.S.*	*0.19*	*1.5*
2012/2013				
Control	2.96	0.38	3.43	18.5
150 + 100	3.17	0.45	3.58	19.8
150 + 50	3.08	0.42	3.52	19.3
100 + 50	3.03	0.39	3.41	18.9
100 + 100	3.11	0.41	3.49	19.4
LSD at 5%	*0.15*	*N.S.*	*N.S.*	*0.94*

Conclusions

In conclusion, the application of N at 150 kg N/feddan (4200 m^2) combined with K at 100 kg K/feddan as five dynamic doses (in descending order for N doses during plant growth cycle and ascending order for K doses during plant growth cycle and while generative stage) is a good fertilization strategy for artichokes productivity.

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