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Full Length Article

Effect of Chemical Fertilization on Yield and Natural Pigments of Cactus Pears Fruits

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Abstract

This study was carried out on a cactus pear orchard grown in calcareous soil at El-Hammam region, Matrouh Governorate, over two consecutive seasons in 2020 and 2021. This work aimed to find the best mineral fertilization treatment for increasing the yield of plants, as it has yet to be studied under the conditions of this region. The study was a randomized complete block experiment. The fertilization treatments were as the following: - (control, 100 g N + 40 g P + 70 g K/plant, 100 g N + 40 g P + 90 g K/plant, 100 g N + 60 g P + 70 g K/plant, 100 g N + 60 g P + 90 g K/plant, 120 g N + 40 g P + 70 g K/plant, 120 g N + 40 g P + 90 g K/plant, 120 g N + 60 g P + 70 g K/plant and 120 g N + 60 g P + 90 g K/plant). Increasing nitrogen, phosphorus, and potassium fertilization rates improved vegetative growth, fruit quantity, and quality traits over control. The highest fertilization rate (120 g N + 60 g P + 90 g K/plant) significantly recorded the best physical characteristics (fruit weight, fruit length, fruit width, fruit volume, juice weight, peel weight, peel thickness, pulp weight/fruit, number of seeds/fruit, and seeds weight/fruit). Furthermore, fruits had suitable chemical parameters (total soluble solids, total acidity content, total soluble solids/acid ratio, and ascorbic acid content). The most useful chemical fertilization amount was the basal dressing of 120 g N, 60 g P, and 90 g K/plant in this area.

Keywords: Cactus pear; NPK fertilization; Fruit; Quantity; Quality; Pigments

Introduction

Cactus pear or Indian fig opuntia (*Opuntia ficus-indica* L., Family: Cactaceae) is a cactus species that is a domestic crop produced throughout arid and semiarid regions of the globe. The cactus pear is the most commercially important cactus. It is grown chiefly as a fruit crop and for other purposes, including food and medicinal industries, cosmetics, fodder, and soil erosion prevention. Cacti are suitable crops for dry zones because they convert water into biomass efficiently. The fruits are commercialized in many parts of the world and consumed raw. They have one of the highest concentrations of vitamin C. As fruits have vitamin C, they were once utilized to mitigate scurvy. Jams are made from fruits. The red color of the fruits and juice is owed to betalains; the fruits also contain flavonoids and are very nutritious. They have 14% fructose, 1% protein, 20% solids, glucose, ascorbic acid, fatty oil, and a resinous substance. The fruits are used to treat diarrhea (Kuti 2004; Neffar *et al*. 2013; Zimmer 2013; Miller 2015; Badr *et al.* 2019; Fattah *et al*. 2020; Ueckert 2020).

Until now, the cactus pear farms did not receive enough attention in the fertilization programs, like other fruit plants in desert areas. The shortage in mineral nutrients influences cactus pear plant metabolism, negatively impacting fruit yield and quality. Cactus pear plants differ physiologically and morphologically from most other crop plants. For this reason, fertilizer recommendations applied to other crops are unsuitable. The mineral nutrition studies on cactus pears show that chemical fertilizer application is generally valuable for fruit production. Nutrient elements influence the cactus pear's fruit yield and quality. Macroelements have the most significant impact on fruit production. N, P, and K are the most limiting nutrients in cacti and affect their yield (Claassens and Wessels 1997; Dubeux *et al.* 2006; Zegbe *et al.* 2014, 2015; Silva *et al.* 2016; Souza *et al.* 2017; Food and Agriculture Organization of the United Nations 2018; Neto *et al.* 2020).

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Cultivating the cactus pear crop is profitable for local farms in the desert due to its low production costs, high-added value crop, and tolerance to environmental conditions such as high temperatures, drought, and poor soils (Mason 2015). Concerning the agriculture processes, many farmers still depend on organic fertilizers only in production without chemical fertilizers, which leads to a decrease in the yield and quality attributes. Other farmers add very high nitrogen fertilizers, resulting in excessive vegetative growth and reduced fruit yield.

Calcareous soils possess high levels of calcium carbonate ($CaCO_3$) that affect soil properties related to plant development. Cultivating calcareous soils presents numerous difficulties, such as low water holding capacity, high infiltration levels, shoddy construction, low organic matter, and clay content. Moreover, low cation exchange capacity (CEC), loss of fertilizers *via* leaching, texture crusting and cracking, increased pH, losing nitrogen fertilizers, and low availability of nutrients (Elgabaly 1973; El-Hady and Abo-Sedera 2006; FAO 2016; Aboukila *et al*. 2018). Therefore, the crops that can resist such poor soil conditions are like the cactus pear. So, calcareous soils are suitable for the cultivation of this plant.

Farmers overlook the importance of chemical fertilization for cactus pear farms, despite its importance in improving fruit crop characteristics such as quantity and quality. This study investigates this topic under calcareous soil conditions in newly reclaimed desert lands in Egypt, as this topic has not previously been studied.

The objective of our research was to investigate the effect of different nitrogen, phosphorous, and potassium fertilizers on the yield and quality of plants cultivated in calcareous soil to improve the characteristics of the fruits by knowing the appropriate fertilizer rates. As a result, the area of this crop on those lands has grown.

Materials and Methods

Experimental details and treatments

Experimental details: The experiment was set up in the cactus pear farm in the El-Hammam region (30° 50′ N and 29° 23′ E), Matrouh Governorate, Egypt, over two seasons in 2020 and 2021. Five-year-old cactus pear plants (*Opuntia ficus-indica* L.) grown in sandy soil and spaced 2 × 5 m apart are subjected to a drip irrigation system. The experimental soil's physical and chemical analyses are shown in Table 1. The chemical analysis of the used water for irrigation is recorded in Table 1. The parameters of compost manure added to the farm are presented in Table 2.

Treatments: This work aimed to determine plants' best-added nitrogen, phosphorus, and potassium levels. Healthy vegetation, nearly in shape and size and productivity were chosen for this experiment. The experiment was designed as a randomized complete block design with four replicates for each treatment. The applied nine fertilization treatments were as the following:

1- Control
2- 100 g N + 40 g P + 70 g K / plant
3- 100 g N + 40 g P + 90 g K / plant
4- 100 g N + 60 g P + 70 g K / plant
5- 100 g N + 60 g P + 90 g K / plant
6- 120 g N + 40 g P + 70 g K / plant
7- 120 g N + 40 g P + 90 g K / plant
8- 120 g N + 60 g P + 70 g K / plant
9- 120 g N + 60 g P + 90 g K / plant

The used chemical fertilizers sources were ammonium nitrate (33% N), calcium superphosphate (15.5% P_2O_5) and potassium sulphate (48% K_2O). Nitrogen fertilizer was divided into two equal doses, the first 50% of nitrogen fertilizer was added at the end of February and the second 50% of nitrogen fertilizer was added after three weeks of full bloom, at the beginning of May, in both seasons. Potassium fertilizer was divided into two equal doses and added as a soil application while adding nitrogen fertilizer. Nitrogen and potassium fertilizers were added as soil applications at a depth of 15 cm and 1 m from the trunk. The ordinary organic fertilization program was 15 kg/plant of compost manure with phosphate added to a trench in the first week of January. Fruits were taken from each treated plant at harvest time to determine the quantity and physical and chemical aspects. The response of cactus pear plants to fertilization treatments was evaluated through the following determinations:

I) Vegetative growth and pigment measurements: Number of cladodes**,** cladodes length (cm), cladodes width (cm), cladodes area (cm^2), chlorophyll a (mg/g), chlorophyll b (mg/g), total chlorophyll and carotenoids (mg/g).

II) Fruiting measurements: Fruit set%, number of fruits/plant, fruit yield (kg)/plant, fruit weight (g), fruit length (cm), fruit width (cm), fruit volume (cm^3), juice weight (g), peel weight (g), peel thikness (cm), pulp weight/fruit (g), number of seeds/fruit, seeds weight/fruit (g), fruit TSS (%), total acidity content (%), fruit TSS / acid ratio, and ascorbic acid (mg/100 mL juice) according to the methods described by (AOAC 1995; Barros *et al.* 2016).

Statistical analysis

The obtained data were subjected to an analysis of variance according to Clarke and Kempson (1997). The means were differentiated using the range test at the 0.05 level (Duncan 1955).

Results

I- Vegetative growth and pigment measurements: Data in Table 3 showed the effect of mineral fertilization on vegetative growth parameters in both seasons. Generally, NPK nutrient addition significantly enhanced growth

Table 1: The soil and irrigation water analyses

Characteristics	Values
Soil physical properties	
Sand	93.10%
Silt	1.04%
Clay	5.86%
Soil texture	Sandy
Soil chemical properties	
Organic matter	0.10%
pH	8.30
Electrical conductivity	294.40 $mg.kg^{-1}$
HCO_3^-	0.02 meq/100 g soil
Cl^-	0.05 meq/100 g soil
SO_4^{2-}	0.35 meq/100 g soil
Ca^{2+}	0.06 meq/100 g soil
Mg^{2+}	0.05 meq/100 g soil
Na^+	0.3 meq/100 g soil
K^+	0.01 meq/100 g soil
$CaCO_3$	39%
Irrigation water chemical properties	
pH	7.45
Electrical conductivity	485.00 $mg.kg^{-1}$
HCO_3^-	4.83 meq/L
Cl^-	1.73 meq/L
SO_4^{2-}	1.04 meq/L
Ca^{2+}	2.04 meq/L
Mg^{2+}	1.38 meq/L
Na^+	2.41 meq/L
K^+	1.78 meq/L

Table 2: The compost manure physico-chemical analysis

Characteristics	Values
Weight of m^3	625 kg
pH	7.85
Electrical conductivity	1760.00 $mg.kg^{-1}$
N	1.60%
C/N ratio	17:1
P	0.70%
K	1.25%
Fe^{2+}	1587.50 $mg.kg^{-1}$
Mn^{2+}	162.50 $mg.kg^{-1}$
Cu^{2+}	65.00 $mg.kg^{-1}$
Zn^{2+}	21.50 $mg.kg^{-1}$

Table 3: Effect of fertilization treatments (g/plant) on number of cladodes, cladodes length, cladodes width, and cladodes area of cactus pear during the two successive seasons

Treatments			Number of cladodes		Cladodes length (cm)		Cladodes width (cm)		Cladodes area (cm^2)	
N	P	K	2020	2021	2020	2021	2020	2021	2020	2021
0	0	0	5.70 f	6.70 i	24.76 e	24.51 f	16.10 e	17.57 d	273.62 e	300.14 g
100	40	70	7.00 ef	8.00 h	32.60 d	31.27 e	17.35 d	19.50 cd	388.28 d	417.41 f
100	40	90	9.00 de	11.00 f	35.35 c	33.46 d	19.35 c	19.49 bc	370.21 c	475.94 de
100	60	70	7.70 ef	9.00 g	34.85 c	35.25 cd	17.85 d	18.46 cd	427.42 d	444.55 ef
100	60	90	10.70 cd	13.00 d	35.85 c	35.75 c	19.35 d	19.83 b	476.83 c	491.53 cd
120	40	70	12.30 cd	14.70 c	38.85 b	38.75 b	19.60 bc	19.59 b	524.00 b	526.31 bc
120	40	90	18.70 a	19.70 a	40.60 b	42.25 a	20.10 bc	20.11 b	561.91 b	565.16 b
120	60	70	11.00 cd	11.70 e	38.60 b	38.75 b	20.60 ab	19.62 b	547.30 b	523.64 bc
120	60	90	16.00 b	17.00 b	43.60 a	41.25 a	21.35 a	21.89 a	640.07 a	659.28 a

Means with the same letter are not significantly different at 5% level of probability

characteristics compared to the control treatment.

Adding the maximum rate of fertilizers of 120 g N + 60 g P + 90 g K/plant significantly surpassed others in terms of the number of cladodes, cladode length, cladode width and cladode area. These measurements for the first season were 16.00 cladodes, 43.60 cm, 21.35 cm and 640.07 cm^2, respectively. In comparison, the records of the second season were 17.00 cladodes, 41.25 cm, 21.89 cm and 659.28

Table 4: Effect of fertilization treatments (g/plant) on chlorophyll a, chlorophyll b, total chlorophyll, and carotenoids of cactus pear during the two successive seasons

Treatments			Chlorophyll a (mg/g)		Chlorophyll b (mg/g)		Total chlorophyll (mg/g)		Carotenoids (mg/g)	
N	P	K	2020	2021	2020	2021	2020	2021	2020	2021
0	0	0	3.75 i	3.58 h	9.27 i	7.93 i	13.02 h	11.68 i	1.21 f	1.34 h
100	40	70	4.41 h	3.88 g	11.50 h	8.10 h	15.93 g	12.52 h	1.91 e	1.75 g
100	40	90	4.86 d	4.82 d	12.08 f	10.52 g	16.95 ef	15.39 g	2.39 bcd	2.22 e
100	60	70	4.55 g	4.69 f	11.87 g	11.55 f	16.43 fg	16.09 f	2.06 de	2.14 f
100	60	90	4.92 d	5.00 c	12.30 d	11.90 e	17.23 de	16.83 e	2.56 b	2.41 d
120	40	70	4.71 f	4.76 e	13.14 c	12.55 c	17.86 bc	17.27 d	2.14 cde	2.26 e
120	40	90	4.90 c	5.17 b	13.22 b	12.63 b	18.13ab	17.54 b	2.72 ab	2.69 c
120	60	70	4.78 b	4.78 de	12.19 e	12.51 d	17.53 cd	17.29 c	2.44 bc	3.08 b
120	60	90	5.09 a	5.28 a	13.59 a	12.96 a	18.68 a	18.05 a	3.02 a	3.23 a

Means with the same letter are not significantly different at 5% level of probability

Table 5: Effect of fertilization treatments (g/plant) on fruit set, number of fruits/plant and fruit yield (kg)/plant of cactus pear during the two successive seasons

Treatments			Fruit set (%)		Number of fruits/plant		Fruit yield/plant (kg)	
N	P	K	2020	2021	2020	2021	2020	2021
0	0	0	50.13 e	49.07 f	53.00 g	51.67 i	3.05 h	2.95 g
100	40	70	56.75 d	55.56 e	99.33 f	97.00 h	8.00 g	8.22 f
100	40	90	60.29 c	61.86 cd	110.00 f	108.67 g	10.79 f	11.44 e
100	60	70	61.49 c	61.72 d	136.33 e	134.00 f	15.42 e	16.15 d
100	60	90	62.45 bc	63.57 bcd	154.33 d	155.67 e	15.27 e	16.11 d
120	40	70	64.97 b	65.95 b	167.33 c	166.00 d	17.24 d	18.31 c
120	40	90	73.49 a	72.33 a	173.00 c	172.67 c	19.77 c	18.96 c
120	60	70	65.28 b	64.77 bc	195.00 b	200.00 b	24.18 b	23.58 b
120	60	90	73.53 a	73.37 a	210.00 a	209.33 a	32.18 a	32.99 a

Means with the same letter are not significantly different at 5% level of probability

Table 6: Effect of fertilization treatments (g/plant)) on fruit weight, fruit length, fruit width, and fruit volume of cactus pear during the two successive seasons

Treatments			Fruit weight (g)		Fruit length (cm)		Fruit width (cm)		Fruit volume (cm^3)	
N	P	K	2020	2021	2020	2021	2020	2021	2020	2021
0	0	0	55.70 f	57.76 f	6.20 e	6.59 h	4.14 e	4.70 i	63.33 f	65.33 f
100	40	70	82.88 e	80.38 e	7.26 d	6.61 g	4.82 d	5.37 h	90.67 e	91.00 e
100	40	90	109.58 c	113.03 c	7.86 c	8.19 d	5.13 bc	5.68 d	110.33 d	112.00 cd
100	60	70	103.91 d	98.17 d	6.29 e	7.57 f	4.95 cd	5.49 g	104.67 d	106.33 d
100	60	90	118.59 b	114.21 c	7.93 bc	8.29 c	5.21 bc	5.71 c	120.00 c	122.00 bc
120	40	70	104.20 d	98.85 d	7.39 d	7.57 f	4.99 cd	5.50 f	107.33 d	110.00 cd
120	40	90	120.96 b	124.01 b	8.29 b	8.62 b	5.29 b	5.76 b	132.00 b	135.67 b
120	60	70	109.31 c	103.10 d	7.62 cd	8.01 e	5.11 bc	5.67 e	110.33 d	110.67 cd
120	60	90	157.09 a	149.89 a	9.23 a	9.48 a	6.03 a	6.64 a	156.67 a	159.00 a

Means with the same letter are not significantly different at 5% level of probability

cm^2 concerning the number of cladodes, cladode length, cladode width, and cladode area, respectively. For the content of the pigments (Table 4), the application of NPK fertilization induced a high positive effect on chlorophyll and carotenoid concentrations over the control of the investigation. The results indicated that the top rate of chemical fertilizers produced the significant maximum contents of chlorophyll a, chlorophyll b, total chlorophyll, and carotenoids. These values for the first season were 5.09, 13.59, 18.68 and 3.02 mg/g and the readings for the second season were 5.28, 12.96, 18.05 and 3.23 mg/g about chlorophyll a, chlorophyll b, total chlorophyll and carotenoids, in the same order.

II) Fruiting measurements: Data in Table 5 presented the effect of NPK fertilization on fruit yield attributes. Also, its influence on fruit's physical properties was shown in Tables 6–8, while the results of its impact on fruit's chemical parameters were exhibited in Table 9. Compared to unfertilized plants, which recorded the lowest values, the added NPK fertilization improved these traits. In most cases, the highest level of NPK fertilizers significantly produced the maximum characters during both study seasons. Concerning fruit yield attributes, values of the first season were 73.53%, 210.00 fruits and 32.18 kg; moreover, data of the second season were 73.37%, 209.33 fruits, and 32.99 kg for fruit set percentage, number of fruits per plant, and fruit yield per plant (kg), respectively (Table 5). Relating to the fruit's physical properties, the measurements for the same fertilization treatment in the first season were 157.09 g, 9.23 cm, 6.03 cm, 156.67 cm^3 (Table 6), 39.83 g, 74.82 g, 0.53 cm (Table 7), 82.27 g, and 187.00 seeds (Table 8). Further, in the second year,

Table 7: Effect of fertilization treatments (g/plant) on juice weight, peel weight and peel thikness of cactus pear during the two successive seasons

Treatments			Juice weight (g)		Peel weight (g)		Peel thickness (cm)	
N	P	K	2020	2021	2020	2021	2020	2021
0	0	0	11.53 f	13.57 g	33.80 e	34.25 f	0.32 e	0.31 f
100	40	70	16.10 e	16.99 f	40.56 d	39.81 e	0.32 e	0.35 e
100	40	90	27.73 bc	27.89 c	48.25 c	48.16 c	0.38 d	0.40 c
100	60	70	24.41 d	25.29 e	45.02 cd	44.09 d	0.36 d	0.35 de
100	60	90	28.39 b	29.49 b	57.70 b	59.78 b	0.40 c	0.41 c
120	40	70	25.14 d	26.54 d	47.51 c	44.38 cd	0.38 cd	0.37 de
120	40	90	28.62 b	29.49 b	60.27 b	59.99 b	0.49 b	0.49 b
120	60	70	26.13 cd	26.72 d	47.91 c	47.62 cd	0.38 d	0.37 de
120	60	90	39.83 a	40.72 a	74.82 a	73.82 a	0.53 a	0.54 a

Means with the same letter are not significantly different at 5% level of probability

Table 8: Effect of fertilization treatments (g/plant) on pulp weight/fruit, number of seeds/fruit, and seeds weight/fruit of cactus pear during the two successive seasons

Treatments			Pulp weight/fruit (g)		Number of seeds/fruit		Seeds weight/fruit (g)	
N	P	K	2020	2021	2020	2021	2020	2021
0	0	0	21.91 d	21.44 d	108.00 g	112.67 g	2.44 d	2.90 cd
100	40	70	42.32 c	43.07 c	118.33 ef	114.67 g	2.61 cd	2.86 cd
100	40	90	61.32 b	61.42 b	132.00 cd	138.67 d	2.99 bcd	3.157 cd
100	60	70	58.89 b	59.82 b	116.33 f	125.33 f	2.35 d	2.61 d
100	60	90	60.88 b	58.81 b	138.33 c	144.33 c	3.63 ab	3.88 ab
120	40	70	56.69 b	59.83 b	124.67 de	133.33 e	2.82 cd	2.903 cd
120	40	90	60.68 b	60.96 b	146.33 b	152.00 b	3.74 a	3.99 a
120	60	70	61.40 b	61.70 b	126.33 d	133.67 e	2.92 bcd	3.13 cd
120	60	90	82.27 a	83.27 a	187.00 a	191.33 a	3.19 abc	3.29 bc

Means with the same letter are not significantly different at 5% level of probability

Table 9: Effect of fertilization treatments (g/plant) on fruit T.S.S., total acidity content, fruit T.S.S. / acid ratio, and ascorbic acid of cactus pear during the two successive seasons

Treatments			Fruit T.S.S. (%)		Total acidity content (%)		Fruit T.S.S. / acid ratio		Ascorbic acid (mg)	
N	P	K	2020	2021	2020	2021	2020	2021	2020	2021
0	0	0	8.90 d	9.03 f	0.47 a	0.50 a	19.17 e	18.16 e	11.22 f	11.26 g
100	40	70	9.80 cd	9.93 e	0.40 b	0.43 ab	24.57 de	23.00 d	11.41 f	11.67 f
100	40	90	11.96 a	12.23 ab	0.30 d	0.43 ab	39.96 a	28.03 c	12.94 de	13.73 d
100	60	70	10.46 bc	10.43 d	0.40 b	0.40 b	26.23 cd	26.23 cd	12.94 de	11.57 fg
100	60	90	12.23 a	12.03 b	0.30 d	0.30 c	40.83 a	40.83 ab	13.61 cd	14.31 c
120	40	70	10.90 b	10.63 d	0.37 bc	0.30 c	30.43 bc	36.36 b	12.84 e	13.30 e
120	40	90	12.26 a	12.03 b	0.30 d	0.30 c	40.90 a	40.90 ab	14.72 b	16.18 a
120	60	70	10.90 b	11.13 c	0.33 cd	0.30 c	33.40 b	36.36 b	14.20 bc	15.33 b
120	60	90	12.63 a	12.56 a	0.30 d	0.30 c	42.10 a	42.10 a	15.41 a	16.31 a

Means with the same letter are not significantly different at 5% level of probability

there were 149.89 g, 9.48 cm, 6.64 cm, 159.00 cm^3 (Table 6), 40.72 g, 73.82 g, 0.54 cm (Table 7), 83.27 g, and 191.33 seeds (Table 8) for fruit weight, fruit length, fruit width, fruit volume, juice weight, peel weight, peel thickness, pulp weight/fruit, and the number of seeds/fruit. The best fruit's chemical parameters came from the treatments of applying 120 g N + 60 g P + 90 g K/plant followed by 120 g N + 40 g P + 90 g K/plant and then 100 g N + 60 g P + 90 g K/plant (Table 9). These constituents of fruit T.S.S. (%), fruit T.S.S. / acid ratio and ascorbic acid in the first season were 12.63, 12.26, 12.23%; 42.10, 40.90, 40.83 ratio; 15.41, 14.72, 13.61 mg and in the second season were 12.56, 12.03, 12.03%; 42.10, 40.90, 40.83 ratio; 16.31, 16.18, 14.31 mg, respectively. On the other side, increasing NPK fertilization decreased the total acidity content of fruits.

Discussion

It was evident that NPK fertilization improved the quantity parameters (number of fruits per plant and yield per plant). Also, it improved the quality characteristics (fruit length, fruit width, fruit volume, juice weight, pulp weight/fruit, fruit TSS, total acidity content, fruit TSS / acid ratio, and ascorbic acid content).

There are several possible explanations for nitrogen fertilizer's role in increased growth and fruit production. It is a component that is necessary for the amino acids. Proteins and enzymes are built from amino acids. Nitrogen is also a component of the chlorophyll molecule, which enables the plant to capture the sun's energy through photosynthesis and thus increase the amount of total chlorophyll it contains. Nitrogen may be a significant component of some chemicals that play an essential physiological role in metabolism, resulting in increased carbohydrate production and improved overall fruit quality. Consequently, there was an increase in the amount and quality of fruits that could be harvested (Nijjar 1985; Mengel *et al*. 2001).

Phosphorus is a component of plants' complex nucleic acid structure, and it controls the production of proteins. Phosphorus plays an essential role in the process of cell division and is linked to the complex transformation of energy. Phosphorus is an indispensable nutrient for producing ATP, which serves as the "energy unit" in the cells of plants. Because of this, every plant needs phosphorus to stay as healthy and robust as possible (Jain 2017).

Potassium plays an essential role in the processes of enzyme activation, protein synthesis, photosynthesis, and cell formation, which may explain why it has a positive effect on crop growth and yield. Potassium is a vital component for plant development. It plays a role in the activation of enzymes that are found within the plant. Potassium regulates the frequency with which stomata open and close, which controls the movement of water vapor, oxygen, and carbon dioxide into and out of the plant. As a result, the fruit's quantity and quality were enhanced (Erner *et al*. 2001; Ganeshamurthy *et al*. 2011).

According to the research published by (Arba *et al*. 2002; Stewart *et al*. 2005; Dubeux *et al*. 2006; Silva *et al*. 2012; Mimouni *et al*. 2013; Zegbe *et al*. 2014; Souza *et al*. 2017), chemical fertilization had a positive effect on the shoot development and fruit production of cactus pear plants. Our findings were in agreement with their findings.

Conclusion

Cactus pear (*Opuntia ficus-indica* L.) plants benefited from the application of NPK fertilizer because it led to enhanced vegetative growth, higher fruit yield and improved fruit quality. At this location in the El-Hammam region, the ideal level of chemical fertilization was provided by a basal dressing consisting of 120 g of nitrogen, 60 g of phosphorus, and 90 g of potassium applied to each plant.

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Author Contributions

All authors contributed equally. All authors read and approved the final manuscript.

Conflicts of Interest

All authors declare no conflicts of interest.

Data Availability

Data presented in this study will be available on a fair request to the corresponding author.

Ethics Approval

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