Effect of potassium fertilization on growth, yield, and some active ingredients of Prunella plant

Shaimaa I.M. Elsayed[a], Rasha Fouad[b], Hend Fouad[b], Saber F. Hendawy[b], Elsayed A. Omer[b]

Departments of [a]Horticultural Crops Technology, [b]Medicinal and Aromatic Plants Research, National Research Centre, Giza, Egypt

Correspondence to Shaimaa I.M. Elsayed, PhD, Department of Horticultural Crops Technology, National Research Centre, El-Behowth Street, PO Box 12311, Dokki, Cairo, Egypt. Tel: +20 114 766 7485; fax:+20 233 370 931; e-mail: shaimaaelsyed83@gmail.com

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Background
Prunella vulgaris L. is a perennial herb belonging to the Lamiaceae family, it is used as antibacterial, antipyretic, antiseptic, antispasmodic, astringent, carminative, diuretic, febrifuge, hypotensive, stomachic, septic, tonic, vermifuge, and vulnerary properties are all seen to be alternatives to whole plants. Potassium is an important macronutrient for plants because of its ability to affect meristem development, water status, photosynthesis, long-distance assimilation of nutrients, enhancement of some enzyme functions, and regulate ionic equilibrium.

Objective
To investigate the effects of various potassium fertilizer applications and the quantity of additions on the growth, production, and some chemical constituents of the *P. vulgaris* plant.

Materials and methods
Prunella plants were cultivated at SEKEM Company Farm, Belbes, Sharkia, using a drip irrigation system during the two successive seasons of 2018/2019 and 2019/2020 to study the impact of application of different potassium doses (20, 40, and 60 U) and number of added portions (each dose added once or divided into two or three portions) on plant diameter, fresh and dry weight of herb (g/plant and ton/ha), and fresh and dry weight of flowering clusters at both seasons. Photosynthetic pigments in leaves (mg/g fresh leaves), total phenols (mg/g dry herb and flowering clusters), and antioxidant activity (%) in herb and flowering clusters and nitrogen, phosphorus, and potassium concentrations (%) were determined.

Results and conclusion
Increasing units of potassium fertilization from 20 to 60 U gave the highest plant diameter, fresh and dry weight of herb, and fresh and dry weight of flowering clusters. It also led to an intensification of total phenolics, antioxidant activity %, chlorophyll content, and N, P, and K percentages of all Prunella herbs, whether it was added at two or three portions.

Keywords:
flowering cluster yield, potassium fertilization, Prunella plants, total phenolic and antioxidant

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Introduction

Prunella vulgaris L. is a perennial herb belonging to the mint family (Lamiaceae) sometimes referred to as ‘self-heal,’ was extremely common in Western, Asian, and Chinese medicine. In order to treat infectious fever among the troops, which was characterized by painful throat and a brown-coated tongue, German military surgeons adopted the term ‘Prunella,’ which was derived from the German word ‘Brunellen,’ which meant ‘inflammation of mouth.’ The name ‘vulgaris’ comes from the Latin adjective ‘vulgar,’ which means ‘common,’ in reference to how widely distributed the plant is. *P. vulgaris* has creeping, self-rooting, tough, square, and reddish stems that branch at the leaf axis and develops to a height of 5–30 cm (2–12 inched).

Similar to other herbs in the mint family, after a plant reaches a certain height, it topples over and if feasible, attaches new roots to the earth. The opposing pairs of lance-shaped, serrated leaves grow along the square stem and are 1.5 cm (half an inch) in width and 2.5 cm (1 inch) in length, with a scarlet tip. Three to seven veins extend from a leaf's center vein to its edge. The leaf stalks are typically small, although they can reach a maximum length of 5 cm (2 inches) [1]. From a club-like, roughly square, whorled cluster, the blooms emerge. The many, tiny (about 12 inches), purple-to-pink snapdragons are clustered in a close cluster at the end of the stem that is 1–2-inches long and ~1-inch broad. The blooms are grouped inside the cluster in whorls of six, each whorl rising above two spreading,

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pointed bracts that resemble leaves. From lower to upper ends of the spike, flowers open up in succession. Depending on the latitude, elevation, temperature, and other factors, bloom occurs from April to September, although primarily in the summer. Four smooth, egg-shaped, one-seeded nutlets are produced by each bloom and are kept in the persistent calyx [2].

Prunella was used for thousands of years, as it contains different active constituents, including phenolics, flavonoids, volatile oil, polysaccharides, triterpenoids, steroids, organic acids, and phenylpropanoids. It has various biological activities, like antioxidant, anti-inflammatory, antitumor, antibacterial, and antiviral, as well as liver protection, immune regulation, antihypertensive, hypoglycemic, sedative, hypnotic, and lipid-lowering effects [3]. Also, it is used for headache, red swelling and eye pain, night pain of eyeballs, breast carbuncle, hypertension, scrofula, and vertigo [4]. Internal bleeding and sore throats are treated with a leaf decoction. It functions as an anti-allergic and anti-inflammatory agent. It is applied externally to treat small wounds, sores, burns, and bruises in western medicine. It may also be used as a mouthwash to cure mouth ulcers. A delicious and energizing beverage may be made by steeping freshly cut or dried and powdered leaves in cold water. A weak infusion of the herb makes a great eye wash for pink eye and stys. For the treatment of fevers, diarrhea, sore throats, internal bleeding, and weakening of the liver and heart, Prunella is used internally as a medicinal tea. Clinical research supports its use as an alternative medicine both orally and topically as an antibiotic and for illnesses and wounds that are difficult to cure because it has an antibacterial effect that prevents the growth of *Pseudomonas*, *Bacillus*, *E. coli*, and *Mycobacterium*. It is promising in the study of diabetes, cancer, AIDS, herpes, and many other illnesses.

So, it is critical to encourage Prunella cultivation in Egypt as well as identify the best means of preserving and enhancing the local region's highly medicinal Prunella species diversity, which is not well-known in Egypt. The market for *P. vulgaris* has continuously risen, but the wild population is unable to supply it. As a result, the cultivation of medicinal plants may help limit overharvesting of wild resources, which disrupts habitat and reduces genetic variety [5]. To satisfy the need for homogeneous and high-quality raw materials on the global market, *P. vulgaris* must participate in balanced agronomic practices [6].

Everyone generally agrees that using chemical fertilizers has had the most impacts on improving crop productivity. This holds true for a variety of crops that are grown globally under a wide range of circumstances. That has been demonstrated in a number of field studies. Depending on the soil characteristics, crop species, cultivars, and availability of plant nutrients, chemical fertilization is the primary growth-limiting factor. All agricultural plants' growth and development are significantly influenced by nutrition. Nutrients can efficiently improve the amount and quality of production medicinal plants [7].

One of the most significant macronutrients that influence plant development is potassium. It participates in a variety of physiological and biochemical processes important for plant development, production, and quality. Potassium (K) is a crucial nutrient for plants because of its capacity to affect meristem development, water status, photosynthesis, long-distance assimilation of nutrients, boost several enzyme functions, aid translocate sugars and starches, raise protein content, and regulate ionic equilibrium [8]. Potassium controls water retention and the opening and shutting of stomata. It assists in the synthesis of proteins, the formation of meristematic tissue, the activation of some enzymatic events, the metabolism of nitrogen, the catalysis of some mineral element activities, and the metabolism and translocation of carbohydrates.

Potassium is more mobile in the soil than phosphorus but less than nitrates, which can be readily leached from light sandy soils. Additionally, weak stalks and roots are more susceptible to infection by root-rotting organisms due to potassium deficit. The plants are more susceptible to being bent (lodged) to the ground by wind and rain as a result of these two elements. Respiration, photosynthesis, chlorophyll formation, and the water content of leaves can all be impacted by a potassium shortage. Potassium accelerates the absorption of carbon dioxide into crop leaves and speeds up the transfer of carbon [9].

Materials and methods

Location and duration

The field experiment was carried out at SEKEM Company Farm, Belbes, Sharkia Governorate west of the Nile Delta, Egypt (30°35'15.65‘N and 31°30'7.20‘ E) using drip irrigation system during the two successive seasons of 2018/2019 and 2019/2020 to study the impact of application of different potassium fertilizer treatments and number of additions on growth, production, and some chemical constituents of *P. vulgaris* plant.

Plant material

Seeds were obtained from Pharmasaat-Seeds and Plants Company (Pharmasaat-Seeds and Plants of Medicinal and Spice Herbs) and cultivated in trays on October 1, 2018 and October 8, 2019, respectively. The seedlings with suitable size and good root system were transplanted in the field on November 10, 2018 and November 27, 2019, respectively. Air temperature and relative humidity of the experimental region during the growing period are illustrated in Table 1.

Nature of soil

The preparation of soil was performed 2 weeks before transplantation. The physical and chemical analyses of the used soil were determined according to Jackson [10] and are presented in Table 2, which shows that the soil was sandy loam soil. During soil preparation, 20 m^3/fed of compost, 400 kg/fed of calcium superphosphate (15.5% P_2O_5), and 75 kg/fed of elemental sulfur (99.9% S) were added.

All treatments received 500 kg/fed of ammonium sulfate (20.5% N) in three doses during plant growth period. Plants were irrigated with drip irrigation system at the rate of 4 l/h. The chemical analysis of the used compost was performed according to Jackson [10] and the results are shown in Table 3.

Experimental design

The factorial experiment was planned in a completely randomized design of all combinations between three doses of potassium sulfate (20, 40, and 60 U) and three added portions (each dose added once) (after 40 days from transplantation) or divided into two (after 40 and 80 days from transplantation) or three (after 40, 80, and 120 days from transplantation). The experiment included nine treatments with three replicates.

Data recorded

Plant diameter, fresh and dry weight of herb (g/plant and ton/ha), and fresh and dry weight of flowering clusters (g/plant and ton/ha) were recorded at the end of May in both seasons. Photosynthetic pigments in leaves (mg/g fresh leaves) were determined according

Table 1 Monthly average of metrological data of the experimental area during 2018/2019 and 2019/2020 seasons

2018/2019 season					2019/2020 season				
	Air temperature (°C)					Air temperature (°C)			
Month	Maximum	Minimum	Average	R.H. %	Month	Maximum	Minimum	Average	R.H. %
October 2018	34	17	26	54	October 2019	35	19	26	59
November 2018	31	15	21	59	November 2019	32	13	22	54
December 2018	23	10	17	58	December 2019	24	9	16	56
January 2019	25	7	14	46	January 2020	21	6	13	59
February 2019	31	10	16	54	February 2020	26	9	15	61
March 2019	29	10	18	55	March 2020	30	10	18	55
April 2019	35	13	21	48	April 2020	34	14	21	50
May 2019	45	16	27	50	May 2020	43	17	26	45

R.H, relative humidity.

Table 2 The physical and chemical properties of the experimental soil during 2018/2019 and 2019/2020 seasons

	Physical properties						
	Very coarse sand (2–1 mm)	Coarse sand (1–0.5 mm)	Medium sand (0.5–0.25 mm)	Fine sand (0.25–0.1 mm)	Very fine sand	Silt +clay (0.5> mm)	Texture
2018	12.73	55.70	0.29	20.04	8.77	2.38	Sandy
2019	10.73	59.03	0.69	18.77	9.27	1.50	Sandy

	Chemical properties									
			(mEq/l)							
	pH (2.5 : 1)	E.C. dSm^{-1} (1 : 1)	Cations				Anions			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{-}	HCO_3^{-}	Cl^{-}	So_4^{-}
2018	8.04	0.55	2.0	0.5	2.64	0.4	–	1.2	3.5	1.84
2019	8.07	0.82	3.0	0.5	4.92	0.5	–	2.0	3.7	3.22

to Moran [11]. Total phenols (mg/g dry weight) were determined in leaves and flowers according to Singleton *et al.* [12]. Antioxidant activity (%) was determined in leaves and flowers depending on the ability of the extract to scavenge DPPH free radicals according to the standard method [13] and the suitable modifications [14]. N, P, and K were determined in acid-digested solution, which was prepared according to Piper [15] using a mixture of perchloric acid and sulfuric acid (4 : 10). Element extraction was made on a known weight of dried samples (0.5 g).

Statistical analysis

The recorded data were analyzed as completely randomized design by analysis of variance using the General Linear Models procedure of Co Stat [16]. Least significant difference test was applied at 0.05 probability levels to compare the mean of the treatments.

Table 3 The chemical analysis of the used compost during 2018/2019 and 2019/2020 seasons

Characters	2018/2019	2019/2020
pH (1 : 10)	7.57	6.99
E.C. (dSm-1) (1 : 10)	3.67	4.16
Organic matter (%)	26.5	39.4
Organic carbon (%)	15.4	22.9
Total nitrogen (%)	0.92	1.28
C/N ratio	17:1	18:1
Total phosphorus (%)	0.12	0.31
Total potassium (%)	1.42	0.56
Ash (%)	73.5	60.6

Results and discussion

Application of the three potassium doses, the number of the added portions, and their interactions significantly affected plant diameter, fresh, and dry weights of *P. vulgaris* in both seasons indicated in Table 4. Increasing potassium fertilization increased plant diameter, where application of 60 U of potassium gave the highest average value of plant diameter.

Dividing the potassium amount into two or three portions was more effective on plant diameter than addition of the amount once to the plant. The highest values of plant diameters were observed with application of 60 U of potassium that divided into three portions in the first season or two portions in the second season.

Increasing potassium fertilization from 20 to 40 U increased fresh and dry weights of *Prunella*, but increasing potassium from 40 to 60 decreased fresh and dry weights in the first season. In the second season, increasing potassium up to 60 U increased both fresh and dry weights.

Dividing the potassium amount into three portions was more effective on plant fresh and dry plant weights than application of the amount once or twice to the plant in both seasons. Regarding the interaction between potassium doses and number of portions, either 40 or 60 U that divided into three portions gave the heaviest fresh and dry weights in both seasons.

Table 4 Effect of potassium fertilization on plant diameter (cm) and herb weight (g/plant) of *Prunella vulgaris* during two seasons

Treatments		Plant diameter (cm)		Fresh weight (g/plant)		Dry weight (g/plant)	
K_2O units	Number of portions	1st season	2nd season	1st season	2nd season	1st season	2nd season
20	1	70.7	74.3	1013.7	939.2	252.1	225.4
	2	72.7	81.3	1124.8	1058.0	279.7	253.9
	3	77.3	86.0	1611.2	1345.0	374.7	322.8
40	1	72.3	79.3	1060.6	1247.2	267.8	299.3
	2	74.3	84.0	1705.6	1558.8	391.6	374.1
	3	81.3	85.3	2052.1	1758.5	497.1	422.0
60	1	75.3	93.0	1143.1	1532.3	293.1	367.7
	2	84.3	93.3	1530.2	1848.2	348.1	443.6
	3	89.3	90.0	1584.7	2064.8	375.0	495.6
L.S.D. at 5%		3.33	5.73	295.85	80.65	65.95	20.09
K_2O units							
20		73.6	80.6	1249.9	1114.1	302.2	267.4
40		76.0	82.9	1606.1	1521.5	385.5	365.1
60		83.0	92.1	1419.3	1815.1	338.7	435.6
L.S.D. at 5%		1.92	3.31	170.88	46.58	38.09	11.60
Number of portions							
1		72.8	82.2	1072.5	1239.5	271.0	297.5
2		77.1	86.2	1453.5	1488.3	339.8	357.2
3		82.7	87.1	1749.3	1722.8	415.6	413.5
L.S.D. at 5%		1.92	3.31	170.88	46.58	38.09	11.60

The same trend previously discussed for both the fresh and dry plant weight of the amount of potassium fertilizer and the number of times of application was observed on the yield of the fresh and dry herb for ton per hectare (Table 5). The interaction between potassium doses and number of portions, either 40 or 60 U that divided into three portions, gave the largest fresh and dry yields in both seasons 34.4, 34.2 ton per hectare fresh yield, and 8.3 ton per hectare dry yield in the first and second season, respectively. Potassium is an essential element for plants to maintain normal growth and development they need, which is taken from the soil.

Because it is necessary for numerous biochemical and physiological activities, such as protein synthesis, glucose metabolism, and enzyme activation, potassium excess or deficiency affects the plant's growth. These results agree with those of Rani *et al.* [17] who mentioned that potassium has an important role for plant growth. Additionally, it affects other essential processes, including the usage of nitrogen, protein production, cell growth, and expansion (by promoting gibberellins). As a result, the plant height, FW, and DW for *Brassica juncea* plants had considerably increased.

The weight (g/plant) and yield (ton/ha) for *P.* vulgaris flowering clusters are shown in Table 6 and showed significant effect for both potassium doses and the number of the added portions along or with their interactions on fresh and dry flowering cluster weights in both seasons. Increasing potassium fertilization increased fresh and dry flowering cluster weight and yield, where application of 60 U of potassium gave the highest average value of fresh and dry flowering cluster weight and yield. Dividing the potassium amount into three portions was more effective on fresh and dry flowering cluster weight and yield than application of the amount once to the plant. The highest values of fresh and dry flowering cluster weight and yield of Prunella plant were observed with application of 60 U of potassium that divided into three portions in both seasons.

Potassium could have improved fresh and dry flowering cluster weight and yield in the Prunella plants by activating the enzymes that control in flowering process. K also enhances the water intake and nutrients, most essentially in the transfer of starch reserves required for the induction of Prunella flowers. These results are in agreement with Daneshkhah *et al.* [18] on rose plants [19], on roselle plant, and [20] on marigold plant, who reported that potassium fertilization increased flowering yield.

There was a significant effect for both potassium doses and the number of the added portions along or with their interactions on chlorophyll a, chlorophyll b, and total carotenoids in both seasons Table 7. Increasing potassium fertilization increased chlorophyll a,

Table 5 Effect of potassium fertilization on herb yield (ton/ha) of *Prunella vulgaris* during two seasons

Treatment		Fresh yield (ton/ha)		Dry yield (ton/ha)	
K_2O units	Number of portions	1st season	2nd season	1st season	2nd season
20	1	16.9	15.7	4.2	3.8
	2	18.7	17.6	4.7	4.2
	3	26.9	22.4	6.2	5.4
40	1	17.7	20.8	4.5	5.0
	2	28.4	26.0	6.5	6.2
	3	34.2	29.3	8.3	7.0
60	1	19.1	25.5	4.9	6.1
	2	25.5	30.8	5.8	7.4
	3	26.4	34.4	6.2	8.3
L.S.D. at 5%		4.93	1.33	1.11	0.33
K_2O units					
20		20.8	18.6	5.0	4.5
40		26.8	25.4	6.4	6.1
60		23.7	30.3	5.6	7.3
L.S.D. at 5%		2.85	0.77	0.64	0.19
Number of portions					
1		17.9	20.7	4.5	5.0
2		24.2	24.8	5.7	6.0
3		29.2	28.7	6.9	6.9
L.S.D. at 5%		2.85	0.77	0.64	0.19

Table 6 Effect of potassium fertilization on flowering cluster weight (g/plant) and yield (ton/ha) of *Prunella vulgaris* plants during two seasons

Treatments		Fresh weight (g/plant)		Dry weight (g/plant)		Fresh yield (ton/ha)		Dry yield (ton/ha)	
K_2O units	Number of portions	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
20	1	32.0	22.8	9.0	6.1	0.53	0.38	0.15	0.10
	2	38.0	31.8	10.6	8.6	0.63	0.53	0.18	0.14
	3	44.4	41.6	12.5	11.2	0.74	0.69	0.21	0.19
40	1	32.4	32.9	9.1	8.9	0.54	0.55	0.15	0.15
	2	39.6	42.3	11.1	11.4	0.66	0.70	0.18	0.19
	3	58.7	61.5	16.4	16.6	0.98	1.03	0.27	0.28
60	1	60.7	62.9	17.0	17.0	1.01	1.05	0.28	0.28
	2	69.3	71.6	19.4	19.3	1.16	1.19	0.32	0.32
	3	73.2	75.7	20.5	20.4	1.22	1.26	0.34	0.34
L.S.D. at 5%		6.32	6.82	1.75	1.84	0.107	0.114	0.030	0.032
K_2O units									
20		38.1	32.0	10.7	8.7	0.64	0.53	0.18	0.14
40		43.6	45.6	12.2	12.3	0.73	0.76	0.20	0.21
60		67.8	70.1	19.0	18.9	1.13	1.17	0.32	0.32
L.S.D. at 5%		3.65	3.94	1.01	1.06	0.062	0.066	0.017	0.019
Number of portions									
1		41.7	39.6	11.7	10.7	0.69	0.66	0.19	0.18
2		49.0	48.5	13.7	13.1	0.82	0.81	0.23	0.22
3		58.8	59.6	16.5	16.1	0.98	0.99	0.27	0.27
L.S.D. at 5%		3.65	3.94	1.01	1.06	0.062	0.066	0.017	0.019

Table 7 Effect of potassium fertilization on photosynthetic pigments (mg/g fresh leaves) of *Prunella vulgaris* plants during two seasons

Treatments		Chlorophyll a		Chlorophyll b		Total carotenoids	
K_2O units	Number of portions	1st season	2nd season	1st season	2nd season	1st season	2nd season
20	1	1.39	2.59	0.57	0.98	0.81	1.38
	2	1.90	3.23	0.80	1.28	1.14	1.75
	3	2.00	3.52	0.86	1.76	1.27	2.02
40	1	1.57	3.67	1.16	1.33	1.12	2.00
	2	2.43	2.55	1.28	1.51	1.59	1.95
	3	2.91	3.10	0.99	1.70	1.96	1.64
60	1	2.25	2.82	1.02	1.35	1.36	1.44
	2	3.06	2.52	1.40	1.66	1.63	1.45
	3	2.55	2.16	1.40	1.72	1.33	1.60
L.S.D. at 5%		0.329	0.173	0.239	0.232	0.242	0.212
K_2O units							
20		1.76	3.12	0.74	1.34	1.07	1.71
40		2.30	3.11	1.14	1.51	1.56	1.87
60		2.62	2.50	1.27	1.58	1.44	1.50
L.S.D. at 5%		0.190	0.100	0.138	0.134	0.140	0.122
Number of portions							
1		1.74	3.03	0.92	1.22	1.10	1.61
2		2.47	2.77	1.16	1.49	1.45	1.72
3		2.49	2.93	1.08	1.73	1.52	1.75
L.S.D. at 5%		0.190	0.100	0.138	0.134	0.140	ns

chlorophyll b, and total carotenoids, where application of 60 U of potassium gave the highest average value of chlorophyll a in the first season and chlorophyll b in both seasons, while application of 20 U of potassium resulted in the greatest value of chlorophyll a, followed by 40 U of potassium with no significant difference between them. Whereas, application of 40 U of potassium gave the highest average value of total carotenoids.

Dividing the potassium amount into two or three portions was more effective on photosynthetic

Table 8 Effect of potassium fertilization on total soluble phenols (mg/g dry weight) and antioxidant activity (%) of *Prunella vulgaris* plants during two seasons

Treatments		Total soluble phenols herb flowers				Antioxidant activity herb flowers			
K_2O units	Number of portions	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
20	1	50.4	55.8	47.4	49.3	49.5	51.8	41.1	42.6
	2	37.8	42.6	35.1	37.9	54.2	55.3	43.3	44.4
	3	67.4	60.9	40.7	45.2	61.2	67.2	47.1	52.1
40	1	57.8	54.9	44.5	49.6	57.7	57.0	44.6	56.9
	2	51.1	63.1	53.1	60.9	65.2	69.1	60.8	63.0
	3	48.7	59.6	62.9	46.3	60.7	73.4	67.8	64.7
60	1	56.0	67.9	41.5	57.0	62.2	67.5	61.1	61.4
	2	57.0	66.6	60.2	62.7	65.3	72.5	61.4	66.4
	3	48.1	58.9	63.5	62.5	68.4	74.3	69.8	67.9
L.S.D. at 5%		1.41	2.61	2.36	2.09	3.35	5.85	5.11	ns
K_2O units									
20		51.9	53.1	41.1	44.1	55.0	58.1	43.8	46.4
40		52.5	59.2	53.5	52.3	61.2	66.5	57.7	61.6
60		53.7	64.5	55.1	60.7	65.3	71.5	64.1	65.2
L.S.D. at 5%		0.82	1.51	1.36	1.21	1.94	3.38	2.95	2.57
Number of portions									
1		54.7	59.6	44.5	52.0	56.5	58.8	49.0	53.7
2		48.6	57.4	49.5	53.8	61.6	65.7	55.2	57.9
3		54.7	59.8	55.7	51.3	63.4	71.6	61.6	61.6
L.S.D. at 5%		0.82	1.51	1.36	1.21	1.94	3.38	2.95	2.57

pigments than adding the whole amount once. The highest values of chlorophyll a and carotenoids in fresh leaves of Prunella plant were observed with application of 60 U of potassium that divided into two portions in the first season, but application of 60 units of potassium that divided into three portions gave the highest values of chlorophyll b in both seasons.

The significant increase in the contents of photosynthetic pigment with increased potassium application may be attributed to the increased nitrogen availability, which may increase chlorophyll formation due to the importance of nitrogen in chlorophyll composition and synthesis, thus increasing its absorption by the plant, accelerated uptake of N, enhanced N metabolism, stimulated assimilation and protein production, and finally increased chlorophyll content. The data are in agreement with those obtained by the authors [9,21,22], they reported increased leaf pigment contents with fertilization with the highest level of potassium.

The total soluble phenols (mg/g dry weight) and antioxidant activity (%) of *P. vulgaris* herb and flowering clusters showed significant effect for both potassium doses and the number of the added portions along or with their interactions on total soluble phenols and antioxidant activity (%) in Prunella herb and flowering clusters in both seasons indicated in Table 8. Increasing potassium fertilization increased total soluble phenols and antioxidant activity in Prunella herb and flowering clusters, application of 60 U of potassium gave the highest average value of total soluble phenols, and antioxidant activity in Prunella herb and flowering clusters.

Dividing the potassium amount into three portions was more effective on total soluble phenols and antioxidant activity (%) than other applications. The highest values of Prunella total phenols in flowering clusters and antioxidant activity (%) in herb and flowering clusters were observed with application of 60 U of potassium that divided into three portions in both seasons. The highest values of total phenols in Prunella flowering clusters were recorded with application of 60 U of potassium that divided into two and three portions in the second season with no significant differences. Kane *et al.* [23] reported that antioxidant activity was associated with photorespiratory detoxification of H_2O_2 through mitochondrial electron transport systems. Potassium similarly plays a significant role in minimizing oxidative stress because it can maintain the level of NADPH oxidase activity and the photosynthetic electron transport system explains antioxidant activation by supplying KNO_3 [24]. Generally, results of many studies reported that applying a high

Table 9 Effect of potassium fertilization on nitrogen, phosphorus, and potassium concentrations (%) of *Prunella vulgaris* plants (herb and flowering clusters) during second season

Treatments				
K_2O units	Number of portions	Nitrogen (%)	Phosphorus (%)	Potassium (%)
20	1	1.70	0.25	4.52
	2	1.84	0.28	4.60
	3	1.99	0.32	5.06
40	1	2.01	0.29	4.74
	2	2.67	0.30	4.95
	3	3.02	0.35	5.00
60	1	2.21	0.31	4.93
	2	3.26	0.36	5.37
	3	3.54	0.40	5.76
L.S.D. at 5%		0.337	ns	0.261
K_2O units				
20		1.84	0.28	4.73
40		2.57	0.31	4.90
60		3.00	0.35	5.36
L.S.D. at 5%		0.195	0.348	0.151
Number of portions				
1		1.97	0.28	4.73
2		2.59	0.31	4.97
3		2.85	0.36	5.27
L.S.D. at 5%		0.195	0.348	0.151

rate of potassium fertilizer increases the secondary metabolites as total phenolic and antioxidant activity in different medicinal and aromatic plants such as [25] on sweet basil plant [26], on sweet fennel, and [27] on red ginger, who revealed that the antioxidant content of red ginger rhizomes was affected by changes in potassium fertilization dosages; the application of 180–300 kg/K/ha had a greater antioxidant content than the control (without K fertilization).

There were significant effects for both potassium doses and the added portions along or with their interactions on the percentage of nitrogen, phosphorus, and potassium in Prunella plants (Table 9).

Increasing potassium fertilization from 20 to 60 U increased concentration of nitrogen, phosphorus, and potassium in dry aerial parts (herb and flowering clusters) of Prunella plant. Fertilization with 60 U of potassium resulted in the highest percentage of nitrogen, phosphorus, and potassium in Prunella plant. Dividing the potassium amount into three portions was more effective on nitrogen, phosphorus, and potassium concentration than adding at once or divided into two portions.

Regarding the interaction between potassium doses and number of added portions, 60 U that divided into three portions gave the highest nitrogen and potassium percentage, but there were no significant differences between this treatment and 60 U that divided into two portions. Whereas, the interaction between potassium doses and number of portions was insignificant on phosphorus percentage. These results may be related to potassium's function in plant metabolism and other significant regulatory mechanisms and it may represent a rise in plant mineral absorption. These results are in harmony with the authors [21,28–30].

Conclusion

The impact of application of different units of potassium and number of added portions on growth, production, and some chemical composition of *P. vulgaris* plant were studied. It may be concluded that increasing the amount of potassium fertilization from 20 to 60 U that added at two or three portions gave the highest vegetative growth and yield parameters of both herb and flowering clusters and increased quality and chemical composition of Prunella plants cultivated in Egypt.

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Conflicts of interest

There are no conflicts of interest.

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