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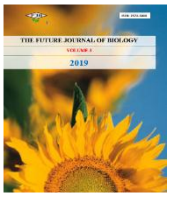

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EFFECT OF PRIMARY MINERAL FERTILIZERS IN DIFFERENT FORMS AND RATES ON THE PRODUCTIVITY, OXALATE AND NITRATE CONCENTRATION IN SPINACH PLANTS

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ABSTRACT: During the winter seasons of 2017/2018 and 2018/2019, this study was carried out at El-Khattara Experimental Farm, Faculty of Agriculture, Zagazig University, Sharkia Governorate (Egypt), to investigate the effects of N, P, and K rates as well as foliar spray with Micro plant 19 compound (MP19) on growth, yield and quality of spinach plants. The treatments were as follows: Fertilizing with 100 % NPK of recommended rate (RR),100% NPK of RR+ spraying with (MP19), 50 % N+75 % P+50 % K of RR + (MP19), 50 % N+100 % P+50 % K of RR + (MP19), 50 % N+125 % P+50 % K of RR + (MP19) and 50 % N+150 % P+50 % K of RR + (MP19). Fertilizing spinach plants with 100 % NPK+ spraying with (MP19) resulted in a significant increase in plant height, number of leaves/plant, fresh and dry weight/plant, in addition, nitrogen, phosphorus and potassium uptake by leaves of plant and total yield per feddan. Whereas, fertilizing spinach plants with 50 % N+150 % P+50% K of RR and spraying with (MP19) reduced both of nitrate and oxalate concentration in leaves.

Key words: Spinach, Mineral fertilizers, Foliar Spray, nitrate, Oxalate and Yield.

INTRODUCTION

One of Egypt's most popular leafy vegetable crops is spinach (*Spinacia oleracea* L.). It is using fresh or frozen or canned. Spinach is a high-value vegetable that is high in antioxidants like beta-carotene and lutein, both of which have antioxidant and anticancer properties (**Cho *et al*., 2008**). It is also a good source of vitamins, minerals, fibres, folic and oxalic acid (**Rabie *et al*., 2014**).

Artificial fertilizers are inorganic fertilizers that have been formulated in the right amounts and combinations. The availability of nitrogen, phosphorus, and potassium had a significant impact on vegetative growth and dry matter. Furthermore, many researchers discovered that providing spinach plants with NPK mineral fertilizers, either by adding them to the soil or spraying them, resulted in the best plant growth and yield (**Popat and Mahorkar, 2009, Ahmadi *et al*., 2010, Hossain *et al*., 2014, Solangi *et al*., 2015** and **Zaman *et al*. 2018).** Moreover, phosphorus is an essential nutrient in plants as a part of several key plant structure compounds and serves as a catalyst in the conversion of a variety of key biochemical reactions. Phosphorus is stimulated root development, increased stem strength, more uniform and earlier crop maturity (**Griffith, 2010**). Also, **Mirjalili and Poorazizi (2018)** found that, super phosphate increased fresh and dry weights of spinach.

On the other hand, Excessive use of chemical fertilizers, particularly nitrogen fertilizers, increases the content of nitrate and oxalate in vegetables, and spinach, like other leafy vegetables, has a tendency to accumulate oxalate, nitrates, and nitrites. (**Jaworska, 2005**). Such compounds are undesirable because they are harmful to human health, Furthermore, a high oxalate diet can cause deficiencies in calcium, iron, magnesium and copper by forming insoluble oxalate salts that are difficult to absorb by the intestines (**Bohn *et al*., 2004**).

Wang and Ito (1998) reported that, increased nitrate uptake by roots resulted in nitrate and oxalate accumulation in spinach leaves. In addition, **Salman *et al*. (2000)** found that, NO_3, NO_2 and oxalate levels increased with increased N levels. Similar findings were obtained by **Odueso (2011), Ali *et al.* (2013), Hafez *et al.* (2015), Nemadodzi (2015), Fouda (2016), Alessa *et al*. (2017), Fekry and Nawar (2017)** and **Mitova *et al*. (2018).**

Therefore, the aim of this research was to determine the best combination of mineral NPK as soil application and foliar spray with Micro plant 19:19:19 for optimum growth, productivity and reducing calcium oxalate and nitrate concentrations in spinach leaves grown in sandy soil.

MATERIALS AND METHODS

A field experiment was carried out during winter seasons of 2017/2018 and 2018 /2019, to study the effect of mineral N, P and K rates and foliar spray with Micro plant 19 on growth, yield and quality of spinach cv. Balady (Sakiat Mekki) grown under sandy soil conditions using drip irrigation system. The used soil properties were: sandy soil in texture for the average two seasons, while it had 0.36% organic matter, 7.89 pH, 1.82 mmhos/cm EC, 14.35 available N, 11.02 available P and 58.41 available K as ppm. This experiment included sex treatments as follows:

1- 100 % NPK of recommended rate (RR).

2- 100 % NPK of RR + spraying with Micro plant 19.

3- 50 % N + 75 % P + 50 % K of RR + Micro plant 19.

4- 50 % N + 100 % P + 50 % K of RR + Micro plant 19.

5- 50 % N + 125 % P + 50 % K of RR + Micro plant 19.

6- 50 % N + 150 % P + 50 % K of RR + Micro plant 19.

The treatments were arranged in a randomized complete block design system with three replicates. Seeds of spinach were sown on 8th November in both growing seasons and space between hills 10cm apart on both sides of dripper line. Each experimental plot area was 12.6 m^2 consisted of 3 dripper lines, 0.7 m width and 6 m length. Micro plant 19: it is a commercial compound product contains 19 % N, 19 % P_2O_5, 19 % K_2O, 1% magniusum, 0.2% iron, 0.05 % molybdenum, 500 ppm manganese, 500 ppm zinc and 500 ppm cobalt. Micro plant 19 was sprayed twice (three and five weeks after planting) at a rate of 1.5 g/liter.

The recommended rates 100 % of NPK mineral fertilizers were 300 kg/fed. ammonium sulphate (20.5 % N), 250 kg /fed. calcium super phosphate (15.5 % P_2O_5) and 100 kg /fed. potassium sulphate (48 % K_2O). All rates of calcium superphosphate were added during soil preparation, potassium sulphate was added three weeks after planting, whereas ammonium sulphate was added in two doses, the first after planting about three weeks and the second after two weeks of the first dose.

Data Recorded

Plant growth: After 60 days from sowing, ten spinach plants were randomly taken from each experimental plot to record the vegetative growth parameters (plant height (cm), number of leaves, root length (cm), as well as fresh and dry weight per plant (g).

Leaf chemical composition: N, P and K contents were determined according to the methods described by **Bremner and Mulvaney (1982), Olsen and Sommers (1982)** and **Jackson (1970)**, respectively, N; P and K uptake were calculated.

Total yield: fresh weight of plants was recorded and calculated to obtain yield/fed.

Oxalate and nitrate concentrations: Nitrate concentration in leaves was determined according to **Chapman and Pratt (1982),** However Oxalate concentration was determined according to Human Nutrition Information Service, **USDA (1984).**

Statistical Analysis

According to **Snedecor and Cochran (1980),** all the obtained data were statistically analysed using the Statistix 9 program and means were separated using the least significant value (L.S.D.) at the 0.05 level of probability.

RESULTS AND DISCUSSION

1. Vegetative growth

Fertilizing spinach plants with mineral N, P and K at 100 % of the recommended rate (RR) plus spraying with Micro plant 19 had significantly increased plant height and number of leaves/plant, followed by fertilizing with 50N + 150 P + 50K % of RR and spraying with Micro plant 19, however, this treatment recorded the highest root length in both seasons (Table 1).

Table 1. Effect of mineral fertilizer rates and foliar spray with (Micro plant 19) on vegetative growth of spinach plants

Treatments	Plant height (cm)		Number of leaves / plant		Root length (cm)	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
100 % NPK of RR	28.75	31.00	13.00	12.25	13.50	13.25
100 % NPK of RR + FS	34.75	34.00	16.25	17.25	14.00	13.25
50 N + 75 P + 50 K % RR + FS	29.25	32.00	14.25	13.75	11.25	12.50
50 N + 100 P + 50 K % RR + FS	32.75	32.00	13.25	13.25	12.50	13.00
50 N + 125 P + 50 K % RR + FS	32.25	32.75	14.00	12.75	15.05	14.75
50 N + 150 P + 50 K % RR + FS	33.25	33.75	15.50	15.25	16.50	17.50
LSD at 0.05 level	0.92	1.48	0.92	1.29	1.11	0.18

FS = foliar spray with Micro plant (19:19:19 NPK). RR= recommended rate of NPK.

On the other hand, fertilizing with the 100 %NPK only recorded the lowest values of plant height and number of leaves/plant, while the lowest value of root length was obtained with fertilizing with 50 N+75 P + 50 K% + spraying with Micro plant 19 in both seasons. The improvement observed in spinach vegetative growth may be due to the positive response of plants to NPK nutrients as soil dressing and spraying Micro plant 19 which contain N, P_2O_5 and K_2O as well as micronutrients such as magnesium, iron, molybdenum, manganese, zinc and cobalt.

Moreover, the good effect of these elements on number of leaves was due to an increase in photosynthesis, which resulted in a higher accumulation of assimilates, which caused vigour plant growth. (**Nemadodzi, 2015**). And according to **Lynch *et al*. (2006)**, the availability of P regulates the growth of adventitious roots in several crops by more than 70%. This will improve nutrient acquisition by increasing soil exploration by the absorptive surface of the root system and P solubilization. In addition, **Azcon *et al*. (1996)** reported that**,** enhanced growth was also related to increased glutamine synthetization and protein formation in the plant body when phosphorus was supplied.

These results were agreeing with those reported by (**Popat and Mahorkar, 2009**, **Ahmadi *et al*., 2010** and **Fekry and Nawar, 2017)** they found that, providing spinach plants with NPK as mineral fertilizers, either added to the soil or sprayed on the plants, gave the best plant growth. Also, **Odueso (2011)** suggested that, NPK (20-10-10) was found to be more effective for spinach growth. In addition, **Joshi and Bhamburdeka (2015)** showed that, spraying micronutrients on spinach produced the best results for plant height and number of leaves per plant.

2. Fresh and dry weight

There were significant differences between all fertilization treatments which tested regarding fresh and dry weight of spinach plants in both seasons (Table 2).

Table 2. Effect of mineral fertilizer rates and foliar spray with (Micro plant 19) on fresh and dry weight/plant of spinach plants

Treatments	Fresh weight/plant (g)		Dry weight/plant (g)	
	Season 1	Season 2	Season 1	Season 2
100 % NPK of RR	37.52	42.48	4.78	4.06
100 % NPK of RR + FS	59.73	64.72	6.88	6.94
50 N + 75 P + 50 K % RR + FS	50.35	54.80	5.86	5.54
50 N + 100 P + 50 K % RR + FS	45.44	44.80	5.12	4.82
50 N + 125 P + 50 K % RR + FS	45.18	46.75	5.64	5.10
50 N + 150 P + 50 K % RR + FS	56.59	58.77	6.10	6.40
LSD at 0.05 level	1.81	1.84	0.08	0.29

FS = foliar spray with Micro plant (19:19:19 NPK). RR= recommended rate of NPK.

Fertilization of spinach plants with mineral NPK at 100 % and spraying with Micro plant 19 significantly increased fresh and dry weight/plant, followed by 50N +150P +50K % of RR plus spraying with Micro plant 19 in both seasons. The least values of fresh and dry weight were recorded with 100 % NPK only in both seasons.

The favourable effects of N, P, K, and micronutrients on plant growth may be due to the increased fresh and dry weight of plant parts. The results of this study concur with that of **Popat and Mahorkar (2009), Ahmadi *et al.* (2010)** and **Alessa *et al.* (2017)** with respect to the effect of NPK fertilizers, **Fouda (2016)** found that, NPK fertilization up to 100 % significantly increased, fresh and dry weight in spinach plants. Also, **Mirjalili and Poorazizi (2018)** reported that, both of nitrogen and phosphorus increased fresh and dry weight of spinach plants. As for foliar spray, **Joshi and Bhamburdeka (2015)** indicated that, spraying with micronutrients at 1 ppm resulted in the optimum fresh and dry weight of spinach shoots.

3. Nitrogen, phosphorus and potassium contents

Data presented in Table 3 illustrate that, there were significant differences between all fertilizing treatments which tested and using NPK at 100 % RR + spraying with Micro plant 19 had a positive effect on both nitrogen and potassium content in leaves, while the highest value of phosphorus content was recorded under NPK at 100 % RR only in both seasons.

Table 3. Effect of mineral fertilizer rates and foliar spray with (Micro plant 19) on N, P and K contents in spinach leaves

Treatments	N (%)		P (%)		K (%)	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
100 % NPK of RR	1.70	1.78	0.160	0.173	5.94	5.03
100 % NPK of RR + FS	1.86	1.85	0.143	0.166	6.04	6.10
50 N + 75 P + 50 K % RR + FS	1.63	1.57	0.125	0.130	4.89	4.17
50 N + 100 P + 50 K % RR + FS	1.77	1.83	0.148	0.155	5.12	4.90
50 N + 125 P + 50 K % RR + FS	1.65	1.80	0.155	0.166	5.59	3.96
50 N + 150 P + 50 K % RR + FS	1.70	1.90	0.126	0.165	5.77	5.35
LSD at 0.05 level	0.09	0.07	0.009	0.007	0.83	0.81

FS = foliar spray with Micro plant (19:19:19 NPK). RR= recommended rate of NPK.

On the contrary, the lowest values of the three minerals content in leaves were obtained with the treatment of 50N + 75P + 50K % of RR + foliar spray with Micro plant 19 in both seasons in most cases. The increase in N, P, and K concentrations with higher NPK fertilization rates could be attributed to increased availability of N, P, and K elements for the plant, as well as improved root growth and thus increased root absorbing area **(Fouda, 2016)**. These findings are consistent with those found by **(Hossain *et al*., 2014** and **Nemadodzi, 2015)**.

4. Nitrogen, phosphorus and potassium uptake

Data presented in Table (4) indicate that, fertilizing spinach plants grown in sandy soil with different rates of mineral N, P and K + spraying with Micro plant 19 reflected a significant effect on N, P and K uptake by leaves in both seasons.

Table 4. Effect of mineral fertilizers rates and foliar spray with (Micro plant 19) on N, P and K uptake by spinach leaves

Treatments	Minerals uptake (mg/g. dry weight)					
	N		P		K	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
100 % NPK of RR	99.62	98.61	9.38	9.58	348.08	278.66
100 % NPK of RR + FS	127.97	128.39	9.84	11.52	415.55	423.34
50 N + 75 P + 50 K % RR + FS	77.91	63.74	5.98	5.28	233.74	169.30
50 N + 100 P + 50 K % RR + FS	90.62	88.21	7.58	7.47	262.14	236.18
50 N + 125 P + 50 K % RR + FS	93.06	91.80	8.74	8.47	315.28	201.96
50 N + 150 P + 50 K % RR + FS	103.70	121.60	7.69	10.56	351.97	342.40
LSD at 0.05 level	5.19	8.16	1.02	0.95	11.34	17.33

FS = foliar spray with Micro plant (19:19:19 NPK). RR= recommended rate of NPK.

The highest values of nitrogen, phosphorus and potassium uptake by spinach plants were achieved by plants which treated with NPK at 100 % RR+ foliar spray with Micro plant 19 treatment, followed by the treatment of 50N +150P +50K % of RR + foliar spray with Micro plant 19, while fertilizing with NPK at 100 % RR only came in the third rank. On the other hand, the lowest values of N, P and K uptake by plant leaves were recorded with the treatment of 50N + 75 P + 50K % + spraying with Micro plant 19 in both seasons.

5. Total yield

Data tabulated in Fig.1 refer that, presence of significant differences between all fertilization treatments concerning yield/fed. in both seasons.

In this regard, two fertilization treatments only i.e., fertilizing with NPK at 100 % RR + spraying with Micro plant 19 and fertilizing with 50N +150P +50K % of RR + foliar spray with Micro plant 19 recorded significant increasing in total yield, while the other treatments recorded decreasing in total yield as compared NPK at 100 % RR only in both seasons. This means that, fertilizing spinach plants with NPK at 100% RR + spraying with Micro plant 19 significantly increased total yield in both seasons.

The increases of total yield /fed. might be due to the favorable effect on dry weight (Table 2), N, P and K uptake /plant (Table 3). In addition, **Griffith (2010)** found that**,** as a result of the added phosphorus, root development was promoted, stem strength was increased, and crop maturity was more uniform and early. Also, **Mirjalili and Poorazizi (2018)** reported that, phosphorus has an effect on spinach yield indices by increasing the area and efficiency of plant roots. These results are consistent with that of (**Odueso, 2011, Ali *et al*., 2013, Hossain *et al*.,2014, Nemadozi, 2015, Solangi *et al*., 2015, Fouda, 2016, Alessa *et al*., 2017 and Zaman *et al*., 2018**).

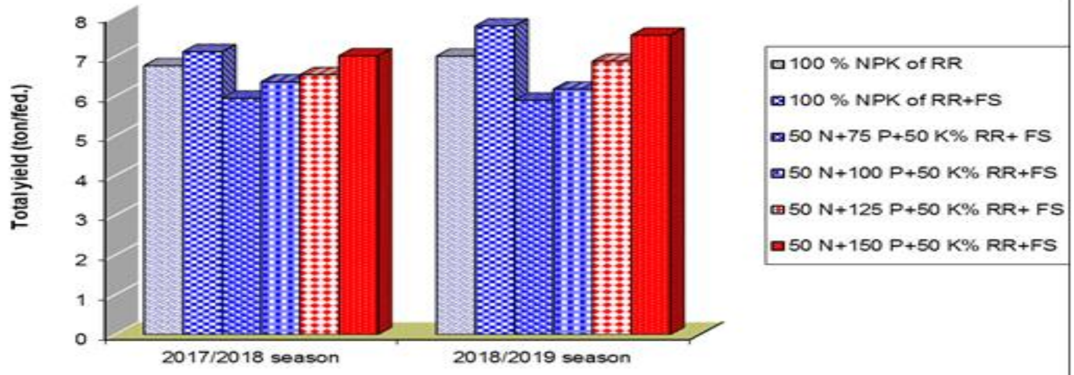

Fig 1 : Effect of mineral fertilizer rates and foliar spray with (Micro plant 19) on the yield of spinach plants

6. Nitrate and oxalate concentration in leaves

Data recorded in Figs 2 and 3 show the effect of soil mineral NPK fertilizers rates added as soil application and foliar spray with Micro plant 19 on nitrate and oxalate concentration in leaves of spinach plants. Fertilizing plants with 50N +150 P +50K % of RR + spraying with Micro plant 19 significantly reduced the concentrations of nitrate and oxalate in leaves, followed by fertilizing with 50N + 125 P + 50 K% + spraying with Micro plant 19 in the 1st and 2nd seasons respectively.

On the other hand, the maximum concentration of nitrate and oxalate were obtained with NPK at 100 % RR only. **Wang *et al.* (1998)** reported that, the enhanced uptake of nitrate by roots resulted in accumulation of nitrate and oxalate in spinach leaves. Similar findings were obtained by (**Odueso, 2011, Ali *et al.*, 2013, Fouda, 2016, Hafez *et al.*, 2015, Nemadodzi, 2015, Alessa *et al*., 2017, Fekry and Nawar, 2017** and **Mitova *et al*., 2018).**

From the foregoing results, it could be concluded that, fertilizing spinach plants with 100 % NPK of RR plus spraying with Micro plant 19 was the best treatment for increasing growth and productivity, while fertilizing with 50N +150 P +50 K % of RR and spraying with Micro plant 19 reduced both nitrate and oxalate concentration in leaves.

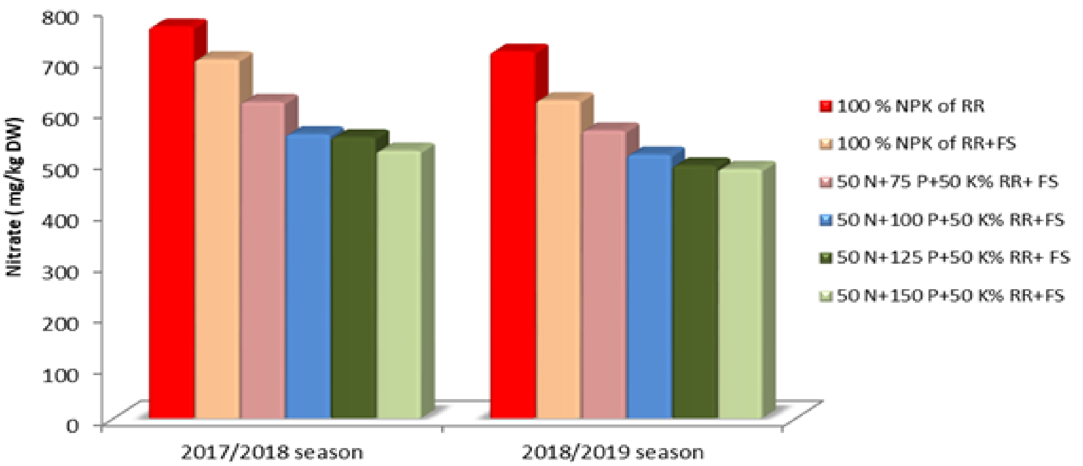

Fig 2: Effect of mineral fertilizer rates and foliar spray with (Micro plant 19) on nitrate concentration in leaves of spinach plants

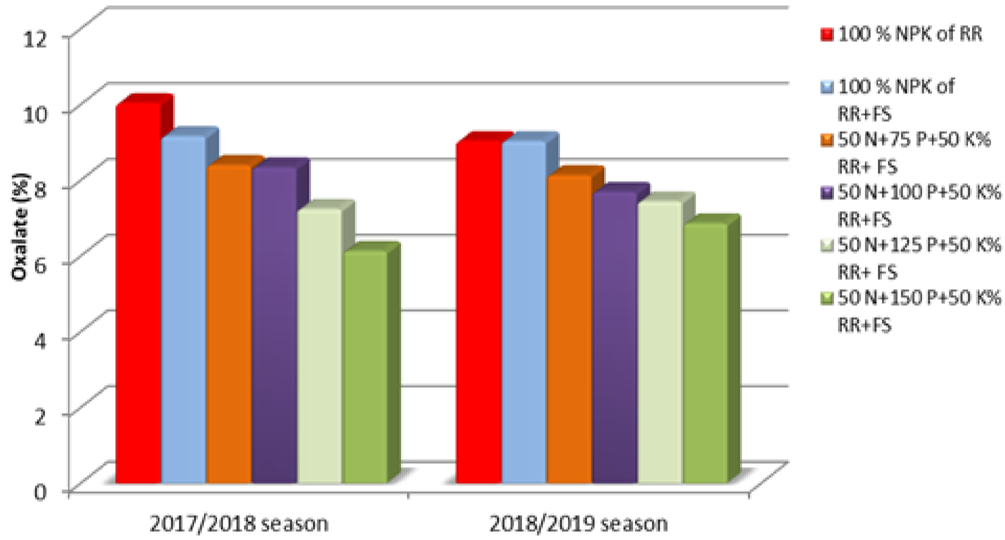

Fig 3: Effect of mineral fertilizer rates and foliar spray with (Micro plant 19) on oxalate concentration in leaves of spinach plants

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