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Influence of fertilizer application on biomass yield and nutritional quality of Mustard Spinach (*Florida)* Broadleaf in South Africa

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Abstract. Mustard Spinach (*Florida Broadleaf*) is an indigenized leafy vegetable grown in Southern Africa. It is a good source of vitamins and mineral nutrients. An understanding of its response to fertilizer application is important in developing cultural practices for improved yield of the crop. Furthermore, improving fertilizer use efficiency such as nitrogen (N), phosphorus (P) and potassium (K) would result in improving cropping system. Therefore, a field experiment was conducted in 2010 and 2011 winter cropping season to determine the influence of NPK applications and their interactions on biomass yield and nutritional values of Mustard spinach. A randomized complete block design replicated four times were used for the experiment. ANOVA showed significant variation among the treatments. The values for total fresh biomass yield ranged from 252–4,510 and 820–4,982 kg ha^{-1} in 2010 and 2011 cropping seasons, respectively. Omission of P had 4,510 kg ha^{-1} of total fresh biomass yield, while omission of K had 4,506 kg ha^{-1} in the first season. The lowest N content (2.63%) was recorded when nitrogen fertilizer was omitted. Full NPK application increased the content of N and K on the leaf tissues of Mustard Spinach. The highest percentage of dietary fiber was observed when K was omitted. The values recorded for ascorbic acid content varied from 126.94 and 117.42 mg $100g^{-1}$, respectively for both seasons. Iron was more concentrated on the treatments, where K was omitted. Mustard Spinach responded to fertilizer application and the results validated that application of NPK had a beneficial effect on increased production and productivity of the crop tested for small scale farmers.

Key words: mustard spinach, marketable, nutrient omission, dietary fibre, interaction, outperformed, micronutrients.

INTRODUCTION

Africa has a wide ranges of indigenous and indigenized vegetables that are under-utilized and marginalized (Smartt & Haq, 1997) can be utilized for food, nutritional and health security. Mustard Spinach (*Florida Broadleaf*), *Brassica juncea* is an exotic leafy vegetable crop mainly grown in most parts of South Africa for its edible parts (Maboko, 2013). The fresh leaves of Mustard Spinach are mainly eaten in different forms (Grubben & Denton, 2004). In South Africa, it is commonly known by the local name 'Motshaina' specially in the northmost part of the country (Maboko, 2013). Maboko (2013) further reported that the crop is a cool season and fast growing crop that reaches maturity at 35–65 days after transplanting to the field. The crop is a good source of dietary fiber, provitamin A, ascrobic acid, vitamin K, thiamine, riboflavin, vitamin B6, folate and mineral nutrients (Van Wyk, 2005). Mustard spinach is commonly grown to provide essential mineral and organic nutrients to humans for the benefit of health, nutritional and food security.

Agricultural production systems in many developing countries needs to provide enough food coupled with nutrients to meet human needs, therefore cultivation of vegetables and their agronomic practices has to be intensified. Intensified agricultural production includes cultivation practices such as irrigation, fertilizer application as well as nutrient use efficiency to maximise yield potential of the crop. Nitrogen, phosphorus and potassium are key mineral nutrient in the production of agricultural crops as they enhance yield by promoting cell division and expansion in leaves, and root development (Makus, 1992). Leafy vegetables such as cabbage, spinach, lettuce and celery provide humans with many kinds of vitamins and mineral elements (Wang et al., 2008). Nitrate that accumulates in leafy vegetables originate from residual soil N, as well as from the application of organic and inorganic N fertilizers (Schenk, 1998; Wang et al., 2008).

It was reported in previous studies that under field conditions, soil is aerobic, and ammonium and urea N are rapidly transformed to nitrate-N; therefore, the effect of fertilizer type on nitrate concentration in vegetables usually is not so pronounced (Wang et al., 2008). Phosphorus is an essential macro element necessary for growth and development of plants. Its shortage restricts growth of plants and they remain immature (Hossain, 1990; Sadia et al., 2013). Wang & Li (2004) reported that crop response to P fertilizer depended on soil available P as well as on crop species. In soil that was deficient in available P, crops respond well to P application but in contrast, their results have shown that addition of P fertilizer to a soil containing 109 mg kg^{-1} (Olsen-P) decreased nitrate concentration by 20.1% in green cabbage (Wang & Li, 2004). Increased nitrate concentration (17.3%) was observed in cabbage and on the other hand, phosphorus application had no significant effect on nitrate accumulation in spinach (Wang & Li, 2004). According to Zhou et al. (1989), potassium can accelerate transport of nitrate from roots to aboveground parts. It was reported that compared to control, nitrate concentration in cabbage decreased by 14.6% (from 482 to 412 mg kg^{-1}) with application rate of 75 kg K ha^{-1}.

Effects of K on growth and nitrate accumulation in leafy vegetables vary with crop species, cultivar and environment. Hydroponic experiments showed that the addition of K decreased nitrate concentrations in cabbage by 26.0% compared to the control treatment (Maynard et al., 2003). In contrast, the addition of K increased nitrate concentrations by 8.2% in spinach. Furthermore, application of K to treatments containing high N levels inhibited spinach growth, but had no significant effect on cabbage (Maynard et al., 2003). Scherer (2001) stated that rates of fertilizer should be recommended based on the available element in the soil and the crops' requirement for that element. With an indigenised crop like Mustard spinach (Tshikalange, & Averbeke, 2006; Van Averbeke & Juma, 2006), had previously reported that there is a great deal of variability in the rates at which producers applied nitrogen, phosphorus and potassium.

According to Van Averbeke et al. (2007a), optimum crop growth and yield depend on the adequate availability and accessibility of different plant nutrients. However, application of fertilizers contributes significantly to variables costs of production. It is of utmost of value to consider that those vegetables grown by smallholder farmers are grown with minimum availability of resources. Efficiency in fertilizer application for optimum growth and yield, is always desired if obtained at minimum costs. The objective of this study therefore, was to evaluate the effects of fertilizer application on biomass yield and nutritional quality of Mustard Spinach under field condition. The study would contribute to the production of Mustard Spinach at small-scale farmers' condition because Mustard spinach is one of those leafy vegetables that farmers grow for their home consumption. Integrating Mustard Spinach into mainstream agriculture production has been slow just like any other indigenous and underutilized plant species in South Africa, but the awareness, consumption and demand is currently increasing at rural and urban community. Therefore, there is an acute need for the scaling up and rapid commercialisation of this leafy vegetable crop towards contributing to food and nutritional security at household level in the country.

MATERIALS AND METHODS

A field trial was conducted at the Roodeplaat research farm of the Agricultural Research Council (ARC), South Africa (25°59'S; 28°35'E at an altitude of 1, 200 m.a.s.l.). The experiment was arranged in a randomized complete block design replicated four times. Mustard spinach seed (the cultivar known as 'Florida' broadleaf) were obtained from Starke Ayres seed Pty. Ltd., South Africa) for the experiment. The trial was established on 03 May 2010 and 02 May 2011 in a 200 cavity polystyrene trays filled with a commercial growth medium, Hygromix® (Hygrotech Seed Pty. Ltd., South Africa) and covered with a thin layer of vermiculite after sowing. The soil type at the experimental site is Fernwood as described by Department of Agricultural Development (DAFF) (1991). The seedlings were transplanted on 25 days after sowing; fertilizer was broadcasted by hand in the demarcated experimental plots and being worked into the soil using rakes (Table 1). Limestone Ammonium Nitrate (28% N) was applied as a source of nitrogen, single superphosphate (12.5% P) was applied as a source of phosphorus and potassium was applied in the form of Potassium chloride, KCL (50% K) (Table 1). Nitrogen was split, 60% applied at planting and the remaining 40% was applied as top-dressing after second harvest. A nutrient omission experiments (Table 1) were laid out in a randomized complete block design with five treatments arranged as follows: NPK (full application); N0PK (nitrogen omitted); NP0K (phosphorus omitted); NPK0 (potassium omitted) and N1/2P1/2K1/2 (half of the full

Table 1. Fertilizer treatments (kg ha^{-1}) of Mustard Spinach (*Florida broadleaf*) planted on Fernwood soil form

Fertilizer treatments	Nitrogen (N)	Phosphorus (P)	Potassium (K)
N0P0K0	Control	Control	Control
NPK	100	150	20
N0PK	Omitted	150	20
NP0K	100	Omitted	20
NPK0	100	150	Omitted
N1/2P1/2K1/2	50	75	10

NPK = 100N: 150P: 20K kg ha^{-1} (which was the recommended application rate for N:P:K); N0PK = 0N: 150P:20K kg ha^{-1}; NP0K = 100N:0P:20K kg ha^{-1}; NPK0 = 100N: 150P: 0K kg ha^{-1}).

application) of nitrogen, phosphorus and potassium replicated four times. Drip irrigation system was used and front wetting detectors was installed for monitoring soil water content. Plots were irrigated to field capacity approximately when 30% of soil plant available water is depleted. The treatments denotes: NPK = 100N: 150P: 20K kg ha^{-1}; N0PK = 0N: 150P: 20K kg ha^{-1}; NP0K = 100N:0P:20K kg ha^{-1}; NPK0 = 100N: 150P: 0K kg ha^{-1} and $N_{1/2}P_{1/2}K_{1/2}$ = 50N:75P:10K kg N:P:K ha^{-1}, based on soil analysis including the control = No fertilizer applied(N0P0K0) (Table 1). The total plot size was 4×5 m (20 m^2) and seedlings were transplanted at a row spacing of 0.4 m and in-row spacing of 0.4 m, therefore the total sampled area was 12.8 m^2. Prior to transplanting soil sample was collected to a depth of 0.4 m with 0.2 m intervals. Average monthly rainfall and rainy days (Fig. 1) and minimum and maximum temperatures (Fig. 2) from 2009 to 2012 at the research farm. The climate of the area is semi-arid and approximately 80% of the annual rainfalls in this area occur in the summer months of September to March.

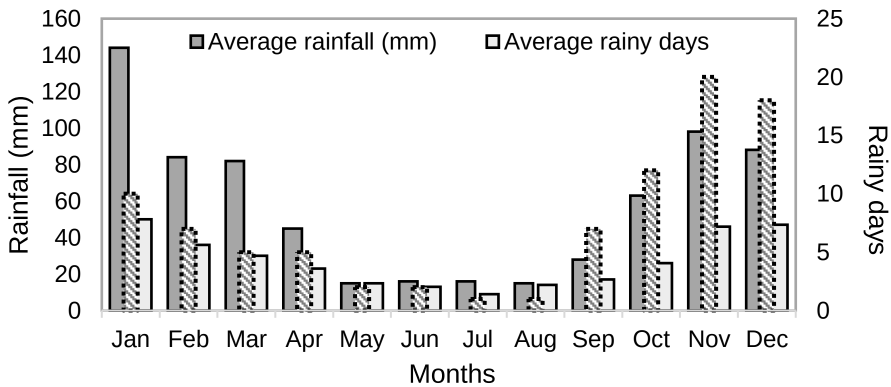

Figure 1. Average monthly rainfall and rainy days during the growth and development of the crop.

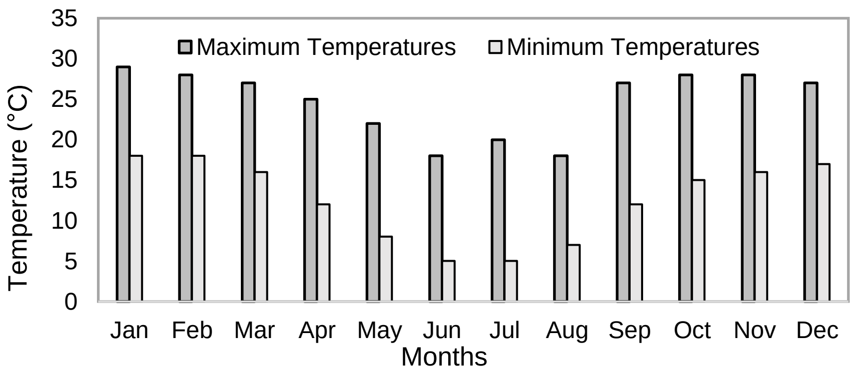

Figure 2. Monthly minimum and maximum temperatures during the growth period of the crop.

Data collection

Soil sampling

Field management practices was carried out as described by Gerrano et al. (2019). The soil samples were collected at a 30 cm depth (Table 2) before planting and collected samples were put in one container and being shaken to mix samples thoroughly. A composite sample was then taken out of the mixed soil sample for laboratory analysis in the analytical laboratory of the ARC (Table 2).

Table 2. Soil chemical content (mg kg^{-1}) and textural analyses (%) at the Roodeplaat experimental site

	Phosphorus		Potassium		Calcium		Magnesium		pH		Texture class	
Year	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011		
Soil depth (cm)											Sand	92
0–20	59.2	61.4	22	32	208	207	78	78	7.74	6.51	Silt	2
21–40	12.4	9.8	19	32	152	193	58	64	6.96	5.8	Clay	6

Sampling for total biomass yield

The first harvest commenced at the eight leaf stage (three weeks after transplanting), when the ninth leaf started to appear. It involved cutting the fifth leaf, which is considered the first marketable leaf, because the first four leaves were too small for marketing purposes (Van Averbeke et al., 2007b). Fresh biomass was determined from harvesting eight plants per plot and put on ADAM® with maximum of 5 kg at d = 0.5 g. Total fresh biomass was determined immediately at harvest. The plants were harvested five times in each growing season when the peduncle elongation starts, which was used as the signal to do the final leaf harvest, because once the plant starts flowering, the leaves become leathery and lose their taste (Tshikalange, 2006). Fresh leaf biomass measurements were done using a portable electronic scale (Scout Pro SPU123®) with a capacity of 5,000 g and an accuracy of 0.001 g, manufactured by Ohaus Corporation.

Sampling of leaves for analysis

Fresh and edible leaves from the same treatment in all replicates were tipped off, combined to constitute a composite sample. Leaves were soaked and thoroughly washed with tap water (four to five times) to remove soil debris and were rinsed with distilled water. Leaves were air-dried on an absorbent paper at room temperature. Leaves were then cut to make a homogenous finer texture using a blender. Samples were transferred to a marked plastic containers, frozen at -20 °C and were sent to the ARC analytical laboratory for ascorbic acid, Dietary fibre, iron and zinc analysis.

Mineral composition analysis

Oven dried (50°C) plant material were analysed for total P, K, Fe and Zn contents according to Campbell & Plank (1991); Kovar (2003) and Wolf et al. (2003) and furthermore, the determination of total N was done according to Gavlak et al. (1996). Plants material were used to determine ascorbic acid content and HPLC-grade acetonitrile (> 99.9%; v/v) from Merck (Darmstadt, Germany) was used. The dietary fiber were analysed by the methods described in AOAC (1990).

Data analysis

Data was subjected to analysis of variance (ANOVA) using the statistical program GenStat® version 11.1 (Payne et al., 2016). Treatment means were separated using Fisher's protected T-test least significant difference (LSD) at the 5% level of significance (Snedecor & Cochran, 1980). Soil sample analysis (Table 1) for phosphors was carried out using P. Bray 1 method (Bray & Kurtz, 1945; Frank et al., 1998) and for potassium, calcium and magnesium, the Ammonium acetate method was used as described by (Chapman, 1965). Samples collected for mineral composition analysis were combined for each treatment and a composite sample was used per treatment, therefore the results were not subjected to statistical analysis.

RESULTS AND DISCUSSION

Marketable fresh leaves biomass yield

Analysis of variance showed that there was a significant variation among the treatment (Table 3) tested. The highest value obtained in the first harvest was 188 kg ha^{-1}, which was recorded for the first season on full package of NPK (Table 3). The omission of N in this experiment had reduced marketable fresh leaf biomass. The result agrees with what Nemadodzi et al. (2017) reported where accumulation of spinach biomass was significantly reduced when N was not applied. There was a significant difference ($p < 0.05$) between P omitted and K treatments. The increment of marketable fresh leaf biomass yield in the interaction of N and P indicates complementarities of nitrogen in the uptake of phosphorous. The values were 102 kg ha^{-1} when P was omitted and increased to 183 kg ha^{-1} when P was applied in combination with N (Table 3). When K was omitted, there was a significant difference ($p < 0.05$) observed among the treatments (Table 3). Visual differences could be noticed in Fig. 3 indicating that there is variation in growth and development of spinach when compared the control ($N_0P_0K_0$); half ($N_{1/2}$:$P_{1/2}$:$K_{1/2}$); full (N: P: K) and P omitted treatments. In year two of the cropping season, the highest yield was 194 kg ha^{-1} in the first harvest, when NPK was applied in full, there was a significant difference ($p < 0.05$) observed between the treatments (Table 3). Omission of N resulted in yield decrease and was the second after the control (where no fertilizer was applied). The results are in line with those of Soundy et al. (2001b) previous report, who found that omission of N caused reduction in leaf biomass yield. It was further revealed in the findings of Soundy & Cantliffe (2001a) that increasing N concentration in the growth medium resulted in an increased shoot growth of lettuce plantlets. The second harvest also resulted in yield increment for both seasons after the crop has been harvested, the highest value recorded was 382 and 401 kg ha^{-1} respectively, in a full fertilizer application treatment (NPK) with a significance difference ($p < 0.05$) across all treatments. Harvest three had its highest values compared to all other harvests during both cropping seasons indicating that biomass accumulation reached the peak on the sixth week after transplanting. There was a significance difference ($p < 0.05$), when NPK was applied in full, the yield obtained was 935 and 1,686 kg ha^{-1}, respectively. When P (920; 1,400) and K (930; 1,680 kg ha^{-1}) were omitted (Table 3) the values obtained were significantly different ($p < 0.05$) in both seasons. A decreased marketable fresh biomass yield was observed on the fourth and fifth harvest, it decreased from 935 and 1,686 kg ha^{-1} (both cropping season) in the third harvest to 788 and 808 kg ha^{-1} on fourth harvest then 423 and 396 kg ha^{-1} on the fifth harvest respectively. In the case of Brassica rapa subsp. Chinensis, the results of Van Averbeke et al. (2007b) indicated a linear response in fresh and dry biomass of marketable leaves. Increment of fresh and dry biomass reached the peak at 200 kg N ha^{-1} application rate then started to decline. The results of *Brassica rapa subsp. Chinesis* presented in the study of Van Averbeke et al. (2007a) indicated that the availability of P affected mass of leaves below some relatively low critical level and once the critical level of P availability in the soil has been attained, adding more P will have no effect. The application of K had a positive effect on the yield of Mustard spinach. Similarly, *Brassica rapa subsp. Chinesis*, showed fresh biomass increased up to 80 kg K ha^{-1} and declined when this optimum rate was succeeded.

Table 3. Response in marketable fresh leaf biomass yield (kg ha^{-1}) of Mustard Spinach (*Florida broadleaf*) to fertilizer application on a nutrient omitted experiment

Fertilizer treatments	W2		W4		W6		W8		W10	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
$N_0P_0K_0$	52f	48f	126f	142f	110f	114f	106f	102f	82f	83f
NPK	188a	194a	382a	401a	935a	1686a	788a	808a	423a	396a
N_0PK	56e	50d	130e	148e	114e	112e	105e	107e	80e	88e
NP_0K	102d	188b	360c	382c	920c	1400c	664c	640c	368c	241d
NPK_0	183b	186c	364b	392b	930b	1680b	782b	801b	419b	372b
$N_{1/2}P_{1/2}K_{1/2}$	176c	189d	344d	371d	731d	1244d	582d	482d	301d	248c

NPK = 100N: 150P: 20K kg ha^{-1} (which was the recommended application rate for N:P:K); N0PK = 0N: 150P: 20K kg ha^{-1}; NP0K = 100N:0P:20K kg ha; NPK_0 = 100N: 150P: 0K kg ha^{-1} and $N_{1/2}P_{1/2}K_{1/2}$ = 50N:75P:10K kg ha^{-1} N:P:K based on soil analysis including the control = No fertilizer applied($N_0P_0K_0$). $LSD_{(0.05)}$. Means followed by the same lower case letter are not significantly different at 5% level; W2 = week two after transplanting; W4 = week four after transplanting; W6 = week six after transplanting; W8 = week eight after transplanting; W10 = week ten after transplanting.

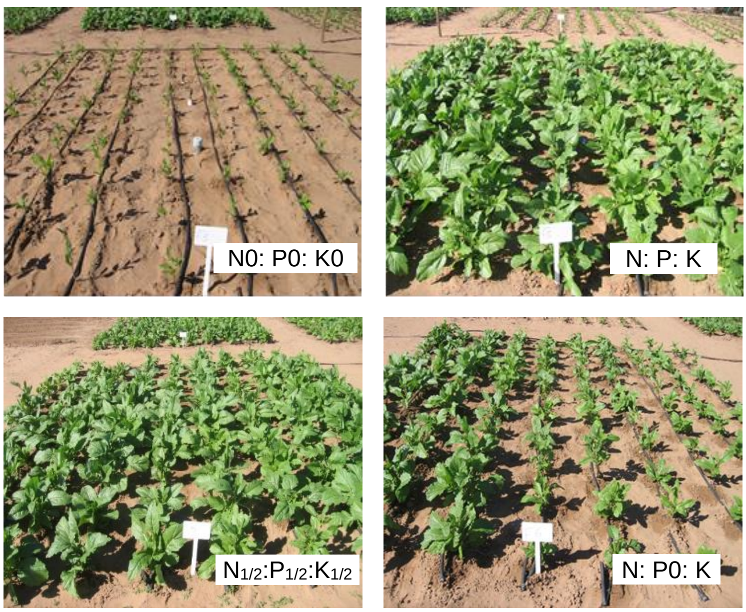

Figure 3. Field trials showing visual differences between treatments, full and halved NPK application, the omission of P and the control (no nutrient was applied).

Total fresh biomass yield (kg ha^{-1})

Yield accumulation of treatment where nitrogen was applied at 100 kg N ha^{-1} and potassium at 20 kg K ha^{-1} outperformed other treatments significantly ($p < 0.05$) (Table 4).

Values obtained on this treatment were 4,510 and 4,982 kg ha^{-1} total fresh biomass yield in both seasons, respectively (Table 4). However, when comparing treatments omission of P and K treatments had no significant difference ($p < 0.05$) on the first season but on the second season there was a significant difference ($p < 0.05$). Omission of P had 4,510 kg ha^{-1} of total fresh biomass yield while omission of K had 4,506 kg ha^{-1} on the first season. The second season obtained 4,982 kg ha^{-1} of total fresh biomass when P was omitted and 3,769 kg ha^{-1} total fresh biomass yield when K was omitted.

Table 4. Total fresh biomass yield (kg ha^{-1}) yield of Mustard Spinach for year one (2010) and year two (2011) in a winter field trials with different fertilizer treatments

Fertilizer treatments	Year 1	Year 2
$N_0P_0K_0$	252e	820f
NPK	3,986c	3,784b
N_0PK	244f	832e
NP_0K	4,510a	4,982a
NPK_0	4,506ab	3,769c
$N_{1/2}P_{1/2}K_{1/2}$	3,521d	2,986d

NPK = 100N: 150P: 20K kg ha^{-1} (which was the recommended application rate for N:P:K); N0PK = 0N: 150P: 20K kg ha^{-1}; NP0K = 100N:0P:20K kg ha; NPK0 = 100N: 150P: 0K kg ha^{-1} and $N_{1/2}P_{1/2}K_{1/2}$ = 50N:75P:10K kg ha^{-1} N:P:K based on soil analysis including the control = No fertilizer applied(N0P0K0). $LSD_{(0.05)}$. Means followed by the same lower case letter are not significantly different at 5% level.

Mineral composition of Mustard Spinach

Mineral elements were presented in percentages in the leaves of Mustard Spinach using composite sampling, which was affected by the rate of fertilizer application (Table 5). On the first season, the lowest percentage (2.63%) was obtained when nitrogen fertilizer was omitted. Full NPK application increased the content of N on the leaves of Mustard Spinach up to 3.29%, followed by 3.15% obtained when P was omitted (Table 5). The second season had the highest percentage of 3.11% when full fertilizer was applied and the omission of N decreased N content up to 2.34%, which was the lowest compared to all treatments (Table 5). P content was below one percent across all treatments; however, the highest percentage obtained was 0.69% on the first season in the potassium omission treatment. (Table 5) On the second season both omission of P and K obtained the same percent, 0.65. The lowest value was obtained when nitrogen was omitted in both seasons; it was 0.43% and 0.37%, respectively (Table 5). Concentration of potassium was affected by NPK application as the highest percentage was obtained on this treatment in both seasons, it was 3.59 and 3.55%, respectively (Table 5). The second highest values were obtained on the halved fertilizer application rate, 3.19 and 3.25% were recorded for

Table 5. Mineral composition presented in percentages (%) as affected by N:P:K application

Fertilizer	N		P		K	
treatments	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
$N_0P_0K_0$	2.57	2.41	0.53	0.48	2.03	2.05
NPK	3.29	3.11	0.59	0.56	3.59	3.55
N_0PK	2.63	2.34	0.43	0.37	2.58	2.55
NP_0K	3.15	3.02	0.62	0.65	3.23	3.11
NPK_0	3.06	2.96	0.69	0.65	2.42	2.38
$N_{1/2}P_{1/2}K_{1/2}$	3.07	3.01	0.63	0.59	3.19	3.25

this treatment (Table 5). The lowest values were obtained in the control and the second lowest values were obtained when K was omitted (Table 5).

Content of dietary fiber, ascrobic acid and micronutrients

Composite samples were used per treatments for determination of dietary fiber, ascrobic acid and micronutrients content. Dietary fibre was presented in percentage, and on the first and second season the highest percentage was obtained on the K omission (N: P: K_0) treatment followed by halved fertilizer application treatment ($N_{1/2}$ $P_{1/2}$ $K_{1/2}$) (Table 6). The lowest percentage was obtained when N was omitted and the second lowest value was in the omission of P treatment. The values obtained in both seasons were 1.03 and 2.54% when N was omitted in both seasons and when P was omitted, 2.18 and 2.54% (Table 6). In the case of ascrobic acid content, the lowest value obtained was in the control, 126.94 and 117.42 mg 100 g^{-1}, respectively for both seasons. On the first season, the highest value obtained was 175.09 mg 100 g^{-1} and on the second season, 191.32 mg 100 g^{-1} when P was omitted (Table 6). The second highest values were observed on the K omission treatment for both season, they were 166.42 and 175.44 mg 100g^{-1}, respectively (Table 6). Iron was more concentrated on the treatment where K was omitted for both seasons. Values were 544.60 mg kg^{-1} on the first season and 542.8 mg kg^{-1}, followed by halved fertilizer treatment, which obtained 469.2 on the first season and 478.5 mg kg^{-1} iron content. In the first season, zinc content was higher at halved fertilizer application (61.4 mg kg^{-1}) treatment and it was lower in the second season (59.3 mg kg^{-1}) compared to the first season but still the highest when compared to the rest of the treatments (Table 6). N: P: K treatment had the lowest zinc content, which was 26.5 and 23.9 mg kg^{-1}, respectively. The omission of both K and P increased the content of zinc compared to when N was omitted. When fertilizer was applied as recommended, zinc content slightly increased from the lowest values obtained in the control treatment. The values increased from 28.1 to 30.9 mg kg^{-1} on the first season and from 23.9 to 26.7 mg kg^{-1} (Table 6).

Table 6. Dietary fiber, ascorbic acid and micronutrients as affected by fertilizer application

	Year 1				Year 2			
Fertilizer treatments	AC (mg 100g^{-1})	DF (%)	Iron (mg kg^{-1})	Zinc (mg kg^{-1})	AC (mg 100g^{-1})	DF (%)	Iron (mg kg^{-1})	Zinc (mg kg^{-1})
$N_0P_0K_0$	126.94	2.96	266.4	28.1	117.42	2.88	276.8	23.9
NPK	142.59	2.46	378.6	30.7	151.89	3.08	371.9	26.5
N_0PK	130.20	1.03	322.7	27.4	166.57	2.53	328.2	29.6
NP_0K	175.09	2.18	364.8	47.3	191.32	2.54	388.7	49.6
NPK_0	166.42	3.16	544.6	42.0	175.44	4.34	542.8	39.6
$N_{1/2}P_{1/2}K_{1/2}$	142.09	3.01	469.2	61.4	172.92	3.78	478.5	59.3

DF = Dietary fibre; AC = Ascrobic acid, NPK = 100N: 150P: 20K kg ha^{-1} (which was the recommended application rate for N:P:K); N_0PK = 0N: 150P: 20K kg ha^{-1}; NP_0K = 100N:0P:20K kg ha^{-1}; NPK_0 = 100N: 150P: 0K kg ha^{-1} and $N_{1/2}P_{1/2}K_{1/2}$ = 50N:75P:10K kg ha^{-1} N:P:K based on soil analysis including the control = No fertilizer applied($N_0P_0K_0$).

CONCLUSION

In the fertilizer omission experiment the current result indicates that the balance in plant nutrient availability and absorption is paramount. Full application NPK

(100N:150P:20K) increased total biomass fresh yield of Mustard Spinach and in this investigation the crop is not a heavy feeder of N, P and K. The synthetic fertilizers are currently expensive due to climate change scenario; such crop may provide a relative economic advantage for smallholder farmers. Application of less amount of inputs on highly nutritious vegetable production will improve the state of food security and nutrition among rural communities and smallholder farmers in South Africa.

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