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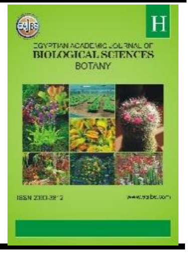

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Influence of Bio and Mineral Fertilizers on Strawberry Performance Grown in Containers Under Different Irrigation Regimes

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ABSTRACT

This study was conducted to evaluate the impact of a partial replacement of full doses of mineral NPK fertilizers with friendly soil microbes enriched with mineral fertilizers on the nutritional status, yield parameters and fruit quality attributes of 'Marmolada' strawberry under drought stress. The experiment included 13 treatments; T1– control (no fertilizer), T2 – NPK, T3 – Filamentous Fungi (FF), T4 – Bacterial Strains (BS), T5 – NPK + FF, NPK + BS, T6 – NPK + Polifoska 6 (Poli 6) + BS, T7 – Urea 100% + FF, T8 – NPK+Poli 6, T9 – NPK + Super Fos Dar (SFD) 40 100% + BS, T11 – Urea 60% + FF, T12 – Poli 6 60% + BS, T13 – Super Fos Dar 40, 60% + BS. All 13 treatments were done under full- and half-dose water requirement supply. The studied characteristics included the mineral content and chlorophyll content of leaves, number of inflorescences, number of flowers, yield, fruit weight, Brix, pH, total acidity, and firmness. The results showed that the treatments under a full dose of water supplement gave satisfactory results in all the studied characteristics except for the number of flowers, fruit weight, Brix and pH. The highest yields under a full dose of irrigation were harvested from T6. On the other hand, all the treatments that included FF or BS enriched with NPK showed remarkable effects on the concerned traits except Brix, pH, and firmness. Treatments with NPK plus FF or BS succeeded to decrease the reduction in yield when plants were subjected to a 50% irrigation regime. The partial application of NPK fertilizers enriched with FF and BS gave satisfactory results concerning the yield and quality of strawberry with or without drought stress.

INTRODUCTION

Generally, the fertilization of plants is essential for maximizing their growth and yield. Fertilization has two forms: one of them is based on minerals and the other on natural sources. Despite mineral fertilization promoting plant growth and fruiting, its intensive applications obviously increase costs and greatly harm the soil environment, pollute underground water, and release greenhouse gases into the atmosphere, which have become

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harmful to humans (Boy and Arcad, 2013). Modern agriculture, especially in organic plant production, is seeking fertilizers that diminish the negative impact on the environment and humans (Arancon *et al*., 2004; Malusa *et al*., 2007; Hassaneen *et al*., 2020; Mosa *et al*., 2021 a; Ghareeb *et al*., 2022). Therefore, fertilization products based on organic- and bio-material origins, such as manures, composts, and friendly soil microbes (FSM), are more favourable (Sas-Paszt *et al*. 2008; Malusa and Sas- Paszt 2009; Grzyb *et al*., 2012; Derkowska *et al*., 2015 a, b; Choudhary *et al*., 2022; Morsy *et al*., 2022). The availability of traditional natural fertilizers, i.e. manure and compost, is gradually decreasing annually; therefore, the trials are devoted to increasing the applications of FSM (Regvar *et al*., 2003; Arancon *et al*., 2004; Sas-Paszt *et al*., 2019 a, b; Kandil *et al*., 2020 a). Several studies have shown that the applications of FSM such as bacteria and fungi give positively affected plant cultivation as well as show remarkable protection of the environment’s condition and human health (Chen 2006; Gousterova *et al*., 2008; Chelariu *et al*., 2009; Derkowska *et al*., 2015 a, b; Sas-Paszt *et al*., 2019 a, b; 2020 a,b). The presence of beneficial microbial strains in the soil results not only in intensifying the physiological processes in plants but also in an enhancement of their resistance to abiotic and biotic stresses (Corte *et al*., 2013; Wally *et al*., 2013; Sas-Paszt *et al*., 2019 a, b; Gomaa *et al*., 2021).

Recently, Filamentous Fungi (FF) and Bacterial Strains (BS) were found responsible for stimulating plant growth, improving the physiological conditions of roots, increasing the mineral uptake of plants, and significantly reducing the application of chemicals in plant cultivation (Sas-Paszt *et al*., 2011; Lingua *et al*., 2013; Grzyb *et al*., 2015 a,b,c; Sas-Paszt *et al*., 2019 a, b; 2020 a, b).

Abiotic stresses, in particular drought, which can restrict the growth, fruiting and yield, as well as the life of plants, can also decrease populations of soil microorganisms (Stewart *et al*., 2005; Yin *et al.,* 2010). Soil application of friendly soil microbes can reduce the negative effects caused by drought (Stewart *et al*., 2005; Esitken *et al*., 2010; Yin *et al*., 2010; Boyer *et al*., 2014; Sas- Paszt *et al*., 2019 a, b; 2020 a, b).

The agricultural practices of employing friendly soil microbes alone or enriched with mineral nutrients on the quality and quantity of plant fruiting under drought stress are varied and not widely investigated (Sas-Paszt *et al*., 2020 a, b). Therefore, the aim of the study was to present the last and the third season of the study concerning applying friendly soil microbes, such as filamentous fungi (a mixture of two species: *Aspergillus niger* and *Purpureocillium lilacinum*) and bacteria (three strains of *Bacillus*; *Bacillus* sp., *Bacillus amyloliquefaciens*, and *Paenibacillus polymyxa*), alone or with mineral fertilization (NPK to strawberry plants on the mineral and chlorophyll content of leaves, flowering, fruiting and quality traits of plants grown in containers under full dose or half dose of required irrigation.

MATERIALS AND METHODS

1. Plant Materials, Location, And Treatments:

The study was carried out in the third season (2020) on three-year-old ‘Marmolada’ (synonym ‘Onebor’) strawberry plants grown in 120-litre earthenware containers filled with podzolic soil (Table 1). Each container had three plants growing 25 cm apart and was buried in the open Experimental Field at Skierniewice (Central Poland, latitude 51.9625 N, longitude 20.1624 E, 128 meters above sea level). Thermal and humidity conditions of the location during the growing season of the study are shown in Table 2 (https://meteoblue.com/pl/pogoda/).

Table 1. Podzolic soil analysis.

Property	Unit	Value
pH		6.2
O.M.	%	1.2
P	mg/100g	7.2
K	mg/100g	12.4
Mg	mg/100g	5.8
Na	mg/100g	3.35
Fe	mg/1000g	862
B	mg/1000g	2.4
Cu	mg/1000g	4.8
Mn	mg/1000g	75.5
Zn	mg/1000g	3.7

Table 2. Monthly thermal and humidity conditions during 2018-2020 seasons.

	Average Temp. °C			Average Relative humidity %			Sunshine hours		
Month	2018	2019	2020	2018	2019	2020	2018	2019	2020
April	13	10	10	60	50	52	235	227	257
May	17	13	13	70	60	67	216	229	194
June	22	22	21	60	50	76	295	217	386
July	25	19	19	75	60	67	268	287	242
August	24	20	20	60	50	71	275	269	274
September	18	14	15	55	55	78	178	190	163
October	10	10	10	60	60	88	125	81	141

The experiment was comprised of two blocks irrigated by drip-technique; under one of them, the plants received the full dose of water (100% irrigated), and under the second block, the plants received the half dose of water. The water requirements were adjusted according to the indications of tensiometers. Each block comprised the same 13 treatments of friendly soil microbes enriched with mineral fertilizers illustrated in Table 3, all treatments under each block were repeated three times.

Table 3. The treatments with friendly soil microbes enriched with NPK fertilizers.

Source / Treatment	N[1]	P[2]	K[3]	NPK[4] mixture	Friendly Soil microbes (FSM)		FF or BS enriched fertilizers[7]		
	Urea g	Super Fos Dar 40 (SFD 40) g	Potassium salt g	Polifoska 6 (Pol 6) g	Bacterial strains [5] (BS) G	Filamentous fungi (FF) [6] g	U+FF g	Pol 6+BS G	SFD 40+BS g
T1 control	-	-	-	-	-	-	-	-	-
T2	8.8	3	12.5	-	-	-	-	-	-
T3	-	-	-	-	-	1.3	-	-	-
T4	-	-	-	-	3.0	-	-	-	-
T5	8.8	3	12.5	-	-	1.3	-	-	-
T6	8.8	3	12.5	-	3.0	-	-	-	-
T7	8.8	-	12.5	-	-	-	-	6.5+3.0	-
T8	8.8	3	12.5	-	-	-	8.8+1.3	-	-
T9	7.5	-	12.5	6.5	-	-	-	-	-
T10	8.8	3.5	12.5	-	-	-	-	-	3+3.83
T11[8]	5	1.8	7.5	-	-	-	5.4+1.3	-	-
T12[9]	4.5	-	7.5	-	-	-	-	3.75+3.0	-
T13[10]	7.5	3.5	9.5	-	-	-	-	-	1.75+3.83

[1] Urea (46 % N) is a granule fertilizer as a source of N. It was added to the soil container in early spring with the amount presented in Table 3, and 5 g urea was added again in mid-summer in all the urea treatments, except in T13 only 3 g of Urea was added.

[2] Super Fos Dar 40 (40 % P_2O_5) is a phosphate fertilizer compromising also micro-elements (Co, Mn, Fe, Zn, and Cu). It was added to the soil container in early spring with the amount presented in Table 3.

[3] Potassium salt is a source of potassium elements. It was added to the soil container in early spring with the amount in Table 3.

[4] Polifoska 6 (6% N, 20% P_2O_5, 30% K_2O) is a mixture of NPK elements. It was added to container soil in early spring as the amount presented in Table 3.

[5] Bacterial strains mixture is a mixture of beneficial soil bacteria containing three strains of *Bacillus* (*Bacillus* spp. Pszenica CZP4/4, *Bacillus amyloliquefaciens* AF75BB and *Paenibacillus polymyxa* CHT114AB). The 3.0 g of the mixture was mixed with each container's soil immediately after planting.

[6] Fungal strains mixture is a mixture of beneficial soil filamentous fungi containing two strains (*Aspergillus niger* G119AA *and Purpureocillium lilacinum* WT15A). The 1.3 g of the mixture was mixed with each container's soil immediately after planting.

[7] Fungi or bacterial strains had been incorporated with mineral fertilizers through the process of granule production.

[8] T11 is a half NPK dose of T8, and FF enriched with a half dose of Urea.

[9] T12 is a half NPK dose of T7, and BS enriched with a half dose of POL 6.

[10] T13 is a 2/3 NPK dose of T10 except for the dose of SFD 40 is the same and BS enriched with a half dose of SFD 40.

Measurements

1. Flowering Traits:

The number of inflorescences and flowers were counted on five plants per treatment**.**

2. Leaves:

2.1. The intensity of the green colour of the leaves was determined with a SPAD 502 meter using a sample of 5 leaves taken from two plants in each replication.

2.2. The concentration of minerals was determined on the basis of a sample of 25 leaves taken from plants from each plot. The leaves, together with petioles, were collected for analysis in mid-August

3. Fruit Yield and Mean Fruit Weight:

Fruit harvesting was done 4 times at 5-day intervals. The number of fruits and total fruit yield per plant (g) were measured, then the mean fruit weight (g) was calculated by dividing the total fruit weight from a plot by the total number of fruits. Fruit yield % and fruit weight % were then calculated.

4. Physico-Chemical Parameters of Fruits:

The soluble solids content (°Brix) was determined using a Mettler Toledo type RE50 refractometer. Titratable acidity (g/100 g citric acid) was determined with PN-90/A-75101/04 using a Mettler Toledo type DL 58 titrator. Active acidity (pH) was measured with a Mettler Toledo type DL 58 titrator. Fruit firmness (N) of the skin was tested on a sample of 15 fruits on their side surface at the level of the largest diameter with a 3.2 mm diameter flat plunger moving at a speed of 50 mm/min using Instron 4303 testing machine (Instron Ltd., High Wycombe, England) equipped with a 10 N measuring head.

Statistical Analysis:

The findings were statistically analyzed according to Duncan's test at $\alpha = 0.05$, using the statistical program Statistica 13.1.

RESULTS

The results under full or half dose of irrigation concerning the chlorophyll content of 'Marmolada' strawberry leaves were significantly different (Table 4). Most of the treatments that included BS inoculation enriched with NPK fertilizers, T8 and T13 and T6, respectively, showed the most intensive green color under a full dose of irrigation. T10, T5, T11 and T13 under water stress represented higher chlorophyll contents in strawberry leaves. It is worth mentioning that all those treatments included FF application, except T10, which included BS application (Table 4).

Table 4. Chlorophyll and macroelement contents in 'Marmolada' strawberry leaves as influenced by FSM enriched with NPK fertilizer treatments under full- or half-dose of irrigation regime in the 2020 season.

Treatments		Traits					
Irrigation regime	FSM enriched with NPK	Chlorophyll Content Spad	N %	P %	K %	Mg %	Ca %
Full dose	T1	34.6 a	1.65 b	0.18 b	0.73 a	0.35 g	1.35 e-g
	T2	39.3 b-d	2.21 e	0.21 cd	2.14 e	0.25 c-e	1.23 d-f
	T3	35.1 ab	1.67 b	0.23 de	1.10 b	0.34 fg	1.41 g
	T4	36.0 a-c	1.52 a	0.20 bc	1.21 bc	0.31 f	1.36 fg
	T5	36.5 a-c	2.05 d	0.21 cd	2.04 e	0.24 b-e	1.22 d-f
	T6	39.6 b-d	2.25 e	0.24 e	2.08 e	0.26 de	1.20 de
	T7	36.8 a-c	2.21 e	0.21 cd	2.02 e	0.26 de	1.27 d-g
	T8	43.4 d	2.02 d	0.20 bc	1.50 cd	0.26 e	1.17 cd
	T9	37.2 a-c	2.08 d	0.20 bc	1.89 de	0.22 a-c	1.12 cd
	T10	33.9 a	1.84 c	0.20 bc	1.59 cd	0.22 a-c	1.03 bc
	T11	37.3 a-c	1.86 c	0.18 b	1.39 bc	0.18 a	0.87 a
	T12	36.0 a-c	1.90 c	0.20 bc	1.59 cd	0.22 a-c	1.03 bc
	T13	40.1 cd	1.83 c	0.13 a	1.12 b	0.21 ab	0.96 ab
Half dose	T1	37.1 a-c	1.51 a	0.16 a	1.19 b	0.24 cd	1.14 ab
	T2	37.2 a-c	2.03 fg	0.21 de	1.55 cd	0.24 cd	1.36 c
	T3	33.3 a	1.70 b	0.19 b-d	0.57 a	0.36 g	1.64 d
	T4	35.6 ab	1.64 b	0.19 b-d	1.46 c	0.27 e	1.35 c
	T5	42.7 cd	1.86 cd	0.19 b-d	1.73 e-g	0.19 a	1.22 a-c
	T6	36.6 a-c	2.02 fg	0.19 b-d	1.94 h	0.24 cd	1.30 bc
	T7	39.0 a-d	2.12 g	0.22 f	1.80 fg	0.30 f	1.30 bc
	T8	39.3 a-d	2.03 fg	0.24 g	2.02 i	0.22 b	1.22 a-c
	T9	38.7 a-d	2.08 g	0.22 f	1.99 hi	0.25 d	1.10 a
	T10	43.9 d	1.95 of	0.20 c-e	1.70 ef	0.26 e	1.23 a-c
	T11	41.7 b-d	1.91 c-e	0.21 ef	1.81 g	0.23 bc	1.08 a
	T12	36.1 a-c	1.84 c	0.21 ef	1.82 g	0.23 bc	1.08 a
	T13	40.9 b-d	1.97 ef	0.18 b	1.64 de	0.26 e	1.19 a-c

Leaf macro-mineral concentrations of N, P, K, Mg and Ca varied significantly due to the treatments under 100% water requirement supply. T6 (8.8 g urea + 3.0 g SFD 40 + 12.5 g potassium salt and 1.3 g FF) and T2 (only NPK; 8.8 g urea + 3.0 g SFD 40 + 12.5 g potassium salt) accumulated highest amounts of NPK in the leaves, however, T3 (1.3 g FF) and T13 (7.5 g urea + 3.5 g SFD 40 + 9.5 g potassium salt and 1.75 g SFD 40 + 3.83 g BS) did not give satisfactory effect on NPK level, followed by T4 (BS only) (Table 4). The percentages of Mg and Ca were remarkably higher in the containers treated with T3 and T1 (control), but their percentages were lower in containers subjected to T11 (Table 4). NPK applications alone or with FSM enriched with NPK under 50% water requirement supply showed positively higher NPK percentages in the leaves than those values recorded in the control leaves and followed by those treated with only FF or BS (T3 and T4). The highest percentages of N were recorded respectively in T7, T9, T8, T2 and T6, which mostly included a kind of NPK fertilizers and FF or BS applications. By contrast, P % was higher in the leaves of plants grown in the containers after the application of T8, T7, T9 and T2, respectively, and K % was higher in plant leaves that received treatments T8, T9 and T6 (Table 4). It should be highlighted that all these treatments included urea and NPK along with FF or BF applications. The data shown in Table 4 demonstrate that Mg % and Ca % were positively increased in strawberry leaves according to T7 and T3, respectively, than those subjected to the other treatments (Table 4).

Under an optimal irrigation regime, application of mineral and/or bio-fertilization failed to show a positive increase in B content in leaves compared with control leaves (Table 5). By contrast, the amounts of Cu, Fe, Mn, and Zn in leaves were increased significantly in T6, T9, T7 and T6, and T10 and T11, respectively (Table 5). Leaves on all treatments showed better Zn content than control leaves, except in T8. On the other hand, under half dose of optimal irrigation, all treatments, in general, that included NPK, POL 6, BS or FF failed to show better results in microelements content in leaves compared with control leaves. The exception was that T3 (only FF), T4 (only BS), T9 and T4 gave the best results for B, Cu, Mn, and Zn in leaves, respectively (Table 5).

Under the full irrigation regime (Table 6), in general, friendly soil microbes enriched with or without NPK fertilizer treatments gave non-significant increases in the number of inflorescences of ‘Marmolada’ strawberry plants compared with the control (T1) in the 2020 season. Moreover, T11, T12, T13, T9 and T10 showed a lower number of inflorescences per plant than T1. On the other hand, a significant effect in the number of inflorescences was detected among the treatments under half dose of irrigation. T3, which included only FF inoculation showed a significant effect and the highest number of inflorescences, followed by T13 and then T4. T2 which included only NPK application represented the lowest number of inflorescences under 50% of the irrigation regime (Table 6).

The same trend in the results was detected with the number of flowers/plant under optimal or shortage/reduced irrigation (Table 6); there was not a significant difference in the number of flowers, regardless of the friendly soil microbes and the type of NPK fertilizer (Table 6). The treatments under 50% shortage of irrigation, however, FF application (T3) without NPK fertilizers resulted in a significant increase in the number of flowers/plants with a value of 49 flowers/plant. A close result in the number of flowers/plants was obtained with the container inoculated by T4 (BS only), followed by T13 (Table 6). The lowest number of flowers was observed in the plants grown in the containers fertilized with NPK only (T2).

Table 5. Microelement contents of 'Marmolada' strawberry leaves as influenced by FSM enriched with NPK fertilizer treatments under full- or half-dose of irrigation regime in the 2020 season.

Treatments		Traits				
Irrigation regime	FSM enriched with NPK	B mg/kg	Cu mg/kg	Fe mg/kg	Mn mg/kg	Zn mg/kg
Full dose	T1	28.5 f	3.70 bc	418 b-d	47 ab	122 b
	T2	24.3 de	3.57 ab	324 ab	95 cd	132 b-d
	T3	25.1 de	3.78 b-d	316 a	30 a	141 c-e
	T4	26.9 ef	3.77 b-d	331 a-c	46 ab	141 c-e
	T5	24.9 de	4.12 b-d	323 ab	80 c	150 e
	T6	24.2 de	4.89 e	356 a-c	99 d	145 de
	T7	29.0 f	4.28 cd	340 a-c	108 d	135 b-d
	T8	24.0 c-e	3.86 b-d	407 a-d	79 c	95 a
	T9	24.7 de	3.90 b-d	519 e	76 c	134 b-d
	T10	18.7 a	4.33 d	376 a-c	57 b	163 f
	T11	21.3 a-c	3.86 b-d	358 a-c	47 ab	168 f
	T12	22.7 b-d	4.07 b-d	421 cd	54 b	130 bc
	T13	20.6 ab	3.10 a	490 de	48 ab	133 b-d
Half dose	T1	24.3 b-d	3.39 ef	444 g	51 bc	259 e
	T2	21.2 a	2.68 c	424 g	44 ab	202 c
	T3	27.0 e	3.59 fg	450 g	35 a	248 de
	T4	26.6 de	3.74 g	443 g	52 b-d	336 f
	T5	22.8 a-c	2.08 a	414 fg	64 d	233 d
	T6	21.8 ab	2.38 b	367 ef	88 ef	238 d
	T7	24.4 b-d	2.93 cd	295 bc	147 h	193 bc
	T8	24.6 c-e	2.83 cd	347 de	91 f	195 bc
	T9	22.7 a-c	2.97 cd	227 a	124 g	160 a
	T10	22.0 a-c	3.13 de	356 de	76 e	182 b
	T11	21.9 ab	2.73 c	309 b-d	78 ef	200 c
	T12	22.3 a-c	2.99 cd	268 ab	88 ef	254 e
	T13	21.2 a	3.07 d	340 c-e	62 cd	238 d

The results in Table 6 concerning yield traits varied significantly among the applications under a full irrigation regime. A yield of 941.2 g per plant was the highest value obtained from the plants treated in T6 (8.8 g urea + 3.0 g SFD 40 + 12.5 g potassium salt and 3.0 g BS) with an increased rate in the yield of 172.4% relative to the control treatment T1 (Table 6). Although T3 and T4 plants inoculated with FF and BS only, respectively, gave higher yields with a rate of 111.6% and 111.0% than the control, they failed to show a significant difference. The plants growing under half dose of irrigation, regardless of the bio- and mineral fertilizers, produced lower yields of about 40% less than those obtained under full dose of irrigation (Table 6). The bio-fertilization alone or enriched with NPK fertilizers succeeded to minimize the reduction in yield under the shortage of irrigation (Table 6), in comparison with the control treatment and NPK only. The best yield results of 'Marmolada' strawberry plants under water stress were obtained respectively from containers subjected to T13 (7.5 g urea + 3.5 g SFD 40 + 9.5 g potassium salt, and 3.83 g BS enriched with 1.75 g SFD 40), T3 (1.3 g FF) and T5 (8.8 g urea + 3 g SFD 40 + 12.5 g potassium salts, and 1.3 g FF).

Table 6. Flowering and yield traits of 'Marmoladae' strawberry as influenced by FSM enriched with NPK fertilizer treatments under full- or half-dose of irrigation regime in season 2020.

Treatments		Flowering traits		Yield traits			
Irrigation regime	FSM enriched with NPK	Number of inflorescences	Number of flowers	Yield g	Yield %	Fruit weigh g	Fruit weight %
Full dose	T1	9 ab	34 a	546.0 a	100.0	42.6 a	100.0
	T2	8 ab	33 a	732.8 b	134.2	51.5 a	120.9
	T3	9 ab	32 a	609.6 a	111.6	49.8 a	116.9
	T4	8 ab	26 a	606.0 a	111.0	46.8 a	109.9
	T5	9 ab	31 a	601.0 a	110.1	43.1 a	101.2
	T6	9 ab	34 a	941.2 d	172.4	51.5 a	120.9
	T7	11 b	33 a	853.7 cd	156.4	50.9 a	119.5
	T8	9 ab	28 a	757.6 b	138.8	51.3 a	120.4
	T9	7 a	21 a	540.0 a	98.9	39.3 a	92.3
	T10	8 ab	26 a	735.5 b	134.7	47.8 a	112.2
	T11	6 a	29 a	590.9 a	108.2	43.7 a	102.6
	T12	7 a	27 a	820.5 bc	150.3	50.9 a	119.5
	T13	7 a	25 a	597.3 a	109.4	41.4 a	97.2
Half dose	T1	8.6 b-e	24.3 b-d	343.3 ab	62.9	33.4 a	78.4
	T2	5 a	12 a	321.7 a	58.9	32.6 a	76.5
	T3	13.3 f	49 f	420.0 c	76.9	33.7 a	79.1
	T4	10 de	31.6 e	384.0 a-c	70.3	33.0 a	77.5
	T5	9.6 c-e	31.3 cd	411.0 a-c	75.3	31.9 a	74.9
	T6	7 a-d	24 b-d	372.7 a-c	68.3	33.7 a	79.1
	T7	6.6 a-c	21.3 a-d	424.0 c	77.7	36.0 a	84.5
	T8	6.6 a-c	17.6 ab	362.0 a-c	66.3	38.4 a	90.1
	T9	5.6 ab	21.3 a-d	377.0 a-c	69.0	34.4 a	80.8
	T10	5.6 ab	17.3 ab	379.3 a-c	69.5	38.1 a	89.4
	T11	6 ab	20.3 a-c	334.7 a	61.3	37.2 a	87.3
	T12	7.6 a-e	22.3 a-d	376.3 a-c	68.9	35.4 a	83.1
	T13	10.3 e	31.6 e	522.0 d	95.6	35.7 a	83.8

Table 6 shows that bio-fertilization alone or enriched with NPK fertilizers caused no remarkable effects on the average fruit weight/plant whether under optimal irrigation or under limited irrigation. T2 (NPK only) plants under 100% irrigation gave the greatest fruit weight, followed by T8, T7 and T12 respectively (Table 6). T8 (8.8 g urea + 3.0 g SFD 40 + 12.5 g potassium salt and 1.3 g FF enriched with 8.8 g urea) under a 50% irrigation regime caused the lowest reduction in fruit weight (only 10% less). Close results were noted for the plants treated with T10 and T11 (Table 6).

Table 7 displays the effects of the treatments on the quality of 'Marmolada' strawberry fruits. It is obvious from the results that the treatments did not show a significant variation in °Bx values, whether under water stress or not (Table 7). The same trend was found with pH, non-significant results were obtained after treatments with both full dose and half dose of irrigation regime (Table 7). By comparison, T10 and then T7 and T2 resulted in the highest values of total acidity in fruits. The T1 application (control treatment), however, resulted in the lowest values of total acidity; these results were found when the containers received a complete water requirement. The trend in the findings of total acidity was different under water deficiency, the lowest values of total acidity were determined in the fruits of the plants treated with T3 (1.3 g FF), whereas the greatest values were detected in the fruits of plants that belonged to T2, and then T7, T10, T11 and T12. Mineral and bio-fertilization achieved a non-positive effect concerning fruit firmness under water limitation or not, compared with the control treatment, which was clear from the data shown in Table

7, except for T13, which gave a significant increase in fruit firmness under full dose of water requirements.

Table 7. Chemical and firmness traits of 'Marmolada' strawberry fruits as influenced by FSM enriched with NPK fertilizer treatments under full- or half-dose of irrigation regime in season 2020.

Treatments		Traits			
Irrigation regime	FSM enriched with NPK	TDS °Bx	pH	Total acidity g/100g	Firmness N
Full dose	T1	5.22 a	3.40 a	0.65 a	1.59 f
	T2	6.35 a	3.47 a	0.81 f	1.49 d
	T3	5.35 a	3.41 a	0.66 ab	1.53 e
	T4	5.96 a	3.39 a	0.68 bc	1.33 b
	T5	6.75 a	3.45 a	0.83 fg	1.52 e
	T6	6.39 a	3.52 a	0.76 de	1.42 c
	T7	6.55 a	3.48 a	0.82 fg	1.22 a
	T8	6.51 a	3.47 a	0.76 de	1.63 g
	T9	6.43 a	3.52 a	0.76 de	1.44 c
	T10	6.30 a	3.41 a	0.84 g	2.11 j
	T11	6.40 a	3.46 a	0.78 e	1.66 h
	T12	6.31 a	3.47 a	0.75 d	1.57 f
	T13	6.25 a	3.47 a	0.69 c	1.72 i
Half dose	T1	5.86 a	3.38 a	0.69 c	1.75 a
	T2	6.15 a	3.37 a	0.89 g	2.23 a
	T3	4.66 a	3.44 a	0.51 a	2.36 a
	T4	5.47 a	3.41 a	0.65 b	2.31 a
	T5	6.31 a	3.41 a	0.83 ef	1.89 a
	T6	6.40 a	3.45 a	0.81 e	1.66 a
	T7	6.72 a	3.49 a	0.85 f	1.72 a
	T8	6.72 a	3.46 a	0.81 e	1.62 a
	T9	7.23 a	3.47 a	0.83 ef	1.46 a
	T10	7.24 a	3.46 a	0.85 f	1.79 a
	T11	7.17 a	3.46 a	0.85 f	1.66 a
	T12	6.57 a	3.48 a	0.84 f	2.12 a
	T13	6.33 a	3.46 a	0.76 d	1.71 a

DISCUSSION

Intensive fertilization of plants with mineral fertilizers, as emphasized by many authors, degrades the natural environment, and this adversely affects the growth and fruiting of plants (Esitken *et al.*, 2010; Boy and Arcad, 2013: Singh *et al*., 2015; Sas-Paszt *et al.*, 2020 a, b; Kandil *et al*., 2020 b; Harhash *et al*., 2021a, b). Therefore, ways are being sought to reduce the negative impact of agriculture on the environment by partially replacing mineral fertilizers with products of natural origin. Such an opportunity is provided by natural and organic fertilizers, as well as enrichment of the soil with endophytic microorganisms, including filamentous and mycorrhizal fungi and beneficial bacteria (Arancon *et al.*, 2004; Malusa *et al.*, 2007; Smith and Read, 2008; Sas-Paszt *et al.*, 2008; Malusa and Sas-Paszt, 2009; Grzyb *et al.*, 2012; Derkowska *et al.*, 2015a; Mosa *et al*., 2021 b).

The results of this research showed that the nutritional status and chlorophyll content of strawberry plants were improved, under water deficiency, due to the application of FSM enriched with NPK in the 2020 season. The trend was previously noticed in the 2019 season (Sas-Paszt *et al*., 2020a).

In general, under 50% of the water requirement supply, the flowering characteristics including the inflorescences and the number of flowers in the 2020 season were markedly increased in comparison with the application of FF (T3), and then with the application of BS (T4) and 50% of NPK + SFD 40+BS (T13).

The results of our research show that limiting the availability of water to plants by half causes a decrease in strawberry fruit yield from 30 to 60%, depending on the type of fertilization. The positive role of filamentous fungi and beneficial bacteria in reducing the effects of water stress was evident. Strawberry yield under full dose or shortage of water was greater in the plants treated with BS and FF enriched partially with NPK (T6, T3, T5, T13). The results followed the line of our 2019 findings. In addition, our results coincided with those obtained by Arancon *et al.*, 2004; Malusa *et al.,* 2007; Sas-Paszt *et al.,* 2008; Smith and Read, 2008; Malusa and Sas-Paszt, 2009; Grzyb *et al.*, 2012; Derkowska *et al.,* 2015a; Einizadeh and Shokouhian, 2018; Sas-Paszt *et al.*, 2019 a, b; 2020 a, b). They reported that using a solution of the commercial preparation "Effective Microorganisms" on strawberry plants of the cultivar 'Paros', obtained better parameters of fruit quality than in the control combination. A two-percent concentration of this preparation proved to be better than the concentrations of one and three percent. In the case of the 2% solution, the fruit had the highest number of soluble solids, but this result was not statistically significant. The application of a 1% solution, compared to the control, gave only slight increases in the yield parameters. Some authors have reported that both microorganisms and vermicompost enriched with *Azotobacter* bacteria and arbuscular mycorrhizal fungi increase the number of flowers, compared to control plants (Singh *et al.,* 2015). In contrast, the application of a consortium of beneficial *Pseudomonas* spp. bacteria and AM fungi (*Rhizophagus intraradices*, *Glomus aggregatum*, *Glomus viscosum*, *Claroideoglomus etunicatum*, and *Claroideoglomus claroideum*) were found to increase the number of strawberry plants only when conventional fertilization was limited to 70% (Bona *et al.,* 2015). The lack of influence of beneficial microorganisms on the number of flowers observed in those studies may have been due to the properties of the microbial strains used or to the plants being sufficiently supplied with minerals. In our research, a clear increase in the number of inflorescences and flowers occurred only in the block of plants with limited irrigation (50%) and where only bacteria and filamentous fungi were used without additional mineral fertilization, which partially coincides with the observations of the authors of the above-mentioned publication.

These outcomes might be related to improving and intensifying the physiological processes in plants that are responsible for resistance to abiotic and biotic stresses due to the application of FSM enriched with mineral fertilizers (Regvar *et al.,* 2003; Corte *et al.,* 2013; Wally *et al.,* 2013; Einizadeh and Shokouhian, 2018; Sas-Paszt *et al.,* 2019 a, b; Mosa *et al.*, 2021 c). Water stress like abiotic stress negatively affects both plant growth and fruiting (Corte *et al.,* 2013). With the application of bacteria of the genera *Paenibacillus*, *Pseudomonas* and *Rhodococcus* there were also increases in the antioxidant activity of enzymes, phytohormones, including gibberellins, indole acetic acid, abscisic acid, cytokinins, indole-3-acetic acid and the production of ACC deaminase, which reduces the level of ethylene in the roots and increases the production of exopolysaccharides (Yang *et al.,* 2009; Dimkpa *et al.,* 2009; Timmusk and Nevo, 2011; Kim *et al.,* 2012; Timmusk *et al.,* 2014).

CONCLUSIONS

The applications of FF and BS enriched with a partial dose of NPK succeeded to limit the negative effects of a 50% water requirement supply on the nutritional status, flowering, and yield characteristics of 'Marmolada' strawberry plants grown in containers during the 2020 season.

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