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Productivity of 'Williams' Banana in Relation to Partial Replacement of Mineral Nitrogen Fertilizers with Mycorrhizal Fungi Inoculation

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Abstract: The present investigation was conducted during 2021 and 2022 on second and third ratoons of 'Williams' banana plants grown in a private farm situated at El- Gendia village, Beni-Mazar District El-Minia Governorate, Egypt, while the soil texture is loamy clay. Twelve stools, each one contains 3 plants uniforms in vigor of 'Williams' banana was chosen for achieving this study. The chosen stools are planted at 3 X 3 meters apart. The partial replaced of mineral nitrogen fertilizers with AMF inoculation (as a bio-fertilizer) at different percentages (25%, 50% and 75%) were examined. The results show that, replaced the mineral nitrogen fertilizer was lead to improving the plants mineral statues, yield (kg/plant) and fruit physic-chemical properties of 'Williams' banana fruit. It is clear that replaced 50% of mineral nitrogen fertilizer by using 50% of AMF inoculation produced the best mineral nutrients status, yield (kg), and fruit physicochemical properties of 'Williams' banana cultivar.

Key words: Williams banana, mineral nitrogen, bio-fertilizer, AMF inoculation, yield fruit quality.

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1. Introduction

Banana plant is among the most widely grown under hot and humid countries, it native to tropical and subtropical zones, it widespread in all African countries. It is one of the largest herbal plants on world. It is monocotyledonous plant, botanically it belongs to Family *Musaceae*. There are dozens of wild and cultivated species of *Musa*, but only few of them consumed as a fresh fruit **(Cheesman, 1987 and Pereira & Maraschin, 2015)**. Banana considered as one of the largest exporting fruit crops all over the world. This prompted to expansion of its cultivation, and increasing its cultivated area (over than 10 million hectares) with world production about 121 million metric tons yearly, more than 50% of the world's production labor in Africa (**FAO, 2021**). Then, some high-yielding varieties were introduced and expanded in Egypt, including the Williams cultivar subject of this study. In Egypt

'Williams' banana fruiting area reached 64382 fed. produced about 995446 tons (Agric. Economic Bull. 2020, Ministry of Agric. and Reclamation, Cairo, Egypt).

'Williams' banana cultivar is a hybrid belongs of *Cavendishi*, it characterized by early season maturity and shortest vegetative growth cycle (**Rao, 1984**). It considered as one of the main bananas cultivars in terms of widespread and economically. Williams cultivar characterized by: hardy pseudostem, which has a good resistance to wind, heavy weight of bunch and large heads, good size of fruit and fruit sweetness (**Maldonado *et al.*, 1998**). Currently, it considered as one of the major banana cultivars in El-Minia Governorate and other Egyptian rejoins.

Banana plant classified as one of the voracity to fertilization especially nitrogen fertilization. In the other side, increasing the mineral fertilization has very dangerous effects on human health and environment. Then reducing the mineral fertilization of banana becomes necessary. In this respect the link between safety fruit and human health is one of the major concerns of consumers. However, natural sources of nitrogen fertilization such as bio-fertilizers such as *Arbuscular Mmycorrhizal fungi* (AMF) can play an important role in this regard (**Sharma and Kumar, (2008); Zhanga *et al.*, 2019; Anli *et al.*, 2021; Bhantana *et al.*, 2021 and Shah *et al.*, 2022**).

2. Material and Methods

The present investigation was conducted during 2021 and 2022 seasons on second and third ratoons of 'Williams' banana plants grown in a private farm situated at El- Gendia village, Beni-Mazar District El-Minia Governorate. Twelve stools, each one contains 3 plants uniforms in vigor of 'Williams' banana was chosen for achieving this study. Where the soil texture is loamy clay and well drained water. The chosen stools are planted at 3 X 3 meters apart. Horticultural practices such: irrigation, strand the bunch, hoeing as well as training and pest control were carried out as recommended.

2.1. Soil characters

Banana orchard soil where the present investigation carried out was loamy clay (table 1). A composite sample was collected and subjected to physicochemical analysis in laboratory according to the procedures outlined by **Wilde *et al.*, (1985**). Then, the data are shown in Table (1).

Table (1). Physical and chemical analysis of banana orchard soils

Constituents	Values
Sand %	9.40
Silt %	18.82
Clay %	71.78
Texture **EC mmhos / cm (1 : 2.5 Extract)**	Loamy Clay 1.05
Organic matter %	1.92
pH (1 : 2.5 extract)	7.6
Total CaCO3 %	1.88
N %	0.21
Available P (Olsen, ppm)	8.11
Exch. K^+ (mg/100g)	482.12
Exch. Ca $^{++}$ (mg/100g)	22.6

2.2. Experimental work

In order to study the effect of partial replacement of mineral nitrogen fertilizer with bio-fertilizer (in form of AMF) on 'Williams' productivity and fruit physicochemical characteristics. Three replaced doses of nitrogen mineral fertilizer namely (NMF); 25%, 50%, and 75% from recommended dose (RD) in form of Ammonium Nitrate 33.5% N, were replaced by using 25%, 50% and 75% AMF inoculation, equal 100, 200 and 300 g AMF / stool.

2.3. Preparation of Mycrrohiza fungi (AMF) its inoculation

The *Arbuscular mycorrhizal fungi* (AMF) which used in this investigation was kindly isolated, clarified and propagated in Microbiology Department faculty of Agriculture, Minia University-Egypt, according to the methods outlined by **Ranganayaki *et al.* (2006)**. AMF were inoculated on onion plants roots, grown in pots. At the end of onion plant growth cycle the plants removed without their roots, the pot soil and root system carefully chopped and mixed. The concentration of AMF spores was jested in order to each gram contained 10^8 spores. Then mixture of root and onion soil was added to the banana in order to 100g/stool, 200 g/stool and 300 g/stool, at first week of May. However, four treatments were achieving: 100% mineral nitrogen fertilization (control), 75% mineral nitrogen + 25% AMF, 50% mineral fertilizer + 50% AMF, and 25% mineral fertilizer + 75% AMF.

2.4. Experimental design and statistical analyses

The present investigation was designed by using randomized complete Block design (RCBD) according to **Gomaz and Gomaz (1990**). Each treatment was replicated three times, one stool (three ratoons per each one). The obtained data were subjected to the proper statistical analysis of variance (ANOVA), using statistical package (MSTATC Program). Comparisons between means were made by using least significant differences (L.S.D) at p= 0.05 (according to **Snedecore and Cochran, 1990**).

2.5. The following parameters were determining

2.5.1. Leaf mineral analysis

Leaf samples were taken from the third upper leaf after bunch shooting during the two experimental seasons. A simple of 10 cm from the middle part of the leaf blades of the third leaf from the top as recommended by **Martin-Préval *et al.* (1984)** and **Ibrahim (2010)** was taken, washed with tap water and distilled water after, air dried and oven dried at 60 C^o overnight until a constant weight. Then, ground by using an electric mill. 0.5 gram of the ground powder material digested by using a mixture of H_2O_2: H_2SO_4 (1: 10 v/v) (according to **Chapman and Pratt, 1965**). The clear digestion transferred to 100 ml volumetric flask. Then the following mineral nutrients were determined: Nitrogen, by using the micro-Kjeldahl method as described by **(Wilde *et al.*, 1985)**. Phosphorus was determined colormetrically, by using Olsen method **(Chapman and Pratt, 1965)**. Potassium was determined by using Flame photometric methods, according to **Martin-Préval *et al.* (1984)**. Magnesium determined by using versene method (**Cottenie *et al.*, 1982 sited in Martin-Préval *et al.* (1984)**.

2.5.2. Yield and fruit quality

The punches picking: when the fingers reached three quarter, bunches were picked during the end of November during 2021and 2022 seasons. Average bunch weight in kg (before artificial ripening), average hand weight (kg) and the number of fingers per hand were measured and recoded. Sample of two hands were taken from the middle of part of bunch, as a sample, for achieving the physical and chemical properties. After the ripening of fingers, the following physical and chemical parameters were determined:

2.5.3. Physical parameters of fingers

Included finger weight (g) by using an accurate digital balance, Fingers dimensions (length and diameter in cm), Pulp to finger ratio (weight / weight) by weighting the pulp and peel. The percentage of each one was calculated and Pulp to fruit ratio was calculated.

2.5.4. Chemical parameters of fingers

A fresh sample was taken from the pulp of five fingers taken and mixed by using electric blender, and the following chemical parameters were determined: TSS% (Percentage of total soluble solids) by using handy refractometer **(Rangana, 1990)**. Reducing, non-reducing and total sugars percentages as well as starch percentage were done by using Lane and Eynon (1965) volumetric method, outlined in **(Rangana, 1990)**. Percentage of titratable acidity (in term of malic acid grams / 100 g fruit pulp) were achieved by using titration against 0.1 N NaOH in presence of phenol-phthalein as an indicator **(AOAC, 1990)**.

3. Results and Discussion

3.1. Leaves mineral contents

Data presented in Table (2) shows the impacts of partial replacement of mineral fertilizer with AMF inoculations on leaves mineral contents, during 2021 and 2022 seasons. It is clear from this table that, treated 'Williams' banana with AMF as a safely and Eco-friendly replacement of mineral nitrogen fertilizers significantly improved 'Williams' banana macro-nutrients (N, P, K and Mg) during the two experimental seasons, compared to using 100% mineral fertilizers. It is clear from this that all replacing ratio of mineral fertilizer significantly enhanced leaves macro-elements contents, this is with the exception of magnesium which did not change significantly when 25% of mineral nitrogen fertilizer was replaced with compost during the two experimental seasons. The control plants (which received 100% RD mineral nitrogen fertilizers) had the lowest percentage of the four macro mineral elements (N, P, K and Mg) in their adult leaves compared to replaced 25%, 50% and 75% of mineral nitrogen fertilizer with AMF inoculations.

The obtained data also shows that, the ratoons received 50% mineral nitrogen + 50% AMF present the highest values of these four macro elements, during the two experimental seasons. In the contrary, during the two experimental seasons (2021 and 2022) the ratoons received 100% of recommended nitrogen dose in form of mineral fertilizer (control) present the lowest values of N, P, K and Mg in their leaves.

The positive effect of AMF inoculation on leaves mineral contents can be related to stimulating the root growth, increasing the availability of mineral elements, decreasing the soil pH level, increasing its uptake of water and mineral elements, inhibition of harmful soil microorganisms, and makes the plants more resistance to extreme environmental condition (**Shaheen *et al.*, 2009; Abdel-Hafiz *et al.*, (2016); Eissa, 2016; Zhanga *et al.*, 2019; Anli *et al.*, 2021; Bhantana *et al.*, 2021; Rajadurai *et al.*, (2022) and Shah *et al.*, 2022)**.

Table (2). Partial replacement of mineral nitrogen fertilizers by using AMF, and its effect on NPK and Mg of 'Williams' banana, during 2021 and 2022 seasons

Treatments	N %		P %		K %		Mg %	
	2021	2022	2021	2022	2021	2022	2021	2022
100% mineral N (Control)	2.6	2.8	0.17	0.18	2.41	2.25	0.51	0.50
75% mineral +25% AMF	2.9	3.3	0.22	0.26	2.93	3.19	0.55	0.53
50% mineral + 50% AMF	3.1	3.5	0.26	0.29	3.03	3.63	0.64	0.69
25% mineral + 75% AMF	2.8	3.1	0.25	0.28	3.02	3.61	0.63	0.66
LSD at 5%	**0.2**	**0.3**	**0.03**	**0.03**	**0.20**	**0.22**	**0.04**	**0.04**

3.2. Yield and its component

Data pertaining the average bunch weight (kg) and hand weight (kg) of 'Williams' banana of second and third ratoons as influenced by inoculation the ratoons with AMF as a partial replacing of conventional mineral nitrogen fertilizers at various doses (25%, 50% and 75%), during 2021 and 2022 seasons. The obtained data indicates that 'Williams' banana yield (in term of bunch weight (kg) and hand weight (kg)) significantly enhanced by replaced the mineral nitrogen at different doses with AMF inoculations, during both experimental seasons. It is worth to mention that all AMF inoculations lead to significant improvement in average bunch and hand weight (kg).

It worth to mentioned that, increasing the replaced percentage of mineral nitrogen from 25% to 50% played an important role of increasing the bunch and hand weights (kg) compared to using 100% of RD in form of mineral nitrogen or replaced 25% only. However, the ratoons received 50% mineral nitrogen plus 50% AMF appear to be superior to those 25% or those received 75% of AMF. The data presented in Table (3) clearly shows that the ratoons received 50% mineral nitrogen fertilizers + 50% AMF produced the highest weights of bunch (27.9 & 30.9 kg) and hand (2.2 & 2.2 kg), during the two experimental seasons respectively. Contrary, the ratoons received 100% in nitrogen recommended dose in form of mineral fertilizer produced the lowest weights of bunch (21.1 & 20.5 kg) and hand (1.7 & 1.6 kg), in both seasons respectively.

The partial replacement of mineral fertilizers (25%, 50% and 75%) with AMF inoculations lead to improve the yield in kg/plant, this positive effect related to increasing the essential nutrients valuably and uptake, decreasing the soil pH level, enhancing other useful microorganisms activity and colonization the soil with fungi hyphens of AMF, produced some plant growth regulators, the growth and activity of fungi can inhibited the other harmful soil microorganisms and makes the plants more resistance to extreme environmental condition (**Shaheen *et al.*, 2009; Zhanga *et al.*, 2019; Anli *et al.*, 2021; Bhantana *et al.*, 2021 and Shah *et al.*, 2022)**.

Table (3). Partial replacement of mineral nitrogen fertilizers with AMF, and its effect on yield and its components of 'Williams' banana, during 2021 and 2022 seasons

Treatments	Bunch weight (kg)		Hand weight (kg)	
	2021	2022	2021	2022
100% mineral N (Control)	21.1	20.5	1.7	1.6
75% mineral +25% AMF	26.4	28.1	1.9	1.9
50% mineral + 50% AMF	27.9	30.9	2.2	2.4
25% mineral + 75% AMF	27.8	28.3	2.0	2.1
LSD at 5%	**2.2**	**2.1**	**0.2**	**0.2**

3.3. Fruit physical properties

The statistical analysis of physical properties data of 'Williams' banana in connection to various partial replacement of mineral nitrogen fertilizer with AMF are illustrated in Tables (6 and 7). The obtained data demonstrated that replaced 25% or 50% of mineral nitrogen fertilizers by using AMF inoculations lead to significant enhancement of fruit physical properties of 'Williams' banana plant during the two experimental seasons. However, increasing the replacement ratio 75% failed to modify significantly the finger dimensions and pulp : fruit ratio during the two experimental seasons. Except the case of fruit diameter and pulp : fruit ration in the second season (2022). Furthermore, the ratoons received 50% mineral nitrogen fertilizers + 50% AMF produced the highest fruit length (14.5 and 16.0 cm), fruit diameter (5.7 and 6.5 cm), and pulp : fruit ratio (76.5 and 76.9), these data were true during the two experimental seasons respectively. In the opposite side, ratoons received 100% mineral nitrogen fertilizers produced the lowest fruit length, fruit diameter and pulp : fruit ratio (76.5 and 76.9), except

the case of fruit diameter in the first season, which the ratoons received 25% mineral nitrogen + 75% AMF in the first season, which produced the lowest fruit length.

The obtained data also shows that, elevated the replacing ratio of mineral nitrogen fertilizers from 25% to 75 % played a remarkable role in improving the fruit weight in grams significantly, except the case of replacing 25%, during the first season only. This increment riche a maximized fruit weight (100.9 and 107.3 g) when replaced 75% of mineral fertilizers by 75% of AMF, during 2021 and 2022 seasons respectively. In the opposite side, the ratoons received 100% in from of mineral nitrogen fertilizer produced the lowest fruit weight (87.3 and 89.7 g) in both seasons respectively.

This positive effect of replacing mineral nitrogen with AMF inoculation on fruit physical properties may refer to the ability of AMF to increase macro and micro nutrients uptake through improvement soil properties. Other words, inoculation with AMF inoculations of 'Williams' banana root growth media can have increased the total protein in leaves (**Emara *et al.*, 2018**). The positive role of partial replacement of mineral fertilizers by using organic or/and bio fertilization on improving fruit physical properties of banana and other evergreen fruit trees was previously conducted by some authors such as: **Baiea and EL-Gioushy (2015),** on 'Grande Naine' banana ratoons grown under sandy soil conditions; **Abdel-Hafiz *et al.* (2016)** on 'Williams' banana grown under heat stress conditions, in Aswan Governorate – upper Egypt; **El-Aidy *et al.* (2018)** on Valencia' orange (*Citrus sinensis*); **Emara *et al.* (2018)** on 'Grand Naine' Banana ratoons (*Musa acuminate*) grown in nursery during adaptation stage under greenhouse conditions; **Rahman *et al.* (2021)** under India environmental conditions on 'Amritsagar (AAA)' banana cultivar and **Rani *et al.* (2021), Sahu *et al.* (2017)** on guava trees and **Abobatta (2020)** on some *citrus spp.*

Table (4). Partial replacement of conventional mineral nitrogen fertilizers with AMF, and its effect on fruit physical properties of 'Williams' banana, during 2021 and 2022 seasons

Treatments	Finger weight (g)		Fruit length (cm)		Fruit diameter (cm)		Pulp to fruit ratio	
	2021	2022	2021	2022	2021	2022	2021	2022
100% mineral N (control)	87.3	89.7	13.7	13.5	5.2	5.3	73.2	73.7
75% mineral +25% AMF	89.1	95.3	14.2	15.9	5.4	6.1	76.2	76.9
50% mineral + 50% AMF	92.3	106.7	14.5	16.0	5.7	6.5	76.5	76.9
25% mineral + 75% AMF	100.9	107.3	13.4	14.0	5.4	6.1	75.0	76.1
LSD at 5%	**4.3**	**5.9**	**0.7**	**0.6**	**0.2**	**0.2**	**2.1**	**3.2**

3.4. Fruit chemical properties

Concerning the chemical properties of 'Williams' banana fruit, the statistical analysis of data in connection to various partial replacement ratio (25%, 50% and 75%) of mineral nitrogen fertilizers with AMF inoculations are illustrated in Tables (5). The obtained data clearly showed that replaced 25% to 75% of mineral nitrogen fertilizers by using AMF lead to significant varying in the must fruit chemical properties of 'Williams' banana plant, during the two experimental seasons.

3.4.1. Total soluble percentage

It is clear from table (5) that replaced 25% or 50% of mineral nitrogen fertilizer with AMF (as a biofertilizer) lead to significant enhancement of 'Williams' banana fruit TSS% during the two experimental seasons. Except, the case of replacing 25% with 25% of AMF, only in the first season (2021), which caused a negligible and non-significant decrease in TSS%. Increasing the replaced mineral nitrogen percentage to 50% with 50% AMF inoculation was associated with sharp increment in

TSS% of 'Williams' banana, during the two experimental seasons. While, increase the replaced mineral nitrogen to 75% with AMF inoculation failed to varyed the TSS% significantly in both experimental seasons. The obtained data showed that, 'Williams' banana ratoons received 50% mineral nitrogen + 50% AMF produced the highest TSS% in their fruits (19.3% and 19.5%), in the both experimental seasons respectively. On the opposite side, the ratoons received 25% mineral nitrogen fertilizers + 75% AMF produced the lowest TSS% in fruit pulp (18.2% and 18.4%), these findings were true during the two experimental seasons respectively.

3.4.2. Effect on fruit sugars contents

It is clear from the same table that, non-significant differences in reducing sugars percentages were observed during the first season. In the same context, during the second season replaced 25% or 75% of mineral nitrogen fertilizers with AMF inoculations failed to enhanced reducing sugars significantly. On the opposite side, replaced 50% of mineral nitrogen with 50% AMF had a significant promotion on reducing sugars. Regarding the percentage of non-reducing sugars, replaced 25% or 50% of mineral nitrogen fertilizers with AMF inoculations (as a bio-fertilization) caused a significant promotion of non-reducing sugars in both experimental seasons, in comparison to control (100% mineral). While, raise the replaced percentage of mineral nitrogen to 75% was associated with slight and non-significant decrement of non-reducing sugars, compared to 100% mineral N fertilization. However, the ratoons received 50% mineral N + 50% AMF produced highest and significant sugars contents in their fruit pulp compared to other treatments or control, during the two experimental seasons. Furthermore, total sugars contents (reducing + non-reducing sugars %) followed the same line of non-reducing sugars contents.

3.4.3. Effect on fruit sugars contents

The obtained results show that, the total acidity % and starch % in fruit pulp don't varied significantly as a result of varying the replaced ratio of mineral nitrogen from 25% to 75% by using AMF inoculation compared to using 100% mineral N fertilization, these data were true during the two experimental seasons.

Table (5). Partial replacement of conventional mineral nitrogen fertilizers with AMF, and its effect on fruit TSS% and sugars contents % of 'Williams' banana, during 2021 and 2022 seasons

Treatments	TSS %		Reducing sugars %		Non-reducing sugars %		Total sugars %		Total acidity %		Total starch %	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
100% mineral N (control)	18.2	18.6	6.0	6.1	11.5	11.3	17.5	17.4	0.312	0.309	1.04	1.05
75% mineral +25% AMF	18.1	19.4	6.3	6.4	12.0	12.3	18.3	18.7	0.311	0.312	1.00	1.01
50% mineral + 50% AMF	19.3	19.5	5.8	6.6	12.2	12.5	18.0	18.9	0.320	0.298	1.09	1.03
25% mineral + 75% AMF	18.2	18.4	6.1	6.2	10.8	10.9	16.9	17.1	0.319	0.318	1.09	1.15
LSD at 5%	0.5	0.6	NS	0.5	0.5	0.4	0.5	0.6	NS	NS	NS	NS

Mutually beneficial relationship between AM fungi and fruit trees hosts was previously confirmed. The AMF gets his energy (in form of carbohydrates) from the roots of fruit tree and it benefits fruit trees by improving the ability of mineral nutrient absorption. It is well known that, AMF is better than fruit trees root at acquiring mineral nutrition (N, P, K, Zn, Cu and Ca) from the soil. AMF can improve a plant's access to water and carbon from the leaves to the rhizospher. In addition, AM fungi have digestive enzymes. Then the AMF is better than fruit trees roots at acquiring nutrients, and it is

also capable to turn inorganic phosphorus and nitrogen into forms easy usable by fruit trees roots. They improve the diversity of plant communities and plant succession (**Smith & Read, 2010** and **Song *et al.*, 2012**). AMF also can Enhancement which improves fruit tree roots to production of some hormones, vitamins and other phyto-active substances. It can also alter the quantity and quality of plant secondary metabolism. AMF also interfere with the phyto-hormone balance of plants, as a bio-regulator, and mycorrhiza act as a bio-protector by inducing tolerance of soil stress. These benefit roles of AMF certainly lead to improve the chemical properties of 'Williams' banana fruit in terms of increasing TSS%, Sugars% and decreasing Total acidity% and starch %, which was noticed in the present study.

4. Conclusion

Under loamy clay soil in El-Minia Governorate, partial replaced of mineral nitrogen fertilizers by using AMF (as a bio-fertilizer) at different percentages (25%, 50% and 75%) was lead to improving the plants mineral statues, yield (kg/plant) and fruit physic-chemical properties of 'Williams' banana fruit. However, replaced 50% of mineral nitrogen fertilizer by using 50% of AMF inoculation produced the best mineral nutrients status, yield (kg), and fruit physicochemical properties of 'Williams' banana cultivar.

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