Scientific Papers. Series B, Horticulture. Vol. LXVI, No. 1, 2022
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

THE EFFECT OF FERTILIZATION REGIME ON EGGPLANT CROPS UNDER GREENHOUSE

Anamaria CIUBOTARITA, Vasile STOLERU, Gabriel-Ciprian TELIBAN, Alexandru COJOCARU, Alexandru HORAICU

"Ion Ionescu de la Brad" Iasi University of Life Sciences, 3 Mihail Sadoveanu Alley, 700440, Iasi, Romania

Corresponding author email: vstoleru@uaiasi.ro

Abstract

Eggplants (Solanum melongena L.*) have become in the last years one of the most appreciated vegetables worldwide due to their high nutritional value. Eggplant fruits contain significant amounts of carbohydrates, mineral salts, vitamins and polyphenols. In order to increase productive potential of eggplant, it is necessary to ensure the optimal level for all the environmental factors as well as the specific technological ones. Soil is the main source of mineral nutrients and water for plants, its ability to provide the needed nutrients varies depending on its level of fertility. Eggplant fruit quality is determined by nutrients quantity and quality. In addition, at the University of Life Sciences from Iasi, an experiment was carried out during 2020-2021 growth season with the purpose to investigate the effect of three different fertilization regimes on the fruit quality and fruit yield and its component of eggplant cultivar Mirval F1 and Bleach Pearl F1 under tunnels. The research indicated significant values in terms of quality and quantity for the microbiologically fertilized Mirval hybrid.*

Key words*: biometrical indicators, cultivars, differentiated fertilizers, eggplant, polytunnels.*

INTRODUCTION

Eggplants (*Solanum melongena* L.) have become increasingly popular in the last 3-4 decades, due to high consumer preferences, but also to the fact that this species finds favourable growing conditions, both in the field and in protected areas, which ensures good economic efficiency (Valerga et al., 2020).
Eggplants are a crop with a particular food and economic impact among vegetable crops because they have a high ecological plasticity, are appreciated by consumers and can be grown in diverse systems (Stoleru et al., 2014).
The growth and development of eggplant plants is influenced by the presence of nutrients.
In the last 30 years, new varieties and hybrids have been introduced in the Romanian market, which most of the time have not adapted to the new environmental conditions and to the high consumer preferences.
Recent research has highlighted that the main factors on which the quantity and quality of the harvest depend in organic and conventional systems are: cultivar, fertilization and irrigation (Caruso et al., 2019).
Nitrogen fertilization at 180 kg/ha increased eggplant yield in the field from 14.8 t/ha in the unfertilized variant to 25.43 t/ha (He et al., 2021).
Biological fertilization significantly influences fruit mass. In the Traviata F_1 hybrid grown in the solar, fruit mass, ranged from 67 g in the unfertilized up to 332.5 g. in the biologically fertilized version (Kostadinov et al., 2019).
Chemical potassium fertilization significantly influenced the total yield in a field eggplant cultivar, ranging from 20.6 t/ha in the unfertilized variant to 37.3 t/ha in the 135 kg/ha potassium fertilized variant (Hochmuth et al., 1993).
In an experiment on eggplant cultivar established in the Mediterranean area, obtained a total yield that ranged from 43.7 t/ha for the organically fertilized to 50.1 t/ha for the chemically fertilized (Leogrande et al, 2014).
Specific research by Smith (1979) highlighted that the N:K ratio in grafted eggplant crops should vary between 1:1 to 1:2 for optimal growth and development, otherwise vegetative growth is induced (Bletsos, 2003) at the expense of poor fruiting (Smith, 1979).

The height of eggplant plants varies within fairly wide limits depending on the number of irrigations, from 97.2 cm in the 12-day irrigated variant to 112.4 cm in the 6-day irrigated variant (He et al., 2021).
Total production in eggplant correlates positively with physiological indicators such as total chlorophyll content, photosynthesis rate, gas exchange, etc.
Total chlorophyll ranged from 0.7 mg/g fresh matter to 1.3 mg/kg fresh matter (Li et al., 2019).
Chlorophyll ranged from 34.56 mg/g fresh matter in the eggplant cultivars Kemer treated with 100 mM NaCl, up to 52.92 mg/g fresh substance in the control Kemer cultivar.
Total chlorophyll ranged from 0.70 mg/g fresh matter in the 80% field capacity irrigated variant to 1.17 mg/g fresh matter in the 100% field capacity irrigated variant.
Chlorophyll a ranged from 0.30 mg/g of FW in the variant irrigated at 40% field capacity to 0.80 mg/g of FW in the variant irrigated at 100% field capacity. Chlorophyll b ranged from 0.28 mg/g FW at the 60% soil capacity irrigated variant to 0.38 la mg/g fresh substance at the 100% soil capacity irrigated variant (Al-Muwayhi, 2019).
The height of eggplant plants ranged from 79.5 cm in the unfertilized variant to 112.7 cm in the variant fertilized with 500 g/m^2 biochar. Fruit weight per plant ranged from 371.4 g in the control variant to 584 g in the variant fertilised with 500 g/m^2 biochar. Chlorophyll a varied from 1.2 mg/g fresh matter in the non-fertilised variant to 8 mg/g fresh matter in the variant fertilised with 500 g/m^2 biochar. Chlorophyll b ranged from 1.1 mg/g fresh matter in the unfertilized variant to 3.4 mg/g fresh matter in the 500 g/m^2 biochar fertilized variant (Ebrahimi et al., 2021).
The influence of photosynthesis rate on the second eggplant cultivar ranged widely from 3.03 µmol m^{-2} s^{-1} for determinations made on the mid-plant leaves of the Black Pearl cultivar to 20.95 µmol m^{-2} s^{-1} for determinations made on the tip leaves of the Aragon cultivar (Acatrinei, 2019).
In the case of *Solanum aethiopicum* L., cv. Legon, temperature influences the rate of photosynthesis, the results varied in wide limits from 9.8 mg CO_2 dm^{-2}h^{-1}, in the fruiting phase at 40^{0}C temperature, to 23.5 mg CO_2 dm^{-2}h^{-1}, in the flowering phase at 30^{0}C temperature (Nkansah, 2001).
The main aim of the research was to investigate the possibility of using new cultivars and fertilisation regimes to increase the quantity and quality of eggplants.

MATERIALS AND METHODS

Experimental site

The research has been carried out during 2020-2021, in the didactic field of the "V. Adamachi" Farm of the University for Life Sciences of Iasi on an eggplant crop, established by seedling between 20-22 April, in a plot on an area of 200 square meters.
The technology of seedling production and crop maintenance was similar to organic crops (Stoleru et al., 2014).
Eggplant crop was preceded by cucumbers on the soil used in the present investigation. The soil was alluvial cambic chernozem soil with the following characteristics: pH 7.2; 3.2% organic matter; 31% clay; 28 mg/kg N, 1.83% K_2O; 1.13% CaO; 0.19% P_2O_5; 0.16% MgO; 0.46% Na_2O; 3.96% Fe_2O_3; 0.11% MnO; 49 ppm Cu; 103 ppm Zn; EC 416 µS/cm.
During the two years, the biological material used was three new hybrid cultivars of eggplant peas Mirval, Aragon and Black Pearl (Figures 1 and 2).


Figure 1. Mirval F1 cultivar


Figure 2. Black Pearl F1 cultivar

An experimental protocol was proposed to achieve optimal nutrition, using Nutrispore® fertilizers, Micoseeds® compared to a control, unfertilised. The combination of the two factors resulted in nine experimental variants. The experiment was a polyfactorial design, in divided plots with three replicates per variant, the area of a replicate being 7.4 m², corresponding to 18 plants per replicate.
Nutrispore® is a solid, water-soluble, chemical fertilizer based on N, P, K, Mg, and complexed with microorganisms of the genus *Glomus* sp.,

in order to provide dual benefits to the crop in terms of fertilization and vigorous plant growth, while also providing benefits to the cultivated soil.

At the first growth stage, 144 g of Nutrispore® - NPK Nutrispore® - NPK (MgO) 30-10-10 with Boron (B), Iron (Fe), Manganese (Mn), Zinc (Zn) were provided.

At the second application, Nutrispore® NPK (MgO) 15-10-30 with Bor (B), Iron (Fe), Manganese (Mn), Zinc (Zn) - 425 kg/ha and Nutrispore® NPK 12-48-8 with Bor (B), Iron (Fe), Manganese (Mn), Zinc (Zn) - 400 kg/ha were applied.

Micoseed® MB is a fertilizer based on *Glomus* sp., *Beauveria* sp., *Metarhizium* sp. and *Trichoderma* sp. (Stoleru et al., 2014). The organic fertilizer was complexed twice during the growing season with Nutryaction® which provides food for microorganisms, ensures growth of eggplant plants and provides enhanced activity of the required microflora. It provides better protection against stress caused by adverse biotic environment and stimulates the development of the root and foliar system of eggplants.

The fertilizers were applied to the soil at a dose of 800 kg/ha for the chemical treatment. Chemical fertilizer was applied three times as follows: 50% of the total amount in coincidence with the final soil preparation prior to planting; 25% when the first fruit reached a 2-3 cm; the last dose (25%) when the fruit of the third cluster reached a 2-3 cm. Biological fertilizer was applied two times as follows: 30 kg/ha at soil preparation and 30 kg/ha when the fruit reached a 2-3 cm from third cluster. The biological fertilizer was complexed with 1.5 L/ha for two time of Nutryaction® applied by fertirrigation system.

Biometrical analyses

In each plot and at each harvest, the number and weight of fruits as well as the mean fruit weight on random 5 fruit samples, were determined. The yield (kg/hg) was calculated by using the following formula: (plants/ha × fruits/plant × average fruit weight)/1000. The plant heights (cm) were measured after the last harvest in each experimental treatment.

Photosynthesis determination

Photosynthesis (μmol $CO_2 \cdot m^{2} \cdot s^{-1}$), was measured with a portable compact system LCi (ADC Bioscientific UK Ltd., Global House, Geddings Road, Hoddesdon, Herts, EN11 0NT, UK), with a Broad Leaf Chamber, with an area of 6.4 cm^2, between 9-10 am. The measurements were performed the day before harvesting, from 9 to 10 am.

Statistical analysis. The experimental results are expressed as means ± SD. The data were statistically processed by two-way ANOVA and Tukey's test was performed for mean separation at $p \leq 0.05$, using SPSS software version 21 (IBM Microsoft, New York, USA).

RESULTS AND DISCUSSIONS

The results on the influence of fertilization on the morphological characters of the analysed cultivars are presented in Table 1.

Fruit diameter for the three cultivars did not show significant differences from the experimental mean of 83.93 mm regardless of the variant. According to the experimental variant, the fruit diameter varied from 74.54 mm for the non-fertilized cultivar Mirval to 86.22 mm for the control cultivar Aragon.

Fruit height for the experimental variants ranged from 17.02 cm in the chemically fertilized Aragon cultivar to 18.68 in the organically fertilized Black Pearl cultivar. Compared to the experimental mean of 18.04 cm the differences were significant at $p \leq 0.05$.

The number of fruits per plant for the analysed cultivars varied according to the experimental variation from 5.77 fruits in the control Black Pearl to 7.93 fruits in the chemically fertilized cultivar Mirval. The values for number of fruits showed significant differences from the experimental mean of 6.56 for $p \leq 0.05$.

The mean mass of a fruit for the experimental variants ranged from 340 g for the Mirval control and Black Pearl control cultivar to 490 g for the organically fertilized Aragon cultivar. Differences from the experimental mean of 388 g were significant at $p \leq 0.5$.

Results on the individual influence of fertilization on leaf surface phosphoactive radiation, substomatal CO_2 concentration, transpiration, stomatal conductance, photosynthesis rate and water use efficiency are presented in Table 2.

Table 1. Results on the influence of fertilization on morphological characters in the analysed cultivars

Treatment	Diameter (mm)	Fruit height (cm)	Fruit mass (g)	No. of fruits
A x Ct	86.22±2.35ns	17.03±0.31bc	0.35±0.01b	6.77±0.23bcd
A x Mo	83.19±1.14ns	18.31±0.22abc	0.49±0.01a	6.87±0.18bc
A x Ch	82.63±0.94ns	17.02±0.29c	0.38±0.01b	7.57±0.19ab
M x Ct	74.51±22.58ns	18.58±0.19ab	0.34±0.01b	6.67±0.38bcd
M x Mo	85.79±1.85ns	18.19±0.37abc	0.39±0.01b	6.97±0.07ab
M x Ch	83.49±0.52ns	17.87±0.33abc	0.39±0.00b	7.93±0.09a
BP x Ct	84.09±2.25ns	18.50±0.46abc	0.34±0.02b	5.77±0.23d
BP x Mo	82.52±0.94ns	18.68±0.33a	0.47±0.02a	5.87±0.18cd
BP x Ch	82.50±1.41ns	18.22±0.23abc	0.36±0.02b	6.57±0.19bcd

*Values represent mean ± standard error. Lowercase letters represent Tukey's test results for p≤0.05 (a- represents lowest value and ns - not significant; A-Aragon; M-Mirval; BP-Black Pearl; Ch - chemical; Mo - microbiological; Ct - control).

The results presented in Table 2 show that the photosynthesis rate was significantly influenced by fertilization, with results ranging from 2.32 in the chemically fertilized cultivar Aragon to 7.31 in the unfertilized variety of the same cultivar.

The results from the statistical point of view on the influence of the cultivar on the transpiration process show that significant results were obtained, ranging from 2.61 in the case of the chemically fertilized variant, in the Aragon cultivar, to 4.66 in the chemically fertilized variant, in the Black Pearl cultivar.

Carbon dioxide, consisting of one carbon atom and two oxygen atoms, is a labile anhydride of carbonic acid ($CO_2.H_2O \sim H_2CO_3$), a chemical compound resulting from the oxidation of carbon, mostly of organic origin. On the other hand, it is a by-product in industrial processes.

Data on the influence of eggplant sorting on CO_2 concentration are presented in Table 2.

From the results obtained, it appears that significant values were obtained, ranging from 336.20 for the cultivar Mirval in the non-fertilized variety to 372.14 for the cultivar Aragon in the chemically fertilized variety.

Measurements recorded for stomatal conductance show that significant values were recorded, ranging from 0.21 in the case of the cultivar Black Pearl in the non-fertilized variety, to 0.46 in the cultivar Mirval in the non-fertilized variety.

Data on water use efficiency show that significant values ranging from 0.89 for the chemically fertilized cultivar Aragon to 2.51 for the non-fertilized variety of the same cultivar were recorded. The recorded data on leaf surface phosphoactive radiation show that significant values ranging from 186.39 were obtained for the organically fertilized cultivar Black Pearl to 316.94 for the chemically fertilized variety of the same cultivar.

Table 2. Results on the influence of fertilization on physiological traits in the analysed cultivars

Treatment	Phosphoactive radiation at the leaf surface (μmol $m^2 s^{-1}$)	CO_2 concentration (vpm) - Ci	Sweat (mol H_2O $m^{-2} s^{-1}$) - E	Stomatal conductance (mol CO_2 $m^{-2} s^{-1}$) - gs	Photosynthesis rate (μmolCO_2 $m^2 s^{-1}$) - A	Water use efficiency A/E
A x Ct	277.02±5.27ab	345.61±2.57bc	2.91±0.02 d	0.46±0.01b	7.31±0.42 a	2.51±0.12a
A x Mo	295.07±18.72ab	347.56±3.00bc	3.28±0.07 c	0.44±0.00a	6.45±0.31a	1.97±0.07b
A x Ch	233.76±12.73abc	372.14±1.84 a	2.61±0.03e	0.23±0.01bcd	2.32±0.18c	0.89±0.07c
M x Ct	274.51±22.58ab	336.20±3.44 c	3.19±0.05c	0.29±0.01	6.08±0.16a	1.91±0.08b
M x Mo	221.41±14.83bc	354.24±5.07 b	3.25±0.07c	0.26±0.00cd	3.27±0.48bc	1.01±0.17c
M x Ch	234.42±15.91abc	352.00±1.97bc	3.47±0.06c	0.22±0.01bc	3.19±0.10bc	0.92±0.05c
BP x Ct	231.19±5.58bc	350.14±1.73bc	3.31±0.08c	0.21±0.01cd	3.03±0.23bc	0.92±0.07c
BP x Mo	186.39±7.34c	343.29±2.54bc	3.94±0.05b	0.25±0.01d	4.24±0.20b	1.08±0.04c
BP x Ch	316.94±31.12a	347.67±5.95bc	4.66±0.05a	0.30±0.00a	4.20±0.67b	0.90±0.14c

*Values represent mean ± standard error. Lowercase letters represent Tukey's test results for p≤0.05 (a- represents highest value; A-Aragon; M-Mirval; BP-Black Pearl; Ch - chemical; Mo - microbiological; Ct - control).

In the experimental period 2020-2022, the influence of cultivar on eggplant production was investigated.
The results obtained for the yields in t/ha of Aragon, Mirval and Black Pearl cultivars are shown in Figure 3.
It can be seen that the highest fruit yield was obtained in organically fertilized cultivar Aragon 82.56 t/ha and the lowest yield was obtained in unfertilized cultivar Black Pearl 54.05 t/ha.
The cultivar Aragon obtained the highest fruit yield of 82.56 t/ha in the organically fertilized cultivar and the lowest of 59.03 in the non-fertilized cultivar. Differences from the experimental mean of 71.11 t/ha were significant for p≤0.5.
The Mirval cultivar obtained the highest fruit yield of 78.57 t/ha with chemical fertilization and the lowest of 63.36 with the non-fertilized variant. Compared to the experimental mean of 71.11 t/ha the results obtained were significant.
The Black Pearl cultivar obtained the highest fruit yield of 80.02 t/ha under chemical fertilization and the lowest of 54.05 under the non-fertilized variant. The differences from the experimental mean of 71.11 t/ha were significant for p≤0.5.
The yield results following fertilization indicated that the only cultivar that responded best to the biological fertilization was the cultivar Aragon while to chemical fertilization the cultivars Mirval and Black Pearl responded best.

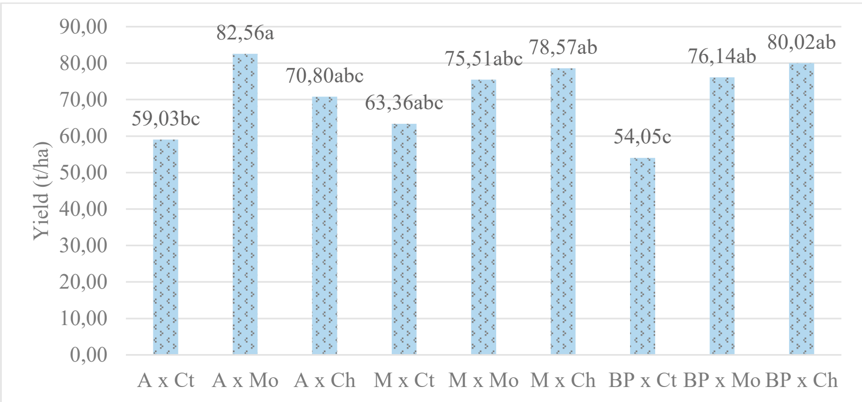

Figure 3. Eggplant production results 2020-2021
(Lowercase letters represent Tukey test results for p≤0.05 (a- represents highest value; A-Aragon; M-Mirval; BP-Black Pearl; Ch - chemical; Mo - microbiological; Ct - control).

CONCLUSIONS

The obtained results highlight the positive effect of chemical and biological fertilization regardless of cultivar, both in terms of physiological and yield indicators.
The new cultivars introduced into the crop provide high yields per unit area, the highest being achieved by Aragon F1.
Biologically fertilised varieties provide high yields compared to chemically fertilised varieties, in the case of Aragon even higher than with synthetic fertilisers.
The high yields of organically fertilised variants are also due to higher photosynthetic activity which correlates positively with the yield achieved.
Fruit diameter and height are in general genetically determined characteristics, therefore differences between varieties are not significantly influenced by fertilisation but by cultivar.
The number of fruits per plant and their mass are superior to the control variants, making significant differences.

ACKNOWLEDGEMENTS

The authors wish to thank the Iasi "Ion Ionescu de la Brad" University of Life Sciences for economic support by PhD programme.

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