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Use and evaluation of new organic fertilizers in the cultivation of *Abelmoschus esculenthus* (Okra)

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Abstract

Research objective: The objective of this work was to evaluate the properties and effect of certain organic fertilizers that can be used in organic farming in comparison with fertilizers of inorganic origin on *Abelmoschus esculenthus* plants. In addition, the interactions that can develop with microorganisms in the rhizosphere and the possible beneficial effects on transplant stress, nutrient uptake by roots and reduction of plant mortality were investigated.

Materials and Methods: The experiments, which began in May 2022, were conducted in the greenhouses of CREA-OF in Pescia on plants placed in pots 12 cm in diameter and on which fertilizers of organic and inorganic origin were evaluated. In September 2022, plant height, number of leaves, leaf surface area, vegetative weight, root volume, root length, seeds per plant, number, weight, girth and length of pods, total substrate bacteria, substrate pH and number of dead plants were analysed.

Results and Discussion: The experiment showed that the application of organic nitrogen and potassium fertilizers can significantly improve the quality and yield of *Abelmoschus esculenthus* plants. In general, a significant increase in height and vegetative and root growth of the plants was observed, especially in nitrogen and potassium synthesis, with an improvement also in the number of fruits and seeds per plant. Plant mortality also decreased significantly compared to the control with synthetic fertilizers, and microbial colonisation of the substrate increased, which probably affected the plants by influencing both vegetative and root growth and defence against biotic stressors.

Conclusions: Organic fertiliser trials showed that these products can significantly improve plant growth by positively affecting the soil microbial component. This is an additional opportunity, especially for those farmers who not only seek to reduce the use of synthetic fertilizers, but also want to use sustainable techniques that better preserve plants and soils, while guaranteeing the production of quality products.

Keywords: *Abelmoschus esculenthus*; Fertilizers; Gombo; Plant growth; Rhizosphere

1. Introduction

Okra (*Abelmoschus esculenthus*) is an annual flowering plant that belongs to the hibiscus family. It prefers nutrient- rich, well-drained soil and needs plenty of sun to bear fruit. It is grown in all tropical and temperate zones; there are many varieties, including early varieties that bear fruit 60 days after sowing (Clemenson spineless, Red burgundy or Green velvet). It grows well at temperatures above 25 °C. It is recommended to sow the plant outdoors from May or in

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seedbeds from April; it does not tolerate transplanting. To make the plant productive, harvest the fruits when they are tender and about 5 cm long [1]. Because of its thin, elongated fruits, okra is also called "lady's fingers". In addition to the pepper-like fruits, this plant also yields a mucilage in the roots that is a natural emollient, while a weaving fibre can be obtained from the complex parts. Since okra secretes a sticky liquid, African children like to stick the small fruits everywhere [2]. The flowers are beautiful, bell-shaped, reminiscent of other mallow plants, and are white or pale yellow, with a purple or red cast at the base of the corolla. They open in the early morning and close in the afternoon. Never lack water in the early stages of seedling development. Depending on the weather and soil conditions, that is, the tendency to dry out more or less quickly after each rain, measures must be taken. Okra is harvested throughout the summer, being careful as the plant is quite stinging on the skin [3]. The fruits, if allowed to ripen, become more than 15 cm long, but for consumption they must be harvested much earlier, when they are still tender and about the size of a finger.

1.1. Curative and medicinal properties of Okra

Okra is not only low in calories, but also high in vitamin A, thiamin, vitamin B6, vitamin C, folic acid, riboflavin, calcium, zinc and fibre. The okra fruit is recommended to pregnant women for its high content of folic acid, which is essential for the formation of the neural tube of the foetus during the 4-12 weeks of pregnancy in the womb. The mucilages in okra also help regulate blood sugar levels by controlling the absorption of blood sugar in the small intestine; they help reabsorb excess water, cholesterol, metabolic toxins and bile. This vegetable helps with constipation, bloating or abdominal distension; it is also an ideal vegetable for weight loss. When eaten regularly, okra promotes the proliferation of good intestinal bacteria called probiotics, relieves irritable bowel syndrome and ulcers, and relieves and refreshes the gastrointestinal tract [4]. The roots are also very rich in mucilage and have a strong emollient effect, better than that of *Althea officinalis*. This mucilage helps in the renewal of blood plasma. An infusion made from the roots is used in the treatment of syphilis. In Nepal, the juice extracted from the roots is used externally to treat cuts, wounds and ulcers [5]. The leaves can also be used to make soothing poultices for wounds. The decoction of the immature fruits has cooling, diuretic, and emollient properties; it is mainly used to treat catarrhal infections, bladder pain, dysuria, and gonorrhoea. The seeds are considered antispasmodic, tonic and stimulant. The infusion of roasted seeds has diaphoretic properties. A decoction of the fruits or leaves can be used as a hair rinse. It is good to cook the fruits sparingly to preserve the mucilages [6].

1.2. Organic fertilizers ' effect on plant growth

In recent years, special attention has been paid to evaluating the effects of organic fertilizers on plant growth. Numerous studies have attempted to determine the mechanisms of action of these products and their characterising active ingredients [7, 8]. Therefore, researchers have attempted to determine the properties of these molecules and develop protocols for their use. The chemical characterization of these products involves the identification of macro- and microelements to ensure that their application does not induce a fertilising rather than a stimulating effect in plants [9, 10]. Determining the dosage is essential to achieve maximum efficacy. Excess of these substances could have phytotoxic effects or, if too low, could not affect plant productivity [11]. Organic fertilizers also contain molecules capable of stimulating plant defence responses to stress and accumulating compounds such as phenols, anthocyanins, flavonoids, and phytoalexins. The biological and ecological importance of these compounds is widely recognised, as phenols, lignins, and other compounds can protect plants from bacterial attack and influence competition [12, 13]. Although there are several methods for evaluating organic fertilizers, it must be emphasised that the extreme heterogeneity and complexity of matrices and formulations with stimulant activity makes their evaluation difficult, as it requires the use of expensive machinery and specialised researchers [14, 15].

Objectives

The objective of this study was to evaluate the properties and effects of certain organic fertilizer that can be used in organic farming compared to fertilizers of inorganic origin on *Abelmoschus esculenthus* plants. In addition, the interactions that can develop with the microorganisms in the rhizosphere and the possible positive effects on transplant stress, nutrient uptake by the roots and reduction of plant mortality were studied.

Figure 1 In the germination phase and two months after the experiment, particular *Abelmoschus esculenthus* in greenhouse cultivation at Crea in Pescia (PT)

2. Material and methods

The experiments, which started in May 2022, were conducted in the greenhouses of CREA-OF in Pescia (Pt), Tuscany, Italy (43°54'N 10°41'E) on *Abelmoschus esculenthus* (Figure 1A,1B) cv 'Clemenson spineless' (Figure 1).

Plants were placed in ø 12 cm pots, 30 plants per work, divided into three replicates of 10 plants each. All plants were fertilised with a controlled-release fertiliser (1 kg m-3 Osmocote Pro®, 9-12 months with 190 g/kg N, 39 g/kg P, 83 g/kg K) mixed with the growing medium before transplanting.

The experimental groups were:

- The group without organic fertilizers (CTRL) (peat 80% + pumice 20%), irrigated with water and previously fertilised substrate;
- The group with fertiliser with organic nitrogen (FN) (peat 80% + pumice 20%), irrigated with water (Rich soil derma Bio N14) (total nitrogen 14%, organic nitrogen 14%, organic carbon 49%, C/N 3.5), 4g/1L of water every week;
- Group with fertiliser with organic nitrogen + potassium (FNP) (peat 80% + pumice 20%), irrigated with water (Glutoran) (total nitrogen 8%, organic nitrogen 8%, potassium oxide 29%, organic carbon 29%), 3g/1L of water every week.

The pH of the zeolite was 6.8, and the plants were watered once a day and grown for five months. After that, the plants were irrigated with drip irrigation. Irrigation was activated by a timer whose programme was adjusted weekly according to climatic conditions and leachate content. On September 1, 2022, plant height, leaf number, leaf surface area, vegetative weight, root volume, root length, seeds per plant, pod number, weight, girth, and length, total substrate bacteria, substrate pH, and number of dead plants were analysed.

2.1. Analysis methods

- Ph: For ph measurement, 1 kg of the substrate was taken from each plant and 50 g of the mixture was placed in a beaker containing 100 ml of distilled water. After 2 hours, the water was filtered and analysed [16];
- Total plate count is the direct determination of total plate count by microscopy of cells contained in a known sample volume using counting chambers (Thoma chamber). The surface of the slide is etched with a grid of squares, with the area of each square known. Determination of viable microbial load after serial decimal dilutions, spatula seeding (1 ml) and plate counting after incubation [17];
- Analytical instruments: IP67 phmeter HI99 series - Hanna instruments; Combined test kit for soil analysis - HI3896 - Hanna instruments; Microbial diversity of culturable cells [18].

2.2. Statistics

The experiment was carried out in a randomised complete block design. Collected data were analysed by one-way ANOVA, using GLM univariate procedure, to assess significant ($P \leq 0.05$, 0.01 and 0.001) differences among treatments. Mean values were then separated by the LSD multiple-range tests ($P = 0.05$). Statistics and graphics were supported by the programs Costat (version 6.451) and Excel (Office 2010).

3. Results

The experiment showed that the use of organic nitrogen and potassium fertilizers can significantly improve the quality and yield of *Abelmoschus esculenthus* plants. In general, a significant increase in height and vegetative and root development of the plants was observed, especially in nitrogen and potassium, with an improvement also in the number of fruits and seeds per plant. In addition, the experiment showed that the use of nitrogen and potassium from organic products could significantly increase leaf production by (60%) and leaf area by (76%), compared to fertilizers from synthetic processes (Table 2) (Figure 2). There was also a significant reduction in plant mortality compared to the control with synthetic fertilizers (FN) by 26% and (FNP) by 33% and an increase in microbial colonisation of the substrate (FN) and (FNP) by 92.3%, which probably interacted with the plants by affecting both vegetative and root growth and defence against biotic stress (Figure 3). A very interesting aspect was the increase in the productive quality of the pods in the theses with organic nitrogen and potassium; in fact, a significant increase in the number, weight, girth and length of the pods produced was observed compared to the control thesis (Table 3). Although okra is a relatively easy crop to cultivate, it often has problems with plant mortality and productivity. Thanks to organic nitrogen and potassium, it seems to improve significantly compared to conventional cultivation. As for the pH of the substrate, only nitrogen synthesis (FN) showed a significant reduction, 6.74, compared to 6.82 in the control and (FNP).

Table 1 Evaluation of organic fertilizers on the agronomic characters of *Abelmoschus esculenthus*

Groups	Plant height cm)	Leaves number (n°)	Leaves surface area (cm^2)	Vegetative Weight (g)	Roots Volume (cm^3)	Roots length(cm)	Plants dead number (n°)
CT	60.09 c	8.12 c	611.33 c	44.56 c	12.19 c	20.15 c	1.8 a
FN	80.13 b	11.46 b	749.68 b	54.95 b	20.45 b	24.57 b	0.4 b
FNP	89.72 a	12.41 a	799.87 a	62.25 a	25.18 a	27.31 a	0.6 b
ANOVA	***	***	***	***	***	***	*

One-way ANOVA; n.s. – non significant; *,**,*** – significant at P ≤ 0.05, 0.01 and 0.001, respectively; different letters for the same element indicate significant differences according to Tukey's (HSD) multiple-range test (P = 0.05).Legend: (CT) control; (FN) nitrogen organic fertiliser;(FNP) nitrogen and organic potassium fertiliser

Table 2 Evaluation of organic fertilizers on pods quality characteristics and interaction with soil microorganisms in *Abelmoschus esculenthus* cultivation

Groups	Seeds per plant (n°)	Pod Number (n°)	Pod weight (g)	Pod circumference (cm)	Pod Length (cm)	Substrate total bacteria (Log CFU/g soil	pH substrate
CT	32.39 c	6.4 c	6.47 b	6.19 c	18.14 c	6.83 b	6.82 a
FN	35.49 b	9.4 b	7.08 a	7.21 b	21.14 b	7.40 a	6.74 b
FNP	38.18 a	12.6 a	7.22 a	8.17 a	24.37 a	7.35 a	6.82 a
ANOVA	***	***	***	***	***	***	*

One-way ANOVA; n.s. – non significant; *,**,*** – significant at P ≤ 0.05, 0.01 and 0.001, respectively; different letters for the same element indicate significant differences according to Tukey's (HSD) multiple-range test (P = 0.05). Legend: (CT) control; (FN) nitrogen organic fertiliser ;(FNP) nitrogen and organic potassium fertiliser

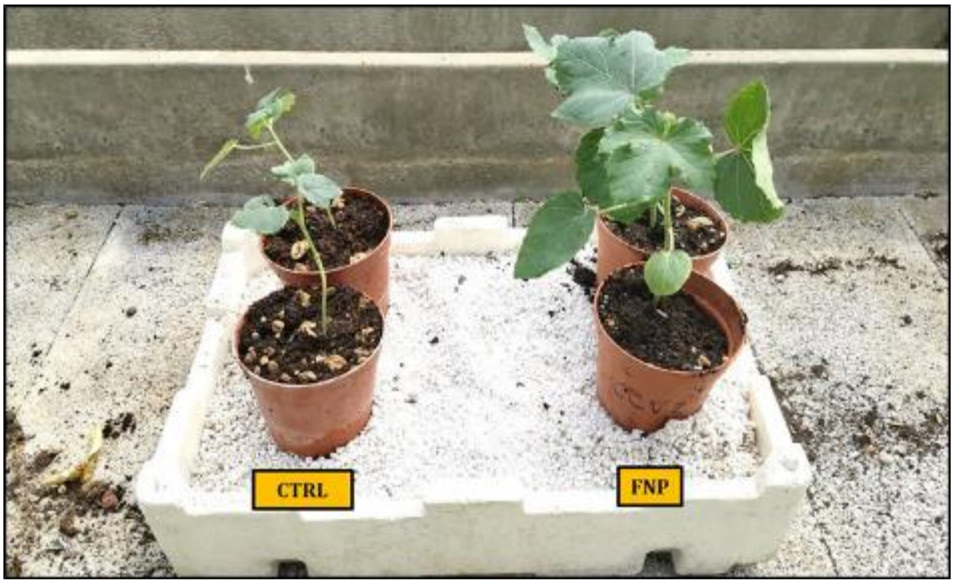

Figure 2 Comparison of plant height and vegetative growth in the thesis with organic nitrogen and potassium (FNP) and the control (CTRL)

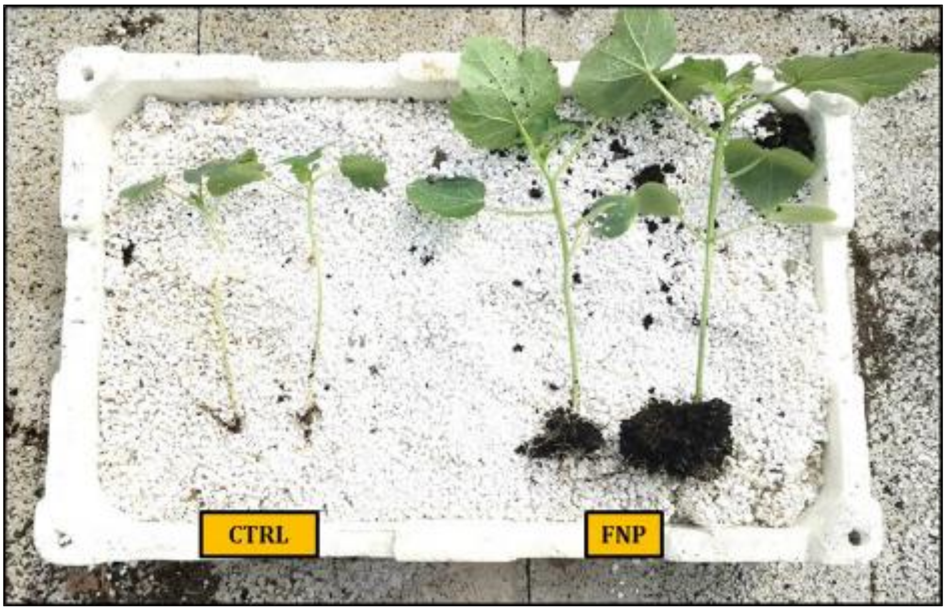

Figure 3 Effect of organic nitrogen and potassium fertiliser (FNP) and control (CTRL) on foliar and root growth of *Abelmoschus esculenthus*

4. Discussion

Solid organic fertilizers are largely products that historically and naturally contain organic nitrogen released more or less slowly. Fermentation manures, manure from hides and skins, brushwood, meat-and-bone meal, cornunghia, to name only the most important, are characterised by the presence of scleroproteins and collagens with slow nitrogen kinetics [19, 20]. Biomasses of agricultural origin and sewage sludges of agro-industrial, civil and industrial origin, which contain organic nitrogen mainly in the form of proteins, i.e., other organic forms, are also different types of nitrogen-rich products of natural origin with slow release [21]. In turn, the chemical and microbiological processes are strongly influenced by climatic conditions (temperature and humidity determine the rate of transformation/mineralization: ideal conditions are soil temperatures between 15 and 30 °C and humidity close to the field water capacity) and soil reaction (pH), which has optimal values towards neutrality and alkalinity, since bacteria prefer a non-acidic environment. It is known that organic nitrogen contained in organic fertilizers can be utilised by plants only after mineralization processes that convert it into mineral nitrogen [22, 23]. These processes occur at different stages of matrix degradation and depend on the metabolism of numerous microorganisms naturally occurring in soils [24]. In recent years, given the problems associated with the use of chemicals in cropping systems, alternative techniques and strategies have been explored to increase agricultural productivity. One example is the use of microorganisms that can increase resistance to biotic and abiotic stresses and promote plant growth and yield by activating specific metabolic and biochemical processes. In this experiment, the use of bioproducts led to an increase in substrate microbiology, which undoubtedly influenced the uptake of nutrients, especially nitrogen [25, 26]. The increased nutrient uptake affected okra plant growth and pod production and size. Microorganisms colonise the rhizosphere and form a symbiotic relationship with the root system. This complex is called the microbiome and is specific to the substrate, cultivation type, and growing conditions [27].

Various experiments show that crop yields are higher with organic fertilizers than when nutrients are applied in mineral form [28]. This can be explained by better nutrient synchronisation, i.e., when organic fertilizers are applied, energy is also supplied to the decomposing microorganisms via the carbon they contain. This process results in a time delay of nitrogen in the soil to build up the microbial tissue, which is available later when the organic material is decomposed [29].

Some authors reported that the combination of organic and mineral nutrients with the mineral source causes a better synchronisation of the release of nutrients taken up by the plants [30]. This mechanism could be explained by the fact that the organic matter not only adds nutrients to the soil, but also improves the physical properties of the soil, which helps to enhance the effect of nutrient addition in real time [31].

The priming effect refers to sudden short-term changes in nutrient turnover caused by the addition of organic matter that is efficiently used by microorganisms. The effects can be positive or negative depending on how the minerals are utilised or immobilised. This can be influenced by microbial biodiversity and the addition of organic material, which in combination affect plant productivity [32].

5. Conclusion

Experiments using organic fertilizers on *Abelmoschus esculenthus* showed that these products could significantly improve plant growth by positively influencing the microbial component of the soil. Furthermore, experimentation has shown that applying organic fertilizers can be better for plants than inorganic fertilizers. This is an additional possibility, especially for those growers who, in addition to aiming for a reduction in synthetic fertilizers , want to use sustainable techniques that are more respectful of plants and soil but at the same time guarantee the production of quality products.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The author declares no conflict of interest.

Statement of ethical approval

The present research work does not contain any studies performed on animal/human subjects.

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