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Full Length Article

OCASE® Biostimulant and NPK Fertilizer Synergies Enhance Growth, Yield, Shelf-life, and Profitability of Onion (*Allium cepa*) in Senegal

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Abstract

Sustainable agriculture focuses on reducing the excessive use of inorganic fertilizers while sustaining crop productivity and improving profitability. In Senegal, onion is an important cash crop and widely grown in the Senegal River Valley and the Niayes agroecological zones. However, its production depends on the intensive use of chemical fertilizers, which has negative effects on soil health and environment. This study assessed the effects of the single or combined application of OCASE® biostimulant, made from nettle (*Urtica dioica*) and dandelion (*Taraxacum officinale*), with decreased rates of NPK on onion growth, yield, shelf-life and economic profitability under field conditions. The experiment was laid out in a randomized complete block design with four replications and six fertilization treatments: control, recommended rate of NPK fertilizer (10-10-20 – 300 kg/ha), OCASE® biostimulant (10 L/ha) and its combination with 75%, 50% and 25% of the recommended of NPK rate. Results showed that OCASE® + 25% NPK significantly enhanced bulb weight (377.5 g), plant height (58.15 cm), and overall yield (67.89 t/ha), which were greater than the recommended rate of NPK. This treatment combination also improved postharvest storability with a decreased water loss and disease incidence compared with the NPK fertilizer alone. The highest economic gain (USD26301.28), profit (USD25891.03), and value: cost ratio (64.11) was also achieved with OCASE® biostimulant + 25% NPK, demonstrating its profitability. In crux, application of OCASE® biostimulant with 25% of the recommended dose of NPK could be a sustainable alternative to synthetic fertilizers for improving onion productivity, postharvest losses and environmental sustainability in Senegal.

Keywords: Onion; Biostimulant; *Urtica dioica*; *Taraxacum officinale*; Yield; Postharvest shelf-life; Sustainable agriculture

Introduction

Onion (*Allium cepa* L.) is one of the most widely consumed vegetables in the world and accounts for 10-25% of vegetable consumption in West Africa (Sansan *et al.* 2024). The area allocated to onion production has more than quintupled in 20 years, mostly due to the development of off-season market gardening, and a diversification of income sources. Global onion production has been rising steadily since the 2000s, from 56.3 million tonnes in 2003 to 111.3 million tonnes in 2023: an increase of 97.56% (FAOSTAT 2025). In Senegal, onions are a major vegetable crop in the horticultural portfolio with a production of 421464 tonnes in 2023, making it the country's leading vegetable crop, ahead of cabbages (*Brassica oleracea* – 153019 tonnes) and tomatoes (*Solanum lycopersicum* L. – 152950 tonnes) (FAOSTAT 2025).

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However, this increase in onion production is often supported by the intensive use of chemical fertilizers, particularly NPK formulations to meet its high nutritional demand (Diatta *et al.* 2024). Excessive reliance on inorganic fertilizers, combined with population growth and rising food demand poses increasing pressure on agricultural systems. Moreover, inefficient use of soil and water resources, and environmental contamination represent major challenges to global food production systems (Hunter *et al.* 2017; Mbow *et al.* 2019; Li *et al.* 2022). In addition, the adverse effects of climate change, declining soil fertility and shrinking arable land increases the pressures on global food production systems (Sangiorgio *et al.* 2020; Debska *et al.* 2022; Gupta *et al.* 2025). These challenges highlight the need to promote sustainable production practices that protect the environment, restore soil fertility and improve the capacity of agricultural systems to produce enough and safe food for a constantly growing population (Jardin 2015; Rouphael and Colla 2020; Diatta *et al.* 2023a).

Biostimulants are now seen as a promising alternative to meet the challenges of high-input, resource-intensive agriculture (Gemin *et al.* 2019; Gupta *et al.* 2021; Ottaiano *et al.* 2021). Plant biostimulants are substances or microorganisms applied to plants that can improve the efficiency of plant nutrient utilization, tolerance to biotic and abiotic stresses, and/or crop quality parameters, regardless of nutrient content (Jardin 2015; Fusco *et al.* 2022). They have shown promising results in agriculture, including increased crop growth, quality, yield and productivity, which has led to the development of several commercial products (Li *et al.* 2022; Vojnović *et al.* 2023; Boutahiri *et al.* 2024). As a result, the worldwide market of biostimulants has rapidly expanded (Ricci *et al.* 2019; Novello *et al.* 2021) with a revenue prediction of USD 4.6 billion by 2030 (Grammenou *et al.* 2023).

Among biostimulants introduced in Senegal, OCASE® is considered a “Natural Preparation of Little Concern (PNPP)” obtained by simple processes such as infusion, decoction, maceration, fermentation of plants such as nettle (*Urtica dioïca*) and dandelion (*Taraxacum officinale*). Nettle slurry is rich in nitrogen, iron, vitamins and trace elements and promotes germination and recovery of young plants (Botineau 2010), vegetative growth, strengthens the natural defenses of plants and acts as a repellent against certain insects (Opačić *et al.* 2024). Dandelion slurry contains calcium, phosphorus, iron, manganese, copper, zinc, and selenium and various bioactive compounds, including flavonoids and phenolic acids (Biel *et al.* 2017). It can therefore promote flowering and increase fruit and vegetable size and regulate plant growth by enhancing its hydration, reducing transpiration and the risk of crop wilting in the event of water stress (Mofidi *et al.* 2024). Therefore, the application of OCASE® biostimulant, made from fermented slurries of nettle and dandelion providing complementary nutrients and bioactive compounds, has the potential to reinforce and stimulate the plant’s natural defense system, stimulates crops and accelerates the emergence of seedlings and young plants, stimulates the root system, and restores deficiencies and revitalizes crops after abiotic stresses (Vasconcelos and Chaves 2019).

Despite these recognized properties, there are no scientific publications on the effectiveness of OCASE® biostimulant on onion productivity, postharvest quality and profitability. Previous studies on biostimulants have generally tested their effects on onion yield or storage traits separately, and in few cases but economic viability but none integrated yield, shelf-life, and economics, particularly for the newly developed OCASE® biostimulant. Addressing this knowledge gap, the present study aimed to evaluate the impacts of OCASE® applied alone or in combination with reduced rates of NPK fertilizers on the growth and yield parameters, yield, shelf-life, and agronomic and economic profitability of onions under field conditions in Senegal.

Materials and Methods

Experimental site, climate and soils

This field study was conducted at the Domaine Agricole Communautaire de Keur Momar SARR (DAC de KMS) experimental station (15°92’70’’ N and 15°87’99’’ W) (Fig. 1). The commune of Keur Momar Sarr belongs to the silvo-pastoral zone. The site is characterized by average temperatures ranging from 24 to 40°C, with an annual thermal amplitude oscillating between 21 and 26°C. Due to sub-desert influences from the north (Mauritania), the Keur Momar Sarr area records high temperatures. The study location is marked by variability in rainfall within the isohyet of between 300 and 400 mm.

The topography of the Keur Momar Sarr commune is essentially flat. The different soil types at the study location are weakly evolved tropical ferruginous soils (with siliceous sand) often used for livestock grazing and peanut crops; lightly leached tropical ferruginous soils (sandy-clay or with ferruginous concretions); and brown sub-arid soils suitable for millet cultivation; and brown, red sub-arid soils suitable for cowpea and watermelon cultivation. The physical and chemical properties of the soil are presented in Table 1.

Plant materials

The study was carried out using the SAFARI onion variety, which is a strict short-day variety (100 to 105 days after transplanting - DAT), characterized by good uniformity, both in terms of size and bulb shape. The variety has a low bolting rate, ensuring the production of high-quality bulbs. The SAFARI onion variety also has good shelf-life qualities provided it is harvested at full maturity - 80% leaf fall and stored in a dry, ventilated place.

Biostimulant formulations

OCASE® biostimulant is based on a synergistic combination of two fermented plant extracts renowned for their agronomic

Table 1: Physical and chemical properties of the experimental soil of the Domaine Agricole Communautaire de Keur Momar SARR (DAC de KMS) (Louga region, Senegal)

Parameters	Clay	Silt	Sand	pH (1:2.5)	EC (1:10)	C	N	C:N	OM	P	Ca	Mg	Na	K
	%	%	%	–	μS/cm	%	%	–	%	mg/kg	cmol/kg	cmol/kg	cmol/kg	cmol/kg
Value	7.25	25.38	67.38	7.4	46	0.17	0.02	9	0.31	6.96	1.88	0.15	0.03	0.02

pH: Hydrogen ion concentration; EC: Electrical conductivity; C: Carbon; N: Nitrogen; C:N: Carbon to nitrogen ratio; OM: Organic matter; P: Available phosphorus; Ca: Calcium; Mg: Magnesium; Na: Sodium; K: Potassium

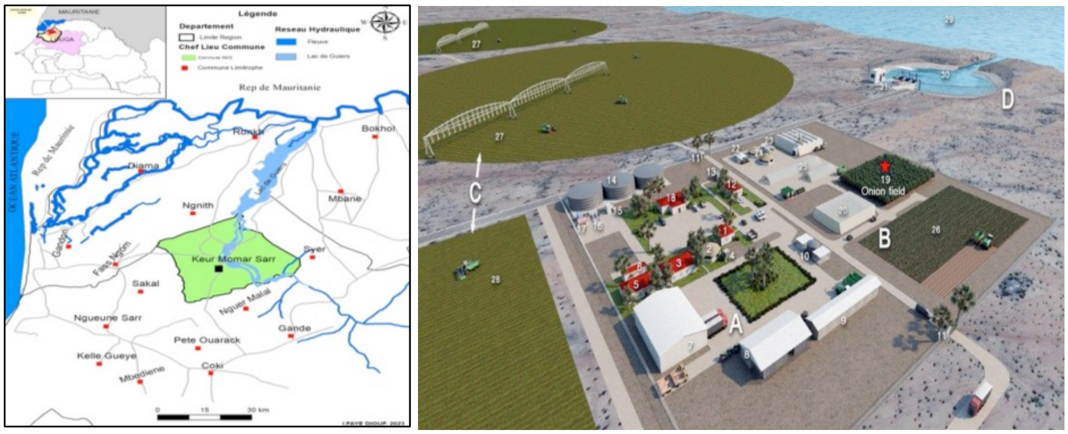

Fig. 1: Study location of the Domaine Agricole Communautaire de Keur Momar SARR (DAC de KMS) (Louga region, Senegal). *The infrastructure of the KMS DAC is organized around four sectors: Sector A: Agricultural Service and Training Center (ASTC); Sector B: Demonstration Farm; Sector C: Commercial Agricultural Plots; Sector D: Pumping Station* (PRODAC 2019)

properties: nettle (*Urtica dioica*) and dandelion (*Taraxacum officinalee*) (SPN Agrobio 2024). The nettle extract is made by chopping around 1 kg of fresh nettle leaves and immersing them in 10 L of water. The mixture is left to ferment at room temperature, away from light, for 10 to 15 days. Daily stirring is recommended to ensure even fermentation, which is considered complete when foaming ceases. Dandelion extract, on the other hand, is made from 2 kg of fresh plant or 200 g of dried plant, also mixed with 10 L of water. Fermentation follows a similar process, with regular stirring until the mixture stabilizes. These two slurries are then combined in a formulation "OCASE®" that makes the most of their complementary properties (Table 2): nettle, rich in nitrogen, iron and trace elements, stimulates vegetative growth and strengthens plants' natural defenses, while dandelion, containing potassium, magnesium, copper and silica, promotes flowering and the physiological balance of crops, and suitable for use in organic farming (SPN Agrobio 2024).

Experimental design

Six fertilization treatments were evaluated in this study: control with no organic or mineral fertilizer; the recommended rate of NPK fertilizer (10-10-20 at 300 kg/ha of NPK as basal plus 300 kg/ha in three top dressing applications), OCASE® biostimulant + 75% of the recommended NPK rate; OCASE® biostimulant + 50% of NPK recommended rate, OCASE® biostimulant + 25% of the NPK recommended rate, and OCASE® biostimulant alone at the dose recommended by the manufacturer (10 L/ha).

The experimental design was arranged as a randomized complete block design with 4 replicates. Each experimental plot measured 12 m² (8 m × 1.5 m). The onion variety SAFARI was planted in 10 rows, 15 cm apart, with 10 cm between plants on the row, giving a density of about 800 plants per plot. Spacing was maintained at 2 m between blocks and 1 m between plots.

Site preparation and basal fertilization

After ploughing and cross-offset using a tractor, well-decomposed organic matter (poultry droppings) was incorporated at a rate of 40 t/ha in all the plots except the control treatment (no input). Mineral fertilizer NPK (10-10-20) was applied as basal dressing at rates corresponding to each treatment: 100% (300 kg/ha), 75% (225 kg/ha), 50% (150 kg/ha) and 25% (75 kg/ha) of the recommended dose. After the basal applications, the soil was lightly ploughed in and levelling was carried out before and after the first irrigation to correct unevenness and ensure uniform water distribution.

Nursery

The nursery was raised in a greenhouse at the KMS DAC on September 4, 2023. The SAFARI onion variety was sown on a 28 m^2 bed (28 m × 1 m) in rows 15 cm apart. The nursery beds received 20 t/ha of well-decomposed organic matter and 300 kg/ha of NPK 10-10-20 synthetic fertilizer as a top dressing. The nursery was maintained by regular weeding to control weeds, ensure good penetration of water into the soil

Table 2: Mineral composition of the OCASE® biostimulant prepared from nettle (*Urtica dioica*) and dandelion (*Taraxacum officinalee*) extracts

Parameters	pH	EC (1:10)	Ca	Mg	Na	K
	–	μS/cm	meq/L	meq/L	meq/L	meq/L
Value	8.8	1656.5	4.0	1.0	4.62	5.58

pH: Hydrogen ion concentration; EC: Electrical conductivity; Ca: Calcium; Mg: Magnesium; Na: Sodium; K: Potassium

Table 3: Application schedule of foliar treatments

Fertilizer	Quantity	Application period
Control	–	Not applicable
NPK (10-10-20)	300 kg/ha (100%)	Basal + top-dressing only
OCASE® + 75% NPK	10 L/ha + 75% NPK	1st: 20 DAT; 2nd: 40 DAT; 3rd: 60 DAT; 4th: 67 DAT; 5th: 75 DAT
OCASE® + 50% NPK	10 L/ha + 50% NPK	1st: 20 DAT; 2nd: 40 DAT; 3rd: 60 DAT; 4th: 67 DAT; 5th: 75 DAT
OCASE® + 25% NPK	10 L/ha + 25% NPK	1st: 20 DAT; 2nd: 40 DAT; 3rd: 60 DAT; 4th: 67 DAT; 5th: 75 DAT
OCASE® alone	10 L/ha	1st: 20 DAT; 2nd: 40 DAT; 3rd: 60 DAT; 4th: 67 DAT; 5th: 75 DAT

NPK (10–10–20): Compound fertilizer containing 10% nitrogen (N), 10% phosphorus (P_2O_5), and 20% potassium (K_2O); 1st, 2nd, 3rd, 4th, and 5th correspond to the number of foliar applications conducted at 20, 40, 60, 67 and 75 DAT, respectively; DAT: Days after transplanting

and reduce evaporation. To protect the nurseries against diseases and pests, phytosanitary treatments were applied every 15 days.

Transplanting

Transplanting was carried out on 02 November 2023 (59 days after nursery). The young plants were transplanted into the previously prepared plots, with pre-irrigation and incorporation of organic matter and mineral fertilizer, to a depth of 2 cm. Roots and leaf tips were trimmed just before transplanting to facilitate plant recovery. After transplanting, drip irrigation was applied daily to maintain adequate soil moisture across all plots.

Crop monitoring

The experimental plots were watered daily using a drip system during the first month of cultivation, and every other day from the second month onwards. Phytosanitary treatments alternating fungicide spray (mancozeb + copper oxychloride 12% + sulfur 20%) with an insecticide spray (lambda-cyhalothrin 30 g/L + acetamiprid 16 g/L + cypermethrin), were applied every 15 days from transplanting to maturity. Weeding was also carried out on the eve of each maintenance treatment application (foliar and NPK), to eliminate weeds and aerate the soil in the plots, to reduce competition for water and nutrients. The treatments applied included NPK (10-10-20) and foliar spraying with the OCASE® biostimulant (Table 3).

Harvesting and storage

All experimental plots were harvested at 147 DAT. Harvesting was carried out manually by digging up the bulbs, then cutting the roots and stalk at the base of the leaves. After harvest, 10 kg of onions were randomly sampled from each plot and then stored in a dry, well-ventilated warehouse for 75 days.

Determination of growth and shelf-life parameters

A first sample of 10 plants was randomly selected from the 6 central rows of each experimental plot. Data on growth parameters were collected 20 DAT, followed by a second observation 10 days after the first, and finally, rest of the observations, which took place every 15 days from the second to 75 DAT. The onion parameters included: the number of leaves per plant, the collar diameter, as well as the size of the bulbs, the plant height, and the bulb weight. The second sample was used to determine the parameters observed at plot level. These parameters were the chlorophyll content of leaves (photosynthetic activity), using a Trimble Greenseeker hand-held optical sensor (Trimble Navigation), date at 80% leaf drop, onion yield, number of bulbs per plot, flowering rate per plot, water loss rates after 75 days of storage, bulb rot rates (collar rot, black mold and bacterial rot).

Assessment of agro-economic parameters

The economic analysis was based on total yield and production costs for each treatment. Total yield was calculated by multiplying onion yield (kg/ha) by the farm-gate price of onion in the Keur Momar Sarr field (250 FCFA or USD0.4 per kg). Production costs included the cost of fertilizers (NPK: 400 FCFA/kg or USD0.70; OCASE® biostimulant: 5000 FCFA/L or USD 8.50) and other input expenses. Net income was obtained by subtracting production costs from total income. The benefit: cost ratio (BCR) was then computed as the ratio of total income to total production cost, indicating the profitability of each treatment.

Statistical analysis

Data processing and analysis was carried out using 2022 JMP Statistical Discovery LLC SAS JMP Pro version 15.0.0 statistical software (SAS Institute Inc., Carey, North Carolina, United States). One-way analysis of variance (ANOVA) was applied to growth, yield and shelf-life parameters as well as agro-economic parameters and a Fisher's protected Least Significant Difference (LSD) was performed when treatment effects were significant at the 5% level.

Results

Effect of OCASE® biostimulant and NPK fertilizer on vegetative growth

The combined application of OCASE® biostimulant and inorganic fertilizer had a significant (*P < 0.05*) effect on leaf number, plant height, collar diameter, and chlorophyll content of onion plants (Fig. 2 – 5). At 60 DAT, the control treatment consistently recorded the lowest number of leaves (5.95/plant), whereas OCASE® + 25% NPK produced the highest number of leaves (11.08/plant) (Fig. 2). The recommended NPK treatment had similar number of leaves (10.85/plant) compared to OCASE® + 25% NPK, while OCASE® + 75% and 50% NPK recorded slightly lower values (10.13 – 10.38/plant). OCASE® applied alone resulted in also modest improvement (10.10/plant) (Fig. 2).

Similar pattern was observed for the height of onion plants. The control treatment has the shortest plants (15 cm), while OCASE® + 25% NPK (58.15 cm) and the recommended dose of NPK (55.58 cm) produced the tallest ones at 60 DAT. OCASE® + 75% and 50% NPK treatments produced plants 51.23–52.25 cm tall, whereas OCASE® alone reached 46.35 cm (Fig. 3). The fertilization treatments also significantly (*P < 0.05*) improved collar diameter (Figure 4). The widest stems were obtained under OCASE® + 25% NPK (25.03 cm), by compared with 6 mm in the control plants, which obtained the lowest values (Fig. 4).

Chlorophyll content was strongly enhanced by OCASE® and NPK application. The lowest values were recorded in the control (0.23), while the highest (0.51) were observed under OCASE® + 25% NPK, though not statistically different from the recommended NPK (0.47) (Fig. 5). Treatments with OCASE® + 75% and 50% NPK showed values of 0.44–0.48 and OCASE® alone reached 0.42 (Fig. 5).

Effect of OCASE® biostimulant and NPK fertilizer on flowering and maturity

Flowering performance of onion plants was significantly influenced by OCASE® biostimulant and NPK fertilizer (Table 4). OCASE® + 25% NPK and OCASE® + 75% produced the greatest flower numbers (411.50 – 400.5) and highest flowering rates (41.15 – 40.05), while OCASE® + 50% NPK, OCASE® alone, and the recommended rate of NPK, showed moderate performance but statistically similar values (Table 4). The lowest flower number and flowering rate occurred in the control treatment.

Crop maturity, measured by the date of 80% leaf fall, showed significant (*P < 0.05*) variations between fertilization treatments (Table 4). Plants fertilized with the recommended rate of NPK (134.50 days) and OCASE® + 50% NPK (135.00 days) reached 80% leaf fall earlier, indicating faster senescence and crop maturity. In contrast, the control plants showed a negative impact of nutrient deficiency on development significantly (*P < 0.05*) and recorded delayed maturity (211.50 days) compared to other treatments.

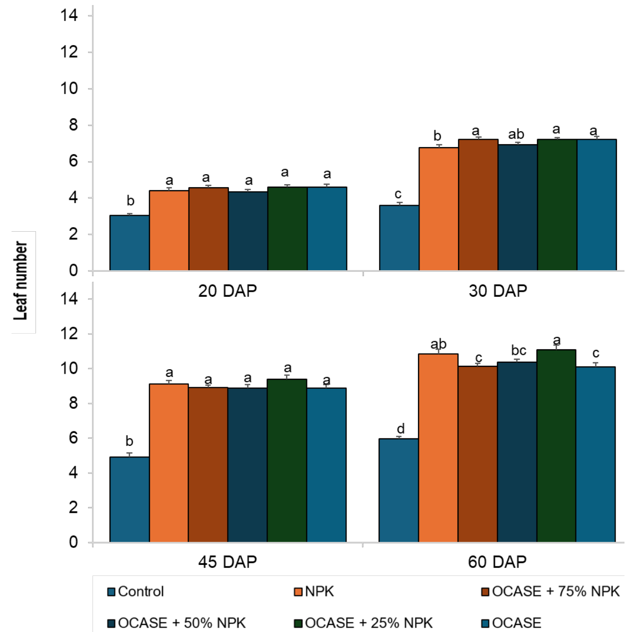

Fig. 2: Effects of fertilization treatments on the onion leaf number
Different alphabetical letters on the error bars indicate statistically significant differences between treatments, determined by Fisher's protected Least Significant Difference (LSD) test (*P < 0.05*)

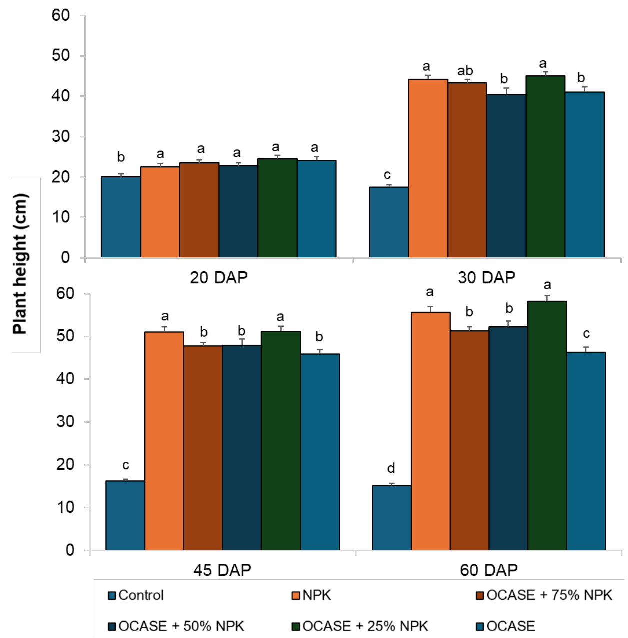

Fig. 3: Effects of fertilization treatments on onion plant height
Different alphabetical letters on the error bars indicate statistically significant differences between treatments, determined by Fisher's protected Least Significant Difference (LSD) test (*P < 0.05*)

Table 4: Effects of fertilization treatments on growth parameters of onion

Treatments	Flower number	Flowering rate (%)	Date at 80% leaf fall (DAT)	Bulb weight (g)	Longitudinal diameter (mm)	Equatorial diameter (mm)
Control	0.00^{b}	0.00^{b}	211.50^{a}	41.00^{e}	41.75^{d}	29.25^{d}
NPK	316.25^{a}	31.63^{a}	134.50^{b}	333.00^{b}	73.25^{bc}	86.25^{b}
OCASE + 75% NPK	400.5^{a}	40.05^{a}	137.00^{b}	289.50^{c}	74.75^{ab}	79.73^{c}
OCASE + 50% NPK	392.25^{a}	39.23^{a}	135.75^{b}	300.50^{c}	73.00^{bc}	79.23^{c}
OCASE + 25% NPK	411.50^{a}	41.15^{a}	137.00^{b}	377.50^{a}	78.75^{a}	90.25^{a}
OCASE	329.00^{a}	32.90^{a}	137.00^{b}	254.00^{d}	69.50^{c}	77.25^{c}

NPK: Nitrogen–Phosphorus–Potassium fertilizer; DAT: Days after transplanting
Means within column followed by different alphabetical letters indicate statistically significant differences between treatments, determined by Fisher's protected Least Significant Difference (LSD) test ($P < 0.05$)

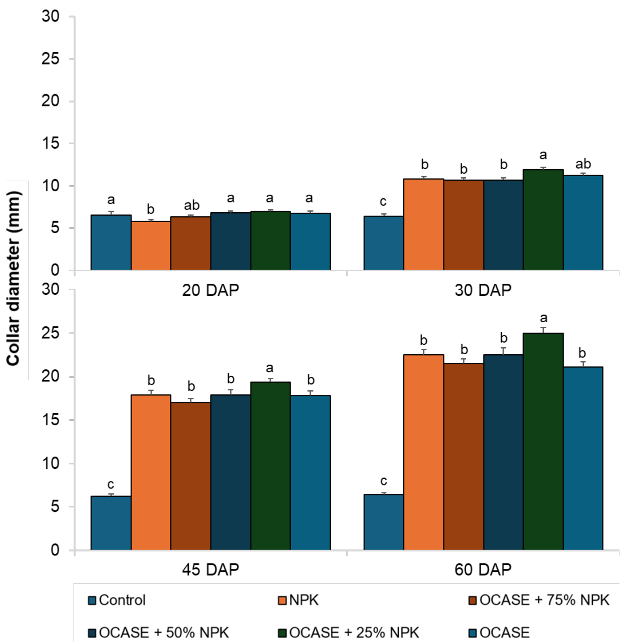

Fig. 4: Effects of fertilization treatments on plant collar diameter. Different alphabetical letters on the error bars indicate statistically significant differences between treatments, determined by Fisher's protected Least Significant Difference (LSD) test ($P < 0.05$)

Effect of OCASE® biostimulant and NPK fertilizer on bulb traits

Bulb weight and dimensions of onions were significantly ($P < 0.05$) affected by OCASE® biostimulant and NPK fertilizer (Table 4). The heaviest bulbs were produced under OCASE® + 25% NPK (377.50 g; longitudinal diameter of 78.75 mm; and equatorial diameter of 90.25 mm), followed by the recommended dose of NPK fertilizers (333.00 g; 73.25 mm; and 85 mm). Bulbs from OCASE® + 75% and 50% NPK weighed 289.50 and 300.50 g, respectively, with longitudinal and equatorial diameters of around 74 mm and 80 mm, while the application of OCASE® alone yielded 254.00 g bulbs. The smallest bulbs were obtained in the control treatment with only (41.00 g; 41.75 mm and 29.25 mm). These results highlight the complementary role of OCASE® in maintaining bulb growth and quality when fertilizer inputs are reduced.

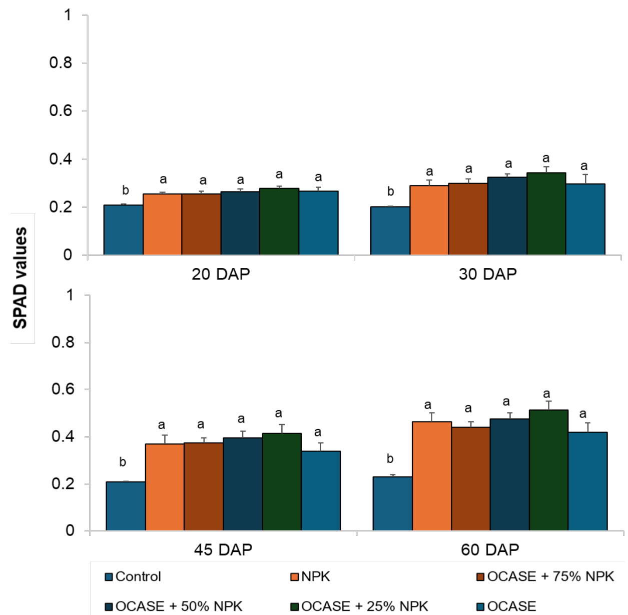

Fig. 5: Effects of fertilization treatments on onion chlorophyll content. Different alphabetical letters on the error bars indicate statistically significant differences between treatments, determined by Fisher's protected Least Significant Difference (LSD) test ($P < 0.05$)

Effect of OCASE® biostimulant and NPK fertilizer on yield

Onion yield responded strongly to the fertilization treatments ($P < 0.05$) (Fig. 6). The highest yield was obtained with OCASE® + 25% NPK (67.89 t/ha), which was not statistically different from recommended NPK (61.31 t/ha) and OCASE® + 50% NPK (60.84 t/ha), demonstrating that fertilizer rates can be reduced by 75–50% without compromising yield when combined with OCASE®. Yields under OCASE® + 75% were 40.49 t/ha, while OCASE® applied alone produced 45.48 t/ha, which was substantially higher than the control (6.35 t/ha), well below the combined treatments (Fig. 6), which demonstrates the importance of nutrient supplementation in onion production.

Effect of OCASE® biostimulant and NPK fertilizer on shelf-life parameters

Shelf-life performance of onion was significantly ($P < 0.05$)

Table 5: Effects of fertilization treatments on total onion yield (t ha^{-1}) on conservation parameters of onion

Treatments	Water loss rate of bulbs (%)	Bulb loss rate due to collar rot (%)	Black mold (%)	Bacterial rot rate (%)
Control	60.47^{a}	0.00^{b}	0.00^{NS}	0.00^{NS}
NPK	10.63^{c}	2.96^{a}	0.00	0.00
OCASE + 75% NPK	16.60^{b}	2.01^{ab}	0.00	0.00
OCASE + 50% NPK	13.04^{bc}	2.33^{a}	0.00	0.29
OCASE + 25% NPK	11.45^{bc}	2.85^{a}	0.00	0.39
OCASE	16.05^{bc}	0.94^{ab}	0.00	0.00

NPK: Nitrogen–Phosphorus–Potassium fertilizer; NS = Non-significant
Means within column followed by different alphabetical letters indicate statistically significant differences between treatments, determined by Fisher's protected Least Significant Difference (LSD) test ($P < 0.05$)

Table 6: Effects of fertilization treatments on economic benefits, fertilizer profit and Value-Cost Ratio (V.C.R.) of onion

Treatments	Economic gain (USD)	Profit from fertilizer (USD)	Value-Cost Ratio (VCR)
Control	0.00^{f}	0.00^{f}	0.00^{f}
NPK	23487.18^{b}	22666.67^{c}	28.63^{d}
OCASE + 75% NPK	14591.88^{e}	13873.93^{e}	20.32^{e}
OCASE + 50% NPK	23286.32^{c}	22722.22^{b}	41.28^{b}
OCASE + 25% NPK	26301.28^{a}	25891.03^{a}	64.11^{a}
OCASE	16722.22^{d}	16294.87^{d}	39.13^{c}

NPK: Nitrogen–Phosphorus–Potassium fertilizer
VCR: Value–Cost Ratio. Values presented are Value–Cost Ratios (VCR), calculated as the ratio of the value of yield increase over the control to the cost of applied fertilizer and/or biostimulant inputs. By definition, the control treatment has a VCR of 0, since no additional inputs were applied. Means within column followed by different alphabetical letters indicate statistically significant differences between treatments, determined by Fisher's protected Least Significant Difference (LSD) ($P < 0.05$)

influenced by OCASE® and NPK treatments (Table 5). Onions bulbs from control treatments lost 60.47% of their weight during storage due to water loss, compared with 10.63 and – 11.45% under the recommended dose of NPK and OCASE® + 25% NPK. OCASE® + 50% NPK treatment showed slightly higher water loss (13.04%), while OCASE® + 75% NPK and OCASE® alone recorded around 16%.

Losses due to collar rot were, overall, minimized by fertilization treatments (Table 5). Collar rot was not reported on bulbs from control plants, while the application of OCASE® alone recorded less than 1% incidence (Table 5). The recommended rate of NPK and the application OCASE® + 25% NPK recorded the significantly ($P < 0.05$) highest incidence (2.96 – 2.85%), compared with 2.33 and 2.01% under OCASE® + 50% and 75% NPK. Black mold was not reported in this study, but bacterial rot incidence was negligible (< 0.5%) in OCASE® + 25% NPK and OCASE® + 50% NPK treatments (Table 5). Overall, Results on onion shelf-life parameters showed that OCASE® with reduced NPK prolongs storage stability and reduces postharvest losses.

Effect of OCASE® biostimulant and NPK fertilizer on economic indicators

Economic indicators differed significantly ($P < 0.05$) among fertilization treatments (Table 6). The highest net income was obtained with OCASE® + 25% NPK (USD 26301.28/ha), which also had the greatest fertilizer profit (USD 25891.03) and value:cost ratio (VCR – 64.11). OCASE® + 50% NPK and OCASE® alone had high economic returns with respectively 41.28 and 39.13. Although the recommended rate of inorganic fertilizers had relatively ranked second on economic gain (USD23487.18), its BCR (28.63) was relatively lower compared with treatments integrating OCASE®, indicating the clear economic advantage of combining OCASE® with reduced mineral fertilizer. The lowest economic gain (USD 14591.88), profit from fertilizer (USD 13873.93) and BCR (20.32) were recorded under OCASE® + 75% NPK. OCASE® alone yielded only USD 16722.22/ha but had a higher BCR compared to the recommended rate of NPK.

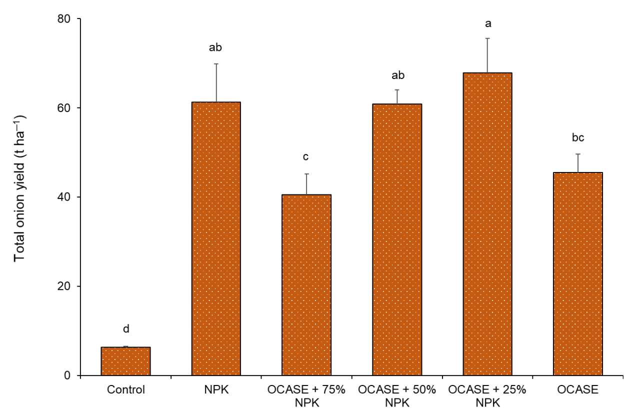

Fig. 6: Effects of fertilization treatments on total onion yield (t ha^{-1})
Different alphabetical letters on the error bars indicate statistically significant differences between treatments, determined by Fisher's protected Least Significant Difference (LSD) test ($P < 0.05$)

Discussion

The combined application of OCASE® biostimulant and the reduced dose rate of NPK significantly increased the vegetative growth of onion compared to their application alone and the control treatment. OCASE® biostimulant + 25% NPK had higher leaf production, plant height and collar diameter than the other fertilization treatments (Novello *et al.* 2021; Prakash *et al.* 2022). The stronger vegetative growth under OCASE® biostimulant + 25% NPK can be explained by the strong and positive interaction between the nutrient contribution of the inorganic NPK fertilizer and the growth-promoting compounds in nettle and dandelion extracts. These molecules improve the availability and uptake of nutrients, root proliferation, stimulates chlorophyll biosynthesis, and can reduce the oxidative stress, resulting in increase accumulation of biomass (Vasconcelos and Chaves 2019; Maričić *et al.* 2021; Filho *et al.* 2024). The observed improvements under biostimulant and reduced NPK fertilizers are consistent with previous bio-based studies on onion and vegetable other crops (Domenico 2019; Novello *et al.* 2021; Prakash *et al.* 2022).

The flowering and maturity of onion were also significantly influenced by fertilization treatments. The earlier flowering and maturity dates for plants treated with OCASE® biostimulant + 25% NPK indicates a faster shift from allocating assimilates for vegetative growth to reproductive organs. This is likely due to enhanced nutrient assimilation and improved hormonal balance, which are known for accelerating the transition from vegetative to reproductive stages in plants (Franks 2015; Andreotti *et al.* 2022). On the contrary, the delayed flowering and maturity dates observed in the control onion plants imply an insufficient supply of nutrients, which prolonged onion vegetative stage (Hunter *et al.* 2017).

Application of OCASE® biostimulant with 25% of the recommended dose of NPK significantly gave the highest values for average bulb weight and longitudinal and equatorial diameters. The higher bulb weight and size under OCASE® + 25% NPK can be attributed to improved assimilate partitioning, increased photosynthetic activity, and stimulation of root growth (Domenico 2019). Biostimulants such as OCASE® as can stimulate metabolic activity as well as water and nutrient acquisition, explaining the larger bulb formation despite only using a quarter of the recommended NPK rate (Ertani *et al.* 2012; Mógor *et al.* 2021). Previous studies have also reported that biostimulant-based fertilization helped reduce chemical fertilizers without compromising crop yields (Gemin *et al.* 2019; Novello *et al.* 2021).

Onion yields followed a similar trend as physiological traits, with OCASE® biostimulant + 25% NPK being statistically equivalent to the recommended rate of NPK. The observed results in our study suggest a compensation of the reduced inorganic inputs by OCASE® biostimulant through the stimulation of root development and the increase of tolerance to abiotic stress (Rouphael and Colla 2020). In addition, improved nutrient use efficiency due to readily available nutrients from NPK and the supplemental effects of biostimulants could also explain the observed increased increase in onion yield under OCASE® biostimulant + 25% NPK (Gebretsadik and Dechassa 2018). Other studies have also reported crop yield improvements after applying biostimulants due to enhanced nutrient use efficiency and abiotic stress tolerance (Canellas *et al.* 2002; Novello *et al.* 2021).

Fertilization treatments significantly influenced shelf-life parameters of onion bulbs with OCASE® + 25% NPK and full NPK treatments recording the lowest water loss but exhibited a minimal bacterial rot during storage. Bulbs from control treatments, on the other hand, had the highest water loss. As for collar rot, a higher incidence was noted from the recommended rate of NPK compared to other treatments, probably due to a high vegetative succulence (Debska *et al.* 2022). Results also show that the phenolic compounds and antioxidants of the biostimulant may have strengthened the structure of onions bulbs and limited the development of pathogens, as similarly observed by Shehata *et al.* (2017) and Giordano *et al.* (2024).

Economic indicators were similar to agronomic results, with OCASE® + 25% NPK achieving the highest economic gain, profit from fertilizer, and Value–Cost Ratios, which indicate sustained onion yields while reducing input addition and costs. Conversely, the treatments with the higher fertilizer rates such a OCASE® + 75% NPK did not proportionally result in yield gains, hence decreasing economic returns (Gemin *et al.* 2019). These results suggest that the combination of biostimulants with the decreased rate of NPK is a cost-effective alternative to conventional agriculture, particularly in resource-limited farming systems (Filho *et al.* 2020; Petropoulos 2020; Diatta *et al.* 2023b).

Despite the promising results from combining OCASE® biostimulant with NPK fertilizer, this research was conducted in one site and during one growing season. Future studies should include multi-site and season settings to verify the reproducibility of these results. In addition, the physiological mechanisms and microbial activities causing the observed biostimulant effects need to be elucidated in order to understand their influence on plant's natural defense system, root system, crop growth and development, adaptation to abiotic stresses.

Conclusion

The use of OCASE® biostimulant, made from nettle and dandelion slurry, as a foliar biostimulant was assessed for the first time. Results showed that the combined application of OCASE® biostimulant + 25% NPK significantly improved all growth parameters, yield components and onion yield, postharvest storability and profitability. This fertilization option has the potential to reduce the reliance of inorganic fertilizers while sustaining crop yields. The combination of OCASE® biostimulant with a reduced dose of synthetic fertilizers could, therefore, be used as a balanced source of nutrients for productive, sustainable and environmentally-friendly agriculture.

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Author Contributions

Conceptualization: AAD, PAD and ABN. Methodology: AAD, PAD and ABN. Validation: JFDCLF, CB, AGBM, and CM. Formal analysis: AAD and JFDCLF. Investigation: AAD. Data curation: AAD. Writing—original draft preparation: AAD. Writing—review and editing: JFDCLF, CM, MB and MS. Supervision: AAD, PAD and ABN. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

Data Availability

The original contributions presented in the study are included in the article; further inquiries can be directed to the corresponding author.

Ethics Approval

Not applicable to this paper.

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