

Treated cocopeat–pumice mixtures influence substrate physico-chemical properties, nutrient uptake and potato yield (*Solanum tuberosum* L.)

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Abstract

Cocopeat has become a widely favored soilless medium for producing potato minitubers, largely because conventional field soils retain water poorly and readily harbour soilborne pathogens. Its high price and irregular supply, however, create a strong incentive to identify blended media that match the performance of pure cocopeat at lower cost. Accordingly, this study assessed how varying cocopeat-to-pumice (C/P) ratios influence the physico-chemical characteristics of the growing medium, nutrient uptake, and tuber yield of *Solanum tuberosum* L. grown under greenhouse conditions. Four blends (v/v), namely 100:0, 75:25, 50:50 and 25:75 C/P, were tested alongside a 100% soil control, laid out in a triplicated completely randomized design. Relative to the other media, the 100:0, 75:25 and 50:50 C/P blends produced marked gains in substrate bulk density, particle density, air-filled porosity, moisture content and water holding capacity, although the control retained the most water (52.0%). Nitrogen, potassium and calcium were absorbed in significantly ($p < 0.05$) higher amounts under the 25:75 and 50:50 C/P blends. The tallest plants and highest number of branches occurred in pure cocopeat (67.57 cm), with the 50:50 blend close behind (63.87 cm). By 14 days after flowering, the normalized difference vegetation index (NDVI) had declined to 9.40%, coinciding with the natural onset of leaf senescence. Tuber yields of 402.68, 375.08 and 372.68 g per plant were obtained under the 100:0, 75:25 and 50:50 treatments, respectively. Although pure cocopeat produced the largest minituber yield in the greenhouse, the 50:50 blend performed well, indicating that pumice can replace a significant proportion of cocopeat without compromising tuber productivity. Such blends therefore offer an affordable and sustainable route to commercial minituber production, particularly where cocopeat is costly or in short supply.

Introduction

In Kenya, potato (*Solanum tuberosum* L.) ranks second only to maize among food crops and stands as the third most important food-security crop globally, behind wheat and rice [1–3]. Roughly 800,000 households cultivate the crop and about 2.5 million Kenyans derive their livelihoods from its value chain, highlighting its role in food security, employment and income generation in both rural and urban settings [2, 4]. Yet national yields have stagnated at a low 8–10 tonnes per hectare, far below the 20–40 tonnes per hectare obtained globally and 40–50 tonnes per hectare attainable under sound agronomy [5, 6]. Output has, in fact, contracted by 62.5% over the last decade, falling from 22.4 tonnes per hectare in 2008 to 8.4 tonnes per hectare in 2022 [7, 8]. Much of this decline is traceable to soilborne and seedborne diseases, including bacterial wilt (*Ralstonia solanacearum*), late blight, soft rot and potato cyst nematodes, which jointly cause an estimated 80% loss in production [9–11]. About 95% of growers depend on the informal seed sector for planting material, which contributes to pest and pathogen incidences, and repeated cropping in the main production zones continue to increase soilborne inoculum levels [2, 4, 6]. Climate variability, declining soil fertility and poor access to certified seed compound these problems, perpetuating the yield gap and eroding competitiveness of the value chain [12–15].

Soilless production has evolved as a practical means of circumventing limitations of soil-based systems for multiplying potato minitubers. Techniques such as aeroponics, hydroponics and substrate culture

confer several advantages over field production [16–19]. They remove exposure to soilborne pathogens, enable adequate control of plant nutrition, enhance water use efficiency and deliver clean, high-quality planting materials [9, 20]. Aeroponics, for example, can produce 60–80 minitubers per plant against 5–10 typical of field culture, which makes it especially useful where seed and resources are limited [5, 21, 22]. In the same vein, pairing soilless culture with suitable plant growth regulators markedly raises both the number and size of minitubers and thus accelerate seed multiplication [14, 21, 23]. These systems eliminate the threat of soilborne pathogens and nematodes and are therefore well matched to pre-basic and basic seed programs [9, 19, 24]. Of the available substrates, cocopeat, obtained from coconut husk (*Cocos nucifera* L.), is particularly prized for its strong water retention, favorable aeration and capacity to support root growth [16, 21, 25]. Its high porosity, low bulk density and slow rate of decomposition make it both durable and effective as a growth medium [16, 20, 26]. Substrate choice has further been shown to shape rhizosphere microbiome, with cocopeat sustaining robust bacterial diversity and beneficial microbes than inorganic media such as vermiculite [19, 24, 27, 28], a richness that can boost nutrient availability, curb pathogens and reinforce plant health and productivity [27, 28].

For all these advantages, relying on cocopeat alone remains impractical in Kenya on account of its cost and uneven availability, particularly away from the coconut-growing coastal belts [6, 28]. Cocopeat also tends to hold high concentrations of sodium (Na) and potassium (K), as it requires buffering through cation exchange with calcium before it performs well as a growth medium [16, 25, 27]. Blending it with low-priced, locally sourced materials such as pumice offers a workable solution. Pumice is a light, naturally porous volcanic rock formed when molten lava cools and solidifies rapidly [18, 29]; its sponge-like architecture enhances aeration, drainage and water retention once combined with other substrates [29–31]. Being both abundant and inexpensive in Kenya, it is a good alternative soil amendment. The literature increasingly endorses pumice-based media for soilless culture [32]. Zhao et al. [30] found that incorporating pumice into coconut coir raised substrate bulk density, improved root anchorage and boosted water holding capacity with no penalty to yield or fruit quality in hydroponic raspberry. Pumice has likewise been reported to foster the establishment and antifungal activity of biocontrol agents, thereby suppressing disease in soilless systems [31, 33, 34]. Its usefulness is nonetheless crop-specific; in grapevine it performed less well than perlite or coir, underlining the need to tailor substrate choice to each crop [31]. Reworking the pore network of cocopeat with pumice has been shown to sharpen key physico-chemical traits, including moisture content, water holding capacity and air-filled porosity, and to improve its behavior as a greenhouse medium [21, 32, 35]. Altogether, this evidence marks pumice as a genuinely promising material for enhancing plant growth and disease management in soilless culture [33, 36].

Despite mounting interest in soilless minituber production, formulating a cocopeat-to-pumice ratio capable of matching the yield of pure cocopeat has proved difficult [24, 28]. The physical and hydraulic behavior of a blended substrate, expressed through bulk density, particle size, air-filled porosity, moisture content and water holding capacity, governs root development, nutrient acquisition and, ultimately, tuber yield, while the supply of nitrogen, potassium and calcium within the blend further conditions growth and productivity [35, 37, 38]. This study was therefore undertaken to assess the cocopeat and pumice

substrates best suited to maximizing the growth and yield of potato minitubers under greenhouse conditions, and thereby to provide an affordable, locally adaptable substitute for the sole use of cocopeat.

Materials and methods

Experimental site

The pot trial was undertaken in a greenhouse at the Climate and Water Smart Agriculture Centre, Egerton University, Kenya, a site situated at 0°23' South and 35°36' East and lying 2,267 m above sea level within agro-ecological zone III [39, 40]. Mean maximum and minimum temperatures inside the greenhouse were 38.5°C and 9.4°C, respectively. The reference soil was a Mollic Andosol, a well-drained, slightly acidic clay of dark reddish colour [40].

Cocopeat treatment, pumice and soil collection

Cocopeat was obtained from Cocoponics Africa Limited (Nairobi, Kenya) and conditioned with $\text{Ca}(\text{NO}_3)_2$. In brief, 1.5 kg of cocopeat was steeped for 36 hours in 15 liters of water containing 100 g of dissolved $\text{Ca}(\text{NO}_3)_2$, with stirring at six-hourly intervals to keep the reaction uniform. The material was then rinsed first with a hydrogen peroxide (H_2O_2) solution (0.5 ml per liter of tap water), using 10 liters of the solution for the 1.5 kg batch, and again with 5 liters of tap water, after which it was left to drain for 24 hours. Pumice was sourced at the Climate and Water Smart Agriculture Centre, Egerton University, Kenya, and passed through an 8 mm sieve. Soil was sampled to a depth of 15 cm at several points across the experimental site, then combined, air-dried and likewise sieved (8 mm) to form a uniform composite.

Treatments and experimental setup

The five treatments comprised four cocopeat-to-pumice ratios (v/v), 100:0, 75:25, 50:50 and 25:75, together with a 100% soil control, arranged in a completely randomized design with three replicates. To fix each ratio precisely, cocopeat and pumice were measured out in a container 0.24 m high and 0.30 m wide before transfer to pots 30 cm tall with base and top diameters of 28 cm. Pumice was laid down first and cocopeat placed above it. Every treatment occupied 11 pots, one plant per pot. The pots were held in six troughs, each 10.9 m long and 0.30 m wide, and every trough was partitioned into three plots of 0.3 m × 3.3 m; gaps of 0.30 m separated the troughs and 0.50 m the plots. Eleven plants were set in each plot at 0.30 m spacing, and planting took place 24 hours after the cocopeat had been treated.

Characteristics of the potato variety used

A single cultivar, Shangi (raised from apical rooted cuttings), was used in the trial, being one of the most extensively grown potatoes in Kenya. The apical rooted cuttings were procured from Stockman Rozen

Limited (Naivasha, Kenya). Shangi is a semi-erect, medium-tall type standing a little under 1 m, with fairly sturdy stems, broad light-green foliage and pink flowers. It performs across almost all Kenyan potato zones but is concentrated in the Central, Rift Valley and Eastern regions, thriving at elevations of 1,500 m and above. Under favorable conditions it matures quickly, in roughly three months, and can yield 30–40 tonnes per hectare, though it is moderately susceptible to late blight.

Physico-chemical properties of cocopeat, pumice and soil used

Treated cocopeat, pumice and soil samples were submitted to the Kenya National Agricultural Research Laboratory (NARL), Kabete, for determination of potassium (K), sodium (Na), calcium (Ca), total nitrogen (N), electrical conductivity (EC) and pH (Table 1). Both pH and EC were read from a 1:2 (w/v) substrate-to-water suspension using a pH meter and a conductivity meter, respectively, adapted after Jin et al. [41]. Total nitrogen was quantified by Kjeldahl digestion [42–44]. Samples were dried at 70°C, oxidized with 30% hydrogen peroxide (H₂O₂) at about 100°C and, once the surplus H₂O₂ had broken down and water evaporated, digested in concentrated 96% sulfuric acid (H₂SO₄) at 330°C with selenium powder as catalyst, before being left to cool overnight [45]. Exchangeable Ca was measured on an atomic absorption spectrophotometer (AAS) at 422.7 nm [46], while exchangeable K and Na were measured by flame photometry at 766 nm and 589 nm, respectively ([47]; Table 1).

Six physical attributes of the cocopeat–pumice blends, evaporation rate, moisture content, air-filled porosity, water holding capacity, bulk density and particle size, were determined before the trial began. For evaporation rate, each sample was first oven-dried and weighed by treatment, then fully saturated with tap water and reweighed; the saturated samples were held at room temperature for five days and the daily weight loss expressed as a percentage [48]. Moisture content was assessed by oven-drying a known mass of each sample at 105°C [49]. Moisture bottles and stoppers were pre-dried, cooled in a desiccator and weighed, filled to about two-thirds with the medium, reweighed, oven-dried at 105°C for 24 hours, cooled and weighed once more, the cycle being repeated until the oven-dry mass stabilized, with the content computed from the cumulative weight loss [50]. Air-filled porosity (AFP) was obtained by the saturation-and-drainage method [20], its percentage was calculated as the volume of drained water divided by the volume of the medium as shown below:

$$\%AFP = \frac{\text{volume of water collected}}{\text{volume of the medium}} \times 100$$

Here, the water draining from the pot corresponds to the air volume, so the water collected reflects the amount of air that had entered the medium. Water holding capacity was measured by the Kneer-Rackzowski box method [51] as the volume of water retained per volume of water supplied. Substrate bulk density followed the core-ring method [52] where rings of medium were saturated over two days, weighed, then oven-dried at 105°C for 24 hours, with bulk density (pb) expressed as:

$$\rho_b = \frac{(W_b - W_r)}{(\pi h d^2/4)}$$

In this expression, $\pi = 3.142$, W_b is the oven-dried mass of the medium plus core ring (g), W_r the mass of the empty core ring (g), h the ring height (cm) and d the ring diameter (cm).

Particle size was obtained by using the measuring-cylinder method [48] and computed as:

$$\text{Particle size (g cc}^{-1}\text{)} = \frac{\text{weight of the sample}}{(V_1 - \text{pore space volume})}$$

Here, V_1 is the sample volume taken, V_2 the volume of water added and V_3 the combined volume of the sample plus the increase recorded at the end of the test, with the pore space volume given by $(V_1 + V_2) - V_3$ ml.

Two plants per treatment were sampled at early bloom, and 50 g of their tubers taken for total N, Ca and K analysis. After oven-drying at 70°C for 72 hours, the tubers were processed for total N, Ca and K exactly as described for the chemical analyses above, and nutrient uptake was derived using the equation of Rani and Sukumari (41):

$$U_i = \frac{n_i \times DW_{tubers}}{100}$$

where;

U_i = uptake of nutrient (i) cmol kg^{-1} , n_i = concentration (cmol kg^{-1}) of nutrient (i) in potato tubers,

i = specific nutrient (N, Ca, K), DW_{tubers} = dry weight of potato tubers (g).

Table 1
Physico-chemical characteristics of the cocopeat, pumice and soil employed in the study

Elements	Cocopeat	Pumice	Soil
Potassium (cmol kg^{-1})	7.18	6.15	1.13
Calcium (cmol kg^{-1})	32.33	16.50	0.29
Sodium (cmol kg^{-1})	1.03	0.50	2.10
Total N (g kg^{-1})	3.30	3.00	3.31
EC (mS cm^{-1})	0.74	0.55	0.41
pH	5.71	7.14	5.60

Experimental management

Hydroponic nutrient solutions A and B, each made up at 1 g L^{-1} and supplying the essential macro- and micro-nutrients, were delivered by drip irrigation. Up to flowering, plants received 0.30 liters of solution every two days; thereafter the interval was extended to every three days at the same volume. Insect pests were controlled with Thunder (imidacloprid 100 g L^{-1} plus beta-cyfluthrin 45 g L^{-1}) applied at 0.5 ml L^{-1} , and late blight with Infinito at 0.5 ml L^{-1} of water. Weeds were removed as required.

Data collection and analyses

Once the blends had been placed in the troughs, their physico-chemical properties were characterized. Samples taken by volume-to-volume ratio were analyzed for evaporation rate, moisture content, air-filled porosity, water holding capacity, bulk density and particle size. For tuber nutrient concentration, two plants were harvested at early bloom and their tubers analyzed for total N, Ca and K. Growth variables, plant height, branch number and NDVI, were recorded before and after flowering with a GreenSeeker handheld sensor [53], while yield variables, total yield, minituber number and size classes; C1 to C4, were taken at harvest. Conformity to the assumptions of analysis of variance (ANOVA) was verified with the Shapiro-Wilk test, and ANOVA was then performed using the General Linear Model (GLM) framework in R [54, 55]. Where the cocopeat-to-pumice ratio exerted significant effects, treatment means were separated by Tukey's Honestly Significant Difference (HSD) test at $p \leq 0.05$. Means that share a letter within a given parameter are not significantly different.

Results

Effects of cocopeat and pumice mixtures on physico-chemical properties of the growing medium

Evaporation increased from day 1 to day 4 across every treatment before decreasing on day 5 (Fig. 1). The 75:25 C/P blend lost water fastest, whereas pure cocopeat lost it slowest and held the most water throughout the five-day period (Fig. 1 & Table S1).

Water holding capacity increased in substrate with more cocopeat and declined in substrate with more pumice, yet the control soil, with a bulk density of 0.84 g cm^{-3} , retained the most water of all (Fig. 2A). Air-filled porosity increased in substrate with more cocopeat and decreased in substrate with more pumice; the control recorded the lowest AFP owing to its high bulk density (Fig. 2B and Table S1). Bulk density varied significantly and increased as pumice content increased, being lowest under pure cocopeat and 75:25 C/P blend and highest in control and pure pumice media (Table S1, Fig. 2C). Since a single soil particle far outweighs a grain of pumice or cocopeat, particle size in the blends similarly increased with pumice content, mirroring the trend in bulk density. Moisture content was greatest in the 100% cocopeat, 100% pumice and 50:50 C/P media and least in the control (Fig. 2D).

Effects of cocopeat and pumice mixtures on potato nutrient uptake

Every treatment except the control absorbed more potassium and recorded the lowest K uptake (Fig. 3). For both calcium and total nitrogen, uptake peaked in 50:50 (T3) and 25:75 (T4) and was lowest under pure cocopeat, indicating that blending cocopeat with pumice in 50:50 (T3) or 25:75 (T4) ratios enhanced nutrient uptake (Fig. 3; Table S2).

Effects of cocopeat and pumice mixtures on potato growth and yield

Plant height, branch number and NDVI all differed significantly ($p < 0.001$) among treatments and between growth stages (Fig. 4A-C). In every treatment, plant height and branch number increased markedly after flowering, whereas NDVI was higher before flowering than after. Prior to flowering, the tallest plants were recorded in the 75:25 and 25:75 C/P blends (Table S3); after flowering, the cocopeat-rich media (100% cocopeat, 75:25 and 50:50 C/P) produced the tallest plants (up to 67.57 cm) and 100% soil and 100% pumice media had the shortest plants (Fig. 4A). Branch number showed a steady pattern across both stages, cocopeat-rich media (100% cocopeat, 50:50 and 75:25 C/P) recorded significantly more branches; control and pure pumice recorded the fewest branches (Fig. 4B). NDVI, both before and after flowering, was highest in pure cocopeat and cocopeat–pumice blends, which held the greenest, most vigorous canopies and clearly surpassed the pure pumice and pure soil media (Fig. 4C). The treatment-by-stage interaction was significant for plant height and branch number but not for NDVI.

In every soilless medium, pure cocopeat, 75:25, 50:50 and 25:75 cocopeat-to-pumice blends, and pure pumice, number of tubers reduced entirely within the smallest grade (C1: <8 g), tuber counts spanned from 250 in pure pumice to 400 in pure cocopeat. The higher counts in the cocopeat-dominated media (100% CP and 75:25 C/P) imply that cocopeat drives the formation of many small tubers, whereas the lower count in pure pumice indicates weaker overall tuberization in that medium (Table 1). The control yielded fewer C1 tubers (220) yet uniquely producing tubers in the larger grades, C3 (16–18 g) and C4 (> 18 g), at 17.5% and 7.5%, respectively (Figure S1). In short, the control produced fewer but larger tubers, while the soilless media, especially the cocopeat-rich ones, produced higher number of smaller tubers. For seed multiplication, where small, uniform tubers are usually preferred, cocopeat-based media hold a clear advantage, whereas soil remains the better choice for raising larger, market-sized tubers.

Table 1
Variation in potato yield, tuber number and size classes across treatments

Treatment	Yield (g plant ⁻¹)	Tubers (plant ⁻¹)	C1 (< 8.00 g)	C2 (8 to 15.99 g)	C3 (16 to 18 g)	C4 (> 18.00 g)
100% cocopeat (T1)	402.68 ^a	17.67 ^a	2.33 ^b	3.33 ^a	5.33 ^a	6.67 ^a
75:25 C/P (T2)	375.08 ^b	14.33 ^b	3.00 ^b	2.67 ^{ab}	4.67 ^{ab}	4.00 ^{bc}
50:50 C/P (T3)	372.68 ^b	13.67 ^b	2.68 ^b	2.67 ^{ab}	3.67 ^{ab}	4.67 ^b
25:75 C/P (T4)	298.87 ^c	11.00 ^c	3.00 ^b	2.00 ^{ab}	3.00 ^b	3.00 ^c
100% pumice (T5)	137.14 ^d	7.67 ^d	4.00 ^a	2.00 ^{ab}	1.00 ^c	0.67 ^d
100% soil (T6)	48.10 ^e	6.33 ^d	4.00 ^a	1.33 ^b	0.67 ^c	0.33 ^d
MSD	2.47	1.83	0.91	1.71	1.71	1.29

Within a column, means labeled with the same letter do not differ significantly by Tukey's HSD test at the 5% level. MSD, minimum significant difference.

Discussion

Effects of cocopeat and pumice mixtures on physico-chemical properties of growth medium

The media differed significantly in their physico-chemical properties. Evaporation increased from day 1 to day 4 and then decreased on day 5, most probably as temperature, humidity, wind and residual moisture altered over the period. This overall rise-then-fall is consistent with earlier report by Kalaivani and Jawaharlal [48]. Media of higher air-filled porosity generally loose more water, and AFP decreased only in the control (soil). Fine-particled, low-density media such as cocopeat tend to refill their pores with air once drainage ceases, which increases AFP [20, 51]; because aeration is governed largely by pore size, low bulk density and particle size of the cocopeat-rich media plausibly account for their higher AFP. At low bulk density, a substrate's pores fill with air when unsaturated and with water when saturated, and such low density also aids root penetration and nutrient uptake. The bulk density differences among treatments potentially reveal variations in particle-size distribution [29, 51]. Our values agree with Awang et al. [25], who recorded a low bulk density for cocopeat (0.07 g cm⁻³) relative to cocopeat combined with rice hull. Media of lower particle size generally show lower bulk density and higher moisture content because of their surface area, with greater surface area retaining more water [29, 49, 50].

In the present study; the control, which had the highest particle size (0.62 g cc⁻¹), also recorded the highest bulk density and least moisture content, whereas pure cocopeat, lowest in both particle and bulk

density, recorded the highest moisture content. Our observations echo Soltani and Naderi [56], who reported a 1:1 (v/v) perlite–peat moss mixture was best suited for carnation production. Kamrani et al. [5] similarly reported that the bulk density of a medium increases when soil is used alone or blended with other materials and decreases when perlite, peat moss or vermiculite is used on its own. The superior water holding capacity of the cocopeat–pumice blends attest to the strong water-absorbing capacity of both constituents. This is consistent with Sachin et al. [57], who reported that cocopeat can retain some 8–9 times its weight in water, while pumice is well known for its high absorption once saturated [58].

Effects of cocopeat and pumice mixtures on plant nutrient uptake

Nutrient uptake here indicates the capture of nutrients by the potato through root interception, mass flow and diffusion [56, 59, 60], a process modulated by soil pH, humidity, light and temperature [61, 62]. Potassium uptake declined in the control, whose high bulk density hampered root penetration and absorption; in soilless media, by contrast, nutrient availability to roots can exceed that of most arable soils [61, 63], and bulk density is likely to affect the mass flow, interception and diffusion of nutrients [26, 57]. Across the cocopeat-to-pumice ratios, potassium uptake was essentially unchanged. Calcium and total nitrogen uptake were lowest in the pure cocopeat treatment. This may be attributed to the medium being inherently rich in both elements in plant-available forms, with the additional supply from the nutrient solution further reducing net uptake. Nevertheless, concentrations of these nutrients remained within the normal range for healthy, mature potato plants. Blending cocopeat with pumice at 50:50 and 25:75 (C/P) enhanced calcium and nitrogen uptake, an improvement likely driven by the pumice fraction.

Effects of cocopeat and pumice mixtures on potato growth and yield

Broadly, increasing the cocopeat fraction of the growing medium improved potato growth and yield. Between the pre- and post-flowering stages, plant height and branch number increased by approximately 24.90% and 19.70%, respectively. Over the same period, the normalized difference vegetation index (NDVI) declined by 9.40%, reflecting decreasing leaf nitrogen concentration as the foliage senesced. A comparable post-vegetative decline in NDVI has been reported for maize by Wang et al. [53]. As the plants approach maturity, chlorophyll content diminishes, attenuating the leaf nutrient signal; accordingly, the low NDVI values recorded in the soil and pumice media were consistent with their poorer yields. NDVI is widely accepted as a reliable proxy for leaf chlorophyll content when the leaf area index is moderately high [41, 64, 65].

NDVI correlated strongly with tuber yield. Relative to the control, plant height in the 100% cocopeat, 50:50 and 75:25 media increased by 19.44, 17.75 and 17.25%, and branch number by 16.33, 15.72 and 16.19%, respectively. The higher particle density of the soil and pure pumice media probably restricted rooting and so curtailed growth and yield; consistent with Gizas and Savvas [29] who observed that the coarser particle size of pumice negatively affect the growth and yield of greenhouse crops in soilless culture. Across all yield traits except for C1, the cocopeat-rich media (100% cocopeat, 75:25

cocopeat/pumice, and 50:50 cocopeat/pumice) proved the most productive, with pure cocopeat consistently outperforming the others. In contrast, pumice alone and the control were poorly suited to minituber production, largely due to their poor physico-chemical properties. Pure cocopeat produced the highest yield at 402.68 g per plant, followed by 75:25 blend (375.08 g) and 50:50 blend (372.68 g). These results confirm that pure cocopeat outperforms both pure pumice and soil under greenhouse conditions. Nevertheless, on economic basis, the 1:1 cocopeat/pumice blend remains a viable option, as it still supports high minituber output while potentially reducing substrate costs.

Conclusion

Soilless culture is indispensable for achieving high minituber output under greenhouse conditions, with either pure cocopeat or a 50:50 cocopeat/pumice blend offering the most favorable physico-chemical properties for hydroponic production. Although blending cocopeat with pumice enhanced nutrient uptake relative to either substrate used alone, higher nutrient concentrations did not, in themselves, translate into superior growth or yield. Tissue nitrogen concentrations declined significantly as the plants matured. The highest plant height and minituber yield were consistently achieved with pure cocopeat, closely followed by the more economical 50:50 blend. By contrast, reliance on 100% soil or 100% pumice generally resulted in lower yields than either cocopeat alone or the 50:50 blend. Future studies may assess the performance of a broader range of potato cultivars for minituber production using pure cocopeat and both the 50:50 and 75:25 cocopeat–pumice blends.

Abbreviations

AAS

Atomic absorption spectrophotometer

AFP

Air-filled porosity

ANOVA

Analysis of variance

Ca

Calcium

Ca(NO₃)₂

Calcium nitrate

cm

Centimeter

cmol kg⁻¹

Centimoles per kilogram

CP

Cocopeat (as in 100% CP)

C/P

Cocopeat-to-pumice ratio

C1

Tuber size class < 8 g

C2

Tuber size class 8–15.99 g

C3

Tuber size class 16–18 g

C4

Tuber size class > 18 g

d

Core ring diameter

Db

Bulk density

Dp

Particle density

DW

Dry weight (e.g., DW of tubers)

EC

Electrical conductivity

g

Gram

g cm⁻³ (g cc⁻¹)

Grams per cubic centimeter

GLM

General Linear Model

h

Core ring height

ha

Hectare

H₂O₂

Hydrogen peroxide

H₂SO₄

Sulfuric acid

HSD

Honestly Significant Difference (Tukey's test)

K

Potassium

kg

Kilogram

L

Liter

L.

Linnaeus (taxonomic authority, as in *Solanum tuberosum* L.)

m

Meter

MC

Moisture content

mg

Milligram

ml

Milliliter

mm

Millimeter

mS cm⁻¹

Millisiemens per centimeter

MSD

Minimum significant difference

N

Nitrogen

Na

Sodium

NARL

National Agricultural Research Laboratory (Kenya)

NDVI

Normalized difference vegetation index

n_i

Concentration of nutrient i in potato tubers

nm

Nanometer

p

Probability value

pH

Potential of hydrogen (measure of acidity/alkalinity)

PM

Pumice (as in 100% PM)

RUFORUM

Regional Universities Forum for Capacity Building in Agriculture

T1

100% cocopeat

T2

75:25 cocopeat/pumice

T3

50:50 cocopeat/pumice

T4

25:75 cocopeat/pumice

T5

100% pumice

T6

100% soil (control)

TAGDev

Transforming African Agricultural Universities to meaningfully contribute to Africa's growth and development

U_i

Uptake of nutrient i

USA

United States of America

V1

Volume of sample taken

V2

Volume of water added

V3

Volume of sample plus the volume increase at the end of the test

v/v

By volume (volume/volume)

w/v

By weight per volume (weight/volume)

Wb

Weight of medium plus core ring after oven-drying

WHC

Water holding capacity

Wr

Weight of core ring

°C

Degrees Celsius

π

Pi (3.142)

ρ_b

Bulk density (symbol)

Declarations

Ethical approval

Not applicable

Consent to participate

Not applicable

Consent to publish

Not applicable

Competing interests

The authors declare no competing interests.

Author Contribution

S.M.M & A.M.K: Conceptualization, Data curation, Formal analysis, Methodology, Resources, Software, Supervision, Validation, Writing—original draft. S.N.G: Data curation, Formal analysis, Methodology, Software, Validation, Writing—original draft. J.B.W & J.K.A: Visualization, Data curation, Methodology. J.K.A, J.B.W & S.N.G: Validation, Writing—review and editing. S.M.M, A.M.K & J.K.A: Funding acquisition, Conceptualization, Project administration, Resources, Writing—review and editing.

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Data Availability

The datasets produced in this study are available within the article and its accompanying supplementary files (Tables S1–S2 and Figure S1).

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Figures

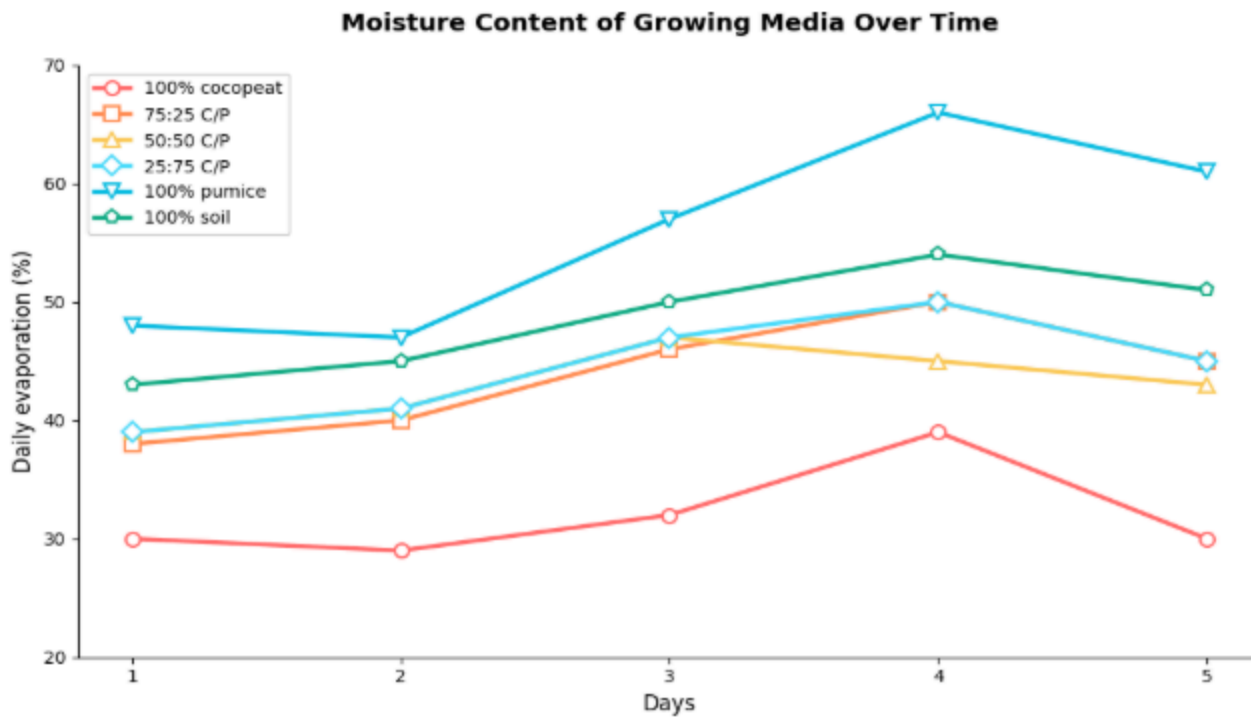


Figure 1

Daily evaporation from cocopeat and pumice blends, expressed as a percentage of total water loss across five days.

Substrate physical properties across cocopeat and pumice blends

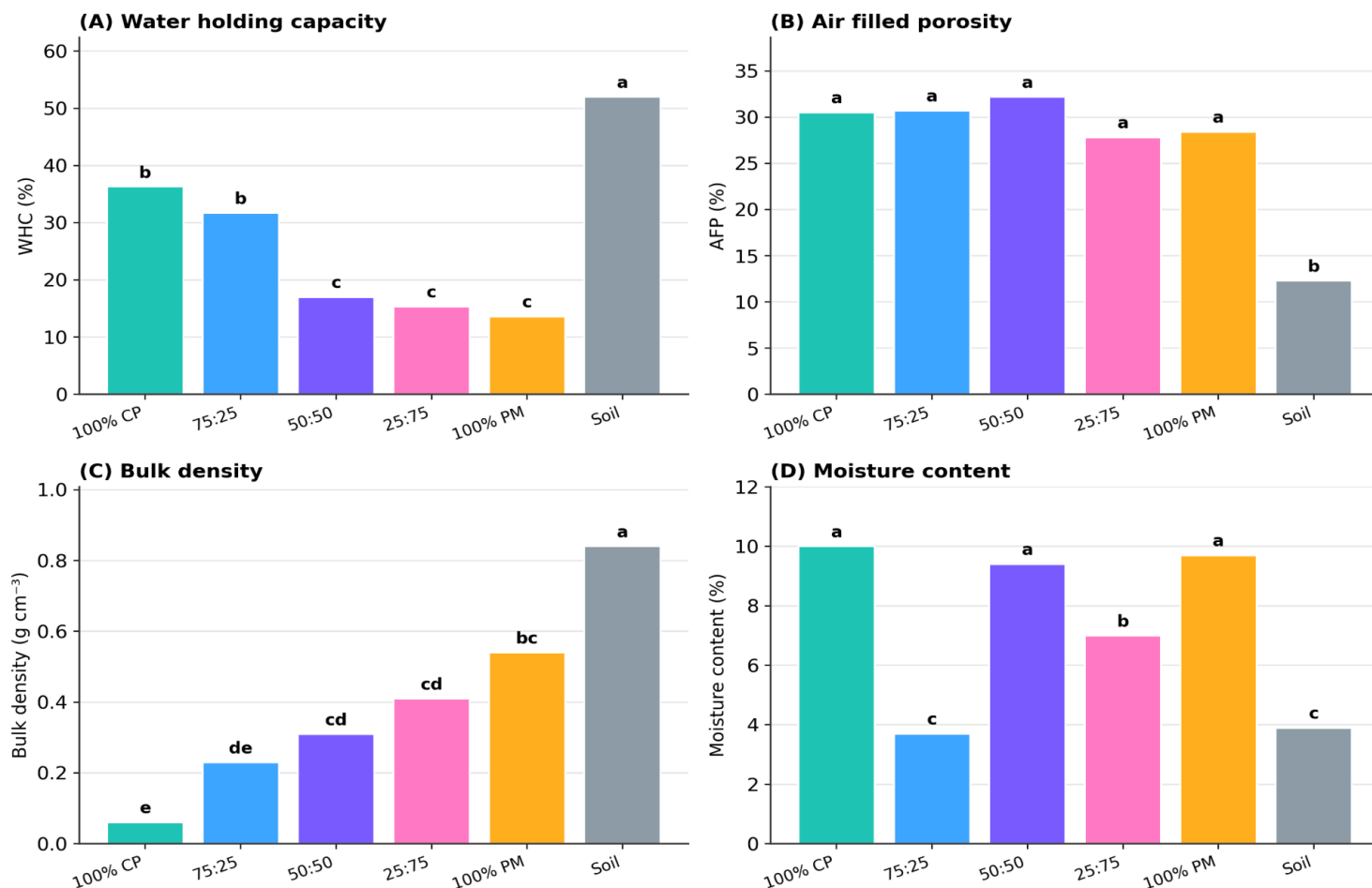


Figure 2

Influence of cocopeat and pumice blends on physical properties of the medium. (A) water holding capacity, (B) air-filled porosity, (C) bulk density and (D) moisture content. Within each panel, bars labelled with the same letter do not differ significantly.

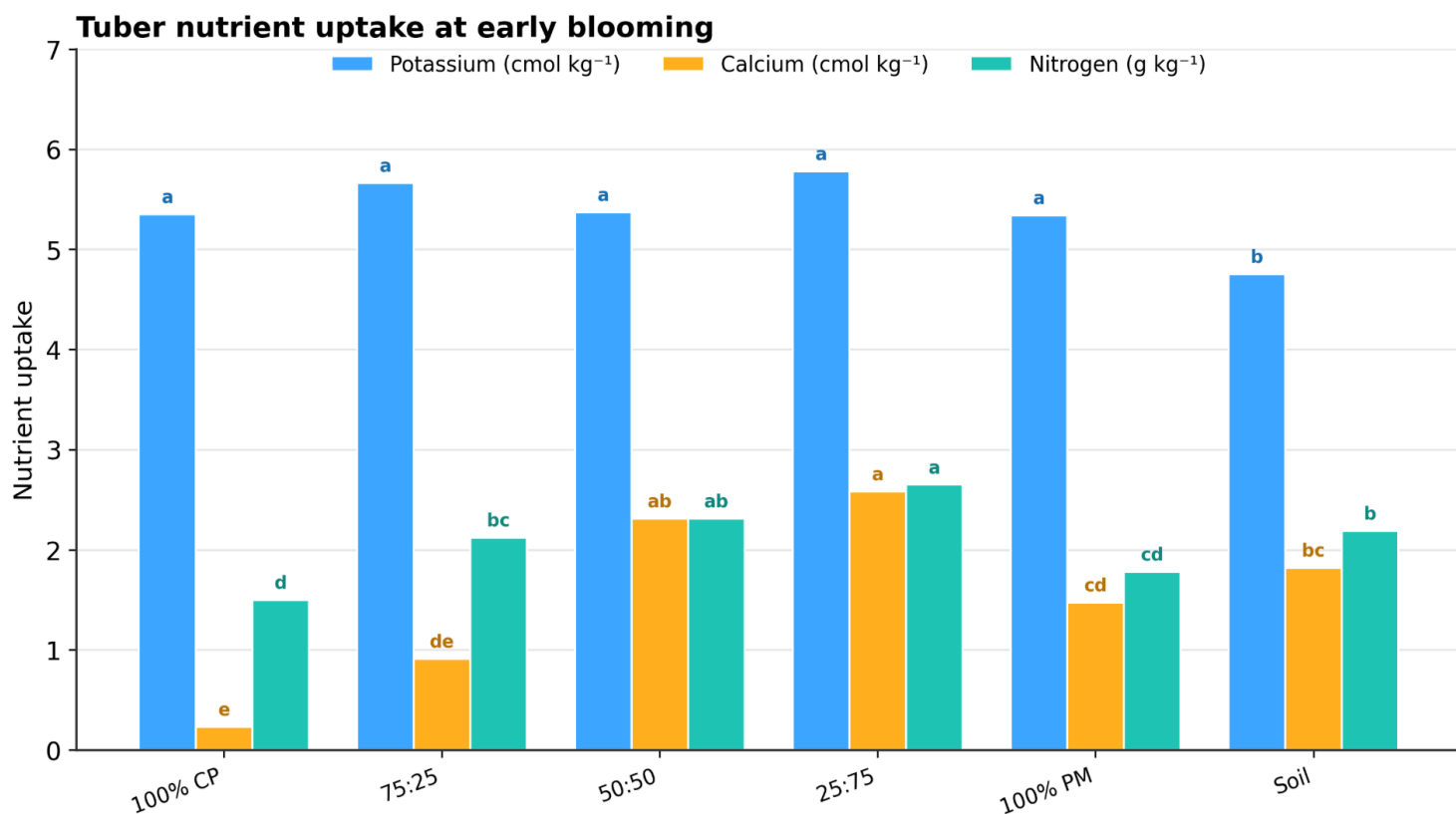


Figure 3

Minituber uptake of potassium, calcium and nitrogen at early bloom under the cocopeat and pumice blends. Within each nutrient, bars bearing the same letter do not differ significantly.

Potato growth before and after flowering across substrates

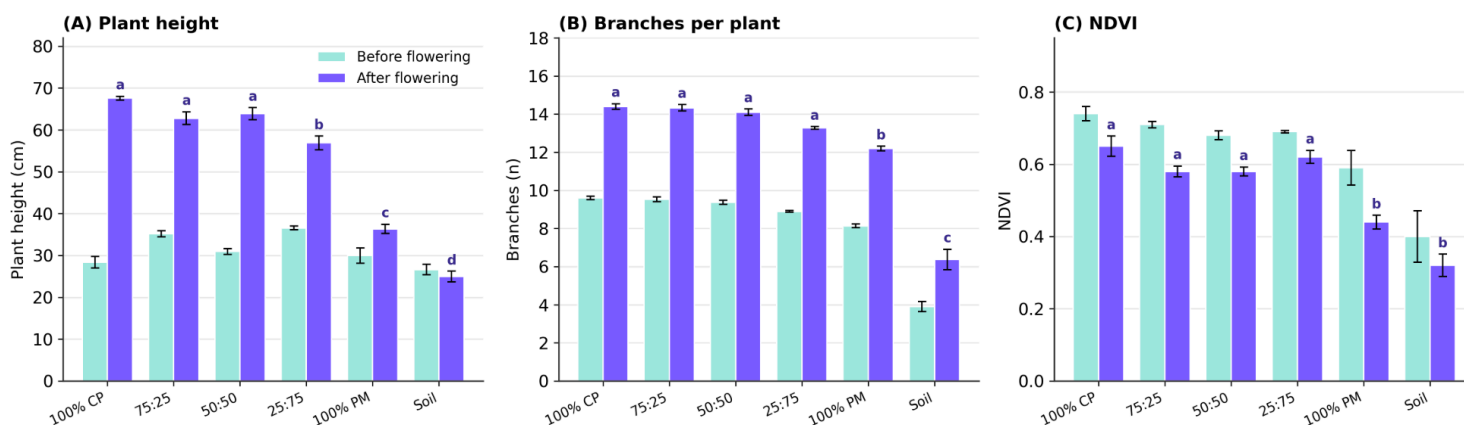


Figure 4

Influence of cocopeat and pumice blends on potato plant height, branch number and NDVI before and after flowering. Within each panel and stage, bars sharing a letter do not differ significantly.

Supplementary Files

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