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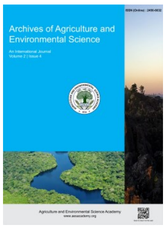

ORIGINAL RESEARCH ARTICLE

Effects of calcium nitrate levels and soaking durations in cocopeat on the growth and yield of potato (*Solanum tuberosum* L.) apical rooted cuttings

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ABSTRACT

This study evaluated the effects of treating cocopeat with calcium nitrate ($Ca(NO_3)_2$) at different soaking durations on potato (*Solanum tuberosum* L.) Apical Rooted Cuttings (ARCs) growth and yield parameters. A greenhouse pot experiment was carried out at the Climate and Water Smart Agriculture Centre of Egerton University, Kenya. An air-dried cocopeat 1.5 kg per treatment, was treated using five soaking durations (12, 24, 36, 48 and 72 hours) × four levels of $Ca(NO_3)_2$ (0, 60, 100 and 150 g) soaked in 15 litres of water. Soil and the un-treated cocopeat were used as positive and negative controls, respectively. The treatments were arranged in a completely randomized design with three replicates. The results showed that there was no significant ($P>0.05$) interaction effect of $Ca(NO_3)_2$ × soaking duration for the number of branches and normalized difference vegetative index. The main effect of 150 g $Ca(NO_3)_2$ gave the highest average number of branches (16.13), NDVI (0.89) and plant height (73.51 cm) followed by 100 g of $Ca(NO_3)_2$. Soaking duration of 36 hours economically produced the highest growth parameters 12.75 and 61.46 cm an average number of branches and plant height, respectively. Significant ($P<0.001$) interaction effects were observed for the plant height and all the yield parameters. The interaction of 100 g $Ca(NO_3)_2$ and soaking for 36 hours gave the highest mini-tuber yield of 464.67 g $plant^{-1}$ and an average number of tubers of 21.67 tubers $plant^{-1}$. Therefore, 100 g $Ca(NO_3)_2$ and a soaking duration of 36 hours to treat 1.5 kg of air-dried cocopeat is recommended for higher ARCs yield and yield parameters.

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INTRODUCTION

In the coming decades, achieving nutrition and sustainability in food for the growing population estimated at 9.7 billion people by 2050 will require significant improvements to the global food system (FAO *et al*., 2018; Waaswa and Satognon, 2020). In contribution to this, potato is one of the potential crops that need such improvement. Based on its demand in over 149 countries, its cultivation is estimated at 19 million hectares globally, with 378 million tonnes of productivity (Campos and Ortiz, 2020). Kenya is now the fourth biggest potato producer in Africa with a total production of 1.8 million tonnes cultivated on 217,315 hectares (FAOSTAT, 2018). Presently, after maize (*Zea mays*) potato is considered the second most important staple food and is valued at approximately USD 500 million annually (Wang'ombe and Dijk, 2013; CIP, 2019). Regardless of Kenya's potential in potato production, there still exist major production challenges. According to KEPHIS, (2016), approximately 2% of the potato-growing areas in Kenya are planted with certified seeds. This means that approximately 98% of the potato-growing areas are planted with uncertified seeds. Due to the use of uncertified planting materials, Kenya's average potato yield is currently at 9-10 tonnes ha^{-1} compared to global productivity of 20-40 tonnes ha^{-1} (VIB, 2019). Increased shortage of certified planting materials has led to low yields, the spread of pests and diseases and poor-quality products (Demo *et al*., 2015). A study conducted by Gildemacher *et al.* (2011), showed that a positive selection of seeds provided smallholder farmers with better quality seeds and led to high yields. To minimize these challenges, techniques such as hydroponics are cardinal for mini-tuber production. Hydroponics technique includes the use of soilless culture and nutrient supply through a fertigation system. This technique is introduced into Sub-Saharan Africa (SSA) to provide a simple but effective technique for multiplying early-generation seeds (Parker *et al.*, 2019). The introduction of hydroponics in SSA has resulted in increased mini-tuber production (Harahagazwe *et al*., 2018).

The use of appropriate growth media leads to higher productivity and returns. Growing media are materials, other than soils, in which plants are grown. This includes organic materials such as cocopeat, compost, tree bark and poultry feathers or inorganic materials such as clay, perlite, vermiculite and mineral wool, amongst others (Rehman *et al*., 2020). Alternative methods for seed multiplication are gradually shifting to the use of soilless media such as cocopeat, pumice, peat moss, vermiculite and sawdust, amongst others (Zimba *et al*., 2014). Mini-tuber production is one of the primary methods for potato production. As such, growth media systems can be used as an effective technique for producing certified seed potato (Lakhiar *et al*., 2018; Campos and Ortiz, 2020). Soilless culture is in the process of becoming a vital part of the world's agriculture. Commercial application of soilless culture has increased over the years as an alternative to costly soil disinfection and high productivity and increased water use efficiency (Chiipanthenga, 2012; Kakuhenzire *et al*., 2017). Using soil as growth media for seed potato production increases the low multiplication rate of tubers and lowers disease prevalence and laborious weed control (Kamrani *et al*., 2019). Aeration, water holding capacity and drainage requirements are typically low in soil compared to soilless media.

Widespread adoption of soilless potting media in global food production has been reported as the technical solution for problems including low productivity, root diseases, root zone oxygen deficiency and fertility control in soil (Kamrani *et al*., 2019). One of the most widely used soilless growing media is cocopeat (Kamrani *et al*., 2019; Wittman, 2020; Halamba and Kuack, 2021). Cocopeat is a planting media made from coconut husk, but its salinity problem is not to be underestimated. It has an easily absorbing and water holding ability which facilitates the exchange of air, and water, it can be reused for about four years, allow for maximum root growth to support the plant physically, and has a low environmental impact (Gohil, 2018; Putra *et al*., 2019). The advantages of soilless systems over soil are that it is pathogen-free, growth and yield are independent of the soil type, has better support for growth through a targeted supply of nutrient solution due to its favourable physical and chemical properties (Goddek *et al*., 2019).

Nevertheless, cocopeat has its challenges. Cocopeat's initial cation exchange sites are naturally loaded with K Sachin *et al.* (2020) and Na with little or no calcium (Ca) and Nitrogen (N); Halamba and Kuack, (2021); Wittman, (2020). Cocopeat is loaded with high potassium (K) 38.5-40 cmol kg^{-1} and sodium 13.04-15 cmol kg^{-1} depending on the source (Gbollie *et al.*, 2021; Kimbonguila *et al.*, 2019; Putra *et al.*, 2019; Wittman, 2020). Excessive concentration of K may increase the leaching of Ca and Mg from the soil, causing soil acidification (Puga *et al.*, 2016). Efforts are made to optimize K in cocopeat before using it as a growing media (Gbollie *et al.*, 2021). Optimizing a high level of K in cocopeat reduces K toxicity, stimulates root development, and grow crops like potato (Shanmugasundaram *et al*., 2014). Due to the limited knowledge about cocopeat treatment in Kenya, most horticultural producers import their cocopeat from India, Finland, Sir-Lanka, and the Netherlands, amongst other countries (AFA-NOCD, 2020). Efforts have been made to make cocopeat suitable for the production of horticultural crops instead of soil. Soaking and leaching of cocopeat with $Ca(NO_3)_2$ reduces elements that are naturally bonded to the cation exchange complex of cocopeat (Gbollie *et al*., 2021; Marock, 2021). The use of $Ca(NO_3)_2$ in this process presents a potential approach to reduce the adverse effects of the locally available cocopeat for use as seed potato growth media. Treated cocopeat has consistent quality in terms of salinity and exchangeable cation concentrations. This research objective was to determine the effects of nutrient contents in cocopeat as the result of $Ca(NO_3)_2$ and soaking duration on the growth and yield of potato under a greenhouse condition. The findings of this study will improve the use of soilless media among potato producers and increase hydroponics mini-tuber production, thereby, increasing mini-tuber productivity and contributing to global food security.

MATERIALS AND METHODS

Experimental site description

A greenhouse pot experiment with each pot of height 30 cm, base diameter of 28 cm and top diameter of 28 cm was carried out at the Climate and Water Smart Agriculture Centre of Egerton University, Kenya. The study site is on a latitude of 0° 23' South, a longitude of 35°36' East with an altitude of 2267 metres above sea level. The experimental site is in agro-ecological zone III (medium potentials) with annual rainfall between 950 and 1500 mm (Amata *et al*., 2009). The average maximum and minimum greenhouse temperatures were 30.79 °C and 14.38 °C, respectively. For the soil treatment, the soil used was Mollic Andosols with well-drained, dark reddish clays, slightly acidic as classified by (Satognon *et al*., 2021).

Experimental procedure and treatments

The experiment was arranged in a completely randomized design with three replicates. The cocopeat used (1.5 kg treatment^{-1}) was treated using five (5) soaking durations (12, 24, 36, 48, and 72 hours) and four (4) levels of $Ca(NO_3)_2$ (0, 60, 100, and 150 g) mixed in 15 L of water (Gbollie *et al*., 2021). The

Table 1. Effects of calcium nitrate and soaking durations on the chemical properties of treated cocopeat

Treatment	K	Na	Ca	Total N	EC	pH
	cmol kg^{-1}			(g kg^{-1})	(mS cm^{-1})	
C0D1	21.88	2.17	3.35	4.97	0.38	5.62
C0D2	20.51	2.10	3.00	5.20	0.43	5.67
C0D3	19.66	1.96	2.75	5.23	0.49	5.68
C0D4	18.38	1.81	2.58	5.10	0.54	5.74
C0D5	17.52	1.81	6.33	5.33	0.57	5.70
C1D1	14.10	1.81	12.83	6.43	0.61	5.72
C1D2	12.82	1.67	13.00	6.50	0.62	5.74
C1D3	10.86	1.60	15.33	6.93	0.63	5.70
C1D4	9.92	1.48	16.67	6.97	0.63	5.64
C1D5	8.72	1.31	17.33	7.17	0.65	5.71
C2D1	8.63	1.23	24.50	7.87	0.67	5.69
C2D2	7.61	1.16	26.17	7.90	0.70	5.72
C2D3	7.18	1.03	32.33	8.30	0.74	5.71
C2D4	6.50	0.95	35.17	8.77	0.75	5.64
C2D5	5.55	0.94	39.83	9.60	0.79	5.65
C3D1	8.72	0.86	49.83	10.27	0.88	5.66
C3D2	5.64	0.65	54.83	11.53	1.01	5.70
C3D3	7.78	0.58	57.17	13.03	0.95	5.65
C3D4	5.56	0.65	64.00	13.03	0.97	5.69
C3D5	7.09	0.59	65.00	13.60	1.11	5.61
C0D0	33.33	13.90	3.51	5.30	1.55	5.83
Soil	1.20	0.28	2.20	3.20	0.13	5.38

Note: C0, C1, C2, C3: are calcium nitrate 0, 60, 100, and 150 g, respectively. D1, D2, D3, D4, and D5: are the soaking durations of 12, 24, 36, 48 and 72 hours, respectively.

mixtures were then soaked for their respective soaking durations. After every six hours, each treatment was mixed to ensure a uniform reaction. Each treatment was separately rainsed using 15 L of tap water after the soaking durations. Thereafter, hydrogen peroxide (H_2O_2) 0.5 ml into one (1) litre of tap water was used for the second rinsing. Ten litres of the H_2O_2 solution were used to rinse each treatment. A third rinsing was done with 5 litres of tap water (without hydrogen peroxide) for each treatment and the media was left standing for 24 hours to drain the remaining water. Seed potato apical rooted cuttings sourced from Stockman Rozen Limited, Naivasha, Kenya were planted in each treatment after 24 hours. The treatments amounted to 22 after the soil and the untreated cocopeat were included as positive and negative controls, respectively.

Treatments and determination of the chemical properties

Samples of the treated cocopeat, the untreated cocopeat that was sourced from Cocoponics Africa Limited and the soil were taken and analysed at the Kenya National Agricultural Research Laboratory (NARL)-Kabete for K, Na, Ca, N, EC, and pH (Table 1). The water quality was evaluated because it affects the exchange reactions of K, Na and Ca on the adsorption complex of cocopeat (Ko *et al.*, 2017). The pH and EC were determined using a 1:2 (w/v) ratio of media to water suspension using a pH metre and conductivity metre for EC (Yadata, 2014). Using the Kjeldahl digestion method as in Okalebo *et al.* (2002) for total N determination, samples of the substrates were dried in an oven at 70 ˚C and oxidized with hydrogen peroxide 30% at a relatively low temperature (100 ˚C). After decomposition of the excess H_2O_2 and water evaporation, digestion was completed with a concentrated 96% sulphuric acid (H_2SO_4) at elevated temperature (330 ˚C) under the influence of selenium powder as the catalyst. After the digested samples were cooled overnight, the exchangeable Ca was determined using an Atomic Absorption Spectrophotometer (AAS) at a wavelength (λ) of 422.7 nm while exchangeable K and Na were determined using a flame photometer at a λ of 766 nm and 589 nm, respectively.

Description of the potato variety used

One apical rooted cuttings potato variety, *Shangi* was used for this experiment. *Shangi* is one of the most grown varieties in Kenya and it is a semi-erect medium-tall variety (slightly below 1 m in height) with moderately strong stems and light green broad leaves with pink flowers (NPCK, 2019). *Shangi* is suitable for almost potato growing regions in Kenya, but mainly in Central, Rift Valley, and Eastern regions. It grows well at an altitude of 1500 metres above sea level or higher. Under favourable conditions, it matures early in about 3 months and has a potential yield of 30-40 tonnes ha^{-1} and it is moderately susceptible to late blight disease (NPCK, 2019).

Experimental management

A drip irrigation system with hydroponics nutrient solutions (A and B) composed of the essential macro and micro-elements were each mixed at the ratio of 1 g L^{-1}. Water + nutrient (fertigation) was supplied at 0.30 litres plant^{-1} every two days up to the flowering period. After flowering, the nutrient/water supply was reduced to 0.30 litres plant^{-1} after three days. Insect pests were controlled with Thunder (Imidacloprid 100 g L^{-1} + Beta-cyfluthrin 45 g L^{-1}) applied at the rate of 0.5ml L^{-1}.

Late blight was controlled using *Infinito* at the ratio of 0.5 ml L^{-1} of water. Weeding was done regularly only on the soil treatment (positive control).

Data collection

Data was collected on the number of branches, NDVI using a GreenSeeker handheld gadget, plant height, yield (total), mini-tuber number, and mini-tuber classes <8.00 g, 8-15.99 g, 16-18 g, and >18.00 g represented as C1, C2, C3 and C4, respectively. The yield projection was computed using the formula:

$$\text{Yield (tonnes hectare)} = \frac{\text{Yield obtained (kg)} \times 10{,}000\text{M}^2}{\text{Number of plants harvested} \times \text{planting distance}}$$

Data analyses

Data collected was subject to the Shapiro-Wilk normality test for the conformation of ANOVA assumptions. General Linear Model procedures of the statistical analysis system (SAS), version 9.0 was used for ANOVA at $P \leq 0.05$ (SAS Institute Inc., 2002). Treatment means for the main effects of soaking duration and $Ca(NO_3)_2$ were separated using Tukey's Honestly Significant Difference (HSD) test at a probability of 0.05. Pearson's correlation tests at $P \leq 0.05$ were performed between cocopeat nutrient content versus the nutrient uptake.

RESULTS AND DISCUSSION

Correlation between nutrient uptake at 50% blooming and cocopeat nutrient content

There were strong positive correlations between K in the media and K uptake (r= 0.90***), Ca in the media and Ca uptake (r= 0.96***) and between N in the media and N uptake (r= 0.84***). These positive relationships were due to the presence of the nutrients in the media thus increasing the uptake. In plants, approximately 80% of all nutrients absorbed by roots are translocated to the shoots (Hochmuth *et al.*, 2018). Nitrogen in the media and Ca uptake was positively correlated (r= 0.94***) as the concentration of N in the tissue depended on the level of $Ca(NO_3)_2$. At higher $Ca(NO_3)_2$ levels, more N was made available for plant uptake. On the other hand, there was a strong negative correlation between K in the media and Ca uptake (r= -0.66**). Potassium and Ca are strongly antagonistic to each other. An excess concentration of one element inhibits the uptake of other elements (Huu *et al.*, 2017). The negative correlation between K in the media and Ca uptake showed that as K concentration decreases, the Ca uptake by potato increases. The positive correlations showed that the higher the concentration of a particular element in the media, the higher the uptake.

Main effects of soaking durations and calcium nitrate levels on Shangi potato growth and yield parameters

There was no significant ($P>0.05$) interaction effect of soaking duration × $Ca(NO_3)_2$ for the number of branches and the NDVI values. However, there was a significant ($P<0.01$) interaction effect for the plant height. The results for the main effect of soaking duration showed that soaking durations 36, 48, and 72 hours significantly gave the highest growth parameters compared to soaking durations 12 and 24 hours. An average number of branches plant^{-1} ranged from 7.2 (0 g) to 16.13 (150 g); NDVI ranged from 0.61 (0 g) to 0.89 (150 g) and plant height from 39.83 cm (0 g) to 73.51 cm (150 g) all at 77 days after planting. Soaking duration of 36, 48, and 72 hours were not significantly different from each other (Table 2). In all the soaking durations, the NDVI values were not significantly different. As for the $Ca(NO_3)_2$ effects, the growth parameters were significantly ($P<0.05$) increased with an increase in the calcium nitrate levels (Table 2). The increasing trend was: 0< 60< 100< 150 g, respectively. The main effect of $Ca(NO_3)_2$ is sufficient to enhance the number of branches and the NDVI of *Shangi* potato apical rooting cuttings. The insignificant differences between soaking durations 36, 48, and 72 hours suggest that soaking cocopeat above 36 hours does not increase the growth parameters. Hence, growers should not waste their time soaking cocopeat for < or > 36 hours to attain higher growth parameters. The growth parameters were also directly proportional to the $Ca(NO_3)_2$ application. Sidhu *et al.* (2018), reported that the applications of $Ca(NO_3)_2$ at different concentrations increase plant growth-related parameters. The growth parameters tend to increase as the $Ca(NO_3)_2$ levels increase.

There were significant ($P<0.001$) interaction effects of $Ca(NO_3)_2$ × soaking duration for all the yield parameters. The results revealed that except for mini-tuber C1, soaking durations of 36 and 48 hours significantly ($P<0.05$) produced the highest yield parameters: mini-tuber C2, C3, C4, number of tubers, and the total yield plant^{-1} (Table 3). As in the growth parameters, soaking cocopeat for more than 36 hours does not also increase the yield parameters. Longer soaking durations may have extracted more elements than needed. Also, soaking cocopeat for <36 hours may extract less K and Na thus affecting the yield parameters and the full effects may not be observed. The yield in durations of 36 and 48 hours was 284.92 g plant^{-1} and 274.42 g plant^{-1}, respectively while the yield in 12 hours was 227.08 g plant^{-1}. As for the $Ca(NO_3)_2$ levels, 100 g of $Ca(NO_3)_2$ significantly ($P<0.01$) gave the highest yield (371.73 g plant^{-1}), number of tubers (15.73 tubers plant^{-1}), C2, C3, and C4 classes (Table 3). The lowest yield parameters were observed in 0 g of $Ca(NO_3)_2$. The total percentage production was 10.1%, 19.7%, 34.4%, and 35.8% in $Ca(NO_3)_2$ 0, 60, 150, and 100 g, respectively. Although the growth parameters are directly proportional to the $Ca(NO_3)_2$ levels, this does not necessarily mean that the yield parameters are also directly proportional to the $Ca(NO_3)_2$ levels. As seen in the results, 100 g of $Ca(NO_3)_2$ significantly produced the highest yield parameters than 150 g of $Ca(NO_3)_2$. This means that $Ca(NO_3)_2$ >100 g may merely increase the growth parameters, but not the yield parameters which are most important to farmers. As reported by Najm *et al.* (2010), the use of excessive N for potato production leads to immoderate growth. The NDVI was directly proportional to the number of branches and plant height because, it quantifies the plant

Table 2. Means separation for the effects of soaking duration and calcium nitrate on potato growth parameters.

Soaking duration (hours)	Number of branches	NDVI	Plant height (cm)
12	11.58^{c}	0.74^{a}	57.05^{b}
24	11.92^{bc}	0.76^{a}	57.95^{b}
36	12.75^{ab}	0.78^{a}	61.46^{a}
48	12.83^{ab}	0.78^{a}	62.14^{a}
72	13.33^{a}	0.78^{a}	63.17^{a}
MSD	0.95	0.06	2.57
Calcium nitrate (g)	**Number of branches**	**NDVI**	**Plant height (cm)**
0	7.20^{d}	0.61^{d}	39.83^{d}
60	11.87^{c}	0.76^{c}	59.37^{c}
100	14.73^{b}	0.81^{b}	68.68^{b}
150	16.13^{a}	0.89^{a}	73.51^{a}
MSD	0.80	0.05	2.15

The means followed by the same letter(s) in the same column are not significantly different using Tukeys' HSD test at a 5% significance level. 0.0, 60.0, 100, and 150 gram of Ca(NO3)2 and 12, 24, 36, 48, and 72 soaking durations hours, MSD: Minimum significant difference.

Table 3. The main effects of soaking duration and calcium nitrate on Shangi potato yield parameters

Soaking durations (hours)	Yield (g plant^{-1})	Tubers plant^{-1}	Tuber weight classes			
			C1	C2	C3	C4
12	227.08^{d}	10.50^{c}	4.00^{a}	2.08^{c}	2.17^{bc}	2.25^{b}
24	247.42^{c}	11.92^{b}	4.33^{a}	2.33^{c}	2.83^{a}	2.42^{b}
36	284.92^{a}	13.17^{a}	4.42^{a}	2.83^{a}	2.50^{ab}	3.42^{a}
48	274.42^{a}	12.00^{ab}	4.00^{a}	2.67^{ab}	2.67^{ab}	2.67^{ab}
72	263.08^{b}	10.33^{c}	4.67^{a}	2.00^{c}	1.66^{c}	2.00^{b}
MSD	11.13	1.20	0.69	0.48	0.54	0.77
Calcium nitrate (g)	**Yield (g plant^{-1})**	**Tubers plant^{-1}**	**C1**	**C2**	**C3**	**C4**
0	104.67^{d}	7.93^{d}	4.13^{b}	2.33^{b}	1.27^{c}	0.20^{c}
60	204.33^{c}	9.87^{c}	3.60^{bc}	2.13^{b}	2.07^{b}	2.07^{b}
100	371.73^{a}	15.73^{a}	3.53^{c}	2.93^{a}	3.87^{a}	5.40^{a}
150	356.80^{b}	12.80^{b}	5.87^{a}	2.13^{b}	2.67^{b}	2.53^{b}
MSD	9.34	1.01	0.58	0.40	0.46	0.64

The means followed by the same letter(s) in the same column are not significantly different using Tukeys' HSD test at a 5% significance level. 0, 60, 100, and 150 gram of Ca(NO3)2 and 12, 24, 36, 48, and 72 soaking durations hours, MSD: minimum significant difference.

biomass (Xue and Su, 2017). As N increases, the growth parameters tend to increase thus increasing the NDVI of the plant.

Interaction effects of calcium nitrate levels and soaking durations on Shangi potato growth and yield parameters

There were significant (P<0.001) differences amongst treatments for all the growth parameters: number of branches, NDVI, and plant height (Table 4). For the number of branches per plant, C2D3 to C3D5 (treatments with >100 g $Ca(NO_3)_2$) had significantly higher branches between 14-17 plant^{-1} than the other treatments. The least number of branches (4.67) were found in Soil (positive control), C0D0 (5.33) (negative control) C0D1, C0D2 and C0D3, respectively. The growth parameters were highly influenced by the concentration of N in the media. Treatments with high $Ca(NO_3)_2$ levels had high N availability, and therefore growth was higher. The tissue analyses showed excessive N concentrations in C3D1 to C3D5. This is one of the factors for high vegetative growth. According to Ruža *et al.* (2013); Banjare *et al.* (2014), N is well known for its influence on potato growth parameters. The highest NDVI values were obtained from C1D4 to C3D5 where the application of $Ca(NO_3)_2$ was 60 to 150 g 1.5 kg^{-1} of cocopeat in 15 litres of water were done. The least NDVI values were found in treatments without $Ca(NO_3)_2$ (C0D1 to C0D5), the untreated cocopeat (C0D0), and the soil treatment. The NDVI values increased with an increase in $Ca(NO_3)_2$ levels. The C3D5, which had the highest N, produced 56.90% and 52.26% more branches than positive and negative controls. Due to the high N concentration in this C3D5, its NDVI and plant height was more significant than the negative and positive controls. All the growth parameters were highly correlated (P<0.001) with the yield parameters, and this was also observed by (Larkin *et al.*, 2021). These positive correlations were due to the nutrient availability to plants, plant health, and the media's suitability in the higher yield treatments. The normalized difference vegetation index that reflects the N level of the plant was correlated with the number of branches and plant height due to the plant's vegetative growth. Other studies have reported that NDVI quantifies the canopy growth, vegetation cover, and growth dynamics of plants (Xue and Su, 2017). The highest plant height was observed in C3D5, C3D4, C3D3, and C2D3. While the least plant height was observed in C0D1 to C0D5 (treatments without $Ca(NO_3)_2$), C0D0, and Soil. The positive relationship between yield and the number of tubers per plant was also observed by Khayatnezhad *et al.* (2011). Contrary to

Table 4. Means separation for the interaction effects of calcium nitrate levels and soaking durations on potato growth parameters.

Treatment	Number of branches	NDVI	Plant height (cm)
C0D1	6.00^{jk}	0.54^{efg}	37.33^{hi}
C0D2	6.33^{ijk}	0.58^{ef}	39.18^{h}
C0D3	7.00^{hij}	0.62^{de}	39.50^{h}
C0D4	8.00^{hi}	0.61^{de}	40.83^{h}
C0D5	8.67^{h}	0.60^{def}	42.33^{h}
C1D1	10.67^{g}	0.72^{bcd}	57.67^{g}
C1D2	11.33^{fg}	0.72^{bcd}	58.67^{g}
C1D3	11.67^{fg}	0.73^{bcd}	57.33^{g}
C1D4	12.67^{ef}	0.79^{abc}	62.00^{efg}
C1D5	13.00^{def}	0.78^{abc}	61.20^{fg}
C2D1	14.00^{cde}	0.78^{abc}	65.70^{def}
C2D2	14.00^{cde}	0.78^{abc}	66.17^{def}
C2D3	16.00^{ab}	0.85^{ab}	73.00^{abc}
C2D4	15.00^{bc}	0.81^{abc}	68.33^{cd}
C2D5	14.67^{abc}	0.83^{abc}	70.20^{bcd}
C3D1	15.67^{abc}	0.85^{ab}	67.50^{cde}
C3D2	16.00^{ab}	0.85^{ab}	67.73^{cde}
C3D3	16.33^{ab}	0.87^{a}	76.00^{ab}
C3D4	15.67^{ab}	0.87^{a}	77.40^{a}
C3D5	17.00^{a}	0.88^{a}	78.93^{a}
C0D0	5.33^{jk}	0.47^{fg}	32.47^{ij}
Soil	4.67^{k}	0.43^{g}	30.12^{j}
MSD	1.95	0.13	6.29

Means followed by the same letters(s) in the same column are not significantly different using Tukeys' HSD test at a 5% level of significance. MSD: minimum significant difference, NDVI: moralized difference vegetation index.

Table 5. Means separation for the interaction effects calcium nitrate levels and soaking durations on the yield, number of tubers, and tuber weight classes

Treatment	Yield (g plant^{-1})	Number of tubers plant^{-1}	Tuber weight classes			
			C1	C2	C3	C4
C0D1	77.33^{k}	8.00g^{h}	4.67^{cde}	2.00^{bcd}	1.33^{def}	0.00^{j}
C0D2	98.33^{jk}	10.00^{efg}	4.33^{bcde}	3.00^{ab}	2.67^{bcd}	0.00^{j}
C0D3	104.33^{jk}	7.00^{gh}	4.33^{bcde}	2.33^{bc}	0.33^{f}	0.00^{j}
C0D4	119.33^{j}	7.33^{gh}	4.00^{cde}	2.33^{bc}	1.00^{ef}	0.00^{j}
C0D5	124.00^{j}	7.33^{gh}	3.33^{de}	2.00^{bcd}	1.00^{ef}	1.00^{hij}
C1D1	175.67^{i}	7.67^{gh}	4.00^{cde}	1.67^{cd}	1.33^{def}	0.67^{ij}
C1D2	192.67^{hi}	9.00^{fg}	3.67^{cde}	1.67^{cd}	2.00^{cde}	1.67^{fghij}
C1D3	204.33^{h}	11.33^{def}	4.00^{cde}	3.00^{ab}	2.00^{cde}	2.33^{efghi}
C1D4	209.67^{h}	11.33^{def}	3.00^{de}	2.33^{bc}	3.00^{bc}	3.00^{cdefg}
C1D5	239.33^{g}	10.00^{efg}	3.33^{de}	2.00^{bcd}	2.00^{cde}	2.67^{defgh}
C2D1	303.33^{f}	11.67^{cdef}	2.67^{e}	2.00^{bcd}	3.00^{bc}	4.00^{cde}
C2D2	328.00^{ef}	14.67^{c}	3.33^{de}	2.67^{bc}	4.00^{ab}	4.67^{bc}
C2D3	464.67^{a}	21.67^{a}	3.33^{de}	4.00^{a}	5.33^{a}	9.00^{a}
C2D4	415.67^{b}	18.00^{b}	3.00^{de}	4.00^{a}	4.67^{a}	6.33^{b}
C2D5	347.00^{cde}	12.67^{cde}	5.33^{abc}	2.00^{bcd}	2.33^{cde}	3.00^{cdefg}
C3D1	352.00^{cde}	14.67^{c}	4.67^{bcd}	2.67^{bc}	3.00^{bc}	4.33^{cd}
C3D2	370.67^{c}	14.00^{cd}	6.00^{ab}	2.00^{bcd}	2.67^{bcd}	3.33^{cdef}
C3D3	366.33^{cd}	12.67^{cde}	6.00^{ab}	2.00^{bcd}	2.33^{cde}	2.33^{efghi}
C3D4	353.00^{cde}	11.33^{def}	6.00^{ab}	2.00^{bcd}	2.00^{cde}	1.33^{ghij}
C3D5	342.00^{de}	11.33^{def}	6.67^{a}	2.00^{bcd}	1.33^{def}	1.33^{ghij}
C0D0	47.33^{l}	7.67^{gh}	4.67^{bcd}	2.00^{bcd}	1.00^{ef}	0.00^{j}
Soil	33.33^{l}	5.67^{h}	4.67^{bcd}	1.00^{d}	0.00^{f}	0.00^{j}
Total	5268.32	244.98	95.00	50.67	48.32	50.99
MSD	28.52	3.08	1.87	1.17	1.34	1.92

Means followed by the same letter(s) in the same column are not significantly different using Tukey's HSD test at a 5% level of

Badr *et al.* (2012), the number of tubers greatly influenced potato yield, as revealed by the correlation test. The growth parameters are important components of crop production under normal circumstances as they are highly correlated with the yield parameters in most crops.

For all the yield parameters: total yield, number of tubers, and tuber class C1, C2, C3, and C4 treatments were significantly ($P<0.001$) different (Table 5). The highest yield (464.67 g plant^{-1} and 415.68 g plant^{-1}) was observed in C2D3 and C2D4, respectively. Similarly, C2D3 and C2D4 gave the highest percentage yield of 8.82% and 7.89%, respectively. On the other hand, the lowest percentage of tuber (3.13% and 2.31%) and yield (0.90% and 0.63%) production was observed in untreated cocopeat and soil, respectively. Out of the total number of tubers (244.95), C2D3 and C2D4 produced 8.85% and 7.35%, respectively. The least number of tubers per plant were also observed in treatments without $Ca(NO_3)_2$, the positive and negative controls. This low production in the soil and the untreated cocopeat treatments may be due to soil compaction in the experimental pots and high Na and K concentrations in the untreated cocopeat. The nutrient availability and balance in media highly influence potato growth and yield parameters (Naumann *et al*., 2020). In all treatments combined, the highest number of tubers class^{-1} were observed in C1 (95.00), C4 (50.99), C2 (50.67), and C3 (48.32). Comparatively, treatments with the highest N and Ca concentrations in the media gave the highest tubers in mini-tubers C1. This was due to high N in the media that lead to higher vegetation and low yield. The use of soil for mini-tuber production has been reported as unsatisfactory, especially in the greenhouse. The yield projection showed that D2D3 and C2D4 productivities were 20.65 and 18.47 tonnes ha^{-1}, respectively. Zimba *et al.* (2014) obtained a similar result, who obtained 19.08 tonnes ha^{-1} of potato using vermiculite, 11.36 tonnes ha^{-1} using sand, and 4.3 tonnes ha^{-1} using sawdust as a growth media. The untreated cocopeat and soil productivities were 2.10 and 1.48 tonnes ha^{-1}, respectively. Due to the high N in the media, C3D2 to C3D5 had higher growth parameters and higher mini-tuber class C1 production compared to C2D3 and C2D4. Excessive N leads to poor tuber quality and delayed crop maturity, whereas nitrogen deficiency usually results in poor vegetative growth and low yield (Banjare *et al*., 2014). Concisely, cocopeat is an alternative to the soil medium for mini-tuber production when it is well treated. The most demanded mini-tuber class by most farmers C4 >18.00 g was dominantly produced in C2D3 (17.63%) and C2D4 (12.41%), while the least percentage production was 0.0%, was in C0D1 to C0D4, untreated cocopeat and soil. This means that when K and Na are not fully reduced in cocopeat, the production tends to reduce significantly. Struik (2007) also argued that using soil for the production of mini-tubers in a greenhouse reduces the number of tubers between 2-5 plant^{-1} depending on the cultivar used. Other studies by Jane *et al.* (2013); Kamrani *et al.* (2019) have also discouraged the use of soil for mini-tuber production. Putra *et al.* (2019) also obtained an average of 5.27 tubers plant^{-1} when an untreated cocopeat was used for mini-tuber production. Significantly, C2D3, C2D4, and C2D2, respectively, gave the highest number of tubers in C4, the most needed mini-tubers class in the market. On the other hand, from C0D1 to C0D4, the positive and negative controls could not produce any tuber in mini-tubers class C4. The relationships between growth parameters and yield showed that there were strong positive correlations between the number of tubers and NDVI (*r*= 0.67), the number of tubers and plant height (*r*= 0.70), tubers and branches (*r*= 0.73), yield and NDVI (*r*= 0.90), yield and number of branches (*r*= 0.95), yield and number of tubers (*r*= 0.87), yield and plant height (*r*= 0.93), and between NDVI and branches (*r*= 0.92) all at P<0.001.

Conclusion

The use of $Ca(NO_3)_2$ above 100 g to treat 1.5 kg of cocopeat irrespective of the soaking durations leads to excessive Ca and N in the media thus inhibiting potato K uptake. Potato growth parameters are increased with an increase in $Ca(NO_3)_2$. The use of $Ca(NO_3)_2$ above 100 g increases the N concentration in the media to excessive levels thus increasing the vegetative parts of the plant and resulting in low yield. Higher mini-tuber yield is attained when 1.5 kg of cocopeat is soaked with 100 g of calcium nitrate for 36 hours. The study further recommends the comparison study of treated cocopeat with other soilless media for mini-tuber production.

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Competing interests

The authors declared that there is no competing interest.

REFERENCES

AFA-NOCD. (2020). The coconut value chain status. Agriculture and Food Authority (AFA), Nairobi.

Amata, Otipa, M., Waiganjo M, M 1, & Thuranira E G. (2009). Incidence, prevalence and severity of passion fruit fungal diseases in major production regions of Kenya. *Journal of Applied Biosciences*, *20*(20), 1146–1152. www.biosciences.elewa.org

Badr, M. A., El-Tohamy, W. A., & Zaghloul, A. M. (2012). Yield and water use efficiency of potato grown under different irrigation and nitrogen levels in an arid region. *Agricultural Water Management*, *110*, 9–15.

Banjare, S., Sharma, G., & Verma, S. K. (2014). Potato crop growth and yield response to different levels of nitrogen under Chhattisgarh plains agro-climatic zone. *Indian Journal of Science and Technology*, *7*(10), 1504–1508.

Campos, H., & Ortiz, O. (2020). The potato crop: It's agricultural, nutritional and social contribution to humankind, Switzerland.

Chiipanthenga. (2012). The potential of aeroponics system in the production of quality potato (*Solanum tuberosum* L.) seed in developing countries. *African Journal of Biotechnology*, *11*(17), https://doi.org/10.5897/ajb10.1138

CIP (2019). Farming Success with Potatoes in Kenya: https://cipotato.org/media/farming- success potatoes Kenya

Demo, P., Lemaga, B., Kakuhenzire, R., Schulz, S., Borus, D., Barker, I., Woldegiorgis, G., Parker, M. L., & Schulte-Geldermann, E. (2015). Strategies to improve seed potato quality and supply in sub-Saharan Africa: experience from interventions in five countries. *Potato Research 58*, 155–167.

FAO, IFAD, UNICEF, WFP, W. (2018). The State of Food Security and Nutrition in the World 2018. Building climate resilience for food security and nutrition. Rome, FAO.

FAO, IFAD, UNICEF, WFP. (2018). The state of food security and nutrition in the world 2018. building climate resilience for food security and nutrition. Food and Agriculture Organization of the United Nations, Rome.

FAOSTAT (2018) Food and Agriculture Organization of the United Nations Statistics. http://www.fao.org/faostat/en/#data

Gbollie, S. N., Mwonga, S. M., & Kibe, A. M. (2021). Effects of calcium nitrate levels and soaking durations on cocopeat nutrient content. *Journal of Agricultural Chemistry and Environment*, *10*(3), 372–388.

Gildemacher, P. R., Schulte-Geldermann, E., Borus, D., Demo, P., Kinyae, P., Mundia, P., & Struik, P. C. (2011). Seed potato quality improvement through positive selection by smallholder farmers in Kenya. *Potato Research*, *54*(3), 253–266.

Goddek, S., Joyce, A., Kotzen, B., & Burnell, G. M. (2019). Aquaponics food production systems. *Springer Nature*. Switzerland.

Gohil, P. (2018). Role of growing media for ornamental pot plants. *International Journal of Pure and Applied Bioscience*, *6*(1), 1219–1224.

Halamba, S., & Kuack, D. (2021). Using coir as a growing substrate. 1–10. https://hortamericas.com/uncategorized/using-coir-as-growing-substrate/

Harahagazwe, D., Condori, B., Barreda, C., Bararyenya, A., Byarugaba, A. A., Kude, D. A., Lung Aho, C., Martinho, C., Mbiri, D., Nasona, B., Ochieng, B., Onditi, J., Randrianaivoarivony, J. M., Tankou, C. M., Worku, A., Schulte-Geldermann, E., Mares, V., Mendiburu, F. De, & Quiroz, R. Q. (2018). How big is the potato (*Solanum tuberosum L.*) yield gap in Sub-Saharan Africa, and why? A participatory approach. *Open Agriculture*, *3*(1), 180–189.

Hochmuth, G., Maynard, D., Vavrina, C., Hanlon, E., & Simonne, E. (2018). Plant tissue analysis and interpretation for vegetable crops in Florida. *Hort Technology*, *28*, 1–48.

Huu Nguyen, H., Maneepong, S., & Suraninpong, P. (2017). Effects of potassium, calcium, and magnesium ratios in soil on their uptake and fruit quality of pummelo. *Journal of Agricultural Science*, *9*(12), 110-121.

Jane Muthoni, J., Shimelis, H., & Melis, R. (2013). Potato production in Kenya: farming systems and production constraints. *Journal of Agricultural Science*, *5* (5), 182-197.

Kakuhenzire, R., Tibanyendera, D., Kashaija, I. N., Lemaga, B., Kimoone, G., Kesiime, V. E., Otazu, V., Ortiz, O., & Barker, I. (2017). Improving mini-tuber production from tissue-cultured potato plantlets with aeroponic technology in Uganda. *International Journal of Agriculture and Environmental Research*, *3* (5), 3948–3964.

Kamrani, H. M., Chegeni, R. A., & Hosseinniya, H. (2019). Effects of different growing media on yield and growth parameters of potato mini-tubers (*Solanum tuberosum L.*). *Communications in Soil Science and Plant Analysis*, *50*(15), 1838–1853.

KEPHIS (2016) Kenya official variety register (2016). Kenya plant health inspectorate service, Nairobi.

Khayatnezhad, M., Shahriari, R., & Gholamin, R. (2011). Correlation and path analysis between yield and yield components in potato (*Solanum tuberosum* L.). *Middle-East Journal of Scientific Research*, 7(1), 17–21.

Kimbonguila, A., Matos, L., Petit, J., Scher, J., & Nzikou, J.-M. (2019). Effect of physical treatment on the physicochemical, rheological and functional properties of yam meal of the cultivar "ngumvu" from dioscorea alata L. of Congo. *International Journal of Recent Scientific Research*, *8*, 19328–19334.

Ko, D., Lee, J. S., Patel, H. A., Jakobsen, M. H., Hwang, Y., Yavuz, C. T., Hansen, H. C. B., & Andersen, H. R. (2017). Selective removal of heavy metal ions by disulfide-linked polymer networks. *Journal of Hazardous Materials*, *332*, 140–148, https://doi.org/10.1016/j.jhazmat.2017.03.007

Lakhiar, I. A., Gao, J., Syed, T. N., Chandio, F. A., & Buttar, N. A. (2018). Modern plant cultivation technologies in agriculture under controlled environment: A review on aeroponics. *Journal of Plant Interactions*, *13*(1), 338–352.

Larkin, R. P., Honeycutt, C. W., Griffin, T. S., Olanya, O. M., & He, Z. (2021). Potato growth and yield characteristics under different cropping system management strategies in Northeastern U.S. Agronomy, 11(1), 1-19.

Marock, D. (2021). How do I buffer Coco Peat? Buffering Coco Coir. 1–10. https://www.lichengroup.co.za/buffering-coco-peat/

Najm, A. A., Haj S. H, Fazeli, F., Taghi Darzi, M., & Shamorady, R. (2010). Effect of utilization of organic and inorganic nitrogen sources on the potato shoots dry matter, leaf area index and plant height, during the middle stage of growth. World Academy of Science, *Engineering and Technology*, *47*, 900–903.

Naumann, M., Koch, M., Thiel, H., Gransee, A., & Pawelzik, E. (2020). The importance of nutrient management for potato production part II: plant nutrition and tuber quality. *Potato Research*, *63*(1), 121–137.

NPCK. (2019). Potato variety catalogue 2019. 1–72, http://varieties.potato.org.uk/varieties/view/Accord

Okalebo, J Robert Kenneth, W Gathua, & Paul, L. W. (2002). Laboratory methods of soil and plant analysis: a working manual the second edition. Sacred Africa, Kenya 1–131.

Parker, M. L., Low, J. W., Andrade, M., Schulte-geldermann, E., & Andrade-piedra, J. (2019). Climate Change and seed systems of roots, tubers and bananas: the cases of potato in Kenya and sweet potato in Mozambique. The Climate -Smart Agriculture Papers. 99-111.

Puga, A. P., Melo, L. C. A., de Abreu, C. A., Coscione, A. R., & Paz-Ferreiro, J. (2016). Leaching and fractionation of heavy metals in mining soils amended with biochar. *Soil and Tillage Research*, *164*(2015), 25–33, https://doi.org/10.1016/j.still.2016.01.008

Putra, F. P., Saparso, S., Suparto, S. R., & Faozi, K. (2019). Relationship of growth and yield mini tubers of potato under cocopeat media and frequency of fertilizer. *Bernas*, *15*(1), 11–19.

Rehman, M. A., Ehsan, H. M., Ashraf, T., Gurmani, Z. A., Khan, S., & Ali, M. (2020). Effect of Growing Media on Plant Growth of Rough Lemon (Citrus jambhiri Lush.) and Poncirus (Citrus trifoliata). *Journal of Innovative Sciences*, *6*(2), 2–10. https://doi.org/10.17582/journal.jis/2020/6.2.206.213

Ruža, A., Skrabule, I., & Vaivode, A. (2013). Influence of nitrogen on potato productivity and nutrient use efficiency. Proceedings of the Latvian Academy of Sciences, Section B: Natural, Exact, and Applied Sciences, *67*(3), 247–253.

Sachin TM, Thakur, N., & Sharma, P. (2020). Use of alternative growing media in ornamental plants. International Journal of Chemical Science, *8*(6): 188-194.

SAS Institute Inc. (2002). Cary, NC, USA.

Satognon, F., Owido, S. F. O., & Lelei, J. J. (2021). Effects of supplemental irrigation on yield, water use efficiency and nitrogen use efficiency of potato grown in mollic Andosols. Environmental Systems Research, 10(1), https://doi.org/10.1186/s40068-021-00242-4

Shanmugasundaram, R., T., J., Sweatha, S. M., M., S., A., G., & Balakrishna, M. (2014). Coco peat - An alternative artificial soil ingredient for earthworm toxicity testing. *Journal of Toxicology and Environmental Health Sciences*, *6*(1), 5–12.

Sidhu, R. S., Sangwan, A. K., Satpal, S., Brar, G. S., & Singh, N. P. (2018). Impact of foliar feeding of Ca (NO3) 2 on plant growth and leaf nutrients of strawberry (Fragaria × ananassa Duch.) cv. Winter Dawn. Horticulture *Flora Research Spectrum*, *7*(2), 115-120.

Struik, P. C. (2007). The canon of potato science: mini-tubers. Potato Research, *50*(3–4), 305– 308.

VIB (2019). Potato in Africa. Fact sheets. http: //www.vib.be/VIBDocumentLibrary/VIB_Facts%20Series_Potato%20in% 20Africa%20LR.pdf.

Waaswa, A., & Satognon, F. (2020). Development and the Environment: Overview of the Development Planning Process in Agricultural Sector, in Uganda. Journal of Sustainable Development, *13*(6), 1, https://doi.org/10.5539/jsd.v13n6p1

Wang'ombe, J. G., & van Dijk, M. P. (2013). Low potato yields in Kenya: Do conventional input innovations account for the yields disparity. Agriculture *and Food Security*, 2(1), 1–11.

Wittman, M. (2020). Buffering up_ adjusting the cation exchange capacity in coco growing media (1). 2–5. https://www.maximumyield.com/buffering-up-adjusting-the-cation- exchange-capacity-in-coco-growing-media/2/1318

Xue, J., & Su, B. (2017). Significant remote sensing vegetation indices: A review of developments and applications. *Journal of Sensors*, 10, 1-17.

Yadata, D. (2014). Detection of the Electrical Conductivity and Acidity of Honey from Different Areas of Tepi. *Food Science and Technology*, *2*(5), 59–63, https://doi.org/10.13189/fst.2014.020501

Zimba, S., Njoloma, J., NyaikaJ, A., Mwaase, W., & Maliro, M. (2014). Miniituber production potential of selected Potato (*Solanum tuberosum* L.) genotypgation media. *African Journal of Biotechnology 613* (48), 1684–5315.