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Effects of Media Type on Growth and Yield of Potato (*Solanum tuberosum* L.) Varieties Apical Rooted Cuttings in Kenya

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ABSTRACT

To address soil-borne virus diseases; a soilless media has been introduced for producing healthy seed tuber based on *in vitro* rapid multiplication of virus-free planting material. The objective of this study was to determine the effect of different media on the growth of potato variety using apical rooted cuttings. A greenhouse study was carried out where five media types; coco-peat + perlite, sand, coco-peat + pumice, coco-peat + vermiculite, and soil were tested along with three local potato varieties (*Shangi*, *Unica* and *Wanjiku*). The study was a 3×5 factorial arrangement laid out in a randomized complete block design (RCBD). Data collected was subjected to a general linear model (GLM) to partition the variance component using SAS software version 9.0 and means separated using Tukey's Honestly Significant Difference Test (HSD) at $P \leq 0.05$. The interaction between varieties and different media had a significant effect on the number of tubers per plant. *Shangi* registered the highest number of mini tubers per plant (21tubers) on coco-peat + perlite which was not significant different from that of coco-peat +pumice mixture (19 tubers). Plant height of 53cm was recorded under coco-peat + perlite mixture. Highest shoot fresh weight was recorded on *Shangi* (24.86g/plantlet) cultivated on coco-peat + pumice mixture, followed by *Unica* and *Wanjiku* (24.64 and 21.17g/plantlet respectively) cultivated on coco-peat + perlite mixture. *Unica* produced the highest yield (64.8g/plantlet) in coco-peat + pumice, followed by *Wanjiku* (59.8g/plantlet) and *Shangi* (40.8g/plantlet) in coco-peat + perlite. This study recommends that for farmers to overcome spread of pests and diseases, use of coco-peat + perlite and coco-peat+pumice as a soilless media should be promoted to enhanced seed potato growth and tuber formation.

Keywords: coco-peat, perlite, pumice, sand, vermiculite

INTRODUCTION

Globally, potato is estimated to be grown on 19 million hectares with a production of 378 million tonnes in 2017 (Campos & Ortiz, 2020). Between 2015 and 2017, potato production in Africa was 6.5% of the world's production. Kenya produced a total of 1.6 million tonnes on 0.4 million hectares which is 7.5% of Africa's harvested area (FAOSTAT, 2020). The current potato production in Kenya is 7-10 t ha^{-1} against the demand of 20-40 t ha^{-1} .The yield gap between what is currently produced and what is achievable is often greater than 20 t/ha (Mutegi *et al*., 2021). This gap is attributed to virus replicons that tend to increase in the seed material during field multiplication cycles, and therefore leading to low yield.

In addition, multiplication of seed potato take place in field (soil), thereby exposing the seed potatoes to soil-borne disease. Soil is the main platform for pest and disease infections to spread, resulting in significant loss of yield and deteriorate tuber quality over seasons To avoid and address this soil-borne disease, soilless media has been introduced for producing healthy seed tuber based on *in vitro* rapid multiplication of virus-free planting material (Altindal & Karadogan, 2010).

A soilless media is any sterile medium for growing plants that doesn't involve soil. The physical properties of soilless media comprises of particle size distribution, porosity and pore

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distribution, water content and water potential. Soil-less media has capability to grow plants in a conditioned, pest and disease free environment. A soilless has gained popularity, as they eliminate or reduce the need for soil disinfestations. Use of soilless media possibly is the most intensive culture system utilizing all the resources efficiently for maximizing yield of crops and the most intense form of agricultural enterprises for commercial production of greenhouse crops (Asaduzzaman *et al*., 2015). They are considered as important technologies for better water use efficiency as well as high good quality and quantity products. Number of organic and inorganic materials such as gravel, sand, peat, sawdust, pumice, tuff, coir, vermiculite, perlite, and rock wool pure or in mixture are used as solid growing media in addition to hydroponics (Hussain *et al.*, 2014; Putra & Yuliando, 2015). Such substrates replace the soil because the natural soils are often poorly suited for cultivation and contain chemical, physical, or biological contaminations (Asaduzzaman *et al.*, 2015).

Apical rooted cuttings are similar to a nursery grown seedling and are produced from tissue culture plants in a screen house, and are clean and free from diseases. They have several other advantages that include; no need to break dormancy hence faster propagation, it's economical and has a high rate of multiplication. With high productivity of apical rooted cuttings, it becomes economical to seed multipliers selling seed after two to three seasons of multiplication, as certified seed are sold normally after three seasons of multiplication. This study was conducted to determine the growth and yield response of apical rooted potato cuttings of local Kenya varieties in different media to produce good quality clean planting materials.

MATERIALS AND METHODS

Experimental Site

The study was carried out in a greenhouse at Egerton University Agronomy Field, Seven, Njoro campus, Kenya. The site lies at a latitude of 0^o 22`11.0``S, longitude of $35^o$ 55`58.0``E and altitude of 2670 m.a.s.l. The site is in agro-ecological zone III with an average annual rainfall range of 800-1500 mm with two seasons. The greenhouse maximum temperature was 22.4^{o}C and the minimum temperature was 7.8^{o}C. The soils are well-drained, dark reddish clays, slightly acidic, and contain medium levels of organic carbon and low levels of phosphorus classified as Mollic Andosols (Jaetzold *et al*., 2006).

Experimental Design and Treatment Application

The experiment was laid in a factorial randomized complete block design (RCBD). Treatments included media at five levels, i.e., coco-peat + pumice, coco-peat + perlite, sand, soil and coco-peat +vermiculite, and three local potato varieties (*Shangi*, *Unica* and *Wanjiku*). Each treatment was replicated three times.

Establishment of Mother Plant

In *vitro* well-rooted shoots (plantlets) obtained from experiment 1, were taken out gently from the culture media and washed with sterile water to remove any traces of agar on the roots and dipped in fungicide solution for 20 minutes (soil-borne disease). The plantlets were transferred to containers filled with sterilized sand for establishment. The plantlets were covered for 25 days with clear polythene to acclimatize to the ambient growth environment. Plants were watered with water until they attained 3-5 nodes (maturity stage). After cutting the apical tips, mother plants were supplied with nutrient solution to enhance the sprouting of new shoots.

Plate 1: Mother plants 14 days after establishment

Hardening of Apical Rooted Cuttings

Before cutting the apical tips from the established mother plant, hands and scissors were disinfected with 70% ethanol. Apical tips of the established mother plants were cut at one node after the mother plant developed ≥ 3 nodes. After cutting the apical tip of the cutting, each mother plant provided 1-3 shoots for cutting. The cuttings were rooted in trays filled with sterilized coco-peat. The cuttings took two to three weeks to root after which they were taken to the different media to produce seed tubers.

Plate 2: Apical rooted cuttings that are ready for planting

Preparation of Media Type

Sand, coco-peat + perlite, coco-peat + pumice, coco-peat +vermiculite and soil media types were prepared. Sand was sterilized by washing with water several times until water became clean. After that it was soaked with hot water for 24 hours to kill germs. Coco-peat was soaked in a mixture of water and calcium nitrate for twelve hours to remove high potassium (K^+) and sodium (Na^+) ions so that plant roots could absorb water efficiently (Marock, 2021). Sand, vermiculite, pumice and perlite were soaked with hydrogen peroxide at a rate of 500ml in 1000litres for 24 hrs.

Data Collection

Several plantlet growth parameters were determined. Plant height was measured from the surface of media until the tip of the apical meristem.

Number of leaves from three samples was counted and the average leaf number was recorded and used for analysis.

Number of branches was counted two weeks after planting until the maturity of the crop. The number of branches was recorded. Data for plant height, number of leaves, and number of branches commenced two weeks after planting at an interval of 14 days.

Plant biomass at harvest was done by weighing (g) the above ground biomass. Number of mini tubers was counted after harvesting and calculated per treatment. Weight of tubers (g) was calculated using a weighing balance.

Number of mini tubers was counted after harvesting and calculated per treatment. Weight of tubers was calculated using a weighing balance.

Data Analysis

The collected data was subjected to Shapiro wilk test at probability $P \leq 0.05$ for normality test using SAS software. For any data not normally distributed, data transformation was performed. The data was subjected to analysis of variance (ANOVA) at $p \leq 0.05$ using PROC GL M code of Version 9.3 (2010) and means of significant treatments was separated using Tukey's Honestly Significant Different Test at $P \leq 0.05$. Correlation analysis was also performed among the response variables: plant height, number of leaves, number of branches, plant biomass, tuber weight and number of minitubers. The RCBD model to fit for the experiment was as follows:

$$Y_{ijk} = \mu + var_i + Tj + varTij + B_k + \mathcal{E}_{ijk}$$

Where, μ = overall mean, var_i = effect due to the i^{th} level of potato varieties, Tj = effect due to the j^{th} level of media, varTij = effect due to interaction of potato varieties and media, B_k =effect of the k^{th} block and $\mathcal{E}_{ijk}$ = random error term.

RESULTS AND DISCUSSION

Plant Height as Affected by Media and Variety

The interaction between varieties and different media was significant on shoot height at P<0.01. Highest plant height was recorded in *Shangi*, followed by *Unica* and *wanjiku* (53.0, 31.6, and 31.0cm), respectively, in coco-peat + perlite (Table 1). However, the result recorded in coco-peat + perlite was not significantly different from that of coco-peat + pumice for plant height recorded on *Shangi*. This could be because of coco-peat +perlite and coco-peat +pumice composition which retain nutrients better and has a high water holding capacity that boosts plant height under greenhouse conditions. This shows that coco-peat and perlite composition is a good media for potato mini-tuber production as tall healthy plants had more photosynthetic area translating to higher yield. The observed results are in consonance with the findings of Awati *et al.* (2019) and Dwelle and Love (2000) who reported that a well-established root and shoot system, is important for subsequent growth which, in turn, influences tuber bulking in potato. The shortest shoot height was observed on *Wanjiku* (24.1cm) grown in soil followed by *Unica* (24.5cm) grown in sand.

Number of Leaves and Branches as Affected by Media and Varieties

Maximum number of leaves were observed on *Wanjiku* (43.53), followed by *Unica* (42.20) and *Shangi* (41.73) in coco-peat + perlite. However, the results were not significantly different from that of coco-peat + pumice for *Wanjiku* and *Unica*, which recorded a mean of 43.40 and 37.87, respectively. Lowest number of leaves was noted on *Unica* in sand. Most numbers of branches were noted on coco-peat + perlite media with *Wanjiku* having the highest, followed by *Unica* and *Shangi* (7.27, 6.53, and 6.33) respectively. However, the number of branches recorded on *Wanjiku* in coco-peat +perlite was not significantly different from that of coco-peat+pumice (6.40). Least number of branches was noted in *Shangi* on sand media (Table 1). This could be due to media type aeration, soil absorbing water capacity and composition variables. Similar findings were reported by Abouzari *et al*. (2012) who recorded that the largest number of lateral shoots (8.593) of Benjamin Tree (*Ficus benjamina*) were observed in cuttings cultivated in composted tea wastes + rice husks compared to other 4 substrates due to higher water retention capacity and draining components which were the best for vegetative plant growth.

Table 1: Effects of media type and varieties on plant height (cm), number of leaves, and number of branches (Mean ±SE) on potato apical rooted cuttings in Kenya

Variety	Soilless Media	Shoot Height	Number of leaves	Number of branches
Shangi	Coco-peat + pumice	52.93±8.55f	30.67±4.76cd	5.93±0.81fg
	Coco-peat + perlite	53.00±9.25f	41.73±6.74fg	6.33±1.05gh
	Coco-peat + vermiculite	42.07±8.00e	30.20±4.20bcd	4.00±0.60bc
	Sand	31.60±4.93d	27.67±4.46b	2.33±0.25a
	Soil	44.47±7.02e	28.67±4.27bc	3.67±0.61b
Unica	Coco-peat + pumice	31.40±4.61cd	37.87±5.66efg	5.73±0.83f
	Coco-peat + perlite	31.60±4.63d	42.2±6.12f	6.53±0.79gh
	Coco-peat + vermiculite	30.07±4.48cd	36.80±6.55e	3.87±0.56b
	Sand	24.47±3.97ab	20.80±2.43a	3.67±0.44b
	Soil	28.33±3.71b	34.40±4.85de	4.53±0.72cd
Wanjiku	Coco-peat + pumice	28.67±4.49cd	43.40±6.90g	6.40±0.96gh
	Coco-peat + perlite	30.93±4.35cd	43.53±7.07g	7.27±0.96h
	Coco-peat + vermiculite	28.67±4.27cd	35.20±4.51e	5.47±0.74ef
	Sand	27.33±4.20bc	26.27±4.36b	3.87±0.49b
	Soil	24.13±2.96a	37.00±5.39ef	5.00±0.67de

Note: Means within a column followed by the same letters are not significantly different ($P \leq 0.05$) according to Tukey's HSD test

Effect of Media and Variety on the Weight of Minitubers per Plant

Variety of media interaction was significant on the weight of minitubers. *Unica* produced the highest yield (64.8g) in coco-peat + pumice, followed by wanjiku (59.8g) and shangi (40.8g) in coco-peat + perlite (Table 2). The variation in yield per variety could be attributed to the influences boosted by media type and varietal genetic composition. These results are similar to those of Awati *et al*. (2019) and Khurana *et al*. (2003). Yields were lower in sand and soil media which correlated with poor plant growth. This could be due to photosynthetic area differences that affects tuber formation of potato apical rooted cuttings. The main role played by physical characteristics of coco-peat + perlite mixture and coco-peat + pumice mixture can be attributed as suitable air-filled porosity, for effective oxygen diffusion and maintaining favorable water content for supplying water, nutrient, and respiration of plant roots unlike sand media that has low water and nutrient holding capacity and can exacerbate deficiencies (Dharti *et al.*, 2021).

Number of Mini-Tuber per Plant as Affected by Media and Varieties

The interaction between varieties and media was significant with respect to the number of tubers per plant (Table 2). *Shangi* registered the highest number of mini tubers per plant (21 tubers) which was not significant different from that of coco-peat + pumice mixture (19 tubers). *Wanjiku* recorded a higher number of mini-tubers (20 tubers) in coco-peat + perlite mixture. However, the results were not significantly different from that of coco-peat + vermiculite. *Unica* produced a higher number of mini-tubers (15tubers) in coco-peat + perlite and coco-peat + pumice mixtures. The variation in the number of tubers per variety could be because of interaction between the genetic constitutions of varieties responding differently to different environments. It could also be as a result of nutrient uptake of plants as it is determined by the media (Asghari *et al.*, 2009). Coco-peat + perlite mixture and coco-peat + pumice mixture indicates their superiority among the other media used. This could be attributed to their ability to hold and retain nutrients which are available to the plants.

Effects of Media and Varieties on the Shoots Fresh Weight and Shoots Dry Weight

Variety by media was significant with respect to the shoots fresh weight and shoot dry weight at $p<0.05$. Highest shoot fresh weight was recorded on *Shangi* (24.9g) cultivated with coco-peat + pumice mixture. This results were not significantly different from that of coco-peat + perlite and coco-peat vermiculite mixtures (20.3g and 20.0g), respectively. *Unica* and *Wanjiku* gave a shoot fresh weight of 24.6g and 21.2g, respectively, in coco-peat + perlite mixture. Highest shoot dry weight was observed on *Unica*, followed by *Wanjiku* (17.2 and 14.8g respectively) cultivated on coco-peat + perlite mixture and *Shangi* (14.4g) cultivated on coco-peat + pumice mixture. However, the shoot dry weight recorded on *Shangi* in coco-peat + pumice mixture treatment was not significantly different from that of coco-peat + perlite and coco-peat + vermiculite mixtures. Lowest shoot fresh and dry weight was noted on sand media among all varieties (Table 2). These results are in agreement with the findings of Haman and Izuno (2003) who reported that plant yields such as biomass production could positively be affected depending on the specific combination of potting mix and water retention capacity.

Table 2: The effects of media type and variety on the number of minitubers, weight of minitubers (grams), fresh and dry weight of shoots (grams) (Mean ±SE) on potato apical rooted cuttings in Kenya

Variety	Soilless Media	Number of minitubers	Weight of minitubers	Shoot fresh weight	Shoot dry weight
Shangi	Coco-peat + pumice	19.33±7.31fg	40.67±11.67d	24.86±4.75e	14.40±2.33f
	Coco-peat + perlite	21.00±2.08g	28.33±1.76b	20.28±5.12de	14.17±3.21fg
	Coco-peat + vermiculite	16.00±2.65e	23.00±9.02b	19.98±9.03de	13.09±2.46f
	Sand	4.67±0.88a	10.67±2.33a	8.39±1.81a	3.81±0.53a
	Soil	6.00±0.58b	10.67±2.33a	11.87±2.47b	6.75±0.88c
Unica	Coco-peat + pumice	15.33±3.53e	64.67±12.98e	16.90±5.80cd	9.96±2.31de
	Coco-peat + perlite	15.33±3.53e	41.33±12.39d	24.64±4.32e	17.19±1.92g
	Coco-peat + vermiculite	13.33±1.76d	47.00±2.00d	16.40±1.91c	9.19±0.64d
	Sand	11.67±2.19d	11.67±1.45a	12.08±3.13b	6.07±1.39c
	Soil	8.00±1.53c	33.00±7.21c	11.78±0.74b	5.23±0.27b
Wanjiku	Coco-peat + pumice	18.67±1.86ef	43.67±14.17d	19.41±2.48d	11.43±1.11e
	Coco-peat + perlite	20.33±3.33fg	59.67±10.27e	21.17±8.16de	14.79±3.17fg
	Coco-peat + vermiculite	16.00±6.03efg	39.67±16.42cd	16.79±4.39cd	10.03±1.02e
	Sand	3.67±1.20a	10.67±1.86a	11.42±1.63b	6.04±0.92c
	Soil	6.67±1.67c	23.67±5.33b	12.38±2.56b	6.77±0.63c

Note: Means within a column followed by the same letters are not significantly different ($P\leq0.05$) according to Tukey's HSD test

Correlation Analysis

There was a significant positive correlation (r=0.97) between the shoots fresh weight and shoots dry weight (Table 3). An increase in shoot fresh weight resulted in an increase of shoot dry weight. There was a positive correlation between the number of leaves and number of branches (r=0.72). The number of leaves increased with increase in number of branches. Shoot fresh and shoot dry weight positively influenced the number of minitubers (r=0.69 and r=0.66). Similar to these results, Otroshy *et al*. (2013) observed that shoot dry weight positively influenced number of minitubers (r= 0.43).

Table 3: Pearson correlation coefficients on the response variables of number of leaves, height, number of branches, number of minitubers, weight of minitubers, leaf fresh weight and leaf dry weight

Response variable	Height	No. of leaves	No. of branches	No. of minitubers	Weight of minitubers	Shoot fresh weight
No. of leaves	0.09ns	-	-	-	-	-
No. of branches	0.03ns	0.72***	-	-	-	-
No. of minitubers	0.32*	0.52***	0.46**	-	-	-
Weight of minitubers	-0.08ns	0.65***	0.55***	0.49***	-	-
Shoot fresh weight	0.32*	0.40**	0.40**	0.66***	0.36*	-
Shoot dry weight	0.35*	0.45**	0.43**	0.69***	0.35*	0.97***

Note: **Correlation is significant at the 0.001 level, **Correlation is significant at the 0.01 level, *Correlation is significant at the 0.05 level

CONCLUSION

The performance of potato varieties varies with propagating media. Coco-peat + perlite was found to be superior in supporting plant growth and tuber formation, followed by coco-peat + pumice. The study has provided valuable information on the media type and the role it plays in increasing the productivity of seed tuber in perspective of commonly used local varieties in Kenya.

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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