# EVALUATION OF THE EFFECTS OF MOTHER PLANT PHYSIOLOGICAL AGE ON PRODUCTION AND FIELD PERFORMANCE OF APICAL CUTTINGS

CIP INTERNATIONAL POTATO CENTER
A CGIAR RESEARCH CENTER

CGIAR RESEARCH PROGRAM ON Roots, Tubers and Bananas

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## OUTPUT 3: EVALUATION OF THE EFFECTS OF MOTHER PLANT PHYSIOLOGICAL AGE ON PRODUCTION AND FIELD PERFORMANCE OF APICAL CUTTINGS

### EXECUTIVE SUMMARY

An experiment was conducted at Stockman Rozen Kenya Ltd to evaluate the effects of mother plant physiological age on production and field performance of apical cuttings. Original tissue culture plantlets (10 replicates) of cvs. Shangi, Wanjiku, Unica and Taurus were grown in potted media under greenhouse conditions. The first cut from each replicate was used to make submothers, which together with the original tissue culture (TC) mothers were used as stock mothers to produce apical cuttings. The stock mothers were evaluated for the maximum number of cuttings a single stock can produce over different rounds or age of cut. A round (or shoot age) refers to the time elapsed between stock planting and the time cuttings were harvested from the subsequent regrowth. The stock mothers in as much as possible, were maintained at juvenile stage to obtain shoot cuttings which have maximum vegetative growth. The apical cuttings from the same stock at different rounds of cut were hardened and grown in the field, 20 plants per cultivar per round. Tuber yield from each round (both numbers and weights) was assessed from 4 sequential harvests taken at weeks 5, 7, 9 and 11-: four plants per harvest. All the cultivars produced observably more cuttings in successive cuts up to the $7^{th}$ round, with exception of Taurus which was clearly the least producer. Shoot age exerted notable effect on tuber numbers for mother stock ≥$7^{th}$ round. The fewer stolon numbers observed in cuttings derived from mature stocks ≥$7^{th}$ round, explained the reduced tuber numbers.


*Photo 1: Screenhouse experiment (a) and field trial (b) at Stockman Rozen Kenya Ltd.*

## 1. BACKGROUND

In Kenya, just like in many tropical and subtropical countries, seed bulking for potato crop is done by repeatedly multiplying a set of disease-free tubers, a method that has low multiplication rate of 3-7 tubers per plant and therefore requires many cycles to obtain sufficient seeds. Continuous field multiplication of seeds by this method exposes the tubers to viral diseases. An alternative rapid multiplication method that employs the use of rooted apical cuttings (RAC) has been tested and validated by CIP and partner institutions and has received endorsement by seed regulatory body in Kenya. The process of RAC production starts with establishment of the invitro tissue culture using meristem tip, after which the produced invitro plantlets are submothered 3 to 4 times using nodal cuts. This is to build a large pool of mother stock and attain rapid multiplication rates. After about 14 days of hardening, the rooted plants are transplanted in the field for production of pre-basic seeds (generation 0). The generation 0 seed tubers obtained are then multiplied in the field for three generations to produce basic seeds. The three generations (1,2 and 3) are only meant to increase the quantity of seeds.

As observed from the trials conducted in Vietnam, Philippines, India and Kenya, a single mother plant can yield up to 150 cuttings in 5 to 9 months. With each cutting producing 10 to 20+ tubers; each tuber producing 8 to 10 seed tubers in the subsequent field multiplications, an increase ratio of 1:170-280 over 3 rounds of multiplication is achievable. Thus, use of apical cuttings has the capacity to attain large number of disease-free seed tubers in a shorter period thereby eliminating the need for many field generations (beyond 3). This technology therefore reduces seed degeneration, minimizes seed production costs, saves time, and achieves high quality seed tubers for further multiplication.

While the extent of these benefits may vary considerably between cultivars, the yield potential may be regulated by physiological age regardless of the cultivar. The physiological age of a potato mother stock depends in part, on its chronological age, measured from the date of planting in the field. There is a general agreement that rather juvenile mother plants produce juvenile cuttings with high yields and vice versa. On the other hand, use of physiologically old stock mother may maximize early yields by reducing the times to tuber initiation and maturity.

Physiological age may also affect the number of shoots per stock mother so that maximum shoots can be obtained from the physiologically young prolific mother and the least from a mature mother. Low vigor may be associated with the accelerated physiological ageing of tubers and formation of small tubers on mature mothers. In this case, maturation refers to the transition from the juvenile to the mature phase, while aging includes loss of vigor associated with increased complexity of the plant.

The vegetative characteristics such as leaf shape, internode length and number, rooting and branching ability, flowering, leaf senesces, tuber formation, and plant vigor have been used as indicators of juvenility or maturity of mother plants. Juvenility affects the rooting ability of cuttings in a way that physiologically young stock plants produce cuttings that are easier to root than the ones from old stock plants. Timely cutting back of stock plants can rejuvenate the mother plant, mainly by its additive effect on rooting and branching of young shoots. Making cuts frequently from the mother plant gives rise to basal and apical axillary stems resulting in additional lateral branches and shoot formation. The rate of shoot formation largely depends on cultivar, planting density, plant nutrient supply and environmental conditions.

In this study, we evaluated the effect of physiological age of stock mother on maximal potential production of rooted apical cuttings considering nine rounds of propagation over a production cycle. The results reported here are only for one season, as the repeat experiment is ongoing. The trial is conducted at Stockman Rozen Kenya Ltd which is a highly specialized apical cutting producer in Kenya.

## 2. RESULTS

## 2.1. SCREENHOUSE EXPERIMENT

### 2.1.1. Effects of physiological age on cutting production

Except for Taurus cultivar, taking cuttings from the same stock mother at 2-3 weeks interval, for up to 7$^{th}$ round allowed the number of cutting rounds to be increased without significant loss of productivity (Table 1).

*Table 1: Comparison of cuttings harvested from a single mother plant over time (August–December 2020).*

| Variety | Stock Mother | Rounds of cuttings derived from the same mother source | | | | | | | | | Av. Total #cuttings per stock mother | Original TC to cutting ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1$^{st}$ | 2$^{nd}$ | 3$^{rd}$ | 4$^{th}$ | 5$^{th}$ | 6$^{th}$ | 7$^{th}$ | 8$^{th}$ | 9$^{th}$ | | |
| | | Number of cuttings from the same stock mother | | | | | | | | | | |
| Shangi | TC | 2±0.2 | 2±0.1 | 3±0.1 | 3±0.1 | 4±0.5 | 9±0.2 | 7±0.2 | 5±0.1 | 3±0.9 | 38bc | 81 |
| | Submother | 3±0.1 | 5±0.2 | 6±0.1 | 6±0.4 | 7±0.3 | 6±0.6 | 4±0.2 | 4±0.5 | 2±0.1 | 43c | |
| Wanjiku | TC | 2±0.1 | 3±0.0 | 4±0.3 | 3±0.3 | 5±0.2 | 8±0.2 | 5±0.4 | 3±0.7 | 3±0.3 | 36bc | 76 |
| | Submother | 3±0.2 | 5±0.2 | 6±0.4 | 6±0.2 | 7±0.2 | 6±0.6 | 3.0.3 | 2±0.1 | 2±0.3 | 40bc | |
| Unica | TC | 2±0.0 | 2±0.2 | 3±0.3 | 3±0.2 | 5±0.4 | 5±0.3 | 4±0.3 | 5±0.3 | 3±0.3 | 32b | 66 |
| | Submother | 2±0.1 | 2±0.1 | 5±0.2 | 4±0.3 | 5±0.2 | 5±0.4 | 3±0.1 | 5±0.5 | 3±0.5 | 34b | |
| Taurus | TC | 2±0.2 | 2±0.2 | 2±0.1 | 1±0.1 | - | - | - | - | - | 7a | 13 |
| | Submother | 2±0.0 | 1±0.2 | 2±0.2 | 1±0.2 | - | - | - | - | - | 6a | |

| F statistics | |
|---|---|
| Factor | Av. Total No. of Cuttings per plant |
| Variety | 0.041 |
| Stock mother | 0.078 |
| Round or age of cutting | 0.068 |

Letters indicate comparisons for means among the mother stocks of different cultivars at $p \leq 0.05$ by Tukey's HSD test.

Observably, Taurus produced mostly shoots with no branches and very few or no buds to regenerate, thus easily succumbing to recurrent cuts and completely stopping regrowth at the 4$^{th}$ round. These shoots were characterized by early tuber formation.

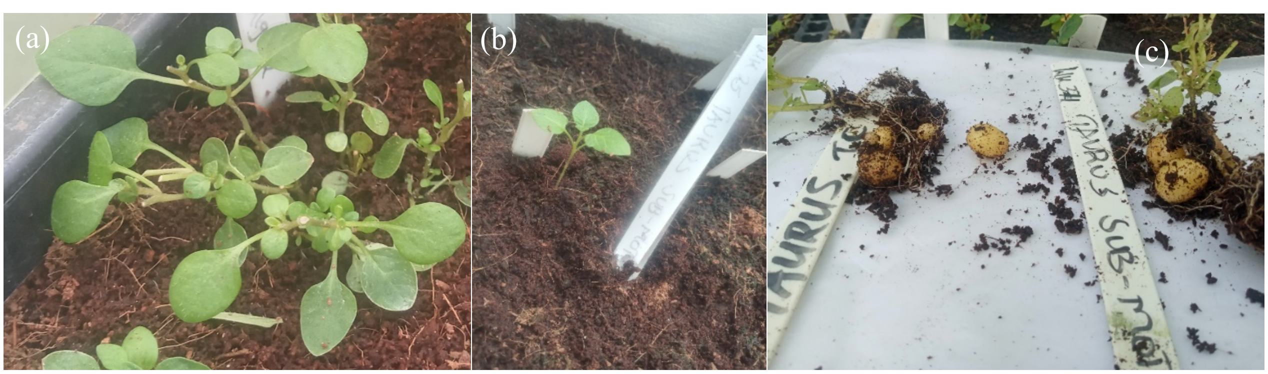


*Photo 2: Multiple shoots of a single stock plant of cultivar Wanjiku (a) in comparison to Taurus (b) at round 2 of cut, and tubers on mother stocks of Taurus at round 4 of cut (c). Take note of the characteristic thin weak stems of Taurus.*

The number of cuttings increased exponentially with subsequent rounds which probably was an effect of increasing root system. Peak production of cuttings occurred between the 5th and 6th rounds of cut for Shangi and Wanjiku, while Unica did not have any clear trend. Submother stocks generally exhibited greater number of cuttings up to the 6th round but were later overtaken by the TC mother stocks. Thus, TC mother stocks exhibited an apparent longer physiological juvenility.

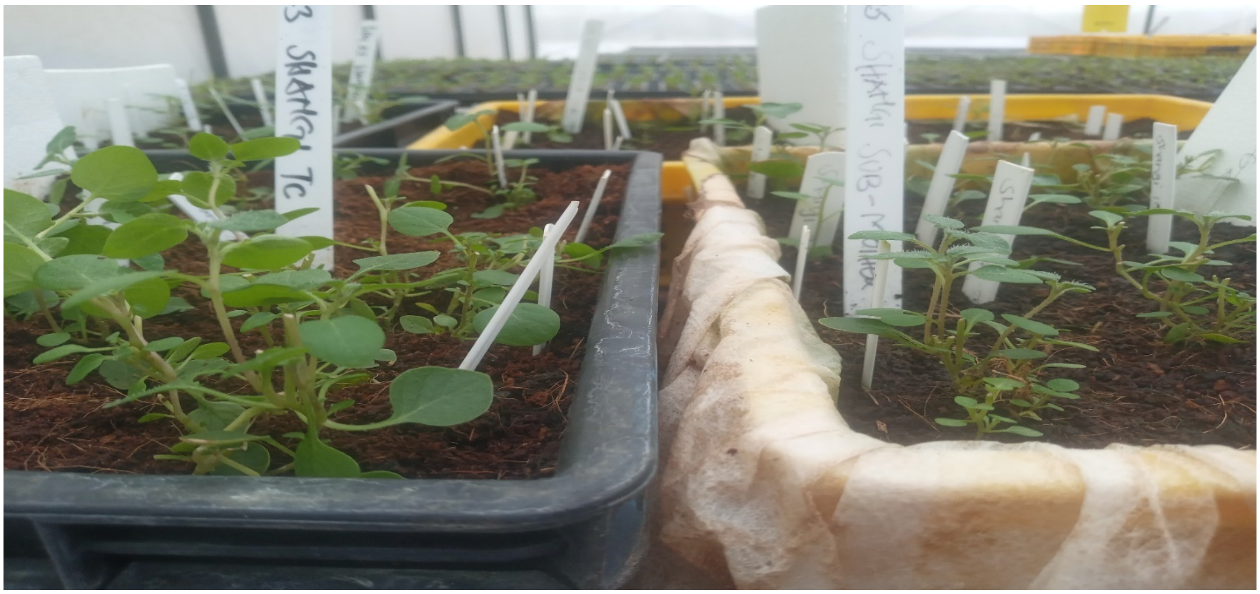

*Photo 3: Mother stocks of Shangi cultivar at round 7 of cut. Not the comparatively higher vigor of TC stock (a) and the less vigor of the submother stocks (b).*

Cultivar effect was evident, with Shangi and Wanjiku producing cumulatively the most cuttings, followed by Unica and Taurus. Taurus produced the least number of cutting as all the stock plants ceased regenerating at the 4th round of harvest. The general reduction in cutting production from the 7th round was indicative of the outset of stock mother plant exhaustion. This was evidenced by the tubers that initiated on the stock plants (at the 7th round) regardless of the cultivar.


*Photo 4: Tubers on stock mothers of cultivars Wanjiku (a), Unica (b) and Shangi (c) at round 9 of cut.*

### 2.2.2. Effects of physiological age and cultivars on internode numbers and length

Mean internode length of each mainstem (total height/number of nodes) was measured in 6 stock mother plant of each genotype (Tables 2 and 3).

***Table 2: Total number of internodes from the same stock mother in different cultivars over time.***

| Variety | Mother source | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th | 9th | Av. #of internodes per shoot |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Number of internodes | | | | | | | | | |
| Shangi | TC | 3.1 | 3.7 | 4.4 | 4.1 | 4.1 | 4.6 | 4.8 | 4.4 | 4.0 | 4.1b |
| | Submother | 3.6 | 4.4 | 5.3 | 5.8 | 5.7 | 4.9 | 4.2 | 3.8 | 3.4 | 4.6b |
| Wanjiku | TC | 4.2 | 3.8 | 5.5 | 4.0 | 5.2 | 5.4 | 4.0 | 4.8 | 4.8 | 4.6b |
| | Submother | 4.4 | 3.8 | 5.7 | 5.8 | 5.8 | 5.8 | 4.1 | 3.4 | 3.9 | 4.7b |
| Unica | TC | 3.8 | 4.2 | 4.1 | 4.8 | 5.4 | 4.8 | 4.1 | 5.4 | 5.0 | 4.6b |
| | Submother | 4.2 | 4.3 | 5.0 | 5.4 | 4.3 | 5.3 | 5.6 | 5.2 | 4.6 | 4.9b |
| Taurus | TC | 2.1 | 2.6 | 2.4 | 2.3 | - | - | - | - | - | 2.4a |
| | Submother | 2.5 | 2.0 | 2.3 | 2.0 | - | - | - | - | - | 2.2a |

| F statistics | |
|---|---|
| Factor | Av. no. of internodes per plant |
| Variety | 0.011 |
| Stock mother | 0.878 |
| Round or age of cutting | 0.049 |

Letters indicate comparisons for means among the mother stocks of different cultivars at $p \leq 0.05$ by Tukey's HSD test.

Submothers notably had internodes which were greater in number and longer in length.

***Table 3: Total number of internodes from the same stock mother in different cultivars over time.***

| Variety | Mother source | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th | 9th | Av. internode length per shoot (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Length of internodes (mm) | | | | | | | | | |
| Shangi | TC | 13.9 | 10.3 | 11.1 | 10.3 | 10.3 | 10.3 | 11.6 | 9.6 | 10.4 | 10.9a |
| | Submother | 12.3 | 11.2 | 10.3 | 13.6 | 10.3 | 10.3 | 10.3 | 12.5 | 16.3 | 11.9a |
| Wanjiku | TC | 11.2 | 11.1 | 10.3 | 10.4 | 9.9 | 12.5 | 12.8 | 10.3 | 11.5 | 11.1a |
| | Submother | 9.6 | 14.1 | 13.8 | 9.5 | 10.5 | 11.8 | 15.4 | 12.4 | 16.8 | 12.7a |
| Unica | TC | 10.3 | 10.3 | 10.7 | 10.7 | 10.2 | 10.3 | 10.3 | 9.5 | 11.1 | 10.4a |
| | Submother | 10.3 | 10.2 | 12.8 | 10.2 | 11.2 | 10.6 | 11.7 | 10.8 | 9.9 | 10.8a |
| Taurus | TC | 21.5 | 16.3 | 14.9 | 21.6 | - | - | - | - | - | 18.8b |
| | Submother | 17.9 | 19.5 | 17.0 | 23.6 | - | - | - | - | - | 19.5b |

| F statistics | |
|---|---|
| Factor | Av. Internode length per plant |
| Variety | 0.051 |
| Stock mother | 0.058 |
| Round or age of cutting | 0.055 |

Letters indicate comparisons for means among the mother stocks of different cultivars at $p \leq 0.05$ by Tukey's HSD test.

No significant cultivar effect on internode length and number was found. However, Taurus exhibited significantly fewer internodes which were significantly longer. Similarly, no significant cultivar and stock mother source effect was found on the average height of stock mother plants (Table 4).

***Table 4: Average stock mother height at different rounds of cut in different cultivars.***

| Variety | Mother source | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th | 9th | Av. Height per plant (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Plant height (cm) from the same stock mother | | | | | | | | | |
| Shangi | TC | 7.3 | 5.2 | 6.7 | 5.7 | 5.7 | 6.1 | 7.1 | 5.4 | 5.6 | 6.1 |
| | Submother | 5.9 | 6.4 | 6.9 | 9.2 | 7.3 | 6.5 | 5.7 | 6.9 | 9.4 | 7.1 |
| Wanjiku | TC | 6.6 | 6.0 | 7.2 | 5.6 | 6.6 | 8.2 | 7.9 | 6.4 | 7.7 | 6.9 |
| | Submother | 5.4 | 8.9 | 9.4 | 6.6 | 7.7 | 8.3 | 8.2 | 6.6 | 8.0 | 7.7 |
| Unica | TC | 5.3 | 5.7 | 6.0 | 6.8 | 7.0 | 6.4 | 5.7 | 6.2 | 7.4 | 6.3 |
| | Submother | 5.7 | 5.8 | 7.9 | 7.0 | 6.7 | 7.2 | 8.1 | 7.4 | 5.8 | 6.8 |
| Taurus | TC | 5.9 | 6.2 | 4.6 | 6.0 | - | - | - | - | - | 5.7 |
| | Submother | 7.3 | 6.9 | 5.9 | 6.4 | - | - | - | - | - | 6.6 |

| F statistics | |
|---|---|
| Factor | Av. height per plant |
| Variety | 0.121 |
| Stock mother | 0.061 |
| Round or age of cutting | 0.093 |

Letters indicate comparisons for means among the mother stocks of different cultivars at $p \leq 0.05$ by Tukey's HSD test.

Generally, the shorter the length of the internodes per stem, the greater the number of internodes observed. This synergy led to greater number of cuttings recorded per stock mother plant (Table 5).

***Table 5: Relationships exhibited by number of cuttings derived from the same mother stock, internode number, internode length and height of the mother stock.***

| Factor | No. of cuttings per plant | Internode number per plant | Internode length per plant (mm) |
|---|---|---|---|
| Internode number per plant | $0.98^{***}$ | - | |
| Internode length per plant (mm) | $-0.92^{***}$ | $-0.96^{***}$ | - |
| Stock mother plant height (cm) | $-0.63^{**}$ | $-0.68^{*}$ | $0.70^{**}$ |

*, **, *** Correlation significant at p<0.001, <0.01 and <0.05, respectively.

### 2.2.3. Effect of physiological age and cultivar on vigor of stock mother

Vigor of stock mother plants was evaluated every time the cut was made using a 1 to 4 scale where 1 = small seedlings, all leaves compound, plant yellowing and stunted, 2 = moderate growth, a few leaves compound, plant stunted, 3 =good growth, foliage is green, most leaves simple, 4 = plant vigorous, foliage very green, and all leaves simple. For TC mother stocks of cultivars Shangi and Wanjiku, vigor scores remained very high (score 4) throughout the production cycle (Table 6).

***Table 6: Vigor scores of stock mother plants of different varieties at different rounds of cut.***

| Variety | Mother source | Rounds of cuttings derived from the same mother source | | | | | | | | | Av. vigor |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th | 9th | |
| | | Vigor scores | | | | | | | | | |
| Shangi | TC | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| | Submother | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 4 |
| Wanjiku | TC | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| | Submother | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 4 |
| Unica | TC | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 |
| | Submother | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 4 |
| Taurus | TC | 4 | 3 | 3 | 2 | - | - | - | - | - | 3 |
| | Submother | 4 | 3 | 2 | 2 | - | - | - | - | - | 3 |

For the submothers, very high vigor score of 4 was maintained till the 7th round but declined to score 3 in the subsequent rounds. Taurus was characterized by low vigor scores from the 2nd round of cut, declining to score 2 at the 4th round. Thus, the clear decrease of vigor across the cultivars, especially towards termination of the experiment pointed to the gradual exhaustion of the stock mother plants.


*Photo 5: Comparison of stock mother vigor of Shangi Tc (a) and submother (b), Wanjiku submother (c) and Tc (d) and Unica submother (e) and Tc (f) at round 7 of cut.*

### 2.2.4. Survival rate of cuttings in the screenhouse hardening units

While only two cuttings per replicate of TC or submother stocks were grown in the field, all the cuttings derived at different rounds were hardened off. The survival rates of the cuttings during hardening of was high (>90%) for Unica, Wanjiku and Shangi, irrespective of the round of cut

(Table 7) but was consistently low for Taurus (<70%). Taurus exhibited cuttings with few nodes, but longer thin internodes that lost out water so fast and shrank at the collar.

***Table 7: Survival rates of cuttings at the screenhouse hardening units.***

| Variety | Mother source | Rounds of cuttings derived from the same mother source | | | | | | | | | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th | 9th | |
| | | Survival rate (%) | | | | | | | | | |
| Shangi | TC | 100 | 100 | 100 | 97 | 100 | 100 | 100 | 100 | 95 | 99b |
| | Submother | 97 | 100 | 100 | 100 | 98 | 100 | 100 | 100 | 98 | 99b |
| Wanjiku | TC | 100 | 97 | 85 | 100 | 100 | 98 | 100 | 100 | 100 | 98b |
| | Submother | 100 | 100 | 90 | 90 | 100 | 100 | 100 | 97 | 100 | 97b |
| Unica | TC | 100 | 100 | 95 | 100 | 100 | 99 | 100 | 100 | 100 | 99b |
| | Submother | 100 | 100 | 100 | 97 | 100 | 99 | 100 | 95 | 100 | 99b |
| Taurus | TC | 75 | 65 | 64 | 64 | - | - | - | - | - | 67a |
| | Submother | 73 | 69 | 71 | 63 | - | - | - | - | - | 69a |

Letters indicate comparisons for means among the mother stocks of different cultivars at $p \leq 0.05$ by Tukey's HSD test.

## 2.3. FIELD EXPERIMENT

### 2.3.1. Survival rates of cuttings derived from same mother at different rounds

Except for Taurus that exhibited significantly lower survival rates in the field, the survival rate remained high for the rest of cultivars irrespective of the round of cut (Table 8).

***Table 8: Comparison of survival rates of field grown cuttings derived from the same mother plant.***

| Variety | Mother source | Rounds of cuttings derived from the same mother source | | | | | | | | | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th | 9th | |
| | | Survival rate (%) | | | | | | | | | |
| Shangi | TC | 100 | 100 | 100 | 97 | 100 | 94 | 100 | 100 | 90 | 98b |
| | Submother | 100 | 90 | 100 | 100 | 90 | 89 | 100 | 100 | 95 | 96b |
| Wanjiku | TC | 95 | 95 | 85 | 100 | 100 | 90 | 90 | 95 | 100 | 94b |
| | Submother | 100 | 60 | 90 | 90 | 100 | 100 | 95 | 95 | 100 | 92b |
| Unica | TC | 90 | 95 | 95 | 100 | 92 | 91 | 100 | 100 | 90 | 95b |
| | Submother | 85 | 60 | 95 | 85 | 100 | 99 | 89 | 100 | 95 | 90b |
| Taurus | TC | 85 | 45 | 64 | 69 | - | - | - | - | - | 66a |
| | Submother | 55 | 60 | 71 | 66 | - | - | - | - | - | 63a |

Letters indicate comparisons for means among the mother stocks of different cultivars at $p \leq 0.05$ by Tukey's HSD test.

We attribute the high survival rates to the proper care and intensive management during the nursery and field establishment period. For Taurus, the low survival rate was explained by the indisposed cuttings, often characterized with poorly developed roots and thin collars that easily shrank and broke off before full establishment.

### 2.3.2. Days to tuber initiation of cuttings derived from same mother at different rounds

The time to tuber initiation was calculated as the mean number of days when 3 randomly sampled plants per plot formed tubers (a tuber was defined as a protruded swelling attached to the stolon). No significant effect of shoot age on days to tuber initiation was found (Table 9). However, cultivar effect was found as Unica initiated tubers 2-4 days earlier than Wanjiku and Shangi, respectively, and 6 days earlier than Taurus.

***Table 9: Days to tuber initiation of field-grown cuttings obtained from a single mother plant of different varieties over time.***

| Variety | Mother source | Rounds of cuttings derived from the same mother source | | | | | | | | | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th | 9th | |
| | | Days to tuber initiation | | | | | | | | | |
| Shangi | TC | 23±2.3 | 23±2.8 | 22±2.2 | 23±2.2 | 23±2.4 | 21±2.9 | 21±1.8 | 21±1.8 | 21±1.9 | 22ab |
| | Submother | 22±2.8 | 22±2.1 | 22±2.9 | 23±1.9 | 23±2.1 | 21±2.1 | 21±1.6 | 20±1.9 | 20±2.1 | 22ab |
| Wanjiku | TC | 20±1.9 | 21±3.0 | 20±2.1 | 20±2.8 | 20±2.8 | 20±2.1 | 20±2.5 | 19±2.4 | 18±1.7 | 20ab |
| | Submother | 20±2.9 | 21±1.9 | 20±1.4 | 20±2.6 | 19±2.4 | 19±2.9 | 20±2.1 | 19±2.3 | 17±2.2 | 20ab |
| Unica | TC | 19±2.1 | 19±2.8 | 19±2.8 | 18±2.7 | 17±2.1 | 18±1.8 | 16±2.4 | 17±2.1 | 16±2.6 | 18a |
| | Submother | 17±1.8 | 17±2.6 | 19±2.7 | 19±1.9 | 19±1.8 | 19±1.9 | 16±2.0 | 16±2.7 | 16±2.2 | 18a |
| Taurus | TC | 24±1.7 | 23±2.8 | 23±3.1 | 23±2.0 | - | - | - | - | - | 24b |
| | Submother | 24±2.7 | 23±2.6 | 23±2.7 | 23±2.9 | - | - | - | - | - | 24b |

| F statistics | |
|---|---|
| Factor | Av. Days to tuber initiation |
| Variety | <0.001 |
| Stock mother | 0.292 |
| Round or age of cutting | 0.093 |

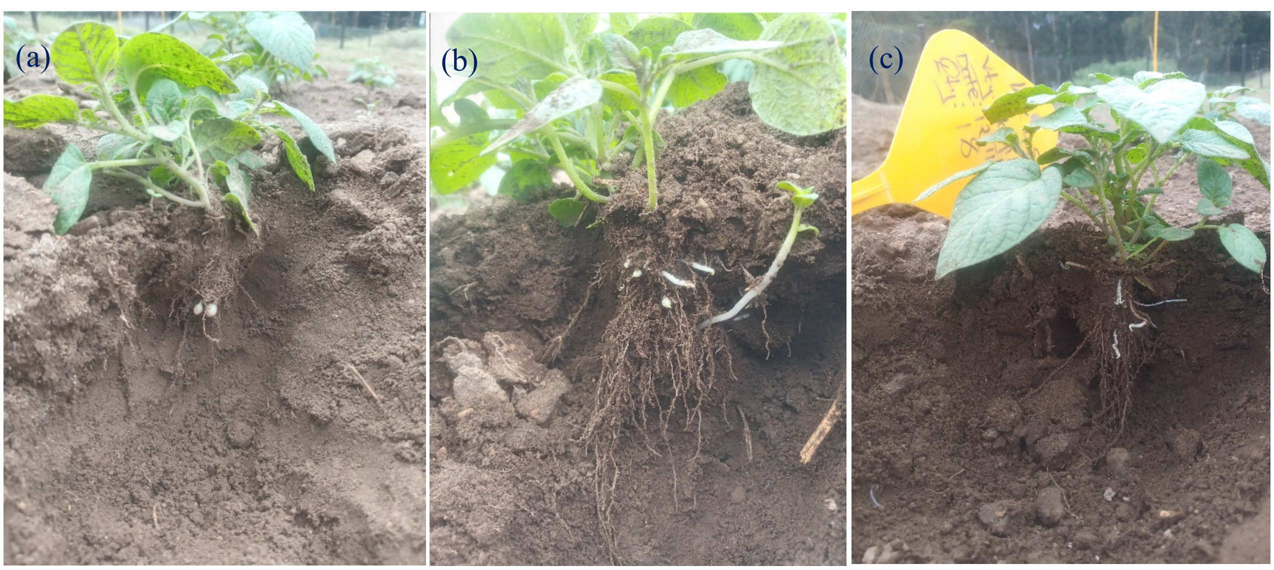


*Photo 6: Tubers initiated on stolons of cultivars Unica (a), Wanjiku (b) and absence of tubers for cultivar Shangi at 18 days after field planting. The cuttings were derived from submother stocks at round 7 of cut.*

### 2.3.3. Time to maturity of cuttings derived from same mother at different rounds

Time to maturity was considered as the mean number of days when at least 75% of the tubers attained seed size; a chicken egg-size. Therefore, it was based on seed size rather than on physiological maturation. Time to maturity was statistically unaffected by shoot age but was observably shorter for the cuttings derived from the 8$^{th}$ and 9$^{th}$ rounds for cultivars Shangi, Unica and Wanjiku (Table 10).

*Table 10: Days to maturity of field-grown cuttings obtained from a single mother plant of different varieties over time.*

| Variety | Mother source | Rounds of cuttings derived from the same mother source | | | | | | | | | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1$^{st}$ | 2$^{nd}$ | 3$^{rd}$ | 4$^{th}$ | 5$^{th}$ | 6$^{th}$ | 7$^{th}$ | 8$^{th}$ | 9$^{th}$ | |
| | | Days to maturity | | | | | | | | | |
| Shangi | TC | 78±4 | 79±3 | 77±4 | 77±2 | 76±2 | 77±3 | 75±3 | 74±3 | 75±2 | 76b |
| | Submother | 77±5 | 77±4 | 77±2 | 75±3 | 78±3 | 75±4 | 75±2 | 73±2 | 74±3 | 76b |
| Wanjiku | TC | 79±4 | 80±3 | 78±4 | 77±3 | 78±3 | 78±2 | 76±3 | 76±3 | 76±3 | 78b |
| | Submother | 75±4 | 78±4 | 77±3 | 76±2 | 77±5 | 77±3 | 73±3 | 76±4 | 74±4 | 77b |
| Unica | TC | 63±5 | 60±3 | 56±4 | 60±3 | 57±2 | 54±2 | 56±2 | 55±2 | 56±2 | 58a |
| | Submother | 63±6 | 57±4 | 54±2 | 58±4 | 53±3 | 54±2 | 54±3 | 54±3 | 55±3 | 57a |
| Taurus | TC | 74±3 | 75±5 | 73±3 | 70±4 | - | - | - | - | - | 73b |
| | Submother | 73±4 | 74±4 | 70±3 | 69±3 | - | - | - | - | - | 72b |

F statistics

| Factor | Av. Days to maturity |
|---|---|
| Variety | 0.021 |
| Stock mother | 0.984 |
| Round or age of cutting | 0.097 |

Letters indicate comparisons for means among the mother stocks of different cultivars at $p \leq 0.05$ by Tukey's HSD test.

Cuttings derived from submothers attained maturity 2 to 3 days earlier compared with those derived from TC mother stocks, irrespective of the round of cut. Unica showed significantly shorter days to maturity compared with other cultivars.

*Photo 7: Tuber sizes at 5 weeks (35 days) after planting round 2 cutting: note the larger tuber sizes with Unica, which is a result of early tuber initiation, and indication of early maturity.*

Taurus and Wanjiku green haulms persisted until very late, indicating their relative lateness.

Generally, individual cultivars did not relate to the length of documented maturity implying that neither did the early cultivars exhibit a rapid rate of physiological ageing nor did the late cultivars exert a slow rate of ageing.

### 2.3.4. Yields of cuttings derived from same mother at different rounds

The number and weights of tubers per plant produced from the rounds of cutting planted in the field were compared. Significant cultivar effect on the number of tubers harvested from cuttings of different rounds was found (Table 11).

***Table 11: Average number of tubers per plant ± SEM from rounds of cuttings derived from the same mother source over time.***

| Variety | Source | Rounds of cuttings derived from the same mother source | | | | | | | | | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1$^{st}$ | 2$^{nd}$ | 3$^{rd}$ | 4$^{th}$ | 5$^{th}$ | 6$^{th}$ | 7$^{th}$ | 8$^{th}$ | 9$^{th}$ | |
| | | Tuber numbers per plant | | | | | | | | | |
| Shangi | TC | 23±4$^{bc}$ | 21±2$^{bc}$ | 25±2$^{c}$ | 23±2$^{b}$ | 26±2$^{c}$ | 25±2$^{c}$ | 16±3$^{ab}$ | 12±2$^{a}$ | 10±2$^{a}$ | 20$^{B}$ |
| | Submother | 23±3$^{bc}$ | 20±2$^{bc}$ | 24±2$^{bc}$ | 26±3$^{c}$ | 21±2$^{bc}$ | 22±2$^{bc}$ | 16±2$^{ab}$ | 11±3$^{a}$ | 8±2a | 19$^{B}$ |
| Wanjiku | TC | 27±4$^{c}$ | 26±3$^{bc}$ | 29±4$^{c}$ | 26±3$^{bc}$ | 29±4$^{c}$ | 26±4$^{bc}$ | 16±3$^{a}$ | 18±2$^{ab}$ | 19±3$^{ab}$ | 24$^{B}$ |
| | Submother | 28±3$^{c}$ | 25±4$^{bc}$ | 30±4$^{c}$ | 27±3$^{bc}$ | 27±5$^{bc}$ | 27±3$^{bc}$ | 18±3$^{a}$ | 20±4$^{ab}$ | 16±2$^{a}$ | 24$^{B}$ |
| Unica | TC | 15±1$^{a}$ | 15±2$^{a}$ | 10±2$^{a}$ | 9±2$^{a}$ | 11±2$^{a}$ | 8±1$^{a}$ | 12±2$^{a}$ | 11±2$^{a}$ | 11±2$^{a}$ | 11$^{A}$ |
| | Submother | 14±2$^{a}$ | 15±2$^{a}$ | 9±3$^{a}$ | 9±2$^{a}$ | 10±1$^{a}$ | 9±2$^{a}$ | 10±2$^{a}$ | 10±2$^{a}$ | 11±1$^{a}$ | 11$^{A}$ |
| Taurus | TC | 10±2$^{a}$ | 11±2$^{a}$ | 9±2$^{a}$ | 8±1$^{a}$ | - | - | - | - | - | 10$^{A}$ |
| | Submother | 8±1$^{a}$ | 11±3$^{a}$ | 10±1$^{a}$ | 6±1$^{a}$ | - | - | - | - | - | 9$^{A}$ |

F statistics

| Factor | Av. tuber numbers per plant |
|---|---|
| Variety | <0.001 |
| Stock mother | 0.094 |
| Round or age of cutting | 0.056 |

Lowercase letters indicate mean comparisons for the same mother stock at different rounds of cut while the uppercase letters compare the average tuber numbers among the cultivars of different source mother plants at $p \leq 0.05$ by Tukey's HSD test.

*Photo 8: Comparison of tuber numbers of different cultivars for round 2 (top) and round 8th (bottom) harvests of cuttings derived from the same mother source.*

Wanjiku and Shangi had the most tubers per plant, followed by Unica and Taurus. Cultivars differed considerably in the age beyond which total number of tubers per plant significantly decreased. For cultivars Shangi, rounds 1 to 6 of cuttings yielded significantly more tuber numbers per plant with significant decreases from the 8$^{th}$ round. No significant age effect was found for cultivars Unica and Wanjiku. Source of mother stock did not exert any significant effect on the average number of tubers recorded per plant.

***Table 12: Mean tuber weight per plant from rounds of cuttings derived from the same mother source over time.***

| Variety | Source | Rounds of cuttings derived from the same mother source | | | | | | | | | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th | 9th | |
| | | Tuber weight per plant (g) | | | | | | | | | |
| Shangi | TC | 651b | 643b | 717b | 650b | 740ab | 725b | 565b | 421ab | 209a | $591^{B}$ |
| | Submother | 596b | 535b | 685b | 729b | 585b | 607b | 608b | 464ab | 242a | $561^{B}$ |
| Wanjiku | TC | 797ab | 752ab | 851b | 743ab | 833b | 731ab | 665ab | 699ab | 531a | $734^{C}$ |
| | Submother | 838b | 731ab | 840b | 740ab | 729ab | 733ab | 587ab | 709ab | 473a | $700^{C}$ |
| Unica | TC | 1122b | 1119b | 797a | 737a | 865ab | 634a | 853a | 774a | 602a | $834^{C}$ |
| | Submother | 1049b | 1035b | 723a | 659a | 797ab | 645a | 676a | 603a | 542a | $748^{C}$ |
| Taurus | TC | 405a | 426a | 435a | 350a | - | - | - | - | - | $404^{A}$ |
| | Submother | 357a | 443a | 418a | 293a | - | - | - | - | - | $378^{A}$ |

| F statistics | |
|---|---|
| Factor | Av. Tuber weight per plant |
| Variety | <0.001 |
| Stock mother | 0.089 |
| Round or age of cutting | 0.893 |

Lowercase letters indicate mean comparisons for the same mother stock at different rounds of cut while the uppercase letters compare the average tuber numbers among the cultivars of different source mother plants at $p \leq 0.05$ by Tukey's HSD test.

Significant cultivar effect was found on the mean tuber weight per plant harvested from cuttings of different rounds (Table 12). Notably, Unica (which had the fewest tubers per plant) yielded significantly greatest mean tuber weight, indicating greater tuber weight per tuber. We attribute this to Unica's inherent high bulking rate. This coupled with the sufficient space occupied by the fewer tubers, allowed better resource use for tuber filling and bulking. Cultivars Shangi and Wanjiku exhibited significant decrease in mean tuber weight per plant from the $7^{th}$ round of cutting, pointing to the gradual loss of potential vigor caused by ageing of the stock mother. No significant age effect was found on the mean tuber weight per plant for cultivars Unica and Taurus. Similarly, mother stock had no significant effect on the mean tuber weight per plant.

## 2.4. CONCLUDING REMARKS

These results suggest that the effects of mother plant age on cutting production and subsequent tuber yield is largely cultivar dependent. In most cases, a good number of Taurus stock mothers did not survive the repeated cuts. One explanation for this is competition among the stock plants left with no leaves to carry out photosynthesis. Continuous cutting back of stock plants when the conditions were above optimal is also a possible reason for the inability of Taurus stock to regenerate. This thus restricts the use of Taurus for apical cutting production. The early tuber initiation by Unica is noteworthy in view of its early maturity, and this underlines its intrinsic tendency to tuberize at an early stage of growth.

Cutting production reached its peak 3 to 4 months after initiating the experiment. January and February months resulted in substantially lower cutting production. For Taurus, peak production occurred in the second month followed by a rapid decline. This is useful to producers in similar environments who should aim to synchronize peak production with demand and avoid wastages during off seasons.

As this study was conducted in a typical midland where planting material is expensive, often not available and the few that may be available are infected with diseases such as bacterial wilt and Erwinia, and pests such as potato cyst nematodes, the use of rooted apical cuttings presents an opportunity in these environments.