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Effects of different light exposure regimes on pre-sprouting and yield performance on potato (*Solanum tuberosum* L.) seed in Central Rift, Kenya

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The major problems affecting potato (*Solanum tuberosum* L.) production in Kenya include timely availability of well-sprouted seed potato tubers. Appropriate techniques of availing well-sprouted potato seed for timely planting for different potato varieties with varied seed dormancy periods is one of the major challenges for yield increase. A study was conducted to determine the effects of different light exposure regimes on pre-sprouting, seed germination and yield performance of potato in Central Rift, Kenya. Three light exposure regimes of 8, 12, and 16 h were evaluated in lighthouse for their effects on breaking dormancy and enhancing pre-sprouting in three potato varieties. The lighthouse experiment was laid on complete randomized design (CRD) with three replicates while field experiment was laid on randomized complete block design (RCBD). Data collected on the number of sprouts, sprout lengths, diameters and colour; emergence rate, plant height, number of tubers per plant, and tuber weight were subjected to analysis of variance (ANOVA) and means were compared using Duncan multiple range test (*P<0.05*). There were significant differences (*P*<0.05) in different light exposures on traits. Light exposure regimes significantly increased sprout thickness by 31 to 43% and sprout length by 15 to 39% when compared with those of control treatment. Light exposure of 16 h resulted in the highest percent seed germination and tuber weight by 9.5 and 25%, respectively. This suggests that increasing period of light exposure by using simple fluorescence system in pre-sprouting stores will enhance breaking of potato seed dormancy resulting in increased yields.

Key words: Potato yield, light, exposure, sprout quality, pre-sprouting dormancy.

INTRODUCTION

In Kenya, potato is grown throughout the year in about 217315 ha of land mainly in highland areas of Rift valley and Western (FAOSTAT, 2018). It is a major cash crop to many small-scale farmers (Muthoni et al., 2013). The major problems affecting potato production in Kenya include timely availability of well-sprouted seed potato tubers (Riungu, 2011). As a physiological requirement, to convert fresh tubers to seed, potato tubers must undergo between two to three months of dormancy after harvesting which is a big obstacle to achieving high-quality disease-free seeds for timely planting (Muchiri et al., 2015). This long period of dormancy should be broken to achieve timely availability of well-sprouted seed potato tubers at the onset of rains. Furthermore, in many

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areas, potato is grown during short rain season after harvesting of the long rain season crops like maize and wheat. This implies that, it is very important to use potato seed tubers with a high growth ability and a short growth cycle, which is currently a major limitation to potato farmers. Limited availability, low quality and low diseased potato seeds can be improved by using a variety of seed technologies that will thrive under smallholder cultivation conditions and also improve the good-quality seed supplies in the local seed industry.

To have an early seed planting material, the idea of exposing seeds to light can be implemented to increase growth ability with good tuber sprouting. Exposing seed tubers to light before the estimated planting date would help in preventing sprout elongation resulting in strong sprouts, fast emergence, early tuber initiation, increased sprouts maximal vigour and relatively mature yields (van der Zaag and van Loon, 1987). The exposure duration is one of the determining effect of light on dormancy (Ballaré and Casal, 2000). Light promotes the multiple sprouting stage and keep sprouts short and strong (Mani, 2015). Pre-sprouting seed potato tubers in light is one way to speed up plant development (Struik and Wiersema, 1999). Light further enhances advanced plant growth and higher early yields (Eremeev et al., 2008). Light exposure methods of pre-sprouting has been found to produce healthier crops and considered very important in regions with cool and short growing seasons (Johansen and Molteberg, 2012). Since the dormancy period differs with the cultivars, it would therefore be of great importance to consider factors such as time and age of the cultivar to enable the farmer to have a wider choice for selection of varieties during pre-sprouting time. Under longer season conditions, temperatures and light during the later stages of seed potato storage may be useful in manipulating tuber size distribution and yields of the desired size grades (Haverkort et al., 1990). These are very important aspects to have high growth vigour, which can be defined as fast emergence and establishment of a green plant. This can be beneficial regarding resistance against diseases and weeds and thereby improve both yield and quality. Well sprouted quality seed has a significant potential of increasing farm productivity due to enhanced vigour. Thus, planting a high-quality seed with vigorous sprouts can bring chances of early harvest, early marketing of the produce and more profitable production, contributing to 30% of the total production (Halmer, 2003; Ellis, 1992). However, in the major growing areas of Kenya, the use of poor-quality non pre-sprouted potato seeds is high and this has been found to accelerate the spread of seed-borne diseases such as bacterial wilt, which has shown to affect 77% of potato farms in the country (Muthoni et al., 2013; Kaguongo et al., 2010).

Furthermore, close to 800 000 farmers were heavily engaged in potato production and due to limited use of high-quality seeds, the potato yields were low, with an average yield of approximately 10 tonnes per hectare (AGRA, 2019). This makes it important that pre-sprouted seed tubers be provided at the right time to farmers during planting which occurs throughout the year. In each year, 1.5 million tonnes of potato are produced, generating livelihood for millions of Kenyans (Kimani, 2016). Potato in Kenya is among those crops contributing to food security and poverty alleviation and it has been found to have the highest yielding capacity in arable land and produces more yields per hectare than any other crops (Chandrasekara and Josheph, 2016). Therefore, cost effective ways of increasing availability of potato seeds by manipulating their responses to physiological ageing to enhance growth, yield and maturity for increased growing seasons should be deployed in a more cost-effective way. Terminating dormancy in freshly harvested potatoes in this scenario is of great importance since it would enable seeds to sprout adequately, which will enhance early planting and increase the productivity of potatoes (Mustefa et al., 2017). This study determined the effect of light exposure regimes on pre-sprouting and seed potato performance in the lighthouse and field conditions.

MATERIALS AND METHODS

Site description

The study was conducted at the Kenya Agricultural and Livestock Research Organization (KALRO), Molo and Egerton University Agro-science Park Research station. Egerton University lies on longitude 35° 35ˈE, latitude of 0° 23ˈS and an altitude of 2238 m above sea level. The site has a mean annual rainfall of 1200 mm and the average temperatures range between 10.2 and 22 ^{o}C (Jaetzold et al., 2007). Kenya Agricultural and Livestock Research Organization Molo lies on latitude of 0.2472°S, longitude of 35.7373° ˈE and altitude 2480 m above sea level. This site experiences a mean annual rainfall of 1100 to 1500 mm and average temperature of 15 to 25°C (Jaetzold et al., 2007). Molo represented high altitude areas while Egerton represented medium altitude zones for potato growing in Kenya.

Germplasm evaluated

Three commercial potato varieties in Kenya, Shangi, Dutch Robijn and Kenya Karibu were used for pre-sprouting, tuberization and yield evaluation (Table 1). Shangi, a newly released variety has short pre-sprouting period and short maturation period. Dutch Robijn, the oldest variety has long maturation of 3.5 to 4.5 months and takes longer period to pre-sprout. Kenya Karibu has moderate pre-sprouting period and long maturity periods of 3.5 months (NPCK, 2019). Shangi and Dutch Robijn are susceptible to late blight while Kenya Karibu is tolerant (Sinelle, 2018).

Experimental procedure

Pre-sprouting of potato seed using varying light regimes in a lighthouse

The experiment was conducted in the lighthouse for 4 to 6 weeks.

Table 1. Kenyan commercial potato varieties evaluated and some of their attributes.

Variety	Year released	Year evaluated	Place evaluated	Maturity time (months)	Potential Yield (ha^{-1})	Dormancy duration under normal conditions (weeks)
Shangi	2015	2017	Nandi, Kenya	≤3	30-40	4-6
Kenya Karibu	2003	2017	Kitale, Kenya	3-4	35-45	4-6
Dutch Robijn	1960	2017	Kitale, Kenya	4-5	35-40	4-6

Source: Crop production Summary (2013) https://www.nass.usda.gov/crop0510.pdf

The seed tubers of each variety were evaluated in cartons having uniform perforations on their tops to allow light penetration under normal temperatures (21-23°C).

Treatments consisted of four daily light exposures of 8, 12 and 16 h and the control, where tubers were subjected to normal room light conditions. The experiment was laid on a Complete Randomized Design (CRD) with 3 replicates. Light exposures were monitored at different times: at 7 am, the two light exposures (12 and 8 h) were switched on and that of 8 h was switched off at 3 pm. The 16 h light was switched on at 3 pm and switched off at 7 am of the following day. The light fluorescent tubes 4ft tubes were used for pre-sprouting potatoes, which have been reported to provide brighter and more reliable light with a stronger chit with light illumination ranging between 500 and 800 Lux. Subsequent sprout and quality seed tuber were determined and evaluated in the field. Data collected in the lighthouse and control conditions included number of sprouts by physical counting, every week. Electronic vernier calliper (stainless hardened MARS battery 1.55 V) was used to measure the length and thickness (mm) of the main sprouts from the 'eyes'. The colour of sprout was determined using visual assessment. Light received by each variety under light exposures of 8, 12 and 16 h was taken once at the beginning of the experiment using a light meter (Digital Lux Meter As823).

Evaluation of pre-sprouted potato seed under field conditions

The pre-spouted seeds were planted at KALRO Molo and Egerton Agro Science Park field station to determine time to emergence, growth and yield. Experimental plots measured 3 m × 1.5 m in a RCBD design. Plots consisted of four rows, spaced at 0.75 m apart and 0.30 m between plants within the rows. A standard fertilizer (NPK 17-17-17) was applied at a rate of 300 kg ha^{-1} to the furrows and incorporated into the soil prior to planting (aimed at giving 51 kg ha^{-1} of N, P_2O_5 and K_2O), respectively to give adequate balanced supply of nutrients to sustain plants' needs and growth.

All agronomic practices were maintained according to procedures described by CIP, 2009. Early blight and late blight were controlled by Ridomil® gold MZ 68 WG (*Metalaxyl*-M 40 gkg^{-1} + *Mnacozeb* 640 gkg^{-1}) at the rate of 50 g/20 L of water. Data recorded included tuber emergence after 7, 14, 21, and 28 days after planting; number of stems per plant was counted at 7, 14, 21, 28 and 35 days after emergency (DAE); plant height (cm) measured from the highest upper leaf base up to the tuber after complete emergence to flowering stage; number of tubers per plant, counted after pulling out tubers (at harvesting time). Grading of tubers were done after harvesting and ranked in three classes; big size: >60 mm diameter; middle size: 30-60 mm diameter; and small size: <30 mm diameter. Different grades were weighed separately and values recorded and converted to t ha^{-1}. The total tuber yields (kg) was determined as mean weight of tubers per plot then converted to tonnes per hectare (t ha^{-1}).

Data analysis

Analysis of variance (ANOVA) was performed using SAS version 9.1.3 software (SAS Institute NC, 2004). Treatment means were compared using Duncan multiple range test ($P<0.05$). Pearson correlation analysis at 5% level of significance was done to determine the statistical relationship between tuber yields, number of sprouts, length and thickness of sprouts, stand count, plant height, number of stems and grade of tubers.

RESULTS

Effects of different light exposures on potato seeds under light-house

There were significant differences ($P<0.05$) among varieties and treatments. The significant effect of treatments was observed in week 1 of pre-sprouting and on the sprout quality (Table 2). The interaction between varieties and treatments showed that varieties' responses varied with treatments.

Light exposure regimes had significant differences ($P<0.05$) on sprout quality measured on sprout thickness and length (Table 3), which varied amongst the varieties. The 8 and 12 h light exposures treated tubers recorded thicker and longest sprouts of 4.76 and 5.09 mm; 8.64 and 7.73 mm compared to 16 h of light exposure and control treated tubers which had 4.66 and 3.56 and 7.16 and 6.21 mm, respectively. Light exposures also significantly increased the sprout thickness by 31 to 43% and sprout length by 15 to 39% compared to control treatment (room conditions). There was, however, a significant difference exhibited by light hours on number of sprouts. Overall, 12 and 16 h had the highest number of sprouts (2.67 and 2.56) than 8 h and control (2.33 and 2.44). The 12 h of light exposure seemed to have significantly influenced the number of sprouts from week 1 of pre-sprouting to week 4 (1-3 sprouts).

The varietal significant differences ($P<0.05$) were observed on the length and thickness of the sprouts (Table 3). Shangi had thickest and longest sprouts (6.19 and 11.92 mm, respectively) followed by Kenya Karibu (4.61 and 6.12 mm) and Dutch Robijn (2.77 and 4.27 mm), respectively. The varieties further showed significant difference ($P<0.05$) on the number of sprouts. Shangi,

Table 2. Mean squares for number of sprouts and sprout quality under light house at Egerton in 2020.

Sources of variance	df	No. of sprouts				Sprout quality	
		Week 1	Week 2	Week 3	Week 4	Thickness	Length
Rep	2	0.000	0.278	0.111	0.583	0.129	0.170
Treatment (T)	3	1.000***	0.0741	0.9167*	0.185	3.979***	9.343***
Variety (V)	2	2.250***	1.778***	5.861***	12.250***	35.153***	192.132***
V ×T	6	0.250***	0.0741	0.417	0.991**	0.440**	1.245
Error	22	0.000	0.088	0.202	0.220	0.086	0.551
Mean		0.050	1.222	1.694	2.500	4.522	7.436
R^2		1.000	0.688	0.795	0.869	0.978	0.972
CV (%)		0.000	24.324	26.526	18.749	6.489	9.983

*, **, ***Significant at (*P<0.05*), (P<0.01), (P<0.001) respectively. CV: Coefficient of Variation, R^2: Coefficient of determination.

Table 3. Means for number of sprouts and sprout quality of light exposures under light house March-April 2020.

Variety	No. of sprouts				Sprout quality	
	Week1	Week2	Week3	Week4	Thickness	Length
Shangi	1.000^a	1.667^a	2.500^a	3.583^a	6.190^a	11.929^a
Kenya Karibu	0.250^b	1.000^b	1.250^b	1.583^c	4.606^b	6.123^b
Dutch Robijin	0.250^a	1.000^b	1.333^b	2.333^b	2.770^c	4.257^c
Treatment						
16 h	0.333^b	1.333^a	2.111^a	2.556^a	4.656^b	7.158^b
12 h	1.000^a	1.222^a	1.667^{ab}	2.667^a	5.091^a	7.731^b
8 h	0.333^b	1.222^a	1.333^b	2.333^a	4.778^b	8.642^a
Control	0.333^b	1.111^a	1.667^{ab}	2.444^a	3.563^c	6.213^c

Means followed by the same letter in the same column are not significantly different (*P<0.05*).

sprouted within the first week of pre-sprouting and it had the highest number of sprouts in the 4th week.

Similarly, Kenya Karibu and Dutch Robijn, developed visible sprouts in the second week of pre-sprouting and had equal number of sprouts averaging 2.5 in the last week of pre-sprouting. Dutch Robijn had light green sprouts while Shangi and Kenya Karibu had purple sprouts.

Growth and yield performance of pre-sprouted potato seeds under field conditions

There was significant (*P*<0.05) interaction between varieties and many traits across the sites, except for germinated plants (stand count). There were significant differences (*P*<0.05) observed due to the effect of site on the performance of varieties and for 12 and 16 h of light treatments (Table 4). The significant (*P*<0.001) difference interaction between site and varieties showed that the response of varieties varied with sites.

The light hours treatments showed significant difference (*P*<0.05) on stand count at week 2 after planting, where 12 and 16 h of light exposure were significantly different from the control (Table 5). The 8 h of light and control treatments showed no significant differences at weeks 3 and 4 after planting. Among the light exposure treatments, the highest percent plant germination was observed for plants that were exposed to 16 h of light (95.778%) followed by 12 h (92.833%) and 8 h of light (89.944%). Control treatment recorded the least overall 87.444% germination. Light exposures (16, 12 and 8 h) increased plant germination by 9.5, 6.2 and 2.9%, respectively. Seed tubers that were exposed to 16 h of light were observed to have the highest percent germination across the weeks while the least was recorded for the control treatment.

There were varietal significant differences (*P*<0.05) on stand count (Table 4). Shangi had the highest percent germination. At week 2 after planting, Shangi had 98.625% germination followed by Kenya Karibu (77.750%) and Dutch Robijn (53.792%) while in the last week Shangi had complete germination (100%), Kenya Karibu (92.375%) and Dutch Robijn (82.125%).

Analysis of variance showed that varieties had significant difference (*P*<0.05) on number of stems and

Table 4. ANOVA for three potato varieties on germinated plants (stand count) at different weeks after planting in Molo and Egerton in 2020 season.

Source of variation	d.f	Stand count		
		Week 2	Week 3	Week 4
Site (S)	1	420.500	1870.681***	854.222***
Rep	2	62.889	63.500	22.625
Variety (V)	2	12079.181***	4665.500***	1930.875***
S×V	2	215.292	675.3889	348.931***
Treatment (T)	3	663.651**	232.273	233.667**
S×T	3	88.736	155.940	18.481
V×T	6	267.547*	72.370	107.042*
S×T×V	6	117.160	67.704	83.245
Error	46	113.078	99.225	41.625
Mean		76.722	86.292	91.500
R^2		0.851	0.763	0.793
C.V		13.860	11.544	7.051

*, **, ***Significant at (P<0.05), (P<0.01), (P<0.001) respectively. CV: Coefficient of Variation, R^2: Coefficient of determination.

Table 5. Mean separation for site, variety and treatment on stand count at different weeks after planting in Molo and Egerton in the 2020 season.

Site	Stand count (%)		
	Week 2	Week 3	Week 4
Molo	79.139^{a}	91.389^{a}	94.944^{a}
Egerton	74.306^{a}	81.194^{b}	88.056^{b}
Variety			
Shangi	98.625^{a}	99.375^{a}	100.0^{a}
Kenya Karibu	77.750^{b}	87.875^{b}	92.375^{b}
Dutch Robijin	53.792^{c}	71.625^{c}	82.125^{c}
Treatment			
16 h	82.371^{a}	89.333^{a}	95.778^{a}
12 h	80.722^{ab}	89.111^{a}	92.833^{ab}
8 h	74.741^{bc}	84.833^{ab}	89.944^{bc}
Control	69.056^{c}	81.889^{b}	87.444^{c}

Means followed by the same alphabetical letter are not significantly different according to DMRT at p≤0.05.

plant height. The significant differences on plant height were observed due to site effect at weeks 2 and 3 of plant emergence (Table 6).

Treatments showed no significant differences (P<0.05) on plant height at week 5 of emergence (Table 7). However, plants exposed to 16 h of light treatment were taller than plants that were exposed to 8 and 12 h of light and control treatments in that order. On average, the tallest plants from 16 h of light treatment ranged between 42.93 and 78.14 cm in weeks 3 and 5 after plant germination and the shortest plants were observed from control treatment with an average of 37.56 to 75.68 cm. Light exposure (8, 12 and 16 h) treatments increased plant height by 1.14, 2.97, and 3.25% (means of 77.93-75.68), respectively, compared to control treatment. Significant differences (P<0.05) were observed on number of stems from weeks 4 and 5 after plant emergence. Plants exposed to 12 h of light had more number of stems than those exposed to other treatments. Varieties showed significant differences (P<0.05) on plant height (Table 7). Tallest plants from weeks 3, 4 and 5 after emergence were recorded in Shangi followed by Kenya

Table 6. ANOVA for the plant height and number of stems at different weeks for the three varieties after plant emergence in Molo and Egerton in 2020 season.

Source of variation	d.f	Plant height (cm) Week 3	No. stems	Plant height (cm) Week 4	No. stems	Plant height (cm) Week 5	No. stems
Site (S)	1	3.520	4.500***	4672.061***	0.347	14726.140***	0.681
Rep	2	62.197	0.264	166.567	0.597	132.166	0.389
Variety (V)	2	10700.788***	27.931***	8994.532***	19.764***	2870.494***	18.764***
S*V	2	239.708**	1.293*	217.069	1.264*	120.100	1.097*
Treatment (T)	3	107.224	0.648	309.039*	1.162*	24.516	2.162***
S×T	3	10.467	0.056	15.749	0.162	16.929	0.051
V×T	6	53.700	0.023	118.938	1.301**	138.020*	1.023*
S×T×V	6	46.811	0.458	119.234	0.356	45.950	0.912*
Error	46	38.498	0.264	91.585	0.336	54.044	0.331
Mean		40.158	2.361	61.435	2.986	77.0711	3.069
R^2		0.928	0.849	0.860	0.788	0.899	0.796
C.V		15.451	21.757	15.576	19.422	9.539	18.741

*, **, ***Significant at (*P*<0.05), (P<0.01), (P<0.001), respectively. CV: Coefficient of Variation, R^2: Coefficient of determination.

Table 7. Mean effects of light exposures on plant height and number of stems at different weeks after plant emergence in the 2020 season of Molo and Egerton sites.

Site	Week 3		Week 4		Week 5	
	Plant height (cm)	No. stems	Plant height (cm)	No. stems	Plant height (cm)	No. stems
Molo	40.379[a]	2.611[a]	69.490[a]	3.056[a]	91.373[a]	3.167[a]
Egerton	39.937[a]	2.111[b]	53.379[b]	2.917[a]	62.770[b]	2.972[a]
Variety						
Shangi	64.123[a]	3.583[a]	82.139[a]	4.000[a]	85.616[a]	4.083[a]
Kenya Karibu	32.067[b]	1.958[b]	58.383[b]	2.708[b]	80.851[b]	2.667[b]
Dutch Robijin	24.285c	1.542c	43.783c	2.250c	64.746c	2.458[b]
Treatment						
16 hours	42.926[a]	2.611[a]	66.004[a]	2.944[ab]	78.138[a]	3.000[a]
12 hours	41.388[ab]	2.167[b]	63.291[a]	3.056[ab]	77.928[a]	3.389[a]
8 hours	38.756[ab]	2.389[ab]	60.029[ab]	3.278[a]	76.535[a]	3.278[a]
Control	37.563[b]	2.278[ab]	56.414[b]	2.667[b]	75.683[a]	2.611[b]

Means followed by the same alphabetical letter are not significantly different according to DMRT at *p*≤0.05.

Karibu and Dutch Robijn. Shangi recorded the tallest plant (85.62 cm) while Dutch Robijn (64.75 cm) recorded the shortest. There was significant difference (*P*<0.05) on number of stems. Shangi had the most number of stems (4) followed by Dutch Robijn (3) and Kenya Karibu (2). There was a significant difference (*P*<0.05) at weeks 4 and 5 on plant height due to site effects. Molo site exhibited taller plants than Egerton site.

Analysis of variance (ANOVA) showed that there were significant differences (*P*<0.05) among the varieties on number of tubers, small and big sized tubers and tuber weight. The site effect was significant (*P*<0.05) on number of tubers and tuber weight (Table 8). There was a significant (P< 0.01) site by variety interaction effect for big and small tubers while interaction was significant (*P*<0.05) for tuber weight.

The treatments revealed significant differences (*P*<0.05) on number of potato tubers. Tubers that were exposed to 16 h light had the highest number of tubers averaging 7 (Table 9). Exposure of seed tubers to 12, 16 and 8 h of light treatments increased tuber weights by 24, 25 and 12%, respectively. There were significant differences (P<0.01) among the treatments on big sized tubers. Plants that were exposed to control treatment had the

Table 8. ANOVA for tuber yield in Molo and Egerton in the 2020 season.

Sources of variance	d.f	Number of tubers	Small size <30 mm	Medium size 30-60 mm	Big size >60 mm	Weight (t ha^{-1})
Site (S)	1	5.418***	1.822	1.714	0.862	3046.292***
Rep	2	0.205	3.899*	0.104	0.905	25.788
Variety (V)	2	2.258***	26.978***	3.277*	30.408***	2018.071***
S×V	2	0.144	3.631*	1.792	1.926*	317.731***
Treatment (T)	3	0.212	0.841	0.370	0.775	79.952
S×T	3	0.156	0.778	0.118	0.228	11.301
V×T	6	0.543	0.359	1.146	0.39	18.039
Error		0.111	1.066	0.834	0.602	38.524
Mean		2.681	7.751	2.717	2.615	20.594
R^2		0.675	0.584	0.320	0.699	0.803
C.V (%)		12.45	13.32	33.600	29.664	30.14

*, **, ***Significant at (P<0.05), (P<0.01), (P<0.001), respectively. CV: Coefficient of Variation, R^2: Coefficient of determination.

Table 9. Mean effects of light exposures on tuber yield in the 2020 season at Molo and Egerton sites.

Site	Number of tubers	Small size <30 mm	Medium size 30-60 mm	Big size >60 mm	Weight (t ha^{-1})
Molo	4.931[b]	59.365[a]	19.383[a]	21.253[a]	14.089[b]
Egerton	7.942[a]	62.479[a]	18.467[a]	19.054[a]	27.098[a]
Variety					
Shangi	8.408[a]	56.230[b]	21.070[a]	22.698[b]	27.551[a]
Kenya Karibu	5.821[b]	47.108c	21.627[a]	31.266[a]	24.028[a]
Dutch Robijin	5.079[b]	79.427[a]	14.078[b]	6.496c	10.203[b]
Treatment					
16 h	7.133[a]	63.381[a]	19.022[a]	17.598[b]	22.369[a]
12 h	6.639[ab]	63.131[a]	20.932[a]	17.730[b]	22.135[a]
8 h	6.267[ab]	59.829[a]	17.439[a]	20.940[ab]	20.007[a]
Control	5.706[b]	57.347[a]	18.307[a]	24.346[a]	17.864[a]

Means followed by the same alphabetical letter are not significantly different according to DMRT at p≤0.05.

highest number of big sized tubers (mean 24) than those that were exposed to 8 (mean 21), 12 (mean 18) and 16 (mean 18) h of light. Higher tuber yields were recorded from tubers that were exposed to 16 and 12 h of light treatment with an average yield of 22.37 and 22.14 tonnes ha^{-1} while 17.86 tonnes ha^{-1} were recorded under control treatment. There were varietal differences (P<0.05) observed on number of tubers, grade and weight (Table 9). Shangi had the highest number of tubers (8 tubers) followed by Kenya Karibu (6 tubers) and Dutch Robijn (5 tubers). Dutch Robijin had the highest number of small tubers (79) compared to Shangi (56) and Kenya Karibu (47). It was observed that Kenya Karibu recorded the largest number of big tuber size (>60 mm) (31 tubers) followed Shangi (23 tubers) and Dutch Robijn (6 tubers) varieties. On average, the highest tuber yield was recorded on Shangi (27.55 t ha^{-1}) followed by Kenya Karibu (24.03 t ha^{-1}) and Dutch Robijn (10.20 t ha^{-1}).

Pearson correlation between sprout, growth and yield parameters for light house and field trails

The correlation analysis results for sprout, growth and yield parameters are presented in Table 10. The results showed that sprout parameters (number, thickness and length) were positively correlated to growth and yield parameters. There were significantly strong and positive correlation between number of sprouts, length and thickness (Table 10). The results further showed that number of sprouts was fairly correlated to stand count with 0.33. However, there was no correlation between number of sprouts and plant height. However, the number of stems was significantly determined by number

Table 10. Combined Pearson correlation coefficient with probability value on sprout, growth and yield parameters in the 2020 season, Egerton lighthouse.

Correlation	No. of sprouts	Sprout thickness	Sprout length	Stand count	Plant height	No. of stems	No. of tubers	Tuber grade (>60 mm)	Tuber weight
Number of sprouts	1.00								
Sprout thickness	0.42***	1.00							
Sprout length	0.62***	0.90***	1.00						
Stand count	0.33**	0.57***	0.54***	1.00					
Plant height	0.16	0.43***	0.36**	0.09	1.00				
Number of stems	0.63***	0.60***	0.69***	0.35**	0.19	1.00			
Number of tubers	0.46***	0.50***	0.54***	0.26*	0.67***	0.39***	1.00		
Tuber grade (>60mm)	-0.11	0.39***	0.24*	0.28*	0.24*	-0.03	0.04	1.00	
Tuber weight	0.22	0.58***	0.49***	0.31**	0.76***	0.22	0.84***	0.41***	1.00

*, **, ***Significant at (*P*<0.05), (P<0.01), (P<0.001) respectively.

of sprouts as there was a strong and positive correlation (0.63) between them. Correlation analysis further showed a low and negative correlation between the number of sprouts and tuber grade (-0.11); no relationship between tuber weight and number of sprouts. There was a strong significant correlation between sprout thickness, length, stand count and plant height. The sprout thickness and length had strong and positive correlation with number of tubers (0.50 and 0.54) and tuber weight (0.58 and 0.59). The results showed the significant positive correlation between plant heights, number of tubers and tuber weight. There was a significantly positive correlation of 0.39 between the number of stems and number of tubers. In general, there was significantly positive correlation between number of stems, number of tubers and tuber weight. The results further showed the significant relationship between tuber grade and tuber weight.

DISCUSSION

Time of exposure did not have any significant (*P*<0.05) effect on the number of sprouts, but, there was significant difference (*P*<0.05) observed on sprout quality (length and thickness). This shows that light is an essential factor for the growth and development of potatoes. Sue (2007) also noted that pre-sprouting of potato tubers in light resulted in thick, strong sprouts, which give a plant advantage of growing fast. Although all light exposure treatments and control resulted in good quality sprouts, seed tubers that were exposed to 16 h of light treatment did not have thick and long sprouts as compared to those exposed to 8 and 12 h light.

Similarly, Van Ittersum (1992) reported that as much as long hours of light do shorten the dormancy, growth of sprouts can be associated with innate dormancy which depends largely on long photoperiod (18 h) light. Suttle (2007) noted that although the presence or absence of light during post-harvest storage has little effect on dormancy duration, it can affect the morphology of emerging sprouts. In this study, there was significant increase on sprout thickness and sprout length attained by light exposures than control. These results are consistent with those of Johansen and Mølmann (2017), who found a significant difference in sprout length but the significance decreased with increasing duration of daily light exposure on sprout length. Morrow (2014) also indicated that light treatments significantly influenced the sprouting of broccoli micro green shoot tissue, but with no significant difference among light treatments.

According to Bushnell (1929), the exposure of seed tubers to a warm light is regarded as hastening early varieties growth. He reported that tubers exposed to light become green, produce short and tough sprouts that adhere during the processes of planting. In the current work, a long dormancy variety like Dutch Robijin attained 54% plant germination in week 2 after planting. In the 4th week after planting, which is the average expected time for potatoes to have emerged; all the varieties had 82 to 100% germination. This indicated the importance of dormancy breaking in potato production. Fast emergence could be attributed to the quality sprouts obtained at the lighthouse after pre-sprouting. Johansen and Molteberg (2012) found that pre-sprouted tubers significantly improved emergence for Asterix and Saturna cultivars as compared to cold-stored seed.

Light hours treatments significantly influenced the varieties ability to sprout. The significant effect (*P*<0.05) was seen on the number of sprouts, length and thickness of the sprouts. Shangi had a higher number of good quality sprouts than Kenya Karibu and Dutch Robijn suggesting that the thicker the sprouts, the higher the chances of plants to germinate; the longer the sprouts the more the plants grow faster hence there was a strong significant correlation between sprout thickness, length, stand count and plant height. In this study, varieties had purple and green sprouts. The green and purple sprouts indicated that the pre-sprouted seed tubers produced healthy sprouts due to treatment effects. Green and purple colours further show that the seed received enough light hence sprouts were able to produce chlorophyll as opposed to white colour which suggested stunted photosynthesis.

Johansen and Mølmann (2017) stated that the pre-sprouted potatoes either in natural or artificial light speeds up plant development. In the current study, there was an increase in plant height as compared to control treatment. The tallest plants were from 16 h of light treated plants. When light hours are eased the day becomes longer and this compensates for the low growth temperatures in the field which can secure the growth and development of a crop leading to satisfactory yield. According to Jao and Fang (2004), the 16 h light period is recommended for optimal growth of potato. Furthermore, the 16 h photoperiod has been found necessary to maintain the vegetative growth of potato plantlets *in vitro* (Seabrook, 2005). The 16 h of light exposure had the highest percent plant germination and plant height, increased tuber weight. Plants exposed to longest hours of light were able to accumulate a larger supply of reserve material for the formation of new tissue as the result of better photosynthesis; therefore they ultimately attained the greatest height. The higher the plant height, the more the tubers are produced and heavy weight hence the results showed the significant positive correlation between plant heights, number of tubers and weight.

Field evaluation further showed that there was a significant difference (P<0.05) observed among varieties for the traits observed across the sites. This could suggest the varieties responses were influenced by the environments under which they were evaluated. The other reasons could be differences due to their genotype or the interaction among the genotypes and the environments. Potato growth and tuber yields have been linked to the duration of the growth cycle, which depends on climate, cultivar, and crop management (Dahal et al., 2019). The differences in growth and in tuber yield among potato cultivars can be explained by differences in accumulated intercepted radiation (Oliveira et al., 2016). There were significant differences (P<0.05) observed among varieties on the number of tubers, big-sized tubers and tuber weight across sites.

CONCLUSION AND RECOMMENDATIONS

Light exposures significantly enhanced the quality of sprout by influencing the thickness and length. This was highly correlated to growth and yield of potato plants. Seeds tubers with good quality sprouts in terms of length and thickness can lead to high vigorous plants which will give good yield. Light exposures reduced the sprouting time by 23 days (from 44 to 21 days) which is advantageous in increasing growing cycles per annum. It also significantly increased sprout thickness and sprout length. Light exposure of 16 h resulted in the highest percent plant germination. The best light regime was 16 h which increased tuber weight by 25% as compared to 8 h that increased tuber weight by 12%. The 16 h of light attained the highest yield in Shangi and Kenya Karibu. These varieties could be recommended when the suitable pre-sprouting conditions are available to the farmers.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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