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Research Article

Effect of Presprouting Plant Growth Regulators and Natural Materials on Dormancy, Growth, and Yield of Potatoes (*Solanum tuberosum* L.)

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Irish potatoes are amongst the most highly grown and demanded crops in Kenya for food, industrial starch, and animal feed. Farmers, however, face a serious challenge regarding the timely availability of well-sprouted seed potato tubers due to the physiological seed dormancy period of 2–3 months, thereby reducing production cycles. This study determined the effects of different chitting methods on enhancing the presprouting of different potato varieties in Kenya. Plant growth regulators (PGR) (Gibberellins (GA_3), 6-Benzylaminopurine, and Zeatin) and natural materials (grass, banana leaves, and soil) were evaluated for their effects in breaking dormancy and stimulating the growth of sprouts under greenhouse conditions in a complete randomized design (CRD) with three replicates. The evaluation of the presprouted seed in the field was conducted at Egerton University and Kenya Agricultural and Livestock Research Organization (KALRO), Molo, in a split-plot design for two seasons. Data was taken on crop emergence, length, thickness, and colour of sprouts, plant height, tubers per plant, tuber thickness, and tuber yield. Data were subjected to a general linear model to partition the variance component using SAS software version 9.13, and means were separated using the least significant difference ($p \leq 0.05$). There were significant ($p \leq 0.05$) main effects on the prespouting time, growth, and yield of tubers. The interaction effects due to variety and treatment were also significant ($p \leq 0.05$) for sprout thickness. Natural materials produced the most vigorous sprouts, increased crop emergence, plant height, and superior tuber yield. Natural materials and PGRs increased tuber size for chitted potato seed by 261% and 103%, respectively. Control treatments had a significantly higher frequency of small-sized tubers than natural materials and PGRs, proving the importance of chitting in increasing tuber size and yields. Natural materials increased sprout quality (thickness and length) better than PRGs and control treatments. This study showed that small-holder farmers could adopt the use of readily available soil, grass, and banana leaves while large-scale growers, with access to better facilities, could use PGRs to break tuber dormancy for increased potato tuber yield.

1. Introduction

Irish potato (*Solanum tuberosum* L.) is one of the major tuber crops and is considered the third most important food crop after rice and wheat in terms of human consumption (FAO, 2017). Its consumption is very high in the world since more than a billion people consume it (FAO, 2017) [1]. Potato is vegetatively propagated from seed tubers [2]. In Kenya, potatoes are grown throughout the year on about 35,000 hectares of land, mainly in highland areas of the rift valley and the western region (KALRO, 2019). It is a major cash crop for many small-scale farmers [3]. The National Breeding Program and International Potato Centre (CIP) in Kenya have undertaken a concerted effort in developing several potato varieties which are now commercially available for growing in different areas. These varieties are adapted to varied agroecological zones and have diverse agronomic traits and market preferences for different multiuses. Some of the attributes considered by farmers in ranking a potato cultivar were high yield potential, late potato blight (*Phytophthora infestans*) resistance, taste, maturity period, market demand, bacterial wilt resistance, size of the tuber, and drought tolerance.

The National Breeding Program, led by KALRO and CIP, has initiated breeding for several abiotic and biotic constraints. However, the potato sector is still affected by numerous problems resulting in diminished yields, affecting an estimated 800,000 potato farmers (KALRO, 2018; [4]), who mostly depend on uncertified local seeds. The dependence on uncertified seeds results in low yields that average 7.3 $t{\cdot}\mathrm{ha}^{-1}$as compared to attainable yields of 25–35 $t{\cdot}\mathrm{ha}^{-1}$ and a global average of 17.4 $t{\cdot}\mathrm{ha}^{-1}$ [4]; (FAOSTAT, 2018). Other major problems affecting potato production in Kenya include the timely availability of well-sprouted seed potato tubers [5]. As a physiological requirement, to convert fresh tubers to seed, potato tubers must undergo between two and three months of dormancy after harvesting, which is a big impediment to availing high-quality, disease-free seed for timely planting [6]. This long period of dormancy should be broken to achieve the timely availability of well-sprouted seed potato tubers at the onset of rains. Furthermore, in many areas, potatoes are grown during the short rainy season after harvesting crops from the long rainy season like maize and wheat. This implies that it is of great importance to use potato seed tubers with a high growth vigour and a short growth cycle, which is currently a major limitation for potato farmers. Limited availability, low quality, and low vigour diseased potato seeds can be improved 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.

One of the most important physiological aspects of preparing potatoes for planting in potato production that must be considered is the presprouting. Presprouting means preparing potatoes for planting by encouraging the production of sprouts before planting [4]. For adequate yields and quantities to be achieved in potatoes, presprouting seeds should be considered, especially in those regions with cool and short growing seasons [7]. Presprouting encourages faster growth and heavier crops once the seed potatoes are planted. According to Chandrasekara [8], potatoes can still be grown in those agroecologies where other crops will fail, and because of this reason, they are likely to play a major role in achieving the Sustainable Development Goal of zero hunger in Sub-Saharan Africa [9].

To have early seed planting materials, the introduction of growth regulators that induce dormancy breaking is important, and GA_3 has been widely used in many countries for breaking tuber dormancy [10]. In general, PGHs have been playing a primary role in the regulation of potato tuber endodormancy and many other aspects of plant development [11]. PGHs are considered to be the most important and efficient endogenous regulators of both tuber dormancy and sprouting. There is evidence that, from the dynamics of endogenous hormones related to stages of dormancy and spouting, there is a possibility to change dormancy duration and sprouting by tuber treatment with hormonal preparation [12]. In this process of dormancy breakage, the hormones suitable for this activity are cytokinins and Gibberellins, since they are required for bud break and sprout growth. There are other methods of breaking dormancy, which among others include magnetic field strengths, light exposure, and physical and chemical pretreatments [13], [14]. This study determined the effects of the presprouting PGRs and natural materials on potato vigour, growth, and yield of selected potato varieties under greenhouse and field conditions, with a goal to improve the timely availability of the presprouted potato seed for cropping cycles and increase yield.

2. Materials and Methods

2.1. Site Description. The greenhouse experiment was conducted at Egerton University, while the field experiment was conducted at two sites, Kenya Agricultural and Livestock Research Organization (KALRO), Molo, and Egerton University. Egerton lies at longitude $35°35'E$, latitude of $0°23'S$, and an altitude of 2238 m above sea level. This site experiences a mean annual rainfall of 1200 mm, and the average temperature ranges between 10.2 and 22 (Jaetzold et al. 2007). The Kenya Agricultural and Livestock Research Organization, Molo, lies at a latitude of $0.2472°S$, a longitude of $35.7373°'E$, and an altitude of 2480 m above sea level. This site experiences a mean annual rainfall of 1100 mm to 1500 mm and an average temperature of 15°C to 25°C (Jaetzold et al. 2007).

2.2. Germplasm Description. Three potato genotypes with varying agronomic traits were used in this study for presprouting, tuberization, and yield evaluation (Table 1). The materials, Shangi, Dutch Robijn, and Kenya Karibu used as commercial varieties, were sourced from KALRO Tigoni. Shangi has a short presprouting period and a short maturation period. It is also a newly released variety. Dutch Robijn is the oldest variety, with a long maturation of 3.5–4.5 months and takes longer period to presprout. Kenya Karibu has a moderate chitting period and long maturity periods of 3.5 months (NPCK, 2019).

2.3. Experimental Procedure

2.3.1. Greenhouse Experiment. The greenhouse experiment was conducted at Field 7, Egerton University, for two seasons (September–December 2019 and April–August 2020). Three PGRs and three natural materials were evaluated as presprouting materials. The PGRs included Gibberellins (GA_3), 6-Benzylaminopurine (BAP), and Zeatin at a concentration of 1 $\mathrm{mg{\cdot}L^{-1}}$ [16]. The three natural materials used were fresh banana leaves, dry grass, and moist soil. The seed tubers from three selected varieties (Dutch Robijn, Shangi, and Kenya Karibu) were laid in 2–3 layers in plastic trays sprayed with three selected plant growth regulators or covered by three natural products. The natural materials were applied in thin layers that filter direct photosynthetically active radiation light, as reported by Bushnell [17]. The controls were the seed tubers placed in a tray, neither sprayed with PGRs nor covered with natural materials. The

Table 1: Varieties are evaluated in this study and some of their attributes.

Varieties	Year released	Year evaluated	Place evaluated	Maturity time	Potential yield	Dormancy duration under normal conditions
Shangi	2015	2017	Nandi, Kenya	≤3 months	30–40 $t{\cdot}ha^{-1}$	4–6 weeks
Kenya Karibu	2003	2017	Kitale, Kenya	3–4 months	35–45 $t{\cdot}ha^{-1}$	4–6 weeks
Dutch Robijn	1960	2017	Kitale, Kenya	4–5 months	35–40 $t{\cdot}ha^{-1}$	4–6 weeks

Source: [15].

experiments were laid out in a complete randomized design (CRD), and a total of 63 trays were used, each tray carrying 20 seed tubers for each variety. At each presprouting period, temperature was maintained at ambient conditions similar to the presprouting storage facilities as Kr Rykaczewska, [18] did in his experiment where the tubers were placed under conditions conducive to their physiological ageing from harvest to planting, in which the appropriate temperature (18°C) was the most important condition. The prechitting process took 44 days, after which the presprouted seed was planted in two sites (Egerton and KALRO-Molo). Data collected included the number of sprouts, which was physically counted at 7, 14, 21, and 28 days up to the presprouting period of 4 to 6 weeks. The length of sprouts and thickness (mm) were measured using an electronic vernier caliper (stainless hardened MARS battery, 1.55V), and colour of sprouts was determined using a visual assessment.

2.3.2. Field Experiment. The prespouted seeds were planted for evaluation in the field at KALRO Molo and Egerton's Agroscience Park field station. The individual field plots had four rows, spaced at 0.75 m apart, and 0.30 m between plants within the rows. Each experimental plot measured 3 m by 1.5 m. A standard fertilizer (NPK 17-17-17) was applied at a rate of 300 $kg{\cdot}ha^{-1}$ to the furrows and incorporated into the soil prior to planting (aimed at giving 70 $kg{\cdot}ha^{-1}$ of N, P_2O_5, and K_2O), respectively. The experimental design used was a split-plot arrangement where the main factors were varieties and the subfactors were plant growth regulators.

All agronomic practices, including weeding, spraying, and earthing up, were maintained. Weeding was carried out by uprooting immediately after the plant emerged, while earthing up was carried out at the flowering stage. Early blight and late blight were controlled by the Ridomil® gold MZ 68 WG (Metalaxyl-M 40 g/kg^{-1} + Mancozeb 640 g/kg^{-1}) at the rate of 50 g/20L of water making one pump and alternated with Milor mostly when more rains were received. These chemicals were sprayed after every 7 days and 14 days, when more and less rain was received, respectively. Data on growth, yield, and yield parameters were taken. These included tuber emergences recorded after 7, 14, 21, and 28 days after planting; the number of stems (shoots) per plant was physically counted at 7, 14, 21, 28, and 35 days after an emergency (DAE); plant height (cm) was measured using a ruler from the highest upper leaf base up to the tuber after complete emergence of all the varieties until flowering stage; and the number of tubers per plant was physically counted after pulling out tubers (at harvesting time). The tubers grades were carried out after harvest and ranked in three classes. Big size: >60 mm diameter; middle size: 30–60 mm diameter; small size: <30 mm diameter. Different grades were weighed separately, and the values recorded were converted to $t{\cdot}ha^{-1}$. The total tuber yield (kg) was determined as the mean weight of tubers per plot, then converted to tonnes per hectare ($t{\cdot}ha^{-1}$).

2.4. Data Analysis. Data were transformed using the square root to meet normality as assumed in the ANOVA. ANOVA was performed using SAS version 9.13. Treatment means were compared using the LSD test at a significance level of $\alpha = 0.05$ level of probability. The Pearson correlation analysis at a 5% level of significance was performed to determine the relationship between tuber yields, number of sprouts, length and thickness of sprouts, stand count, plant height, number of stems, and grade of tubers.

3. Results

3.1. Response of Seed Tubers to PGRs and Natural Materials under Greenhouse

3.1.1. Number of Sprouts and Sprout Quality. Analysis of variance (ANOVA) showed that there were significant differences ($p \leq 0.05$) among the treatments and varieties (Table 2). Furthermore, there was a significant ($p \leq 0.05$) interaction between season and treatment for spout length, and variety by treatment for spout thickness.

Combined data analysis revealed a significant difference ($p \leq 0.05$) amongst the treatments for the number of sprouts on tubers, which varied with treatments (Table 3). The sprout quality (length and thickness of the sprouts) was significantly ($p \leq 0.05$) affected by the presprouting treatments, which affected the colour of the tubers during chitting. Purple was observed on seed sprouts treated with natural materials and green on seed sprouts treated with PGRs, showing that treatments resulted in the production of flavonoid variants of the presprouted seed tubers. Seeds treated with grass, soil, and banana leaves produced the thickest and the longest sprouts, with thickness ranging from 3.86–4.71 mm and lengths ranging from 5.49–6.73 mm, compared to seeds treated with PGRs (GA3, Zeatin, and BAP) and control sprouts with thickness ranging from 2.59–2.97 mm and lengths ranging from 3.44–3.69 mm; 1.59 and 2.39 mm, respectively. Natural materials (soil, grass, and banana leaves) increased sprout quality by 174% and 159%, respectively (means of $(4.49 + 4.71 + 3.86) - 2.26$ (control),

Table 2: The mean squares for a number of sprouts and sprout quality under a greenhouse in the 2019–2020 seasons.

Sources of variance	df	Number of sprouts				Sprout quality	
		Week 1	Week 2	Week 3	Week 4	Thickness	Length
Season	1	0.22	0.37*	0.35*	0.56**	1.83	0.02
Treatment	6	0.83***	1.08***	1.18***	1.15***	22.61***	49.37***
Season*treatment	6	0.04	0.02	0.04	0.02	0.56	1.87
Variety	2	1.18***	0.47**	0.79***	0.22	71.65***	163.20***
Season* variety	2	0.10	0.25*	0.26*	0.16	1.13	3.66*
Variety*treatment	12	0.11	0.07	0.06	0.06	1.07*	1.87
Error	94	0.09	0.08	1.06	0.08	0.55	0.92
Total	125						
CV		20.38	15.68	20.06	18.53	22.58	21.34
R^2		0.57	0.59	0.67	0.66	0.85	0.89

*, **, ***, significant at ($p \leq 0.05$), ($p \leq 0.01$), ($p \leq 0.001$), respectively. CV: coefficient of variation; R^2: coefficient of determination.

Table 3: Means for the number of sprouts and sprout quality of six plant growth regulators and natural materials under a greenhouse in the 2019–2020 seasons.

Treatments	Number of sprouts				Sprout quality	
	Week 1	Week 2	Week 3	Week 4	Thickness (mm)	Length (mm)
Grass	2.06ab	3.11a	3.72ab	5.00a	4.49a	6.31a
BL	2.28a	3.00a	3.83a	5.33a	4.71a	6.73a
Soil	1.50bc	2.56ab	2.94c	3.89b	3.86b	5.49b
BAP	0.94cd	1.83c	2.56c	3.78b	2.76c	3.44c
GA3	1.44bc	2.06bc	3.11bc	3.78b	2.97c	3.69c
Zeatin	1.67ab	2.56ab	3.00c	3.50b	2.59c	3.49c
Control	0.33d	0.72d	1.22d	1.83c	1.59d	2.39d
Mean	1.46	2.26	2.91	3.87	3.28	3.51
LSD	0.20	0.69	0.68	0.93	0.49	0.64
$P < 0.05$V	***	**	***	***	***	***
Season	ns	*	*	**	ns	ns

Key: means followed by the same letter in the same column are not significantly different ($p \leq 0.05$), BL: banana leaves, GA3: Gibberellins, and BAP: 6-Benzylaminopurine.

Table 4: Means for the number of sprouts and sprout quality of three potato varieties under a greenhouse in the 2019–2020 seasons.

Varieties	Number of sprouts				Sprout quality	
	Week 1	Week 2	Week 3	Week 4	Thickness (mm)	Length (mm)
Shangi	2.02a	2.64a	3.43a	3.83 b	4.52a	6.53a
Kenya Karibu	1.05b	1.88b	2.40c	3.29b	3.41b	4.39b
Dutch Robijn	1.31b	2.26ab	2.91b	4.50a	1.92c	2.60c
Mean	1.46	2.26	2.91	3.87	3.28	4.51
LSD	0.44	0.45	0.46	0.61	0.32	0.42
CV	20.38	15.68	20.07	18.53	22.58	21.34

Key: means followed by the same letter in the same column are not significantly different ($p \leq 0.05$).

compared to PGRs that increased by 74% and 48%, respectively. Seeds treated with banana leaves had good-quality sprouts as defined by thickness (4.71 mm) and length (6.73 mm) compared to seeds treated with GA_3, with lengths and thicknesses of 3.69 mm and 2.97 mm, respectively. Banana leaves increased sprout quality by 196% (means of 4.71–1.59) and 182% (means of 6.73–2.39), compared to percentage increases of 87% and 54% (means of 2.97–1.59) and (means of 3.69–2.39) from GA_3 treatment.

The varieties showed significant differences ($p \leq 0.05$) for number of sprouts and sprout quality (thickness and length) (Table 4). During the 4th week of chitting, Dutch Robijn had the highest significant ($p \leq 0.05$) number of sprouts (Table 4). The varietal difference was significant for the thickness and length of the sprouts. Shangi had good quality sprouts (4.52 and 6.53 mm) compared to Kenya Karibu (3.41 and 4.39 mm) and Dutch Robijn (1.92 and 2.60 mm), respectively.

3.1.2. *The Influence of PGRs and Natural Materials on Growth Parameters under Field Conditions.*

An analysis of variance (ANOVA) showed that there were significant differences ($p \leq 0.05$) among the treatments, varieties, and the interaction effects between site by season and replication by variety. The effect due to sites was significant ($p \le 0.05$) for stand count at week 2, week 3, week 4, and week 5 after planting (Table 5).

The interaction between varieties with treatments showed a significant difference ($p \le 0.05$). for the germinated plants (stand count) throughout all the weeks after planting. The interaction effects due to natural material treatments by varieties were highest for the number of plants that were established through all the weeks compared to PGR treatments and control (Figures 1(a)–1(c)). Generally, the interaction effects due to Shangi by banana leaves, grass, and soil treatments resulted in the highest numbers (19, 18, and 17), respectively on stand count in week 5 after planting compared to Zeatin, GA_3, BAP, and control (16, 16.16, and 13), respectively. The interaction between varieties and natural material treatments increased stand count by 56%, 55%, and 38% compared to PGR treatments at 36%, and 23% and control. It was observed that amongst natural material treatments, the interaction between banana leaves treatment and the three varieties gave a higher stand count ranging between 18 and 19 plants per plot, while amongst PGRs, the highest stand count was recorded under GA_3 treatment with 15–16 plants per plot (Figure 1).

The treatments showed a significant difference ($p \le 0.05$) for stand counts. The plants treated with natural materials had the highest number of plants established across the weeks, averaging 10–18 per plot, compared to the plants treated with PGRs (9–15) and control (5–12). It was observed that the percent increase exhibited by natural materials and PGRs on stand count varied with varieties. Natural materials and PGRs increased stand counts by 57% (means of $17.44 + 18.11 + 16.58$)–11.81 (control) and 29% (means of $15.39 + 15.56 + 14.92$)–11.8 (control), respectively. The effect of sites was significant ($p \le 0.05$) for stand count through the 5 weeks after planting. The interaction effects were insignificant ($p \le 0.05$) (Table 6).

The results further showed that the significant difference ($p \le 0.05$) for stand count varied with varieties (Table 7). Shangi had the highest number of germinated plants [3, 6, 7, 9, 16] than Kenya Karibu and Dutch Robijn.

There were significant differences ($p \le 0.05$) among the treatments and varieties for plant height and number of stems. Sites and seasons had significant effects ($p \le 0.05$) on potato varieties at week 3, week 4, and week 5 after plant emergence. The significant differences ($p \le 0.05$) were further observed for the interaction effects due to site by season andreplication by variety (Table 8).

The interaction effects between varieties and treatments were significant for plant height. Natural material treatments gave the tallest plants compared to the effects of interactions involving PGRs on the varieties. Plant heights of 71–83 cm, 68–81 cm, and 65–76 cm were recorded from plants treated with banana leaves, soil, and grass across, respectively, all the varieties at week 5 after plant emergence, while 63–74 cm, 63–70 cm, 59–74 cm, and 46–59 cm, in that order, were recorded from plants treated with GA_3, BAP, Zeatin, and control, respectively (Figures 2(a)–2(c). Amongst natural materials, the highest numbers (71, 71, and 83 cm) of plant height were observed from plants treated with banana leaves treatment for all the varieties; 63, 67, and 74 cm from plants treated with GA_3 treatment (Figure 2).

The site had a significant ($p \le 0.05$) effect on plant height and number of stems. The season also showed a significant difference ($p \le 0.05$) for plant height through the weeks after plant emergence. Natural material treatments produced the tallest plants, averaging35.56–75.86 cm compared to plant growth regulator treatments (31.22–68.23 cm) and control (19.19–51.37 cm). The pre-sprouting seeds improved the growth vigour of the tuber plants, and this was observed on plant heights where natural materials treatments increased plant height by 43%, 36%, and 48%; 33%, 30%, and 27% PGRs, respectively. The number of stems was significantly different ($p \le 0.05$) among treatments. Plants treated with banana leaves had the highest number of stems among natural materials treatments while, the highest number of stems were recorded from plants treated with GA_3. Control treatment recorded the lowest number of stems (Table 9). The significant difference ($p \le 0.05$) in plant height varied with varieties. Shangi had the tallest plant, followed by Kenya Karibu and Dutch Robijn in that order. Shangi and Dutch Robijn showed no significant differences in the number of stems (Table 10).

There were significant interactions ($p \le 0.05$) for site by season and replication by variety. When the combined data analysis of variance was performed, the site was significant ($p \le 0.05$) for number of tubers and weight. Seasons and varieties main effects were not significant (Table 11).

The location had a significant ($p \le 0.05$) effect on the number of tubers and weight when data were combined for both sites, seasons, and varieties. The treatments significantly influenced the number of tubers, grade, and weight in the field trials. Plants treated with grass, banana leaves, and soil were significantly ($p \le 0.05$) different from plants treated with BAP, Zeatin, GA_3, and control in terms of the number of tubers produced by each plant. The greatest number of tubers 8, 7, and 7 were recorded from plants treated with banana leaves, grass, and soil treatments, and the lowest 6, 6, 5, and 3 were recorded from plants treated with Zeatin, GA_3, and BAP and control treatments, respectively. Significant differences ($p \le 0.05$) were observed between small-sized tubers and big-sized tubers. Plants treated with natural materials had the highest number of big-sized potatoes (48, 48, and 45); GA_3, Zeatin, and BAP (27, 27, and 25, respectively); and, control [9]. The percent increase of 261% $((48 + 48 + 45) - 13)$ in big-sized potatoes was recorded for natural materials treated plants compared to those treated with PGRs (103%). Control had a significantly ($p \le 0.05$) higher percent (64%) of small-sized tubers than natural materials and PGRs.

The results further showed that plants treated with natural materials, PGRs, and control had significant differences ($P < 0.05$) for tuber weight. Most weight was recorded from those materials treated with grass ($23.63\, t{\cdot}ha^{-1}$), banana leaves ($23.51\, t{\cdot}ha^{-1}$), and soil ($22.20\, t{\cdot}ha^{-1}$) compared to those treated with BAP ($15.85\, t{\cdot}ha^{-1}$), GA_3 ($16.74\, t{\cdot}ha^{-1}$), Zeatin ($16.35\, t{\cdot}ha^{-1}$), and control ($7.585\, t{\cdot}ha^{-1}$), respectively (Table 12).

Table 5: The mean squares for three potato varieties on germination (stand count) at different weeks after planting.

Stand count					
Sources of variance	*df*	Week 1	Week 2	Week 3	Week 4
Site	1	2853.59***	2565.14***	2328.40***	2120.48***
Season	1	143.25*	44.59	55.25*	35.81
Variety	2	871.00***	358.54***	122.61**	52.11**
Season*variety	2	19.06	14.46	6.21	5.25
Site*variety	2	67.49	32.44	2.50	2.49
Site * season* rep* variety	25	32.26***	19.04***	14.00***	9.22***
Treatment	6	293.57***	254.04***	193.88***	153.20***
Variety*treatment	12	3.13	2.56	1.05	1.28
Error	198	4.91	3.34	2.19	1.75
Total	251				
CV		22.97	14.69	10.35	8.44
R^2		0.89	0.89	0.91	0.91

*, **, ***, significant at ($p \leq 0.05$), ($p \leq 0.01$), ($p \leq 0.001$), respectively. CV: coefficient of variation; R^2: coefficient of determination.

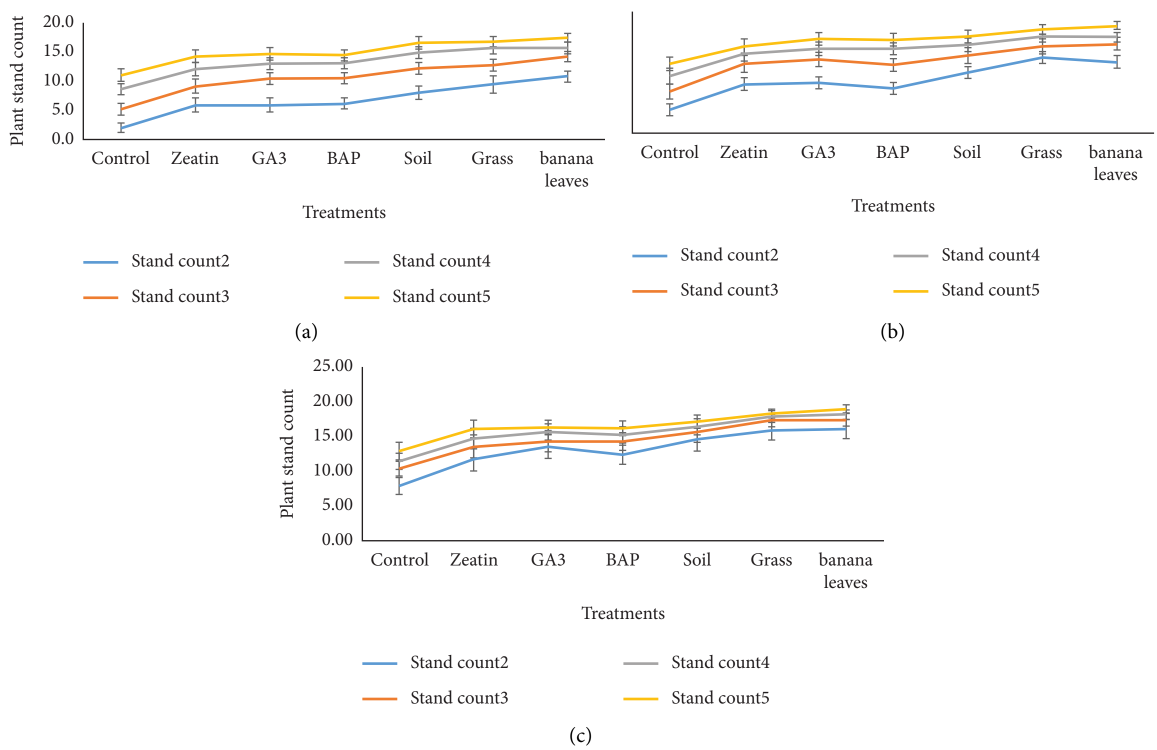

Figure 1: Means and standard error bars of germinated potato varieties (plant stand count) as affected by natural materials (soil, banana leaves, and grass) and plant growth regulators (GA_3, BAP, and Zeatin). Stand counts 2, 3, 4, and 5 weeks after planting. (a) Dutch Robijn; (b) Kenya Karibu; and (c) Shangi variety.

The varieties showed no significant difference ($p \leq 0.05$) in the number of tubers. The biggest tubers were recorded in Shangi, although there were no significant differences observed among varieties. Kenya Karibu was the highest yielding variety (20.24 $t \cdot ha^{-1}$), followed by Dutch Robijn (17.31 $t \cdot ha^{-1}$) and Shangi (16.50 $t \cdot ha^{-1}$) (Table 13).

3.1.3. Correlation between Sprout, Growth, and Yield Parameters for Greenhouse and Field Trails. Sprout parameters (number, thickness, and length) were positively correlated to growth and yield parameters. The number of sprouts was fairly correlated to stand count and tuber grade but strongly correlated to plant height, number of stems, and tuber weight. Sprout thickness and length had a significantly strong positive correlation with stand count, plant height, tuber grade, and tuber weight (Table 14).

4. Discussion

Seed availability at the right planting time is a very important contributory factor in potato production. This study suggests that seeds with different dormancy periods can be available at any time of the planting season once the dormancy period

Table 6: Means effects of plant growth regulators and natural materials are on germinated plants (stand count) at different weeks after planting.

Stand count					
Treatments	Week 2	Week 3	Week 4	Week 5	Overall mean
Grass	12.64a	14.83a	16.56a	17.44b	15.36
BL	12.89a	15.50a	16.61a	18.11a	15.78
Soil	10.89b	13.58b	15.31b	16.58c	14.09
BAP	8.64c	12.06cd	14.11c	15.39de	12.55
GA3	9.28c	12.33c	14.22c	15.56d	12.85
Zeatin	8.58c	11.39d	13.36d	14.92e	12.06
Control	4.58d	7.47e	9.83e	11.81f	8.42
LSD	1.03	0.85	0.69	0.62	
Variety	***	***	**	**	
Season	*	ns	*	ns	
Site	***	***	***	***	
Season*variety	ns	ns	ns	ns	
Site * variety	ns	ns	ns	ns	

Key: means followed by the same letter in the same column are not significantly different ($p \leq 0.05$).

Table 7: The mean comparison of three potato varieties on germinated plants (stand count) at different weeks after planting.

Stand count					
Varieties	Week 2	Week 3	Week 4	Week 5	Overall mean
Shangi	13.19a	14.73a	15.65a	16.58a	15.03
Kenya Karibu	8.83b	11.94b	13.83b	15.37b	12.49
Dutch Robijn	6.90c	10.69b	13.37b	15.11b	11.52
Mean	9.64	12.45	14.29	15.69	
LSD	1.81	1.38	1.19	0.97	
CV	22.97	14.68	10.35	8.44	

Key: means followed by the same letter in the same column are not significantly different ($P < 0.05$).

Table 8: The mean squares of three potato varieties on plant height and number of stems at different weeks after plant emergence.

Sources of variance	Plant height number of stems					
	Week 1	Week 2	Week 3	Week 1	Week 2	Week 3
Site	1240.75*	8078.38**	16851.23***	47.98**	79.20***	86.52***
Season	2382.93**	9136.64**	3168.50*	2.64	2.04	0.65
Rep	48.36	127.20	105.20	0.51	0.23	0.46
Variety	7522.43***	6204.55**	2913.74*	21.55**	38.14***	46.05***
Season*variety	321.36	14.00	82.88	0.91	1.27	3.54
Site*variety	1280.01*	1160.14	711.43	3.65	2.55	1.87
Site* Season*Rep*variety	281.02***	674.36***	701.30***	3.54***	3.21	3.63***
Treatment	1777.43***	1694.56***	2280.78***	8.79***	14.22***	19.10***
Variety*treatment	69.14	63.07	54.92	0.18	1.04	0.90
Error	41.63	47.56	47.71	0.68	0.68	0.77
CV	19.65	12.98	10.27	33.11	26.08	23.22
R^2	0.83	0.86	0.86	0.65	0.72	0.73

*, **, ***, significant at ($p \leq 0.05$), ($p \leq 0.01$), ($p \leq 0.001$), respectively. CV: coefficient of variation, $R.^2$: coefficient of determination.

is accelerated. There are several methods involved in dormancy breaking, and one of those methods can be the use of chemicals (Ezekiel and Singh, 2003). In this study, the response of three potato varieties varied with the presprouting treatments (soil, grass, and banana leaves; Zeatin, BAP, GA_3, and control). The significant differences ($p \leq 0.05$) among the treatments and varieties showed the greatest influence of natural materials and plant growth regulators in breaking the dormancy of different varieties. Seeds that were treated with natural materials have been found to have good quality sprouts under greenhouse and obtained higher yields in the field than those that were treated with plant growth regulators (Zeatin, BAP, GA_3) and control. Among the seed tubers that were treated with natural materials treatments;

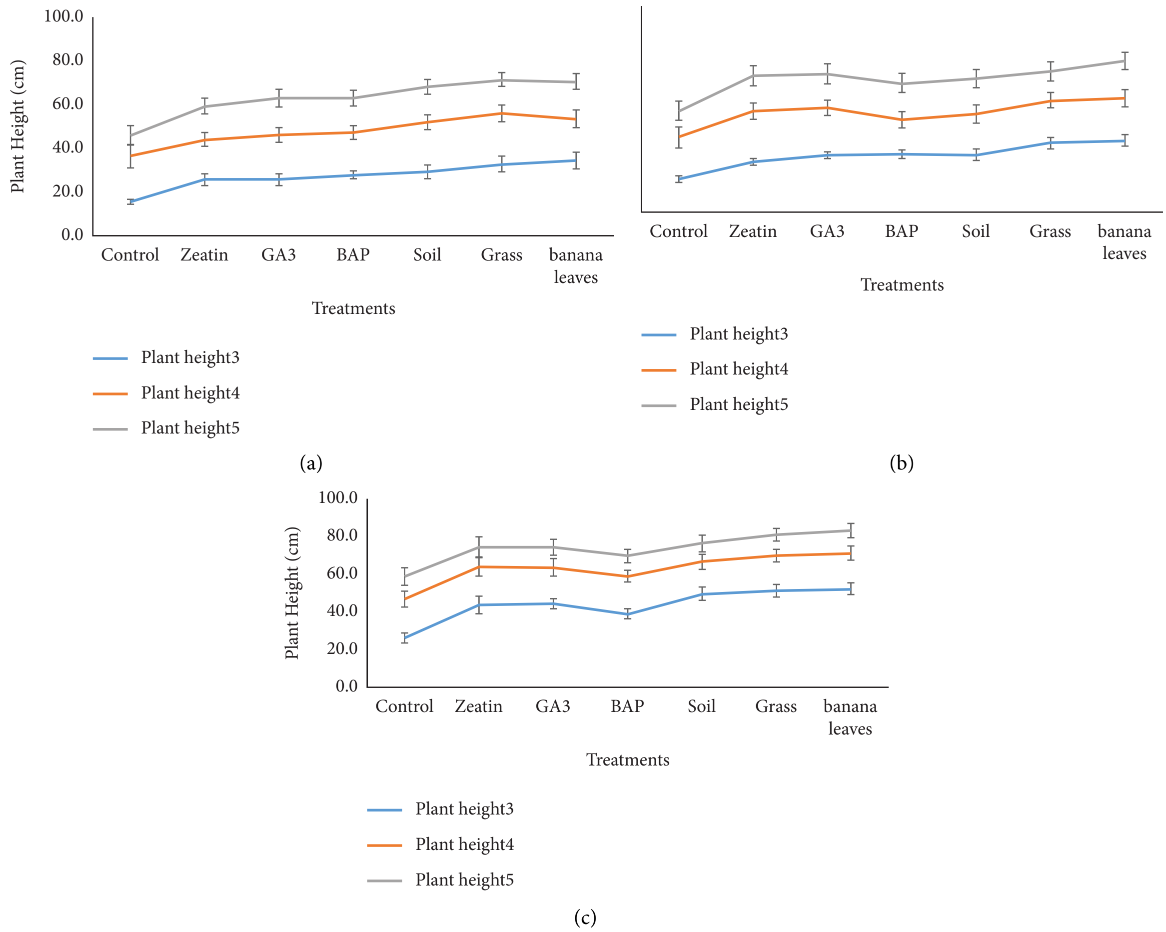

Figure 2: Means and standard error bars of potato plant height as affected by natural materials (soil, banana leaves, and grass) and plant growth regulators (GA3, BAP, and Zeatin). Plant height 3, 4, and 5 weeks after planting. (a) Dutch Robijn; (b) Kenya Karibu; and (c) Shangi variety.

seeds treated with banana leaves had many good-quality sprouts. This could be due to the fact that banana leaves contain ethylene that induces sprouting.

In the experiment conducted by Salda and Bayogan [19], where they evaluated practical methods of breaking tuber dormancy, they found that more than yellow "saba" bananas and madre cacao leaves gave more sprouts per tuber. They further showed that over 80% of tuber sprouting was recorded by seed tubers treated with bananas when compared with dark-stored tubers and nonethylene source treated tubers. The results of this study showed the effectiveness of banana leaves in breaking dormancy, which is in agreement with their results. They further mentioned that bananas and madre cacao leaves are ethylene sources, which have been found to have high levels of ethylene according to [20]. Rlyski et al. [21] stated that ethylene can prematurely terminate dormancy when applied for a short period.

Natural materials increased sprout quality (thickness and length) by almost 174% and 159%, and PGRs by 74% and 48%, compared to the control, indicating the importance of presprouting the seeds in potato production. The pre-sprouted seeds germinate faster and mature early, which has been found to increase yields. Grass and banana leaves have been used for so many years in crop production as mulch and for decomposing the soil, but there is little information on their use on presprouting seed tubers. These materials produced vigorous sprouts, induced sprouting faster, and obtained a higher yield when compared to plant growth regulators and control. This could be attributed to the increased heat generated by the coverage of banana leaves, soil, and grass in a thin layer in the greenhouse, which allowed a portion of light, darkness, and warmth that is needed by a seed to germinate. Suttle [22] reported that heat treatment and dark conditions induce sprouting, which supports the results of this study [17]. Who, in his study, used a small pile of seed potatoes with alternate layers of straw and soil during winter and discovered that natural materials do maintain temperature. The dormancy period of seed tubers can be reduced by higher temperatures, as said by the authors of [23].

The potential of banana leaves, grass, and soil together with plant growth regulators in terms of performance were seen under field evaluation. More than 50% of the seeds treated with natural materials had emerged in the second week of planting and these included Kenya Karibu and Dutch Robijn varieties that have a medium and long

Table 9: Means effects of plant growth regulators and natural materials on plant height and number of stems at different weeks after planting.

Treatments	Week 3	Week 4	Week 5	Overall mean (cm)
Plant height (cm)				
Grass	39.14a	60.02a	73.65a	57.60
BL	40.49a	60.02a	75.86a	58.79
Soil	35.56b	55.49b	69.94b	53.66
BAP	31.68c	50.41c	65.19c	49.09
GA3	32.51c	53.56bc	68.23c	51.43
Zeatin	31.22c	52.54bc	66.68c	50.15
Control	19.19d	39.94d	51.37d	36.83
LSD	3.00	3.21	3.21	
Variety	***	**	*	
Season	**	**	*	
Site	*	**	***	
Season*variety	ns	ns	ns	
Site*variety	*	ns	ns	
Number of stems				
Grass	2.83a	3.64a	4.42a	3.63
BL	3.03a	3.61a	4.40a	3.68
Soil	2.43b	3.28ac	4.16ab	3.29
BAP	2.65ab	3.14c	3.46c	3.08
GA3	2.67ab	3.43ac	3.95b	3.35
Zeatin	2.34 b	3.25c	3.77bc	3.12
Control	1.50c	1.80d	2.33d	1.88
LSD	0.38	0.38	0.41	
Variety	**	***	***	
Season	ns	ns	ns	
Site	**	***	***	
Season*variety	ns	ns	ns	
Site*variety	ns	ns	ns	

Key: means followed by the same letter in the same column are not significantly different ($P < 0.05$), BL: banana leaves, GA3: Gibberellins, BAP: 6-Benzylaminopurine.

Table 10: Means of three potato varieties on plant height and number of stems at different weeks after planting.

Varieties	Week 3	Week 4	Week 5	Overall mean (cm)
Plant height (cm)				
Shangi	43.76a	63.06a	74.02a	60.28
Kenya Karibu	27.47b	48.41b	64.64b	46.84
Dutch Robijn	27.26b	47.95b	63.16b	46.12
Mean	32.83	53.14	67.27	
LSD	5.33	8.25	8.42	
CV	19.65	12.98	10.28	
Season*variety	ns	ns	ns	
Site*variety	*	ns	ns	
Number of stems				
Shangi	2.84a	3.50a	4.11a	3.48
Kenya Karibu	1.91b	2.39b	2.94b	2.41
Dutch Robijn	2.73a	3.60a	4.31a	3.55
Mean	2.49	3.16	3.78	
LSD	0.60	0.57	0.61	
CV	33.11	26.08	23.23	
Season*variety	ns	ns	ns	
Site*variety	ns	ns	ns	

Key: means followed by with the same letter in the same column are not significantly different ($p \leq 0.05$).

dormancy period, while less than 50% had germinated under plant growth regulator treatments. In this scenario, natural materials had increased germination by 57% and PGRs by 29% in week 5 after planting, which was the expected week (28 days) for potato seeds to have emerged. As much as cytokinins and Gibberellins are responsible for bud breakage

Table 11: The mean squares for tuber yield in Molo and Egerton in the 2019–2020 seasons.

Sources of variance	Number of tubers	Small size < 30 mm	Medium size 30–60 mm	Big size > 60 mm	Weight ($t{\cdot}ha^{-1}$)
Site	1139.89***	0.91	8.48*	1.80	2279.41***
Season	4.15	1.61	4.99	0.18	3.13
Rep	15.12	0.19	1.48	0.19	826.57***
Variety	10.97	0.53	0.88	3.41	325.83*
Season*variety	2.87	1.26	5.17	0.18	663.91**
Site*variety	4.27	0.92	2.50	5.09*	270.30*
Site * season* rep* variety	17.56***	0.67**	1.71*	1.19*	103.73***
Treatment	91.70***	8.14***	2.26*	17.67***	1149.13***
Variety*treatment	0.59	0.65*	0.71	0.81	33.13
Error	1.61	0.36	1.01	0.73	25.42
CV	21.04	17.00	24.11	26.64	21.98
R^2	0.87	0.53	0.33	0.53	076

*, **, ***, significant at ($p \leq 0.05$), ($p \leq 0.01$), ($p \leq 0.001$), respectively. CV: coefficient of variation, R^2: coefficient of determination.

Table 12: Means for tuber yield and the effects of plant growth regulators and natural materials in the 2019–2020 seasons at Molo and Egerton sites.

Treatments	Number of tubers	Small size < 30 mm	Medium size 30–60 mm	Big size > 60 mm	Weight $t{\cdot}ha^{-1}$
Grass	7.30b	24.93c	26.98ab	48.09a	23.63a
BL	7.95a	22.57c	29.44a	48.00a	23.51a
Soil	7.01b	27.28c	27.48ab	45.24a	22.20a
BAP	5.39c	48.37b	26.21ab	25.42b	15.85b
GA3	5.66c	48.14b	24.94ab	26.95b	16.74b
Zeatin	5.73c	48.89b	24.47ab	26.64b	16.35b
Control	3.13d	64.38a	22.28b	13.34c	7.85c
Mean	6.02	40.66	25.97	33.38	18.02
LSD	0.59	7.54	6.24	6.21	2.34
Variety	ns	ns	ns	ns	ns
Season	ns	**	*	ns	ns

Key: means followed by with the same letter in the same column are not significantly different ($p \leq 0.05$), BL: banana leaves, GA3: Gibberellins, BAP: 6-Benzylaminopurine.

Table 13: The mean comparison for tuber yield of three potato varieties in the Molo and Egerton 2019–2020 seasons.

Varieties	Number of tubers	Small size < 30 mm	Medium size 30–60 mm	Big size > 60 mm	Weight ($t{\cdot}ha^{-1}$)	Overall mean
Shangi	5.83a	41.30a	23.70a	35.01a	16.50b	24.47
Kenya Karibu	5.80a	39.99a	25.19a	34.83a	20.24ab	25.21
Dutch Robijn	6.44a	40.68a	29.02a	30.31a	17.31 b	24.75

Key: means followed by with the same letter in the same column are not significantly different ($p \leq 0.05$).

Table 14: Combined peasant correlation coefficient with probability values on sprout, growth, and yield parameters.

	Stand count	Plant height	Number of stems	Number of tubers	Tuber grade (>60 mm)	Tuber weight	Number of sprouts	Sprout thickness	Sprout length
Stand count	1.00								
Plant height	0.68***	1.00							
Number of stems	0.50***	0.56***	1.00						
Number of tubers	0.71***	0.58***	0.47***	1.00					
Tuber grade (>60 mm)	0.02	0.03	0.07	-0.10	1.00				
Tuber weight	0.49***	0.52***	0.45***	0.49***	0.19**	1.00			
Number of sprouts	0.17**	0.23***	0.22***	0.22***	0.15*	0.44***	1.00		
Sprout thickness	0.37***	0.31***	0.23***	0.19**	0.30***	0.25***	0.14*	1.00	
Sprout length	0.34***	0.26***	0.20**	0.17**	0.31***	0.26***	0.16*	0.92***	1.00

Key: *, **, ***, significant at ($p \leq 0.05$), ($p \leq 0.01$), ($p \leq 0.001$), respectively.

and sprout growth [11], this study showed that Zeatin, BAP, and GA_3 initiated the sprouting of seed tubers, but they seemed to be very slow compared to natural materials. Thus, the short, medium, and long dormancy periods of Shangi, Kenya Karibu, and Dutch Robijn varieties were effectively enhanced by natural materials rather than PGRs. Hassani (2014), indicated that the application of growth regulator hormones and gibberellic acid caused the postponement of sprouting in his results. However, when compared to the control (washing with water), he found out that plant growth regulator hormones caused significant differences in the number of days to break dormancy. As shown by the results of this study, plant growth regulators did enhance sprouting when compared to control, which is in agreement with his results. The effectiveness of natural materials was again reflected in plant height and yield. Natural materials treated plants were tallest, averaging 75.86 cm, compared to 68.23 cm and 51.37 cm obtained from PGRs treated plants and controls, respectively. The differences could be attributed to fast and slow emergence due to the quality of sprouts obtained from the greenhouse.

In the yield performance evaluation, Kenya Karibu and Dutch Robijn with medium and long dormancies produced higher tuber yields than Shangi, a known high-yielding variety with a short dormancy. However, although Dutch Robijn was the superior in terms of tuber yield, it had a relatively high proportion of small and medium-sized tubers. The increased yields could be due to the effect of presprouting treatments, which have been found to be very effective in hastening tuber dormancy, resulting in increased tuber number, grade, and weight. This result is in line with Johansen's [7] results, who found that the presprouted seeds increased total tuber yield, marketable tubers, and tuber numbers per plant in both of the years he carried out his experiment compared to cold-stored seeds.

The correlation coefficient showed that sprout thickness and length had a significantly strong positive correlation with stand count, plant height, tuber grade, and tuber weight. This means that when sprouts are thick and long, they become more vigorous, resulting in the higher chances of plant emergence and growth. That's according to Solomon's (2006) 5-point scale of sprout vigour. Moreover, the length and thickness of the sprouts, as shown by the peasant correlation coefficient analysis of this study, can increase the size of the tubers and weight due to the high growth rate of the crop. However, it is not guaranteed that the length and thickness of the sprouts can increase the number of tubers, as indicated by the results, where the length and thickness were fairly correlated with the number of tubers but the number of sprouts resulted in a higher number of tubers. The same results were found by Cavalcante et al. [24] that the number of tubers per plant correlated with the number of stems, especially when the tubers were more sprouted.

5. Conclusion

The findings of this study showed that the effect of natural materials and plant growth regulator treatments and their interaction with varieties were significant for yield and for hastening tuber dormancy. Although the tested varieties responded differently to the treatments, natural materials increased sprout quality in terms of length and thickness by 174% and 159%, respectively compared to controls. On the other hand, PGRs increased sprout quality in terms of length and thickness by 74% and 48%, indicating that natural materials are best for chitting. Overall, using natural materials and PGRs increased tuber size by 261% and 103%, respectively. These results suggest that natural materials, which are readily available and cheaper, are effective methods for breaking dormancy for small-scale farmers and hence would boost farmers' yields if adopted. PGRs (GA3, Zeatin, and BAP) also increased yields, but required better facilities like stores and were slightly more expensive, hence can be recommended for use by the large-scale farmers who continuously plant throughout the year and need seed continuously. The Dutch Robijn variety recorded a heavier weight than Shangi, but it had a greater number of small and medium tubers. Therefore, Shangi and Kenya Karibu can be recommended under the presprouting conditions as high-yielding varieties to be used in potato production since they both had good quality sprouts, a good grade, and a heavy weight. [25–29]

Data Availability

The data supporting the results of this study can be found publicly in the manuscript, and datasets analysed or generated during the study are also available.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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References

[1] R. G. F. Visser, C. W. B. Bachem, J. M. de Boer et al., *2009. Sequencing the potato genome: outline and first results to come from the elucidation of the Sequence of the World's third most important food crop American Journal of Potato Research*, vol. 86, pp. 417–429, 2009.

[2] G. K. Asalfew, "Review on the effect of gibberellic acid on potato (*Solanum Tuberosum* L.) Tuber dormancy breaking

and sprouting," *Journal of Biology, Agriculture and Healthcare*, vol. 6, pp. 68–79, 2016.

[3] J. Jane Muthoni, H. Shimelis, and R. Melis, "Potato production in Kenya: farming systems and production constraints," *Journal of Agricultural Science*, vol. 5, no. 5, p. 182, 2013.

[4] CIP, *Seed Potato Production and Certification Guidelines*, Wageningen University, Wageningen, Netherlands, 2018.

[5] C. Riungu, "No easy walk for potatoes. Horticultural news," *The East African Fresh Produce Journal*, vol. 19, pp. 16-17, 2011.

[6] P. D. Muchiri, G. K. Gathungu, M. Njogu, R. Nyankanga, J. Ambuko, and J. Landeo, "Optimization of seed potato (*Solanum tuberosum* L.) tuber dormancy and sprouting capacity through integrated gibberellic acid and benzylaminopurine application," *Journal of Agriculture and Ecology Research International*, vol. 4, no. 4, pp. 188–198, 2015.

[7] T. J. Johansen and E. L. Molteberg, "Effect of storage and presprouting regimes on seed potato performance in Norway," *Potato Research*, vol. 55, no. 3-4, pp. 279–292, 2012.

[8] A. Chandrasekara and T. Josheph Kumar, "Roots and tuber crops as functional foods: a review on phytochemical constituents and their potential health benefits," *International Journal of Food Science*, vol. 2016, Article ID 3631647, 15 pages, 2016.

[9] D. Harahagazwe, B. Condori, C. Barreda et al., "How big is the potato (*Solanum tuberosum* L.) yield gap in Sub-Saharan Africa and why? A participatory approach," *Open Agriculture*, vol. 3, no. 1, pp. 180–189, 2018.

[10] N. Benkeblia, A. A. Alexopoulos, and H. C. Passam, "Physiological and biochemical regulation of dormancy and sprouting in potato tubers (Solanum tuberosum L.)," *Fruit Vegetable Cereal Science Biotech*, vol. 2, pp. 54–68, 2008.

[11] J. C. Suttle, "Physiological regulation of potato tuber dormancy," *American Journal of Potato Research*, vol. 81, no. 4, pp. 253–262, 2004.

[12] N. P. Aksenova, L. I. Sergeeva, T. N. Konstantinova, S. A. Golyanovskaya, O. O. Kolachevskaya, and G. A. Romanov, "Regulation of potato tuber dormancy and sprouting," *Russian Journal of Plant Physiology*, vol. 60, no. 3, pp. 301–312, 2013.

[13] A. Bahadir, N. K. Sahin, R. Beyaz, and M. Yildiz, "Magnetic field effect on breaking tuber dormancy, early sprouting, seedling growth, and tuber formation in potato (Solanum tuberosum L.)," *ScienceAsia*, vol. 46, no. 5, pp. 619–625, 2020.

[14] M. Yildiz, R. Beyaz, M. Gursoy, M. Aycan, Y. Koc, and M. Kayan, "Seed dormancy," *Advances in Seed Biology*, pp. 85–101, Intech, UK, 2017.

[15] Crop Production Summary, *National Agricultural Statistics Service: Agricultural Outlook Forum*, United States Department of Agriculture, Washington, DC, USA, 2013.

[16] A. M. Kumlay, "Combination of the auxins NAA, IBA, and IAA with GA3 improves the commercial seed-tuber production of potato (Solanum tuberosum L.) under in vitro conditions," *BioMed Research International*, vol. 2014, Article ID 439259, 7 pages, 2014.

[17] J. W. Bushnell, *The Normal Multiple Sprouting of Seed Potatoes*, Ohio Agricultural Experiment Station, Wooster, Ohio, USA, 1929.

[18] K. Rykaczewska, "Assessment of potato mother tuber vigour using the method of accelerated ageing," *Plant Production Science*, vol. 16, no. 2, pp. 171–182, 2013.

[19] V. B. Salda and E. R. V. Bayogan, "Practical methods of breaking potato dormancy [Philippines]," *Food and Agriculture Organization of the United Nations*, vol. 11, 1986.

[20] M. S. Tirtosoekotjo and O. K. Bautista, "Acceleration of tomato ripening with ethylene from leaves," *Postharvest Research Notes*, vol. 1, no. 3, pp. 75–77, 1984.

[21] I. Rylski, L. Rappaport, and H. K. Pratt, "Dual effects of ethylene on potato dormancy and sprout growth," *Plant Physiology*, vol. 53, no. 4, pp. 658–662, 1974.

[22] J. C. Suttle, "Dormancy and sprouting," in *Potato Biology and Biotechnology*Elsevier Science BV, Amsterdam, Netherlands, 2007.

[23] M. J. Potts, "Potato production in Benguet Province. Philippines: an example of vegetable production in the Philippines," *MA and PCARRD*, vol. 3, no. 2, pp. 31–79, 1983.

[24] A. C. P. Cavalcante, M. E. P. Soares, G. A. V. d. Andrade, C. D. d. Silva, C. E. M. d. Santos, and L. A. d. Aquino, "Influence of seed tuber size and sprouting stage on the phytotechnical characteristics of the potato var. Ágata," *Australian Journal of Crop Science*, vol. 13, no. 02, pp. 282–286, 2019.

[25] G. O. Abong, M. W. Okoth, J. N. Kabira, J. Ogolla, J. Ouma, and C. W. Ngunju, "Physico-chemical changes in popular Kenyan processing potato varieties as influenced by storage condition," *Current Research in Nutrition and Food Science Journal*, vol. 3, no. 2, pp. 112–120, 2015.

[26] R. V. B. Emma, "Altenative methods of breaking dormancy in seed potato," *Conference: Workshop on Potato Postharvest Technology*, Kunming, Yunnan, China, 1988.

[27] J. Hagman, "Different pre-sprouting methods for early tuber harvest in potato (*Solanum tuberosum* L.)," *Acta Agriculturae Scandinavica, Section B-Soil & Plant Science*, vol. 62, no. 2, pp. 125–131, 2012.

[28] S. M. Malekhooa, P. K. Kimurto, and M. E. Oyoo, "Effects of Plant Growth Regulators, Light and Natural Materials on Dormancy, Growth and Yield of Potato (*Solanum Tuberosum* L.) in Kenya," Msc Thesis, Faculty of Agriculture, Egerton University, Njoro, Kenya, 2021.

[29] Muireann, "Chitting Potatoes," 2017, https://www.fruithillfarm.com/chitting-potatoes.