

Full Length Research Paper

Effect of phosphorus application rates on the quality of potato propagated from rooted apical cuttings

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This study determined the effect of phosphorus application rates on quality of potato tubers. Field experiments were set up at Egerton University, Njoro and Kenya Agricultural Livestock and Research Organization (KARLO), Molo. A randomized complete block design with split plot arrangement and three replicates were used. Main plot factors were varieties (*Shangi*, *Dutch Robyjn*, *Unica* and *Wanjiku*). Sub plot factors were phosphorus levels (0, 30, 60, 90 kg P ha⁻¹). Data collected was subjected to analysis of variance (ANOVA) using SAS software version 9.3. Application of 0 and 60 kg P ha⁻¹ at KARLO Molo resulted in significantly higher (P<0.05) tuber dry matter contents of 23.49 and 25.76%, respectively. *Unica* variety at Egerton site and *Dutch Robyjn* and *Wanjiku* at KARLO, Molo site recorded significantly higher (P<0.001) dry matter and starch contents of 24.70, 25.52, and 23.45%, respectively. *Wanjiku* variety and application of 60 kg P ha⁻¹ resulted in significantly higher (P<0.05) tuber starch content of 22.07%. *Shangi* with 0 and 60 kg P ha⁻¹, *Dutch Robyjn* and *Unica* with 0, 30, 60 and 90 kg P ha⁻¹ and *Wanjiku* with 0, 30, and 60 kg P ha⁻¹ recorded significantly higher (P<0.001) specific gravity of tubers. Application of phosphorus is recommended for improvement in quality of potato propagated from rooted apical cuttings.

Key words: Dry matter, potato, rooted apical cuttings, specific gravity, starch content.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is a major staple food crop in Kenya, second to maize (Janssens et al., 2013), and is important for national food and nutritional security. It is cultivated on 158,000 ha of land mostly by small scale farmers. The potato industry provides employment, income, and facilitates economic growth (Abong et al., 2015). Important quality attributes for processing of potato include dry matter content, starch content and specific gravity. These quality traits are influenced by varieties, environmental conditions, cultural practices and fertilizer application (Öztürk et al., 2010; Hassanpanah,

2011; Abebe et al., 2013; Abong et al., 2015; Mohammed, 2016). Temperature and day length influence the dry matter content through growth of the plants (Kooman and Haverkort, 1995).

Phosphorus promotes early tuber development, increases tuber size and starch synthesis through accumulation of amylose and starch pasting properties in the potato tubers (Jenkins and Ali, 2000; Leonel et al., 2017; Koch et al., 2020). Application of phosphorus in deficient soils improves the tuber specific gravity and dry matter content because it increases starch synthesis and

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fastens maturity (Laboski and Kelling, 2007). Excessive or limited plant nutrition can reduce quality of potatoes (Nand et al., 2011). The study by Misgina (2016) and Kingori et al. (2015) reported that with increase in the phosphorus rates, the dry matter content of the potato tubers reduced significantly, with no significant effect on the starch content of potato tubers.

There is lack of information on effect of phosphorus rates on tuber quality of potato varieties propagated from rooted apical cuttings in Kenya, under varying environments. Hence, this was the objective of this current study.

MATERIALS AND METHODS

Site description

The study was conducted concurrently at two study sites between September 2019 and January 2020. The first site was Egerton University agricultural experimental field (35° 35' E; 0° 23' S) located in Njoro, Nakuru County, Kenya, at an altitude of 2200 m above sea level (masl). The site experiences a tropical climate and the annual mean temperatures range between 15 to 21°C (Climatic data.org, 2019). It receives an annual rainfall of 1132.2 mm. Soils are predominantly sandy loam, well drained and dark brown in colour (Jaetzold et al., 2006). The pH of the top soil (0 - 15 cm) was moderately acidic (5.78) with low available P (25 ppm).

The second site was the Kenya Agricultural Livestock and Research Organization (KALRO), located in Molo (35.7373° E; 0.2472° S), Nakuru County, Kenya. The area receives an average rainfall of 1100 to 1500 mm annually and is located at an altitude of 2500 m asl. The annual mean temperatures range between 15 and 25°C (Climatic data.org, 2019). The site is characterized by loam soils which are moderately well drained, reddish brown with low fertility (Jaetzold et al., 2006). The pH of the soil (0-15°C) was moderately acidic (5.69), with adequate P (30 ppm).

Treatments and experimental design

The experiment was conducted using randomized complete block design (RCBD) with a split plot arrangement, and three replicates. The main plots consisted of four potato varieties (Shangi, Dutch Robyn, Unica and Wanjiku) and the subplots were four levels of phosphorus (0, 30, 60, and 90 kg P ha⁻¹) giving a total of 16 treatment combinations.

Agronomic practices

Primary and secondary cultivation was carried out manually. Rooted potato apical cuttings, were obtained from Stokman Rozen Company located in Naivasha, Kenya. They were acclimatized to the external environmental conditions through hardening off process in the screen houses before planting to the open fields. They were planted at spacing of 75 cm between plants and 35 cm between rows. Triple super phosphate (46% P₂O₅) fertilizer was applied as per the treatment rates in the planting holes and mixed thoroughly with the soil. Urea (46%) was applied in all plots, at a rate of 50 kg N ha⁻¹ in two splits; two weeks after planting and during the vegetative stage of potato, prior to flowering. Muriate of potash (60% K₂O) was applied at rate of 30 kg ha⁻¹ as basal fertilizer during planting to supply potassium. Weeding was done two weeks after planting and during the vegetative stage. During

tuber initiation stage, earthing up was done to reduce effect of direct sunlight from the tubers. After reaching maturity, tubers from five plants were harvested from internal rows in each plot.

Data collection

Tubers from each plot were randomly picked and washed. A sample weighing 500 g was sliced and dried in an oven at 105°C for 72 h to determine the dry matter content (Bewell, 1937). The dry matter was then calculated as follows:

$$\text{Dry matter (\%)} = \frac{\text{weight of sample after drying}}{\text{Initial weight of sample}} \times 100$$

The specific gravity of tubers was determined by weighing potatoes in air and when immersed in water (Lulai and Orr, 1979).

$$\text{Specific gravity} = \frac{\text{weight in air}}{\text{Weight in air} - \text{weight in water}}$$

Starch content of tubers was determined according to methods described by McGrance et al. (1998).

Statistical analysis of data

Data collected was subjected to analysis of variance (ANOVA) using SAS software version 9.3 where the Fishers' F-test was significant at P<0.05, and highly significant at P<0.01, the means were separated using the least significant difference (LSD) test at P<0.01.

RESULTS AND DISCUSSION

Dry matter content

The interaction effects of study sites and phosphorus rates, and location with potato varieties on tuber dry matter content were significant at P<0.05 and P<0.001, respectively (Table 2). Application rates of 0 and 60 kg P ha⁻¹ at KALRO Molo resulted in significant (P<0.05) tuber dry matter contents of 23.49 and 25.76%, respectively (Table 3). Environmental factors such as temperature, rainfall, solar radiation and day length influence tuber dry matter content (Kooman and Haverkort, 1995; Abong et al., 2015). Unica variety at Egerton site and Dutch Robyn and Wanjiku at KARLO, Molo site recorded significantly higher (P<0.01) dry matter contents of 24.70, 25.52, and 23.45%, respectively (Table 3). Other researchers reported significant differences in tuber internal traits due to varieties (Hassanpanah, 2011; Abebe et al., 2013). The effect of interaction between varieties and phosphorus rates on dry matter content was not significant (P<0.05) (Table 1). This result agrees with the findings of Zelalem et al. (2009) who reported decreased dry matter content of tubers with increase in phosphorus and nitrogen rates.

Table 1. Summary of analysis of variance for potato tuber dry matter content, starch content and specific gravity as influenced by phosphorus rates, varieties and study site.

Source of variation	d.f	Dry matter		Starch content		Specific gravity	
		F Value	Pr > F	F Value	Pr > F	F Value	Pr > F
Replicate	2	0.02	0.97	0.09	0.91	0.00	0.99
Replicate × Variety	6	0.18	0.98	0.16	0.98	0.01	1.00
Location	1	1.48 ^{ns}	0.22	0.16 ^{ns}	0.69	6.17**	0.015
Variety	3	2.53 ^{ns}	0.06	1.58 ^{ns}	0.20	3.04**	0.03
Location × Variety	3	10.56***	<0.0001	19.34***	<0.0001	4.63**	0.005
Phosphorus	3	7.05**	0.0004	6.17**	0.0009	13.85***	<0.0001
Location × Phosphorus	3	2.80**	0.04	1.46 ^{ns}	0.23	4.33**	0.007
Variety × Phosphorus	9	1.58 ^{ns}	0.14	2.82**	0.007	5.42***	<0.0001
Error	65	-	-	-	-	-	-
CT	95	-	-	-	-	-	-
CV	-	12.70	-	21.79	-	12.43	-
R ²	-	0.56	-	0.63	-	0.67	-

Significant at (P≤0.05); *significant at (P≤0.001).

Table 2. Interaction effect of study sites and phosphorus rates on dry matter content, starch content and specific gravity of tubers (mean ± SD).

Study site	P rates	Dry matter content (%)	Starch content (%)	Specific gravity
Egerton	0	21.73 ± 0.81 ^{bc}	15.04 ± 0.89 ^{ab}	1.06 ± 0.01 ^a
	30	21.71 ± 0.75 ^{bc}	13.91 ± 0.63 ^b	1.01 ± 0.02 ^a
	60	22.88 ± 1.49 ^{bc}	17.66 ± 2.02 ^a	1.06 ± 0.02 ^a
	90	21.40 ± 0.63 ^{bc}	15.28 ± 0.97 ^{ab}	0.96 ± 0.02 ^a
KALRO Molo	0	23.49 ± 0.55 ^{ab}	15.41 ± 0.83 ^{ab}	1.02 ± 0.01 ^a
	30	20.51 ± 0.75 ^c	15.78 ± 0.82 ^{ab}	1.00 ± 0.02 ^a
	60	25.76 ± 1.41 ^a	18.60 ± 2.16 ^a	1.07 ± 0.02 ^a
	90	20.77 ± 0.76 ^c	13.22 ± 1.16 ^b	0.75 ± 0.12 ^b
P		0.001	0.001	0.05
Mean		22.27	15.61	0.99
CV (%)		12.70	21.79	12.43

Means within a column followed by the same letters are not significantly different (P<0.05), (P<0.001). CV= Coefficient of variation.

Starch content

The interaction effects of study sites and varieties, and varieties and phosphorus rates on tuber starch content were highly significant at P<0.001 and P<0.05 (ANOVA), respectively (Table 1). Unica variety at Egerton site and Dutch Robyn at KALRO Molo recorded highly significant (P<0.01) starch contents of 20.53 and 19.16%, respectively (Table 3). Wanjiku variety and rate of 60 kg P ha⁻¹ resulted in significantly higher (P<0.05) tuber starch content of 22.07% (Table 4). Phosphorus contains nucleic acids, nucleotides, coenzymes and phospholipids that are responsible for biochemical and physiological

reactions using ATP (Taiz and Zeiger, 2006) that involves photosynthesis and conversion of sugar into starch in plants (Taheri et al., 2012; Kumar et al., 2017).

Specific gravity of potato tubers

The interaction effects of study sites and phosphorus rates, and study sites and varieties on specific gravity of potato tubers were significant (P<0.05) (Table 2). Application of 90 kg P ha⁻¹ led significantly lower specific gravity (P<0.05) at KALRO, Molo (Table 3). Wanjiku at KARLO Molo had significantly lower (P<0.05) values

Table 3. Interaction effect of study sites with varieties on dry matter content, starch content and specific gravity of potato tubers (mean \pm SD).

Study site	Variety	Dry matter content (%)	Starch content (%)	Specific gravity
Egerton	Shangi	21.12 \pm 0.87 ^{bc}	14.52 \pm 0.81 ^{cd}	1.00 \pm 0.02 ^a
	Dutch Robyjn	20.72 \pm 0.73 ^c	12.17 \pm 0.94 ^d	1.00 \pm 0.02 ^a
	Unica	24.70 \pm 1.14 ^a	20.53 \pm 1.29 ^a	1.04 \pm 0.02 ^a
	Wanjiku	21.18 \pm 0.63 ^{bc}	14.68 \pm 0.44 ^{cd}	1.05 \pm 0.00 ^a
KALRO Molo	Shangi	20.87 \pm 0.71 ^{bc}	14.52 \pm 1.16 ^{cd}	0.93 \pm 0.02 ^{ab}
	Dutch Robyjn	25.52 \pm 0.57 ^a	19.16 \pm 0.67 ^{ab}	1.04 \pm 0.01 ^a
	Unica	20.69 \pm 0.70 ^c	12.79 \pm 0.62 ^d	1.03 \pm 0.01 ^a
	Wanjiku	23.45 \pm 1.53 ^{ab}	16.54 \pm 2.11 ^{bc}	0.84 \pm 0.13 ^b
Mean		22.27	15.61	0.99
CV (%)		12.70	21.79	12.43

Means within a column with the same letters are not significantly different at ($P < 0.05$), CV= Coefficient of variation.

Table 4. Interaction effect of varieties and P rates on starch content and specific gravity of potato tubers (mean \pm SD).

Variety	P rates	Starch content	Specific gravity
Shangi	0	16.96 \pm 1.10 ^{bc}	1.00 \pm 0.03 ^{abc}
	30	18.85 \pm 1.28 ^{cd}	0.89 \pm 0.01 ^c
	60	15.49 \pm 1.30 ^{bcd}	1.07 \pm 0.01 ^{ab}
	90	11.78 \pm 1.16 ^d	0.91 \pm 0.02 ^{bc}
Dutch Robyjn	0	14.32 \pm 1.00 ^{bcd}	1.07 \pm 0.02 ^a
	30	16.57 \pm 1.06 ^{bcd}	1.03 \pm 0.00 ^{abc}
	60	15.63 \pm 2.89 ^{bcd}	0.99 \pm 0.02 ^{abc}
	90	16.15 \pm 2.16 ^{bcd}	0.99 \pm 0.04 ^{abc}
Unica	0	16.31 \pm 1.54 ^{bcd}	1.05 \pm 0.00 ^{ab}
	30	16.05 \pm 0.32 ^{bcd}	1.05 \pm 0.01 ^{ab}
	60	19.33 \pm 3.76 ^{ab}	1.09 \pm 0.02 ^a
	90	14.95 \pm 1.51 ^{bcd}	0.96 \pm 0.00 ^{abc}
Wanjiku	0	13.32 \pm 0.41 ^{cd}	1.04 \pm 0.00 ^{abc}
	30	12.91 \pm 0.84 ^{cd}	1.06 \pm 0.00 ^{ab}
	60	22.07 \pm 2.88 ^a	1.12 \pm 0.02 ^a
	90	14.13 \pm 0.77 ^{cd}	0.57 \pm 0.21 ^d
Mean		15.61	0.99
CV (%)		21.79	12.43

Means within a column with the same letters are not significantly different at ($P < 0.001$), CV= Coefficient of variation.

(Table 4). The interaction effect of varieties and phosphorus on specific gravity of potato tubers was highly significant ($P < 0.001$) (Table 1). Shangi with 0 and 60 kg P ha⁻¹, Dutch Robyjn and Unica with 0, 30, 60 and

90 kg P ha⁻¹ and Wanjiku with 0, 30, and 60 kg P ha⁻¹ recorded significantly higher ($P < 0.001$) specific gravity of tubers (Table 4). However, increasing the amount of phosphorus to 90 kg P ha⁻¹ reduced the specific gravity of

potato tubers for Wanjiku variety. The factors that affect specific gravity of tubers are variety, location and fertilizer treatments applied (Islam and Nahar, 2012; Khan et al., 2020). Zelalem et al. (2009) also reported that application of high P rates had no significant effect on specific gravity of tubers. The dry matter content was significantly and positively correlated with starch content of the tubers ($r = 0.80^{***}$). Specific gravity of tubers was significantly correlated with dry matter content ($r = 0.28^*$) and starch content ($r = 0.29^*$). This is consistent with the findings of Chala et al. (2017), which showed that there was positive correlation between specific gravity and dry matter content.

Conclusions

Phosphorus is a very important element for physiological and metabolic crop growth. The application of phosphorus improved quality attributes of potato varieties propagated from rooted apical cuttings in both study sites. The application of P application, even at low rates, is recommended in the acidic soils which have the capacity for P retention.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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