POTATO PRODUCTION UNDER IRRIGATION IN HOT CONDITIONS: A REALITY OR A MIRAGE?

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ABSTRACT
In Kenya, potato is the second most important crop after maize in terms of production and consumption. It is grown in the highlands (1500 and 3500 mabove sea level). Traditionally high potential areas are becoming drier due to effects of climate change. Over 80% of Kenya's landmass is hot and dry and therefore unsuitable for arable farming especially for production of cool season crops like potato. Kenya is endowed with fresh water bodies mostly rivers which have traditionally been used for production of paddy rice under irrigation. Rice has traditionally been rotated with maize in these irrigation schemes. Maize necrotic virus disease has recently led to huge losses in maize. The disease has no cure and maize production in the country is becoming a gamble. Maize takes a long time to mature; an alternative short-duration crop such as potatoes could fill in the gap. A study was undertaken at National Irrigation Board Perkerra station to evaluate the performance of local potato germplasm under irrigation in hot conditions. The study was carried out between 6th November 2013 and 21st February 2014. The experimental materials consisted of 33 potato genotypes; 12 advanced clones from CIP and 21 released/farmers' varieties that are already being grown by farmers in the country. Generally, locally released/farmer varieties had higher % plant survival and stand establishment than the advanced clones from CIP. All varieties had lower yields than they do when grown in the cool highlands. The older varieties introduced into the country long ago had lower yield reduction compared with recently released varieties; possibly the older varieties have become adapted to local climatic conditions. The study needs to be repeated to validate these results.
Key words: *Advanced clones, Hot Conditions, Irrigation, Potatoes*

INTRODUCTION
In Kenya, potato is the second most important crop after maize in terms of production and consumption. The crop is grown mainly by small scale farmers as a cash and food crop and therefore plays an important role in food and nutrition security (MoA, 2005, 2008). Potato is grown by about 800 000 farmers, on 158 000 hectares per season, with an annual production of about 1 million tonnes in two growing seasons (Riungu, 2011). Potato is a cool season crop and grows best between 15^0 C and 18^0 C (Haverkort et al., 1990) and soil pH of 5.5 (Kanyanjua and Agaya, 2006). The potato has been grown traditionally in the high potential areas of the country which are characterized by cool temperatures with high rainfall of at least 1000 mm per annum and are situated at altitudes between 1500 and 3500 meters above sea level. With the increasing population and consequent diminishing land sizes in these areas, there has been migration to the lower, warmer and drier areas, where the migrants have moved with their cropping systems including the potato. Over eighty percent of Kenya's landmass is hot and dry and therefore unsuitable for arable farming especially for production of cool season crops like potato (FAO, 2008). Luckily, the country is endowed with fresh water bodies mostly rivers which have traditionally been used for production of paddy rice under irrigation. Rice has traditionally been rotated with maize in these irrigation schemes. However, the maize necrotic virus disease has recently led to huge losses in maize. Currently, the disease has no cure and maize

production in the country is becoming a gamble. In addition, maize takes a long time to mature; an alternative short-duration crop such as potatoes could fill in the gap.Although irrigation may mitigate the problems of low and erratic rainfall, high temperatures and high soil and water pH may limit the production of potatoes in these areas. This calls for development of locally adapted potato varieties that may tolerate heat without compromising on tuber yield and quality. In any successful breeding programme, identification of potential parents through screening of the available germplasm is crucial. Against this background, a study was undertaken at National Irrigation Board Perkerra station to evaluate the performance of local potato germplasm under irrigation in hot conditions.

MATERIALS AND METHODS

Site Characterization

The study was carried out at the National Irrigation Board at Perkerra irrigation scheme. The station is situated about 100Km north of Nakuru in Marigat township, Baringo County, in the former Rift Valley Province. It lies at an altitude of 1067 meters above sea level, latitude 0^0 28' 30'' N and longitude 35^0 56' 20'' E. The average annual rainfall is 654 mm with a bimodal distribution and potential evapotranspiration is 1360 mm. A long rainy season occurs between March and May while a short rain season is between October and December (Jaetzold et al., 2006a). The mean temperature ranges from 16.8 to 32.4^{0}C with an average of 24.6^{0}C. The station is situated in agro ecological zone 5 and the major land uses are irrigated and dryland farming, pastoralism involving rearing of cattle, goats, sheep, and camels and beekeeping. The soils are volcanic fluvisols of sandy/silty clay loam texture; they are slightly acid to slightly alkaline, fertile with adequate P, K, Ca and Mg but low in N and C(UNESCO, 1977).

The study was carried out for one season between 6th November 2013 and 21st February 2014. The experimental material consisted of 33 potato genotypes (Table 1). The advanced clones from CIP have high heat tolerance.

Table 1. Potato genotypes used in the study

Genotypes	Genetic type	Source of experimental material
300046.22	Advanced clones	CIP
392079.4	Advanced clones	CIP
393077.159	Advanced clones	CIP
394611.112	Advanced clones	CIP
39818.253	Advanced clones	CIP
398190.89	Advanced clones	CIP
398193.511	Advanced clones	CIP
398201.51	Advanced clones	CIP
398208.219	Advanced clones	CIP
39906.115	Advanced clones	CIP
39962.118	Advanced clones	CIP
703580	Advanced clones	CIP
Arka	Officially released variety	KARI-Tigoni
Asante	Officially released variety	KARI-Tigoni
Bishop Gitonga	Farmer variety	KARI-Tigoni
RoslinEburu (B53)	Officially released variety	KARI-Tigoni
RoslinBvumbwe	Officially released variety	KARI-Tigoni
Desiree	Officially released variety	KARI-Tigoni
Dutch Robyjn	Officially released variety	KARI-Tigoni
Kenya Baraka	Officially released variety	KARI-Tigoni
Kenya Furaha	Officially released variety	KARI-Tigoni
Kenya Karibu	Officially released variety	KARI-Tigoni
Kenya Mavuno	Officially released variety	KARI-Tigoni

Kenya Mpya	Officially released variety	KARI-Tigoni
Kenya Sifa	Officially released variety	KARI-Tigoni
Meru Mugaruro	Farmer variety	KARI-Tigoni
Pinpernel	Officially released variety	KARI-Tigoni
RoslinTana	Officially released variety	KARI-Tigoni
Romano	Officially released variety	KARI-Tigoni
Shangi	Farmer variety	KARI-Tigoni
Sherekea	Officially released variety	KARI-Tigoni
Sterling	Officially released variety	KARI-Tigoni
Tigoni	Officially released variety	KARI-Tigoni

The experiment was laid out as a randomized complete block design replicated three times. Furrows, 75 cm apart were dug and potatoes were planted 30 cm apart on the shoulder of the furrows. Each plot measured 6.75 m^2 and consisted of 30 plants. During planting, DAP (18%N: 46%P_2O_5) was applied at the recommended rates of 500 kg ha^{-1} in furrows before planting. Watering was done through furrow irrigation by gravity when need arose. Weeding, earthing-up and spraying against pests and late blight were carried out as per recommendations for potato production in Kenya (KARI, 2008).

Data Collection and Analysis

During plant growth, data collected included number of emerged plants per plot (taken 21 days after planting) and number of plants that survived until harvest. This data was used to calculate % stand establishment and % plant survival, respectively. When the plants were mature (genotypes matured at different times) all the plants that survived in a plot were harvested. Data collected on plot basis included number and weights of tubers of different sizes i.e. <30, 30-60 and 60< mm in diameter. This data was used to calculate total yields (ton/ha) and % ware potato yields.

Data was analysed using Genstat statistical package, 14th edition (Payne et al., 2011) and means separated using Fisher's Protected LSD Test at 5% (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

The Perkerra site was generally hot throughout the study period (Table 2).

Table 2. Weather data at Perkerra during the study period

	2013				2014		
	Sep.	Oct.	Nov.	Dec	Jan	Feb	March
Min. Temp.	15.9	16.3	17.2	16.4	16.7	17.6	18.2
Max. Temp.	37.2	37.7	35.6	36.3	38.3	39.2	39.3
Mean. Temp.	29	26.2	24.9	25.7	28	27.9	27.9
Total rainfall (mm)	41.7	39.6	90.4	97.8	3	29.0	4.3
No. rainy days	16	15	15	9	5	5	5

The soils in the study area were slightly basic (Table 3).

Table 3. Soil characteristics at Perkerra

	pH	N%	P(ppm)	K (Me%)
Soil	7.8	0.038	39	1.00

There were significant differences ($P<0.05$) among the potato genotypes in terms of % stand establishment and % plant survival (Table 4). Most of the advanced clones from CIP had poor stand establishment and low plant survival. Among the locally released/farmer varieties, Romano, Kenya Sifa, RoslinBvumbwe, Kenya Furaha, Pimpernel and Asante yielded better than the advanced clones 300046.22 and 393077.159 (Table 4).

Generally, locally released/farmer varieties had higher % plant survival and stand establishment than the advanced clones from CIP (Fig.1). This could be due to the fact that the locally released/farmer varieties have been in production locally over time and have somehow become adapted to the local environmental conditions especially the high temperatures. This could also explain the similar yields between advanced clones and locally released/farmer varieties despite the fact that the former are reported to be heat tolerant.

This yield reduction was mainly due to poor stand establishment and low survival rate of the emerged plants. The recently-released late maturing CIP-derived varieties such as Kenya Karibu, 398208.219, Kenya Sifa, 398193.511, 393077.159 and 398190.89 experienced high yield reduction at Perkerra (Table 5). This yield reduction could be due to shorter time to maturity the genotypes underwent at Perkerra probably due to the high temperatures (Table 3). For some older CIP- derived varieties such as Kenya Mavuno and Asante, the yield reduction was less. The case was the same for the older European varieties such as Dutch Robyjn. Because this old European variety has been grown in Kenya over a long period of time, it is likely that is has become adapted to the local conditions.

Generally, the low yields realised from this study could be attributed to the high temperature, high soil pH or both. High temperature leads to faster crop maturity and hence low yield due to shorter dry matter accumulation duration. Potato is a C_3 crop and excessively high temperatures are likely to lead to inefficiency in photosynthesis due to high photorespiration (Monteith, 1973). High soil pH is responsible for phosphorus fixation to form the insoluble calcium phosphate; this leads to low availability of phosphorus to the plant (Ochapa, 1984). Phosphorus fixation is at a minimum at pH levels of 6.0 to 6.5 (Ochapa, 1984). Phosphorus, as phospholipids, is a constituent of all membranes. All nucleotides and nucleic acids and certain proteins contain phosphorus. It stimulates good root development.

Table 4. Potato performance at Perkerra

Genotype	% stand establish-hment		Genotype	% plant survival		Genotype	Tuber yields (ton/ha)	
39962.118	3.33	a	39962.118	0	a	39962.12	0	a
703580	4.45	ab	703580	0	a	703580	0	a
398193.511	10.00	abc	39906.115	30.00	ab	Kenya Karibu	1.68	ab
398208.219	11.11	abc	393077.159	39.05	b	39906.12	2.47	abc
39906.115	12.22	abc	398190.89	52.38	bc	398190.9	3.80	abcd
398190.89	13.33	abcd	398193.511	53.33	bcd	393077.2	4.05	abcde
393077.159	14.44	abcd	Kenya sifa	57.22	bcde	398208.2	4.20	abcde
Kenya Karibu	15.56	abcd	398208.219	61.11	bcdef	Sterling	4.64	abcde
Sterling	24.45	abcde	Kenya Karibu	73.81	cdefg	398193.5	5.78	abcdef
394611.112	30.00	bcdef	394611.112	74.10	cdefg	Meru Mugaruro	6.42	abcdef
Kenya Furaha	32.22	cdefg	39818.253	78.70	cdefg	Kenya sifa	7.70	abcdefg
Kenya sifa	38.89	defgh	Sterling	81.11	cdefg	Bishop Gitonga	9.83	abcdefgh
RoslinTana	42.22	efghi	392079.4	82.39	cdefg	RoslinTana	9.98	abcdefgh
Kenya Baraka	42.22	efghi	Pimpernel	85.42	cdefg	Kenya Baraka	10.91	bcdefghi
300046.22	44.44	efghij	Tigoni	85.59	cdefg	Kenya Furaha	10.96	bcdefghi
398201.51	50.00	efghijk	398201.51	86.06	defg	394611.1	11.83	cdefghij
RoslinBvumbwe	54.44	fghijkl	Dutch Robyjn	86.42	defg	39818.25	12.00	cdefghij
39818.253	56.67	ghijkl	RoslinEburu (B53)	87.08	efg	Shangi	13.43	defghijk
Romano	56.67	ghijkl	RoslinBvumbwe	88.99	efg	392079.4	14.03	efghijk
Desiree	60.00	hijklm	Meru Mugaruro	89.29	efg	300046.2	14.82	fghijk
392079.4	60.00	hijklm	RoslinTana	89.66	efg	Sherekea	15.26	fghijk
Shangi	61.11	hijklm	300046.22	91.03	fg	Arka	17.63	ghijkl
Arka	62.22	hijklm	Romano	91.03	fg	Tigoni	18.82	hijklm
Sherekea	63.33	hijklm	Sherekea	91.76	fg	Kenya Mpya	19.56	hijklm
RoslinEburu (B53)	67.78	ijklmn	Asante	91.79	fg	Romano	20.20	ijklm

Pimpernel	70.00	jklmn	Kenya Mpya	92.11	fg	Desiree	20.20	ijklm
Meru Mugaruro	72.22	klmn	Kenya Mavuno	93.15	fg	398201.5	21.43	jklm
Tigoni	74.44	klmn	Bishop Gitonga	94.34	fg	Kenya Mavuno	22.42	klm
Kenya Mpya	76.67	lmn	Shangi	94.44	fg	RoslinBvumbwe	22.47	klm
Asante	78.89	lmn	Desiree	94.56	fg	Pimpernel	22.92	klm
Bishop Gitonga	78.89	lmn	Kenya Furaha	94.87	g	RoslinEburu (B53)	23.21	klm
Kenya Mavuno	84.44	mn	Kenya Baraka	96.08	g	Dutch Robyjn	27.46	lm
Dutch Robyjn	90.00	n	Arka	97.10	g	Asante	28.64	m
Overall Mean	47.20			75.9			12.99	
LSD	25.97			33.65			10.08	

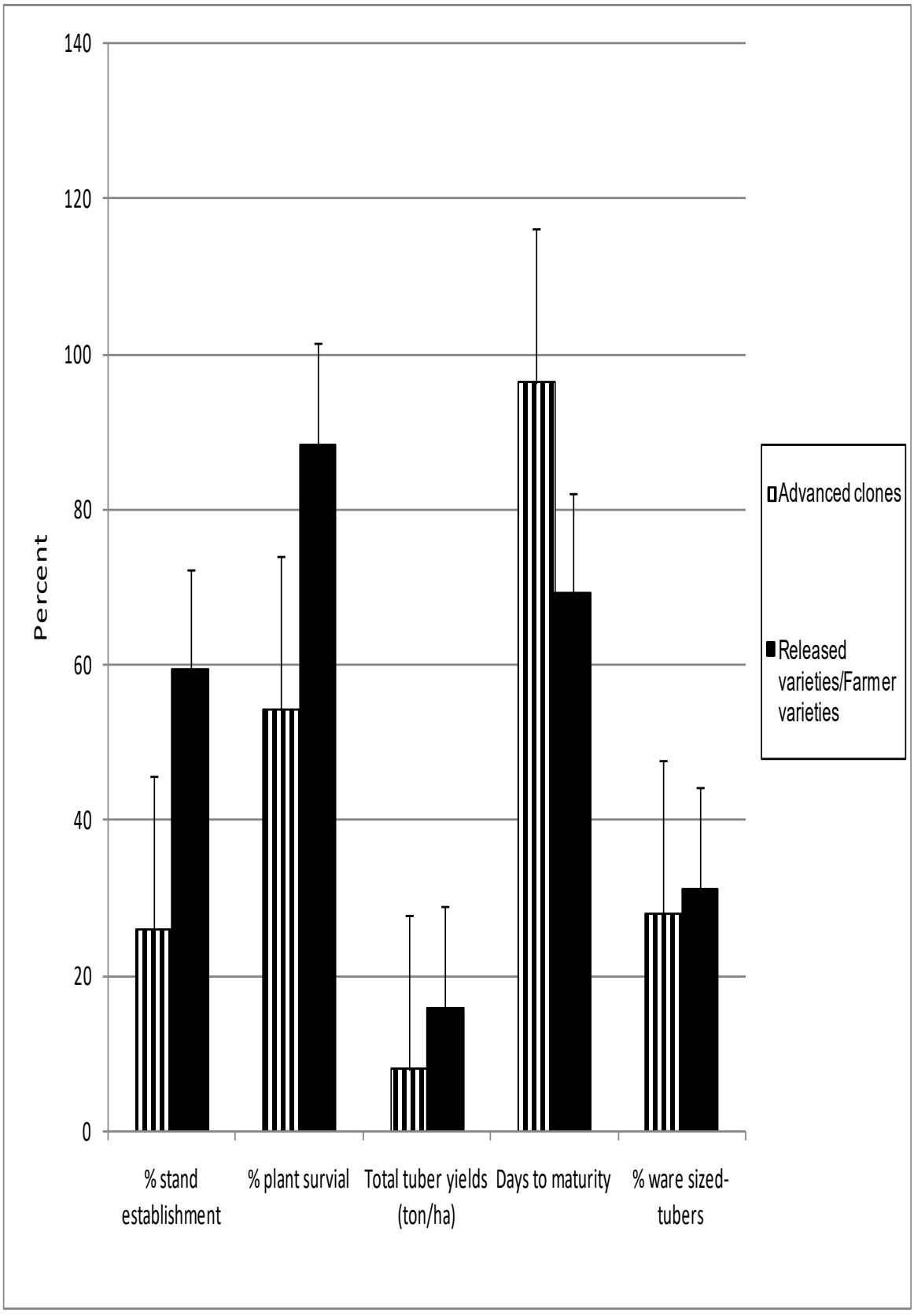

Figure 1. Mean performance of different genotypes

Potato yields realised at Perkerra were far below the potential yields under the same conditions (Table 5).

Table 5. Potential and actual potato tuber yields at Perkerra

Genotype	*Potential tuber yields (ton/ha) at Perkerra	Actual tuber yields (ton/ha) at Perkerra	% yield reduction	Potential yield (ton/ha) under recommended conditions **
39962.118	0.00	0.00	0.00	
703580	0.00	0.00	0.00	
39906.115	8.23	2.47	69.99	
Meru Mugaruro	9.65	6.42	33.47	
Bishop Gitonga	13.80	9.83	28.77	
Kenya Karibu	19.56	1.68	91.41	35-45
Shangi	23.29	13.43	42.34	
Sterling	23.70	4.64	80.42	
39818.253	24.96	12.00	51.92	
398190.89	25.85	3.80	85.30	
Sherekea	25.98	15.26	41.26	40-50
Arka	26.90	17.63	34.46	
Kenya Baraka	27.13	10.91	59.79	
Kenya Mpya	27.85	19.56	29.77	35-45
Kenya Mavuno	28.22	22.42	**20.55**	35-40
RoslinTana	28.37	9.98	64.82	35-45
392079.4	29.75	14.03	52.84	
Tigoni	30.06	18.82	37.39	35-45
Desiree	35.79	20.20	43.56	
393077.159	36.91	4.05	89.03	
Dutch Robyjn	**36.92**	**27.46**	**25.62**	**35-40**
RoslinEburu (B53)	**38.13**	**23.21**	**39.13**	**25-35**
300046.22	38.61	14.82	61.62	
Asante	**39.81**	**28.64**	**28.06**	**35-45**
Pimpernel	39.93	22.92	42.60	40>
Romano	**40.82**	**20.20**	**50.51**	**21-30**
394611.112	42.65	11.83	72.26	
Kenya Furaha	42.66	10.96	74.31	
RoslinBvumbwe	**50.02**	**22.47**	**55.08**	**35-45**
398201.51	50.09	21.43	57.22	
398193.511	50.99	5.78	88.66	
Kenya sifa	**69.11**	**7.70**	**88.86**	**35-45**
398208.219	74.07	4.20	**94.33**	
Mean	32.10	12.99	59.53	

*Assuming 100% stand establishment and 100% plant survival.
**Production under recommended temperature, altitude and management conditions in the highlands.

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