EFFECTS OF FERTILLIZERS ON THE PRODUCTIVITY OF SELECTED POTATO CULTIVARS GROWN IN THE TAITA HILLS KENYA.

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ABSTRACT

Potato (*Solanum tuberosum* L) is an important food crop in Kenya that is produced and consumed by a large population. It creates direct employment to farmers and indirect employment to those working in its value chain. However, in the recent past, production in the Kenyan highlands has been constrained by the rapid decline in soil fertility occasioned by continuous cultivation without adequate replenishment of nutrients. The objective of this study was to establish the suitable high yielding climate smart cultivar and fertilizer rate for the Taita Hills. Yield parameters were measured for four selected potato cultivars grown in Taita hills, (Shangi, Tigoni, Kenya Mpya and Dutch robjin) and eight fertilizer treatments (cattle manure, 0.05ton/ha NPK, 0.1ton/ha NPK, 0.15ton/ha NPK, manure + 0.05ton/ha NPK, manure + 0.1ton/ha NPK, cattle manure and 0.15ton/ha NPK and a control for two seasons. The results from this study showed that the potato cultivar with the highest tuber yield was Shangi. A combination of NPK fertilizer and manure improved the yields. Shangi resulted in an increase in tuber yield with fertilizer than without any fertilizer application. The combination of cultivar and fertilizer rate gave higher tuber yield in the long rains season than in the short rains. The study identified Shangi cultivar as the most suitable for the Taita hills.

Keywords: Cultivar, Productivity, Fertilizer, Season

INTRODUCTION

Potato (*Solanum tuberosum* L.) was introduced in Kenya by the white settlers in the 19th century for consumption and later for export purposes. It is cultivated mainly in the high-altitude areas between 1,500 and 3,000 meters above sea level. Potato is grown in thirteen major counties in Kenya, which include; Meru, Nyeri, Nyandarua, Kiambu, Taita-Taveta, Nakuru, Narok, Bomet, ElgeyoMarakwet, Trans-Nzoia, Bungoma, Uasin- Gishu and West Pokot; Other potato producing counties include Kisii, Nyamira, Kirinyaga, Muranga, Baringo, Nandi, Laikipia and Kericho. (MOALF&CO, 2021) . The importance of potato is attributed to its high nutritive value, good productivity and good processing qualities for starch, flour, bread, soap, alcohol, weaning foods and animal feed (CIP, 2022).

The major constraint to potato production in the cool highlands of Kenya is low yields due the rapid decline in soil fertility occasioned by continuous cultivation without adequate replenishment of mined nutrients (Muthoni, 2009). Soil phosphorus in major potato growing areas of Kenya is as low as 2.9 parts per million (ppm) while total nitrogen is lower than 0.15% (Muthoni, 2019). The situation is exacerbated by the inherently high soil acidity with pH values of 4 to 5 being common in those areas. Due to small land sizes, farmers continuously plant crops on the same land, practicing intensive cropping systems that mainly involve double and relay cropping of different crops without a fallow period (Muthoni, 2009)

Low and declining yield and caused by several factors including low quality and quantity of seed, climate change, inadequate extension services, pests and diseases and more importantly low and declining soil fertility, particularly phosphorus (Akoto *et al.,* 2020). Low soil fertility and fertilizer use in potato production in the country is below the recommended rates. This situation is compounded by the low soil pH resulting into nutrient imbalances in the soils. Though soils in most potato growing areas in the country have low pH due to acidic parent rock, the commonly used fertilizer for potato production [di-ammonium phosphate (DAP) (18:46:0)] has been lowering the soil pH even further over

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time. In order to alleviate the situation, there is need to change the fertilizers used in potato production in Kenya (Muthoni, 2019). Thus, the main objective of the study was to determine the effect the different fertilizer (NPK 17:17:17) levels and manure on the yields of the selected potato cultivars grown in the Taita hills.

MATERIALS AND METHODS

The study site

The study was carried out in the Taita hills (3.4192° S, 38.4980° E), Taita Taveta County (Figure 1). The area has an average monthly temperature ranging from a minimum of 9.3 to 13.5° C to a maximum of 17.9 to 24.4° C. The Taita Hills has a maximum elevation of 2,208 metres above sea level

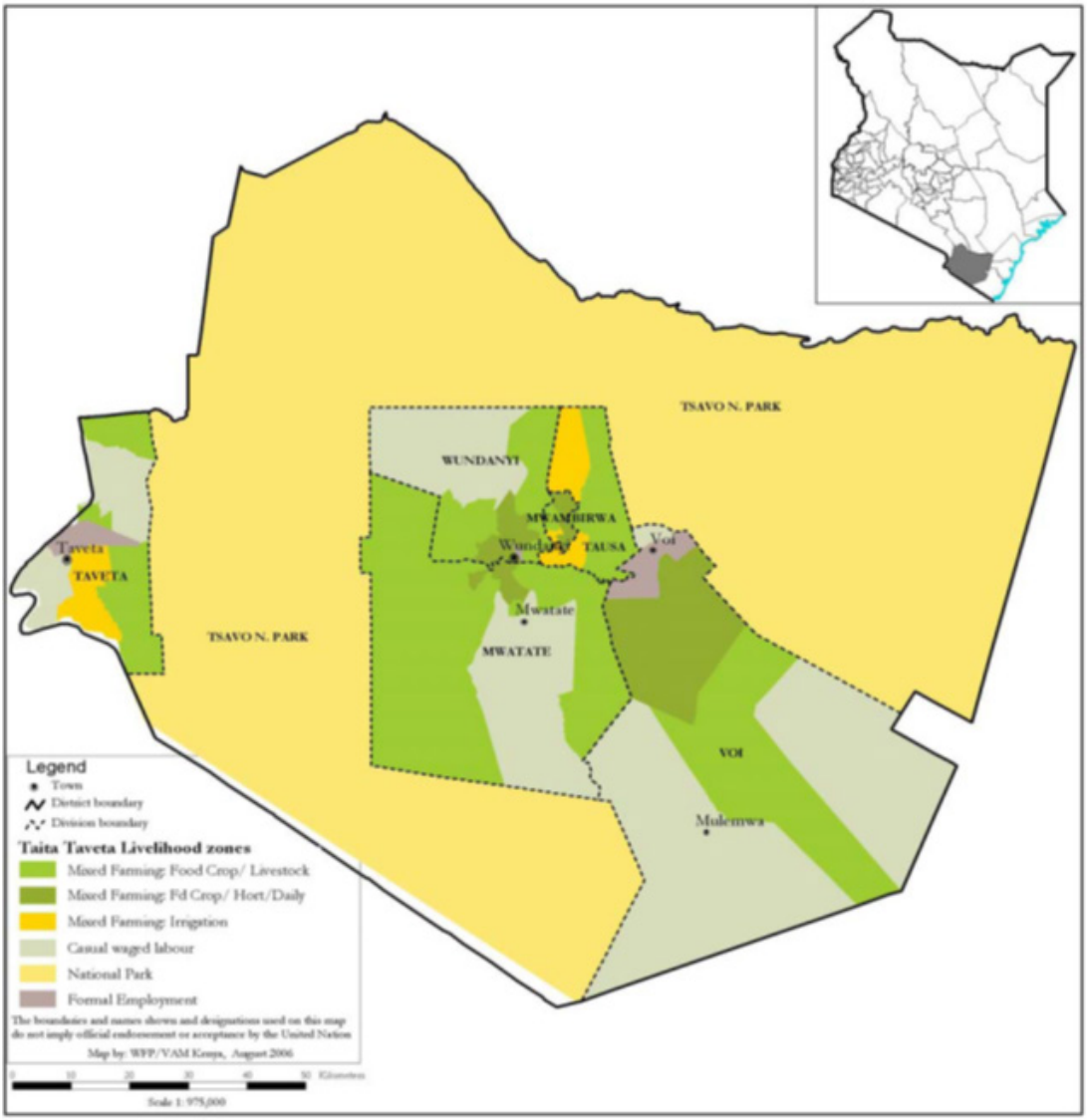


Figure 1. Map of Taita Taveta County showing the study site.

The Selection of the study area was mainly based on the suitability for potato growing (NPCK, 2021)Taita Taveta is among the major potato producing counties in the country with part of the county, around Wundanyi, highland (Taita hills) providing favorable climatic conditions for growing potatoes .The other advantage of the county is its proximity to the major markets of Mombasa, Malindi and Lamu giving it a comparative advantage over other potato producing counties (NPCK, 2021). Figure 2 show the monthly rainfall and average atmospheric temperature, with rainfall and atmospheric temperatures peaks in April and November, respectively.

Climate and soils

Soil sampling for this experiment was done randomly at a depth of 0-30 cm at the study site. Five soil samples were taken in a cross sectional method, mixed thoroughly, air dried, and processed through a 2-mm sieve. The soil was analysed for total nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), copper (Cu), zinc (Zn) and organic carbon (O.C). The total N was analysed using the Kjeldahl method (Bremner, 2009), and P, K, Ca, Mg, Fe, Mn, Cu and Zn using the Mehlich 3 extraction (Mehlich, 2008). Soil pH was measured in water paste with a 1:2 ratio of soil to water. The results are presented in Table 1 showing the pH, N, P, K, Ca, Mg, Fe, Mn, Cu, Zn and organic carbon percentages.

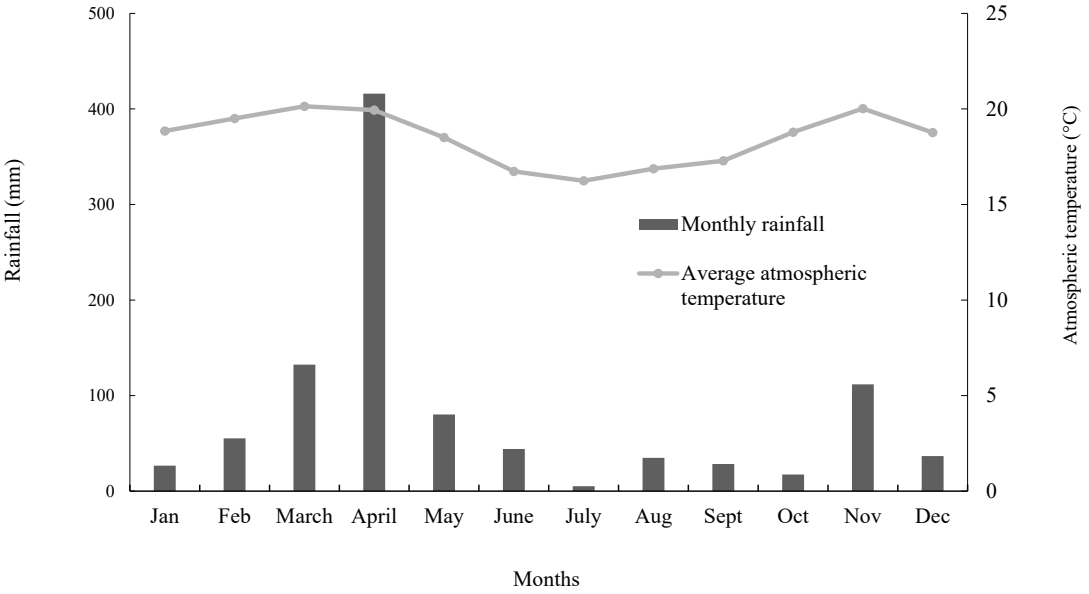


Figure 2. Rainfall and average atmospheric temperature in the study area

TABLE I - RESULTS OF INITIAL SOIL ANALYSIS AT TAITA TAVETA UNIVERSITY - NGERENYI CAMPUS STUDY SITE

				Cmol/kg				**PPM**				
	pH (H_2O)	*%O.C*	*%N*	*K*	*Na*	*Ca*	*Mg*	*Zn*	*Cu*	*Fe*	*Mn*	*P*
Top soil	6.02	3.95	0.40	0.62	0.65	3.16	0.79	7.40	1.85	28.5	16.4	96.2
Top compost	8.78	7.90	1.05	3.05	1.10	16.8	8.5	10.1	0.64	40.5	53.8	1050
Critical Level	5.5	2.5	0.25	0.2	-	0.9	0.3	0.6	0.2	-	-	30.0

Plot Layout

The experiment had two factors, fertilizer and potato cultivar. Fertilizer treatments had eight levels and cultivar four levels. Four selected potato cultivars were treated with seven fertilizer levels and one control for two seasons. A total of thirty-two experimental units measuring 3 m x 3 m were replicated three times. The experiment was established in a randomized complete block design (RCBD).

Land preparation, fertilizer application and planting

The land was ploughed to a depth of 20 cm to break the soil clods and achieve a fine firm, weed free tilth. Furrows of 8-12 cm deep were dug and the tubers placed at a spacing of 75 cm between rows and 30 cm between plants. NPK (17:17:17) was applied at three levels of 0.05ton/ha, 0.1ton/ha and 0.15ton/ha each of (N_2, P_2O_5, and K_2O) during planting. To prevent scorching of the sprouts, the fertilizer was thoroughly mixed with the soil. Well decomposed cattle manure was applied to improve the fertility of the soils for efficient potato production at a rate of 7 tons/ha.

Data collection

At harvest, quantitative data on yield parameters were collected and recorded. Additionally, data on tuber number per plant, total tuber yield and tuber classes.

Data Analysis

The data was subject to test of normality, and independence before ANOVA using Shapiro wilk test (Stephanie, 2022). A three-way analysis of variance (ANOVA) was conducted on the data to compare potato yields on four cultivars under eight fertilizer treatments in two seasons. The collected data on yield parameter were subjected to analysis of variance (ANOVA) using the Proc. GLM statement, and the means separated by Fisher's Least Significant Difference (LSD), at a 95% confidence level using SAS software version 9 (30) . The cultivars, treatments and their interactions were fixed factors while the blocks were random factors over two seasons.

RESULTS

The yield of potato was significantly different between the two seasons, among the cultivars, the nutrient sources, and the interaction between the seasons and cultivars (Table II). The highest significant yield was achieved by Shangi and Tigoni (Figure 3a) in season, respectively.

The results also indicate that Dutch Robjin and Kenya Mpya had similar yields (Figure 3b). The application of 0.15ton/ha NPK plus cattle manure led to the higher yields, although this was similar to the yields on the application of 0.1ton/ha NPK, 0.15ton/ha NPK with or without manure and application of 0.05ton/ha NPK with cattle manure (Figure 3c). Application of no fertilizer or manure led to the lowest yield (Figure 3c).

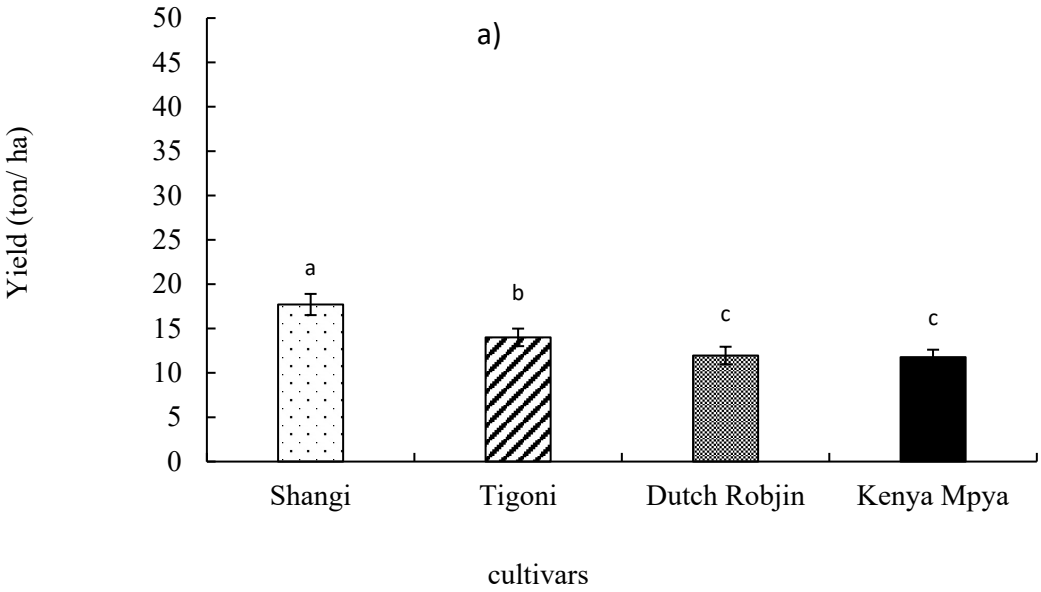
TABLE II - ANOVA RESULTS FOR THE EFFECT OF CULTIVAR, TREATMENT AND SEASON

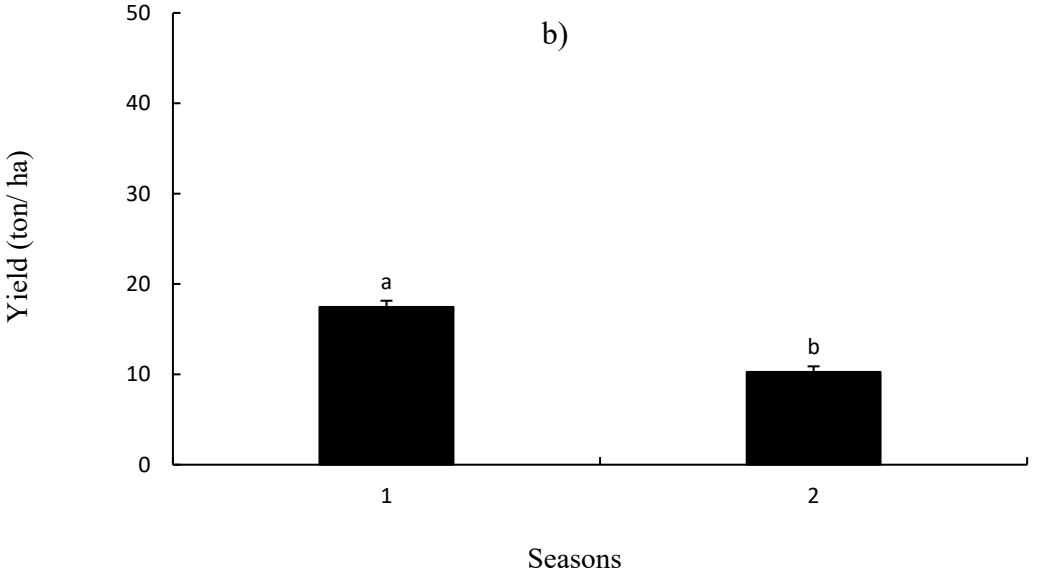
Source	DF	Sum of Square	Mean Square	F Value	*P*
Replicate	2	274.755	137.378	6.500	0.0020
Season	1	2474.300	2474.300	4.140	0.0001
Rep *Season	2	1194.335	597.168	28.470	0.0001
Cultivar	3	1095.884	365.295	17.420	0.0001
Cultivar *Season	3	755.9063	251.969	12.010	0.0001
Treatment	7	629.460	89.923	4.290	0.0003
Season *Treatment	7	178.010	25.430	1.210	0.3008
Cultivar* Treatment	21	670.512	31.929	1.520	0.0815
Cultivar*Season*Treatment	21	475.988	22.667	1.080	0.3772

TABLE III- INTERACTION OF CULTIVAR AND SEASON

	Seasonal production (t/ha)		
Cultivar	Season 1	Season 2	Mean
Dutch Robjin	17.2	6.7	11.9
Kenya Mpya	11.9	11.5	11.7
Shangi	22.3	13.1	17.7
Tigoni	18.3	9.7	14.9
Mean	17.45	10.3	13.85
$LSD_{(0.05)}$	2.65	2.64	2.81
CV%	26.2	44.6	50.3

LSD = Least Significant Difference, CV = Coefficient of Variance





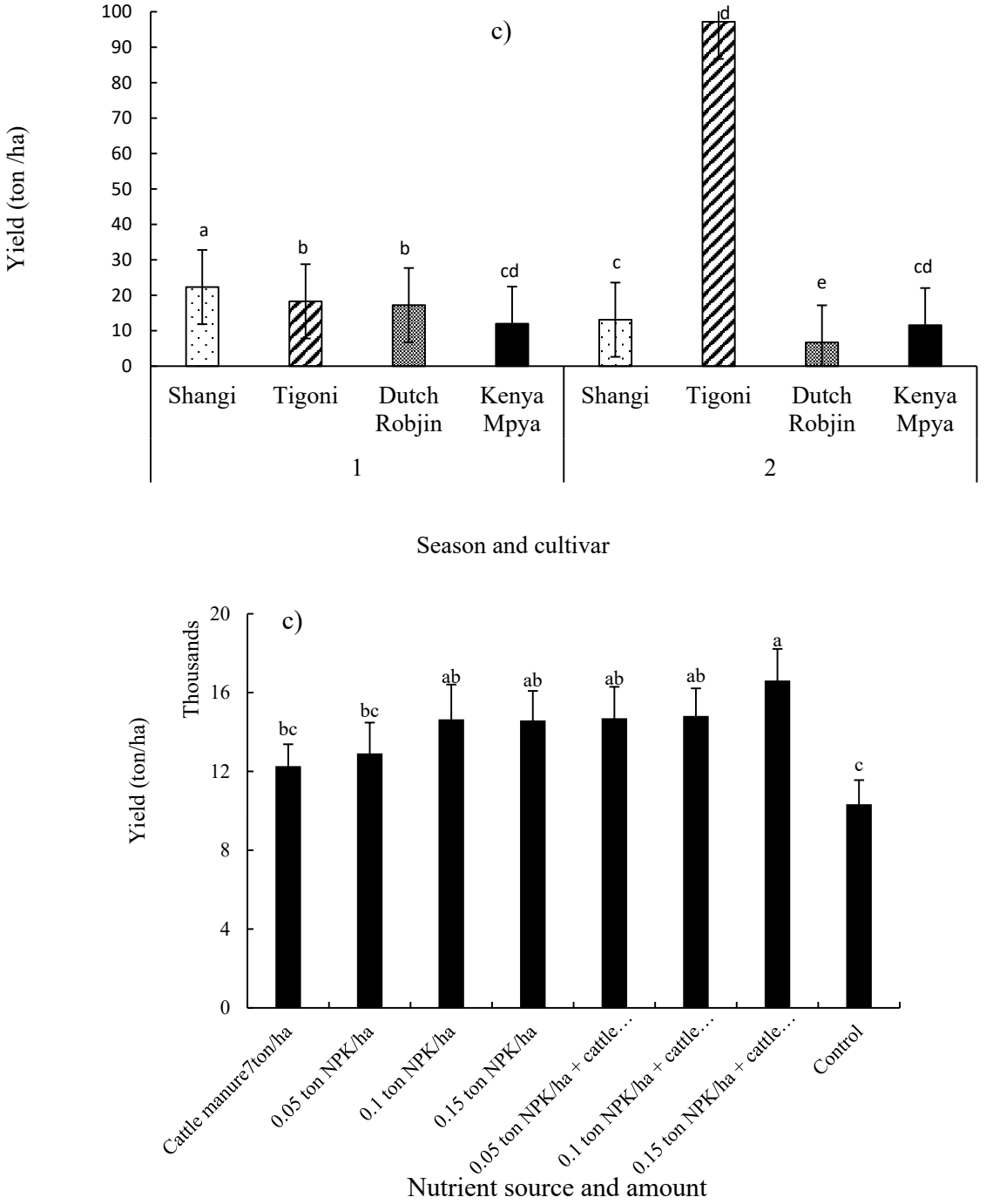


Figure 3. The effect of: a) different cultivars b) various seasons, c) interactions between seasons cultivars on the yield of potatoes and d) sources of nutrient and amounts.

DISCUSSION

The yield of the potato was higher in season one (Figure 3a) due to more charts, medium, large and extra-large tubers. Indeed, Zheng *et al*. (2016) also observed that high number and weight of tubers cumulatively increased yield. Furthermore, during the first season, the rainfall pattern and amounts were ideal (Figure 1) and more than season two. Potato requires 350 - 550 mm annually depending on the cultivars, soil, length of the growing season and atmospheric demand (Begum *et al.*, 2018). However, the rainfall records indicated that this was lesser in season two. Also, the atmospheric temperature in season one was optimum than in season two (Figure 1). Rykaczewska, (2015) reported that atmospheric temperatures from 20 to 25 °C promoted shoot growth, while 15- 20 °C encouraged tuberization and tuber development. This could have been the case in season one and thus higher yield.

Potato cultivar with the highest tuber yield was Shangi, 33.5% above the yield of Kenya Mpya, a cultivar with the lowest yield. Shangi outperformed all the other cultivars due to various reasons. Shangi is a vigorous early maturing cultivars (Kaguora *et al.*, 2017), and this could have led to synchronizing nutrient uptake and plant growth (Jones *et al.,* 2015) before extensive leaching and efficient usage of other resources, such as light before competition from other plants within the season or even pest and disease escape (Campos and Ortiz, 2019).

Applying 0.15ton/ha NPK and cattle manure led to high potato tuber yields, although, this was only about 12% and 38% higher than applying 0.1ton/ha NPK, and not applying any fertilizer or cattle manure. Furthermore, applying this combination of 0.15ton/ha NPK plus cattle manure had about 26% yield advantage against cattle manure application, while cattle manure application had about 16% yield benefit against lack of fertilizer application. Also, applying 0.15ton/ha NPK without cattle manure showed an estimate of 16% yield benefit against cattle manure application alone. In all these scenarios, it would be prudent to give an answer through cost benefit analysis too, if applying such amount of fertilizer (0.15ton/ha NPK plus cattle manure) is economically viable. However, focusing on potato response to the fertilizer and nutrients applied will take precedence. Whereas not applying any fertilizer still produced some potato tubers, application of fertilizer was beneficial. Initial soil analysis indicated that most of the nutrients were not below critical levels in these soils, for example the pH, N, P and K were 6.0, 0.45%, 0.62 Cmol / kg, 96.2 ppm in the soil while the critical levels were 5.5, 0.25%, 0.2 Cmol / kg and 30 ppm, respectively (Mugo *et al.*, 2020).

Remarkably, as Kenya Mpya produced the lowest yields, it is Dutch Robjin that yielded fewer medium, large and marketable tubers, but more charts and seeds. This suggest that Dutch Robjin is not suitable for the test site. These results are supported by Dutch Robjin's agro ecological zone requirement. According to the National Potato Council of Kenya, Dutch Robjin is suited in areas with an altitude of 1800-2600 m above the sea level (a.s.l.) (Kaguora *et al.*, 2017).

The results from this study showed that Shangi was the best performing cultivar whilst Kenya Mpya was the least performer in terms of yields per hectare. Growing potato in the first long rainy season was advantageous than in the second short rainy season and a combination of NPK fertilizer and manure improved the yields. The combination of cultivar and fertilizer rate gave higher tuber yield in the long rains season than the in short rains.

CONCLUSION

The study resulted in various conclusions: the potato variety that is more adaptable to the agro-ecological conditions of Taita hills is Shangi. Whereas Kenya Mpya produced the lowest tuber yield, Dutch Robjin produced fewer medium, large and marketable tubers. Summing the growth, yield and yield parameters, besides leaf area index and germination percentage, Dutch Robjin was less suitable for the Taita hills. Secondly, potato grown in the first long rainy season of March to June performed better than in the short rainy season of October to December, thus first season in Taita hills is suitable for higher potato yields. Thirdly, although application of 0.15ton/ha NPK plus 7ton/ha of cattle manure led to higher yield, the yield was only considerably different from applying 7tonnes cattle manure per ha alone, 0.05ton/ha NPK alone and no fertilizer application. This indicates that a gross margin analysis is required in future to determine the most profitable nutrient and fertilizer combination. Overall, this study has identified the potato variety (Shangi) suitable for Taita hills, the amount of fertilizer (0.15ton/ha NPK plus 7ton/ha of cattle manure) specific for that site and the season (March-June) in which maximum tuber yields can be obtained, a site-variety-nutrient specific study.

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