Eastern Journal of Agricultural and Biological Sciences (EJABS)
ISSN: 2753-3247
Website: https://qabasjournals.com/index.php/ejabs

Determination of Different Rates of Farmyard Manure application on productivity of Irish Potato (Solanum Tuberosum L.) at Southern Oromia, Ethiopia

Solomon Teshome*[1]& Arega Amide[2]

[1]*Oromia Agricultural Research Institute, Crop Research Process, Addis Ababa, Ethiopia, +251910012149*
[2]*Bore Agricultural Research Center, Crop Research Process, Bore, Ethiopia, +251910407817*

Corresponding Author: Solomon Teshome, E-mail: *solomtesh41@gmail.com*

ARTICLE INFO

Received: December 20, 2022
Accepted: February 24, 2023
Volume: 3
Issue: 2

KEYWORDS

Farmyard manure, Marginal rate of returns, Potato, Winter, Yield, Zero.

ABSTRACT

The field experiments were conducted during the two successive winter seasons to study the response of potato plant (Solanum tuberosum L.) by the application of organic FYM rates on growth, yield and yield components and to identify their economically appropriate rates that maximize yield of Irish potato. The experiment was arranged in four level of farmyard manure (0, 3, 6 and 10 tons ha-1) in one way Anova with blocking of RCBD with 3 replications. The result of the experiment indicated that main effect of FYM significantly ($P<0.05$) influenced most growth and yield and yield related parameters except, on days to emergency, flowering and unmarketable yield. Application of farmyard manure improved the productivity of potato plants and it was increased with increasing of the rate of farmyard manure levels up to 10 t ha-1 in both seasons. The highest plant height (65.43 cm) was obtained at 10 t ha-1 FYM, while the lowest plant height (37.00 cm) was recorded at control treatment. The maximum stem number per plant (8.5) was recorded at 10 t ha-1 FYM, while the minimum (3) was recorded at control treatment. And also the highest (265.7 kt ha-1) marketable tuber yield was observed with 10 t ha-1 of FYM levels and the lowest (143.9 kt ha-1) was recorded with the zero treatment. The maximum (308.7 kt ha-1) fresh total tuber yield was recorded with 10 t ha-1 FYM rates and the least (206.1 t ha-1) total tuber yield was recorded at rate of zero application. Therefore treatments with farmyard manure gave the highest yield with high significant difference in comparison to the rest treatments. Considering the whole our economic analysis result proved that the maximum net benefit of 350962 Birr ha-1 with an acceptable MRR of 4088.95 % was obtained from treatment that received 10 t ha-1 of FYM fertilizer rates and could be recommended for production of potato in the study area.

1. Introduction

Irish Potato (Solanum tuberosum L.) is one of the most economically important and widely grown tuber crops in the high and mid altitudes of southern region. The crop is widely grown in Bore and Anasora areas. As a productive crop, it can greatly contribute in securing food in these highly populated areas. Basically it is also an important alternative crop for grain is the staple food for the countries of Africa and the major crop having great effect daily of the areas. In Ethiopia root and tuber crops are part of the traditional food systems of the people especially in the southern, southwestern and western part of the country. There is enormous possibility for millions of poor farmers to boost production and their livelihood using root and tuber crops which are strategic crops for the country's economy (Amsalu et al., 2008).

As it was mentioned by Ali et al (2009) fertilizers is one of the most important inputs of increasing the productivity of crops and modern varieties of different crops. It is obvious that now a days the price of those organic fertilizers was dramatically on an increment situation. But according to the economic status of the most farmers they were unable to purchase and use for it. So even though this organic fertilizers completely replace readily available of those synthetic fertilizers, it can be used as readily available resource in the farming community.

Similarly the use of organic manure to supplement inorganic fertilizer use helps to reduce the high cost of soil mineral input as it was hypothesized above. A number of studies carried out on organic and inorganic fertilizers combination in potato have

officially the positive effects on yield of the crop (Palm et al., 1997). Currently, potato yields have stay the same between 5 and 9 tons per hectares compared to the achievable farmer yields of about 20 tons per hectare (Otieno, 2019). The low yields could be attributed to soil infertility, improper use of fertilizer, foliar pests and diseases, use of poor quality tuber seeds and low yielding varieties, untimed weed control, and within-season droughts as reported by (Schulte, 2013; Muthoni and Kabira, 2016; Otieno, 2019b; Okeyo et al., 2019; Mugo et al., 2020).

In general, farmers in the study area mostly do not use fertilizers rather organic in Irish potato production. Even though they use nutrients it was un-recommended rate. Although there are more than enough amount of Farm Yard Manure in the area, farmers often do not use FYM for potato production and do not know its possible effect on the productivity of the crop. Now a day there is no research information on combined use of organic application particular to tuber yield and yield related traits of Irish potato in the study area. In view of this fact, a systematic investigation of the effect of using organic nutrients like accessible and affordable FYM is felt to be of paramount importance for increasing the production of Irish potato in the study area. Therefore, to address the problem, study was conducted to assess the effects of FYM on yield related traits and tuberous root yield of Irish potato; and to identify economically feasible rates of farm yard manure for Irish potato production in the study area.

2. Methodology

2.1. Description of the study area

The experiment was conducted at Bore station, for two cropping season to select and recommend high yielding and diseases tolerant improved Irish potato varieties through participatory variety selection. Bore Agricultural Research Center site is located at the distance of about 8 km west of the town of Bore in Songo Bericha 'Kebele' just on the side of the main road to Addis Ababa via Hawasa town. Geographically, the experimental site is situated at the latitude of 06°23'55''N and longitude of 38°35'5''E at an altitude of 2736 m above sea level. The climatic condition of the area is most humid and sub humid moisture condition, which relatively longer growing season.

2.2. Description of Experimental Materials

Irish potato variety "Gudene" was used as experimental material. The seeds of the variety were obtained from the team seed maintenance program. The choice of this variety was due to its good adaptability and yield. The variety is found at large on farmers hand and it is widely cultivated and consumed in different highland parts of the Zone and best variety for highlands of the area.

2.3. Experimental Design and Treatments

The field trial was conducted for two main cropping season at the Bore Agricultural Research Centre which is located in Guji Zones, of Southern Ethiopia with the objective of determining the effect of application of organic FYM rates on growth, yield and yield components of Irish potato and to identify their economically appropriate rates that maximize yield of Irish potato. The experiment was arranged in four level of farmyard manure (0, 3, 6 and 10 tons ha-1) in RCBD with 3 replications. The spacing of the plants was 75 cm between rows and 30 cm between plants. The distance between plot and block was 1.5 m and 0.60m, respectively. Four rows per plot and seven plants per row, totally 35 plants per plot were established in gross plot size of 3.00m*2.1 m (6.30m2).

2.4. Soil and Farmyard Manure Sampling and Analysis

After harvest soil sampling was taken in the "W" manner from 12 different plots. Then the sample was composited per treatment and samples were analyzed for physico-chemical properties of the soil mainly for organic carbon, total N, soil pH, available phosphorus, cation exchangeable capacity (CEC), and texture at Horticoop Ethiopia Plc laboratory for soil and manure, respectively. The manure was collected from known farmer near to the experimental site and composted in the research station and air dried, and analyzed at laboratory for pH, total N, available P, available K, available S, CEC, organic carbon content and Textural class.

2.5. Crop data collection

Days to 50% emergency, flowering, maturity, plant height (cm), stem number, average tuber weight (g), average tuber number per plant, marketable and unmarketable yield and total yield (kg) per plot was measured and converted to hectares. Cost benefit analysis was done to determine the relative economic returns on the applied treatments using the prevailing market prices.

$$\text{MRR (\%)} = \frac{\text{Marginal benefit}}{\text{Marginal Cost}} \times 100$$

2.6. Statistical Data Analysis

Analysis of variance procedures was used on every measured parameter to determine the significance of differences between means of treatments using the SAS 9.1.3 systems software for each parameters, and separated by the least significant difference test at 0.05 level of probability using the statistical package. The collected data on various parameters of the crop under study was statistically analyzed.

3. Results and Discussion

3.1. Soil and Farmyard Manure Sampling and Analysis

The analysis of the experimental soil after harvest for pH, available phosphorus, total nitrogen, sulfur, available potassium, organic carbon, cation exchange capacity and texture and chemical properties of our farm yard manure analysis result was indicated in Table 1 and 2 below. Similarly, the FYM sample applied to the experimental field before planting was analyzed for some selected chemical properties. The data on these chemical properties were determined in a Horticoop laboratory. It had pH of 7.64 which is almost moderately alkaline. Accordingly, the results obtained were total nitrogen content of 1.76%, available phosphorus content of 859.74 mg/kg, available Potassium 151.89 ppm, Organic carbon 33.99 %, CEC 42.63 Meq/100g.

Table 1 Chemical properties of farmyard manure used in the experiment

FYM characters	Values	Examination standards	Rating
pH (by 1: 2.5 soil water ratio)	7.64	ES ISO 10390:2014(1:2.5)	Moderately alkaline
Total nitrogen (%)	1.76	ES ISO 11261:2015(Kjeldahl Method)	Very high
Organic carbon (%)	33.99	Walkley and Black Method	High
Total phosphorous (mg/kg (ppm))	859.74	ES ISO 11261:2015(Olsen Method)	High
Cation exchange capacity (Meq/100g)	42.63	Ammonium Acetate Method	Very high
Available potassium (mg/kg (ppm))	151.89	Ammonium Acetate Method	High
Available sulfur (mg/kg (ppm))	164.65	Turbidometreic	

Source: *Horticoop Ethiopia Plc*

The analysis of the experimental soil after harvest result showed pH value of 7.64 which is almost fall under strongly acidic. Accordingly, the results obtained from the experimental plots have total nitrogen content of ranging from 0.3-0.31% that indicates very high and available phosphorus content of 7-23.23 mg/kg which means that medium to high in content, Organic carbon 3.03-3.15 % which means high content in all treatment plots.

Table 2 Selected soil analysis result of experimental site after crop harvest for physico-chemical

Treatment		PH	P(mg/kg)	S(mg/kg)	K(mg/kg)	CEC(Meq/100g)	OC (%)	OM (%)	TN (%)	C:N ratio	Sand	Clay	Silt	Class
Trt	FYM(t/ha)													
1	0	4.85	23.23	12.53	124.8	31.23	3.11	5.37	0.3	10.24	18	44	38	clay
2	4	4.76	7.08	13.6	283.5	23.49	3.14	5.42	0.31	10.01	30	44	26	clay
3	6	4.39	8.13	15.02	84	29.11	3.15	5.44	0.31	10.07	26	44	30	clay
4	10	4.1	10.02	14.54	99.75	27.41	3.03	5.22	0.3	10.03	26	44	30	clay

Source: *Horticoop Ethiopia Plc*

3.2. Phenological and Growth Parameters of Irish Potato

3.2.1. Effect of Farmyard manure on Days to emergency, Flowering and Maturity

The main effects of phosphorus and FYM significantly ($P<0.05$) influenced days to maturity of Irish potato. From our Anova analysis results table (3) showed significant difference in days to maturity amongst treatment and its decrease significantly the days to maturity of potato plants as compared with the control. But the Analysis of data for different FYM application rates showed non-significant ($P>0.05$) differences on days to emergency and flowering.

The fastest days in maturity (102 days) was recorded at application rates of 3, 10 t ha^{-1} FYM and untreated treatment. The late days in maturity (111 days) was observed at 6 t ha^{-1} FYM application rates. The result make clear that increasing rate of FYM delayed time of maturity of Irish potato to some extent then declines for maturity which may be attributed to the role that nutrients plays significant role in encourages vegetative growth for that reason delaying plant maturity. Fuchs (1970) also reported that phosphorus fertilizers improve the establishment of crops while those from mineralization of organic manure promoted and prolonged vegetative growth and yield.

Table 3 Effect of organic farmyard manure in Phenological Parameters of Irish Potato

Treatments FYM (t ha^{-1})	DE (days)	DF (days)	DM (days)
0	15.17	67.83	102.3^{b}
3	14.33	69.17	102.7^{b}
6	14.50	67.67	111.0^{a}
10	14.33	68.50	102.3^{b}
G mean (kt ha^{-1})	14.58	68.29	104.6
LSD (5%)	ns	ns	7.38
CV (%)	20	3	5.8

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance. Where DE=days to emergency, DF=days to flowering, DM=days to maturity, FYM= Farmyard manure, LSD (0.05) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation

3.2.1. Effect of organic Farmyard manure on plant height and Stem number

The analysis of variance revealed that the plant height, stem number per plant, tuber number and tuber weight of Irish potato plants was not significantly influenced by the main effects of FYM (Table 4). The highest plant height (65.43 cm) was obtained at application rate of 10 t ha^{-1} FYM with, while the lowest plant height (37.00 cm) was recorded at control treatment. As it was seen from our Anova result the height of the plant was positively increased as the rate increases. A correct balance between neither macronutrients nor micronutrients is essential to obtain the best results possible from potato production. A deficiency of any nutrient is enough to limit crop growth and the availability of each nutrient needs to be related to the crop requirements. Where organic fertilizer has slow nutrient release capacity that caused lower plant height. Results under the present experiment on plant height was strongly supported by Souza et al. (2008).

Similarly the maximum stem number per plant (8.5 number) was recorded at the application rates of 10 t ha^{-1} Farmyard manure, while the minimum (3 number) was recorded at control treatment. The number of stem per hill was found significant due to the effect of different organic manure application rates. The maximum number of stem per hill (8.5) was produced at the application rates of 10 t ha^{-1} Farmyard manure while the minimum number of stem per hill (3) was observed in control or without organic manure treatment (Table 4). The number of main stems per hill in potato is generally related to the number of sprouts in a tuber eye pieces. Anand and Krishnappa (1988) formally mentioned that character is mainly dependent on the cultivars and physiological stage of the seed rather than the fertility of the soil. This finding is in accordance with notices of Al-Balikh (2008).

3.3. Effect of Farmyard Manure on Yield and Yield Related Traits of Irish Potato

3.3.1. Effect of organic Farmyard manure on tuber number per hill

The present result had demonstrated that tubers number per plant had an effect by the application of different manure rates. The maximum (13.16 number) tubers number per plant was recorded with the application of 10 t ha^{-1} of farmyard manure and the least (4.33 number) tubers number per plant was recorded at rate of zero. These results showed that the production of the number of tubers plot per plot increase with the increasing organic manure. It is absolutely proved that nutrient application is co-factor in any plant growth and yield to an economical application. But here in our research the curve is in an increment style. That's may be due to manure not quickly releasing its nutrient or readily available to the soil. The result of the present study is similar to Hossain *et al.* (2011).

3.3.2. Effect of organic Farmyard manure on tuber weight

Analysis of variance revealed that the main effects of Farmyard manure had significantly difference ($P<0.05$) on the tuber weight. Among the organic FYM, the highest tuber weight (189 g) was found from 10 t ha^{-1} manure application while the lowest tuber weight (88.8 g) was found from the no manure doses (Table 3). Data presented in table 4 clearly show that application of farmyard manure influenced the weight of potato plants and significantly increased with increasing of different farmyard manure levels up to 10 t ha^{-1}. Generally Using of animal manure such as cattle manure has positively beneficial effects on vegetative growth, yield and tuber quality (Kolay, 2007; White *et al.,* 2007).

Table 4 Effect of organic farmyard manure in Growth and yield related Parameters of Irish Potato

Treatments FYM (t ha^{-1})	PH (cm)	Stm (No)	TNP (No)	TW (g)
0	37.00^{d}	3.000^{c}	4.333^{d}	88.8^{d}
3	49.64^{c}	5.333^{b}	6.667^{c}	125.3^{c}
6	56.46^{b}	6.833^{b}	10.00^{b}	155.2^{b}
10	65.43^{a}	8.500^{a}	13.167^{a}	189.0^{a}
G mean (kt ha^{-1})	52.1	5.92	8.54	139.58
LSD (5%)	6.67	1.59	1.158	3.13
CV (%)	10.5	22.2	11.2	1.9

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance. Where PH=plant height, Stm=stem no per plant, TNP= Tuber number per plant, TW=Tuber weight, FYM=Farmyard manure, LSD (0.05) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent

3.3.3. Effect of Organic Farmyard Manure on Marketable Tuber Yield

Data analysis showed that productivity of potato plants was significantly (P<0.05) affected by application of different farmyard manure levels (Table 5). The yield of potato plants was increased with increasing of different farmyard manure levels which in turn reflected on the marketable yield as in both seasons. The highest values (265.7 kt ha^{-1}) of the marketable tubers yield were observed with the highest (10 t ha^{-1}) of farmyard manure levels in both seasons. On the other hand, the lowest values (143.9 kt ha^{-1}) were recorded with the zero farmyard manure application rates. This result was in harmony with the finding of Mauromicale *et al.,* (2006) that stated enhancement of tubers yield of potato plants as a results of using farmyard manure at different levels attributed to the positive effects on the vegetative growth characters of potato plants which as a result increased photosynthesis efficiency and synthesis of carbohydrates such as starch content which reflected on increasing of tubers yield.

Table 5 Effect of organic farmyard manure in yield Parameters of Irish Potato

Treatments FYM (t ha^{-1})	MRK (kt ha^{-1})	UMRK (kt ha^{-1})	TYD(kt ha^{-1})
0	143.9^{c}	62.27	206.1^{b}
3	163.2^{bc}	72.44	235.7^{b}
6	184.0^{b}	52.80	236.8^{b}
10	265.7^{a}	43.02	308.7^{a}
G mean (kt ha^{-1})	189.2	57.6	246.8
LSD (5%)	23.68	ns	40.60
CV (%)	10.3	39.8	13.60

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance. Where PH=plant height, Stm=stem no per plant, TNP= Tuber number per plant, TW=Tuber weight, FYM=Farmyard manure, LSD (0.05) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent

3.3.3. Effect of Organic Farmyard Manure on Marketable Tuber Yield

Unmarketable tuber yield was non-significantly (P>0.05) affected by the main effects of different Farmyard manure fertilizer application rates (Table 5). Basically, the logic of unmarketable tuber yield is that in terms of size, defects and disease. Therefore during application of those organic manures may not respond different and show us the data variation significantly but they show numeric variation.

3.3.4. Effect of Organic Farmyard Manure on Total Tuber Yield

The results of analysis of data verify that main effect of NPSB fertilizer rates had significant (P<0.05) effect on fresh total tuber yield of Irish potato plant. The maximum (308.7 kt ha^{-1}) fresh total tuber yield was recorded with the application of 10 t ha^{-1} farmyard manure fertilizer rates treatment, and the least (206.1 t ha^{-1}) total tuber yield was recorded at rate of zero nutrient application.

3.4. Partial Budget Analysis

The economic analysis was done and the comparative benefit from potato cultivation as influenced by organic manures was observed. In this study, the costs of FYM application, transport and weeding were varied while other costs were constant for each treatment. In order to recommend the present result for end users, it is important to estimate the minimum rate of return acceptable to farmers in the recommendation interest. The total cost of production ranged between 500 ETB to 7733 ETB only for variable cost where the maximum cost of production 7733 ETB was needed when maximum dose of farmyard manure was used and where minimum cost of production was needed for control treatment. In this study the result of the economic analysis proved that the maximum net benefit of 350962 Birr ha^{-1} with an acceptable marginal rate of returns (MRR) of 4088.95 % was obtained from treatment that received the application of 10 t ha^{-1} of FYM fertilizer rates (Table 6). From the economic point of view, the above result indicated that the use of higher rates of FYM was more profitable than other treatment combinations because of higher marketable yield, maximum gross and net return achieved. From the above results, it can be concluded that the FYM alone recorded the best results on the basis of growth, yield and yield contributing characters and also on economic analysis. Therefore the most attractive rates for producers with low input cost of production and higher benefits in this case was 10 t ha^{-1} of FYM and can be recommended for farmers.

Table 6 Cost and return analysis of Irish potato considering farmyard manure application

Farmyard manure rate (t ha^{-1})	Adjusted yield (t ha^{-1})	Total cost of production	Gross benefit (Birr ha^{-1})	Net Benefit (Birr ha^{-1})	Dominance Analysis	MRR (%)
0	129.51	500	194265	193765	ND	0
3	146.88	2800	220320	217520	ND	1032.83
6	165.6	5100	248400	243300	ND	1120.87
10	239.13	7733	358695	350962	ND	4088.95

Where t=tone, ha=hectare, MRR=marginal rate of returns and ND=non dominant

4. Conclusion

Crop response to nutrient application is highly influenced by the soil fertility status and the capacity to release these nutrients to the targeted crop. Irish Potatoes, like other crops, require adequate and balanced supply of nutrients demands. The trial was conducted at the Bore Agricultural Research Centre with the objective of determining the effect of application of organic FYM rates on growth, yield and yield components of Irish potato and to identify their economically appropriate rates that maximize yield. The result of the experiment indicated that the main effect of FYM significantly ($P<0.05$) influenced days to maturity, number of branches per plant, plant height, tuber number per hill, tuber weight, marketable tuber yield and total fresh tuber yield. But the main effect of Farmyard manure was non-significantly ($P>0.05$) effected on days to emergency, flowering and unmarketable yield. The application of 10 t FYM ha^{-1} gave the maximum (189 g) tuber weight, the highest marketable tuber yield (265.7 kt ha^{-1}) and total tuber yield (308.7 t $ha^{-1)}$ of Irish potato. Though most of the sweet potato growth parameters showed good response to farm yard manure.

From the economic analysis result the use of higher rates of FYM was more profitable than other treatment combinations because of higher marketable yield, maximum gross and net return achieved. The highest net benefit (350962 Birr ha^{-1}) for tuber yield of Irish potato was recorded from the application of 10 t FYM ha^{-1}. Therefore, as a recommendation, cash incomes of small holder Irish potato growers of the study areas could be significantly enhanced if doses of 10 t FYM ha^{-1} are applied to the potato crop. Moreover, farmers in the study areas should be encouraged to use organic farmyard manure since manure contains nitrogen, phosphorus, and other nutrients that plants need to grow. Farmers can often save money by properly using manure as a fertilizer and can also sell manure or manure products to gardeners, landscapers, golf courses, and others who use nutrients to grow plants.

ACKNOWLEDGEMENTS

The authors express their gratefulness and respect to the Oromia Agricultural Research Institute and Bore Horticulture Research team for their co-operation in carrying out the research work and for sharing me their practical knowledge.

CONFLICT OF INTEREST

The authors have done this research and wrote the article and there is no conflict of interest including any personal or other relationships with other researchers.

References

Al-Balikh K., 2008. The Influence of Kind and Quantity of Manure on Productivity and Quality Characteristics for Spring Potato in Raqqa Province Raqqa Research Center Alfurat University, Faculty of Agriculture.

Ali M.R, Costa D.J, Abedi M.J, Sayed M.A, and Basak N.C., 2009. Effect of fertilizer and variety on the yield of sweet potato. Bangladesh J. Agril. Res. 34(3): 473-480.

Amsalu N., Weyessa G., Assefa T., Wubishet A., Asefa k. and Edossa E., 2008. Other root and tuber crops. pp 301 -326. In: Gebremedhin et al., (eds.), Root and tuber crops, the untapped resources, by Ethiopian Institute of Agricultural Research, EIAR, Addis Abeba, Ethiopian.

Anand, S. and Krishnappa, K.S., 1988. Effect of different levels of N and K on the growth, yield and quality of potato in sandy loam soil. Mysore, *Journal of Agricultural Science, 22(4):* 483–488.

Fuchs W, Rauche K and Wicke H.J., 1970. Effects of Organic Manure, Mineral Fertilizer and Organo-Mineral Fertilizing on development and yield of cereals. Abreoht-Thaer-arch 14: 359-366.

Hossain, M.S. Zakaria, M. Hossain, M.M. and Rashid, M.H., 2011. Effect of Seed Size and Cutting Methods on the Yield and Profitability of Potato. *The Agriculturists*, *9(1and 2):* 54–62.

Kolay, A.K., 2007. Manures and fertilizers. New Delhi, India. Atlantic Publishers and Distributors.

Mauromicale, G., Iema, A., Marchese, M., 2006. Chlorophyll fluorescence and content in field grown potato as affected by nitrogen supply, genotype and plant age. *Photosynthetic,* 44: 76 82.

Mugo, J. N., Karanja, N. N., Gachene, C. K., Dittert, K., Nyawade, S. O., and SchulteGeldermann, E., 2020. Assessment of soil fertility and potato crop nutrient status in central and eastern highlands of Kenya. *Scientifi Reports*, *10*(1), 1-11.

Muthoni J., and Kabira J. N., 2016. Potato production under drought conditions: Identification of adaptive traits. *International Journal of Horticulture*, 6(12), 1-10.

Okeyo, G. O., Narla, R. D., Otieno, H. M. O., and Schulte-Geldermann, E., 2019. Response of Selected Potato Genotypes to Natural Virus Infection in the Field. *Asian Journal of Research in Crop Science*, 1-13.

Otieno, H. M. O., 2019a. Evidence-Based Production Technologies for Improving Potato (*Solanum tuberosum*) Yields. *World Scientifi News*, *134*(2), 220-241.

Otieno, H. M. O., 2019b. Impacts and Management Strategies of Common Potato (*Solanum tuberosum* L.) Pests and Diseases in East Africa, *Frontiers in Science*, *9*(2), 33-40.

Palm C.A, Myers R.J.K, Nandwa S.M., 1997. Combined use of organic and inorganic nutrient source for soil fertility maintenance and replenishment. Replenishing soil fertility in Africa, pp: 193-217.

Schulte-Geldermann, E., 2013. Tackling low potato yields in Eastern Africa: an overview of constraints and potential strategies.

Souza PA, Souza GLFM, Menezes JB, Bezerra N.F., 2008. Evaluations of cabbage cultivar grown under organic compost and mixed mineral fertilizers. Hortic Bras. 26:143-145.

White, P.J., Wheatley, R.E., Hammond, J.P., Zhang, K., 2007. Minerals, soils and roots. In: Potato biology and biotechnology: advances and perspectives. Elsevier, Oxford, U.K. Pp. 395 409.