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FERTILIZER MANAGEMENT PRACTICES AND PROFITABILITY OF POTATO CROP AMONG SMALLHOLDER FARMERS IN BUURI

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ABSTRACT
In Kenya, average production of potatoes has stagnated around 2.9 million tons per year in the past 5 years. While seed potato and total land area under cultivation has risen by 4% and 12.3%, respectively; marginal production have gradually declined by 9%. This decline in production could be attributed to farm management practices, specifically fertilizer management. This study analysed how fertilizer management practices influence potato profitability among small-holding farmers. The specific objectives were to determine: adoption and application of fertilizer management practices, profitability of a potato crop farming and association between fertilizer management and profitability of potato crop enterprise in Buuri Sub-county. The study was anchored on the Allocation Theory and employed a cross-sectional correlational research design, a sample size of 377 respondents drawn from target population of 26,604 households. Questionnaire was used to obtain primary data and analysed using descriptive and inferential analysis tools. The result revealed farmers use fertilizer at planting and growth stages while not at tube formation; DAP fertilizer is used at planting, DAP & NPK at growth stage and CAN fertilizer at tube formation stage. Results on traditional methods of rate of application revealed that: farmers use table spoon full at planting, one handful at vegetation and tube formation stage, while for modern measures were 10 grams at planting and 10-20 grams at vegetation & 10 grams at tube formation stages. Result for placement shows farmers apply fertilizer in potato seed hole before placement of seed and four weeks after planting during vegetation. Correlation result shows weak correlation for right type of fertilizer (r=0.041), strong for right time (of r=0.647), very strong for right rate (r=0.913) and right placement (r=0.882). Fertilizer management contributes 98.7% variation in the profitability of potato crop, with a partial effect of right type at 0.024, right time at 0.014, right rate at 0.581 and right placement at 0.504. Thus fertilizer management practices significantly influence profitability of potato crop.
Keywords: Profitability of potato, Smallholder farmers

INTRODUCTION

Potato is among the most consumed produce in Kenya, coming second to Maize (Wambua, 2018). Nationally, approximately 600,000 small-scale farmers engage in potato production on about 120,000 hectares, of which majority (90%) own less than a hectare piece of land (Janssens, 2018). The production of potatoes in the country has for the last five years stagnated around 2.3 to 2.9 million tons (Kyalo, 2019). Economic Survey Report (2019 reported a slight increase of about 9% in potato production between the years 2013 and 2018, compared to 4% rise in potato seed planted (from 104,000 to 108,000 tons) and 12.3% rise in total land area under potato cultivation in the last 5 years. This clearly indicate the increase in potato production could be as a result of expansion of acreage under the crop, despite the continued use of fertilizers.

The decline in potato production, despite increase in area under cultivation, could be attributed to inappropriate management of fertilizers, commonly characterised by smallholding farmers across the globe. According to Kaushik et al (2013), fertilizer use efficiency is central to the best management practices (FBMP), which embraces right

source, right place, right timing and right application method, also known as "The 4R Nutrient Stewardship Concept". These four "rights" are all necessary for sustainable management of plant nutrition, which ultimately increases the productivity of crops. However, on the contrary, according to Masah and Azadegan (2016), inappropriate management of fertilizer have contributed to soil compaction and degradation, and water pollution leading to decreased yields. Good potato husbandry can be a laborious task in some circumstance requiring ground preparation, harrowing, ploughing rolling along with a little grace from the weather and a good source of water (Alene et al, 2008). Although there are several methods of applying fertilizer in potato crop production, namely; broad-casting which is done by hand after ploughing and harrowing then ridge or flat for planting; side dressing or band application which is applied on both sides both of the ridges after the potato has been planted, usually 10-15 cm away from the position of the potato seed and ring application in which fertilizer are applied around each plant in the field (Crawford, Jayne & Kelly, 2005), the efficiency of fertilizer uptake and use by potato crop is varied and could be the contributing factor to declining yield.

The time of fertilizer application and source of fertilizer and placement of fertilized are key critical factors that affect efficient fertilizer management practices. Past research indicate that efficient fertilizer management results in increased crop production in an environmentally friendly way. Empirical evidence exists on the importance of fertilizers in increasing the fertility of soil and in influencing its productivity (Kariuki et al., 2017; Harold, 2016; Stewart & Roberts, 2012). However, there is paucity of knowledge on the relationship between fertilizer management practices and profitability of potato crop in Kenya.

Over the years, farmers have used fertilizer on potato crop production in Buuri Sub County, which is a major producer of the crop in Meru County. The sub-county has a total of 4,900 hectares dedicated to the potato production with an average of 7.1 tons per hectare, though the sub-county has a potential of raising the productivity of the crop up to 25 tons per hectare. Potato yield has been on the decline by 9% despite the persistent effort to expand the farm acreage. In addition, yield per acre in terms of quantity, quality and size too is also on decline, adversely affecting the profitability of potato farming enterprise. Attempts have been made to address the profitability through formation of cooperative union in order to control market pricing, this too has born insignificant result. Consequently, it is imperative that in order to increase profitability, there is a need to expand the yield per acre, which could be best achieved through fertilizer management practices. Information on fertilizer management practices is scarce and this could be the contributing factor in inefficiency in the practice. Particularly, very little or probably no empirical evidence exists to explain fertilizer management practices among Smallholder farmers in Buuri Sub County. Inorganic fertilizer is used to supplement the natural elements for optimum crop growth. Their correct use is very beneficial, but when used in the wrong place at the wrong time, they become pollutants. This study examined the adoption and application of fertilizer management practices, and its influence on profitability of potatoes crop enterprise, to benefit extension agents in offering proper guidance to farm enterprises. The findings would be of value to smallholding farmers in improving their yield per hectare and ascertaining their potential to satisfy various markets sustainably. Study finding would aid policy makers to design appropriate and optimal fertilizer management practice for potatoes farming and formulating best agricultural policies depending on production potentials for Buuri Sub-County and other related regions.

There exist enormous empirical studies on farm management practices. Fertilizer management, as an element of farm management practice, has also attracted scholarly attention especially in developed nations, and mixed results have emerged. To commence with, Braimoh and Vlek (2006) analyzed the effect of fertilizer use on production of maize in Ghana. The study used a multiple linear regression analysis of the fertilizer management practices. The study finding revealed that five variables significantly affect maize yields in Northern Ghana: soil quality index, fertilizer use, household size, distance from main market, and the interaction between fallow length and soil quality. The study further reported that soil quality is the most important determinant of maize yield in Northern Ghana and suggested that organic fertilizer techniques and inputs restore depleted soils and sustain crop yields at limited levels.

Similar study by Xu, Govereh, Black, and Jayne (2006) analyzed Maize Yield Response to Fertilizer and Profitability of Fertilizer use Among Small-scale Maize Producers in Zambia. Their study attempted to determine whether fertilizer use is profitable for small farms in Zambia. The study reported that households that obtain fertilizer on time and use the right quantity experienced significant marginal maize yield per unit farm. Onasanya *et al*. (2009) studied Growth and Yield Response of Maize to Different Rates of Nitrogen and Phosphorus Fertilizers in Southern Nigeria. The study used a field study research design, multiple regression analysis with a sample size 564 respondents farmers. The finding revealed that applying 120 kg/Ha of nitrogen fertilizer by itself or applying 60 kg/Ha of nitrogen with 40 kg/Ha of phosphorus fertilizer significantly increased maize yields.

Shively and Ricker-Gilbert (2013) examined the effectiveness of the subsidy program at increasing fertilizer use, and further examine whether increasing fertilizer application affected crop yields in Malawi. Result found that female-headed households tend to use less fertilizer for crop than male-headed ones. In addition, chemical fertilizer use is positively correlated with the overall wealth of a household, and farmers that plant improved varieties of crop tend to use about 50 kg more fertilizer than those that do not. Thus, the researchers found a significant and positive correlation between the amount of fertilizer application and yield; however, at higher rates of fertilizer use this relationship exhibits declining returns to fertilizer use.

Hill (2014) studied maize response to fertilizer and fertilizer-use decisions for farmers in Ghana. This study determined the marginal effects of inorganic fertilizer on maize output using Ordinary Least Square (OLS) and quantile regressions, and the profitability of fertilizer at the subsidized and unsubsidized prices using the value-cost ratio. The study found that fertilizer use has a positive and significant effect on maize yields however on the contrary; study also reported that fertilizer is not sufficiently profitable for the average Ghanaian farmer to incentivize additional application. Fertilizer placement is an integral part of efficient crop management. Correct placement often improves the efficiency by which plants take up nutrients and consequently encourages maximum yields of intensively managed agronomic crops (Heisey & Norton, (2017). Accordingly, correct fertilizer placement is critical for maximum crop yields under reduced tillage operations and protection of both surface and groundwater quality. According to (Duflo *et al*, 2009) the various methods of right fertilizer placement are broadcast and foliar, banding, and fertigation.

Broadcasting fertilizer application, according to Matsumoto *et al* (2011), refers to a uniform distribution of fertilizer material on the soil surface. When applied after planting, a broadcast application is often referred to as a top dress application. When a broadcast application is incorporated into the soil, it is referred to as broadcast incorporated. Trierweiler *et al.* (2005) observed the advantages broadcast top dress to include; easy to apply, results in relatively uniform fertilizer distribution, and requires inexpensive application equipment. On the contrary, its disadvantages are it leaves more fertilizer available to weeds, enhances nutrients losses by volatilization, denitrification, and erosion compared. Mahler (2001), in his study of fertilizer placement reported that nitrogen and phosphorus fertilizers broadcast applications produce yields equal to banded applications only under optimal conditions. In addition, banding both Nitrogen and Phosphorus fertilizers increases yields and generally produces the best results yield. According to Vetsch *et al.* (2009), banding fertilizer placement refers to placing nutrients below, above, on one side, or on both sides of the seed or seedlings at planting. Accordingly, fertilizer bands should be placed at least 2 inches away from the seed to prevent salt damage and ammonia toxicity (Upendra, 2008). The advantages of banding fertilizer placement are; it places fertilizer where seedling root systems can more readily use the nutrients, provides crops additional nutrients if side dressed during the growing season, improves nutrient use efficiency and requires less fertilizer per acre than broadcasting. It also positions fertilizers so that they are more available to the crops than to the weeds, improves crop tolerance of root diseases, permits application in one operation with planting or in separate operations, retains nutrients during soil erosion. However, the disadvantages are increases nitrogen and sulpherrous leaching losses compared with surface placement, slows planting if applied with a drill and requires more costly equipment or equipment modification (Vetsch *et al.* 2009). The objective of the study, therefore, was to determine the adoption and application of fertilizer management practices among smallholder potato farmers in Buuri Sub-county.

RESEARCH METHODOLOGY

The study was undertaken in Buuri Sub-county in Meru County, Kenya. The study area has a rich fertile soil with favourable climate for farming economic activity, which accounts for 80% of smallholding farmers. A cross-sectional correlational research design (Frankel, 2015) guided data collection and analysis. Data was obtained from 377 smallholder farmers sample (Krejcie and Morgan, 1979) from target population of 26,604 households (GoK, 2019). Stratified simple random sampling (Kumar, 2011) was used to select participant households. The study employed a semi-structured questionnaire to collect primary data (Kumar, 2011). the insrument was pilot tested and adopted after it achieved an overall reliability alpha value of 0.840 (Charity *et al*., 2017). Collected data was cleaned for completeness and analysed through Statistical Package of Social Science (SPSS) version 20 for descriptive analysis.

RESULTS AND DISCUSSION

Important of Fertilizer at Different Growth Stages of Potato Crop

Respondents were asked to indicate the important of fertilizer at the planting, vegetation and tube formation stages of potato crop growth phases. Result are shown in Figure 1, and indicates that majority of respondents agreed that fertilizer are very important at potato crop planting (57.9%, n =146); at potato crop vegetation (57.1%, n =144); while not important at tube formation (44.4%, n = 112). These findings shows that respondents agreed that fertilizers

are important for potato crop at planting and vegetation, however not important at the tube formation stage.

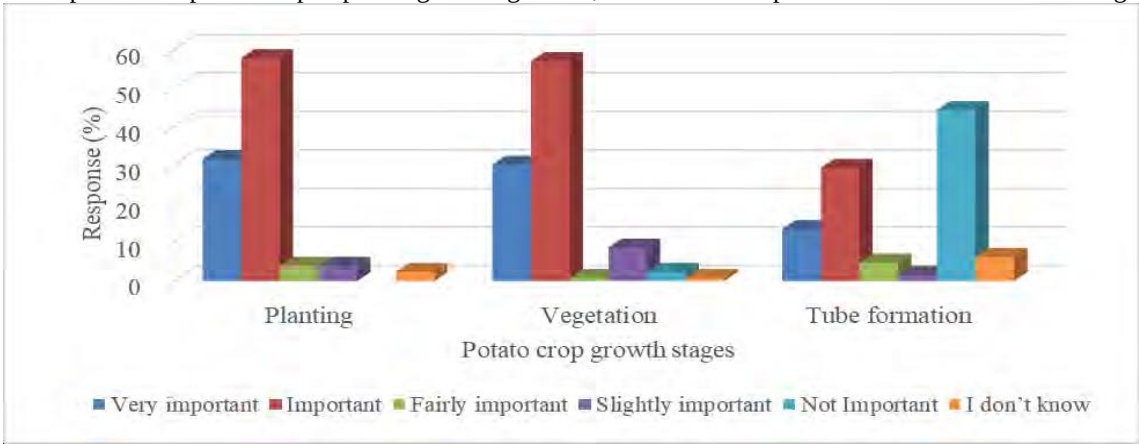

Figure 5: Result for important of fertilizer at growth stages of potato crop

Use of fertilizer at Different Growth Stages of Potato Crop

Result of how frequent smallholding farmers fertilizer at the planting, vegetation and tube formation growth stages is shown in Figure 2. Results shows that majority of farmers use fertilizer during planting (95%, *n* =242); and vegetation stage (91.3%, *n* =230). Moreover, majority do jot use fertilizer at tube formation (42.1%, *n* =106). This finding reveal that majority of respondents use fertilizer during planting and vegetation stages while do not use fertilizer during tube formation.

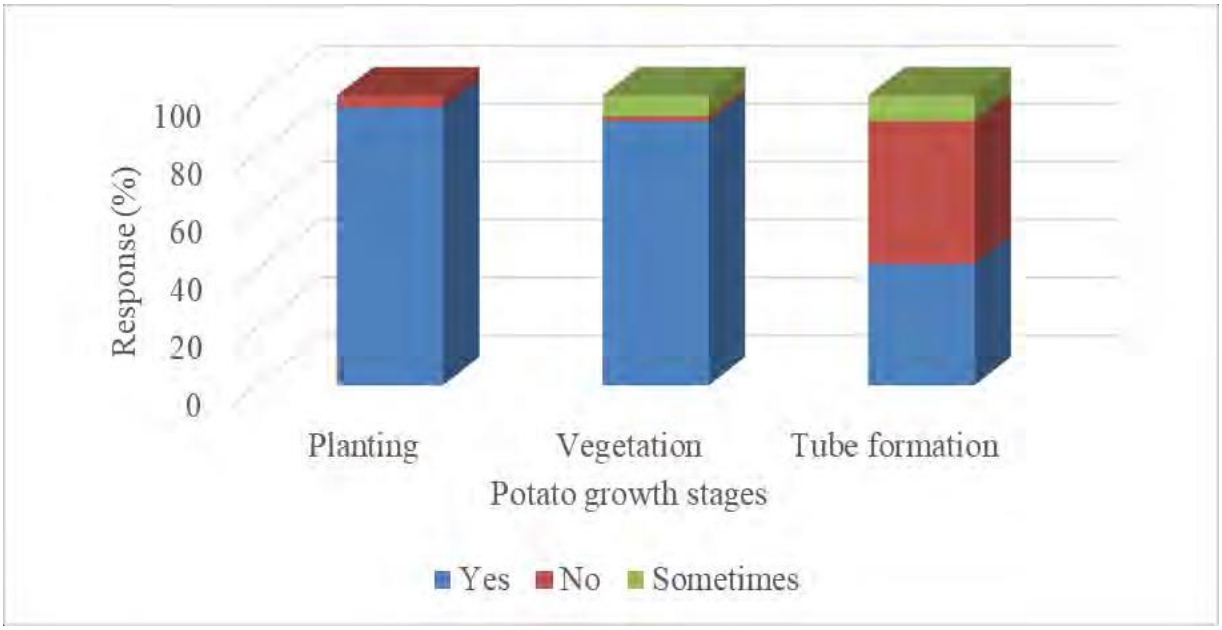

Figure 6: Result for use of fertilizer at growth stages of potato crop

Type of fertilizer used at growth stages of potato crop (Right Type)

The study further inquired on the type of fertilizer used at different stages of potato crop farming. Results are presented and discussed below.

Fertilizer used at planting stage

Result for type of fertilizer used at planting stage is shown in Figure 3, and revealed that majority (78.6%, *n* =198) of farmers use DAP at planting stage, with small proportion using NPK (9.5%, *n* =24) and organic fertilizer (6.7%, *n* =17) among others. This result implied that DAP fertilizer is commonly used at planting stage of potato crop.

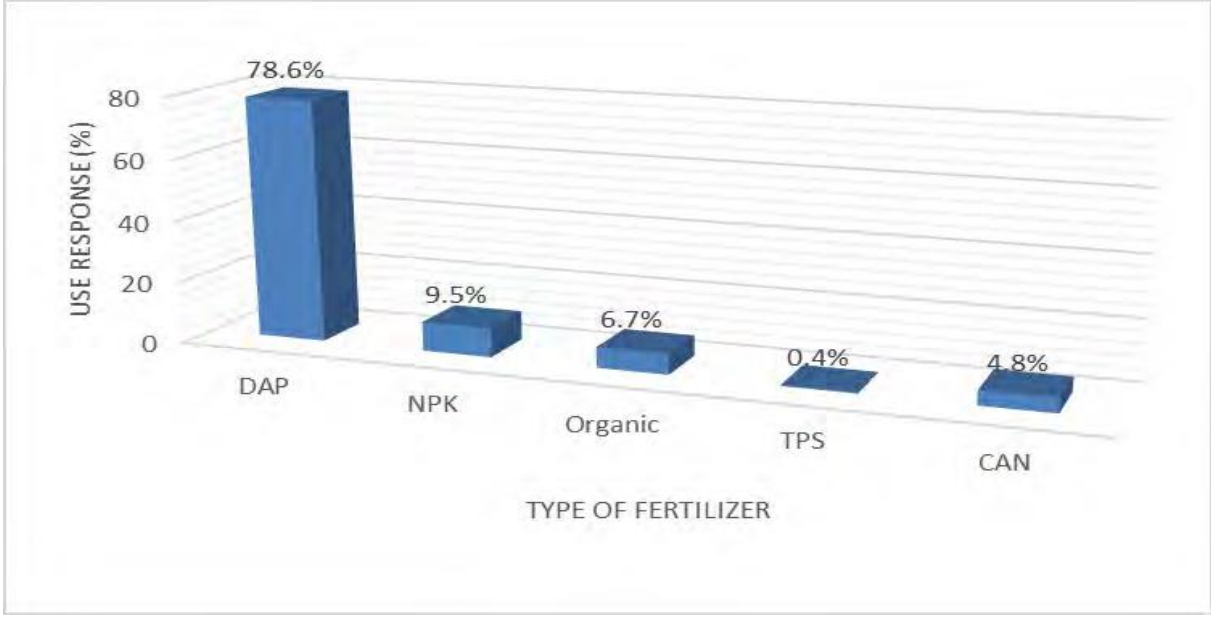

Figure 7: Result for use of fertilizer at growth stage of potato crop

Fertilizer used at vegetation

Result for type of fertilizer used at vegetation stage is given in Figure 4, and shows that majority of farmers use NPK (42.1%, *n* =106) and CAN (40.5%, *n* =102) fertilizers among others at vegetation phase. This result implied NPK and CAN fertilizers are commonly used at vegetation stage of potato crop growth phase.

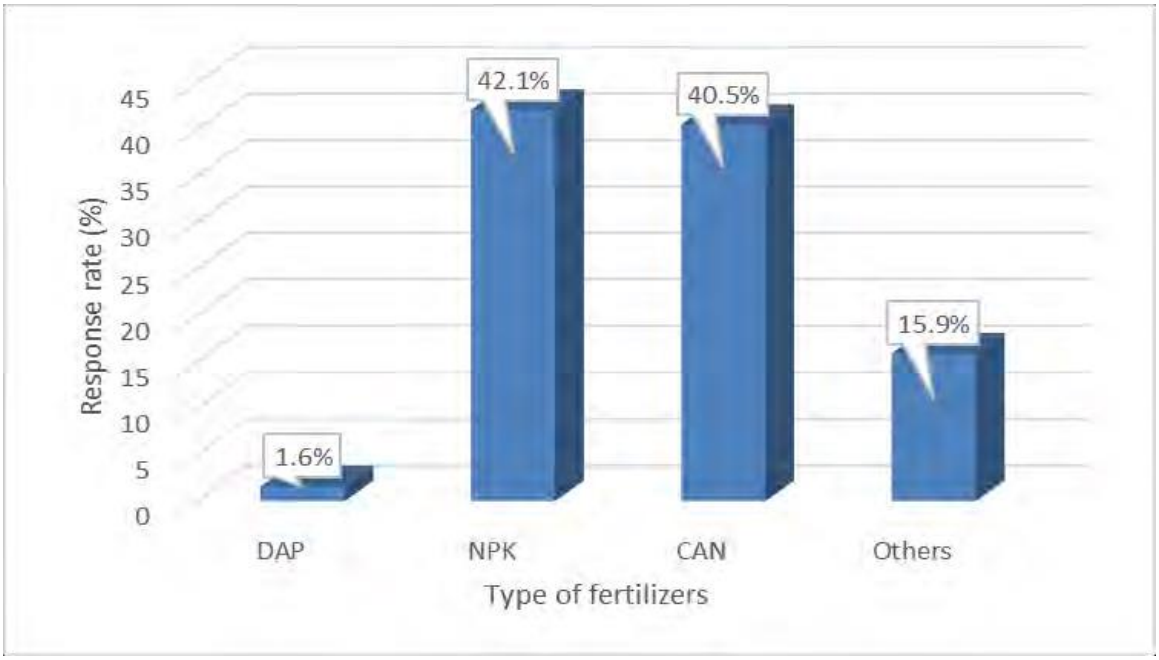

Figure 8: Result for use of fertilizer at growth stage of potato crop

Fertilizer used at tuber formation stage

Result for type of fertilizer used at flowering and tube formation stage is illustrated in Figure 5, and indicates majority of farmers 74.6%, *n* =188) use CAN fertilizers at flowering / tube formation stage, implying the commonly used fertilizer at tube formation is CAN.

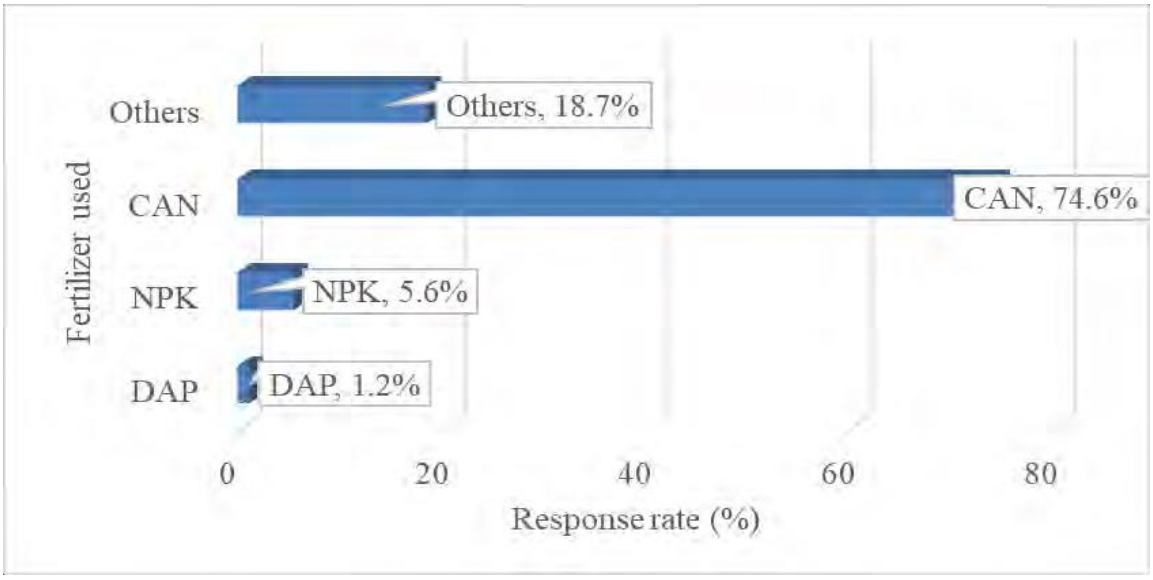

Figure 5: Result for use of fertilizer at tube formation stage of potato crop

How often Respondents use fertilizer at Different Growth Stages of Potato Crop

This result is shown in Figure 4.7, and shows majority of smallholding farmers always use fertilizer at at planting stage (76.2%, *n* =192) and vegetation stage (61.1%, *n* =154) of potato crop growth stages. In addition, 37.3% (*n* = 97) always use fertilize at tube formation stage, with majority of farmers having never use (47.6%, *n* =120) fertilizer at this stage. These results indicated that fertilizer are always used during planting and vegetation stages while during tube formation they are never used.

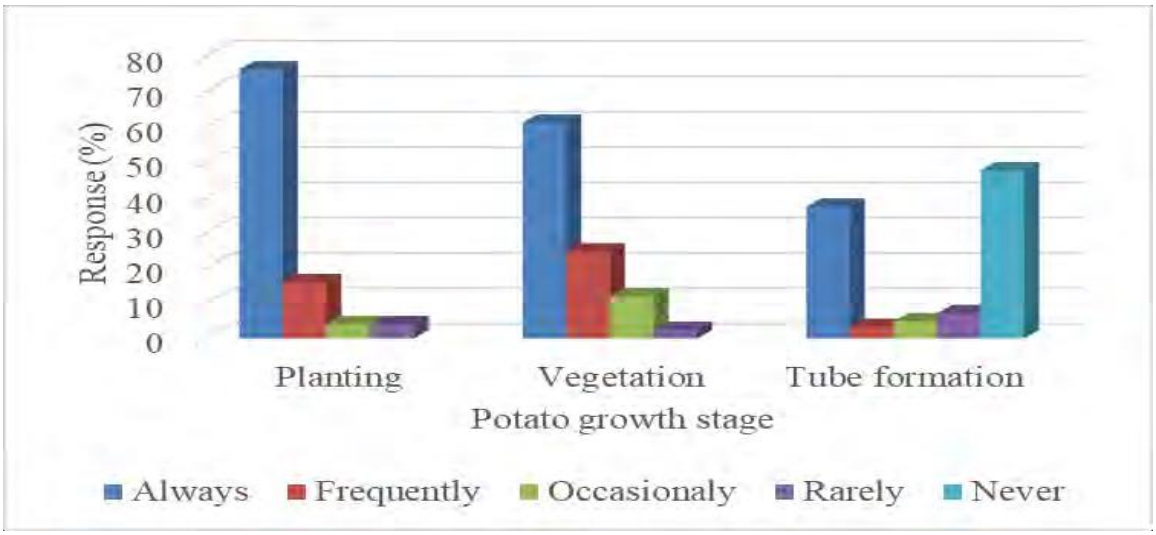

Figure 7: Result for how often fertilizer are used at various stage of potato crop

How do farmers measure the fertilizer applied at growth stages of potato crop (right rate)

Tradition measurement of amount of fertilizer per crop

Result for traditional method of fertilizer application at different stages of potato crop growth is given in Figure 8. Result shows majority of farmers: measure one handful fertilizer per crop at planting (79%, *n* =199) and vegetation (96%, *n* =193) stages. In addition, majority of farmers at tube formation also measure one handful fertilizer (76.2%, *n* =192) per crop. These results imply that the common traditional method of measuring the right amount of fertilizer per crop at planting, vegetation and tube formation is use of hand, with one handful being the right measure per potato plant.

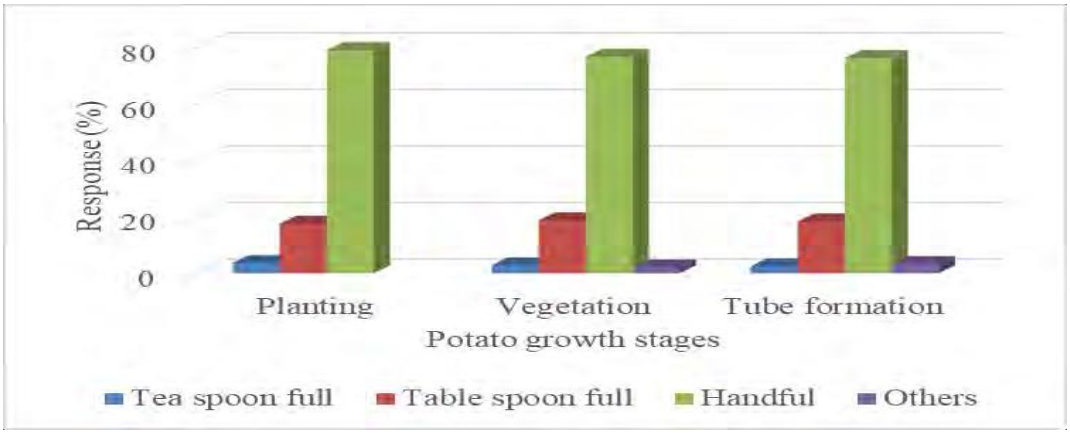

Figure 8: Traditional method of measuring fertilizer at different growth stages of potato crop

Modern measurement of fertilizer amount per crop

Result of modern method of fertilizer application at different stages of potato crop growth is shown in Figure 9. Results shows majority of farmers: at planting stage measure 10 grams of fertilizer (36.7%, *n* =90) per crop; at vegetation stage used 20 grams (57.1%, *n* =144) per crop. Similarly, at tube formation stage majority uses 20 grams (57.1%, *n* =144) per crop. These results indicate commonly used amount of fertilizer at planting stage is 10 grams and at vegetation and tube formation is 20 grams.

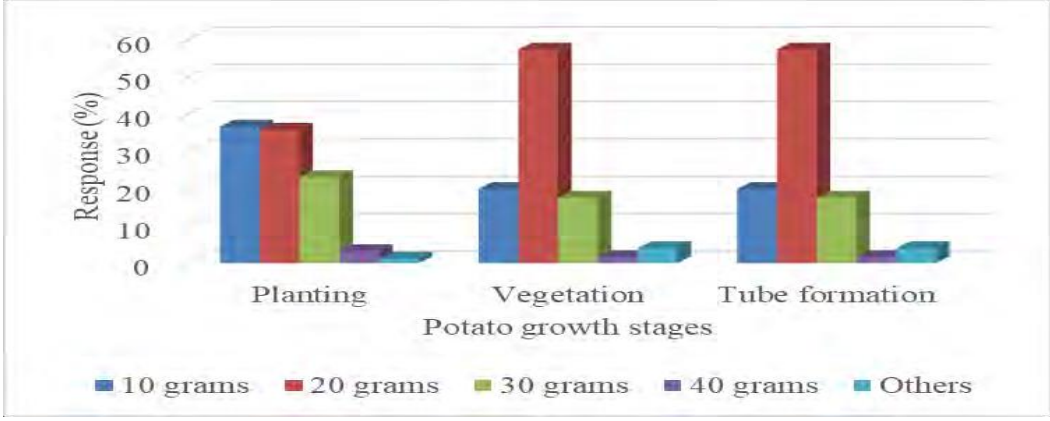

Figure 9: Result for modern methods of measuring fertilizer at growth stage of potato crop

Time of fertilizer application at growth stages of potato crop (Right Time)

Right time of fertilizer placement at planting stage

Result of fertilizer application time during planting is presented in Table 1, and indicates that majority of farmers (64.3%, *n* =162) place the fertilizer in potato seed hole before placement of seed, and 25.4% (*n* =64) place the fertilizer after placement of seed but before covering the hole. The findings imply that majority of respondent place fertilizer in hole before placement of seed.

Table 1: Result for fertilizer application time during planting

Category		Frequency	Percent
Valid	In potato seed hole before placement of seed	162	64.3
	In potato seed hole after placement of seed but before covering	64	25.4
	On top of soil after planting immediately	6	2.4
	One week after planting	4	1.6
	Two week after planting	16	6.3
	Total	252	100.0

Right time of fertilizer placement at vegetation stage

Result of fertilizer application time during planting is presented in Table 2. majority of farmers (46.8%, *n* =118) apply top dressing fertilizer four weeks after planting; with 12.7% (*n* =32) apply five weeks and the rest after five weeks. The findings imply top dressing fertilizer is commonly applied four weeks or one month after planting.

Table 2: Result for fertilizer application time during vegetation

Category		Frequency	Percent
Valid	Two week after planting	8	3.2
	Three week after planting	84	33.3
	Four week after planting	118	46.8
	Five week after planting	32	12.7
	Others	10	4.0
	Total	252	100.0

CONCLUSIONS

Smallholder potato farmers agree fertilizers are important for potato crop at planting and vegetation and not at the tube formation stage. Farmers use fertilizer during planting and vegetation stages while few do during tube formation stage. Smallholder farmers in Buuri Subcounty use DAP fertilizer at planting, NPK or CAN fertilizers at vegetation stage and CAN fertilizers at flowering and tube formation growth phase. Further to this, farmers always use fertilizer during planting and vegetation stages and rarely during tube formation. Traditional and modern methods of measuring fertilizer per crop are applied. Common traditional measure is one handful amount of fertilizer per crop at planting, vegetation and tube formation; while for modern method measure, 10 to 20 grams of fertilizer at planting stage, 20 grams of fertilizer at both vegetation and tube formation stages. On right placement, the study concludes farmers commonly apply fertilizer in hole before placement of potato seeds at planting and uses top dressing fertilized four weeks or one month after planting for vegetation. Fertilizer management practices contributes 98.7% of potato crop profitability, and there exist very strong relationship between right rate of fertilizer application, right placement and right time of application in the order, with profitability of potato crop, while very weak correlation with type of fertilizer. In terms of partial interdependency, right rate has the highest rate followed by right placement, right type and right time.

RECOMMENDATIONS

Smallholder potato farmers should embrace and continue to use fertilizers and the practice good fertilizer management practices. Based on the finding of low or no usage of fertilizer during flowering and tube formation stage, farmers should use fertilizer at this stage for better yield and thus productivity and profitability. Based on the finding of the significant use of traditional methods of measuring fertilizer, which also appears to be wasteful, the study recommends the adoption of modern measurement methods. Further recommendation is that farmers should be guided by the fertilizer manufacturer guide on the right amount per crop given the variability in nutrients content across manufacturers.

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