Sustainable Potato Production Through Intensification of Modern Agricultural Technology

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Abstract

Potato is a cash crop for smallholder farmers and has been deemed important in food security. However, yields only range from 6 to 10 MT/ha, far below the attainable yields of 25–35 MT/ha. Thus, technology adoption by farmers became necessary to address the challenges of farm productivity. This study analyzed the adoption of potato production technologies among farmers in Bokkos, Plateau state, Nigeria. The multi-stage sampling procedure was used in selecting the 98 respondents. Data were analyzed using descriptive statistics, adoption, and mean score indices. Results indicated that a variety of agricultural technologies had been disseminated in the area. Most respondents adopted a minimum of one production technology. These technologies critically affect the level of farm productivity and income. The result also showed that 59.2% of the farmers had low levels of adoption index, with a range between 0.11$\geq$0.33, indicating a need to mitigate this trend. Furthermore, the benefits of adopting potato production technologies among the respondents were very vital, as indicated by their respective indexes: improved output (2.56), increased income (2.53), improved welfare (2.43), reduced disease outbreak (2.41), improved adaptability to climate variability (2.38), improved technical efficiency (2.31), and improved productive capacity (2.19). As such, factors with a score index $\geq$2 were considered critical benefits. The identified constraints critically affected potato farmers' capacity to adopt agricultural technology. These constraints negatively affected their adoption decisions, thereby resulting in a further decline in the adoption of agricultural technology in the study area.

Keywords: Adoption index, agricultural sustainability, agricultural technology, constraints, farm yield, potato production

Introduction

Potato *(Solanum tuberosum L.)* is the fourth most important staple food crop in the world after rice, wheat *(Triticum aestricum)*, and maize *(Zea mays)* (Li, 1985). It was ranked first in the world's root and tuber crop production, followed by sweetpotato *(Ipomoea batatas)*. In terms of yield, potato is the third crop, and first in root and tuber crops, followed by sweetpotatoes (CIP, 2008). Potato has the potential to relieve the pressure of food insecurity on rural farmers since the crop has a short maturity period. It matures in about 60 to 90 days, giving it the advantage of being cultivated two to three times a year (Okunade and Ibrahim, 2011), (NRCRI, 2005). About 85% of potato produced in Nigeria comes from Jos, Plateau state, which has near-temperature climatic conditions that favor potato production (NRCRI, 2005). Potatoes are grown for food as well as a cash crop. It is a major source of income among rural farmers in the producing area during the rainy and dry seasons. It provides a reliable source of income, employment, and food to many populations in developing countries (FAO, 2008). However, yields in Sub-Saharan Africa (SSA) only range from 6 to 10 MT/ha, far below attainable yields of 25–35 MT ha [1] and the 2010 global average of 17.4 MT/ha. Demand for potatoes is increasing, but the trend is to increase the production area rather than tackle productivity constraints (yields), which is not sustainable. Although the solution is to increase productivity, major bottlenecks include limited access to quality seeds of suitable varieties, and poor agronomic and disease management which reduces yields, food availability, and farmers' incomes. The health status of the seed defines the potential yield of the potato crop. Typically, farmers often use local varieties for planting which, are generally of low quality and sourced from their fields or local markets. (Kudi et al., 2011) reported that the Irish potato gave the highest yield per unit area among roots and tuber crops in Nigeria and increased the income of farmers more than other roots and tuber crops. Thus, a major challenge facing potato production was the low level of awareness about the adoption of new and improved technologies. Other challenges faced by the potato farmers were marketing their farm produce which was attributable to poor market linkages, inadequate storage facilities for their harvest, and disease outbreaks.

Technology adoption by farmers becomes necessary to address the challenges of farm productivity. Some of these modern agricultural technologies include (i) improved seed variety, (ii) agrochemical application, (iii) fertilizer application, (iv) irrigation farming, (v) plant protection measures, (vi) adjustments in planting dates (vii) seed rate, (viii) plant spacing, and (ix) improved agronomic practices. Disseminating these technologies to farmers is important to increase the level of farm productivity (Mignouna et al., 2011). Other aspects and characteristics are vital for a farmer to decide whether or not to adopt an innovation. These include educational level, access to credit, and extension services. Technology-specific attributes have been shown in the past to significantly determine a farmer's decision to adopt a technology (Idrisa et al., 2010). The actions taken by the farmer mostly depended on the evolution of the outcomes depending on their perspectives. Since the role of any technological improvement in agriculture is to improve production, the adoption of improved potato technologies may be influenced

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largely by the farmer's perception (Idrisa et al., 2010). Farmers' lack of knowledge to select quality seed is compounded by limited access to varieties with robust traits (such as drought, heat, and disease tolerance and biofortified with essential micronutrients, specifically iron and zinc), lack of knowledge of good agricultural practices, and minimal capacity to store. Although seed certification standards exist, most national policies do not recognize more practical quality standards, such as Quality Declared Planting Material (QDPM). These quality standards further limit access to quality seed. Policy advocacy for more practical quality standards is required at national levels. Strategic partnerships for going to scale, accompanied by strategic research to assess cost-effectiveness and gender inclusiveness, constitute the necessary next steps. However, despite all the efforts, there is a dearth of information on the adoption of the disseminated agricultural technologies and factors hindering or promoting their adoption, particularly on potato production in the study area; therein lies the research gap. Therefore, analysis of the adoption of potato production technologies is crucial and this can be achieved through (1) identifying agricultural technologies available in the area, (2) ascertain the level of adoption of agricultural technologies, (3) evaluate the benefits of adopting the production technology, and (4) identify the constraints of adoption among the respondents.

Methodology

Study Area

This study was conducted in 2018 (potato cropping season) at Bokkos Local Government Area (LGA), Plateau State, Nigeria. The LGA has an area of 1.682 km^2 with a population of 178,894 (projected population 2016). It lies between latitude 9°N and 10°S and longitude 8°W and 9°E. The LGA has eight (8) districts, namely Bokkos, Mushere, Tangur, Manguna, Butura, Sha, Daffo, and Mbar (Anon, 2003). The area has a monthly average temperature of 12°C – 28°C with an annual rainfall of 1500mm (Anon, 2003). The local government is largely rural and the people are mainly farmers engaged in marketing and production of agricultural commodities, which include potato, cassava, sweetpotato, yam, maize, rice, etc. Livestock reared include pigs, poultry, cattle, sheep, and goats. The major ethnic groups are Ron, Mushere, and Kulere (Anon, 2003).

Sampling Procedure

A multi-stage sampling technique was employed to the selected respondents for this study. In the first stage, four (4) districts were purposively selected, namely Bokkos, Tangur, Butura, and Mbar. These four (4) districts were considered because they were the major producers of potatoes in the LGA (NRCRI, 2005). The second stage involved the selection of two villages from each of the selected districts. These villages were selected due to the predominant population of potato farmers. The third stage involved the collection of a compiled list of potato farmers from a local Agricultural Extension Agent. The last stage involved the random selection of 5% of the total population from the compiled list to represent the sample size of the study.

Data Collection

The primary data was collected through the use of structured questionnaires administered to the respondents in the study area.

Analytical Techniques

The analytical tools used in analyzing the objectives were (1) frequency distributions and percentages to analyze objectives 1 and 4, (2) adoption index to analyze objective 2, and (3) mean score index to analyze objective 3.

Adoption Index

Determination of efficacy of delignification process of different pretreatment process:

The level of adoption of potato production technology for the individual farmer was measured using the adoption index computed based on Saka and Lawal (2009):

Equation 1: $Bi = \Sigma\,(Ri/RT)$ . . . . (1)

Where:

Bi = adoption index of agricultural technology by the ith farmer;

Ri = number of potato production technology adopted by the ith farmer; and

RT = Total number of potato production technology available to the ith farmer.

i = (1. . . . . .n)

For this study, the adoption of production technology was indicated as follows: $\geq$3 production low level; 4-6 mid-level, and 7-9 high level. The modern agricultural technologies available in the study area included (i) improved seed variety, (ii) agrochemical application, (iii) fertilizer application, (iv) irrigation farming, (v) plant protection measures, (vi) adjustments in planting dates (vii)seed rate, (viii) plant spacing, and (ix) improved agronomic practices.

Mean Score Index

Mean score index was used to evaluate the benefits of the adoption of agricultural technology. To determine the mean, each item was calculated using the equation below.

Equation 2: $X_{si} = \Sigma\,(f_n x_n)/N$ . . . . (2)

Where: X_s = mean score; Σ = summation; f_n = frequency of 'n' occurrence; X_n = Score assigned to 'n' occurrence

Table 1. Distribution based on potato production technology adopted by the farmers

Technology	Frequency	Percentage (%)
Improved seed variety	96	97.9
Agrochemical application	69	70.4
Fertilizer application	93	94.8
Irrigation farming	91	92.8
Plant protection measures	54	55.1
Planting dates	51	52
Seed rate	94	95.9
Plant spacing	95	96.6
Agronomic practices	48	48.9

Given that; 1 = indifferent (I), 2 = aware (A) and 3 = fully aware (FA)

N = Total number of respondents

X_{si} =1+2+3=6/ 3=2

Thus, for this study, factors with a score index ≥2 were considered very vital and critical benefits of agricultural technology adoption among the respondents. The identified benefits were therefore ranked using their mean scores.

Results and Discussion

Potato Production Technology Available to the Farmers

Based on Table 1, the adoption of technology by the farmers can be ranked as follows: improved seed technology (97.9%), plant spacing technology (96.9%), improved seed (95.9%), improved fertilizer application (94.8%), irrigation technology (92.8%), and improved agrochemical application (70.4%). The result indicates that the farmers in the study area adopted a minimum of one potato production technology. Adoption of these production technologies critically affects potato yield and enhances the overall level of farm productivity and profitability. However, there was low adoption of potato production technology in the study area; hence, low farm productivity and profitability were reported among the respondents. This result corroborates with (Namwata et al., 2010) and (Oladele and Kareem, 2003), who reported similar results on the adoption of improved agricultural technology among Irish potato farmers in the Mbeya district, Tanzania, and the adoption rate of selected arable crops technology among farmers in Oyo state, Nigeria, respectively.

Level of Adoption of Agricultural Technology

Table 2 shows the distribution based on the level of adoption of agricultural technology. Results indicated that 59.2% of the farmers had an adoption index of 0.1≥0.33 (low level), 0.44≥0.66 (30.6%) mid-level, and 0.77≥1 (10.2%) high-level technology adoption. Thus, it is evident that several modern

Table 2. Distribution based on the level of adoption of agricultural technology

Adoption index	Frequency	Percentage (%)
$0.11 \geq 0.33$	58	59.2
$.44 \geq .66$	30	30.6
$0.77 \geq 1$	10	10.2

agricultural technologies for sustainable potato production are available in the area. However, the index of adoption of these technologies was unsatisfactory and was responsible for the existing low farm productivity of potatoes in the area (Idrisa et al., 2012). It is well known that in sub-Saharan Africa (SSA), low farm productivity among smallholder farmers is attributed to poor adoption of modern agricultural technologies. Therefore, the identification of factors hindering the adoption/uptake of improved agricultural technologies has been an important research agenda in most farming communities (Oladele and Kareem, 2003); (Namwata et al., 2010); (Adebiyi and Okunlola, 2010); (Okoedo-Okojie and Onemolease, 2009); (Ayinde et al., 2010).

Benefits of Adoption of Potato Technology

Table 3 shows the distribution based on the benefits of the adoption of potato technology. The findings revealed that the benefits of adoption of production technologies among the respondents were very vital, as indicated by their respective mean score index: improved output (2.56), increased income (2.53), improved welfare (2.43), reduced disease outbreak (2.41), improved adaptability to climate variability (2.38), improved technical efficiency (2.31), and improved productive capacity (2.19). These benefits critically affect technology adoption decisions among the potato farmers in the study area. This result agrees with the findings of (Idrisa et al., 2012) and (Mignouna et al., 2011), who reported similar results on the benefits of adoption of farm technology.

Constraints in the adoption of agricultural technology

Results reveal the distribution based on the constraints in the adoption of agricultural technology. The constraints in the adoption of potato production technology in the study area included the cost of improved seed varieties (95.9%), financial constraint (94.9%), cost of production technology (93.9%), cost of improved farm tool /implement (91.8%), poor access to agricultural credit and extension services (90.8%), poor access to production technology (86.7%), inadequate storage facilities (81.6%), poor supply of agricultural input (79.6%), fragmented farmlands (71.4%), cost of labor (65.3%), poor technical knowledge of technology (56.1%), and poor extension services (51%). All the constraints identified by the farmers were very vital and critically affected their capacity to adopt potato production technology in the study area. Thus, these constraints negatively affected their adoption decisions, thereby resulting in a further decline in the adoption of agricultural technology among the

Table 3. Distribution based on the benefits of the adoption of potato technology

Benefits	Fully aware	Aware	Indifferent	Mean index
Improved output	65	23	10	$2.56^{a,b}$
Increased income	60	30	8	$2.53^{a,c}$
Improved welfare	55	30	13	$2.43^{a,d}$
Reduced disease outbreak	50	38	10	$2.41^{a,c}$
Adaptability to climate	45	45	8	$2.3^{a,f}$
Improved technical efficiency	40	48	10	$2.31^{a,g}$
Improved productivity capacity	35	47	16	$2.19^{a,h}$

^{a}= significant at 5% (p≥0.05) level; ^{b,c,d,e,f,g,h} = Ordinal mean index ranking (1^{st} to 7^{th})

Table 4. Distribution based on the constraints in the adoption of agricultural technology

Constraints	Frequency*	Percentage (%)
Cost of seed varieties	94	95.9
Financial constraints	93	94.9
Cost of production technology	92	93.9
Cost of improved farm tool /implement	90	91.8
Poor access to agricultural credit & Extension services	89	90.8
Poor access to production technology	85	86.7
Inadequate storage facilities	80	81.6
Poor supply of agricultural input	78	79.8
Fragmented farmlands	70	71.4
Cost of labor	64	65.3
Poor technical knowledge of technology	55	56.1

* = Multiple responses

respondents in the study area. This result agrees with the findings of (Namwata et al., 2010); (Adebiyi and Okunlola, 2010), who reported similar constraints in the adoption of agricultural technologies among rural farmers. Based on the foregoing, this study, therefore, recommends agricultural input subsidies, improved access and supply of agricultural technology, credit, and extension services, improved market linkages, and tenure policy modification to mitigate excessive land fragmentation.

Conclusion

This study analyzed the trends in adoption and mean score indices of modern agricultural technologies among potato farmers, where a multi-stage sampling procedure was used in selecting the respondents. This study revealed that a range of agricultural technologies had been disseminated in the area, and the respondents adopted a minimum of one potato production technology. Low adoption of production technologies critically affected potato yield, thus, the overall level of farm productivity and profitability among the respondents in the study area. Furthermore, most potato farmers had a low adoption index of 0.1≥0.33. This index of agricultural technology adoption was unsatisfactory and a critical determinant for the existing low farm productivity of potatoes in the area, indicating a need to mitigate this trend. Further, the farmers identified benefits that positively affected technology adoption decisions among the respondents in the study area. In addition, all constraints identified by the potato farmers negatively affected their adoption decisions, thereby resulting in a further decline in technology adoption among respondents in the study area.

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