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Returns to Wheat Research, Varietal Adoption and Turnover Rates and Wheat Production Risks in Kenya

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A lot of public funds have been used for investment in wheat research in Kenya. The concern is whether it is worthwhile to continue investing. The problem is there is no information on what returns to investments have been achieved to guide the continued allocation of resources to wheat research. To address this problem, this paper seeks to estimate returns to wheat research investments in Kenya, and the wheat varietal adoption and turnover rates that influence it. The Benefit-Cost Analysis (BCA) model was applied to estimate the returns to wheat research, in terms of three indicators: Benefit-Cost Ratio (BCR), Net Present Value (NPV), and Internal Rate of Return (IRR). Adoption index was used to estimate wheat varietal adoption rates (VAR). The area-weighted average variety age (WAVA) was used to estimate the varietal turnover rate (VTR). The Five-Point Likert scale model was used in assessing production risks. A field survey was used for data collection in selected wheat-producing Counties of Kenya. The results generated were a BCR of 1.47, an NPV of 23.31 million Kenya Shillings, an IRR of 41%. The VAR was 42% and VTR was

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15.65 years. The main wheat production risks were output price fluctuations, seed availability, pests, and diseases in that order of ranking. In conclusion, return on investments in wheat research is positive, though relatively low compared to other countries, largely due to low varietal adoption and turnover rates and prevalence of high production risks. The recommendation is that to improve returns to wheat research in Kenya, varietal adoption and turnover rates should be improved and production risks should be minimized or eliminated.

Keywords: Wheat; Benefit-cost analysis; adoption rate; varietal turnover rate; production risks.

1. INTRODUCTION

Agricultural research is one of the most important determinants for enhancing the production of the agricultural sector [1]. Varietal improvements have greatly contributed to agricultural yield and output growth in the past [2,3]. Crop varietal improvements are beneficial to farmers through improving yield potential, increasing resistance to biotic and abiotic stresses, and improving other qualities of crops such as nutrition and processing [3]. As a result, if adopted by farmers, the improved varieties would contribute to increased productivity, better quality grain, reduced food prices for consumers, and reduced negative impacts on the environment [3].

Given the competing needs for public resources and a trend of decreased public funding for research and development [4] further support for wheat varietal research depends on the justification and confirmation of the benefits and returns derived from these investments [5].

The reality of declining public funding emphasizes the need for the wheat research program to demonstrate its returns to public investments to prove its worth for continued funding. An estimation of the returns from wheat research would provide important arguments to decision-makers in the prioritization and allocation of public funding for wheat varietal research and other research needs.

In Kenya, wheat is one of the most important sources of nutrition and revenue for many smallholder households [5]. It can also contribute to at least eight Sustainable Development Goals (SDGs) outlined by the United Nations, [5] and the 'Big Four agenda' particularly in contributing towards improved food and nutrition security. However, growth in wheat production in Kenya lags far behind that in other regions of the world and is well below the growth required to meet food security and poverty reduction goals [6].

The trends in production, imports, and consumption of wheat products from 1960 to 2018 are shown in Fig. 1. Consumption has been growing at an average of over 4 percent per annum and there is no sign of slowing down. With production largely stagnant, the gap has been met by the elimination of exports in the early 1960s and a continuous increase in imports, [7]. Kenya is currently producing about 40% of its total requirements and the deficit is met through imports [7].

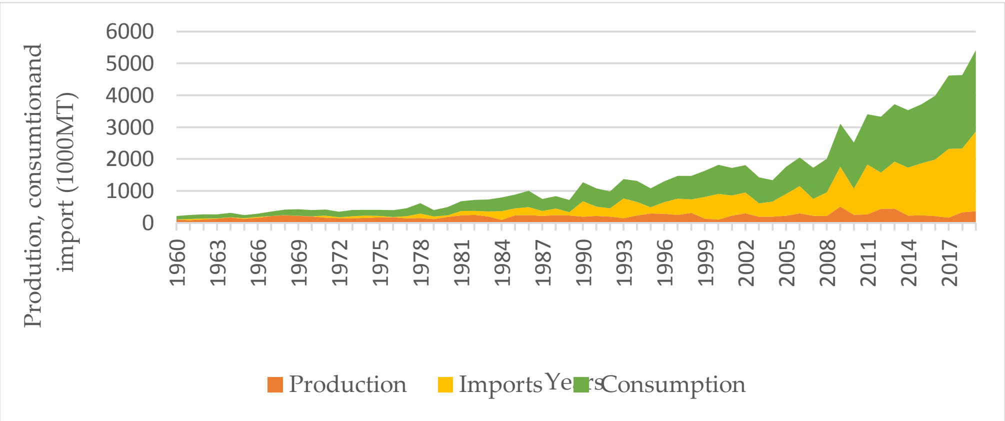

Fig. 1. Wheat production, consumption and import (1000MT) in Kenya (1960- 2016)

A lot of public investments have been put into wheat research in Kenya for many years. The current concern is whether it is worthwhile to continue with the investments. The problem is that there is no information on the returns to investments so far achieved to guide and justify the continued allocation of resources to wheat research.

High-yielding wheat varieties have been developed and released by the Kenya Agricultural and Livestock Research Organization (KALRO). However, variety release alone cannot bring the expected returns unless the new ones are adopted by farmers. Farmers can harness the potential gain from plant breeding only if they replace old varieties with newer varieties as and when they are released. This research attempts to estimate returns to wheat research, varietal adoption, and turnover rates and identify production risks faced by wheat farmers.

2. MATERIALS AND METHODS

2.1 Sampling Procedures and Sample Size

A multistage sampling technique was used in the selection of Counties, Sub-counties, and respondents. Due to resource constraints, the first stage involved a purposive selection of two out of the seven wheat-growing counties in Kenya, namely Nakuru and Narok, Fig. 2. The second stage involved the selection of four sub-counties, two from Narok County, and two from Nakuru County. The sample size was determined using precision criterion, which assumes that the dominant characteristics of a population would occur if the confidence interval is set at 95%. In total, the sample size selected for the detailed household survey was 344 households from Narok and Nakuru Counties in Kenya. Data collection took place between May - July 2018.

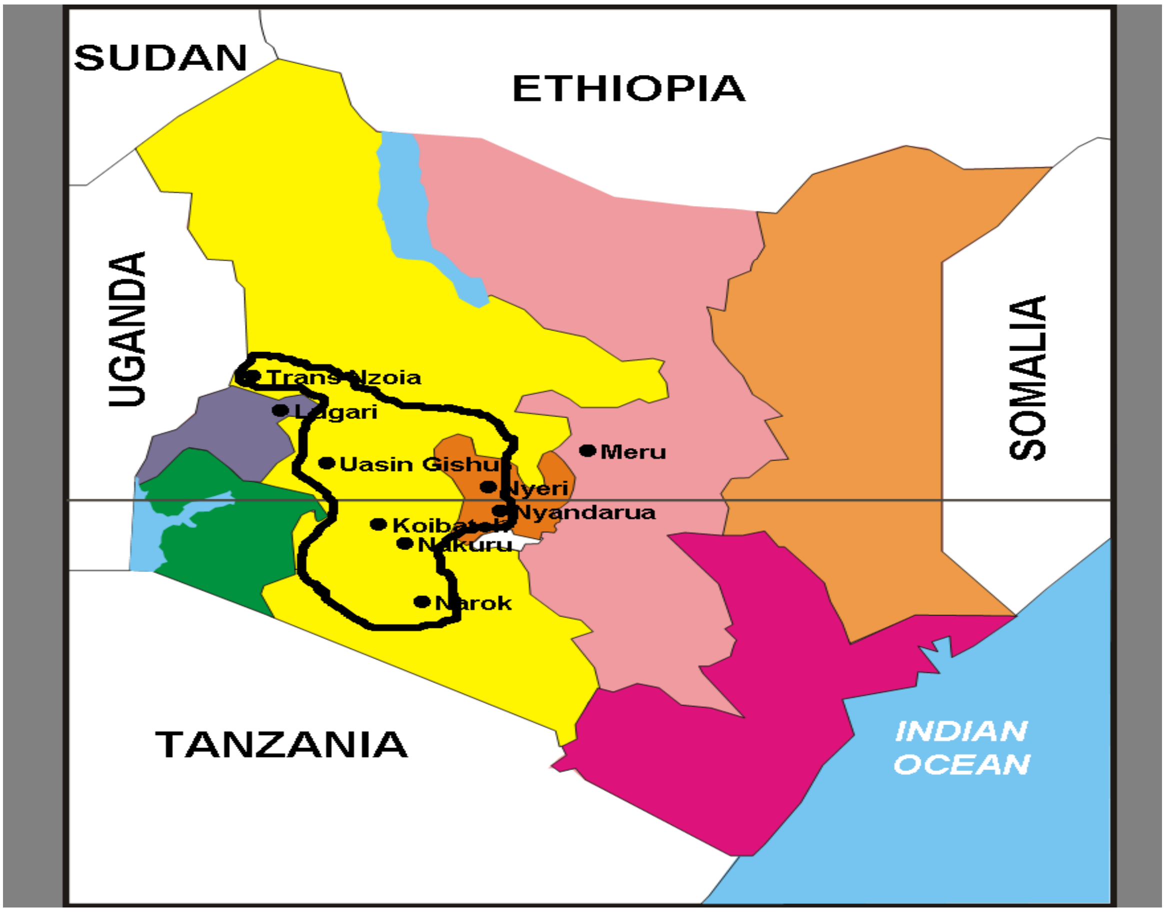

Fig. 2. Wheat growing areas of Kenya
Key: Dots represent the wheat producing areas
Source: KARI, 2012

Due to resource constraints and therefore limited sample size for this study, the results obtained may not be generalizable to the rest of Kenya. However, the results would be a good indicator of returns to wheat research in Kenya and could be augmented by further similar studies in the country.

3. METHOD OF DATA ANALYSIS

3.1 Model Specification of Analytical Models

3.1.1 Benefit-cost analysis of investments in wheat research

The BCA model by Brennan et al [9] was applied to estimate the returns to wheat research, in terms of the three indicators: BCR, NPV, and IRR. Following Bernann et al [9] the aggregate benefit of wheat research in Kenya (B), for 7 years from 2010 to 2016, annual change of genetic improvement of variety due to breeding program (Kt), and fixed and variable costs of wheat breeding research (TC) were estimated as:

$$B_t = P_t * Q_t * K_t \quad (1)$$

$$K_t = \sum V_{it} * g_t \quad (2)$$

$$TC = C^s S + C_{vt} \quad (3)$$

where:
P_t: Price of wheat in year t (t=1=2010, …., t=7=2016);
Q_t : Quantity of wheat in tonnes produced in year t ;
V_{it}: Proportion of area planted variety in year t ;
g_i: Genetic improvement for variety i ;
S: Number of full-time breeders and technicians in the breeding program ;
C_s : The costs accrued to breeders and technicians in year t ;
C_{vt}: Fixed and variable costs of research in year t

Following Brennan et al [9] and Soltani [10] the economic parameters were estimated as shown below:

$$PVB_t = \sum_{t=0}^{n} \frac{\beta_t}{(1+r)^n} \quad (4)$$

$$PVC_t = \sum_{t=0}^{n} \frac{TC_{(t)}}{(1+r)^n} \quad (5)$$

Where:
PVB: Present value of benefits accrued from the research program ;
PVC: Present value of Costs incurred in the research program ;
r: Discount rate ;
n: period.

Benefit Cost Ratio (BCR) was estimated by dividing the total discounted value of the benefits by the total discounted value of the costs incurred in the wheat research program:

$$NPV_t = \frac{\sum_{t=0}^{n} \frac{\beta_{(t)}}{(1+r)^n}}{\sum_{t=0}^{n} \frac{TC_{(t)}}{(1+r)^n}} \quad (6)$$

Internal Rate of return (IRR) is a metric used in financial analysis to estimate the profitability of potential investments. IRR is a rate that makes the net present value (NPV) of all cash flows equal to zero in a discounted cash flow analysis. It is calculated in a way that the net present value of all the cash flows (both positive and negative) from the project equal zero.

$$IRR_{(t)} = NPV_t = \frac{\sum_{t=0}^{n} \frac{\beta_{(t)}}{(1+r)^n}}{\sum_{t=0}^{n} \frac{TC_{(t)}}{(1+r)^n}} \quad (7)$$

3.1.2 Wheat Varietal Adoption Rate

This study uses an adoption index by Phillip et al. [11] and Saka et al. [12] The adoption index was computed for individual farmers as follows:

$$Adoption_i = \frac{\sum_{i=1}^{n} p_i}{\sum_{i=1}^{n} T_i} \quad (8)$$

Where: $Adoption_i$ = Adoption rate for a specific new improved wheat variety by farmer i,
P_i = Land area in acres under a new improved wheat variety by farmer i,
T_i = Total land area in acres grown to wheat by farmer i.
i = [1, n]

The new improved wheat variety adoption rate is calculated by dividing the area for new improved wheat variety adopted by the total area planted to wheat, ranging from zero to 100.

Improved variety adoption rate (%)=
$$\frac{Area\ for\ improved\ variety\ adopted}{Total\ area\ for\ \text{wheat}}\times 100$$

3.1.3 Varietal turnover rate

Varietal turnover rate was estimated using the weighted average age of a variety model by Brennan and Byerlee, [13]. The rate of varietal turnover at a period 't' was calculated as the average age of the cultivated varieties weighted by the area under cultivation. As first proposed by Brennan and Byerlee [13] weighted average age of a variety is estimated as follows:

$$WAVA_t = \varepsilon_i P_{it} R_{it} \quad (9)$$

$$A_{it} = (Year_{it} - Year_{ir}) \quad (10)$$

$$W_{it} = \left(S_{it} / ST_{it} \right) \quad (11)$$

Where:
$WAVA_i$: (area)- weighted average variety age
A_{it}: is the proportion of the crop's area cultivated in variety i in year t
W_{ir}: is the number of years at time t since the variety's release.

3.1.4 Wheat production risks

Likert scale with responses on a 1-5 scale represented by 1=no/negligible risk, 2=low, 3=medium, 4=high and 5=extremely high risk, was used in ranking the risks in order of importance to the wheat farmers. To rank the different sources of risks, the mean of the five Likert scales was used.

4. RESULTS AND DISCUSSION

4.1 Returns to Wheat Research

Using the total cost and benefit we calculated the net present value (NPV), benefit- cost ratio (BCR) and the internal rate of return (IRR) for wheat varieties released by KALRO (2011-2016). Table 1 presents the annual streams of Benefits and Costs (TCs) that were discounted in a table in the appendix 1 of the paper. The results obtained by the application of the BCA model in terms of BCR, NPV, and IRR are 1.41, KES 23.31 million, and 41.0%, respectively (Table 1).

The BCR of 1.41 means that a one-shilling investment in the research returned KES 0.4per year over the investment period. The NPV of Ksh 23.3 million indicates that the benefits derived from the research investments exceeded the costs expended. And the IRR of 41% also shows a positive return on investments.

These results show that the investments in wheat research in Kenya by KALRO are worthwhile and should be continued. However, the BCR and IRR are relatively low when compared with those obtained elsewhere, for example, these results are comparable with studies undertaken by [14] for the Iranian wheat breeding program, where the BCR and IRR of four irrigated wheat varieties were estimated at 5.6 and 48.5%, respectively.

4.2 The Adoption Rate of Improved Wheat Varieties

Overall, the adoption rate of the new improved wheat varieties (NIWV) is 42% (Table 2). Therefore, almost 58% of the wheat area has remained under the old improved wheat varieties. The proportion of farmers adopting the NIWV is 56%, which is higher than the proportion of area under the NIWV, indicating that many farmers grow the NIWV in only a part of their wheat area. According to Wang et al 2010, it can take many years for farmers to accept the newly introduced varieties due to the uncertainties and risks. Thus, farmers typically grow the new improved varieties initially in a small area and expand this area over time as they become more confident about the suitability of the new varieties in their fields. The use of a new variety may be discontinued if farmers find it to be unsuitable. This experimenting and learning process is an important part of the adoption of any new technology, (Feder, Just, and Zilberman, 1985).

4.3 Proportion of Wheat Farmers Recycling the New Improved Wheat Seeds

Seed recycling is a common practice in wheat growing areas of Kenya. As shown in Fig. 3, about 85% of the sample farmers depend on recycled seeds while only 15% used new seeds. Further examination of Fig. 3 reveals that about 33% of the sample farmers recycle wheat seeds at most for 5 years whereas 30% of the sample farmers recycled wheat seeds at most for two years.

Table 1. Summary economic analysis of returns to wheat research in Kenya

Measures of economic viability	Parameter level
Discount Rate	10%
Present Value of Benefits (Ksh)	80,302,690
Present Value of Costs (Ksh)	56,989,662
Net Present Value (Ksh)	23,313,028
Benefit: Cost Ratio (BCR)	1.41
Internal Rate of Return (IRR)	41%

Source: Research Data (2018)

Table 2. Adoption rate of new improved wheat varieties (NIWVs)

County	Sub-County	Location	Households Adopting NIWV (%)	NIWV Area to wheat Area (%)
Nakuru	Rongai	Mossop	50	44
		Okilgei	27	12
		Ngata	15	13
	Njoro	Rikia	91	26
		Njoro	38	27
		M-Narok	76	58
Narok	Narok South	Nkareta	78	59
		Melelo	87	74
		Naisoya	76	71
	Narok North	Osupuko	59	53
		Suswa	34	26
		Loroito	44	41
Total			56	42

Source: Own calculation

4.4 Wheat Varietal Turnover Rate

Results in Fig. 4 show that the average varietal age was about 21 years. Nakuru County farmers growing old varieties with an. The average varietal age grown by farmers in Nakuru County was found to be more than 20 years compared to the age varieties with farmers in Narok County with an average of about 14 years. The weightage varietal age of more than 20 years showed, still the domination of old improved wheat varieties in Nakuru County.

The results also show that the small-scale farmers grew varieties of older varieties with an average of more than 20years compared to the large and medium-scale farmers who grew varieties less than 15years old. These results are similar to those found by Krishna et al, (2014) who found that in India, the average age of wheat varieties in farmers' fields was 10–15 years in 2007-08.

4.5 Wheat Production Risks

From the results presented in Table 3, it is clear that wheat farmers were vulnerable to natural, climatic conditions such as drought and rainfall fluctuations. Risks due to pests and diseases in wheat production also emerged as major sources of risks according to the farmers' responses. Lack of seed, with a mean of 3.10, was found to be one of the most highly ranked sources of technical risks by the sampled wheat farmers, followed by pests/diseases and flood/high rainfall with a mean of 2.84 and 2.18, respectively. A few respondents (about 5.3%) of the respondents cited drought as a major risk affecting wheat production in the study areas. Output price fluctuation had a mean of 3.24 was cited as the most important market risk followed by the high cost of inputs with a mean of 2.39. Financial risk occurs when enterprise profitability (rate of return) is less than the cost of using the capital fund, [15]. However, in this study, the high cost of credit was found to be very low with a mean of 1.19. Overall, the biggest challenge to the wheat farmers and the most important source of risk perceived by respondents is price fluctuations as it is reflected in its high ranking (mean 3.27 on a five-point Likert scale). The second source of risk cited by the respondents is drought (mean 3.10). Pests/ disease and insect attacks were ranked as the second and the third important wheat production risk sources with mean scores of 2.73 and 2.47, respectively. Hence, production and marketing risks are the major sources of risks in the study Counties and this is a reflection of the other wheat-producing Counties.

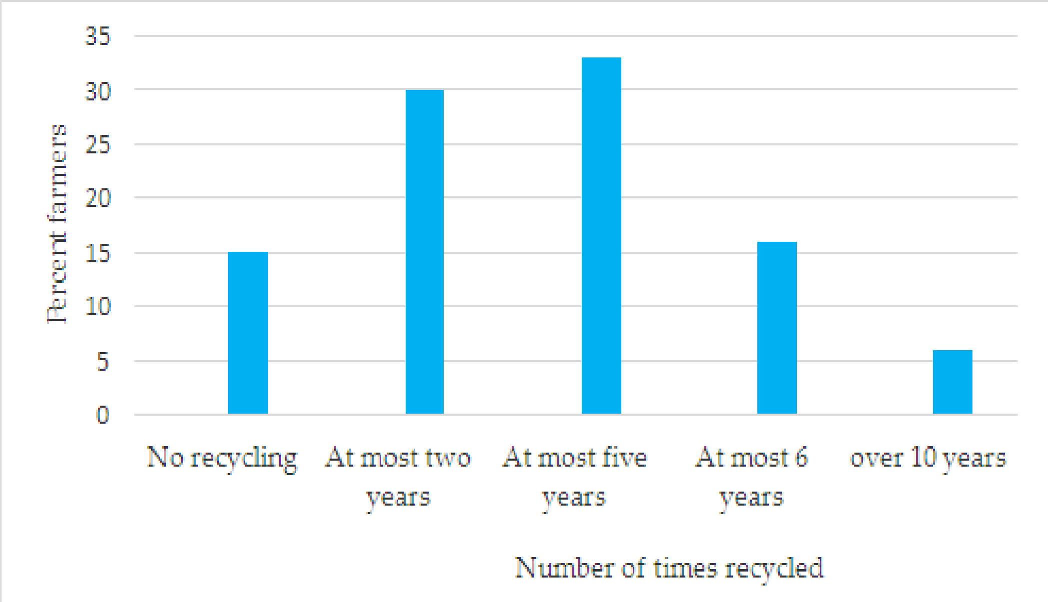

Fig. 3. Proportion of wheat growers recycling wheat seeds
Source: Research Data (2018)

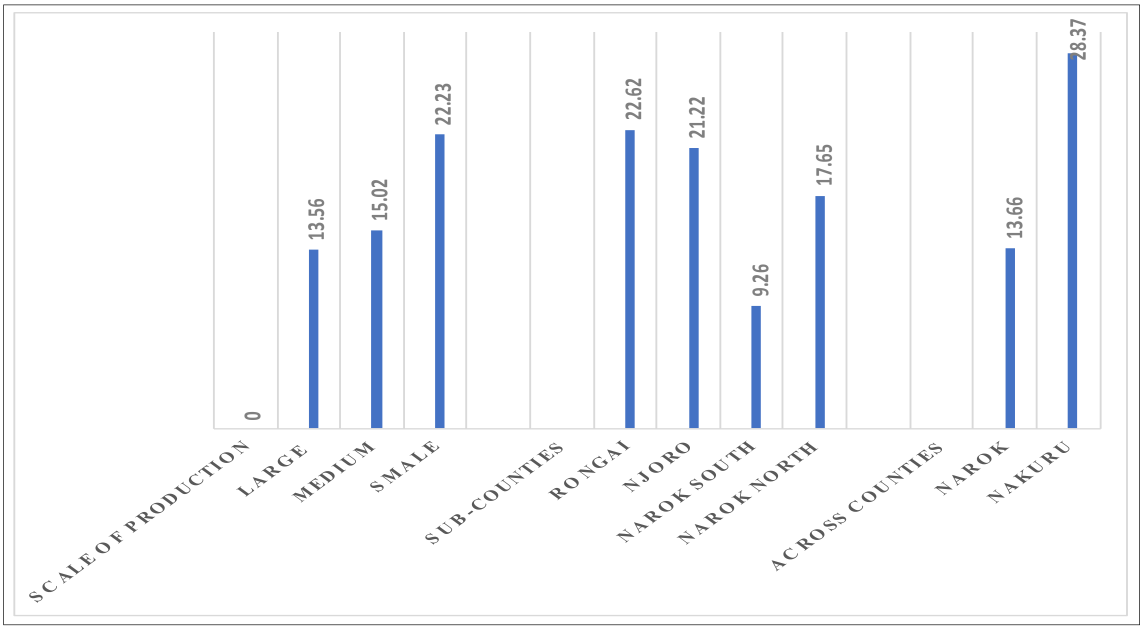

Fig. 4. The varietal age (yrs.) by scale of production, Sub- County and within the Counties
Source: Own compilation

Table 3. Mean scores and rank of major wheat production risk sources (n=344)

Sources of risks	Percentage response					Mean	SD	Rank
	1st	2nd	3rd	4th	5th			
Seed not available	10.9	20.9	21.6	41.6	5.3	3.10	1.127	2
Drought	19.3	10.9	50.1	17.9	3.2	2.84	1.054	3
Flood/high rainfall	34.7	30.9	22.4	7.8	4.7	2.18	1.129	5
Pests/ Diseases	10.1	21.6	23.2	26.3	19.3	3.24	1.268	1
Output price fluctuation	32	22.4	31.6	13.2	3.2	2.38	1.136	4
High costs of inputs	53.9	29.3	10.9	3.9	2.34	1.74	0.968	6
Weeds	64.8	23.5	6.4	6.3	2.4	1.63	1.017	7
High cost of credit	89.4	4.7	4.8	1.6	1	1.19	0.582	9

Source: Research data (2018)

Note: 1st =no risk, 2nd =low risk, 3rd =medium risk, 4th =high risk, 5th =very high risk

5. CONCLUSIONS

This research adopted benefit-cost analysis (BCA) for investigating the justification of investments in a wheat research program on wheat varieties released between 2010-2016. In this regard, NPV, IRR, and BCR, as the most popular economic indices were applied. Varietal adoption and varietal turnover rates were also evaluated. Given the results of the returns to wheat research, NPV, BCR, and IRR of wheat varieties were estimated at KES 23.31 million, 1.41, and 41%. The results also estimated varietal adoption as 42% and a varietal turnover of about 15.65years. Production and marketing risks are the major sources of risks The main conclusion from these results is that the return on investments in wheat research over the past years in Kenya is positive, even though relatively low compared with returns achieved elsewhere, largely due to low varietal adoption and turnover rates and high production risks.

It is recommended that to improve returns to wheat research in Kenya, varietal adoption and turnover rates should be enhanced and production risks should be minimized. That means that the research institutions, especially Kenya Agricultural and Livestock Research Organization (KALRO), should support the policies that accelerate the rate of variety adoption and turnover rates and reduction or elimination of production risks in all wheat growing regions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX 1. EXPENDITURES AND REVENUES FROM WHEAT RESEARCH (2010-2018)

Item	**Unit**		**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
					WHEAT EXPENDITURES AND REVENUE						
Government budget allocation to wheat research	Ksh	8,004,780	4865232	11361336	8764416	9804072		8869872	3106260	6398616	7921116
Donor funding for wheat research	Ksh	115,147.00	4,320,123.54	(84,645.07)	3,073,162.00	2,833,432.00		2,337,330.00	2,181,267.20	6,438,886.20	6,689,611.00
Sub -total budget	**Ksh**	**8,119,927.0**	**9,185,355.5**	**11276690.9**	**11837578**	**12637504**		**11,207,202.00**	**5,287,527.20**	**12,837,502.20**	**14,610,727.00**
Capital Expenditure	Ksh										
Land	Ksh	60,500.00	1,163,000	1,163,000	1,227,800	1,294,700		1,294,700	1,175,500	2,689,200	2,552,200
Buildings	Ksh	500,000	515,000	515,000	530,450	546,364		562,754	600,000	618,000	639,000
Equipment	Ksh	306,000	324,000	318,000	355,636	375,305		375,305	375,305	321,000	342,000
Sub-total Capital Expenditure	Ksh	866,500	2,002,000	1,996,000	2,113,886	2,216,369		2,232,759	2,150,805	3,628,200	3,533,200
Operating Expenditure											
Staff Salaries & Benefits	Ksh	6,619,910.00	2,619,910.00	1,779,899.00	1,923,103.00	1,068,040.00		5,223,080.00	(1,324,680.0 0)	(6,767,600.00)	2,986,990.00
Training	Ksh		0	0	0	0		0	1,015,000	1,015,500	1,015,000
Office operations	Ksh	500,000	-						50,000	565,000	536,000
Other	Ksh	133,517	4,563,446	8,500,792	8,800,589	9,353,095		3,751,363	3,396,402	5,396,402	4,539,537
Sub-total Operating Expenditure	Ksh	7,119,910	7,183,356	10,280,691	10,723,692	10,421,135		8,974,443	3,136,722	209,302	9,077,527
Grand Total Expenditure	**ksh**		**8,119,927.00**	**12,276,690.93**	**12,837,578.00**	**12,637,504.00**		**11,207,202.00**	**5,287,527.20**	**3,837,502.20**	**12,610,727.00**
Revenue from Wheat Production											
Hectares ('000 ha)	Ha		130	142	149	163		147	120	153	150
Yield per ha ('000 t)	Ton		2.5	2.5	2.5	2.5	2.5	2.5	2.9	2.6	2.9
Total Wheat production	ton		325	330	355	373	408	368	348	398	435
Average price per ton	Ksh		36,770	33,980	42,850	43,480	39,750	36,280	36,630	36,630	36,630
Total Gross Revenue	**Ksh**		**11,950,250**	**11,213,400**	**15,211,750**	**16,196,300**	**16,198,125**	**13,332,900**	**12,747,240**	**14,571,414**	**15,934,050**

Item	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018
Net Revenue (Loss/ Profit)	**Ksh**	**3,830,323**	**2,028,044**	**2,935,059**	**3,358,722**	**3,560,621**	**2,125,698**	**7,459,713**	**10,733,912**	**3,323,323**
YEAR	Y	2010	2011	2012	2013	2014	2015	2016	2017	2018
Economic Analysis: Measures of Economic Viability		-								
Discount Rate	10%									
Present Value of Benefits, Ksh	80,30 2,690									
Present Value of of Costs, Ksh	56,98 9,662									
Net Present Value (NPV), Ksh	23,31 3,028									
Benefit: Cost Ratio (BCR)	1.41									
Internal Rate of Return (IRR)	41%									

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