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Potato (*Solanum tuberosum* L.) On-farm Economic Study for Phosphorus and Potassium Fertilizers in Northwestern Ethiopia

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Abstract

In 2018/19, a study was conducted in the East Gojjam Zone of Northwestern Ethiopia to show the current potato cultivation problems relating to inorganic fertilizers at the farm level. The study used a mixture of 0, 34.5, and 69 kg P_2O_5 and 0, 100, 200, and 300 kg K_2O. RCBD (Randomized Complete Block Design) was used with three replications. Using a mixture of 34.5 kg P_2O_5 and 200 kg K_2O yielded a significant total and marketable yield of 49.14 t ha and 48.32 t ha, respectively (with an Ethiopian birr in the net reward of 236,172.40), In addition, this treatment surpass other treatments and produced a marginal rate of return that was higher than the least acceptable marginal rate of return. As a result, it is recommended that a combined fertilizer application method be used to optimize the economic return from potato production in the study area.

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INTRODUCTION

A weighty tuber crop, the potato (*Solanum tuberosum* L.) is grown all over the world. Over the previous 15 years, the overall production of this tuber has more than doubled in some countries in Sub-Saharan Africa (SSA)[1]. Ethiopia and the Amhara Region, on the other hand, are dominated by cereals.

But despite being vast, vegetable and fruit crop output are underused. For obvious reasons, root and tuber crop production potential is still untapped[2]. Due to its capacity to mature sooner than most other yields during periods of increased nutritional demand, the potato is key for food security and hunger substitution crop in the Amhara region.

The potato is well known for being the most efficient tuberous crop in terms of time to maturity, with tubers ready to harvest 60 to 120 days after sowing[3]. Potatoes are valued as a foundation of reserves and vitamins for food since they are a major source of energy with a high energy passage per unit of land, water, and time[4]. Accordingly, potatoes are one of the most widely consumed food crops in the region. As a result, the crop is incentivizing peasant farmers to plant a wide range of root crops. Ethiopian central statistical agency reported that, in the 2019/20 Meher season, the percentage distribution of potato crop area was 1.70%. The main activities in the entire production process for optimum potato yield are variety improvement, fertility management, and crop cultivation.

Low potato production, on the other hand, is associated with low soil fertility and a lack of intentional replacement of nutrients to cultivated soils in the cropping cycle after crop harvest in Ethiopia[5]. This is a problem in other African countries as well, including Tanzania[6]. Agricultural progress necessitates the continuous improvement of yield inventive knowledge on the farm[7].

Due to a lack of economic advantage over traditional production systems, farmers do not support some revolutionary technologies developed at trial stations[8]. Partially analyzing the budget can also help clarify best options because it can present useful evidence. A farmland feasibility review tin is kept on hand to assess the impact of planned farmstead outlays as well as earnings[9].

The impact of new technology on agricultural projects' yield, effectiveness, appropriateness, and competitiveness can be examined[10].

The use of the appropriate type of interaction (nutrition and higher-quality varieties), as well as the cost of these inputs, are related to the success of potato cultivation[11].

Potato is a crop that takes a huge amount of nutrients[12]. It necessitates macro and micro nutrients for proper growth and reproduction. Nitrogen and phosphorus fertilizers are currently used in potato production based on blanket recommendations[13]. Without taking into account physical and chemical conditions, as well as soil fertility and environmental conditions, the current suggested rates are 176 kg (Urea) (81 kg N) and 150 kg ha Diammonium phosphate (DAP) (69 kg P_2O_5)[14].

Regardless of the fact that the potato crop has a high demand for potassium, it has been completely ignored for many years.

Phosphate fertilizers' beneficial effect on growth could be explained in terms of canopy growth and increased radiation interception[15]. Increased phosphorus rate typically increased petiole-phosphorus concentration, and a decrease in the number of leaves in phosphorus-deficient plants can be attributed to decreased leaf initiation and shoot meristem activity[16].

Phosphorus has a significant impact on carbohydrate metabolism and energy transfer in potatoes, and it is a component of deoxyribonucleic acid, Ribonucleic Acid, adenosine triphosphate, and phospholipids in membranes.

With exception of nitrogen, phosphorus, and most other essential nutrients, potassium does not become a part of the plant's chemical structure[17]. As a result of its mobility within the plant, it can influence almost every aspect of plant growth. The response of potato growth to potassium application is frequently related to its yield potential and the number of tubers that can be produced[18]. Fast potato growth produces large tubers and responds more to potassium than slow growth produces small tubers. Potassium boosts crop leaf photosynthetic rate and carbon dioxide assimilation, as well as facilitating carbon movement[19]. Potassium is also important in the transport of photosynthates from source to sink.

Despite determining the cost-effectiveness of an exclusive flair aimed at a current assignment, the economic assessment is small[20]. It also acts as a foundation for comparing the relative viability of various operations, weighing in on their unevenness, and determining how healthy returns emerge when yield or contribution models are changed significantly.

Direct economic reasoning is used to assess the overall viability of reception by utilizing clear and concise budgeting, primacy, and disputable searching of distinctive processing[21].

Investigating the outlays and reimbursements of various configurations is done with a fractional budget inquiry[22]. This contained the regular harvests for individual variables, the accustomed products, full benefit, and finally the shifting expenses.

In some cases, the rates for content have different costs. It is the summation of all rates used for additional transactions that determine the overall expenses that are different. As a result of personal involvements, growers may or may not benefit.

As a result, a farming feasibility analysis would be conducted to determine the long-term benefit as well as any new income that may be obtained as a result of various extra activities[23]. When it comes to the overwhelming of potato studies, the focus is on fertilization concerns, with little consideration made towards another tuber economic factor[24]. Potato production can be a more flexible way to feed an increasing population than cereal production[25].

Accordingly, the study aimed to identify the grower's existing production technique, evaluate the feasibility of the method, and examine the impact of major factors. The study's specific goals were as follows:

1. Determining the economic feasibility of treating the Belete potato variety with P and K fertilizer.

2. Identifying the most profitable potato yield set from a substantial number of treatments.

MATERIAL AND METHODOLOGY

Area Description

The investigation was conducted in the East Gojjam zone of Northwestern Ethiopia (Fig. 1). The study site was

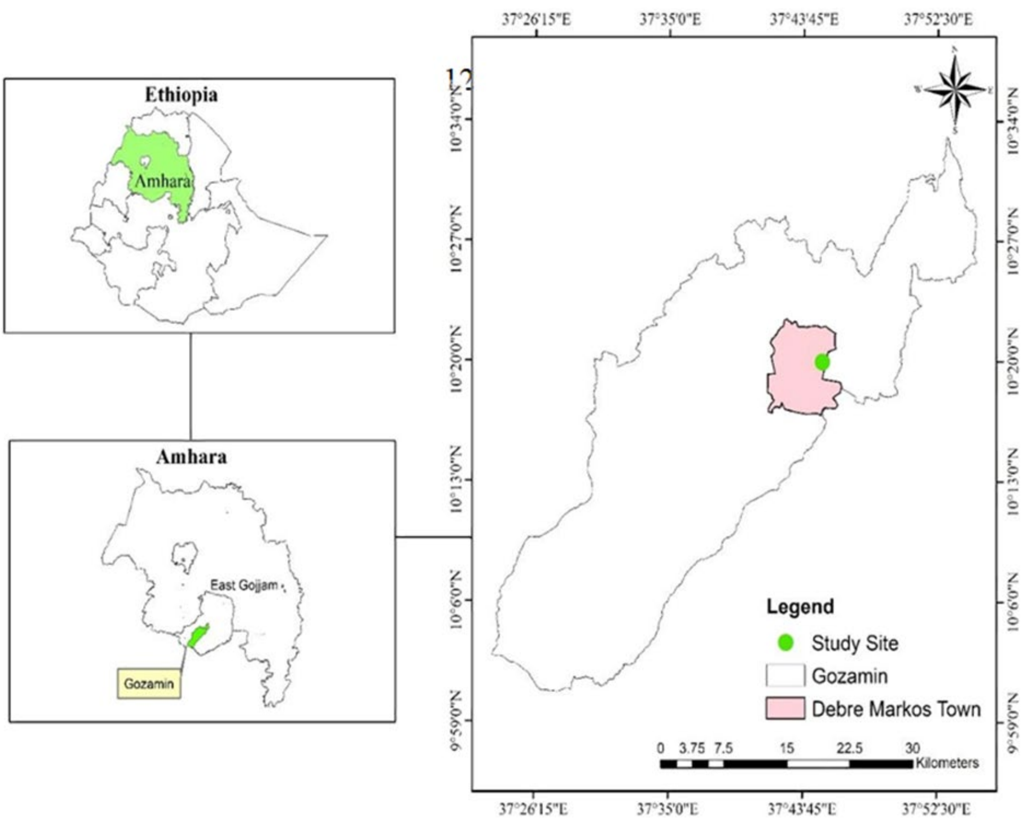

Fig. 1 Map of the study site.

characterized by its soil properties, such as pH 5.5, total nitrogen 0.09%, available phosphorus 8.30 ppm (parts per million), and exchangeable potassium 0.135 mole and CEC (cat ion exchange capacity) 23.64 mol. In latitude, it is between 10°1'46" and 10°35'12" north, while in longitude, it is 37°23'45" east. At an altitude of 2,460 meters above sea level, the location has long-term weather data collected from a meteorological station. In the area, long-term weather data from a local meteorological station shows a yearly rainfall total of 1,307 mm. May to mid-September is considered the rainy season, with the heaviest rainfalls occurring in July and August. It was 9.2, 25.8, and 16.00 ºC, respectively, for the mean minimum and maximum air temperatures. The meteorological station at Debre Markos University provided the data. There are a variety of soil types in the area, with nitisols being the most prevalent type[26].

Treatments and Experimental Design

The Belete potato variety was used in the study, which was conducted in rain-fed conditions. This variety has been widely adopted and recommended in the study area. The potato was acquired from Debre Tabor, a cooperative that produces potato seed and sown on a prepared field. The treatments included all possible combinations of 0, 34.5, and 69 P_2O_5 and 0, 100, 200, and 3,000 kg K_2O. It used all possible combinations of P_2O_5 0, 34.5, and 69, as well as K_2O 0, 100, 200, and 300. TSP (Triple Super Phosphate) and KCl were consistently used as P_2O_5 and K_2O sources all through the experiment.

Three replications of RCBD (randomized complete block design) were used in the experimentation. The rows and plants were spaced at a distance of 75 cm by 30 cm. 3 m (length) × 3.75 m (width), 5 lines/plot, 10 potatoes/row, 50 plants total. As part of the sampling process, plants that were growing on the margins were not taken into consideration. Blocks and plots were separated by one and a half meters, respectively[27].

Experimental Procedures

It was needed to dig out the experimental area 3 times by hand, following the directions in the crop package. 15 days before the tubers were planted, the layout was done and the tubers were planted. On the other hand, a random draw technique was used to apply fertilizer to experimental units[28].

All P_2O_5 rates and half potassium rates were applied during tuber sowing, and the half-rate was applied after 40 days of sowing[29]. Urea at the proportion of 176 kg/ha (81 kg/ha N) was applied in two equal splits to all experimental plots as commended by ARARI (Amhara Regional Agricultural Research Institute). Other agronomic methods such as weeding, hoeing, earthing, and insect management was implemented as a result of the recommendation[30].

Methods for Partial Budget Analysis

Three techniques were employed entirely to develop technical packages that are not only profitable but also have a virtuous advantage and remain viable in a variety of contribution and harvest values[31]. First, a reasonable probability evaluation was conducted, which resulted in remaining compensation substitutes being considered. When it came to net reparations, the comparison was made with a proportionate budget by examining the extent of complying with unpredictable expenses[30].

Parameters of the Collected Data

(AvY): Gross average tuber yield in hectares (t/ha). AjY (adjusted yield): To observe the difference between experimental yield and farmer productivity, the average has been adjusted by 10%. It's like this: t/ha = AvY (1 − 0.1). Therefore:

GFB/ha (gross field benefit/hectare) = Farm gate price/Quintal × AjY

Total variable cost: The cost of the fertilizers used for the experiment. There were no significant differences in the costs of other inputs and production processes such as the labor costs for land preparation (preparation of the soil), sowing, weeding, crop protection, and harvesting (labor expenses). For each treatment, the NB (net benefit) (ETB/ha) was calculated by deducting all of the expenses from the gross benefits. Therefore, NB = GFB − Total cost. MRR (Marginal rate of return) was calculated by dividing the change in net benefit by the change in cost[32]. Thus:

$$\mathrm{MRR} = \frac{\Delta \mathrm{NB}}{\Delta TVC} \text{ or } \frac{\text{Marginal benefit}}{\text{Marginal cost}} \times 100$$

Table 1. Fertilizer input costs, application costs, and total variable costs.

Treatment ($P_2O_5 + K_2O$)	Input costs		Application cost Labor cost (ETB)	Total variable cost
	TSP	KCl		
0:0	0.00	0.00	0.00	0.00
0:100	0.00	1,100.00	400.00	1,500.00
0:200	0.00	2,200.00	400.00	2,600.00
0:300	0.00	3,300.00	400.00	3,700.00
34.5:0	422.625	0.00	200.00	622.20
34.5:100	422.625	1,100.00	400.00	1,922.60
34.5:200	422.625	2,200.00	400.00	3,022.62
34.5:300	422.625	3,300.00	400.00	4,122.62
69:0	845.25	0.00	200.00	1,045.2
69:100	845.25	1,100.00	400.00	2,345.2
69:200	845.25	2,200.00	400.00	3,445.2
69:300	845.25	3,300.00	400.00	4,545.2

TSP (Triple Super Phosphate), KCl (Potassium Chloride), ETB (Ethiopian Birr).

Table 2. P and K fertilizers applications on potato production: a net benefit estimate.

Treatment ($P_2O_5 + K_2O$)	AY (t/ha)	ADY (t/ha)	FP/Q (00 ETB)	GFP	TVC (ETB/ha)	NB (ETB/ha)
0:0	21.19	19.07	550.00	104,885.00	0.00	104,885.00
0:100	22.49	20.24	550.00	111,320.00	1,500.00	109,820.00
0:200	24.96	22.46	550.00	123,530.00	2,600.00	120,930.00
0:300	22.04	19.84	550.00	109,120.00	3,700.00	105,420.00
34.5:0	20.47	18.42	550.00	101,310.00	622.2	100,687.40
34.5:100	38.57	34.71	550.00	190,905.00	1,922.6	188,982.40
34.5:200	48.32	43.49	550.00	239,195.00	3,022.6	236,172.40
34.5:300	39.92	35.93	550.00	197,615.00	4,122.6	193,492.40
69:0	25.70	23.13	550.00	127,215.00	1,045.2	126,169.8
69:100	33.89	30.50	550.00	167,750.00	2,345.2	165,404.8
69:200	42.37	38.13	550.00	209,715.00	3,445.2	206,269.8
69:300	38.12	34.31	550.00	188,705.00	4,545.2	184,159.8

All abbreviations are mentioned above (Parameters of Collected Data).

RESULTS AND DISCUSSION

To evaluate farming feasibility, CIMMYT (International Maize and Wheat Improvement Center) of 1988 estimated that changes between 5 and 30% are appropriate for on-farm promises depending on the tuber's normal yield. 10% of the tuber was reduced for agronomical consequences intended for farmers.

Cost-Effectiveness

For the economic information, the standard products of each treatment were retained in favor of total replications. Given all this, Table 2 gives the apparent advantage of aiming at 12 various treatments. There was a net benefit of 236,172.40 ETB by applying 34.5 kg P_2O_5 + 200 kg K_2O ha followed by 34.5 kg P_2O_5 + 100 kg K_2O ha, and 69 kg P_2O_5 + 0 kg K_2O ha, with a net benefit of 188,982.40 and 126,169.8 ETB, respectively.

Whereas the lowest net benefit of 100,687.40 ETB was recorded from half rate of phosphorus combined with 0 kg of potassium, followed by the control with a net benefit of 104,885 ETB. Because of low yield and high-cost dominant treatment combinations, the poor net gain may be due to a low net benefit. The general costs increased till a certain point, as well as the straight profit also expanded. There was a net benefit, though, if one blended advanced flexible expenses with lower earnings, because total costs vary at the ideal level[33].

Analysis of Dominance

Growers prefer the best products for the best return (little rate thru big revenue)[34]. As a result of an emphasis on attitude, the concern required to conduct an examination gained. Even though these activities make a considerable amount of money, they still fall short of what individuals can achieve through subordinate adjustable expenses[35].

The dominance analysis is used to eliminate certain treatments from further consideration in shortening the analysis[36]. From the lowest to the highest costs, the dominant (undominated) treatments were ordered[24]. But on the other side, net gain curves specify a certain consciousness and persuaded scheduling regarding distant costs of response, which equates to genuine increments of outlays then returns within all possess about particular treatments[37]. An incomparable change request led the overall percentage of deviation to increase, resulting in a net-benefit drop for the business. Farmers are reluctant to receive more dominant responses than incomparable alternatives because of this. An increase in support during skirting led to a rise in assumptions about ambiguous tasks like returns[38].

Return Margin

The study mainly applied a partial budget analysis for scrutinizing the monetary value of the inputs in agricultural production. Hence, estimation of benefit-cost ratio, marginal benefit, and marginal rate of return can be used to compare the cost and value of those inputs in the production process. Thus, the benefit-cost ratio (BCR) summarizes the overall relationship between the relative costs and benefits of a proposed amount of the P_2O_5 and K_2O fertilizers with respected potato yield expressed in monetary terms. Therefore, the study found the overall benefit-cost ratio of the application of 34.5 kg of P_2O_5 and K_2O is 200 kg, which implied the value of the potato yield is much higher than the value of the cost of these inputs in monetary terms per hectare of potato-producing land. Similarly, estimation of marginal benefits (MB) infers the maximum amount of potato yield a farmer may produce from an additional utilization of the inputs. It can also be expressed in monetary terms by deducting the marginal value of the potato yield from the marginal cost. This is due that marginal benefit and marginal

Table 3. Dominance analysis of the effect of phosphorus and potassium fertilizer rates on potato tuber yield.

Treatment ($P_2O_5 + K_2O$)	TVC (ETB/ha)	NB (ETB/ha)	B: C ratio
0:0	0	104,885.00	
34.5:0	622.2	100,687.40D	161.82
69:0	1,045.2	126,169.8	120.71
0:100	1,500.00	109,820.00D	73.21
34.5:100	1,922.6	188,982.40	98.29
69:100	2,345.2	165,404.8D	70.52
0:200	2,600.00	120,930.00D	45.51
34.5:200	3,022.6	236,172.40	78.13
69:200	3,445.2	206,269.8D	59.87
0:300	3,700.00	105,420.00D	28.49
34.5:300	4,122.6	193,492.40D	46.93
69:300	4,545.2	184,159.8D	40.51

TVC: total variable cost, NB: net benefit, B: C ratio: benefit-cost ratio, D: dominated treatments.

Table 4. Different fertilization rates of phosphorus and potassium affect the potato's marginal return rate (MRR).

Treatment	TVC (ETB/ha)	MC (ETB/ha)	NB (ETB/ha)	MB (ETB/ha)	MRR (%)
0:0	0		104,885		
69:0	1,045.2	1,045.20	126,169.8	21,284.8	2,036.4
34.5:100	1,922.6	877.40	188,982.40	62,812.6	7,178.9
34.5:200	3,022.6	1,100.00	236,172.40	47,190.00	4,290.0

NB (Net benefit), MB (marginal benefit), and MRR (marginal rate of return), TVC (total variable cost), and MC (marginal cost).

cost are the two measures of how the value or cost of a product changes. Therefore, the study found the marginal benefit of the application of an additional unit of P_2O_5 and K_2O is 236,172.40 Ethiopian Birr. Finally, the study found the marginal rate of return (MRR) for these inputs by dividing the exclusive marginal return of P_2O_5 and K_2O in the production process. Hence, it shows the rate is in decreasing circumstances to show the inputs are substitutable to some extent than utilization of only one of the inputs in Ethiopia farming. Furthermore, the study found the MRR at using a mix of 34.5 kg ha P_2O_5 and 200 kg ha K_2O is 4,290.0, implying that it is at the optimal (advisable) rate of utilization of these inputs.

As shown in net benefit-cost ratios, while the cost was 1 Birr, the gain was 73.22 Birr to 161.82 Birr for the most prevailing possible treatments. There had been a minimum rate of return (MRR%) calculated into each of the two listed yields. As per the MRR % among every two dominant responses, fertilizer betting yielded a certain return per share[39].

Table 4 summarizes the results of this analysis. One technique to analyze this change is to divide a specific difference in net benefits by a certain variation in expenses[40]. The minimal net profit is considered a small amount of return[41]. As a result of this analysis, the minimum acceptable return on farmer recommendations was set at 100%. Because of this, it's important to note that the minimum permissible return for farmers' suggestions is 50%.

Influenced marginal quantity of return found was to be greater than the specific lower passable level of the beginning being changed to ensure terminating response by the strong loftiest rate of establishment[42]. As a result, the study revealed an appeal of 34.5 kg P_2O_5 + 200 kg K_2O ha through a total gain of 236,172.40 ETB, which was the highest recommendation. There was no (definitely) maximum marginal point of improvement for responses to the insignificant percentage of gain. But there was a maximal and apparent application congregated by an acceptable marginal return for responses to the minimal part of gain[43]. Expense compensation can be split by using a specific deviation within costs as a way of evaluating similar change[44]. A 100% increase was determined to be the smallest acceptable gain from farmers' perspectives. It's important to note that CIMMYT indicates how farmers can expect higher of between 50 and 100 %.

CONCLUSIONS

There is no doubt that the potato (*Solanum tuberosum* L.) is the world's most significant tuber vegetable. A variety of chips and other products are made from potatoes. There is indeed a study done being undertaken in Ethiopia's northwest region of East Gojjam in 2018/19. To evaluate the economic feasibility of Phosphorus and Potassium fertilizer treatments on a Belete potato variety, the analysis was carried out under rain-fed conditions. The experiment was set up in RCBD (randomized complete block design) with three replicates seeking three P rates and four potassium levels. In this study, no fertilizer application was used as a control. A total of 49.14 tons of tubers per hectare were produced by sets of plots that received phosphorus fertilizer and potassium fertilizers. In addition, the highest marketable yield (48.32 t ha) of Belete was grown on a combined offer of phosphorus and potassium, which isn't yet measured in some substantial commendation of mineral nutrients. Fertilization with 34.5 kg P_2O_5 and 200 kg K_2O resulted in an additional 24.42 t ha of marketable harvest as compared to non-fertilized crops. In this study, the on-farm investigation has also been used, keeping in mind the total adjustable-rate and apparent benefit, as well as the outlying amount of gain. While all dominant treatments had marginal rates of return higher than the lowest acceptable marginal rate of return, the contemporaneous use of half kg P_2O_5 and 200 kg K_2O fertilizers was economically acceptable when compared to other dominant treatments. Accordingly, it is suggested that half kg of P_2O_5 and 200 kg of potassium be applied to maximize economic returns from potato production in the research area.

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Conflict of interest

The author declares that there is no conflict of interest.

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