Agronomic and Economic Performance of Potato (*SolanumTuberosum*L.)in Response toNitrogen and Phosphoroussupply at Bekoji, SoutheasternEthiopia

Abstract

An experiment was conducted at Bekoji in southeastern Ethiopia during the 2021 and 2022 cropping seasons to evaluate different N and P fertilizerrates on agronomic performance, tuber yield, and economic profitability of potato tuber production. The treatments used consisted of four levels of nitrogen (0, 46, 92, and 138 kg ha^{-1}) and phosphorus (0, 46, 69, and 92 kg ha^{-1}) combined with factorial arrangements and laid out in a randomized complete block design with three replications. The results revealed that almost all parameters were significantly affected by the main effect of nitrogen and phosphorus fertilizer rates, still their interaction did not affect yield except potato plant height. As a result, in both seasons, the highest total tuber yield was obtained at the combined application of 138 kg N with 92 kg P_2O_5 ha^{-1}. However, the partial budget analysis indicated that the combined application of 92 kg N and 92 kg P_2O_5 ha^{-1} gave the highest net benefit with an acceptable marginal rate of return (MRR) of 644.68%, which might be taken as a profitable rate for the test area. Therefore, based on economic performance, it can be concluded that the fertilizer application at the rate of 92 kg N ha^{-1}in combination with 92 kg P_2O_5 ha^{-1} fertilizer rates is more economical and hence, recommended for potato production in the study area.

Keywords: Nitrogen,Phosphorus,Potato, Partial budget, Yield

INTRODUCTION

Potato(*Solanumtuberosum*L.)isthemajoreconomicimportancecropandthenumberonenon-cerealfoodcommodity in the world [1]. It is characterized as a cheap and nutritious food security crop, because of its high yield with good nutritive values per unit area and per unit of time compared with other major cereal crops [2][3]. Ethiopia has an immense potential to boost the productivity of potato, especially in the highlands [4][5]. The potential yield of potato can reach up to 50 t ha^{-1}[6]. But the average national potato productivity in Ethiopia is 10.5 t ha^{-1}, while progressive farmers who use improved agronomic practice attained yields of 25 t ha^{-1}. This is due to the currentpotatoproductionpracticewithinappropriatenutrientmanagementpractices[7]and constrained by several problems.In addition to this continuous cropping without replacing the removal nutrient removal by the crop from crop biomass and other organicsource are the majorsourceofnutrientdepletion in Ethiopia [8].

Nitrogen, phosphorus and potassiumare the major essentialnutrients to increase the yield of potato [9].Deficiency of any or combinations of these nutrients can result in retarded growth or complete crop failure under severe cases [10].Providinganoptimumamountofnitrogenencouragesrootgrowth and development as well as the absorption of other nutrients[11].Asufficientamountofphosphorusnutrientalsoimproveafewaspectsofplantphysiology, includingthefundamentalprocessesofphotosynthesis,rootgrowth especially the development of lateral roots and fibrousrootlets[11].On the other side, too much N and P might result in decreased production and profitability [12]. As a result, determining the proper N and P fertilizer rate is critical for maximizing economic yields.In addition to that lack of optimum nitrogen and phosphorus application rates, there are a number of production problems accounting for low yields of potato in Ethiopia. These constraints include limited supply of high quality seed tubers of potato [13], inappropriate agronomic practices and inadequate storage [14], and limited knowledge resulting in poor seed tuber selection [15]. This situation would become more critical in potato production in view of the fact that the crop is one of the heavy feeders of soil nutrients [16].

Different recommendations have been reported by different researchers at different locations for the combined application of NP fertilizer on the yield of potato [7]. Researchconductedby [17]showedthatcombinedapplicationof nitrogenandphosphorusfertilizershadincreasedthe yieldofpotatoby12.26tha^{-1}ascomparedtocontrol (unfertilized plot).The highest tuber yield (40tha^{-1}) was obtainedbyapplyingrateof138kgNha^{-1}and46kg$P_2O_5$$ha^{-1}$fertilizersat southGondar[18].Similarly,Wubengeda*et al*[19]reported thatbyincreasingtheratesofthetwo(NandP)nutrients theyieldandyieldcomponentsofpotatowereincreased. Desalegn*et al*[20] alsoreportedthatincreasing theratesofnitrogenandphosphoruscanenhancethe tuberyieldby361and358%ascomparedwithunfertilizedtreatment.Generally,theabove-mentionedstudies showed that appropriate agronomic practices includingsitespecificfertilizerrecommendationplaysasignificant role in potato production.

As a result, there is an increasing demand for site-specific or agro ecology-based fertilizer recommendations. Greater application of improved recommendations, combined with more demand, is one of the key strategies for boosting potato yields in Ethiopia. Moreover, to provide useful information and making decisions to recommend the result of the field experiment to the farmers, conducting agronomic and partial budget analysis is important. Partial budget analysis can be used for comparing the impact of a technological change on farm costs and returns [21]. New technology can be evaluated in terms of its impact on the productivity, profitability, acceptability and sustainability of farming systems[22]. As a result, a fertilizer trial was conducted with the primary goal of developing an economically optimal fertilizer recommendation for potato tuber production in Bekoji highland Nitosolarea of the Arsi.

2. MATERIALS AND METHODS

2.1. Description of the Study area

The field experiment was conducted at Bekojistation, Southeastern Ethiopia during the growing season of 2021 and 2022. Bekoji is located between latitude and longitude of07^0 32’ 37’’ N and 39^0 15’ 21’’ E (Figure 1). The altitude of Bekoji is 2810 meters above sea level and the annual minimum and maximum temperature of 3.8 and 20.4 ^{0}C respectively with annual rain fall of 939 mm. The rainy season over the sites extends from June on October and is sufficient for crops with a maturity period of 120–150days (Table 2). The soil type of the area was Clay soil (Nitosols) with pH of 5.15 as indicated in Tables 1.

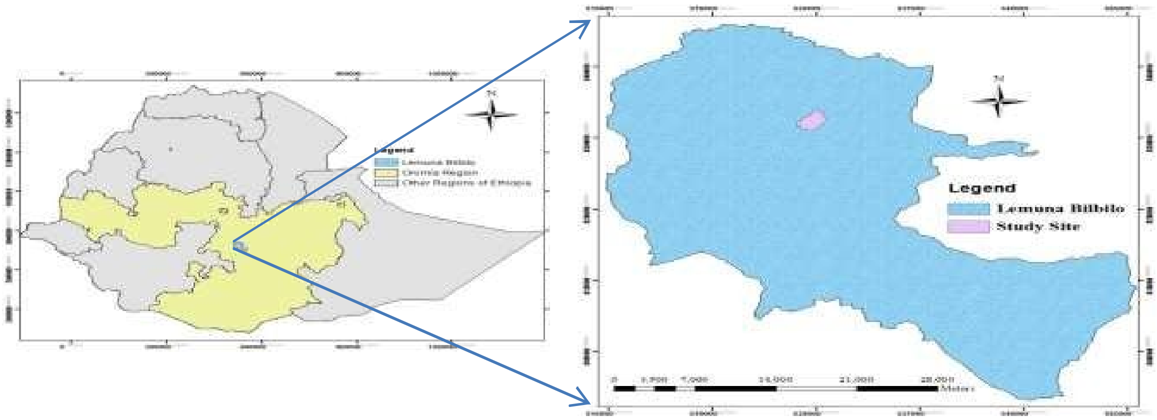


Figure 1. Map of the study site

Table 1. Physicochemical properties of soils atBekoji experimental site.

Soil physical and chemicalproperties							
Soil pH	Total N (%)	Available P (ppm)	Available K(Cmol^{+}. kg^{-1})	CEC (Meq per 100g)	Organic matter(%)	Organic carbon(%)	Texture
5.15	0.19	11.79	0.83	23.72	1.89	2.16	Clay loam

Source: Kulumsa Agricultural Research Center, Soil laboratory.

Table 2. Meteorological parameters at the experimental site for the year 2021 and 2022

Cropping season	Cropping months	Mean monthly Rainfall (mm)	Mean air temperature (^{0}C)		Relative humidity (%)
			Minimum	Maximum	
	May	74.2	3.5	21.0	72
2021	June	82.6	3.1	23.3	78
	July	213.0	3.1	23.2	81
	August	193.3	3.5	20.8	82
	September	100.1	3.2	19.4	77
	October	57.5	3.1	20.3	78
	May	6.8	4.3	23.4	79
	June	163.8	3.6	25.0	84
2022	July	199.7	3.9	19.2	76
	August	135.8	3.6	19.7	74
	September	89.8	4.0	20.1	80
	October	97.8	2.8	19.8	76

Source: Kulumsa Agricultural Research Center, Bekoji Meteorology station, 2021&2022

2.2 Experimental Design and Treatments

Potato variety Belete was used for the study. The treatments consisted of four levels ofN (0, 46, 92 and 138 kg/ha) andP_2O_5(0, 46, 69 and 92 kg/ha). The entire rate of P and the half of the N fertilizers were applied at the time of planting. The remaining half of the N was applied 45 days after planting. Urea (46% N) andTriple Super Phosphate (46% P_2O_5) were used as fertilizer for N and P, respectively.The design used was a 4 x 4 factorial experiment arranged in a Randomized Complete Block, replicated three times. The plot size was four rows of each 3 m long and medium size and well-sprouted potato tubers were planted at a spacing of 75 cm between rows and 30 cm between plants. Spacing between plots and replications were 1 and 1.5 m, respectively. Cultural practices such as weeding, cultivation and ridging were practiced as per the recommendation.

2.3 Soil Sampling and Analysis Prior to the Experiment

The composite soil samples were collected to identify the initial physico-chemical properties of the experimental soil. Thesoilwasanalyzedfortextureandsoiltotalnitrogen,availablephosphorous,pH,OC,andCEC.The texture of the soil was determined by the hydrometer method [23]. Total soil N was analyzed by the Kjeldahl digestion method with sulphuric acid [24].Soil pH was determined from the filtered suspension of 1:2.5soils to water ratio using a glass electrode attached to a digitalpHmeter,apotentiometer[25].Organiccarboncontentwasdeterminedbased on theWalkley-Black chromic acid wet oxidation method [26]. The available soil phosphorus was determined bythe Olsen method [27]. Exchangeable potassiumwas extracted by ammonium acetate at pH 7 [28]anddeterminedbyanAtomicabsorptionspectrometer. The cations exchange capacity (CEC) of the soilwas determined following the 1N ammonium acetate extraction(pH7)method.

2.4 Agronomic Data Collection and Measurements

The agronomic data were collected at different stages of growing period and after harvesting from the representative samples. Theseparameters include: phenology and growthparameters; days to 50% flowering, days to physiological maturity, plant height(cm) and average stems number per hill. For yield parameters; average tuber number per hill, marketabletuberyield (t ha^{-1}), unmarketable tuber yield (t ha^{-1})and totaltuberyield(t ha^{-1}) were recorded.

2.5 Partial Budget Analysis

To consolidate the analysis of variance of the agronomic data, economic analysis was performed for each treatment. For economic evaluation, cost and return, and benefit to cost ratio was calculated according to the procedure given byCIMMYT. Actual marketable tuber yield was adjusted downward by 10% to reflect the difference between the experimental tuber yield and the tuber yield that farmers would expect to get from the same treatment.The economic analysis was based on the formula developed by CIMMYT [29].

2.6 Statistical analysis

Analysis of variance was carried out for the growth, yield and yield components following the standard statistical procedures using R software. Whenever treatment effects were significant, the means differences were separated using the least significant difference (LSD) at 5% level of significance. The economic analysis was performed following the CIMMYT partial budget analysis methodology [29].The Urea (46% N) and Triple Super Phosphate (46% P_2O_5) cost 1284.05 and 1158.58 Birr per 100 kg, respectively. At Bekoji, the potato farm gate price (Birr100kg^{-1}) was 1200 Ethiopian Birr.

3. RESULTS AND DISCUSSION

3.1. Soil of the study site

The textural class of the soil at the experiment's site was Clay loam, and it was believed to be suitable for producing potato and other major crops (Table 1). According to [30], the soil at the study site had low levels of total N (0.21%), moderate levels of available P (11.79 mg kg^{-1} soil), low levels of organic matter (1.89%), and medium levels of organic carbon (2.16%). It was also moderately acidic in reaction (pH = 5.25) [31]. The study area's low OC and low N content indicate the soil's low fertility state [32]. This can be the result of continuous cultivation without the addition of organic components (Table 1). Therefore, nutrients must be provided in the form of synthetic fertilizer, organic fertilizer, or in combination for the greatest potential potato production. The study site's exchangeable K for soil was 0.83 cmolc kg^{-1}. According to IPI [33], the soil K analysis result was higher than the research sites' essential limits. Following to the results of Amare [18], this showed that K is not restricting yield for the cultivation of annual crops, such as potatoes, in the research locations.

The analysis of variance (ANOVA) showed that there was a significant($P \leq 0.05$) difference among the main impacts of nitrogen and phosphorous rates, but there was no interaction effect between them for most of the parameters except on the potato plant height over both cropping seasons. Thus, the mean squares from the analysis of variance for both main effects on potato genotypes are presented in Table 5. While phosphorus mostly affected the marketable and total yield of potatoes in the 2022 season, nitrogen had a substantial impact on all parameters in both years (Table 4). Phosphorous primarily affected potato marketability, overall yield, and plant height in 2021(Table 3). Most of the yield traits of potato were strongly impacted by the main effects of nitrogen and phosphorus fertilization.

Table 3ANOVA for the response of N and P fertilizers on the phenology, growth and yield parameters of potato 2021

Source of variation	DF	Mean square values							
		Days to flowering	Days to maturity	Plant height	Stem number per plant	Average tuber number per plant	Unmark etable yield	Marketable yield	Total yield
P	3	13.81*	3.39^{ns}	792.75*	0.11^{ns}	47.52*	3.25^{ns}	590.16*	686.81*
N	3	50.31^{ns}	14.17*	1446.60*	3.14*	33.96*	9.16*	1676.28*	1933.33*
P * N	9	3.95^{ns}	2.26^{ns}	45.12*	0.81^{ns}	4.12^{ns}	2.81^{ns}	48.62^{ns}	49.82^{ns}
Error	30	3.04	4.70	20.79	0.55	3.47	1.40	23.83	26.06
Total	45								

ns non-significant, * and ** significant and highly significant respectively

Table 4 ANOVA for the response of N and P fertilizers on the phenology, growth and yield parameters of potato2022

Source of variation	DF	Mean square values							
		Days to flowering	Days to maturity	plant height	stem number per plant	Average tuber number per plant	Unmark etable yield	Marketable yield	Total yield
P	3	5.06^{ns}	3.25^{ns}	190.47*	0.13^{ns}	45.13*	0.30^{ns}	1184.11*	1185.66*
N	3	6.94^{ns}	1.19^{ns}	646.78*	1.38^{ns}	19.60*	0.29^{ns}	853.93*	874.27*
P * N	9	4.56^{ns}	1.69^{ns}	55.89*	0.55ns	2.93^{ns}	1.00^{ns}	39.53^{ns}	39.00^{ns}
Error	30	3.62	2.91	23.39	0.51	2.15	1.30	89.21	93.78
Total	45								

ns-non-significant, * and ** significant and highly significant respectively

Table5. CombinedANOVAfortheresponseofNandPfertilizerson the phenology, growth and yield parametersofpotato

Source of variation	DF	Mean square values							
		Days to flowering	Days to maturity	Plant height	Stem number per plant	Average tuber number per plant	Unmarketable yield	Marketable yield	Total yield
P	3	11.24*	6.29ns	849.53*	0.08ns	90.40*	1.23ns	1701.02*	1807.19*
N	3	21.01*	9.57*	2011.25*	2.97*	48.40*	5.60*	2317.19*	2579.29*

P * N	9	1.50	2.07ns	78.31*	0.57ns	3.14ns	1.49ns	59.15ns	51.89ns
Error	30	3.27	4.18	26.01	0.53	2.82	1.31	59.06	62.68
Total	45								

ns non-significant, * and ** significant and highly significant respectively

3.2. Phonological parameters

Nitrogen and phosphorous fertilization interactions had no significant effect on the phonological parameters, but nitrogen has a substantial impact on the number of days required for flowering and physiological maturity of potato in 2021. Nitrogen levels showed a significant effect on days to physiological maturity, while phosphorus levels were found to be non-significant. When compared to the unfertilized treatment, the highest fertilized rate delayed flowering and maturity in the first 2021 cropping season (Table 7). Similarly, the result was supported by the findings of Israel*et al.*[34] and Worku*et al.* [35], who observed that higher nitrogen levels delayed the flowering and maturity of potatoes, which could account for their higher tendency to initiate vegetative development, including larger plants and more stems per hill. The physiological maturity of the potato was not affected by phosphorus fertilization, which, on the other hand, had no significant effect, whereas increasing phosphorus application from 0 to 92 kg ha^{-1}.

3.3. Growth and Yield

Plant height

The combined interaction of nitrogen and phosphorus significantly ($P \leq 0.05$)affected the plant height of potatoes (Table 6). The maximum plant height (79.33cm) was measured for the combination of 138 kg N and 92 kg P_2O_5 ha^{-1}, while the minimum plant height (43 cm) was recorded for the control plot (Table 6). A good supply of nitrogen stimulates root growth and development, as well as the uptake of other nutrients [36]. The interaction showed that the contribution of application of phosphorus fertilizer alone in increasing plant height was almost none, while plant height increased with increasing phosphorus fertilizer levels when combined with the application of 92 and 138 kg N ha^{-1}. Increasing the rates of both N and P from zero to the maximum has increased plant height by 46% over the control. This effect might be due to the obvious role of nitrogen in enhancing vegetative growth, which seemed to be more enhanced due to the presence of phosphorus. The results of the present experiment are in agreement with the findings of Alemayehu *et.al*[37] and Sharma*et al*[38], who reported that plant height increased with increasing fertilizer levels of nitrogen and phosphorus. This could be attributed to the enhanced availability of nutrients to the crop, which may have resulted in increased photosynthetic efficiency and increased metabolic activities of the plant with an increase in fertilizer level. Similarly, Firew*et al.*[17] and Zelalem *et al.*[7] also reported that increasing applications of nitrogen and phosphorus significantly increased the height of potato plants.

Table 6. Mean of pooled data analysis (2021-2022) results of interaction (N x P)effects of thetreatmentsonplant height atBekoji.

	P(kgha^{-1})			
N(kgha^{-1})	0	46	69	92
0	43j	47.00ij	49.83hi	50.50ghi
46	50.83ghi	56.33efg	56.00efg	58.50ef
92	54.87fgh	61.00de	68.67bc	69.83bc
138	55.17efgh	65.50cd	73.40b	79.33a
LSD(0.05)	8.68			
CV(%)	2.943			
Significant (N×P)	**			

Numberofstemperhill

The stem number per hill was not significantly (P≤0.05) influenced by the main effects of nitrogen and phosphorus, and their interaction were not significant in both seasons (Table 7). This might be related to the fact that the main stem number is mostly dependent on the number of sprouts per tuber. In line with the present finding, Worku *et al*[35] have reported that P fertilization did not significantly affect stem number per hill; on the contrary, the highest number of stems per hill was obtained at a rate of 138 kg N ha^{-1}.

Numberoftubersperhill

The main effect, use of different rates of phosphorus and nitrogen fertilizer has a considerable effect on the quantity of tubers per hill, but their interaction has not significantly affected the number of tubers per hill in both seasons. The maximum tuber number per plant was recorded at a rate of 92 kg P_2O_5 ha^{-1} (12.13 per hill), and the minimum value (7.47 per hill) was obtained from the control in the 2021 cropping season (Table 7). While in the 2022 season, at the rates of 138 kg N ha^{-1} and control plot, respectively, the maximum (10.07) and minimum (7.03) tubers were obtained. As a result, the number of tubers per hill increased as the level of nitrogen fertilizer increased. Similarly, increasing the level of applied sole nitrogen and phosphorus significantly increased the total tuber number per hill in both seasons (Tables 7 and 8). The increment in total tuber number per hill with increasing nitrogen fertilizer levels could be explained by the maintenance of photosynthesis, active leaves for longer durations. Thus, an increase in photosynthetic activity and the translocation of photosynthesis to the sink might have helped in the initiation of more tubers. As reported elsewhere, nitrogen application to potatoes before tuber initiation increases the number of tubers per plant and the mean fresh tuber weight [39]. In agreement with the present finding, Worku *et al*[35] have reported a significant tuber number increment in response to nitrogen fertilizer application. On the other hand, Israel *et al*[40] have also noted that the application of phosphorus increased the number of tubers set per unit area.

Table 7. Main effects of N and P_2O_5 on selected agronomic parameters 2021at Bekoji.

Sources of variation	DF	DM	PH	SN	AvTN	UmY	MY	TY
N (Kg ha^{-1})								
0	56.08b	116.5b	40.17d	3.53	7.93c	2.04b	21.97d	24.4d
46	56.58b	116.58b	50.28c	4.13	10.07b	2.7b	32.85c	36.05c
92	55.92b	117.08ab	59.42b	4.38	11.88a	2.67b	43.88b	47.04b
138	60.25a	118.83a	65.28a	4.75	10.93ab	4.11a	48.35a	53.22a
P_2O_5 (Kg ha^{-1})								
0	58.75a	117.75	42.58c	4.08	7.47c	2.3	27.19c	29.92c
46	57.08b	117.42	53.08b	4.17	10.16b	3.04	37.11b	40.7b
69	56.67b	116.5	58.95a	4.25	11.05ab	2.67	38.81b	41.97b
92	56.33b	117.33	60.53a	4.31	12.13a	3.52	43.95a	48.12a
ANOVA								
N	**	**	**	NS	**	**	**	**
P_2O_5	**	NS	**	NS	**	NS	**	**
N*P	NS	NS	**	NS	NS	NS	NS	NS
Mean	57.21	117.25	53.78	4.2	10.2	2.88	36.76	40.17
CV	3.05	1.85	8.47	17.67	18.27	40.98	13.27	12.71

Table 8. Main effects of N and P_2O_5 on selected agronomic parameters of 2022 at Bekoji.

Sources of variation	DF	DM	PH	SN	AvTN	UmY	MY	TY

N (Kg ha^{-1})								
0	62.58	126.58	55.00c	3.02b	7.03c	1.58	32.41c	33.99c
46	62.25	125.92	60.55b	3.42ab	8.31b	1.76	42.34b	44.1b
92	64.00	126.42	67.77a	3.83a	9.04ab	1.95	41.28b	43.23b
138	62.83	126.58	71.42a	3.55ab	10.07a	1.85	53a	54.85a
P_2O_5 (Kg ha^{-1})								
0	63.00	127.08	59.35c	3.47	6.14c	1.82	29.95c	31.77c
46	62.92	126.33	61.83bc	3.47	7.99b	1.62	39.36b	40.98b
69	63.67	125.83	65ab	3.57	10.2a	1.99	46.65ab	48.64ab
92	62.08	126.25	68.55a	3.32	10.12a	1.71	53.07a	54.78a
ANOVA								
N	NS	NS	**	**	**	NS	**	**
P_2O_5	NS	NS	**	NS	**	NS	**	**
N*P	NS	NS	*	NS	NS	NS	NS	NS
Mean	62.92	126.37	63.68	3.45	8.62	1.78	42.26	44.05
CV	3.02	1.35	7.59	20.62	17.01	63.79	22.35	21.98

* and **, significant at $p<0.05$ and $p<0.01$, respectively. ns= non-significant difference, CV (%) = coefficient of variation in percent, DF= Days to flower, DM=Days to physiological maturity, PH = Plant height (cm), SN=steam number per plant, AvTN= Average tuber number per plant, UmY (t ha^{-1}) = unmarketable tuber yield, MY (t ha^{-1}) = marketable tuber yield, TY (t ha^{-1}) = total tuber yield tons per hectare,

Marketableyield(tha^{-1})

The main effect of nitrogen and phosphorus levels showed a significant effect on marketable yield (t ha^{-1}). The maximum marketable yields of 48.35 t ha^{-1} and 43.95 t ha^{-1} were obtained from the plot received at rates of 138 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1}, respectively, in the 2021 cropping season. Increasing the rate of nitrogen to 138 kg N ha^{-1} increased marketable tuber yield by 56% over the control (Table 7). At rates of 138 kg N ha^{-1}, the maximum (53.0 t ha^{-1}) and control plots obtained the minimum (32.41) marketable yield, which increased by 39% in the 2022 cropping season. The yield of potato increased with an increase in nitrogen levels. This result is in line with the findings of Sebnie *et al*[41], Fayera [42] and Isreal*et al*[40], who reported that the application of high levels of nitrogen increases marketable yield in different areas.

Phosphorus fertilization also significantly increased marketable tuber yields. Increasing application of phosphorus increased marketable tuber yield per hectare. The maximum (53.07 t ha^{-1}) marketable tuber yield was recorded at 92 kg P_2O_5 t ha^{-1},and the minimum (29.95 t ha^{-1}) was obtained from the unfertilized plot. Increasing the application of phosphorus from 0 to 92 kg ha^{-1} increased marketable tuber yield by 44% over the control in the 2022 season (Table 8). Application of phosphorus at 69 and 92 kg ha^{-1} had no significant difference on marketable tuber yield. Our finding on phosphorus was somewhat in line with the results of Alemayehu and Jember [43], who recommended 102 kg P_2O_5 ha^{-1} for variety 'Belete' under low P conditions in the Koga irrigation scheme.

Totaltuber yield(tha^{-1})

The different levels of main factor application showed a significant ($P \leq 0.05$) effect on total tuber yield per hectare, but the interaction effect of two factors was not significant. Application of different levels of N fertilizer significantly affected the total tuber yield. The maximum 53.22 t ha^{-1} and minimum 24.4 t ha^{-1} in the 2021 season and 54.85 t ha^{-1} and 33.99 t ha^{-1} in the 2022 season were obtained from the plot received at the rate of 138 kg N ha^{-1} and the unfertilized plot, respectively (Tables 7 and 8). Increasing the rate of nitrogen alone will increase potato tuber yield by 54.2 and 43.4% in the 2021 and 2022 seasons, respectively, over no fertilized treatment. The yield of potato increases with an increase in nitrogen levels from 0 to 138 kg ha^{-1}. This result is in line with the findings of Fayera[42], Worku*et al*[35], and Amare *et al*[18], who reported that the application of a high 138 kg ha^{-1} level of nitrogen increases marketable yield. Application of phosphorus also significantly increased total tuber yield of 54.78 t ha^{-1} and 31.77 t ha^{-1} were obtained from the plot received at the rate of 92 kg P_2O_5 ha^{-1} and unfertilized plot, respectively. Also, increasing the rate of phosphorous alone will increase potato tuber yield by 37.3 and 38.2% in the 2021 and 2022 seasons over no fertilizer treatment. In general, different rates of nitrogen and phosphorus fertilizer application had yield advantages (Table 7). The result is also similar; Mulubrhan[44], Sandhu*et al*[45] andIsrael *et al*[40]have reported that increasing phosphorus application increased the total tuber yield of potatoes.

3.4. Partial budget analysis

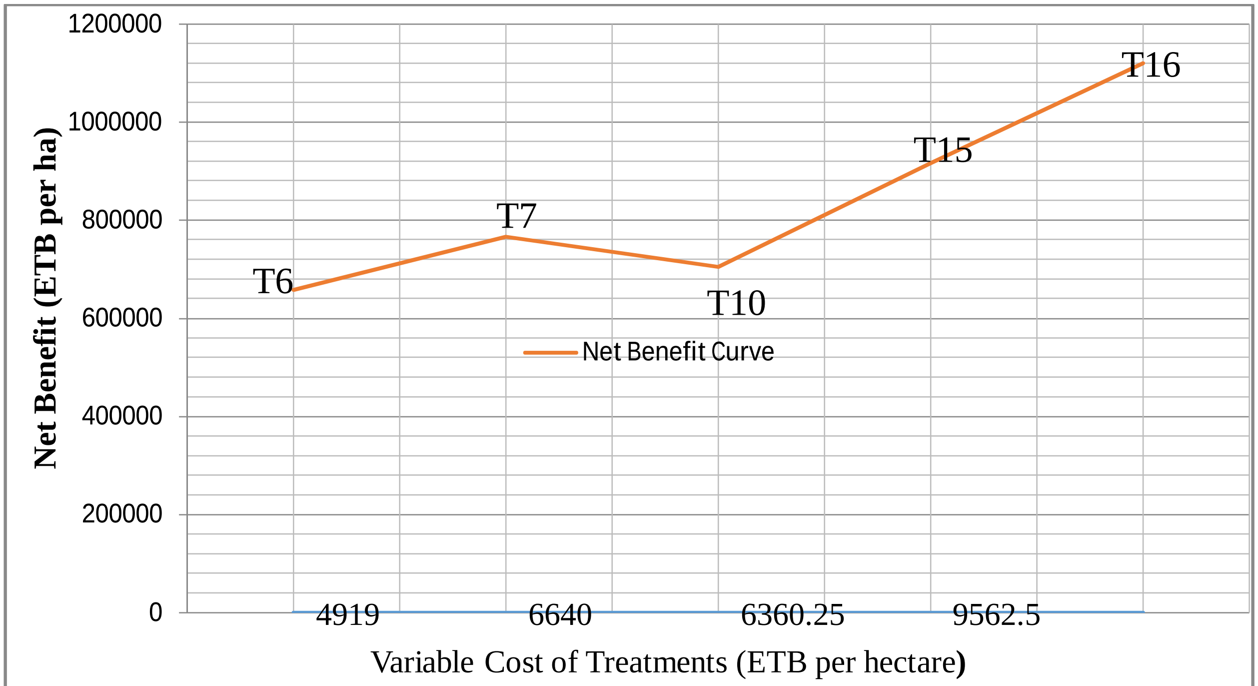
Potato production under fertilizer management involved different costs, which affected the total production cost that varied within each treatment (Figure 2). Accordingly, all treatments produced a higher and positive net benefit (NB) relative to the control treatment. The result showed that the marginal rate of return (MRR) for the combined rates of 92 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1} was 644.68% (Table 9). This implies that for every 1.00 birr the farmer invested in the N and P fertilizer application in potato production, farmers can recover 6.45 birr for the respective rates. Further increases beyond 92 kg of N and 92 kg of P_2O_5ha^{-1} will incur additional costs without compensating for the benefit. According to CIMMTY[29], the minimum acceptable rate of return should be above 100%. Therefore, on economic grounds, the application of 92 kg N ha^{-1} with a combination of 92 kg P_2O_5ha^{-1} would be more economical and rewarding for potato production in the study area.

Table 9.Partialbudgetanalysisof N and P fertilizerrateonPotatoproduction atBekoji 2021 and 2022.

P_20_5 kgha^{-1}	N kgha^{-1}	10% Adj. AY (t ha^{-1})	TVC (ETB ha^{-1})	GFB (ETB ha^{-1})	NB (ETB ha^{-1})	DT	MRR %
0	0	16.88	0	337680	337680.0		
0	46	25.59	3221	511740	508519.0	D	-
0	92	28.40	6166.5	568080	561913.5	D	-
0	138	31.98	9112	639540	630428.0	D	-
46	0	24.60	3198	491940	488742.0	D	-
46	46	33.15	4919	662940	658021.0		314.30
46	92	38.65	6640	772920	766280.0		284.68
46	138	41.24	8361	824760	816399.0	D	-
69	0	25.70	4659.25	513900	509240.7	D	-
69	46	35.56	6360.25	711180	704819.7		358.54
69	92	39.93	8101.25	798660	790558.7	D	-
69	138	52.65	9822.25	1053000	1043177.7	D	-
92	0	30.70	6120.5	613980	607859.5	D	-
92	46	41.05	7841.5	820980	813138.5	D	-
92	92	46.31	9562.5	926100	916537.5		644.68
92	138	56.57	11283.5	1131300	1120016.5		65.40

10% Adj.AY = Adjusted marketable tuber Yield Down to 10%; TVC= Total Variable Cost (Birr ha^{-1}); GFB = Gross Field Benefit (Birr ha^{-1}); NB= Net Benefit (ETB);MRR= Marginal Rate of Return; D = Dominated Treatment; ETB=EthiopianBirr.

Figure 2. Net benefit curve of Potato in response of N and P fertilizer at Bekoji(2021-2022).



4. Conclusion and recommendation

To increase potato yield using economically viable rates of phosphorus and nitrogen fertilizers, a thorough on-field study was carried out at Bekoji for two rainy seasons. The outcome shows that controlling soil fertility with nitrogen and phosphorus fertilizers greatly increases potato productivity. In the study area, potato producers use a blanket recommendation of 242 kg NPS ha^{-1} and 165 kg Urea ha^{-1}, which is much higher than the current result of the economic recommendation of 92 kg N and 92 kg P_2O_5 ha^{-1} because most tuber crops as potato can give high yields if we increase the amount of fertilizer application. Thus, it needs to identify the economic application that is profitable based on the marginal rate of return.

As a resultin 2021 and 2022 seasons, respectively, the yield of potato tubers improves by 54.2 & 38.2% and 37.8 & 43.4% when optimum amounts of nitrogen and phosphorus fertilizers are applied instead of no fertilizer. Plant height was considerably influenced by the combined application of 92 kg P_2O_5 ha^{-1} and 138 kg Nha^{-1}, as indicated by the interaction effect. At the combined application of 138 kg N and 92 kg P_2O_5 ha^{-1}, the maximum average number of tubers per plant, marketable tuber, and total tuber yield were obtained. With an acceptable MRR of 644.68%, the combined application of 92 kg N and 92 kg P_2O_5 ha^{-1}gave the highest net benefit, according to the partial budget analysis. This rate could be considered profitable for Bekoji area.Based on the findings, it can be concluded thatit is more cost-effective and advisableto use fertilizer at the rate 92 N kg ha^{-1}combined with $92P_2O_5$ kg"ha^{-1}fertilizer rates for potato production in the study area.

Data Availability Statement

The above data discussed is available with the authors.

Ethics Approval Statement

Study did not involve human or animal subjects.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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