Int.J.Curr.Res.Aca.Rev.2025; 13(5): 61-75

International Journal of Current Research and Academic Review

ISSN: 2347-3215 (Online) Volume 13 Number 5 (May-2025)

Journal homepage: http://www.ijcrar.com

doi: https://doi.org/10.20546/ijcrar.2025.1305.008

Response of Potato (*Solanum tuberosum* L.) to Different Rates and Timing of Nitrogen Fertilizer Application in Guji Zone, Southern Oromia, Ethiopia

Arega Amdie*, Solomon Teshoma and Miressa Mitiku

[1]*Bore Agricultural Research Centre, Guji, Ethiopia*
[2]*Oromia Agricultural Research Institute, Addis Ababa, Ethiopia*

**Corresponding author*

Abstract

Potato is one of the most important food security and cash crops in Ethiopia. However, its production and productivity are affected due to lack of N-fertilizer rate and timing application recommendations based on the local conditions. The existing climatic changes, inadequate poor agronomic practices, depletion of soil fertility, and lack of high yielding varieties. There is limited information on the timing and rates of nitrogen fertilizer application to boost potato production and productivity. As a result, a field experiment was conducted at the Bore on station and Ana Sora on farm in the highland areas of Guji zone during the 2022/23 and 2023/24 cropping seasons to determine the optimum rates and timing of N-fertilizer application for potato production, as well as to assess the cost and benefit of rates and timing of nitrogen fertilizer application for potato production. The treatments comprised of four rates of nitrogen (23, 46, 69, and 92 kg ha-1) and three timing of nitrogen split: all at planting, two times of application and three times of application, plus 200 kg of blended NPSB ha-1, which were applied to all plots equally. The experiment was laid out as a randomized complete block design in a 4 x 3 factorial arrangement replicated three times. An improved potato variety called Gudane was used as a test crop. The combined analysis of variance across years and locations revealed that nitrogen fertilizer rates and timing of application significantly influenced number of tuber per hill, marketable tuber yield, and total tuber yield of potato. However, nitrogen fertilizer rates and timing of application did not influence the days of 50% flowering, days to 90% maturity, plant height, and number of stem per plant, tuber weight, or unmarketable tuber yield of potato. So, the two times application with 69 kg N ha-1 fertilizer rates produce highest marketable tuber yield(43.34tha-1), maximum net benefit (773520 ETB/ha) and acceptable marginal rate of returns(600.80%)respectively. Therefore, it is recommended to use nitrogen two times application (½ doses at planting and ½ doses at 15 days after emergency) with 69 kg/ha-1 fertilizer rate for potato production since economically feasible to the farmers in the study area..

Article Info

Received: 22 March 2025
Accepted: 28 April 2025
Available Online: 20 May 2025

Keywords

N-fertilizer, Partial budget analysis, Rate, Time and Marketable tuber yield.

Introduction

Potato (*Solanum tuberosum* L.) belongs to the family *Solanaceae* and genus *Solanum* (Thompson and Kelly, 1972). Potato is one of the most important crops that contribute to food security on a global scale, due to its high yield per unit of cropland and time (Devaux *et al.*, 2014). It is considered to be the world's fourth important food crop after maize, wheat, and rice because of its high yield potential and nutritive value (Kumar *et al.,* 2013; Pandey *et al.,* 2014) and the third most important food crop after rice and wheat is being grown and consumed in all over the world (FAO, 2022). Potato plays an important role both in human diet and processing industry (Zaheer and Akhtar, 2016). Potato is a major carbohydrate supplier in the diets of millions of people in the world. It also provides significant amount of proteins with essential amino acids, vitamin C, minerals and micronutrients which are vital for human nutrition (Mu *et al.,* 2017).

It is also contains about 79% water, 18% starch as a good source of energy, 2% protein and 1% vitamins including vitamin C, minerals including calcium and magnesium and many trace elements (Ahmad *et al.,* 2011). Farmers consider potato as a transitional crop that helps them survive the severe and prevailing food shortage that occur every year (Semagn *et al.,* 2007).

Generally, Potato requires altitude 1800 to 2500 (Bezabih and Mengistu, 2011), optimum soil temperature 16-19°C (Anonymous, 2004), high rainfall ranging between 1000 and 1500 mm per year (Gusha, 2014), temperate climates (Hijmans, 2003) and naturally loose soils, which offer little resistance for tuber enlargement, are preferred. Potatoes grow best in loose, well-drained, non-crusting, sandy loam or loam soils with high organic matter content and pH between 5.5 and 6.5 (Martha and Ann, 2017).

In Eastern Africa, Ethiopia is the major producer of potato, and 70% of the arable land is suitable for potato cultivation b/c of suitable agro ecology but the average national yield of potato 16.687 tha^{-1} (CSA, 2022), the average yield of potato yield (29.4tha^{-1}) in Guji zone (Dembi *et al.,* 2017) also it is very low as compared to the yield in developed countries 30 to 40 tha^{-1} (FAO, 2000). The low yield is due to lack of high yielding varieties, poor soil fertility, diverse climatic condition, lack of appropriate agronomic practices, diseases and insect pests (Adane *et al.,* 2010; Haverkort *et al.,* 2012; Gebremedhin, 2013; Tewodros, 2014 and Egata, 2021).

On the other hand, because of low levels of chemical fertilizer usage, limited knowledge on time and rate of fertilizer application (Amsal *et al.,* 2000). Ethiopian soil is lack of seven nutrients N, P, K, S, Cu, Zn, and B (EthioSIS, 2013).

The limit crop yield due to depletion of macro and micro nutrients (FAO, 2006). Potato is a heavy feeder and highly responsive to nutrient input, where the proper quantity and timing of nutrient supply is most critical component in achieving high productivity for its cultivation (Karubakee *et al.,* 2024). It require high amounts of fertilizer due to the characteristics of shallow and inefficient rooting system (Dechassa *et al.,* 2003).

The requirement of potato is influenced by climatic conditions, soil type, soil fertility, preceding crop, variety, and practices of crop management (Vander, 1981). Optimal N nutrition contributes to rapid formation of vegetative parts, intensive photosynthesis, and allows utilizing soil moisture reserves more meaningfully during crop formation (Eleshev *et al.,* 2017). Nitrogen split application is attributed to the fact that it reduces fertilizer leaching losses by matching fertilizer applications with crop nutrient uptake and by synchronizing nutrient availability and crop demand (Gathungu *et al.,* 2000).

Potato N uptake is very slow at the early growth stages, rapidly increasing after tuber initiation, decrease during tuber maturation stage. Potato crops need N particularly during the vegetative growth, tuber initiation and tuber bulking stages (FAO, 2006). The requirement of potato for N is critical because soil N concentration changes with soil water availability (Iern and Tenorio, 2011). Properly used N fertilizer increases agronomic performance of crops by maintaining balanced canopy structure, proper shoot to root ratio, increased rooting area and depth and increased water use efficiency (Arnon, 1975).

Appropriate timing nitrogen application is the most important factor for N fertilizer management. Plant use efficiency of N depends on several factors including application time, rate of N applied, cultivar and climatic conditions (Moll *et al.,* 1982). The time of nitrogen application play a significant role in minimizing NO_3-losses from agriculturally for crops grown under wet and warm conditions. A once application of nitrogen lost due to de-nitrification, leaching and volatilization and therefore making them unavailable during the critical stages of plant growth (Jamaati *et al.,* 2010). Nitrogen split application is better and advised to apply about two-thirds of the nitrogen recommendation in the seedbed and the remainder top-dressed shortly after emergence if top dressing is planned for management reasons or to reduce the risk of leaching for crops grown on light sand and shallow soils (Roy *et al.,* 2006).

An efficient N fertilizer program should balance application timing and N rate to match crop N demand, leading to increased potato growth and yield (Love *et al.,* 2005). Adequate soil N availability at emergence and tuber initiation growth stages, when potato plants are characterized by fast growth and an exponential N uptake, will positively impact crop development (Rens *et al.,* 2018; Djaman *et al.,* 2021).

Rens *et al.,* (2015b) reported that tuber yield linearly increased in response to N fertilizer rates at emergence ranging from 0 to 168 kg ha^{-1}; yields increased by 18 % from the lowest to the highest rate. Split application of nitrogen is one of the strategies of improving nitrogen use by the crops (Sithole, 2007).

Potato is one of the most important food security and cash crop for farmers in highland parts of Ethiopia, particularly in Guji zone where is it grown abundantly. There is lack of information on potato rates and time of N fertilizer split application in the highland areas of Guji Zone and still no research work has so far been conducted on rate and time of nitrogen split. The major problems resulting in lower potato productivity in Guji zone due to lack of N-fertilizer rate and timing application recommendations based on the local conditions, the existing climatic changes, inadequate/poor agronomic practices, depletion of soil fertility, and lack of high yielding varieties. To tackle these bottle neck problems with the following objectives to determine the optimum rates and timing of N-fertilizer application for potato production and to assess the cost and benefit of rates and timing of nitrogen fertilizer application for potato production.

Materials and Methods

Description of the Experimental Site

The field experiment was carried out under rain fed conditions during the 2022/2023 and 2023/2024 cropping seasons at Bore on station and Anna sora on-farm in the Guji zone, Southern Ethiopia. The first experimental were located at Bore research site at the distance of about 8 km north of the town of Bore in Songo Bericha '*Kebele'* just on the side of the main road to Addis Ababa via Awassa town. Geographically, the experimental site is situated at the latitude of 06°23'55''N and longitude of 38°35'5''E at an altitude of 2728 m above sea level. The major soil type is clay in texture and strongly acidic with pH value of 5.1 (Arega, 2020). The second experimental site was located at Anna sora at the distance of about 30 km East of the town of Bore in Raya Boda '*Kebele'* just on the side of the main road to Addis Ababa via Adola town. Geographically, the experimental site is situated at the latitude of 06°10'N and longitude of 380°380'E at an altitude of 2451 m above sea level and soil type is Clay (Tekalign *et al.,*2019).

Experimental Materials

An improved potato variety called 'Gudane' which was released by Holeta Agricultural Research Centre (HARC) in 2006 (MoANR, 2017), were used as a planting material. The variety was selected on the basis of its high yield, wider adaptation and moderate resistance to late blight in highlands of Guji Zone.

Treatments and Experimental Design

The treatment consists of four levels of Nitrogen rates (23, 46, 69, and 92 kg ha^{-1}) and three time of nitrogen split:-all at planting, two times application and three time's application and plus 200 kg blended NPSB ha^{-1}were applied to all plots equally.

The experiment was laid out as a Randomized Complete Block Design (RCBD) in a factorial arrangement and replicated three times per treatment. There are 12 treatment combinations, which was assigned to each plot randomly. The total number of plots will be 36 and each plot will have 3m length and 2.4 m width= 7.2 m^2 in size consisting of four rows, each row accommodating 10 plants, and 40 plants per plot at the spacing of 0.75 m and 0.30 m between rows and plants, respectively. While the net harvested area 2.4 m (2 rows x 0.75 m) =3.6 m^2 (the two central rows).

The spacing between plots and adjacent blocks was 0.6 m and 1m, respectively. The first, second and third earthling-up was done 15, 30, and 45 days after planting to prevent exposure of the tubers to direct sunlight, promote tuber bulking and ease of harvesting. Haulms were mowed two weeks before harvesting at physiological maturity for reducing skinning and bruising during harvesting and post-harvest handling. All important management practices was carried out following the recommendation of the crop.

Soil Sampling and Analysis

The composite soil samples were collected by using Auger (Soil sampler) from 0-20 cm depth based on the procedure outlined by Taye *et al.,* (2000) and using the zigzag method (Carter and Gregorich, 2008). The collected samples were sent to soil at Horti coop Ethiopia soil and water analysis laboratory.

Data collection

Phenology, Growth, tuber yield and yield components were collected:- Days to 50% flowering, Days to 90% maturity, Plant height (cm), Number of stem per plant, Number of tuber per hill, Average tuber weight (g), Marketable tuber yield (t ha^{-1}), Unmarketable tuber yield (t ha^{-1}), and Total tuber yield (t ha^{-1}).

Partial Budget Analysis

The partial economic analysis was carried out by using the methodology described in CIMMYT (1988). Only the cost that varied among different treatments was taken into account. The yield of the crop was adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers expect from the same treatments. The treatment which gives the highest NB and a MRR greater than the minimum is considered acceptable to farmers (>1 or 100%). To compare the costs that varied with the net benefits, the marginal rate of return was calculated as

NB = TR – TVC

$$MRR\% = \frac{\text{Change of Net Benefit } (\Delta NB)}{\text{Change of Total Varaible Cost } (\Delta TVC)} \times 100$$

Data Analysis

Field data were analyzed by using SAS software for the data following the standard procedures outlined by Gomez and Gomez (1984). Comparisons among the treatment means were done using Duncan's Multiple Range Test (DMRT) tests at 0.05 level of significant.

Results and Discussion

Physico-Chemical Soil Properties of the Experimental Site

The result of laboratory analysis revealed high total nitrogen and available P levels in the experimental soils of Bore and Ana sora, according to EthioSIS (2014). The soil's available P ranged from 0-15 to 0.5, with low available phosphorus due to fixation in acidic soils. At increased soil acidity (low pH), phosphorus is fixed to surfaces of Fe and Al oxides and hydrous oxide, which is not readily available to plants (Sikora *et al.,* 1991). The soil's available sulfur ranged from 9.53-13.96 to 7.89-10.48 mg kg^{-1}, with low available S and K content. The soils CEC ranged between 35.36 and 35.66 meq/100 g, with high to very high nutrient holding capacity and water holding capacity. The soils organic carbon content was high, with a nutrient class containing >8.0, 7.0-8.0, 3.0-7.0, 2.0-3.0, and <0.2 mg/kg of OM. The soil's OM content ranged from 5.41-6.96%, with an optimum pH of 5.06-5.12 and 5.72-5.94% (Table 3). The soils pH was rated strongly to moderately acidic, with phosphorus fixed to surfaces of Fe and Al oxides and hydrous oxide, which are not readily available to plants. Therefore, the soils pH is a critically important chemical property, which has a major influence on nutrient availability. Fortunately, potatoes can be grown successfully in soils with pH values as low as 5.5 or lower.

Mean Squares of Potato Parameters

The combined analysis of variance two years and over location revealed that the interaction effect of rate nitrogen, time of fertilizer application, years, and locations showed statistically significant differences ($P \leq 0.05$) were observed on days to 50% flowering, tuber number per hill tuber weight, marketable tuber yield, and total tuber yield (Table 4). However, the non-significant differences ($P>0.05$) were observed among their rates of nitrogen, time of fertilizer application, years, and locations of nitrogen fertilizer application on the days to 90% physiological maturity, plant height, stem number, and unmarketable tuber yield (Table 3). Moreover, overall years and locations analysis of variance showed that the interaction effect of rate and time of nitrogen application showed significant differences ($P \leq 0.05$) observed on tuber number, marketable tuber yield, and total tuber yield. However, non-significant differences ($P>0.05$) were observed among their interaction of rate nitrogen and time nitrogen application on days to 50% flowering, days to 90% physiological maturity, plant height, tuber weight, and unmarketable tuber yield (Table 4).

Phonological Parameters of Potato

Days to flowering and physiological maturity

The combined mean revealed that the latest days to 50% flowering and days to 90% maturity fertilizer (65.63 and 111.52) were obtained at the all-dose nitrogen fertilizer application at planting, respectively, while the earliest days to 50% flowering (65.60) were recorded at the three-time application of N-fertilizer and the earliest days to 90% maturity (111.00) were recorded at the two-time nitrogen fertilizer application. The latest days to 90%

maturity (112.42) were obtained at the application of 69 kg N ha^{-1}, while the lowest earliest (111.36) was obtained at the application of 46 kg N ha^{-1}, which is statistically the same but numerically different. The latest days to 50% flowering (66.44) were obtained at the application of 92 kg N ha^{-1}, while the earliest (65.58) was obtained at the application of 69 kg N ha^{-1}, but the application of 23 and 46 kg N ha^{-1} is numerically and statistically the same(Table 5). This result is supported by previous studies Nitrogen fertilizer prolongs days to flowering (Kleinkopf *et al.,* 1987). In addition, Mulubirhan (2004) reported that Nitrogen fertilizer significantly prolonged days to flowering. This result is also in line with the findings of Zelalem *et al.,* (2009) who reported that application of higher rate of nitrogen fertilizer delayed days to flowering and maturity.

Growth Parameters of Potato

Plant height and Number of stem per plant

The tallest plant height and highest number of stem per plant (76.31 cm and 7.01) was recorded at the two-time and three-time nitrogen fertilizer application respectively, while the lowest plant height and number stem per plant (74.43 cm and 6.54) was recorded three-times and all dose nitrogen at planting application of nitrogen fertilizer respectively. The tallest plant height and highest number of stem per plant (76.46 cm) was obtained at the application of 46 kg N ha^{-1}, while the lowest (74.02cm) was recorded at the application of 46 kg N ha^{-1} which is statistically the same but numerically different. The highest number of stem per plant (7.05) was obtained at the application of 46 kg N ha^{-1}, while the lowest (6.44) was obtained at the application of 46 kg N ha^{-1} but application of 23 and 69 kg N ha^{-1} which is numerically different but statistically the same (Table 6). Number of stem per plant might be influenced due to the different tuber size that we have used as planting material. Number of stem is not influenced much by mineral nutrient rather by other factors such as storage condition of tubers, number of viable sprouts at planting, sprouts damage at time of planting and growing conditions (Allen, 1978).

Yield and yield component parameters of potato

Average tuber weight

The highest average tuber weight (91.38 and 91.24g) was recorded at two-time and N 46 kg ha^{-1} fertilizer application while the lowest (88.53 and 89.80g) was recorded at all dose nitrogen application and N 92 kg ha^{-1} fertilizer rate application respectively (Table 7). Nitrogen application to potatoes before tuber initiation increases the number of tubers per plant and mean fresh tuber weight (Kanzikwera *et al.,* 2001). The increase in average tuber weight of tubers in response to the increased supply of fertilizer nutrients could be due to more luxuriant growth, more foliage and leaf area and higher supply of photosynthesis which may have induced formation of bigger tubers thereby resulting in higher yields (Patricia and Bansal, 1999). This is not consistent with the finding of Zelalem (2009) who reported that the average tuber weight progressively increased with increasing N rate up to 138 kg/ha and tended to decrease at the highest rate of 207 kg/ha.

Unmarketable tuber yield

The unmarketable yield was not affected by the split application of nitrogen fertilizer. In general, the response of unmarketable tuber yield of the crop to both fertilizers was not vigorous. This result is consistent with the suggestion of Berga *et al.,* (1994) that unmarketable tuber yield might be controlled more importantly by manipulating other factors such disease incidence, harvesting practice, etc. rather than mineral nutrition. The highest Unmarketable tuber yield (4.81 and 5.09 t ha^{-1}) was recorded all dose at planting and 23 N kg ha^{-1} fertilizer application while the lowest (4.05 and 4.22 t ha^{-1}) was recorded at three time nitrogen application and 69 N kg ha^{-1} fertilizer rate application respectively but the application of 46, 69 and 92 kg N ha^{-1} which is numerically different but statistically the same (Table 7).

In general, the response of unmarketable tuber yield of the crop to both fertilizers was not vigorous. This result is consistent with the suggestion of Berga *et al.,* (1994) that unmarketable tuber yield might be controlled more importantly by manipulating other factors such disease incidence, harvesting practice, etc. rather than mineral nutrition.

Numbers of tuber per plant

The highest number of tuber per plant (12.86) was recorded with the two-time and 69 kg ha^{-1} fertilizer application and followed two-time with the application of 92 kg N ha^{-1} while the lowest (9.01 was recorded three time with the application of 23 kg ha^{-1} fertilizer rate (Table 8). Nitrogen application to potatoes before tuber initiation increases the number of tubers per plant and mean fresh tuber weight (Kanzikwera *et al.,* 2001).

Marketable tuber yield

The maximum marketable tuber yield (43.34tha^{-1}) was obtained two times with the application of 69 kg N ha^{-1} fertilizer rate and followed (38.61tha^{-1}) two times with the application of 46 kg N ha^{-1} fertilizer rate (Table 8). In this case, the highest marketable tuber yield was obtained already two times at the rate of 69 kg N ha^{-1}. On the other hand, the reduction in yield due to the high rate of N application could be explained by the phenomenon that extra nitrogen application often stimulates shoot growth at the expense of tuber initiation and bulking (Somerfield and Knutson, 1965). Otieno and Mageto (2021) also reported that nitrogen should be applied at rates not more than 150 kg N ha, and two critical stages for N application are at planting for early establishment to boost growth and at tuber initiation to maintain the high N concentration required for proper tuber development. Similar ideas have been explained by Banjare *et al.,* (2014) for the increase in potato tuber yield per hectare as both the fertilizer application rate and the fertilizer split application frequency increased. On the contrary, in the work of Long *et al.,* (2004), using the highest N-fertilizers did not enhance potato yields.

Total tuber yield

The maximum total tuber yield (47.68tha^{-1}) was obtained two times with application of 69 kg N ha^{-1} followed (43.09tha^{-1}) two times with 46 kg N ha^{-1}fertilizer rate (Table 9), which indicates that nitrogen is an important limiting factor for increasing productivity of the crop. However, all dose and three times and beyond application of 69 kg N ha^{-1}, total tuber yield rather decreased (Table 9). In this case, the highest total tuber yield was obtained already two times at the rate of 69 kg N kg ha^{-1}.

Table.1 List of experimental treatments and their descriptions

No.	Treatment	
	N-rates kg ha^{-1}	Time of N- split
1	46	two times application(½ dose at planting and ½ dose after 15 DE)
2	69	all dose at planting
3	92	two times application(½ dose at planting and ½ dose after 15 DE)
4	23	three times application (¼ dose at planting,(½ dose at 15 DAE and ¼ at mid-stage (45DAE)
5	46	all dose at planting
6	23	all dose at planting
7	92	all dose at planting
8	23	two times application(½ dose at planting and ½ dose after 15 DE)
9	46	three times application (¼ dose at planting,(½ dose at 15 DAE and ¼ at mid-stage (45DAE)
10	69	two times application(½ dose at planting and ½ dose after 15 DE)
11	92	three times application (¼ dose at planting,½ dose at 15 DAE and ¼ at mid-stage (45DAE)
12	69	three times application (¼ dose at planting,½ dose at 15 DAE and ¼ at mid-stage (45DAE)

Table.2 Selected physico-chemical properties and analyzed method used

Soil property to analyzed	Soil analyzed method used
pH (1: 2.5 soil H_2O ratio)	1:2.5 soils & H_2Omixture by using a pH meter(Rhoades, 1982).
Organic matter (%)	by multiplying the OC% by a factor 1.724.
Organic carbon (%)	Walkley and Black method (Walkley & Black, 1934)
Total N (%)	Kjeldhal Method (Jackson, 1958).
CEC (meq/100 g soil)	Ammonium acetate (Chapman, 1965).
Available P (ppm)	Bray II methods (Bray and Kurtz, 1945).
Soil texture	Bouyoucos Hydrometer Method (Bouyoucos, 1962)
Available potassium(ppm)	Melich-3 methods (Mehlich, 1984).
Exchangeable Bases[Cmol$_{(+)}$kg^{-1}soil]	
Exchangeable K,Mg,Na, Ca, and Al	Melich-3 methods (Mehlich, 1984).

Table.3 Selected physico-chemical properties of the experimental soil at pre plant and post-harvest effects of N- rates and Time of N- split to Potato at bore on –station in 2022/23 cropping season

Soil parameters	2022/23		2023/24		Rating and Range	Reference
	Soil result at pre-planting		Soil result at pre planting			
	Bore on station	Ana sora	Bore on station	Ana sora		
pH (1:2.5 H2O)	5.12	5.94	5.06	5.72	Strongly to moderately acidic(<5-5.6-6.5)	Ethio SIS (2014)
OC (%)	3.97	4.04	3.63	3.14	high (> 3.0)	Tekalign (1991)
OM (%)	6.84	6.96	6.26	5.41	Optimum (3.0-7.0)	Ethio SIS (2014)
TN (%)	0.38	0.37	0.34	0.34	high (0.3-0.5)	Ethio SIS (2014)
P (mg/kg ppm)	7.70	3.33	4.14	4.40	very low (0-15)	Ethio SIS (2014)
S (mg/kg ppm)	13.96	10.48	9.53	7.89	low (10-20)	Karltun (2013)
B (mg/kg ppm)	0.50	1.13	0.45	0.67	medium to very low (1-20 to<0.5)	Ethio SIS (2014)
K (mg/kg ppm)	260.50	365.04	88.25	340.64	Optimum(190-600)	Ethio SIS (2014)
CEC (meq/kg soil)	35.66	42.36	35.36	39.34	high to very high(25-40 to >40)	Murphy (2007)
Sand	34	36	34	34	-	-
Clay	32	32	34	40	-	-
Silt	28	26	27	26	-	-
Textural class	clay	clay	Clay	clay	clay	(USDA,1987)

Table.4 Mean squares of ANOVA for Potato Phenology, growth, yield and yield component effects of N- rates and Time of N- split Bore on-station and Ana Sora on-farm in 2022/23 and 2023/24 cropping season

Source of Variables	Parameters								
	DF	DM	PH	SN	TN	TW	MTY	UnMTY	TTY
Rep.	0.86ns	44.39ns	15.05ns	0.30ns	2.19ns	1158.92*	169.81*	1.45ns	145.39ns
Year	935.34**	2328.06**	50.03ns	379.89**	91.41**	4163.91*	47.82ns	134.91**	343.11*
Rate	11.97*	15.84ns	41.02ns	2.82ns	15.74*	35.85ns	152.09*	6.78ns	156.34*
Time	0.01ns	24.64ns	47.80ns	2.84ns	9.56ns	98.17ns	525.81**	7.19ns	531.85**
Loc	57.51*	3958.51**	18244.36**	139.10**	26.49*	34358.95**	15.16ns	2.29ns	5.69ns
Rate*Time	4.525ns	12.53ns	8.15ns	1.08ns	13.89*	66.94ns	36.81**	0.47ns	43.03**
Rate*Year	13.45*	6.58ns	32.03ns	1.91ns	9.01ns	311.01ns	35.15ns	1.66ns	45.09ns
Time*Year	1.38ns	11.52ns	35.78ns	0.42ns	3.76ns	366.03ns	23.19ns	0.94ns	31.87ns
Rate*Loc	27.87*	21.88ns	111.24*	1.13ns	4.05ns	299.87ns	56.43ns	5.41ns	59.49ns
Time*Loc	42.13ns	7.79ns	163.99*	0.22ns	1.31ns	295.93ns	83.84ns	0.95ns	71.82ns
Rate*Time*Year*Loc	124.21**	23.51ns	30.69ns	1.55ns	3.72ns	3479.29**	154.63**	3.63ns	173.79**

Significant='*' ≤ 0.05, highly Significant= '**' ≤ 0.01, DF=Days to 50% flowering, DM= Days to 90% maturity, PH=Plant height (cm), SN= Steam Number hill^{-1},TN= Tuber number hill^{-1},TW=Tuber weight (g/tuber), Marketable tuber yield (t ha^{-1}), UnMTY (t ha^{-1})= Unmarketable tuber yield (<200mm,isect attacked, cracked, diseased, deformed) (t ha^{-1}),TTY= Total tuber yield(t ha^{-1}).

Table.5 Over year s and location pooled mean main effects of Time of N- split and N fertilizer rates on days to 50% flowering and days to 90% maturity

Treatments	Phonological parameter	
Time of N- split	Days to 50% flowering	Days to 90% maturity
all dose at planting	65.63	111.52
two times app.	65.62	111.00
three times app.	65.60	112.42
LSD (5%)	1.75	3.56
Nitrogen rates (kg ha^{-1})		
23	65.22b	110.94
46	65.22b	111.36
69	65.58b	112.50
92	66.44a	111.78
Mean	65.62	111.65
LSD (5%)	1.75	3.56
CV (%)	3.29	3.93

Table.6 Over year Pooled mean main effects of Time of N- split and N fertilizer rates on plant height (cm) and number of stem per plant

Treatments	Growth parameters	
Time of N- split	Plant height (cm)	Number of stem per plant
all dose at planting	75.95	6.54
two times app.	76.31	6.68
three times app.	74.43	7.01
LSD (5%)	5.29	1.05
Nitrogen rates (kg ha^{-1})		
23	76.00	6.89ab
46	76.46	7.05a
69	75.77	6.58ab
92	74.02	6.44b
Mean	75.56	6.74
LSD (5%)	5.29	1.05
CV (%)	8.63	19.09

Table.7 Over year Pooled mean main effects of Time of N- split and N fertilizer rates on Average tuber weight (g) and Unmarketable tuber yield (t ha^{-1})

Treatments	Yield and component parameters	
Time of N- split	Average tuber weight (g)	Unmarketable tuber yield (t ha^{-1})
all dose at planting	88.53	4.81
two times app.	91.38	4.52
three times app.	90.06	4.05
LSD (5%)	14.58	1.50
Nitrogen rates (kg ha^{-1})		
23	90.28	5.09a
46	91.14	4.36ab
69	89.80	4.22b
92	88.75	4.16b
Mean	89.99	4.46
LSD (5%)	14.58	1.50
CV (%)	19.98	14.33

Table.8 Over location and year pooled mean interaction effects of Time of N- split and N fertilizer rates on tuber number hill^{-1} and marketable tuber yield (t ha^{-1}) of Potato

Time of N- split	Tuber number hill^{-1}				Marketable tuber yield (t ha^{-1})			
	Nitrogen (kg ha^{-1})				Nitrogen rates (kg ha^{-1})			
	23	46	69	92	23	46	69	92
all dose at planting	9.16b	9.72b	10.16b	9.08b	34.38bcd	32.16cd	33.31bcd	29.54d
two times app.	9.29b	9.07b	12.86a	9.88b	36.45bc	38.61ab	43.34a	35.62bc
three times app.	9.01b	9.72b	9.07b	10.12b	32.36cd	33.83bcd	35.31bc	31.77cd
Mean=9.76					Mean= 34.72			
LSD(0.05)=1.58					LSD(0.05)=5.49			
CV (%) =19.98					CV (%) = 19.54			

Table.9 Over location and year pooled mean interaction effects of Time of N- split and N fertilizer rates on total tuber yield (t ha^{-1}) of Potato

Time of N- split	Total tuber yield(t ha^{-1})			
	Nitrogen (kg ha^{-1})			
	23	46	69	92
all dose at planting	40.12bc	36.88cd	37.79bcd	33.84d
two times app.	41.35bc	43.09ab	47.68a	3997bc
three times app.	37.01cd	37.70cd	39.15bcd	35.60cd
Mean=39.18				
LSD(0.05)=5.86				
CV (%) =18.45				

Table.10 Correlation analysis effect of N-fertilizer rate and timing of application to potato at Bore on station and Ana sora on-farm in 2022/23 and 2023/24 cropping season

Character	Character								
	DF	DM	PH(cm)	SN	TN	TW (g)	MTYld (t/ha)	UnMTYld (t/ha)	TTYld (t/ha)
DF	1	-0.156ns	-0.133ns	-0.423**	-0.069ns	0.537**	0.333**	-0.067ns	0.298**
DM		1	-0.527**	0.039ns	0.089ns	-0.345**	0.027ns	0.268**	0.086ns
PH (cm)			1	0.468**	0.233**	0.402**	0.176**	0.035ns	0.173**
SN				1	0.315**	0.053ns	0.079ns	0.326**	0.148ns
TN					1	0.173**	0.382**	0.197**	0.404**
TW (g)						1	0.521**	0.030ns	0.497**
MTYld (t/ha)							1	0.151ns	0.97497**
UnMTYld (t/ha)								1	0.367**
TTYld (t/ha)									1

Table.11 Partia budgets and marginal rate of return analysis effects of N- rates and Time of N- split to Potato variety at Bore on-station and Ana sora on-farm in 2022/23 and 2023/24 cropping season

Treatments		Unadjusted MYLD ($kgha^{-1}$)	Adjusted MYLD ($kgha^{-1}$)	Total variable cost	Total Revenue	Net benefit	MRR%
N- rates kg ha^{-1}	Time of N- split						
23	all dose at planting	34380	30942	2100	618840	616740	0
23	two times app.	36450	32805	2200	656100	653900	371.6
23	three times app.	32360	29124	2300	582480	580180	D
46	all dose at planting	32160	28944	4200	578880	574680	D
46	two times app.	38610	34749	4400	694980	690580	579.5
46	three times app	33830	30447	4600	608940	604340	D
69	all dose at planting	33310	29979	6300	599580	593280	D
69	two times app	43340	39006	6600	780120	773520	600.8
69	three times app.	35310	31779	6900	635580	628680	D
92	all dose at planting	29540	26586	8400	531720	523320	D
92	two times app.	35620	32058	8800	641160	632360	272.6
92	three times app	31770	28593	9200	571860	562660	D

Where, N cost = Birr 20 kg^{-1}, N- fertilizer Application cost 2 persons 100 kg ha^{-1}, each 100 ETB day^{-1}, Field price of Potato during harvesting= Birr 20 birr kg^{-1}, MYLD=Marketable tuber yield, MRR (%) = Marginal rate of return and D= Dominated treatment.

Correlation analysis

The correlation analysis was performed to determine a simple correlation coefficient between phenology, growth, yield, and yield component parameters as effects of time of N-split and N fertilizer rates. The present finding has indicated that the number of stems per plant was positively correlated with the number of tubers per plant (r = 0.315), whereas the number of tubers per plant was inversely (negatively correlated) related with days to 50% flowering (r = -0.069) (Table 10). Marketable tuber yield was significantly and positively correlated with the number of tuber plants (r = 0.382) and tuber weight (r = 0.521). Days to 90% maturity, plant height, number of stems per plant, number of tubers per plant, and unmarketable tuber yield were inversely (negatively correlated) related with days to 50% flowering (Table 10). Correlation coefficients close to +1 or -1 indicate a close fit to a straight line (strong correlation), and values closer to zero indicate a very poor fit to a straight line or no correlation. The correlation coefficient analysis attempts to measure the strength of relationships between two variables using a single number.

Partial Budget Analysis

The results of the study indicated that time of N-split and nitrogen fertilizer rates had promoted benefit over the control. Partial budget analysis was done based on the view of CIMMYT Economics Program (1988) recommendations, which stated that application of fertilizer with the marginal rate of return above the minimum level (100%) is economical. As the result of this study, partial budget analysis revealed that the maximum net benefit of Birr 773,520 with an acceptable marginal rate of returns (MRR) of 600.80% was recorded in the treatment that received the two-time application with 69 kg N ha^{-1} fertilizer rates, respectively (Table 11). However, the lowest net benefit of Birr 523,320 and non-acceptable marginal rates of return (MRR) were obtained in the treatment that received the all dose at planting application with 92 kg N ha^{-1} fertilizer rates (Table 11). The two-time application with 69 kg N ha^{-1} gives the highest net benefit and a marginal rate of return greater than the minimum considered acceptable to farmers (>1 or 100%). The identification of a recommendation is based on a change from one treatment to another if the marginal rate of return of that change is greater than the minimum rate of return. Based on this result, two times application with 69 kg N ha^{-1} resulted in the highest adjustable marketable tuber yield (39006 kg ha^{-1}) and was profitable to the farmers in the study area (Table 11).

Conclusions and Recommendation

Potato is one of the most important food security and cash crops for farmers in high-land areas of Guji Zone. The major factors that contribute to low potato productivity take account of many biotic and abiotic factors in the study area, such as inappropriate crop management practices, a lack of improved variety, a lack of fertilizer management, and diseases and insects. To tackle these constraints associated with nutrient management, apply fertilizer rate and timing according to the nutrient demand of potatoes to boost potato production. Nitrogen is a very dynamic plant nutrient, and its abandoned application can considerably raise the price of agricultural production. Proper N management is one of the most important factors required to obtain reasonable yields of potatoes. So, the combined analysis of variance across years and locations revealed that nitrogen fertilizer rates and timing of application significantly influenced the number of tubers per hill, marketable tuber yield, and total tuber yield of potatoes. However, nitrogen fertilizer rates and timing of application did not influence the days of 50% flowering, days to 90% maturity, plant height, number of stems per plant, tuber weight, or unmarketable tuber yield of potatoes. The two-time application with 69 kg N ha^{-1} fertilizer rates produces the highest marketable tuber yield (43.34%), maximum net benefit (773520 ETB/ha), and acceptable marginal rate of return (600.80%) respectively. Therefore, it is recommended to use nitrogen two times application (½ doses at planting and ½ doses at 15 days after emergency) with a 69 kg/ha fertilizer rate for potato production since it is economically feasible to the farmers in the study area.

Acknowledgement

We thank all the colleagues and trial farmers in the different sites, who were my co-learners and whose glad involvement made this research possible. We profusely thank IQQO, Other ARC and BoARC for their generous financial, facilities, and research material support for this Research, which resulted in this manuscript.

References

Adane, H., Meuwissen, M.P.M., Agajie Tesfaye, A., Lommen, W.J.M., Lansink, A.O., Tsegaye, A., Struik, P.C.2010, Analysis of seed potato systems in Ethiopia. Amer. J. Potato Res., 87, 537-552

Ahmad, N., Khan, M.A., Khan, N.A., Binyamin, R. and Khan, M.A. 2011, Identification of resistance source in potato germplasm against PVX and PVY. *Pakistan Journal of Botany*, 43(6), pp.2745-2749.

Allen, E.,J. 1978, Plant density. *In* : P.M. Harris (Ed). The potato crop, the scientific basis for improvement. Chapman and Hall Ltd. London 278-326.

Amsal, T., Tanner, D.G., Taye, T., and Chanyalew, M. 2000,Agronomic and economic evaluation of the on-farm N and P response of bread wheat grown on two contrasting soil types in central Ethiopia. pp. 239-252. In: 88The Eleventh Regional Wheat Workshop for Eastern, Central, and Southern Africa. CIMMYT, Addis Ababa, Ethiopia.

Anonymous. 2004, Directory of released crop varieties and their recommended cultural practices. Ethiopian Agricultural Research Organization, Addis Ababa, Ethiopia.

Arega Amdie, Nigussie Dechassa, and Wassu Mohammed.2020, Response of Potato (*Solanum tuberosum* L.) to Blended NPS and Potassium fertilizers at Bore, Southern Ethiopia, *International Journal of Agriculture and Biosciences*; P.232-245.

Arnon, I. 1975, Physiological Principles of Dry Land Crop Production. NewYork, JohnWilley and Sons. Pp.3-145.

Banjare S., Sharma, G., and Verma, S. K. 2014, Potato Crop Growth and Yield Response to Different Levels of Nitrogen under Chhattisgarh Plains Agro-climatic Zone. *Indian Journal of Science and Technology,* Vol 7(10), 1504–1508.

Berga Lemaga, Gebremedhin Woldegiorgis, Teriessa Jalleta, and Bereke-Tsehai Tuku. 1994. December. Potato agronomy research in Ethiopia. *In*: *Proceedings of the 2nd National Horticultural Workshop,* (pp. 101-109).

Bezabih, E., and Mengistu, N. 2011, Potato value chain analysis and development in Ethiopia: Case of Tigray and SNNP regions. International potato center (CIP-Ethiopia), Addis Ababa.

Bouyoucos, G.J. 1962, Hydrometer Method Improved for Making Particle Size Analyses of Soils 1.*Agronomy journal*, 54(5), pp.464-465.

Bray, R. H. and Kurtz, L. T. 1945, Determination of total, organic and available forms of phosphorus in soils. *Soil Science*, 59: 39-46.

Carter, M. R and Gregorich, E. G. 2008, Soil sampling and methods of analysis (2 ed.). Taylor and Francis group.

Chapman, H. D. 1965, Cation exchange capacity by ammonium saturation. 891-901. *In*: Black, C.A., L.E. Ensminger and F.E. Clark (ed.), Method of soil analysis. *American Society of Agronomy,* Madison Wisconsin, USA. Chaudry, E.H., V. Timmer, A.S. Javed and M.T. Siddique. 2007. Wheat response to micronutrients in rainfed areas of Punjab. *Soil and Environ*, 26: 97-101.

CIMMYT (International Maize and Wheat Improvement Center). 1988,From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition. Mexico. D.F. ISBN 968-61 27-18-6.

CSA (Central Statistical Agency).2022, Report on Area and Production of Major Crops. Agricultural sample survey Addis Ababa Statistical Bulletin V.(1) pp: 143,10-111.

Dechassa, N., Schenk, M.K.,and Steingrobe, N.2003.Phosphorus efficiency of cabbage (*Brassica oleraceae* L. var. capitata), carrot (*Daucus carota* L.), and potato (*Solanum tuberosum* L).Plant and Soil, 250: pp.215-224.

Dembi Korji and Basha Kebede. 2017, On farm demonstration of adapted Potato (*Solanum tuberosum L.*) in Highlands of Guji zone, Oromia Region, Ethiopia. *Academic Research. Journal Agriculture Science*, Vol. 5(7), pp. 514-520.

Devaux, A., P. Kromann, and O. Ortiz. 2014, Potatoes for Sustainable Global Food Security. Potato Res. 57, 185-199. Doi: 10.1007/ s11540-014-9265-1.

Djaman K., S. Irmak, K., Koudahe, S. Allen.2021,Irrigation management in potato (*Solanum tuberosum* L.) production: a review Sustainability, 13, p. 1504.

Egata Shunka. 2021, A Review on Responses of Potato to Macro and Micro Fertilizers, Advances in Life Science and Technology, Vol.87 Pp.1-13.

Eleshev, R. E., Balgabaev, A. M., and Nurmanov, E. T.2017, Effect of N fertilizer on productivity and quality potato variety Tamasha. News of the National Academy of Sciences of the Republic of Kazakhstan Agric. Sci. 1 : 56-62.

Ethiosis (Ethiopia Soil Information System).2014, Soil fertility status and fertilizer recommendation atlas for Tigray regional state, Ethiopia. Ethiopia.

Ethiosis (Ethiopia Soil Information System).2013,Towards improved fertilizer recommendations in Ethiopia-Nutrient indices for categorization of fertilizer blends from EthioSIS woreda soil inventory data. Adiss ababa, Ethiopia.

FAO (Food and Agriculture Organization). 2000, Fertilizers and their use; 4th edit: Food and Agriculture Organization of the United Nations International Fertilizer Industry Association, Rome, Italy.

FAO (Food and Agriculture Organization). 2006,Plant nutrition for food security: A guide for integrated nutrient management. FAO, Fertilizer and Plant Nutrition Bulletin 16, Rome.

FAO(Food and Agriculture Organization),2022,Role and Potential of Potato in Global Food Security pp.1-37.

Gathungu, G., Shibairo, S., Githiri, S., Mburu, M., Ojiambo, P. and Kidanemariam, H.2000, Effect of Source, Time and Method of Nitrogen Application on Growth and Yield Components of Potato in Kenya. African Crop Science Journal, 8, 387. https://doi.org/10.4314/acsj.v8i4.27679

Gebremedhin, W., Abraha, E., Lemaga, B., Schulz, S.2013,Participatory Potato Seed Production in Tigray. Proceedings of the National Workshop on Seed Potato Tuber Production and Dissemination: Experiences, Challenges and Prospects. Gebremedhin Woldegiorgis, Steffen Schultz and Baye Berihun (eds.). 12-14 March 2012, Bahir Dar, Ethiopia, 91-100.

Gomez, K.A. and Gomez, A.A. 1984,Statistical Procedures for Agricultural Research, 2nd edition, John Wiley and Sons, New York, p.680.

Gusha, S. 2014,From Potato Fields to Potato Sacks. Pastorial Response.Anglical Diocese of Harare, Zimbabwe.

Haverkort, A.J., Koesveld, M.J., van Schepers, H.T., Wijnands, J.M., Wustman, R. and Zhang, X.Y. 2012,Potato Prospects for Ethiopia: On the Road to Value Addition. Lelystad: PPO-AGV. The Netherlands, 528: 1-66.

Hijmans, R.J.2003,The effect of the climate change on Global Potato Production.

Ierna, A. and Tenorio, J.2011,Effects of pre-sowing treatment on plant emergence and seedling vigour in true potato seed. *Journal of Horticultural Science and Biotechnology* 86, 467–472.

Jackson, M.L.1958,Soil chemical analysis Prentice-Hall. Introduction. Sixth printing Department of Soil Science, University of Wiscosin, and Madison. P.496.

Jamaati, S., Samarin, E. O., Hashemimajd, K. 2010,Effects of nitrogen fertiliser and plant

Journal of Science and Technology, Vol 7(10), 1504–1508, October 2014

Kanzikwera, C.R., Tenywa J.S., Osiru D.S., Adipala E. and Bhagsari A.S. 2001, Interactive effect on nitrogen and potassium on flowering and berry set in true potato seed mother plants. African Crop Sciences Journal, 109-125.

Karltun, E., Lemenih, M. and Tolera, M.2013, Comparing farmers' perception of soil fertility change with soil properties and crop performance in Beseku, Ethiopia. Land Degradation and Development, 24 (3): 228-235.

Karubakee, S., Bama Shankar Rath, Manoranjan Satapathy, Ashok Mishra.2024,Effect on Yield, Nutrient Uptake and Quality of Potato Under Integrated Nutrient Management, Notulae Botanicae Horti Agrobotanici Cluj-Napoca, Doi:10.15835/Nbha52213288.

Kleinkopf, G.E., western, D.T., wille, M.J., and kleinscmidt, G. D.1987, Specific gravity of Russet Burbank potatoes. American Potatoes Journal 64:579-587.

Kumar, C.V., Prakash, S.S., Prashantha, G.M., Mahendra, K.M.B., Lohith, S. and Chikkaramappa, T. 2013, Dry matter production and yield of potato as influenced by different sources and time of fertilizer application and soil chemical properties under rainfed conditions. *Research Journal of Agricultural Sciences,* 4(2): 155-159.

Long, C.M., Snapp, S.S., Douches, D.S., Chase, R.w.2004,Tuber yield storability and quality of Michigan cultivars in response to nitrogen management and seedpecies spacing, American journal of potato Research 81,347-357.

Love, S.L., Stark, J.C.,Salaiz, T. 2005, Response of four potato cultivars to rate and timing of nitrogen fertilizer Am. J. Potato Res., 82, pp. 21-30.

Martha and Ann. 2017, Organic Potato Production on the California's Central Coast: A Guide for Beginning Specialty Crop Growers by Jim Leap, Darryl Wong, Orin Martin, and Kirstin Yogg-Comerchero, PP.1-12.

Mehlich, A. 1984, Mehlich-3 soil Test Extractant: A Modification of Mehlich-2 Extractant. *Communications in Soil Science and Plant Analysis*, 15(12): 1409-1416.

MoANR (Ministry of Agriculture and Natural Resources). 2017, Plant Variety Release, Protection and Seed Quality Control Directorate**.** Crop Variety Register Issue No. 19 pp: 1-318.

Moll, R.H., Kamprath, J., & Jackson, W.A.1982, Analysis and interpretation of factors which contribute to efficiency of nitrogen utilization. Agronomy Journal, 74, 562-564

Mu, T., Sun, H. and Liu, X. 2017, Types of Potato Staple Food: A Brief Description. In Potato Staple Food Processing Technology, Springer Singapore, pp. 7-17.

Mulubirhan, H. 2004, The effect of nitrogen, phosphorus and potassium fertilization on the yield and yield components of potato *Solanum tuberosum* L., grown on vertisols of mekele area. M.sc thesis, Alemaya University, Ethiopia 1-24.

Murphy, B.W. 2007, Soils their properties and management.' 3rd edn. (Oxford University Press: Melbourne).

Otieno, H. M. O., & Mageto, E. K. 2021, A review on yield response to nitrogen, potassium and manure applications in potato (*Solanum tuberosum* L.) production. *Archives of Agriculture and Environmental Science*, *6*(1), 80-86, https://dx.doi.org/10.26832/24566632.2021.0601011.

Pandey, N.K., Dhiraj, K. and Kumar, R.S. 2014, Summer School on "Current Trends in Quality Potato Production, Processing and Marketing" (8th to 28th July, 2014). Central Potato Research Institute, Shimla, New Delhi.

Patricia,I, Bansal, S.K.1999. Potassium and integrated nutrient management in potato. A paper presented at the Global Conference on Potato, 6-11 December 1999, New Delhi, India.

Rens L.R.,Zotarelli, L., Rowland, D.L., Morgan, K.T. 2018, Optimizing nitrogen fertilizer rates and time of application for potatoes under seepage irrigation Field Crop Res., 215, pp. 49-58.

Rens, L.R., Zotarelli, L.,Cantliffe, D.J., Stoffella, P.J., Gergela, D., Fourman, D. 2015. Biomass accumulation, marketable yield, and quality of atlantic potato in response to nitrogen Agron. J., 107, pp. 931-942.

Rhoades, J.D.1982, Soluble salts. In: Page, A.L. (Ed.), Methods of Soil Analysis, Part 2, Second edition. Agronomy Monograph No: 9 American Society of Agronomy, Inc., Madison, WI, USA, p. 167- 179.

Roy, R.N., Finck, A., Blair, G.J. and Tandon, H.L.S. 2006, Plant nutrition for food security: A guide for integrated nutrient management. FAO fertilizer and plant nutrition bulletin. FAO of the United Nations, Rome.

Semagn Asredie, Abdulwahab Aliyi and Abdissa Yohannes. 2007, Potato and sweet potato research achievements in North Shewa. *In*: Proceedings of the 1st annual Regional Conference on Completed crop Research Activities. 14-17. August, 2006, ARARI, Bahir Dar.

Sikora, FJ, Copeland, J.P., Mullins, G.L., Bartos, J.M. 1991,Phosphorus dissolution kinetics and bio-availability of water insoluble fractions from mono-ammonium phosphate fertilizers. Soil Science Society of America Journal. ;53: 362–8.

Sithole, S. 2007, A guide to potato growing. Department of Agriculture. Paris: The international fertiliser industry association

Somerfield, T. G., & Knutson, K. W. 1965, Effects of nitrogen and phosphorus on the growth and development of Russet Burbank potatoes grown in southeastern Idaho. American Potato Journal, 42(12), 351-360.

Taye, B., Verkuijl, H., Mwangi, W. and Tanner, D. 2000., Adoption of Improved Wheat Technologies in Adaba and DodolaWoredas of the Bale Highlands, Ethiopia. Second National Maize and Wheat Workshop.12-16 November 2000; Addis Ababa. International Maize and Wheat Improvement Center) and Ethiopian Agricultural Research Organization (EARO). Addis Ababa, Ethiopia.

Tekalign Afeta, Bulti Tesso and Dagnachew Lule. 2019, Interaction Effects of Genotype by Environment and AMMI Stability Analysis of Seed Yield and Agronomic Performance of Faba Bean Genotypes in the Highlands of Oromia Region, Ethiopia, International Journal of Research in Agriculture and Forestry, Volume 6, Issue 10, 2019, PP 22-31.

Tekalign Mamo and Hezekeil Tase. 2015, Series "innovative ideals on effective last mile delivery". Available on www.fertilizers.org/nutrientstewardship. Accessed on July /20/2015.

Tekalign,M., and Haque, I.1991, Phosphorus status of some Ethiopian soils, II. Forms and distribution of inorganic phosphates and their relation to available phosphorus. *TropicalAgriculture*68: 1: 2-8.

Tewodros, A., Paul, C.S., Adane, H.2014, Characterization of seed potato Storage, pre - planting treatment and marketing systems in Ethiopia: the case of West-arsi zone. African Journal of Agricultural Research, 9(15), 1218-1226

Thompson, H.C. and Kelly, W.C. 1972, Vegetable crops. Tata Mc Graw. Hill Publication Co.Ltd., New Dehil, pp: 372-385.

USDA (United States Department of Agriculture). 1987, Forest Service. n.d. Soil resource inventory. Umatilla National Forest, Pacific Northwestern Region.

Vander Zaag.1981, Soil Fertility Requirements for Potato Production, International Potato Center (CIP), Lima – Peru, pp.1-23.

Walkley, A., and Black, I. A. 1934.,An examination of the digestion method for determining soil organic matter and a proposed modification of the chromic and titration method.*Soil Science,* 37:29-38.

Zaheer, K., and Akhtar, M. H. 2016, Potato production, usage and nutrition-a review. Critical reviews in food science and nutrition. 56(5): 711-721.

Zelalem, A.; Tekalign, T., and Nigussie, D. 2009, Response of potato (*Solanum tuberosum* L.) to different rates of nitrogen and phosphorus fertilization on vertisols at Debre Berhan, in the central highlands of Ethiopia. African J. Plant Sci., 3 (2): 16-24.

How to cite this article:

Arega Amdie, Solomon Teshoma and Miressa Mitiku. 2025. Response of Potato (*Solanum tuberosum* L.) to Different Rates and Timing of Nitrogen Fertilizer Application in Guji Zone, Southern Oromia, Ethiopia. *Int.J.Curr.Res.Aca.Rev.* 13(05), 61-75. doi: https://doi.org/10.20546/ijcrar.2025.1305.008