Research Article

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Determining the Profitability of Different NPSB and Nitrogen Fertilizer Rates on Yield and Yield Attributes of Irish potato (Solanum tuberosum L.) at Southern Oromia, Ethiopia

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Abstract

This is a traditional practice and most farmers and district offices only use fertilizers containing nitrogen and phosphorus in almost all soils in Guji districts. These nutrients are detrimental to increasing crop yield and must be applied during the planting schedule. This experiment was conducted to investigate the profitability of Irish potatoes when applying different rates of NPSB and N fertilizers and the economically appropriate rate to maximize potato yield. The results showed that the combined application of mixed NPSB fertilizer and N2 was significantly influenced days to 50% flowering, plant height, tuber number per plant, average tuber weight, marketable tuber yield, unmarketable tuber yield and total tuber yield. However, 80 % days to maturity was not affected by the combined application of NPSB blended and N2 fertilizer. The highest marketable tuber yield (22.86 t ha^{-1}) and total tuber yield (24.76 t ha^{-1}) were recorded from combined application of 200 kg ha^{-1} of blended NPSB fertilizer and 69 kg ha^{-1} of N2; while the lowest values 12.25 t ha^{-1} and 14.43t ha^{-1}, respectively were recorded from the control. The MRR, which determines the acceptability of any treatments shows that treatments that received 200 kg ha^{-1} NPSB and 69 kg ha^{-1} N2 nutrient yielded best result of 7700 % marginal revenue. Therefore it can be recommended that application of 200 kg NPSB ha^{-1} and 69 kg ha^{-1} N2 is the appropriate rate for optimum productivity of Irish Potato for Adola Rede areas and similar agro-ecologies.

Keywords: Application, Irish Potato, Partial Budget, Profitability, Tuber Yield.

1. Introduction

In terms of dry matter production per hectare, the potato is one of the most productive crops in developing countries such as Ethiopia. This crop is a very important source of nutritious food for various parts of the country. Annual potato production in Ethiopia has increased from 349,000 tons in 1993 to approximately 743,153 tons in 2018 and can potentially be grown on approximately 70% of the country's arable land [1,2]. Potato cultivation is an important part of the agricultural industry and contributes to food security and economic growth in many regions.

However, in the highlands and central regions of southern Ethiopia, particularly in the Guji zone, the enormous potential of the soil is not sufficiently exploited due to predominantly suitable soils. Like any cultivated plant, potatoes are not immune to problems. However, a major problem farmer's face is fertility problems when growing potatoes. Although the potato industry faces fertility issues, it is important for growers to take proactive measures to promote sustainable harvesting. Surprisingly, most farmers in these regions rely on only two types of fertilizers to meet the nutritional needs of their crops, without considering the fertility status of the soil, the environment and the type of varieties used, as summarized by Tewodros [3].

To minimize nutrient leaching from potato production systems, fertilizer recommendations based on evidence of their effects on the potato plant are required. The average nutrient deficiency in East Africa, particularly in Ethiopia, is estimated to be around 47-88 kg ha^{-1} $year^{-1}$ overall and 100 kg ha^{-1} $year^{-1}$, particularly in the highlands [4]. The main factors contributing to this depletion are soil erosion, phosphorus fixation and leaching of nitrogen and potassium, which are accelerated by harmful land management practices due to high population levels. It is true that in most areas of Guji, nutrient deficiency is very high due to high rainfall.

Plants require various elements for their growth and development, of which N, P and K are the most important essential nutrients. Deficiency of these elements has deleterious effects on plant growth and development [5]. In addition, the high mobility of N and the high affinity of P and K for chemical reactions and fixation in soil solids place these plant nutrients on the priority list of soil fertility management research [6].

In Ethiopia, variety trials conducted at multiple locations for different crop species clearly demonstrated that soil nutrient deficiency is the most important parameter controlling crop yield [7]. However, it is important to note that response to fertilizers is directly related to soil and crop types, highlighting that soils with different fertility status and different crop types respond differently to fertilizer applications. Among several factors limiting production in Guji district, low soil fertility is considered as one of the major problems. The area is one of the oldest agricultural areas in the country and due to loss of soil fertility and lack of pasture; now it has difficulty feeding its population and relies on external inputs of inorganic and organic fertilizers to increase crop yields [8].

Understanding the extent of nutrient deficiencies is important for developing and commercializing improved fertilizers. In some regions of southern Ethiopia, such as the Guji region of southern Ethiopia, soil acidity causes serious problems for crop production, and in most cases, soil acidity is related to nutrient uptake. Farmers in the study area were also aware of the response of potatoes to input nutrients and used farm manure and household waste to grow the crop on their farms. But that's not the case. Understand the type and amount of fertilizer you need to apply to individual plant species and varieties to improve crop productivity. For a long time, the farmer used DAP and urea. However, after the soil calibration was performed by Ethio-SIS, the target nutrients required for a specific area were identified. According to the study, most soils in Ethiopia are deficient in macronutrients (mainly nitrogen, phosphorus, and sulfur) and micronutrients (copper, B vitamins, and zinc) due to years of frequent cultivation of staple crops. [9].

Most of the farmers in this region rely on unknown mixed fertilizers to meet the nutritional requirements of their crops without considering the soil fertility status. Farmers in the study area were also aware of potato responses to nutrient addition and increased crop yield. However, fertilizer application is very demanding in terms of quantity, type, and impact on yield. Furthermore, a uniform recommendation of 100 kg ha-1 of urea and 100 kg ha-1 of diammonium phosphate for potato cultivation, regardless of soil fertility or variety type, has long been used in this region. I did. But just a year ago, the Ministry of Agriculture introduced mixed fertilizers for farmers based on the research of Ethiopia and his SIS. However, fertilizer application is very demanding in terms of quantity and impact on yield. Based on these evidentiary facts and circumstances, determine the impact on Irish potatoes of applying different amounts of NPSB and N2 fertilizers to determine whether it is economically appropriate to improve yields of Irish potatoes in the Adora region of Ireland. Experiments were begun to determine the amount. Maximize your Guji zone for 2 years.

2. Materials and Methods

2.1. Description of the Study Sites

The experiment was conducted during summer growing seasons at Bore Agricultural Research Center's 2021 and 2022 on the farm's Adola substation premises. The objective was to determine the application of different levels of NPSB and N fertilizer and the impact of that fertilizer application on Irish potatoes. The effect of determining economically appropriate rates that maximize profits. The region is located in the Guji zone of southern Ethiopia, estimated to be 470 kilometers from Addis Ababa. Astronomically speaking, this area lies between 050 53` 680 " and 0380 59` 007 " in northern or eastern latitudes. The average annual rainfall in the district is approximately 900 mm and the temperature ranges from 12 to 34 degrees Celsius.

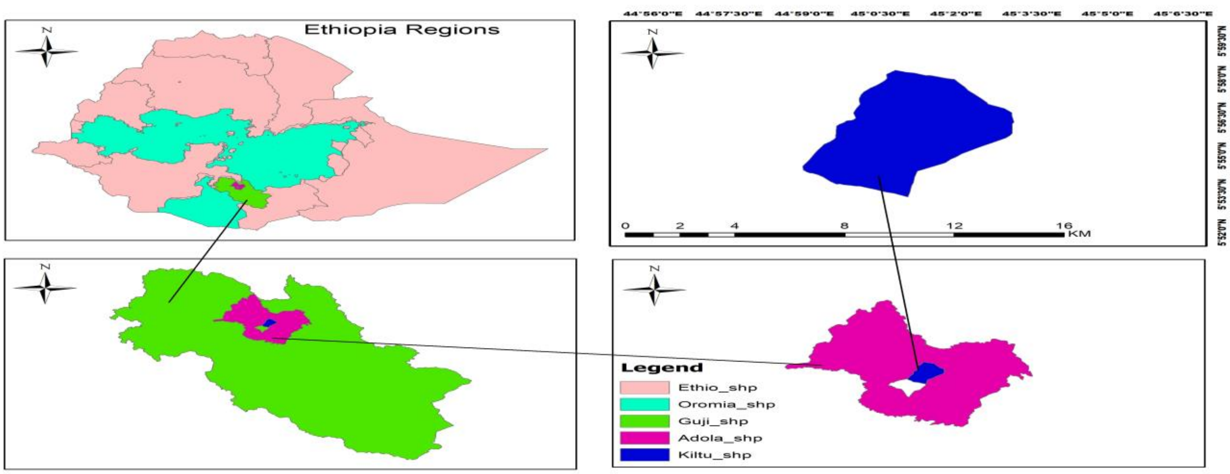

Figure 1: Geographical Location of The Study Area in Guji Zone of Southern Ethiopia

2.2. Description of Experimental Materials

The Irish potato variety Zemen was used in the study. Planting material was obtained from seed management. The selection of the varieties was made as part of our participatory variety evaluation process and based on the fact that the varieties have fundamental advantages in terms of yield and adaptability in the study area.

2.3. Description of Experimental Design and Treatments

The design used was a 4 x 4 factorial experiment arranged in randomized complete blocks and repeated three times. The treatments used were four concentrations of N (0, 11, 21, and 32 kg/ha) and four concentrations of P (0, 54, 72, and 90 kg/ha) or urea (0, 23, 46 and was composed of a combination of 69) and NPSB (0, 150, 200, 250). At the time of planting, we applied all the phosphorus and half the nitrogen dose. The other half of urea was applied 45 days after planting. Urea (46% N + 0% P2O5) and NPSB (18% N + 36% P2O5 + 7% S + 0.71% B) were used as N, P, and B fertilizer sources. The plot size was medium-sized with four columns, each 3 m long and 2.4 m wide. Well-germinated potato tubers were planted at a distance of 75 cm between rows and 30 cm between plants. The distance between plots and replicates was 1 and 1.5 m, respectively. Cultural practices such as weeding, plowing, and ridge-setting were adopted as recommended by the Horticulture Department of the Boa Agricultural Research Center.

2.4. Data Collection and Analysis

Days to flowering were recorded when 50% of the plant population reached the flowering stage. The plant height of the sample was determined by measuring the height from the base to the tip of the main stem at full bloom. The number of stems per mound was recorded as the average number of stems in five mounds per plot at the flowering stage. Only the stem that emerged from the mother tuber was considered as the main stem. The number of days to physiological maturity was also recorded and the leaves of 70% of the plants in the plot became yellowish. The number of tubers and yield per hill were expressed using the average yield per plot. Healthy tubers weighing 50 g or more (weighed on a sensitive scale) are considered suitable for market, but rotten, diseased, insect-infested, deformed tubers or those weighing less than 50 g are considered suitable for market. The tubers were deemed unfit for market. The average fresh weight of tubers was determined by dividing 20 times the fresh weight of tubers removed from the plot by the total number of fresh tubers weighed.

2.5. Soil Sampling and Analysis

First, before land preparation, soil samples at a depth of 30 cm were collected from different locations in the experimental field using an auger. Then, to analyze the physicochemical properties of the soil, composite soil samples were prepared in the laboratory, air-dried, ground, and passed through a 2-mm sieve. After harvest, soil samples were also collected from 0-30 cm soil depth for each replicate and combined treatments. The composite soils were then analyzed to determine soil structural class, pH, CEC, organic carbon, exchangeable cations, organic matter, total nitrogen, available phosphorus, available potassium, and sulfur. The values of individual physicochemical properties of the test soils are shown in the following table.

2.6. Simple Correlation Coefficient (r) Analysis

Explain the obvious relationships between nutritional parameters and yield components. This value explains that changes in one variable are accompanied by changes in other variables.

2.7. Partial Budget Analysis

A partial budget analysis was performed to determine the relative economic return of the applied treatments based on prevailing market prices. Finally, the marginal rate of return (MRR) was calculated, which is the ratio of the change in profits to the change in total variable costs when moving from a low-cost treatment to a high-cost treatment [10].

2.8. Statistical Data Analysis

The data collected on various parameters of the studied crops were statistically analyzed using SAS statistical package and Genestat 18th edition. The least significant difference test was used to separate the means at a 5% significance level.

3. Result and Discussions

Visual Observations

The picture below is taken the same day as the plants were at flowering stage and shows all of the 3 replicates from all 16 treatments.

Figure 2: Overview of plants from all treatments with nutrient levels

3.1. Soil Physicochemical Properties of Site before Planting

Pre-planting soil analysis revealed that the soil has a clay structure. The soil pH was 6.11, which was normal (Table 1). Plant nutrients are best utilized when the pH is between 5.5 and 7. However, different crops have different requirements. Soil pH is therefore suitable for Irish potatoes. Other soil chemical properties were organic carbon (OC) content 2.81%, total nitrogen 0.21%, available P 9.27 mg kg^{-1} and CEC 20.26 Meq 100 g^{-1} soil. As reviewed by Tekalign 1991, Olsen et al. 1954 and London 1991, soil organic matter content is moderate (2.1-4.2%). Total nitrogen (TN %) is classified as very low (0.25) by Tekalign (1991) [11]. Therefore, the nitrogen content of the soil in the study area is moderate. According to Olsen et al. (1954), the P (mg Kg^{-1}) content was 9.27 [12]. In that case, the P value available at that site was low. Generally, the total nitrogen content of the soil on the site is moderate. This may be because some growth and yield components responded better to P than N. According to the Food and Agriculture Organization of the United Nations, a 1982 global study on soil micronutrients and nutritional status classified boron (mg/kg) as very low (ppm) at (2.0). In general, soil analysis in the study area shows moderate boron content.

FERTILITY							
Parameter		Result	Unit	Target Range	Low	Normal	High
Acidity	PH-H2O	6.11	-	5.50 - 7.00			
Organic Carbon	OC	2.81	%	1.00 - 3.00			
Total Nitrogen	N	0.21	%	0.12 - 0.25			
Phosphorus	P	9.27	mg/kg(ppm)	20 - 30			
Calcium	Ca^{2+}	1,324.49	mg/kg (ppm)	1000 - 2000			
Magnesium	Mg^{2+}	235.21	mg/kg(ppm)	120 - 360			
Potassium	K^{+}	209.25	mg/kg(ppm)	90 - 190			
Sodium	Na^{+}	5.09	mg/kg(ppm)	69 - 161			
Sulfur	SO4-S	1.46	mg/kg(ppm)	4 - 12			
Cation Exchange Capacity		20.26	Meq/100g soil	15 – 25			
Boron	B	0.38	mg/kg (ppm)	0.25 - 0.50			

PHYSICAL PROPERTIES - GRANULOMETRY		
Textural Class	Clay	
Parameter	Result	Unit
Sand	33	%
Clay	55	%
Silt	12	%

Reference: *Tekalign et al. (1991), Berhanu (1980), Moore (2001), Olsen et al. (1954) and Hazelton and Murphy (2007)*

Table 1: First Year Soil physical and Chemical Properties of the Experimental Site before Planting

3.2. Soil Physico-Chemical Properties of Experimental Site after Crop Harvest

The study site was thoroughly analyzed post-harvest to assess the levels of various soil components. Key parameters such as Acidity, Available Phosphorus, Total Nitrogen, Sulfur, Available Potassium, Organic Carbon, Cation Exchange Capacity, Boron, Sodium, Magnesium, Calcium, and Texture were evaluated for the first-year season. Detailed analytical findings are presented in Table 2 below.

The analysis revealed that the soil's texture class is clay loam soil profile. Furthermore, the results indicated that the soil acidity across all treatment plots remained within the neutral range, with values ranging between 6.89-7.20%. This implies that the soil maintains optimal pH levels conducive for crop growth. One noteworthy observation was the substantial increase in available phosphorus (8.24 mg/kg) when the maximum rate of nutrient application was utilized. In contrast, the control application exhibited a lower value of 3.30 mg/kg of Available P. These findings emphasize the need for blended fertilizer application on this site to fulfill its nutrient requirements effectively. The application of blended NPSB and N2 fertilizers significantly elevated the total nitrogen (TN) levels from 0.25-0.31% after harvest. According to Tekalign (1991), total nitrogen percentages are rated as very low (<0.05), low (0.05 to 0.12), medium (0.12 to 0.25), and high (>0.25) [11]. Thus, the laboratory analysis results indicate that the soil at this site exhibits high total nitrogen content, ensuring favorable conditions for crop growth. Based on the comprehensive physical and chemical analysis results, it is evident that the soil in the experimental fields holds substantial potential for productive Irish potato cultivation. The soil's favorable chemical quality, as shown by the analytical findings, validates its response to fertilizer applications. The detailed analysis conducted on the soil characteristics at the study site provides valuable insights into its composition and fertility. The data generated highlights the significance of employing appropriate nutrient management strategies, particularly blended fertilizer applications, to optimize crop growth and productivity.

Treatment(kg ha^{-1})		Nutrient content												
NPSB	N	pH 0-14	Ava.P mg/kg	SO4-S mg/kg	CEC Meq/100g soil	OC %	OM %	TN %	C:N Ratio	Fe mg/kg	Mn mg/kg	Zn mg/kg	Cu mg/kg	B mg/kg
0	23	7.11	7.21	9.79	27.79	4.02	6.93	0.29	14.11	24.39	73.69	7.86	5.03	0.54
200	0	7.20	7.21	6.18	27.36	4.15	7.16	0.28	14.78	24.37	113.18	3.67	4.68	0.47
250	69	6.99	7.83	7.21	25.07	4.02	6.93	0.28	14.26	26.82	123.58	5.42	4.97	0.53
250	23	7.14	5.56	14.06	28.06	4.02	6.93	0.28	14.62	23.98	120.74	3.82	4.62	0.48
150	0	7.18	6.39	6.18	29.36	4.02	6.93	0.28	14.41	24.17	104.34	3.53	4.97	0.45
0	0	7.18	3.30	26.26	28.53	4.02	6.93	0.27	14.78	23.15	100.00	3.52	4.80	0.53
0	69	7.16	3.71	23.69	28.92	3.93	6.78	0.27	14.61	17.95	84.09	3.09	4.53	0.42
150	46	7.10	8.24	18.54	27.09	3.98	6.85	0.28	14.46	21.65	100.06	3.24	4.60	0.41
200	23	7.23	6.59	21.63	28.16	3.93	6.78	0.27	14.61	18.14	48.72	3.15	4.79	0.48
200	69	7.16	4.74	20.60	26.55	3.98	6.85	0.27	14.84	22.82	112.81	4.84	4.61	0.39
200	46	7.13	4.33	22.66	30.28	3.93	6.78	0.26	15.00	28.93	93.17	3.19	4.70	0.42
250	46	7.10	8.24	27.81	26.43	3.62	6.24	0.31	11.75	22.78	79.09	3.39	4.74	0.39
150	69	7.07	6.39	16.48	27.75	3.80	6.55	0.27	14.01	20.75	101.19	3.13	4.73	0.38
250	0	7.03	6.18	21.12	26.18	3.89	6.70	0.26	14.78	20.78	77.90	3.24	4.72	0.41
150	23	7.05	4.53	19.06	27.89	3.84	6.62	0.25	15.49	22.69	102.06	2.91	4.88	0.38
0	46	6.89	3.71	24.72	26.45	3.53	6.08	0.25	14.00	21.17	86.04	2.93	4.77	0.39
Average		**7.11**	**5.89**	**17.87**	**27.62**	**3.92**	**6.75**	**0.27**	**14.41**	**22.78**	**95.04**	**3.81**	**4.76**	**0.44**

Where, pH=soil acidity, P=phosphorus, SO4-S= sulfate, CEC=cation exchange capacity, OC=organic carbon, OM=organic matter, TN=total nitrogen, C: N=ratio of nitrogen to carbon, Fe=Iron, Mn=manganese, Zn=zink, Cu=copper and B=boron

Table 2: Soil Physical and Chemical Properties of the Experimental Site After Crop Harvest for First Year Data

3.3. Second Year Soil Physicochemical Properties of Site

Parameters																
Sand	Clay	Silt	Textural	PH-H2O	Ca	Mg	Na	K	Avail. P	S	B	CEC	TN	OC	OM	C/N
%	%	%	Class	0-14	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	meq/100g soil	%	%	%	ratio
30	**46**	**24**	**Clay**	**6.04**	**2,846.6**	**343.2**	**16.6**	**228.3**	**6.09**	**8.97**	**0.84**	**23.06**	**0.29**	**1.82**	**3.14**	**6.28**

Table 3. Soil Physical and Chemical Properties of the Experimental Site Before Planting

The physicochemical properties are presented in Table 3. The results revealed that the soil was clay in texture with normal acidic in reaction (pH 6.04). According to Fageria et al. (2011) optimum growth of potato was found within the soil pH range of 5.2 to 6.5 [13]. Therefore the soil was conducive for production of potato plant. Furthermore, the clay soil texture was suitable for the production of potato and other major crops due to its good ability to retain nutrients and soil water. The experimental soil had medium CEC, 23.06 Cmol (+) kg^{-1} soil, and also medium in total nitrogen, 0.29 % [9,14]. Here the target range could be 0.12-0.25%. The available phosphorus (6.09 mg kg^{-1}) was low as per Olsen et al. (1954) [12]. Exchangeable potassium (228.3 mg kg^{-1}) was high at experimental site. The available sulfur (8.97 mg kg^{-1}), sulfur (8.97 mg kg-1) and sodium (16.6 ppm) were low at the experimental site in accordance with EthioSIS (2014) [9]. According to Jones (2003), soil boron content was high (0.84 mg kg^{-1}) [15]. Because the target range is 0.25-0.50 mg kg^{-1}. The organic carbon (1.82%) was medium at the experimental site [11]. These results signify that the soils require additional supply of plant nutrients for those mentioned medium and low nutrient content to enrich the soil and make them available to the plants.

3.4. Phenology Parameters of Irish Potato

3.4.1. Days to 50% Flowering

In the realm of plant growth and development, one of the crucial stages is flowering time determination. It plays a significant role in the overall reproductive success of plants. Flowering time exhibited noteworthy variations under the influence of N, P, and S application, as evidenced by the NPSB and N interaction effects observed (Table 3). Upon comprehensive analysis1, it was found that the combined application of 200*69 and 250*46 kg ha^{-1} NPSB and UREA fertilizers resulted in the maximum recorded days to flowering, a total of 52 days. This observation emphasizes the importance of nutrient balance in influencing flowering time.

NPSB (kg ha^{-1})	**Nitrogen (kg ha^{-1})**				**Mean**
	0	**23**	**46**	**69**	
0	48.33^{c}	49.00^{abc}	47.33^{c}	49.33^{abc}	48.5
150	49.00^{abc}	49.00^{abc}	51^{abc}	50.33^{abc}	49.83
200	48.33^{ac}	49.33^{abc}	48.67^{abc}	52.33^{a}	49.67
250	49.00^{abc}	50.00^{abc}	52.33^{a}	47.67^{c}	49.75
LSD (5%)	3.37				
CV (%)	4.1				

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance.
Where, LSD (0.05) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent

Table 4: Mean of days to 50% Flowering as Affected by the Interaction Effect of Blended NPSB and Nitrogen Rates

3.4.3. Days to 90% Maturity

Our findings shed light on the effects of nitrogen (N) and NPSB treatments on the time required for potato plants to reach their maturity stage. Statistical analysis revealed that while both factors significantly influenced maturity (P<0.05), their interaction did not yield a significant effect (Table 4). Interestingly, we observed that N and phosphorus (P) treatments exerted opposing impacts on maturity time. Specifically, higher N rates prolonged the maturity period, whereas P treatments did not have a significant effect. For instance, the control treatment required approximately 92 days to reach maturity, while the rate of 69 Kg UREA ha-1 only took 93 days. Moreover, varying NPSB rates did not significantly affect the days to maturity. Supporting the findings of previous studies, the excessive presence of N promotes above ground organ growth and consequently prolongs the physiological maturity period. This aligns with research conducted by Ambecha O (2001), Cole (1975), and Zelalem et al. (2009), wherein it was observed that higher rates of nitrogen fertilizer delayed both flowering and maturity [16-18]. This delay can be attributed to the behavior of the N fertilizer itself.

NPSB (kg ha^{-1})	**Days to maturity(days)**
0	91.17
150	91.92
200	92.42
250	92.33
LSD (5%)	1.604
N (kg ha^{-1})	
0	91.58^{ab}
23	91.25^{b}
46	91.92^{ab}
69	93.08^{a}
LSD (5%)	1.6
CV (%)	2.1

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance.
Where LSD (0.05) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent

Table 5: Mean values of days to Maturity as Affected by Main Effect of Blended NPSB and Nitrogen Rates

3.5. Growth Parameters of Irish Potato

3.5.1. Plant height (cm) and Stem Number of the Plant

The combined analysis of data reviled that in both consecutive conducted years the interaction treatments between different NPSB levels and different inorganic Nitrogen fertilizer rates have significantly (P<0.05) influenced plant height.

Results showed that in most situations, differences in nutrient application rates led to an increase in average plant height from year to year. Different fertilizer treatments showed an increase in plant height compared to the control. The treatment (200 kg NPSB and 46 kg N) resulted in the highest plant height (96 cm), while the control resulted in the lowest result (54.06 cm). It is clear that nutritional deficiencies in plants such as Irish potatoes usually manifest as stunted growth. At this speed, the maximum plant height (89.99 cm) was recorded, similar to the previous speed, but on average different from the maximum speed. The analysis results showed that the presence of boron in the fertilizer nutrient mixture significantly increases plant height due to its important role in cell division and nitrogen uptake from the soil.

NPSB (kg ha^{-1})	Nitrogen (kg ha^{-1})			
	0	23	46	69
0	54.06^{d}	71.83^{bcd}	71.06^{cd}	72.20^{bcd}
150	73.56^{bc}	79.06^{abc}	75.89^{bc}	76.72^{bc}
200	75.56^{bc}	79.39^{abc}	96.00^{a}	79.17^{abc}
250	76.06^{bc}	80.22^{abc}	82.61^{abc}	89.89^{ab}
LSD (5%)	9.65			
CV (%)	7.5			

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance. Where, LSD (0.05) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent

Table 6. Mean of Plant Height (Cm) as Affected by the Interaction Effect of Blended NPSB and N Rates

A combined analysis of our data showed that the interaction between different NPSB values and different amounts of inorganic nitrogen fertilizer had a significant effect in two consecutive years ($P<0.05$) different between each means on stem number per plant. Many researchers have investigated the effects of different amounts of nitrogen and phosphorus on growth parameters and found positive effects. Birtukan (2016) conducted in southwestern Ethiopia shows that the combined effects of nitrogen and phosphorus had a significant impact on potato growth [19]. The fertilizer treatment showed an increase in the number of plant stems compared to the non-fertilized treatment. The combination of 200 kg ha-1 N fertilization and 46 kg ha-1 N fertilization increased the average number of stems per plant, while the combination of NPSB 0 and 23 kg ha-1 N treatments resulted in the least. (Table 6). The increase in plant height due to the addition of nutrients can be attributed to the fact that it promotes plant growth, increases the number and length of vines, leading to a gradual increase in PH and STMN. Koul (1997) reported similar results.

NPSB (kg ha^{-1})	Nitrogen (kg ha^{-1})				Mean
	0	23	46	69	
0	5.778^{cd}	5.389^{d}	5.833^{cd}	5.778^{cd}	7.31
150	7.056^{bcd}	7.722^{abcd}	5.778^{cd}	8.167^{abcd}	6.85
200	7.944^{abcd}	6.444^{bcd}	9.944^{a}	6.167^{bcd}	7.24
250	8.444^{abc}	7.833^{abcd}	7.389^{abcd}	8.778^{ab}	7.22
LSD (5%)	2.39				
CV (%)	20.1				

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance. Where, LSD (0.05) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent

Table 7. Mean of Stem Number as Affected by The Interaction Effect of Blended NPSB and N Rates

3.6. Effect of Fertilizers on Yield and Yield Components

3.6.1. Number of Tubers Per Hill

The results of analysis of data verify that different interaction effect of NPSB and N fertilizer rates had significant ($P<0.05$) effect on tuber number of Irish potato plant.

Treatments		*Yield attributed parameters*	
NPSB (kg ha^{-1})	**Nitrogen (kg ha^{-1})**	***TNP(No)***	***ATW(g)***
0	0	8.444^{b}	51.50^{d}
0	23	8.000^{b}	62.83^{bcd}
0	46	7.500^{b}	74.17^{abcd}
0	69	8.000^{b}	54.67^{cd}
150	0	8.778^{b}	92.83^{a}
150	23	10.389^{b}	75.83^{abcd}
150	46	10.889^{b}	68.50^{abcd}
150	69	10.778^{b}	77.67^{abcd}
200	0	7.833^{b}	93.33^{a}
200	23	9.944^{b}	68.67^{abcd}
200	46	8.722^{b}	95.00^{a}
200	69	8.556^{b}	90.83^{a}
250	0	10.556^{b}	81.83^{abc}
250	23	15.944^{a}	84.67^{ab}
250	46	7.778^{b}	85.83^{ab}
250	69	11.111^{b}	81.50^{abc}
Mean		9.58	77.5
LSD (0.05)		4.393	23.70
CV (%)		27.5	18.3

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance. Where, TNP=tuber number per plant, ATW=average tuber weight, LSD (0.05) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent

Table 8: Combined Interaction Effects of Blended NPSB and N Fertilizers on Tuber Number Per Plant, And Average Tuber Weight, of Irish Potato at Bore in 2018 and 2019

The statistical analysis of variance highlighted a marked difference between the various treatments (Table 7). Potato cultivation is greatly influenced by fertilizer application, specifically the combination of NPSB and N2. Significant variations in the number of tubers per plant were observed due to the different fertilizer treatments administered. Notably, the interaction of 250 kg NPSB with the addition of 23 kg N2 ha^{-1} yielded the highest tuber number per plant, reaching an impressive 15.94. On the other hand, the lowest tuber number per plant (7.5) occurred when zero NPSB fertilizers were combined with 46 kg N2 ha-1 treatment. The number of tubers per plant is greatly influenced by the fertilizer application regime. The interaction between 250 kg NPSB and 23 kg N2 ha^{-1} resulted in the highest tuber number per plant, while the absence of NPSB fertilizers combined with 46 kg N2 ha-1 treatment led to the lowest tuber number per plant. Across all seasons, a consistent trend was observed in terms of yield and yield components. However, the second season exhibited a significant decrease in most traits. This decline in yield can be attributed to the occurrence of moisture stress at the location during the second cropping season.

3.6.2. Average Tubers Weight

The results of analysis of data proved that tuber weight of our treatment was highly significantly influenced by the interaction effect of application of different NPSB and Nitrogen fertilizers rates (P<0.05). Fertilizer treatment increased fresh weight compared to non-fertilizer treatment. The 200 × 46 kg ha^{-1} treatment had the highest fresh weight of tubers (95 g), while the control treatment had the lowest (50.50 g) (Table 7). Statistical analysis revealed highly significant differences between treatments. The highest average tuber weights observed when fertilizer was used may be due to increased nutrients in the soil, which stimulates growth and allows plants to produce more food. You can Zelalem et al. (2009) and Israel et al. (2012) also reported that N2 and P_2O_5 fertilization had a significant impact on potato productivity as measured by marketable tuber yield and total yield [18,20].

3.7. Effect of NPSB and Nitrogen fertilizer Rates on yield of Irish Potato

3.7.1. Marketable Fresh Tuber Yield

The effect of inorganic NP fertilizer rate on marketable tuber yield followed similar change during both cropping seasons (Figure 1). At all levels of inorganic NPSB and N2 fertilizer rates, the marketable tuber yield differently significant across the treatments (P<0.05).

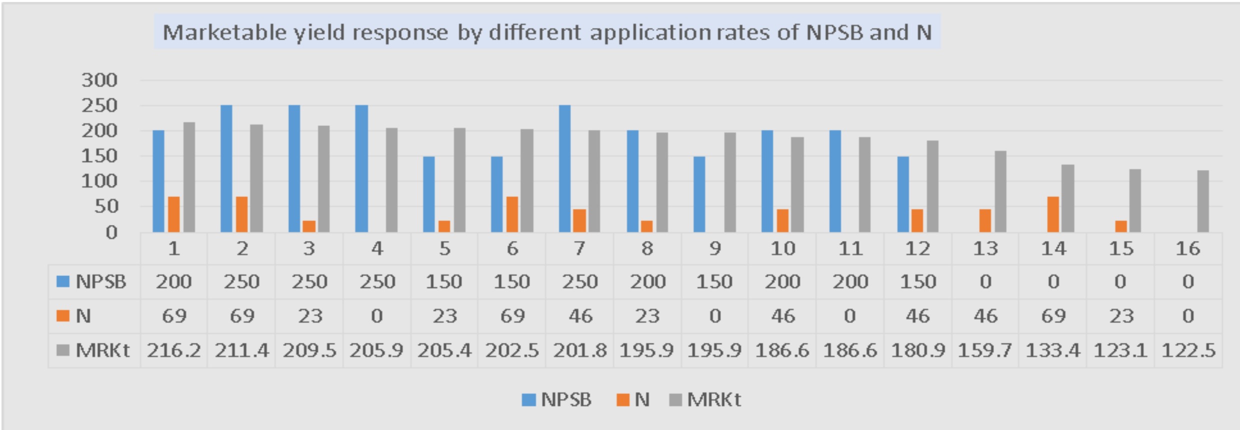

Figure 3: Marketable Yield Response by Blended NPSB and Nitrogen Fertilizer Application Rates

In tuber cultivation, achieving a high marketable yield is paramount. It has been observed that the application of blended NPSB fertilizer and Nitrogen independently, as well as their interaction, significantly ($P<0.05$) influence the marketable yield. The combined application of 200 kg ha^{-1} blended NPSB fertilizer and 69 kg ha^{-1} N2 showcased the highest marketable total tuber yield (21.6 t ha^{-1}) compared to other treatments. Conversely, the control treatment recorded the lowest total tuber yield (12.3 t ha-1). This outcome highlights the importance of optimizing fertilizer application for obtaining healthy and marketable tuber yield. To optimize marketable tuber yield, it is crucial to implement a well-calibrated fertilizer application strategy. The combined use of blended NPSB fertilizer and nitrogen emerges as a promising approach, reflecting the highest marketable tuber yield in this study.

3.7.2. Unmarketable Fresh Tuber Yield

In this study, we sought to investigate the impact of blended NPSB fertilizer and N2, both individually and in combination, on the unmarketable tuber yield. The resulting analysis of variance showcased significant effects ($p<0.05$) for both the main effects and their interaction. The unmarketable tuber yield (t ha^{-1}) exhibited an upward trend with increasing rates of NPSB and N_2 for both treatments. Remarkably, the highest unmarketable tuber yield of 3.21 t ha^{-1} was achieved with the application of 250 kg ha^{-1} NPSB and 23 kg ha^{-1} N_2 fertilizers. On the contrary, the lowest yield of 1.44 t ha^{-1} was observed when no NPSB was applied along with 69 kg ha^{-1} N_2 fertilizer. These results emphasize the critical role of optimal fertilizer application in tuber quality improvement. The term "unmarketable tuber" refers to tubers that exhibit extremely large or small sizes (less than 50 g) as well as those afflicted with diseases or decay. Consequently, the application of maximum fertilizer rates and a lack of fertilizer control may contribute to these undesirable tuber characteristics.

NPSB (kg ha^{-1})	Nitrogen (kg ha^{-1})				Mean
	0	23	46	69	
0	2.366^{ab}	2.120^{ab}	1.931^{ab}	1.440^{b}	1.96
150	1.870^{ab}	2.847^{ab}	2.338^{ab}	2.287^{ab}	2.34
200	2.449^{ab}	1.741^{ab}	2.331^{ab}	1.896^{ab}	2.11
250	2.486^{ab}	3.213^{a}	3.198^{ab}	2.583^{ab}	2.86
LSD (5%)	1.47				
CV (%)	54				

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance.
Where, LSD (0.05) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent

Table 9: Mean of Unmarketable Tuber Yield as Affected by the Interaction Effect of Blended NPSB And Nitrogen Rates (t ha^{-1})

3.7.3. Total Fresh Tuber Yield

The effect of different inorganic NPSB and nitrogen fertilizer rates on total tuber yield showed significant variations throughout all planting years (Table 9). Total tuber yield demonstrated significant differences across all levels of inorganic NPSB and N2 fertilizer rates. Notably, the combined application of 200 kg ha_{-1} NPSB and 69 kg ha^{-1} N2 and 250 kg ha^{-1} NPSB and 23 kg ha^{-1} N2 fertilizers resulted in the highest total tuber yields of 24.76 t ha^{-1} and 24.17 t ha^{-1} respectively. Conversely, the lowest total fresh yields of potatoes (14.61, 14.43, 14.55, and 14.78 t ha^{-1}) were observed in control plots and with the application of 23 kg ha-1 N2, 46 kg ha^{-1} N2, and 69 kg ha^{-1} N2 treatments.

From our comprehensive analysis, the aggregated yearly marketable yield appears to be below the national average. However, it is noteworthy that the experiment was conducted in mid-altitude areas where moisture levels tend to be low. Taking this into account, the results can be considered satisfactory considering the conditions. It is crucial to highlight that the potato yield showed a positive correlation with increasing nutrient levels up to 250 kg ha-1 NPSB and 69 kg ha-1 N2 application; beyond this point, the yield declined.

These findings align with previous research conducted by Firew (2014) and Israel et al. (2012), which emphasized the significant influence of essential nutrients, specifically nitrogen and phosphorus, on total tuber yield. Additionally, Mulubrhan (2004), Zelalem et al. (2009), and Guler (2009) further supported these findings by reporting notable increases in total tuber yield in response to higher levels of nitrogen and phosphorus application [18,20-23]. In conclusion, the impact of inorganic NPSB and nitrogen fertilizer rates on total tuber yield is a vital aspect to consider for farmers aiming to optimize their crop productivity.

NPSB (kg ha^{-1})	Nitrogen (kg ha^{-1})				Mean
	0	23	46	69	
0	14.43^{c}	14.55^{c}	14.61^{c}	14.78^{c}	14.59
150	17.06^{bc}	20.90^{ab}	20.43^{ab}	21.54^{ab}	19.98
200	21.11^{ab}	21.33^{ab}	21.02^{ab}	24.76^{a}	22.01
250	21.17^{ab}	24.17^{a}	23.34^{a}	23.72^{a}	23.09
LSD (5%)	4.172				
CV (%)	18				

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance.
Where, LSD (0.05) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent

Table 10: Mean of Total Tuber Yield as Affected by The Interaction Effect of Blended NPSB and Nitrogen Rates (t ha^{-1})

3.8. Partial Budget Analysis of N and NPSB Fertilizer

A partial budget analysis was conducted based on the recommendations of the CIMMYT Economic Program (1988) [10]. The program states that it is economical to use varying amounts of fertilizer at marginal yield rates above a minimum level (100%). A sub-budget analysis was conducted to identify satisfactory treatments as farmers sought to evaluate the economic benefits of actual changes. The marketable tuber yield was adjusted by 10% adjustment coefficient for management difference to reflect the difference between the experimental yield and the yield that farmers could expect from the same treatment and the marginal rate of return (MRR) and net benefits are calculated by current NPSB and Urea price was 49.80 and 51 birr kg^{-1}, respectively and field price of Irish potato was 20 birr kg^{-1}. In this study, NPSB, urea fertilizer costs, fertilizer application, transportation, and weed control labor costs varied, while other costs remained constant for each treatment. In order to recommend the current results to farmers, it is necessary to estimate the minimum return that farmers can tolerate within the recommended range. The economic analysis showed that the highest net benefit of 442,341 birr ha^{-1} was achieved by applying 200 kg ha^{-1} NPSB and 69 kg ha-1 N2 fertilizer, while the lowest in the control treatment (no fertilizer application). It was shown that there was a net benefit. Approximately 245,500 birr ha-1. This indicates the profitability of fertilizer processing. The MRR, which determines the acceptability of all treatments, shows that the treatment that received 200 kg ha^{-1} NPSB and 69 kg ha^{-1} N2 nutrients achieved the best results, i.e. a marginal return of 7700%. This means that for every 1.00 Birr invested in inputs of 200 kg ha^{-1} NPSB and 69 kg ha^{-1} N2 nutrients and applied to the field, the farmer recovers his 1.00 Birr and in addition he earns 77. It means you can expect to receive 00 Birr. Therefore, the treatment combination of 200 kg ha^{-1} NPSB and 69 kg ha^{-1} nitrogen fertilizer was economically priced for producers with low production costs and high profits.

Treatments	Adjusted yield (t ha^{-1})	Gross Benefit (Birr ha^{-1})	Total variable cost (Birr ha^{-1})	Net Benefit (Birr ha^{-1})	MRR (%)
0*0	12.25	245000	500	244500	0
0*23	12.31	246200	1873	244327	D
0*46	12.62	252400	3171	249229	300.77
0*69	13.34	266800	4254	262546	1200.29
150*0	15.19	303800	8375	295425	700.97
150*23	18.05	361000	9593	351407	4500.96
150*46	18.09	361800	10786	351014	D
200*0	18.66	373200	11910	361290	900.14
150*69	19.25	385000	12014	372986	1200.46
200*23	19.59	391800	12453	379347	1400.48
200*46	18.66	373200	13656	359544	D
250*0	18.68	373600	13800	359800	D
200*69	22.86	457200	14859	442341	7700.94
250*23	20.95	419000	14998	404002	D
250*46	20.18	403600	16201	387399	D
250*69	21.14	422800	17419	405381	D

Where, D=dominate, t=ton, ha=hectare

Table 11: Cost Benefit Analysis of NPSB and N Fertilizer Rate on Irish Potato Production

3.9. Pearson Matrix Correlation Coefficient (r) Analysis

Simple correlation coefficients (r) calculated to show the relationships between and among the agronomic parameters of Irish potatoes, as shown in Table 11. Correlation values describe apparent associations between nutritional parameters and yield components and clearly indicate the size and direction of the association. Among various parameters, plant height and total yield were moderately positively correlated with nitrogen and NPSB application rates, and as nitrogen and NPSB application rates increased, plant height and total yield increased. Marketable yield, total yield, plant height, and days to maturity were positively correlated with nitrogen and NPSB application rates. This relationship may be related to the increase in fertilizer application from NPSB ha^{-1} 150 to 250 kg ha^{-1} and from 23 to 69 kg ha^{-1}, which increases the availability of nutrient N in plant growth and development. , which shows the importance of P and K. To Babaji et al. (2009) [24]. Meanwhile, days to flowering, number of stems, and average tuber weight were negatively correlated with nitrogen and NPSB rates according to correlation analysis, but not significantly.

Correlation analysis between marketable yield (t ha^{-1}) and growth characteristics showed that marketable yield was significantly affected by average days to flowering (r=0.126), plant height (r=0.057), and number of tubers per plant (r= 0.155). .correlation). However, days to maturity and number of stems per plant (r=0.197 ns) and (r=0.039 ns), respectively, were correlated with marketable yield, while non-marketable yield (r=-0.841**) showed a strong positive correlation. Marketable yields are correlated. This indicates that improving any of these parameters can lead to improved overall yields of Irish potatoes. Therefore, the yield of marketable fresh tubers was significantly positively correlated with growth. Yield and yield-related characteristics, excluding days to flowering and average tuber weight.

	N	NPSB	DYF	DM	PH	STMN	ATBN	ATW	MRK	UMRK	TOY
N	1.000										
NPSB	-0.194^{ns}	1.000									
DYF	-0.020^{ns}	-0.026^{ns}	1.000								
DM	0.054^{ns}	0.028^{ns}	0.973^{**}	1.000							
PH	0.392^{*}	0.186^{ns}	-0.096^{ns}	0.104^{ns}	1.000						
STMN	-0.238^{ns}	-0.015^{ns}	0.095^{ns}	-0.087^{ns}	0.422^{*}	1.000					
ATN	-0.049^{ns}	0.139^{ns}	0.026^{ns}	0.086^{ns}	-0.223^{ns}	0.242^{ns}	1.000				
ATW	-0.216^{ns}	-0.099^{ns}	0.068^{ns}	0.016^{ns}	0.087^{ns}	0.042^{ns}	-0.294^{ns}	1.000			
MRK	0.197^{ns}	0.129^{ns}	0.126^{ns}	-0.197^{ns}	0.057^{ns}	-0.039^{ns}	0.155^{ns}	0.260^{ns}	1.000		
UMRK	-0.092^{ns}	0.111^{ns}	-0.096^{ns}	0.118^{ns}	0.078^{ns}	0.038^{ns}	0.081^{ns}	0.002^{ns}	0.841^{**}	1.000	
TOY	0.039^{ns}	0.315^{*}	-0.038^{ns}	0.003^{ns}	0.188^{ns}	0.025^{ns}	0.291^{ns}	0.261^{ns}	0.427^{*}	-0.846^{**}	1.000

*Where N= Nitrogen, NPSB=blended fertilizer, DYF=days to flowering, DM=days to maturity, PH=plant height, STMN=stem number per plant, ATBN=tuber number per hill, ATW=tuber weight, MRK=marketable yield, UMRK=unmarketable yield, TOY=total yield, ns=non-significant difference, * indicates significant at 5%, ** indicates significant at 1%.*

Table 12: Simple Linear Correlation Coefficient (R) For NPSB And Nitrogen Fertilizer Rates on Phenological, Growth, Yield and Yield Components of Irish Potato

4. Conclusion and Recommendations

Irish potato (Solanum tuberosum L.) is an economically important crop worldwide and the most important non-cereal food product [25]. Potato productivity can reach an achievable yield of up to 30 t ha-1, but its productivity in Ethiopia is very low, less than 11.88 t ha-1 [26,27]. There are many complex reasons why the country's actual potato yield is so low. According to most reviews around the world, potato production and production in Ethiopia is well below the world average due to soil fertility issues, pests, diseases, and agronomic factors. Plants require essential nutrients for optimal growth and development. The most important of these are N, P, and B, which are required in large quantities in addition to boron. Deficiency of these nutrients adversely affects plant growth and development. The use of modern agricultural inputs, such as soil nutrients, is considered the key to improving crop productivity and overall agricultural production. Therefore, optimizing the productivity of potato soil fertility management should be a major challenge for growers. Various experiments conducted in Ethiopia have shown that nutrient application is positively associated with achieving higher yields of Irish potatoes.

This experiment was conducted to demonstrate the impact of Irish potatoes on different levels of NPSB and N fertilizer application and to determine economically appropriate levels to maximize yields for 2021 and 2022 in the Adora district. It was conducted at the Boa Agricultural Research Center during the summer growing season. The design used was a 4 × 4 factorial experiment arranged in randomized complete blocks and repeated three times. The combined data analysis revealed that the 200 kg NPSB and 46 kg N treatment resulted in the highest plant height (96 cm), whereas the control resulted in the lowest result (54.06 cm). In contrast, the number of tubers per plant was significantly affected by differences in fertilization. The maximum number of tubers per plant (15.94) was recorded with the interaction effect of 250 kg NPSB with the addition of 23 kg N2 ha-1 treatment, and the lowest number of tubers per plant (7.5) was recorded with the rate of zero NPSB fertilizer and at 46 kg N2 ha-1. Also, the application treatment of 200 × 46 kg ha-1 had the highest fresh weight of tubers (95 g), while the control treatment had the lowest (50.50 g). Marketable tuber yield was significantly ($P<0.05$) influenced by the application of blended NPSB fertilizer and N2 independently, and by the interaction. The highest marketable total tuber yield (21.6 t ha-1) was obtained from the combined application of 200 kg ha-1 blended NPSB fertilizer and 69 kg ha-1 N2. On the other hand, the lowest (12.3 t ha-1) total tuber yield was measured from the control treatment.

Therefore, our study confirmed that NPSB and N2 fertilizers and their interaction have promising effects on marketable potato total tuber yield. Based on partial budget analysis, the highest net benefit of 442,341 Birr ha-1 was achieved from the treatment combination of 200 NPSB and 69 N2 kg ha-1, with a marginal benefit of 7700.94%. Therefore, in this case, the treatment combination 200 NPSB and 69 N kg ha-1 was the most attractive tariff for producers with low production costs and high profits. Both the agronomic and economic feasibility analysis results showed that applying NPSB fertilizer and N2 fertilizer at the rate of 200 kg NPSB ha-1 and 69 kg ha-1 N2 resulted in higher yields than the control treatment in the conducted areas. It has shown to be advantageous. Area achieved. Therefore, application of 200 kg NPSB ha-1 and 69 kg ha-1 N2 can be recommended as a suitable proportion to optimize Irish potato productivity in the Adola Redde area and similar agro-ecologies.

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