Growth And Yield Of Irish Potato (Solanum Tuberosum L.) Response Under Different Levels Of N_2-P_2O_5 Fertilizer And Farmyard Manure At Bore, Southern Oromia, Ethiopia

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Oka Abstract: The field trial was conducted during 2018 and 2019 main cropping season at the Bore Agricultural Research Centre which is located in Guji Zones, with the objective of determining the effect of combined application of inorganic N_2-P_2O_5 fertilizer and FYM rates on growth, yield and yield components of Irish potato and to identify their economically appropriate rates. The experiment was arranged in factorial combination of four level of farmyard manure (0, 3, 6 and 10 tons ha^{-1}) with five level of Urea (0, 44, 88, 132 and 176 kg ha^{-1}) and NPS (0, 49, 98, 147 and 197 kg ha^{-1}) in combination in RCBD with 3 replications. Our data analysis showed that maximum number of stems per plant (10) was recorded in fertilizer rate of 132 kg N_2 + 147 kg P_2O_5 and 6 t ha^{-1} FYM, meanwhile minimum number of stem number (4.66) was recorded for 0 kg N_2-P_2O_5 and 3 t ha^{-1} FYM treatment. Application rates of 132 kg N_2 + 147 kg P_2O_5 ha^{-1} with 6 t ha^{-1} FYM recorded maximum (14.77) tuber number while application of zero N_2-P_2O_5 fertilizers + 6 t ha^{-1} FYM, recorded the least (8.22) tuber number. The combined application of 6 t FYM ha^{-1}+ 132 kg N_2 + 147 kg P_2O_5 ha^{-1} produced the highest marketable root yield (39.4 t ha^{-1}) while the lowest yield (12.55 t ha^{-1}) was from 4 t ha^{-1} FYM+0 kg P_2O_5 ha^{-1}. Maximum total tuber yield (45.98 t ha^{-1}) was obtained at 6 t FYM ha^{-1}+ 132 kg N_2 + 147 kg P_2O_5 ha^{-1} whereas the lowest (17.71 t ha^{-1}, 18.29 t ha^{-1} and 18.65 t ha^{-1}) was obtained at combined application of control treatment, 0 N_2-P_2O_5 + 4 t FYM ha^{-1} and 0 N_2-P_2O_5 + 6 t FYM ha^{-1} application rates, respectively. The MRR, which determines the acceptability of any treatment shows that, treatment receiving 132 kg N_2 + 147 kg P_2O_5 ha^{-1} fertilizer rates in combination with 6 t ha^{-1} of FYM yielded good results of 26943.2% marginal revenue. Therefore the most attractive rates for producers with low cost of production and higher benefits in this case were 132 kg N_2 + 147 kg P_2O_5 ha^{-1} with 6 t ha^{-1} farmyard manure combination and can be recommended for farmers in Bore and other areas similar agro ecologies.

Keywords: Combined, Factorial, Farmyard Manure, Marginal Rate of Return, Rate

1. Introduction

Potato (Solanum tuberosum L.) is one of the most widely grown tuber crops in the high and mid altitude areas of southern region. The crop is widely grown in Bore and Anasora areas (Personal). As a high yielding crop, it can greatly contribute in securing food in these highly populated areas. Declining soil fertility is one of the major problems causing yield reduction in Ethiopia. Farmers at Bore and Anasora apply both organic and inorganic fertilizers to overcome the problem and increase yield. A research conducted in Taiwan indicated that application of manures increased the availability of N and P [9]. In addition to providing essential nutrients, compost also improve soil structure and benefit soil organisms [13]. In Ethiopia root and tuber crops are part of the traditional food systems of the people especially in the southern, southwestern and western part of the country. There is enormous possibility for millions of poor farmers to boost production and their livelihood using root and tuber crops which are strategic crops for the country's economy [4]. Ethiopia has the highest livestock resource in Africa. Hence, achieving sustainable increases of agricultural production has been the highest priority of the country. Especially in an area with high livestock resource like Guji, FYM would be an excellent input for crop production. Highland parts of Guji Zone have humid and sub humid moisture condition, which have longer growing season. Most cereal crops like maize take too long to mature. But vegetable crops like Irish potato which are dominantly cultivated by the farmers mature in short growing season. However, since manures contains less nutrient concentration as compared to chemical fertilizers and it releases nutrients slowly, it doesn't provide all the nutrients which are highly required by crops [19]. Use of integrated nutrient management and correct agricultural practices such as optimum application of nutrients has to be adhered for successful vegetable production [8]. [40] Reported that the area was well known with the livestock resource. Livestock population size of the District was about 1095916 during year 2000 .Out of the mentioned size, cattle, goats and sheep account for 709722, 338386 and 36523 respectively those are a good quality source of organic fertilizer. However, the productivity of Irish potato per unit area is quite low as compared to developed countries of the world. Therefore, the use of integrated nutrient management is very important and best approach to maintain and improve soil fertility. So the integrated use of both manure and chemical (inorganic) fertilizers is the best alternative to provide balanced and efficient use of plant nutrients and increase productivity of soil. Therefore, the current project was proposed to determine the effect of combined application of inorganic NPS fertilizer and FYM rates on growth, yield and yield components of Irish potato and to identify their economically appropriate rates that maximize yield of Irish potato.

2. Literature Review

2.1. Origin and Ecology

The potato was first cultivated in South America between three and seven thousand years ago, though scientists believe they may have grown wild in the region as long as 13,000 years ago. The genetic patterns of potato distribution indicate that the potato probably originated in the mountainous west-central region of South American, Peru. There are strongly evidences that potato was widely distributed throughout the Andes from Colombia to Peru and also in Southern Chile [17]. Globally, it is one of most important crop in terms of production as well as consumption and ranks fourth after wheat, rice and maize [11]. It also ranks first among root and tuber crops followed by Cassava, Sweet potatoes and Yams [17]; [11]. Potato was introduced to Ethiopia in 1859 by the German botanist Schimper [15]. Potato production has increased considerably through the twentieth century. Potato is best adapted to a high altitude 2000- 3000 meters above sea level and the frost resistant species grow from 3000-4000 masl best yielders at 2500-3500 masl [29]. In Ethiopia Most of the Central Highlands, at altitudes ranging from 1,500-3,000 masl and annual precipitation of 600-1200 millimeters are more favorable [15].

2.2. Response of Vegetables to Nutrient Application

In developing countries, it is common that excessive fertilizer rates are applied to vegetable gardens and fields to attain high yield. High application rates of fertilizers in urban areas are thought to be economically reasonable due to limited agricultural land and low cost of organic fertilizer inputs as compared to the value of the marketable product. However, proper fertilizer balance is required for optimum growth and development of vegetables since excessive rates increases their susceptibility to fungal diseases and deterioration of keeping quality [24]. [27] found that using mineral fertilizer (N, P, and K) increasing leafy vegetables vegetative growth, yield and quality. Both yield and tubers qualities are affected by variety, environmental conditions and cultural practices. Fertilizer application has important effects on the yield and quality of potatoes [37]. Potato is highly responded to N fertilizer and it is usually the most specific essential nutrient for potato plant growth on all soils, especially on sandy soils [10]. Previous studies have shown that nitrogen fertilizer can increase the growth characteristics, such as plant height, shoot dry matter, leaf area index and tubers yield [20], [31]; [42]. Appropriate use of nitrogen fertilizer can lead to accomplishment of optimum foliage development and subsequently increases tubers yield. The excessive use of nitrogen can lead to increase vegetative growth rather than tubers production and delay potato maturity [21]; [20] and reduces tubers quality [41]. Likewise, [1] indicated that vegetative growth characters, tubers yield, marketable tubers percentage and tubers quality were influenced by different rates of nitrogen fertilizer.

2.3. Response of Irish Potato to Nitrogen, Phosphorus and Manure Application

Plant nutrition is the practice of providing to the plant the right nutrient, in the right amount, in the right place, at the right time. Nutrients can be applied in various ways to meet the requirements for potato production. [32] Have shown that the high yield and good quality of potato can be achieved by an efficient use of fertilizers. Various factors affect crop growth in addition to the nutrient supply. However, yields have been significantly increased by applying the recommended doses of mineral nutrients in time, provided that all other factors are in a reasonable balance. Some work has been done on the efficient use of fertilizer in the Sudan. [26] Reported that the optimum rate of nitrogen fertilizer for potato in the Sudan was 169.28 kg N/ha applied in two equal doses. But [2] stated that the applied nitrogen should be in bands at the rate of 5.4 kg of pure nitrogen per feddan in two equal doses. Despite the negative effects of excessive chemical N fertilizer, application of chemical nitrogen fertilizer has remarkably increased during the last years [14]. So, the developments of new methods become an urgent need for potato producers to use other nutrient sources [16]. Today, the price of mineral fertilization has been raised so much. It becomes more than the ability of the majority of framers. Besides, the high price of mineral fertilization increases the production costs. Using of chemical fertilizers alone may not be sufficient under intensive agricultural management and result in a possible depletion of essential micronutrients thereby resulting in an overall reduction in total crop productivity [18] and significant soil problems such as soil degradation and soil pollution causes by high application rates of chemical fertilizers [33]. The animal manure such as cattle manure is another source of N and other nutrients, which can decease the demand of chemical fertilizer and it has been used for many centuries to increase soil fertility Except for the supply of nitrogen fraction, animal manure can improve chemical, physical and biological characteristics of the soil [6]. Nitrogen is the motor of plant growth. It makes up 1-4% of dry matter of the plant. It is taken up from the soil in the form of nitrate ($NO3^-$) or ammonium ($NH4^+$). In the plant, it combines with compounds produced by carbohydrate metabolism to form amino acids and proteins. Being the essential constituent of proteins, it is involved in all the major processes of plant development and yield formation. A good supply of nitrogen for the plant is also important for the uptake of the other nutrients [5]. [12] Conduct an experiment to know the effects of nitrogen and phosphorus on growth and yield of potato using Bubu Potato variety. The authors applied four rates of nitrogen (0, 56, 112 and 168 Kg N ha^{-1}) and four rates of phosphorus (0, 46, 92 and 138 Kg P2O5 ha^{-1}) and observed that plant height increase with increasing of nitrogen level up to 168 kg ha^{-1}. Maximum (88.67 cm) plant height was recorded at a rate of 168 kg ha^{-1}. [7] Stated that Phosphorus fertilization significantly increased the marketable tuber yield. Increasing application of phosphorus has increased marketable tuber yield per hectare. Maximum tuber yield was recorded at a rate of 135 kg ha^{-1} with 98% yield advantage over control treatment. Phosphorus performs functions in plants, such as a structural element forming part of the macromolecular structures such as nucleic acids (RNA and DNA) and in the phospholipids of cell membranes [23].

3. Material and Methods

3.1. Description of the Study Sites
The climatic condition of the area is most humid and sub humid moisture condition, which relatively longer growing season. Bore is found at Latitude of 6°26'52" N and Longitude 38°56'21" E at an altitude of 2736masl. The annual rainfall ranges from1400-1800 mm with a bimodal pattern that extended from April to November. The mean annual minimum and maximum temperature is around 10.1 ^{0}C and 20 ^{0}C, respectively (Anonymous, 2014). The soil is clay in texture and very strongly acidic with pH around 4.01-5.33.

3.2. Description of Experimental Materials
Irish potato variety "Gudene" was used as experimental material. The seeds of the variety were obtained from the team seed maintenance program. The choice of this variety was due to its good adaptability and yield. The variety is found at large on farmers hand and it is widely cultivated and consumed in different highland parts of the Zone and best variety for highlands of the area.

3.3. Experimental Design and Treatments
The field trial was conducted during 2018 and 2019 main cropping season at the Bore Agricultural Research Centre which is located in Guji Zones, of Southern Ethiopia with the objective of determining the effect of combined application of inorganic N_2-P_2O_5 fertilizer and FYM rates on growth, yield and yield components of Irish potato and to identify their economically appropriate rates that maximize yield of Irish potato. The experiment was arranged in factorial combination of four level of farmyard manure (0, 3, 6 and 10 tons ha^{-1}) with five level of Urea (0, 44, 88, 132 and 176 kg ha^{-1}) and NPS (0, 49, 98, 147 and 197 kg ha^{-1}) in combination. The experiment was laid out in RCBD with 3 replications. Urea (46% N) and NPS (38% P_2O_5 + 19% N + 7% S) treatments was used as sources of N and P, respectively. The spacing of the plants was 75 cm between rows and 30 cm between plants. The distance between plot and block was 1.5 m and 0.60m, respectively. Four rows per plot and seven plants per row, totally 35 plants per plot were established in gross plot size of 3.00m*2.1 m (6.30m^2).

3.4. Soil and Farmyard Manure Sampling and Analysis
Soil samples to a depth of 30 cm were collected in a zigzag way from different spots of the experimental field before land preparation and after harvest were taken and composited. After harvest soil sampling was taken in the same manner as taken for the pre planting in a zizag way from 15 different plots. Then the composite samples were analyzed for physico-chemical properties of the soil mainly for organic carbon, total N, soil pH, available phosphorus, cation exchangeable capacity (CEC), and texture at Horticoop Ethiopia Plc laboratory for soil and manure, respectively. The soil pH was measured potentiometrically in the supernatant suspension of 1:2.5 soil-water suspensions with standard glass electrode pH meter. The Walkley and Black method was used to determine the organic matter content and the result was obtained by multiplying percent organic carbon by conversion factor of 1.724. The total nitrogen content of the sampled soil was determined following Kjeldahl digestion, distillation and titration procedure as described by Cottenie. Besides, available phosphorus was determined by Olsen method. The cation exchange capacity (CEC) was measured using 1Mneutral ammonium acetate. The soil particle size distribution was determined using the hydrometer technique. The manure sample was taken from the well decomposed collected material. The manure was collected from known farmer near to the experimental site and composted in the research station and air dried, and analyzed at laboratory for pH, total N, available P, available K, available S, CEC, organic carbon content and Textural class.

3.5. Crop Data Collection
Days to 50% emergency, flowering, maturity, plant height (cm), stem number, average tuber weight (g), average tuber number per plant, marketable and unmarketable yield and total yield (kg) per plot was measured and converted to hectares. Cost benefit analysis was done to determine the relative economic returns on the applied treatments using the prevailing market prices.

3.6. Partial Budget Analysis
Variable cost of fertilizer and wage for incorporation was largely used for partial budget analysis**.** Price fluctuations during the production season were considered. Marginal Rate of Return, which refers to net income obtained by incurring a unit cost of fertilizer, was calculated by dividing the net increase in yield of potato due to the application of each rate to the total cost of fertilizer and FYM applied at each rate. This enables to identify the most economic rate and source of N and P fertilizer for cabbage production. This was achieved by dividing the total variable cost by the net benefit multiplied by 100.

$$\text{MRR (\%)} = \frac{\text{Marginal benefit}}{\text{Marginal cost}} \times 100$$

3.7. Statistical Data Analysis
Analysis of variance procedures was used on every measured parameter to determine the significance of differences between means of treatments using the SAS 9.1.3 systems software for each parameters, and separated by the least significant difference (LSD) using the statistical package. The collected data on various parameters of the crop under study was statistically analyzed using SAS statistical package. The Least Significant Difference (LSD) test at 5% level of significance was used to separate the means.

4. Result and Discussions

4.1. Soil and Farmyard Manure Sampling and Analysis

4.1.1. Soil Physicochemical Properties of Site before Planting
From the soil analysis result before sowing it was clearly revealed that the soil textural class was clay with constituents of sand (28%), clay (42%) and silt (28%) which is ideal for Irish potato as the crop is grown mostly on light-textured soils ranging from coarse and fine sands

to sandy clay loams [28]. The soil pH (H_2O) of 4.35 rated as strongly acidic, total nitrogen (0.31%) is as high, available phosphorus (4.62 ppm) as low, cation exchange capacity (23.12 Meq/100g) as moderate according to the classification by Landon and available potassium concentration of (269.5 mg/kg (ppm)) as high according to the rating of [25] (Table 1). Thus, moderate to low mineral content of the soil implied that there was necessity of applying or ignoring essential nutrients to the experimental plot of the study area and also need to improve the physical nature of the soil including soil acidity.

Table 1. *Soil Physiochemical properties of experimental site before planting.*

Soil characters	Values	Examination standards
pH (by 1: 2.5 soil water ratio)	4.35	ES ISO 10390:2014(1:2.5)
Total nitrogen (%)	0.31	ES ISO 11261:2015(Kjeldahl Method)
Organic carbon (%)	3.09	Walkley and Black Method
Available phosphorous (mg/kg (ppm))	4.62	ES ISO 11261:2015(Olsens Method)
Cation exchange capacity (Meq/100g)	23.12	Ammonium Acetate Method
Available potassium (mg/kg (ppm))	269.50	Ammonium Acetate Method
C:N	9.97	
Available sulfur (mg/kg (ppm))	31.19	Turbidometreic
Soil texture:		Bouyoucos Hydrometer Method
Sand	28	
Clay	42	
Silt	30	
Class	Clay	

Source: *Tekalign et al. (1991), Berhanu (1980), Moore (2001), Olsen et al. (1954), Jones, J. Benton (2003) and Hazelton and Murphy (2007)*

Table.2 *Chemical properties of farmyard manure used in the experiment*

FYM characters	Values	Examination standards
pH (by 1: 2.5 soil water ratio)	7.64	ES ISO 10390:2014(1:2.5)
Total nitrogen (%)	1.76	ES ISO 11261:2015(Kjeldahl Method)
Organic carbon (%)	33.99	Walkley and Black Method
Available phosphorous (mg/kg (ppm))	859.74	ES ISO 11261:2015(Olsens Method)
Cation exchange capacity (Meq/100g)	42.63	Ammonium Acetate Method
Available potassium (mg/kg (ppm))	15189	Ammonium Acetate Method
Available sulfur (mg/kg (ppm))	164.65	Turbidometreic

Source: *Horticoop Ethiopia Plc*

4.1.2. Soil Physico-chemical Properties of Site after Crop Harvest

The analysis of the experimental soil after harvest for pH, available phosphorus, total nitrogen, sulfur, available potassium, organic carbon, cation exchange capacity and texture is indicated in Table 2. The analytical results indicated that the textural class of the soil was clay loam soil profile. The result obtained from soil analysis showed that the treatments with combined rate of 132 kg N ha^{-1} and 147 kg P ha^{-1} with 10 t ha^{-1} of FYM gave an increase of 5.7 % pH. However control treatment gave an increased available P of 23.23 mg/kg of soil and high (31.23 Meq/100g) level of CEC. According to Booker CEC 25-40 Meq/100g valued as high. Similarly, the combined application of 132 kg N ha^{-1} and 147 kg P ha^{-1} with 4 t ha^{-1} of FYM increased the OC level from 3.32 % after harvest. Below the analysis result shows as the rate of FYM increases up to 6 t ha^{-1}, the soil OM characteristic parameters were increased with increase in nitrogen and phosphorus concentration. Maximum available K (283.5 mg/kg) was recovered, when control nutrient with 4 t ha^{-1} FYM applied with relatively higher rate of potassium. This implies that FYM application possibly increased the pH, total nitrogen of the soil and organic matter so that Irish potato utilized the nutrients for proper growth and development that lead to higher yield. Moreover, the addition of 132 kg N ha^{-1} and 147 kg P ha^{-1} fertilizer rate increased the level of available S in the soil by 1.44 mg/kg. Generally, the soil physical and chemical analysis results indicated that the soils of the experimental fields are potentially productive from the perspectives of chemical properties of soils for potato growth and had a potential to respond to fertilizer application.

Table 3. *Soil analysis result of experimental site after crop harvest*

Treatment														
NP(kg/ha)	FYM(t/ha)	PH	P(mg/kg)	S(mg/kg)	K(mg/kg)	CEC(Meq/100g)	OC (%)	OM (%)	TN (%)	C:N ratio	Sand	Clay	Silt	Class
0	0	4.85	23.23	12.53	124.8	31.23	3.11	5.37	0.3	10.24	18	44	38	clay
0	4	4.76	7.08	13.6	283.5	23.49	3.14	5.42	0.31	10.01	30	44	26	clay
0	6	4.39	8.13	15.02	84	29.11	3.15	5.44	0.31	10.07	26	44	30	clay
0	10	4.1	10.02	14.54	99.75	27.41	3.03	5.22	0.3	10.03	26	44	30	clay
44*49	0	4.45	8.13	15.02	120.75	22.64	2.95	5.08	0.3	9.66	26	46	28	clay
44*49	4	4.53	9.69	14.2	106	28.66	3.06	5.27	0.31	9.77	26	46	28	clay
44*49	6	4.7	8.63	9.49	206.7	19.74	2.95	5.08	0.3	9.76	26	46	28	clay
44*49	10	5.31	9.69	14.68	79.5	21.33	3.07	5.29	0.31	10	26	42	32	clay

88*98	0	5.64	21.77	15.64	116.6	22.18	3.07	5.29	0.3	10.41	30	42	28	clay
88*98	4	5.61	14.14	15.64	127.2	20.31	2.87	4.94	0.31	9.3	28	44	28	clay
88*98	6	5.62	12.75	15.96	215.25	20.03	3.2	5.52	0.33	9.8	28	42	30	clay
88*98	10	5.37	10.4	13.13	130.8	22.37	3.24	5.59	0.32	10.03	30	40	30	clay
132*147	0	5.37	11.38	18.44	127.2	24.13	3.27	5.65	0.32	10.36	30	42	28	clay
132*147	4	5.5	8.34	3.78	189	22.01	3.32	5.73	0.31	10.2	30	44	26	clay
132*147	6	5.51	13.8	10.82	105	21.25	3.24	5.59	0.32	10.26	30	42	28	clay
132*147	10	5.7	18.42	10.82	126	22.13	3.24	5.59	0.3	10.74	30	42	28	clay
176*197	0	5.46	12.66	14.68	106	22.07	3.08	5.31	0.3	10.45	30	44	26	clay
176*197	4	5.34	10.23	17.38	105	18.98	3.15	5.43	0.3	10.58	28	44	28	clay
176*197	6	5.53	18.84	13.6	99.75	22.47	3.16	5.45	0.3	10.47	28	42	30	clay
176*197	10	5.44	10.23	14.07	105	20.16	3.08	5.31	0.32	9.72	28	42	30	clay

4.2. Phenological Parameters of Irish Potato

4.2.1. Days to Emergency

The interaction effects of Mineral NP and FYM significantly (P<0.05) influenced days to bud sprouting of sweet potato Moreover, this trait was significantly influenced by the interaction effect of FYM and phosphorus. Data of table 4 demonstrated that application of farmyard manure and N_2-P_2O_5 had positively influence on phenological characters days to emergency, flowering and maturity of potato plants. The fastest days to emergency (12 days) was recorded at combination of 10 t ha^{-1} FYM with all rates of N_2-P_2O_5, which may be due to better water holding capacity of the applied FYM around root zone of the cuttings which enables initiation of roots and make the seed emerge early. The longest days to emergency (17 days) was recorded at combination of control application of N2-P_2O_5 with all rates of FYM. Days to emergency was delayed at treatments with no fertilizer and minimum rates which indicated that application of nutrients is crucial for root initiation which speeds up emergency of tubers (Tables 4).

4.2.2. Days to 50% flowering

The combined analysis of our data shows that in both consecutive two years interaction treatments between different farmyard manure levels and different inorganic nitrogen and phosphorus fertilizer rates have significantly (P<0.05) different between each means on days to flowering. The maximum (79) days to flowering was recorded by the combined application of 176*197 and 132*147 kg ha^{-1} N_2-P_2O_5 with 6 t ha^{-1} FYM.

4.2.3. Days to 90% Maturity

The two main effects significantly (P<0.05) difference on days to maturity of potato. Similarly, it was significantly affected by the interaction effect of the two fertilizers. The highest days to physiological maturity (122.33) was observed at the interaction of 4 t FYM ha^{-1} and 176*197 kg N_2-P2O5 ha^{-1}, but the lowest day (86) was observed at 4 t FYM ha^{-1} and 88*98 kg N_2-P2O5 ha^{-1}. The result indicated that increasing rate of FYM delayed time of maturity of Irish potato which may be attributed to the role that nutrient plays significant role in promoting vegetative growth before the start of tuberous root development as nitrogen promotes vegetative growth thereby delaying plant maturity.

Table 4. *Combined Interaction effects of FYM and N-P_2O_5 fertilizers on days to emergency, days to flowering, maturity, plant height and stem number per plant of Irish potato at Bore in 2018 and 2019*

Treatments		Yield and yield related Parameters				
NP(kg/ha)	FYM(t/ha)	DE (days)	DF (days)	DM (days)	PH (cm)	STMN (No)
0	0	12^{d}	74^{bc}	95^{ef}	55.58^{a-f}	7.33^{bc}
0	4	13.33^{bc}	71^{cd}	113^{a-e}	46.41^{fghi}	6^{bcd}
0	6	12^{d}	74.66^{bc}	104.33^{a-e}	63.33^{a}	8.33^{ab}
0	10	14^{b}	74^{bc}	103.33^{b-f}	50.91^{d-h}	6.66^{bcd}
44*49	0	14^{b}	68.33^{d}	104.66^{a-e}	52.50^{c-g}	6.66^{bcd}
44*49	4	17^{a}	68^{d}	102.33^{def}	37.66^{i}	5.66^{cd}
44*49	6	13.33^{bc}	70^{d}	86^{f}	56.83^{a-e}	7^{bcd}
44*49	10	14^{b}	74^{bc}	105^{a-e}	49.41^{efgh}	6.33^{bcd}
88*98	0	17^{a}	69^{d}	111^{a-e}	38.58^{i}	5.33^{cd}
88*98	4	12^{d}	76.33^{ab}	122.33^{a}	62.08^{ab}	7.66^{abc}
88*98	6	16^{a}	70^{d}	112.66^{a-e}	52.66^{c-g}	7^{bcd}
88*98	10	17^{a}	69.66^{d}	102.33^{def}	42^{hi}	6^{bcd}
132*147	0	12^{d}	79^{a}	119.33^{a-d}	61.08^{abc}	7.33^{bc}
132*147	4	12^{d}	75.33^{ab}	116^{a-d}	64.08^{a}	5.66^{cd}
132*147	6	12^{d}	79^{a}	116.33^{a-d}	55.33^{a-f}	8.33^{ab}
132*147	10	12^{d}	77.66^{ab}	119.33^{a-d}	54.08^{b-f}	10^{a}
176*197	0	13.33^{bc}	74.66^{bc}	108.66^{a-e}	56.16^{a-e}	7.33^{bc}
176*197	4	12^{d}	77.33^{ab}	120.66^{abc}	57.25^{a-e}	7.66^{abc}
176*197	6	12.66^{cd}	75^{b}	121.33^{ab}	59.66^{a-d}	7.66^{abc}

176*197	10	17[a]	67.33[d]	102.66[cdef]	44.08[ghi]	4.66[d]
	Mean	13.73	73.21	109.31	52.98	6.93
	LSD (5%	1.06	3.67	18.20	9.19	2.47
	CV (%)	4.7	3.03	10.09	10.51	21.63

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance. Where DE=days to emergency, DF=days to flowering, DM=days to maturity, PH=plant height, STMN=stem no per plant, T= NP rate, F= FYM rate, LSD (0.01) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent

4.3. Growth Parameters of Irish Potato

4.3.1. Plant height and Stem number of the plant

Significant variation was found in plant height at different application rates of N_2-P_2O_5 fertilizers and FYM (Table 4). Our combined Anova result showed that plant height of potato plants was significantly (P<0.05) affected by application of different inorganic N_2-P_2O_5 fertilizers and FYM rates at Bore. The highest plant height (64.33 cm and 64.08 cm) was obtained at combination rate of 0 and 6 t ha^{-1} FYM with 176*197 kg of N_2-P_2O_5 fertilizers respectively, while the lowest plant height (37.66 and 38.58 cm) was recorded at control treatment and 6 t ha^{-1} FYM with 0 kg N_2-P_2O_5 ha^{-1}. In our result the plant was benefited from inorganic fertilizers for plant height development that may be due to nutrients of FYM is not readily available. Also this might indicate that potato uses little from NP to increase its height compared to the good effect that it derived from farmyard manure.

4.3.2. Stem Number of the Plant

The results of analysis of data revealed that main effects of FYM and different NP fertilizer rates and their interactions had significant (P<0.05) effect on stem number of Irish potato plant in both years (Table 4). Our data analysis showed that maximum number of stems per plant (10) was recorded in plants planted with fertilizer rate of 132 kg N_2 + 147 kg P_2O_5 and 6 t ha^{-1} FYM, meanwhile minimum number of stem number per plant (4.66) was recorded for 0 kg N_2-P_2O_5 and 3 t ha^{-1} FYM treatment. The more is the number of stems per plant the more will be the number of tubers per plant. Number of stems per plant is also important for tuber size. Less number of stems per plant had tubers of large size and vice versa. This parameter is primarily recorded to see the impact of total sun shine received as well as spread of the root system of the plant [35].

4.4. Yield Components and Yield of Irish Potato

4.4.1. Tuber Number per Plant

The results of analysis of data revealed that main effects of planting date and different NP fertilizer rates and their interactions had significant (P<0.05) effect on tuber number of Irish potato plant. The maximum (14.77) tuber number per plant was recorded with the interaction effects of 132 kg N_2 + 147 kg P_2O_5 ha^{-1} with 6 t ha^{-1} FYM treatment and the least (8.22) tuber number per plant was recorded at rate of zero N_2-P_2O_5 fertilizers + 6 t ha^{-1} FYM, respectively. This may be due to optimum nutrient addition which enriched the soil for the uptake of macro and micro nutrients which are important for increasing tuber number. [36] Showed that organic manure such as cow dung improved the soil pH which facilitated nutrient uptake by the plant. Addition of farmyard manure in combination with N fertilizer helped in maintaining the original organic matter status of the soil thereby facilitating for better tuber set.

4.4.2. Average Tuber Weight

The analysis of variance indicated that the average tuber weight was influenced significantly (P<0.05) by the interaction effect of FYM and N_2-P_2O_5. The maximum (187 g) average tuber weight was recorded at 10 t FYM ha^{-1}+ 132 kg N_2 + 174 kg P_2O_5 ha^{-1} and the lowest yield (109 g) was recorded at control treatment. The different between each treatment may be due to the fact that since the nutrient content and the rate of nutrient release vary among organic fertilizers and the level of growth is affected either positively or negatively.

Table 5. *Combined interaction effects of FYM and N_2-P_2O_5 fertilizers on tuber number per plant, and average tuber weight, of Irish potato at Bore in 2018 and 2019*

Treatments		TNP	ATW
NP(kg/ha)	**FYM(t/ha)**	**(No)**	**(g)**
0	0	11.55[a-d]	147[bcd]
0	4	10.89[bcd]	133.33[b-e]
0	6	11.16[a-d]	139[b-e]
0	10	11[a-d]	151.67[bc]
44*49	0	9.50[cd]	149.33[bc]
44*49	4	11.66[a-d]	109[e]
44*49	6	9.89[cd]	138.33[b-e]
44*49	10	12.22[abc]	134.33[b-e]
88*98	0	8.22[d]	132.33[b-e]
88*98	4	11.16[a-d]	126.33[cde]
88*98	6	9.16[cd]	133.67[b-e]
88*98	10	9.94[bcd]	150b[c]
132*147	0	10.33[bcd]	152.67[c]
132*147	4	10.77[bcd]	140.67[bcd]
132*147	6	12.72[abc]	187[a]
132*147	10	14.77[a]	158.33[ab]
176*197	0	11.11[a-d]	137.67[b-e]
176*197	4	11.55[a-d]	156.33[abc]
176*197	6	13.78[ab]	154.67[bc]

176*197	10	11.11[a-d]	117.67[de]
Mean		11.12	142.46
LSD (5%)		3.84	30.79
CV (%)		20.92	13.09

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, T= NP rate, F= FYM rate, LSD (0.01) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent

4.4.3. Marketable Tuber Yield

The mean overall year ANOVA result demonstrated that combined application of different FYM and N_2-P_2O_5 fertilizers rate highly significantly (P<0.05) influenced Irish potato yield. The combination of 6 t FYM ha^{-1}+ 132 kg N_2 + 147 kg P_2O_5 ha^{-1} produced the highest marketable root yield (39.4 t ha^{-1}) while the lowest yield (12.55 t ha^{-1}) was from 4 t ha^{-1} FYM+0 kg P_2O_5 ha^{-1}. The highest yield at the highest rates of both FYM and N_2-P_2O_5 fertilizers rate may be due to the nutrient use efficiency of a crop increased through a combined application of organic manure and inorganic fertilizer as result of positive interaction and complementarities between them. These results are in agreement with those obtained by the studies [3] and [30] who reported that the increase in nitrogen application amounts up to a definite point, increases growth parameters including tuber but beyond that, reversely decreases them. Over-application of nitrogen may result in a decrease in yield. This may attribute to the fact that in such conditions, vegetative growth of the aerial parts can be increased and hence, prevented transferring of photosynthetically matters into the tubers. The yield difference between treatments was in line with the findings of Forbes and [36] who reported a positive interaction between organic and inorganic inputs when applied simultaneously. Integrated nutrient management implies the maintenance or adjustment of soil fertility and of plant nutrient supply to an optimum level for sustaining the desired crop productivity on one hand and to minimize nutrient losses to the environment on the other hand [34].

4.4.4. Unmarketable Tuber Yield

Combined application of FYM and N_2-P_2O_5 fertilizers had significantly ($P < 0.05$) affect unmarketable tuber yield. The highest (9.28 t ha^{-1}) unmarketable tuber yield was obtained at 3 t FYM ha^{-1}+ 176 kg N_2 + 197 kg P_2O_5 ha^{-1} whereas the lowest (3.18 t ha^{-1}) unmarketable tuber yield was recorded at control treatment at Bore, respectively (Table 6). Plants grown at minimum and over nutrient application produced high unmarketable tuber yield than plants grown at optimum rate. When increased nutrient application rate, also increased the yield of unmarketable tuber yield. This might be zero and minimum rates had high competition of plants for growth factors due to nutrient deficiency than over nutrient application which led to produce high tubers size which was high unmarketable tuber yield.

4.4.5. Total Fresh Tuber Yield

Interaction effect of different FYM and N_2-P_2O_5 fertilizers application rates had significantly ($P < 0.05$) affected total tuber yield. Maximum total tuber yield (45.98 t ha^{-1}) was obtained at 6 t FYM ha^{-1}+ 132 kg N_2 + 147 kg P_2O_5 ha^{-1} whereas the lowest (17.71 t ha^{-1}, 18.29 t ha^{-1} and 18.65 t ha^{-1}) was obtained at combined application of control treatment, 0 N_2-P_2O_5 + 4 t FYM ha^{-1} and 0 N_2-P_2O_5 + 6 t FYM ha^{-1} application rates, respectively. The production difference between the treatments may be due to the low fertility level of the experimental site which gives lowest yield at control and at treatments which are treated with low level of FYM combined with nitrogen and phosphorus due to low level of the experimental site which made the yield not consistent but when it was treated with FYM in combination with N and P, the soil became productive and enabled to give optimum yield. According to the reports of [39] soil treated with manure was found to be loose, which probably provided adequate aeration and moisture into the soil and improved soil microbial activities which resulted in higher growth and maximum root yield and above ground biomass of crops.

Table 6. *Combined Interaction effects of FYM and N-P_2O_5 fertilizers on of Irish potato at Bore in 2018 and 2019*

Treatments NP(kg/ha)	FYM(t/ha)	MY (t ha^{-1})	UMY (t ha^{-1})	TY (t ha^{-1})
0	0	23.17^{fgh}	5.90^{b-g}	29.07^{def}
0	4	20.32^{g-j}	6.08^{b-f}	26.41^{efg}
0	6	19.19^{hij}	6.68^{a-d}	25.88^{e-h}
0	10	18.72^{hij}	3.47^{fg}	22.19^{gh}
44*49	0	25.25^{efg}	8.13^{abc}	33.39^{c}
44*49	4	15.11^{jk}	3.18^{g}	18.29^{i}
44*49	6	20.86^{f-i}	4.13^{d-g}	25^{fgh}
44*49	10	24.07^{fgh}	3.89^{efg}	27.25^{efg}
88*98	0	15.03^{jk}	3.61^{fg}	18.65^{i}
88*98	4	31.05^{cd}	9.28^{a}	40.33^{ab}
88*98	6	16.79^{ijk}	3.63^{fg}	20.42^{hi}
88*98	10	15.53^{jk}	3.80^{efg}	19.33^{hi}
132*147	0	26.11^{def}	4.93^{d-g}	31.04^{cd}
132*147	4	20.24^{g-j}	5.49^{c-g}	25.73^{e-h}
132*147	6	37.12^{ab}	6.02^{b-f}	43.15^{ab}
132*147	10	39.4^{a}	6.56^{a-e}	45.98^{a}
176*197	0	21.93^{f-i}	5.91^{b-g}	27.85^{d-g}
176*197	4	32.02^{bc}	3.62^{fg}	35.64^{b}
176*197	6	30.01^{cde}	8.23^{ab}	38.24^{b}
176*197	10	12.55^{k}	5.16^{d-g}	17.71^{i}
Mean		23.51	5.71	29.21
LSD (5%)		5.49	2.73	5.68
CV (%)		14.17	29.05	11.78

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance. Where MY=Marketable yield, UMY=Unmarketable yield, TY=Total yield, T= NP rate, F= FYM rate, LSD (0.01) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent

4.4.6. Correlation Coefficient Analysis

Simple correlation coefficient values (r) computed to display the association between and within agronomic parameters of Irish potato as shown in Table 7. Days to maturity and tuber weight did not significantly correlate with an application of N_2-P_2O_5. Among the several parameters, days to emergency was strongly negatively correlated with the N_2-P_2O_5 application rates but not significantly negatively correlated with application rates of FYM indicating that as the rate of nitrogen increased, the days to emergency was decreased. Days to flowering, plant height, tuber number per hill, marketable yield and total yield of the plant had a significant positive correlation with application rates of N2-P2O5 and FYM. Similarly, unmarketable yield responded moderately negatively correlated to the rates of N2-P2O5 and farmyard manure but not significantly. The correlation analysis between total yield (t ha^{-1}) and growth characters indicated that, total yield was strongly positively correlated with mean days to flowering (r=0.451**), plant height (r=0.588**), tuber per hill (r=0.49**), marketable yield (r=0.988**) and unmarketable yield (r=0.464**). However, days to maturity and average tuber weight were weakly correlated ($r=0.15^{ns}$) and ($r=0.16^{ns}$) with the total yield respectively, but stem number per plant (r=-0.34**) was moderately positively correlated to the total yield. Days to emergency was highly and significantly negatively correlated with the total yield of Irish potato (r= -0.727**). This shows that improving any of these parameters may lead to the improvement in total yield of Irish potato. Therefore, total fresh tuber yield was significantly positively correlated with most growth; yield and yield related traits with the exception of days to emergency strongly negatively correlated with phenological traits.

Table 7. *Simple linear coefficient (r) for phenological, growth, yield and yield components of Irish potato*

	T	R	DE	DF	DM	PH	STM	TNP	TW	MKY	UMK	TYD
T	1.000	0.00^{ns}	-0.841^{**}	0.691^{**}	0.324^{ns}	0.80^{**}	0.454^{*}	0.624^{**}	0.112^{ns}	0.754^{**}	0.14^{ns}	0.728^{**}
R		1.000	-0.209^{ns}	0.406^{**}	0.192^{ns}	-0.016^{ns}	0.034^{ns}	0.33^{*}	0.24^{ns}	0.127^{ns}	-0.384^{**}	0.058^{ns}
DE			1.000	-0.758^{**}	-0.223^{ns}	-0.762^{**}	-0.504^{**}	-0.682^{**}	-0.192^{ns}	-0.788^{**}	0.069^{ns}	-0.727^{**}
DF				1.000	0.349^{**}	0.496^{**}	0.547^{**}	0.691^{**}	0.227^{ns}	0.521^{**}	-0.235^{ns}	0.451^{**}
DM					1.000	0.324^{*}	-0.045^{ns}	0.412^{**}	-0.021^{ns}	0.162^{ns}	-0.016^{ns}	0.15^{ns}
PH						1.000	0.296^{*}	0.456^{**}	0.092^{ns}	0.614^{**}	0.079^{ns}	0.588^{**}
STM							1.000	0.605^{**}	0.322^{*}	0.388^{**}	-0.157^{ns}	0.339^{**}

TNP	1.000	0.335**	0.538**	-0.093^{ns}	0.49**
TW		1.000	0.178^{ns}	-0.04^{ns}	0.161^{ns}
MKY			1.000	0.327*	0.988**
UMK				1.000	0.464**
TYD					1.000

Where T= N_2-P_2O_5, R=Farmyard manure, DE=days to emergency, DF=days to flowering, DM=days to maturity, PH=plant height, STM=stem number per plant, TNP=tuber number per hill, TW=tuber weight, MKT=marketable yield, UMK=unmarketable yield, TYD=total yield, ns=non-significant difference, * indicates significant at 5%, ** indicates significant at 1%.

4.4.7. Partial budget analysis of FYM and N_2-P_2O_5 Fertilizers Application

In this study, the costs of FYM application, transport, weeding and cost of fertilizers were varied while other costs were constant for each treatment. In order to recommend the present result for end users, it is important to estimate the minimum rate of return acceptable to farmers in the recommendation interest. Based on the economic analysis, the net benefit gained from the experiment ranged from N_2-P_2O_5 fertilizers application alone is birr 177023 to 266507 per hectare compared with non-application of nutrients which is birr 161388 per hectare (Table 8). For the FYM treatments alone net benefit ranged from birr 133290 to 164949 per hectare benefit. According to our economic analysis is an indication of the level of profitability of the inorganic fertilizers application treatments. This may be due to not readily availability of nutrients and slow release of nutrients from FYM. The highest marketable tuber yield (39.4 t ha^{-1}) was recorded at 6 t FYM ha^{-1}+ 132 kg N_2 + 147 kg P_2O_5 ha^{-1} fertilizer rates. The partial budget analysis indicated that the highest net benefit of 416843 Birr ha^{-1} was recorded at 6 t FYM ha^{-1}+ 132 kg N_2 + 147 kg P_2O_5 ha^{-1} fertilizer rates. From the above results, it was apparent that the treatment with 6 t FYM ha^{-1}+ 132 kg N_2 + 147 kg P_2O_5 ha^{-1} fertilizer rates was more profitable than other treatment combinations. Marginal rate of tuber analysis was operated on non-dominated treatments to recognize treatments with the optimum return to the farmers' effort. The marginal rate of returns, which determines the acceptability of any treatment shows that, treatment receiving 132 kg N_2 + 147 kg P_2O_5 ha^{-1} fertilizer rates in combination with 6 t ha^{-1} of FYM yielded good results of 26943.2% marginal revenue. This means that for every 1.00 birr invested for 6 t FYM ha^{-1}+ 132 kg N_2 + 147 kg P_2O_5 ha^{-1} fertilizer input and its application in the field, farmers can expect to recover the 1.00 birr and obtain an additional 269.43 birr. Therefore the most attractive rates for producers with low cost of production and higher benefits in this case were 132 kg N_2 + 147 kg P_2O_5 ha^{-1} with 6 t ha^{-1} farmyard manure combination and can be recommended for farmers in Bore area and other areas with similar agro ecological condition.

Table 8. *Cost Benefit Analysis of Irish potato*

Treatments	Adjusted yield (t ha^{-1})	Gross Benefit (Birr ha^{-1})	Total variable cost (Birr ha^{-1})	Net Benefit(Birr ha^{-1})	Dominance Analysis	MRR
T1F1	15.11	13.60	1800	161388	ND	0
T1F2	12.55	11.30	2250	133290	D	0.00
T1F3	15.03	13.53	2625	159699	D	7042.40
T1F4	15.53	13.98	2775	164949	ND	3500.00
T2F1	16.79	15.11	4309	177023	ND	787.09
T2F2	18.72	16.85	4534	197642	ND	9164.00
T2F3	20.32	18.29	4909	214547	ND	4508.00
T2F4	24.07	21.66	5059	254797	ND	**16100.00**
T3F1	25.25	22.73	6193	266507	ND	1132.50
T3F2	20.86	18.77	6418	218870	D	D
T3F3	23.17	20.85	6793	243443	D	D
T3F4	32.02	28.82	7943	338873	ND	8298.26
T4F1	21.93	19.74	8077	228767	D	D
T4F2	30.01	27.01	8302	315806	D	D
T4F3	39.4	35.46	8677	416843	ND	**26943.20**
T4F4	37.12	33.41	8827	392069	D	D
T5F1	19.19	17.27	9999	197253	D	D
T5F2	31.05	27.95	10224	325116	D	D
T5F3	20.24	18.22	10599	207993	D	D
T5F4	26.11	23.50	10749	271239	D	D

Where, t=tone, ha=hectare and MRR= marginal rate of return, ND= non-dominant, D=dominance

5. Conclusions and Recommendation

The experiments confirmed that adequate application of nitrogen and phosphorus increases the production of potato as described by [38]. Besides, application of organic fertilizer integrated with mineral fertilizer decreases the cost of production due to the continuous increase in the prices of mineral fertilization. Many reports in the literature have showed that continuous use of sole artificial fertilizer nutrient sources may lead to shortage of nutrients not supplied by the chemical fertilizers which will in turn lead to chemical soil degradation [22]. On the other hand, sole application of organic matter is constrained by low availability of N to the current crop, low or imbalanced nutrient content, unfavorable quality and high labor demands for transporting bulky materials. The objective of the study was to assess the effects of combined application of FYM and N_2-P_2O_5 fertilizer on yield related and tuber yield of potato and to identify economically feasible rates of FYM and N_2-P_2O_5 fertilizer rates for sweet potato production in the study area. The experiment was arranged in factorial combination of four level of farmyard manure (0, 3, 6 and 10 tons ha^{-1}) with five level of Urea (0, 44, 88, 132 and 176 kg ha^{-1}) and NPS (0, 49, 98, 147 and 197 kg ha^{-1}) in combination. The experiment was laid out in RCBD with 3 replications. Applied FYM and N_2-P_2O_5 fertilizer levels revealed significant differences ($P<0.05$) on days to emergency, days to flowering, days to maturity, plant height, number of stem numbers, average tuber weight, tuber number per hill, marketable, unmarketable and total yield. Combined application of FYM and N_2-P_2O_5 fertilizers had significantly ($P < 0.05$) affect unmarketable tuber yield. The highest (9.28 t ha^{-1}) unmarketable tuber yield was obtained at 3 t FYM ha^{-1}+ 176 kg N_2 + 197 kg P_2O_5 ha^{-1} whereas the lowest (3.18 t ha^{-1}) unmarketable tuber yield was recorded at control treatment at Bore over years, respectively. Generally the maximum total tuber yield (45.98 t ha^{-1}) was obtained at 6 t FYM ha^{-1}+ 132 kg N_2 + 147 kg P_2O_5 ha^{-1} whereas the lowest (17.71 t ha^{-1}, 18.29 t ha^{-1} and 18.65 t ha^{-1}) was obtained at combined application of control treatment, 0 N_2-P_2O_5 + 4 t FYM ha^{-1} and 0 N_2-P_2O_5 + 6 t FYM ha^{-1} application rates, respectively. Based on partial budget analysis the highest net benefit 416843 Birr ha^{-1} was obtained from treatment combinations of 6 t FYM ha^{-1}+ 132 kg N_2 + 147 kg P_2O_5 ha^{-1} with a marginal rate of return of 26943.2 %. Therefore the most attractive rates for the producers with low cost of production and higher benefits in this case were treatment combination 6 t FYM ha^{-1}+ 132 kg N_2 + 147 kg P_2O_5 ha^{-1}. More importantly farmers in the study areas should be motivated to use integrated nutrient management system rather than inorganic fertilizer alone because of the system helps in maintenance or adjustment of soil fertility and of plant nutrient supply to an optimum level for sustaining the desired crop productivity on one hand and to minimize nutrient losses to the environment on the other hand.

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Conflict of Interest

All the authors do not have any possible conflicts of interest.

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