International Journal of Agricultural Economics
2016; 1(3): 71-77
http://www.sciencepublishinggroup.com/j/ijae
doi: 10.11648/j.ijae.20160103.14

Effects of Nitrogen and Phosphorus Fertilizer Levels on Yield and Yield Components of Irish Potato (*Solanum tuberosum*) at Bule Hora District, Eastern Guji Zone, Southern Ethiopia

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To cite this article:
Desalegn Regassa, Wakene Tigre, Dawit Mellise, Tolessa Taye. Effects of Nitrogen and Phosphorus Fertilizer Levels on Yield and Yield Components of Irish Potato *(Solanum tuberosum*) at Bule Hora District, Eastern Guji Zone, Southern Ethiopia. *International Journal of Agricultural Economics*. Vol. 1, No. 3, 2016, pp. 71-77. doi: 10.11648/j.ijae.20160103.14

Received: July 26, 2015; **Accepted**: August 12, 2016; **Published**: September 2, 2016

Abstract: This fertilizer experiment was undertaken at Bule hora district, Eastern Guji zone, southern Ethiopia in 2016. The objective of the experiment was to study the effect of different NP rates on the yield and yield components of Irish potato to determine biological and economic optimum NP rate at the area. Adapted and recommended variety of Irish potato variety (Gudane) was used for the experiment under rainfall. The treatment consisted of combination of five levels of N (0, 50, 80, 110 and 140 kg N.ha^{-1}) and four levels of P (0, 45, 90 and 135 kg P ha^{-1}). Data were collected on parameters like plant height, number of branch per hill, tuber weight, marketable yield per hectare, unmarketable yield per hectare and total yield per hectare. ANOVA and Partial budget analysis were used to determine biological and economic optimum NP rate. Tuber yield was significantly affected by both P and N levels. There was also a significant N and P interaction effect on tuber yield. The maximum total tuber yield (195.06qt ha^{-1}) was obtained when 50 kg N ha^{-1} and 135 Kg P ha^{-1} were combined, and it was closely followed by 193.21 qt ha^{-1} obtained at 110-90 kg ha^{-1} NP combinations, resulting in grain yield benefit of 361 and 358% over the control, respectively. Almost all collected parameters were significantly affected by P rate but did not respond to N rate. This could be due to substantial amount of total N in the soil (0.61%) which was in the high range. As to partial budget analysis, treatment 110-90 kg ha^{-1} NP combination had highest net benefit and acceptable marginal rate of return (473.67%). Based on this experiment, 110-90Kg ha^{-1} NP combination was found profitable and recommended for Irish potato farmers of Bule hora district and similar areas.

Keywords: Irish Potato, Fertilizer, Yield, Yield Component

1. Introduction

Potato (*Solanum tuberesum* L.) is native to South America near the present border of Peru and Bolivia, not Ireland[1] and [2]. It is named after Ireland because it is closely associated with the Irish potato famine, a historical famine caused by a mold infestation of the Irish potato crop [3]. It belongs to the family Solanaceae and genus solanum [4]. It has been introduced to Ethiopia in 1859 by German Botanist, called Schimper [5].

It is one of the most important food crops in the World. Among the root and tuber crops, potato ranks top followed by cassava, sweet potatoes and yam in order [6]. It ranks fourth in terms of volume of production after maize, rice and wheat and 3rd in terms of human consumption after rice and wheat [7]. In Ethiopia, it is one of the most widely grown root and tuber crops and stands second next to inset in area of coverage. It is very important food and cash crop in the country especially when the grains get depleted from the store and contributes to food security [8]. Potato production has been considered as the first priority compared to other food crops because of its contribution to food security, income generation and double cropping advantages and its utilization in different forms [9].

The national (9.9t/ha) productivity of potato during 2014 season [10] is very low as compared with world average of 17.16 t/ha [7]. A number of production problems that accounts for low national yield have been identified. The major ones are lack of improved and adapted varieties, low soil fertility and poor agronomic practices. In Bule hora district Irish potato is a staple food for large number of people. There was no research conducted concerning fertilizers and others in the area on Irish potato. As a result of this fact the farmers depend on traditional practices and local cultivars. Most of the farmers in the area do not use fertilizer and few others use very much below the recommended rate. Therefore, there is a need to study the effect of different NP rates on the yield and yield components of Irish potato to determine biological and economic optimum NP rate at the area.

2. Materials and Methods

2.1. Description of Study Area

The experiment was conducted in Bule hora district, eastern Guji zone, southern Ethiopia under rain fed condition in the year 2015. The site is located at N05.75879and E038.28458with altitude of 2321 m.a.s.l. The soil at the site is characterized as sandy loam with pH of 5.11 (Table A1). It is located at 446 km along Addis Ababa-Moyale main road. Monthly total rainfall, average maximum and minimum temperature of the area in the experimental year was indicated in Table A1.

2.2. Planting Materials and Experiment Methodology

Adapted and recommended variety of Irish potato called Gudane was used for the experiment under rainfall. The treatment consisted of combination of five levels of N (0, 50, 80, 110 and 140 kg N.ha-1) and four levels of P (0, 45, 90 and 135 kg P ha-1). The twenty treatment combinations were randomly replicated three times in factorial RCB Design. Nitrogen was applied in the form of urea, while P was applied in the form of triple supper phosphate (TSP). Nitrogen was applied in split, half during sowing and half during flowering stage. There were a total of 20x3=60 plots each measuring 4.2 m x 1.8 m (7.56m^2). Six rows and six plants per row with 70cm between rows and 30cm between plants and spacing of 2 m between blocks and 1 m between plots were used for this experiment. No serious diseases were observed during this experiment.

2.3. Data Collection and Statistical Analysis

Data were collected on parameters like Plant height (cm), number of branches per hill, tuber weight (g), marketable yield per hectare (qt), Unmarketable yield per hectare (qt) and Total yield per hectare. Unhealthy and tubers with a weight of less than 25gram were recorded as unmarketable.

Analysis of variance for the collected parameterswas performed as per the methods described by[12] using SAS computer software[13] for randomized complete block designand treatment mean comparison is done by Fisher's list significance difference (LSD) at 5%.

Simple partial budget analysis was employed for economic analysis of fertilizer application. It was carried out for combined tuber yield data. To estimate the total costs, mean market prices of Urea and TSP were taken from market assessment at the time of planting and market price of potato tubers was taken after harvest. The economic analysis was based on the formula developed by [14].

3. Results and Discussion

3.1. Pre Planting Soil Analysis

Pre planting soil analysis result indicated that texture of the soil is sandy loam. pH of the soil was 5.11 (slightly acidic) (). Other soil chemical properties were: organic matter (OM) content 12.23%, total N 0.61%, available P 1.98 ppm and CEC 38 meq/100g soil (Table A1).

3.2. ANOVA for Yield and Yield Components

Tuber yield was significantly affected by both P and N levels. There was also a significant N and P interaction effect on tuber yield (Table 1). The maximum total tuber yield (195.06 qt ha^{-1}) was obtained when 50 kg N ha^{-1} and 135 Kg P ha^{-1} were combined, and it was closely followed by 193.21 qt ha^{-1} obtained at 110-90 Kg ha^{-1} NP combinations, resulting in grain yield benefit of 361 and 358% over the control, respectively. The NP combination 50-135 Kg ha^{-1} was not significantly different from 110-90, 140-90, 110-135, 80-90, 80-135 and 50-45 Kg ha^{-1} NP combinations. But it was significantly different from all other combinations (Table 3). The maximum marketable yield was obtained at 110-90 NP combination. In the absence of P fertilizers, there was a decreasing trend in tuber yield with the increase of N application rates (Fig. 2). At 90kgha^{-1} P application, there was a more or less constant rate of tuber yield increment with the increase in N application rates. However, for the remaining three P levels (45 and 135 Kg ha^{-1}) there was a curvilinear response showing an initial increase in grain yield up to N levels of 90 Kg ha^{-1} and declining afterwards. This result is in line with the finding of [15] and [16] who reported that application of nitrogen and phosphorus increased the total tuber yield. Normally N facilitates uptake of P. But, at higher N rates availability of P might be affected due to decrease in pH. From soil analysis, available P was decreased with increasing N rates even though it was statistically non significant (Table 4).

Plant height was not significantly affected by different N rates whereas P application significantly affected plant height (Table 1). Application of P increased plant height (Table 2). The shortest plant height of 45.65cm was recorded at 0 Kg ha^{-1} application of P and the longest height of 64.11cm was recorded at 90 Kg ha^{-1} P rate application. Literature also indicates that phosphorus deficiency is usually expressed as stunted growth [15].

Number of branches per hill significantly responded to P, but was not significantly affected by N and NP interaction (Table 1). Highest number of branch per hill was recorded at P level of 90 Kg ha^{-1} which was not statistically different from P level of 135 Kg ha^{-1} (Table 2). Number of branches per hill at P rates of 90 and 135 Kg ha^{-1} were significantly superior to number of tillers at 45 and 0 Kg ha^{-1} (Table 2). According to this experiment N did not significantly affect all yield related traits except total yield.

Similar to number of branches per hill, number of tubers per hill was also highly significantly affected by P rate, but did not respond to N rate. This could be due to substantial amount of total N in the soil (0.61%) which was in the high range. The highest number of tubers per hill of 9.6 was observed at 90 kg ha^{-1}P application rate which was not statistically different from the highest P rate (135 kg ha^{-1}) where as the lowest of 5.92 was observed at 0 kg ha^{-1} P application (table 2).

Tuber weight was significantly increased by P application rate but not significantly affected by N rate. There was also significant N and P interaction effect on tuber weight (table 1 and 2). The maximum tuber weight (63.58 g) was obtained, when 50 kg N ha^{-1} and 135 Kg P ha^{-1} were combined, and it was followed by 47.92 g obtained at 110-135Kg ha^{-1} NP combinations. NP combination of 50-135 Kg ha^{-1} was not significantly different from 110-135 Kg ha^{-1} NP combination but it was significantly different from all other combinations. In the absence of P fertilizer and 45 kg ha^{-1} P rate, there was a curvilinear decrement in average tuber weight with the increase of N application rates. At 90 kg ha^{-1} rate, there was a more or less constant rate of tuber weight increment with the increase of N application rates (Fig. 1).

3.3. After Harvest Soil Analysis

From soil analysis after harvest of each treatment, the amount of total N was lower than total N of the pre-sowing soil analysis at all N treatment rates (Table 4 and Table A1). This was attributed to uptake of N by plants and loss of N by leaching. The amount of total N did not show much variation with increasing P levels. Available P in the soil also didn't show a significant variation with increasing N rates (Table 4). Other soil chemical properties such as pH, OM, CEC and BSP were also tested. CEC significantly increased at higher N rates (Table 4). Others did not show significant variation with application of either N or P.

3.4. Economic Analysis

As indicated in Table 5, except treatments of NP combinations of 0-0, 0-90, 50-45, 80-90, 50-135 and 110-90 Kg $ha^{-1,}$ all the other treatments were dominated. This is because the net benefit that was obtained from these treatments was lower than the net benefit obtained from the treatments with lower variable cost. This implies that, there was no proportional increment in the net benefit with increase in variable cost. These treatments were eliminated from calculating MRR. As a result, only MRR of the six non dominated treatments were calculated (Table 6.)

Marginal rate of return which is the change in net benefit divided by the change in variable cost evaluates the extent of increase in benefit by increasing variable cost from one treatment to the other.

The shift from 50-135 Kg ha^{-1} to 110-90 Kg ha^{-1} NP combinations gave MRR of 473.67% well above 100% which is the minimum accepted value of MRR for farmers [14]. Beyond 110-90 Kg ha^{-1} NP combinations, treatments did not give MRR greater than 100% because of increased cost. Therefore, treatment 110-90 Kg ha^{-1} NP combination had highest net benefit and acceptable marginal rate of return (473.67%). Hence, the NP combination of 110-90 Kg ha^{-1} was profitable and can be recommended for farmers in the area.

4. Conclusion

The experiment was conducted in Bule hora district, Eastern Guji zone, southern Ethiopia under rain fed condition in the year 2015 to study the effect of different NP rates on the yield and yield components of Irish potato to determine biological and economic optimum NP rate at the area. Data were collected on parameters like Plant height (cm), number of branch per hill, tuber weight (g), Marketable yield per hectare (qt), Unmarketable yield per hectare (qt) and Total yield per hectare. Analysis of variance for the collected parameters and Simple partial budget analysis was employed for economic analysis of fertilizer application.

Tuber yield was significantly affected by both P and N levels. There was also a significant N and P interaction effect on tuber weight. The maximum total tuber yield (195.06qtha^{-1}) was obtained when 50 kg N ha^{-1} and 135 Kg P ha^{-1} were combined, and it was closely followed by 193.21 qtha^{-1} obtained at 110-90 Kg ha^{-1} NP combinations, resulting in grain yield benefit of 361and 358% over the control, respectively. Almost all collected parameters were significantly affected by P rate but did not respond to N rate. This could be due to substantial amount of total N in the soil (0.61%) which was in the high range.

As to partial budget analysis, treatment 110-90 Kg ha^{-1} NP combination had highest net benefit and acceptable marginal rate of return (473.67%). Based on this experiment, 110 - 90Kg ha^{-1} NP combination was found profitable and recommended for Irish potato farmers of Bule hora district and similar areas.

Table 1. *Mean square of Irish potato fertilizer trial at Gerba in 2015 cropping season.*

Source of variation	Df	PH	ANBPH	ANTPH	ATW	MYH	UMYH	TYH
Replication	2	289.97ns	1.18ns	17.92**	263.29ns	3913.60ns	291.85*	4154.73ns
Phosphorus (P)	3	1140.22***	1.17ns	37.24***	2593.63***	42208.33***	671.67***	51838.47***
Nitrogen (N)	4	87.69ns	1.94ns	5.75nS	247.73ns	3185.84ns	22.93ns	3550.60*
(N*P)	9	114.40ns	1.91ns	5.18ns	220.67*	2782.55*	82.64ns	3354.90*
Error	32	125.01	1.79	3.03	105.54	1313.39	70.14	1418.52

Ns =Non significant. *, **, *** indicate significance level at probability level of 5%, 1% and 0.1% respectively; Df=degree of freedom; PH=Plant height (cm); ANBPH= Average number of branch per hill; ATW= Average tuber weight (g); MYH=Marketable yield per hectare (qt); UNMY=Unmarketable yield per hectare (qt); TYH= Total yield per hectare (qt); qt=quintal, which is 100kg

Table 2. *Mean values of Irish potato (Gudane) fertilizer trial as affected by N and P atGerba in 2015.*

	PH	ANBPH	ANTPH	ATW	MYH	UMYH	TYH
N kg/ha							
0	55.93	4.18	7.23	27.59	63.09	20.45	83.53b
50	60.07	4.98	7.85	39.06	97.69	22.92	120.60a
80	60.95	4.40	9.00	30.74	102.47	22.92	125.38a
110	55.85	4.50	7.67	32.49	97.30	20.29	117.59a
140	55.13	5.13	8.45	28.55	80.79	20.45	101.24ab
LSD 5%	ns	ns	ns	ns	ns	ns	31.13
P kg/ha							
0	45.65b	4.95c	5.92c	14.86c	22.28c	11.42b	33.70c
45	56.52a	4.53b	7.89b	27.89b	68.33b	24.45a	92.78b
90	64.11a	4.77a	9.60a	39.91a	131.54a	24.07a	155.62a
135	64.07a	4.31ab	8.75a	44.08a	130.90a	25.68a	156.58a
LSD 5%	8.26	ns	1.29	7.59	26.79	6.19	27.84
CV	19.42	28.82	21.64	32.42	41.06	39.13	34.34

Df=degree of freedom; PH=Plant height (cm); ANBPH= Average number of branch per hill; ATW= Average tuber weight (g); MYH=Marketable yield per hectare (qt); UNMY=Unmarketable yield per hectare (qt); TYH= Total yield per hectare (qt); NS=Non significant; Means in the column with the same letter are not significantly different.

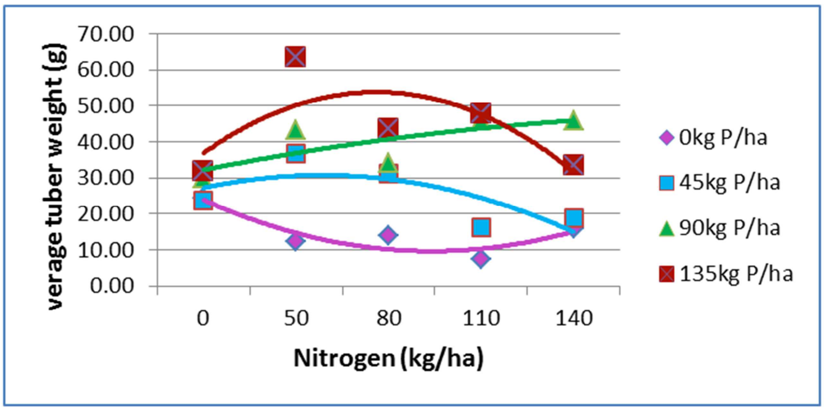


Fig. 1. *Average Tuber Weight (g) as affected by the interaction effect of N and P rates.*

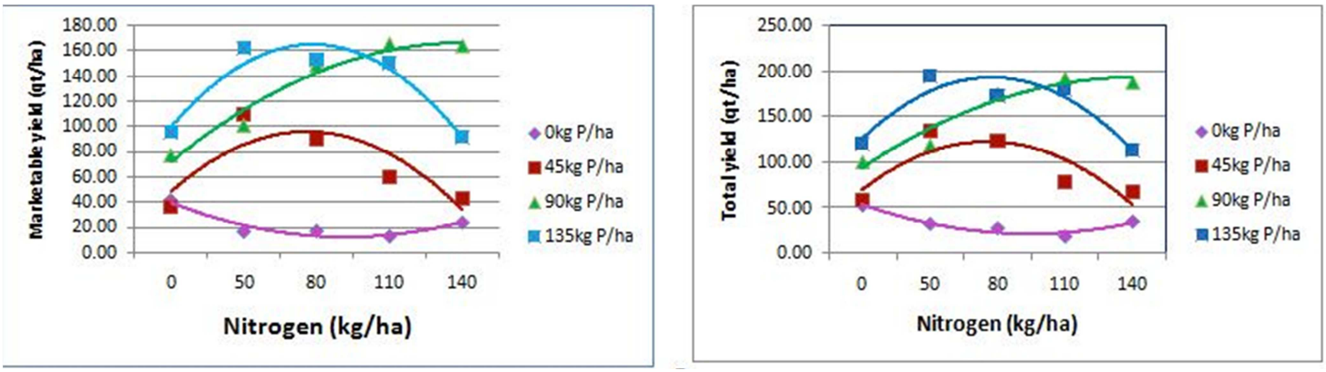


Fig. 2. *Marketable yield (right), Total yield (left) as affected by the interaction effect of N and P rates.*

Table 3. *Mean values of Total yield (qtha^{-1}) as affected by the interaction effect of N and P rates.*

	P kg/ha				
N kg/ha	**0**	**45**	**90**	**135**	**Mean**
0	54.01	58.64	100.92	120.56	83.53
50	32.72	135.19	119.44	195.06	120.60
80	27.78	124.07	175.92	173.76	125.38
110	18.52	78.71	193.21	179.94	117.59
140	35.50	67.28	188.58	113.58	101.24
Mean	33.70	92.78	155.61	156.58	
LSD (P<0.05)	62.25				

Table 4. *Effects of applied N and P levels on total N, available P, available K+, PH, OM (%), CEC contents of the soil of Irish potato fertilizer trial at Gerba in 2015.*

Treatments	Total N (%)	Available P (ppm)	Available k+ (mg/kg soil)	pH	OM (%)	CEC	BSP
N Kg ha^{-1}							
0	0.43	3.04	1.56	4.58	8.55	25.14b	58.03
45	0.42	5.13	1.93	4.58	8.48	30.49a	64.42
90	0.49	2.15	2.26	4.69	9.88	32.07a	68.98
135	0.5	5.06	2.69	4.67	9.92	30.00a	58.72
LSD (5%)	ns	ns	ns	ns	ns	3.08	ns
P Kg ha^{-1}							
0	0.37	4.17	2.29	4.77	7.45	23.33	62.63
50	0.46	6.22	2.05	4.63	9.15	28.98	59.2
80	0.4	3.89	1.95	4.62	8.07	29.78	63.4
110	0.52	2.79	1.77	4.54	10.5	29.62	61.78
180	0.47	2.2	2.49	4.68	9.39	28.98	64.63
LSD (5%)	ns	ns	ns	ns	ns	ns	ns
CV (%)	15.42	61.27	52.39	2.3	15.41	6.77	14.95

Table 5. *Cost benefit analysis of each treatments in partial budget analysis.*

N-P Kg ha^{-1}	Average yield (qt ha^{-1})	Adjusted yield (qt ha^{-1})	Variable cost (birr)	Gross field benefit (birr)	Net benefit (birr)
0-0	41.67	37.50	0.00	30000.02	30000.02
0-45	37.04	33.34	1477.17	26668.80	25191.63^{d}
50-0	16.36	14.72	1521.74	11779.20	10257.46^{d}
80-0	16.97	15.28	2434.78	12220.78	9785.99^{d}
0-90	77.78	70.00	2954.35	55999.22	53044.88
50-45	110.18	99.16	2998.91	79329.60	76330.69
110-0	12.66	11.39	3347.83	9112.82	5765.00^{d}
80-45	90.12	81.11	3911.96	64888.78	60976.82^{d}
140-0	23.76	21.39	4260.87	17109.58	12848.71^{d}
0-135	95.87	86.28	4431.52	69024.02	64592.50^{d}
50-90	101.54	91.39	4476.09	73108.80	68632.71^{d}
110-45	60.49	54.44	4825.00	43555.18	38730.18^{d}
80-90	149.07	134.16	5389.13	107330.40	101941.27
140-45	43.83	39.45	5738.04	31557.60	25819.56^{d}
50-135	162.65	146.39	5953.26	117108.00	111154.74
110-90	165.43	148.89	6302.17	119109.60	112807.43
80-135	153.71	138.34	6866.30	110671.20	103804.90^{d}
140-90	163.89	147.50	7215.22	118000.80	110785.58^{d}
110-135	150.62	135.56	7779.35	108446.40	100667.05^{d}
140-135	91.67	82.50	8692.39	66000.02	57307.63^{d}

Note: Price of UREA=1400 birr t^{-1}, price of TSP= 1510 birr t^{-1}, field price of potato = 800 birr qt^{-1}, d=dominated.

Table 6. *Marginal rate of return of the non-dominated treatments.*

N-P Kg ha^{-1}	Adjusted yield (qt ha^{-1})	Variable cost (birr)	Marginal cost (birr)	Gross field benefit (birr)	Net benefit (birr)	Marginal benefit (birr)	Marginal rate of return (%)
0-0	37.50	0.00		30000.02	30000.02		
0-90	70.00	2954.35	2954.35	55999.22	53044.88	23044.85	780.03
50-45	99.16	2998.91	44.57	79329.60	76330.69	23285.81	52251.09
80-90	134.16	5389.13	2390.22	107330.40	101941.27	25610.58	1071.48
50-135	146.39	5953.26	564.13	117108.00	111154.74	9213.47	1633.22
110-90	148.89	6302.17	348.91	119109.60	112807.43	1652.69	473.67

Acknowledgements

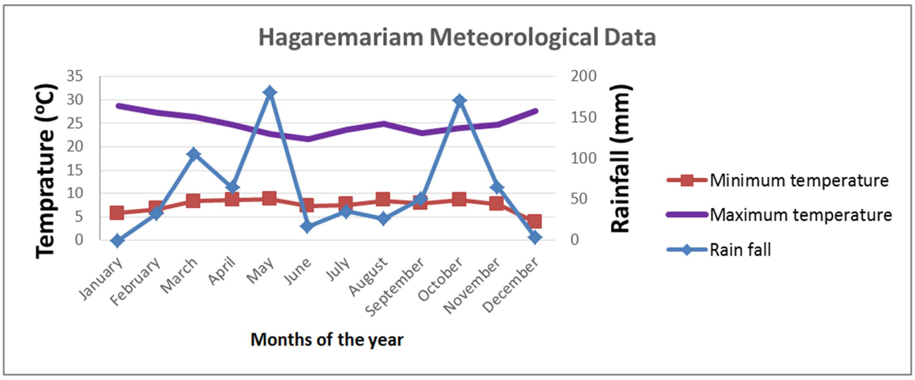
We thank Oromia Agricultural Research Institute for providing research fund. Science publishing group teams also deserve special appreciation and sincere thanks for their unconditional assistance in editing and finalizing the paper from draft.

Appendix

Table A1. *Soil physical and chemical properties of the experimental site (Gerba) before planting in 2015 sampled from top 30cm depth.*

Properties	Value
Chemical properties	
CEC (meq/100g soil)	38
PH	5.11
Organic matter (%)	12.229
Organic carbon (%)	7.02
Total nitrogen (%)	0.605
Available phosphorus (ppm)	1.98
EC(mmhos/cm at 25ºC)	0.099
Physical properties (%)	
Sand	74
Silt	12
Clay	14
Texture class	Sandy loam

EC= electro conductivity; CEC= CationExchangable Capacity; PH: in water suspension with soil to water ratio 1:2.5 by PH meter; EC: in water suspension with soil to water ratio 1:2.5 by electro Conductivity meter, % OC: Walkey& Black method; Available phosphorusby Olsen etal., 1954; Textureby Hydometer; CEC= CationExchangable Capacity by Ammonium Acatate (1 M NH4OAC).



Source: National Meteorology Agency

Fig. A1. *Monthly total rainfall (mm), average maximum and minimum temperature (°C) of Hagaremariam in 2015. Metrology station 24 Km far from experimental site.*

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