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Effect of Combined Application of Cattle Manure, Mineral Nitrogen and Phosphorus Fertilizer on Soil Physico-Chemical Characteristics and Tuber Yield of Potato (Solanum Tuberosum L.) In Masha District, South-Western Ethiopia

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Abstract

Soil fertility depletion due to soil erosion and nutrient leaching caused by heavy and continuous rainfall is one of the major causes for declining of soil productivity and crop yields in Masha district of south-western Ethiopia. Soil Hence, a field experiment was conducted in Belg and Meher seasons at Abelo area, Masha district, south-western Ethiopia, to determine the effect of combined application of cattle manure (CM) with inorganic nitrogen (N) and phosphorus (P) on potato tuber yield, and selected soil physico-chemical characteristics. The treatments comprised of combinations of three rates (2.5,5, 7.5 t ha^{-1}) of CM with 25%, 50% and 75% of recommended rates of mineral NP, respectively. In addition, 100% recommended rate of mineral NP (165kg N ha^{-1} and 137kg P_2O_5 ha^{-1}) and zero rates were used for comparison. The experiment was laid out in a randomized complete block design with three replications. The results revealed that applying 7.5 t ha^{-1} CM combined with 75% mineral NP gave significantly highest potato total tuber yield of (40 and 34 t ha^{-1}), the same rate increased tuber yield by 55.9% and 43.45% in Belg and by 51.19%, and 36.64% in Meher over the control and the application of 100% recommended rate of NP fertilizers, respectively soil pH (5.15 and 4.94), Organic carbon (21.1 and 12.7 g kg^{-1}), total N (1.71 and 1.51 g kg^{-1}), available P (7.55 and 6.27 mg kg^{-1}), CEC (22.04 and 23.96cmol (+) kg^{-1}), exchangeable Ca^{+2} (8.36 and 8.28cmol (+) kg^{-1}), exchangeable Mg^{+2} (3.14 and 2.06cmol (+) kg^{-1}), total porosity (51.1 and 54.97%) more over the treatment decreases exchangble acidity (2.32 and 2.08cmol+kg^{-1}) and exchangeable aluminum (1.46 and 1.41cmol (+) kg^{-1}), bulk density (1.07 and 1.30g cm^{-3}) in Belg and Meher seasons, respectively. Therefore, it can be concluded that the use of combined application of 7.5 t of ha^{-1} CM together with 75% of recommended rates of inorganic N (123.75kg N ha^{-1}) and P (103.05kg P_2O_5 ha^{-1}). can significantly increase potato tuber yield and improve the soil properties and reduces soil acidity.

Keywords: Cattle Manure; Physico-Chemical Properties; Nitrogen; Phosphorus; Tuber Yield

Introduction

Land degradation is a serious and widespread problem for agricultural development and food security in developing countries Adejumo [1] Dell'Angelo [2] The wearing a way of soil in Ethiopian high land is quite pronounced with the average annual soil erosion rate nationwide was estimated at 12 tons ha^{-1}, giving total annual soil loss of 1493 million tons EPA [3]. As a result, most of the Ethiopian soils, particularly within the highlands, are low in nutrient content due to erosion, leaching and absence of nutrient utilization Zeleke [4]. The major causes of land degradation in Ethiopia high-land area are natural and anthropogenic factors such as rapid population growth, deforestation, overgrazing, low vegetative cover and unbalanced crop and livestock production. limited recycling of dung and crop residues to the soil, limited application of external sources of plant nutrients, resulting in low nutrient content Temesgen [5]. Potato (Solanumtuberosum L.) is one of the most important tuber crops in the world. It's tuber consists of mainly carbohydrates, proteins, and lipids. The tuber is used locally alone or together with meat, vegetable and a substituent with a pulse in stew preparation in Sheka Zone, south-western Ethiopia Isreal [6]. It is a preferable crop in the study area due to that it can be produced more than twice per year. In

Masha District, south-western Ethiopia, the potato is one of the major and widely cultivated tuber crops covering an area of 15% of arable land (3255ha) with the total production of 24447 t and productivity of 7.52 t ha^{-1} in 2014/15 cropping season SZARDO [7], which is far below the average national yield of 13.5tha^{-1} CSA [8].

It is one of the heavy feeders of root and tuber crop requiring relatively large quantities of fertilizers. However, leaching of nutrients due to heavy and continuous rainfall, soil acidity, low nutrient reserves in arable soils and poor crop residue management by potato growers, are the major factors contributing to low soil fertility and low yield of potato in the study area. In addition to the high cost, continuous use of mineral fertilizer is leading to declining soil chemical physical and, biological properties and thus, negatively affecting overall total soil health Mahajan [9]; Compaore [10]; Bayu and Gebeyehu [11]., nutrients supplied exclusively through chemical sources, lead to unsustainable productivity over the years Mahajan [9], Fekadu [12]. Thus, the undesirable impacts of chemical fertilizers, coupled with their high cost, have prompted the interest in the use of organic fertilizers as a source of nutrients. The combined application of organic together with inorganic fertilizers has been reported to improve crop growth by supplying plant nutrients including micro-nutrients as well as improving soil physical, chemical, and biological properties thereby provide a better environment for root growth by improving the soil structure Dejene and Lemlem [13]: Kang [14]. Major inputs of soil nutrients like the addition of mineral fertilizers, organic sources, and, biological nitrogen fixation are less than major outputs such as harvested products, crop residue removal, leaching, gaseous losses, and soil erosion. This shows a net loss of soil fertility or imbalance between the inputs and the outputs as reported by Lesschen [15] this is also true In Masha district, south-western Ethiopia and encourages the application of organic sources and mineral nitrogen and phosphorus to correct balances of nutrient inputs and outputs.

The combined application of organic and inorganic fertilizers can improve soil health and nutrients supply for plant growth and subsequently would be resulted in economic profitability. Many research findings showed that neither inorganic fertilizers nor organic sources alone can result in the sustainable productivity Yadav [16]: Fekadu [12]. Furthermore, the price of inorganic fertilizers is increasing and becoming unaffordable for resource-poor smallholder farmers. The best remedy for soil fertility management is, therefore, a combination of both inorganic and organic fertilizers, where the inorganic fertilizer provides readily available nutrients and the organic fertilizer mainly increases soil organic matter and improves soil structure and buffering capacity Yadav [17]. The combined application of inorganic and organic fertilizers, usually termed as integrated nutrient management, is widely recognized as a way of increasing crop yields through sustainable soil health and productivity Mahajan [9]; Kang [14]). Several researchers e.g. Mahajan [9], Getachew [18]; Gafar [19] Agegnehu and Amede [20] verified the beneficial effect of integrated nutrient management in moderating the deficiency of a number of macro- and micro-nutrients.

In view of this fact, identifying the optimum dose of integrated organic and inorganic fertilizers is crucial and is required to supply sufficient amount of nutrients for increased crop yields. Daniel and Nigussie [21] reported high tuber yield of potato (29.59 t ha^{-1}) when cattle manure at the rate of 10tha^{-1} was combined with inorganic nitrogen at 111kg Nha^{-1} and phosphorus at 90 kg P_2O_5 ha^{-1} on Nitosols. Similarly, Shiferaw [22] reported the highest mean potato tuber yield (41.88 t ha^{-1}) with combined application of 15t ha^{-1}cattle manure with the application of 100% recommended rate of NP (100kg ha^{-1}), which increased tuber yield by 393.9%, over control. Likewise, Biruk [23] obtained the highest potato tuber yield (38.68 t ha^{-1}) by application of 30 t $ha^{-1}$of cattle manure along with nitrogen at 120kg N ha^{-1} and phosphorus at 92 kg $P_2O_5ha^{-1}$. Thus, the integrated nutrient management involving judicious use of combined organic and inorganic fertilizer sources is a feasible and productive approach to overcome soil fertility constraints Efthimiadou [24].

However, research on integrated nutrient management for potato production has not yet been conducted at Abelo area, Masha district of Sheka Zone, south-western Ethiopia where soil fertility depletion is very severed. In order to address the key issue of soil fertility depletion attributed and reduction of potato yields the study area, different rates of cattle manure and mineral NP was conducted in Belg and Meher seasons. The objective of the study was to determine effects of combined application of CM with inorganic NP fertilizers on selected soil physico-chemical properties and potato tuber yield and subsequently to improve soil fertility and crop productivity of the study area.

Materials and Methods

Description of the Study Site

The experimental site lies between 7º.44'17.6"- 7º.44' 20.1" N latitude, 35º.29'18"- 35º.29'41.9" E longitude and located at an elevation of 2205 m.a.s.l. The total area of the sites 5603m^2 (0.56 ha), which is found in Abelo area, Masha District of Sheka Zone in South-west Ethiopia (Figure 1). Abelo area is a well-known area of high potential for root and tuber crops production including potato in Masha District (Figure 1). The rainfall pattern of the site is characterized by monomodal distribution with the relatively small rainy season in Belg (February -May) and main rainy season's Meher (June -October). The total rainfall was 633 and 1153mm in 2016 Belg and Meher cropping seasons, respectively. The maximum temperature of 2016 Belg season varied from 24.98 °C (February) to 24.62 (May) and 24.74 (June) to 26.19 °C (October) and mean maximum temperature of 25.05 and 25.56 °C in Belg and Meher seasons, respectively. The minimum temperature varied between 16.01°C (February) to 13.9°C (May) in Belg and 12.64(June) to 13.48°C (October) in the Meher season. Mean minimum temperature was 14.5 and 13.15°C in Belg and Meher seasons, respectively as indicated in Figure 2.

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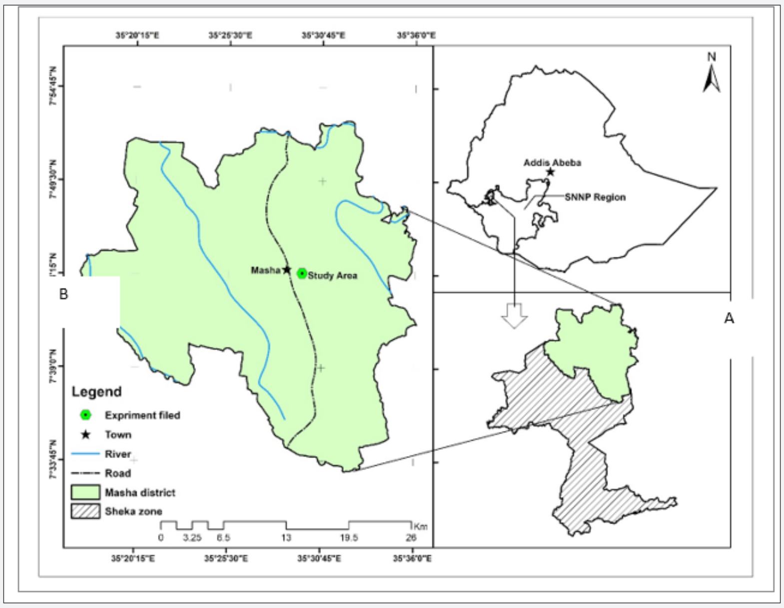

Figure 1: Map of Ethiopia showing the location of SNNPRS (A), a map of SNNPRS showing the location of the study area (B) and a map of the study area showing the location of soil sampling points.

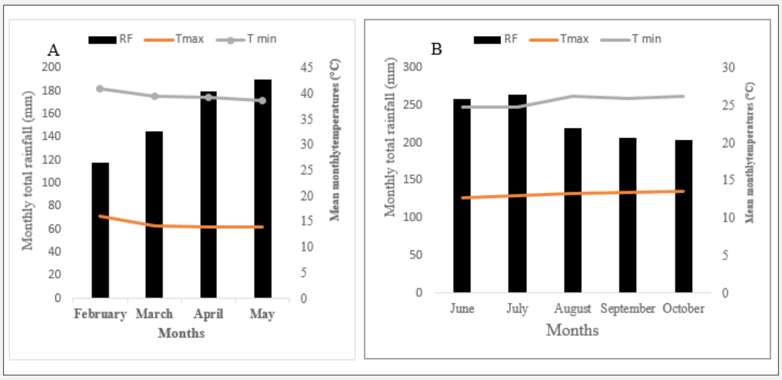

Figure 2: Monthly total rainfall (mm) and mean monthly minimum (Tmin) and maximum (Tmax) temperatures (°C) of the study site in 2016 *Belg*(A) and 2016 *Meher*(B) cropping seasons.

Source: Masha Meteorological Station (2016).

Experimental Materials

Potato variety 'Belete' from Holeta Agricultural Research Center was used for this experiment. The variety was realse in 2009 and has been accepted by farmers due to its high yielding ability, consumers' preference, wider adaptation, better cooking ability and relative resistance to late blight compared to local and other improved potato varieties. As a result, this variety is being cultivated widely in the study area. It is well performing at an altitude of 1600-2800m.a.s.l and requires rainfall of 750-1000 mm per season. It reaches maturity within 90-120 days. The productivity of this variety ranges from 29.13 t ha^{-1}under farmers 'field and 44.8 t ha^{-1} at research stations MOARD [25]. Urea (46% N) and TSP (46% P_2O_5) were used as inorganic N and P sources whereas CM was used as an organic fertilizer. CM was obtained from sustainable land management (SLM) project in Masha district; where Urea and TSP were obtained from Teppi Soil Testing Research Center.

The pH and electrical conductivity (EC) of the cattle manure were determined in extracts of 1:10(w/v) cattle manure to distilled water ratio as described by Ndegwa and Thompson [26]. Total N was measured by the Kjeldahl method. Organic carbon (C) was determined by the Walkley and Black method Walkley and Black [27]. Total P, Ca, Mg and K were extracted following the wet digestion method Okalebo [28]. The concentration of P was determined by the molybdenum blue coloration method. Total cations (Ca and Mg) were determined from the wet digested samples by atomic absorption spectrophotometer, while total K and Na were estimated by aflame photometer Okalebo [28]. The results of all analyzed parameters for cattle manure are depicted in Table 3.

Treatments and Experimental Design

Treatments consisted of three rates of cattle manure (2.5, 5, 7.5 t ha^{-1}) and three rates of recommended inorganic NP fertilizers (0, 25%, 50%, and 75%) and 100% recommended rate of inorganic

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NP fertilizer (165 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1}) and zero rates were used. The field experiment was laid out in the Randomized Complete Block Design (RCBD) with three replications. Gross and net plot sizes were (4.5m row width * 3.6m raw length) 16.2 m^2 and (3m raw length*3m raw width) 9m^2, respectively. Treatments were assigned to each plot randomly. Each plot was comprised of six rows with 12 plants/hills. The total number of plats per plot was 72. Spacing was 30cm between plants/hills within rows and 75cm between rows, which gave a planting density of 4.4 plants/hills m^{-2}. The spacing between plots and replications were 1 and 1.5m, respectively.

Experimental Procedure

The experimental land was well prepared prior to planting. In the first season, it was plowed three times with oxen and the plots were leveled manually. The soil was pulverized, leveled using human labor. each individually. The plot was prepared and addition ridging and then a division of the experimental units was done manually. Cattle manure was applied to the respective plots thoroughly and then incorporated into the soil layer (0-20cm) a month prior to planting at the rate of 2.5,5 and7.5 t ha^{-1} on dry weight bases. Phosphorus was applied in the form of triple superphosphate (46% P_2O_5) by drilling along the furrows and per hill and mixed well with the soil. Pre-sprouted potato tuber seeds were planted on 2nd February 2016 during Belg and on 2nd June 2016 during Meher seasons. Nitrogen was side-dressed in three split application methods (i.e.,1/4th at plant emergence; 2/4th at mid-stage-at 40 days after planting; and 1/4th at the initiation of tubers) because of its mobility and possible injury to the crop. Conventional agronomic practices such as hoeing, weeding, and earthing-up were carried out uniformly to all plots. Dehaluming were done to thicken tuber periderm when the plants reached physiological maturity and senesced. This was done two weeks before harvesting to toughen the periderm in order to reduce bruising and skinning during harvesting and post-harvest handling. Tubers were harvested on May 15, 2016, in Belg and on October 8, 2016, in Meher seasons, when 70% of haulms were dried from plants grown in the four middle rows. Harvesting was done manually using hand hoe with great care and only parts of plants grown in the central parts of the plots were used for data collection to reduce border effect. Thus, 40 plants in the net plot were used to collect potato yield and finally converted into tha^{-1}.

Soil Sampling and Analysis

Prior to planting, soil samples (0 - 20cm), from ten spots across the experimental fields were collected in a zig-zag pattern, in 2016 during Belg and Meher cropping seasons. One composite sample was made. The soil sample was prepared for physicochemical analyses. Soil and were air dried ground and passed through 2mm sieve for the analysis of physicochemical properties except for total nitrogen and organic carbon which were passed through 0.5mm sieve. Soil Particle size distribution was analyzed by the hydrometer method Day [29] after destroying OM using hydrogen peroxide (H_2O_2) and dispersing the soils with sodium hexametaphosphate Na (PO_3)6. Soil bulk density was determined by the undisturbed core sampling method Blake [30] after drying the soil samples in an oven at 105 °C to constant weights, while particle density was estimated by the pycnometer method Barauah and Barthakulh [31] Percent total pore space was computed from the values of bulk density (BD) and particle density (PD) as described by Hillel [32].

$$TP(\%) = [1-(\frac{BD}{PD})]*100$$

Soil pH-H_2O was measured using a pH meter in a suspension of 1:2.5 soils: water ratio. The soil OC content was determined following the wet oxidation method as outlined by Walkley and Black [27] Total N content in the soil samples was determined titrimetric ally following the Kjeldahl method as described by Jackson [33]. Available P was determined using Bray II method Bray and Kurtz [34]. Cation exchange capacity (CEC) and exchangeable bases (Ca, Mg, K and Na) were determined after extracting the soil samples by ammonium acetate (1N NH_4OAc) at pH 7.0. Exchangeable Ca and Mg in the extracts was analyzed using atomic absorption spectrophotometer while Na and K were analyzed by a flame photometer Rowell, 1994). Cation exchange capacity was thereafter estimated titrimetrically by distillation of ammonium that was displaced by sodium after leaching with NaCl solution Chapman [35]. Percentage base saturation (PBS) was calculated as the ratio of the sum of the charge equivalents of the base-forming cations (Ca, Mg, Na and K) to the CEC of the soil.

Exchangeable acidity was determined by saturating the soil samples with 1M KCl solution and titrated with 0.02 M NaOH as described by Rowell (1994). From the same extract, exchangeable Al in the soil samples was titrated with a standard solution of 0.02M HCl. Finally, exchangeable H was obtained by subtracting exchangeable Al from exchangeable acidity (Al + H) (Rowell, 1994). Available micronutrients (Fe, Mn, Zn and Cu) were extracted from the soil samples with Diethylene Triamine Pentaacetic Acid (DTPA) as described by Lindsay and Norvell [36] and all were measured by atomic absorption spectrophotometer at their respective wavelengths. Just after harvesting of the crop, composite surface (0 - 20cm) soil samples were collected from three spots for each plot from every replication. These samples were composited to yield one representative sample per replication from each plot for determination of CEC, pH, total N, available P, available K and organic carbon contents using procedures indicated for pre-sowing soil analysis. The extract of K was analyzed using flame photometer Black [30]. The bulk density (BD) of the soil was measured from the undisturbed soil samples collected from each plot using core sampler, which was weighed at field moisture, and after drying the pre-weighed core soil sample to a steady weight in an oven at 105 0 C according to the procedure described by Okalebo [28], while particle density (PD) was measured using pychnometer Barauah and Barthakulh [31].

$$TP(\%) = [1-(\frac{BD}{PD})]*100$$

where, BD = bulk density; PD= particle density (Hillel, 2004).

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Statistical Data Analysis

The post-harvest soil and tuber yield data were subjected to analysis of variance (GLM procedure) using SAS software program version 9.2 SAS Institute [37]. Homogeneity of variances was calculated using the F-test as described by Gomez and Gomez (1984) and since the F-test has shown heterogeneity of the variances of the two seasons for all of the agronomic parameters, a separate analysis was used for the two seasons. The Fisher's protected least significant difference (LSD) test at 0.05 probability level was employed to separate treatment means where significant treatment differences occurred.

Results and Discussion

Soil physical and chemical properties before planting

The bulk density value of the soil was 1.37g cm-3.in Belg and 1.38 g cm-3 in Meher season where particle density was 2.58g cm^{-3} of soil in Belg and 2.6 g cm-3 in Meher and total porosity was 46.80% in Belg and 46.92% in Meher. According to Barauah and Barthakulh [31], soil bulk density and particle density rating of this soil has moderate compaction. The moderate compaction of the soil could be due to continuous cultivation which causes disintegration of the soil structure and exposure of surface soil to the direct raindrops. The total porosity of this soil was 46.96% which was classified as high according to the rating of Hillel [32]. Therefore, the soil is good for optimum movement of air and water through the soil and there is no problem on tuber growth and expansion in the soil. Soil particle size analysis results showed that texture of the soil is sandy clay loam in both seasons with particle size distribution of 57% sand, 18% slit,25% clay in Belg and 56% sand, 16% silt and 28% clay in Meher seasons (Table 1). This soil is, therefore, expected to have poor in structure, unstable because of low content of clay and organic matter, slightly weak in strength when relatively dry, which creates no problem for emerging seedlings and susceptible to leaching leading to loss of available plant nutrients especially basic cations that cause deficient in macronutrients like N, P, K, Ca, Mg and S. These results of the initial soil test analysis showed that the soil at the site was strongly acidic, with pH of (5.01) in Belg and Very Strongly acidic (4.8) in Meher season Low status of total N of 1 and 0.8g kg^{-1}) content could possibly be due to either low initial organic matter content of the soil, which contributes about 90-95% of soil nitrogen or leaching of nitrate by torrential rainfall prevalent in the experimental areas (Aziz et al., 2010:Ahmad and Arshad, 2015). Low status of organic carbon, (12g kg^{-1}) in Belg and (10.2 g kg^{-1}) in Meher seasons, Low status of available phosphorus of the soils 5.5ppm in Belg and 5ppm in Meher season This could be attributed to the poor management of crop residue, poor land management practices, slash-and-burn agricultural systems, low soil organic matter, high soil erosion. low inherent fertility of soil, fixation of phosphorus in acidic soil resulting in nutrient reduction and the decline in soil fertility Thus, the response to added organic and mineral fertilizer at different season is expected to show responses on the crop and the soil. The soils analysis also revealed that in both study seasons have medium CEC of 20cmol (+) kg^{-1}) in Belg season and 19.3cmol (+) kg^{-1}), in Meher season, high in micronutrient cations Fe, Mn, Cu, and Zn both in Belg and Meher season due to increased availability at low pH, cations being less strongly bound to the soil and readily exchangeable and trace in exchangble sodium according to the rating of Tekalign [38] (Table 2). The soil had also relatively high content of exchangeable acidity (3.83cmolc (+) kg^{-1}) and aluminum (3.82cmolc (+) kg^{-1}) in Belg and exchangeable aluminum (2.01cmolc (+) kg^{-1}) in Belg and (2.46cmolc (+) kg^{-1}). in Meher season.

Table1: Initial soil physical characteristics of the experimental site. During Belg and Meher seasons.

Soil Parameters	Belg Season		Meher Season		References
	Value	Rating	Value	Rating	
% Sand	57		56		
% Slit	18		16		
%clay	25		28		
Textural class	Sandy clay loam		Sandy clay loam		
Bd (g cm^{-3})	1.37	Medium	1.38	Medium	Barauah and Barthakulh [31]
PD (g cm^{-3})	2.58	Medium	2.6	Medium	Barauah and Barthakulh [31]
%porosity	46.80		46.92	high	Hillel [32]

Bd=bulk density Pd-particle density.

Table 2: Initial soil chemical characteristics of the experimental site. During Belg and Meher seasons.

Soil Parameters	Belg Season		Meher Season		
	Value	Rating	Value	Rating	
pH (1:2.5 H_2O)	5.01	Strongly acidic	4.8	Very strongly acidic	Tekalign [38]
O.C(g kg^{-1})	12	Low	1.02	Low	Tekalign [38]

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N (g kg^{-1})	1	Low	0.08	Low	Tekalign [38]
C: N	12	Low	12.75	low	Hazelton and Murphy [68]
Available P (mg kg^{-1})	5.5	Low	5	Low	Jones and Benton [69]
ExchangeableCa (cmol (+) kg^{-1} soil)	6.5	Medium	6.3	Medium	FAO [67]
Exchangeable Mg (cmol (+) kg^{-1} soil)	2.1	Moderate	1.4	Moderate	FAO [67]
Exchangeable K (cmol (+) kg^{-1} soil)	0.42	High	0.36	High	FAO [67]
Exchangeable Na (cmol (+) kg^{-1} soil)	0.06	Very low	Nill	Very low	Landon (1991)
CEC (cmol (+) kg^{-1} soil)	20	Medium	19.3	Medium	Hazelton and Murphy [68]
Pbs (%)	45.4	Medium	41.7	Medium	Hazelton and Murphy [68]
Available potassium (ppm)	96			85	
Exchangeable Al (cmol (+) kg^{-1} soil)	2.01	High	2.46	High	Hazelton and Murphy [68]
Exchangeable acidity (cmol (+) kg^{-1})	3.83	High	3.82	High	Hazelton and Murphy [68]
Cu (mg kg^{-1}) (DTPA)	8	High	6	High	Jones and Benton [69]
Fe (mg kg^{-1}) (DTPA)	120	High	80	High	Jones and Benton [69]
Zn (mg kg^{-1}) (DTPA)	1.5	High	1.2	High	Jones and Benton [69]
Mn(mgkg^{-1}) (DTPA)	25	High	20	High	Jones and Benton [69]

DTPA = Diethylene Triamine Pentaacetic Acid, Pbs=percent base saturation.

Table 3: Nutrient content of cattle manure used in the experiment in Belg and Meher season.

Parameters	Belg	Meher
pH (1:2.5 H_2O)	6.8	7.1
Electrical conductivity (uS cm^{-1})	182	148
Carbon (g kg^{-1})	250	220
Total N (g kg^{-1})	192	160
C: N	13:1	14;1
Totoal phosphorus (g kg^{-1}))	13.74	119
Total Ca (g kg^{-1})	78.54	67.48
Total Mg (g kg^{-1})	13.3	9.9
Total K (g kg^{-1})	46.74	52.2
Total Na (g kg^{-1})	0.7	0.9
Moisture content (%)	78	1

Table 4: Analysis of variance for potato tuber yield and soil physico-chemical properties after crop harvest.

Soil parameter and tuber yield	Season	Source of variation with a degree of freedom			
		Replication (2)	Treatment (10)	Error(20)	CV (%)
Potato Tuber Yield	Belg	16.43^{ns}	70.09^{**}	4.92	6.74
	Meher	5.75^{ns}	33.28^{**}	1.77	4.62
Bulk density (g cm^{-3})	Belg	0.02^{ns}	0.011**	0.00096	2.7
	Meher	0.017^{ns}	0.00587^{**}	0.0008	2.02
Particle density (g cm^{-3})	Belg	0.00117^{ns}	0.0034^{ns}	0.00095	1.16
	Meher	0.032^{ns}	0.11^{**}	3.22	1.04
Porosity (%)	Belg	0.68^{ns}	2.73^{**}	0.581	1.54
	Meher	36.70^{ns}	5.23^{**}	0.45	1.37

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pH (1:2.5 H_2O)	Belg	0.10ns	0.01**	0.00075	0.54
	Meher	0.02ns	0.007**	0.00049	0.45
O.C	Belg	0.0104ns	0.018**	0.0071508	4.334051
	Meher	0.0026ns	0.017**	0.00333038	5.21
T. N	Belg	0.00014ns	0.00054**	0.00015727	8.672782
	Meher	0.00459ns	0.0012**	0.00003363	4.92
Available phosphorus	Belg	0.61ns	1.19 **	0.31837543	8.610600
	Meher	0.099ns	0.315**	0.04958257	3.92
Calcium(cmol(+) kg^{-1})	Belg	0.089ns	1.75**	0.11	4.86
	Meher	0.90ns	0.157**	0.098	2.15
Magnesium(cmol(+) kg^{-1})	Belg	0.375ns	0.16**	0.038	6.79
	Meher	0.23ns	0.035**	0.018	4.62
Potassium(cmol(+) kg^{-1})	Belg	0.00022ns	0.0033**	0.0005	6.17
	Meher	0.000055ns	0.0025**	0.00017	6.18
Sodium (cmol(+) kg^{-1})	Belg	0.000075ns	0.0000051	0.001	23.12
	Meher	0.0029ns	0.0003	35.79	35.79
Exchangeable acidity(cmol(+) kg^{-1})	Belg	0.0096ns	0.63**	0.01	3.63
	Meher	0.02ns	0.09**	0.02	4.86
Exchangeable Aluminum (cmol(+)$^{-1}$)	Belg	0.0044ns	0.28**	0.013	5.93
	Meher	0.18ns	0.033**	0.01	4.00
Cation exchange capacity(cmol(+) kg^{-1})	Belg	0.075ns	9.83**	0.63	4.29
	Meher	27.06ns	2.96**	4.10	0.63
Percent base saturation (PBS) (%)	Belg	2.013 ns	3.4 **	0.19	0.9
	Meher	0.00185 ns	0.00185**	0.002	0.38

Ns non-significant more than 5% level of significance (P>0.05), Significant at 5% level of significance (P < 0.05) and ** highly Significant at 1% level of significance. (P < 0.01) as established by LSD test; *

Analysis of the composition of soil and cattle manure revealed better nutrient composition in Belg than in Meher season because in Belg season there is optimum soil temperature, moisture and pH that might create suitable condition for microorganism multiplication both in number and species causes fast decomposition of materials this results in narrow carbon to nitrogen ratio and release of more nutrients Therefore, the microbial-based indicators can be used as early indicators of soil degradation or improvement (Tables 1 & 2). The analysis of cattle manure presented in Table 3 indicated that it contains relatively higher content of carbon, N, P, pH, total N, Ca, Mg, K, Na, CEC, EC and moisture content in Belg season as compared to Meher season possibly Because of its fast decomposition elevated contents of salts it can be utilized to raise the pH of acid soils Therefore, cattle manure can be used as an alternative to lime either by itself or as a mixture of mineral NP (Table 3). Mean square value due to combined application of cattle manure and mineral Were highly significant (p<0.01) and low coefficient of variation indicating good precision of the experiment for all the 12 studied soil physicochemical characteristics and tuber yield of potato at Masha in 2016 Belg and Meher season the overall result showed the existence of sufficient variation for studied tuber yield and soil physicochemical properties and result is presented in Table 4.

Total Tuber Yield of Potato

Total tuber yield of potato was highly significantly (P<0.01) affected by the application of cattle manure and inorganic NP (Table 4). Increasing the application rates of cattle manure and inorganic NP from 0 to 7.5 t ha^{-1} increased the total tuber yield from 25.78 to 40.20 t ha^{-1} and 22.63- 34.22 t ha^{-1} (Table 5). The highest yield was obtained at 7.5 t ha^{-1} CM+75% NP ha^{-1}, but the lowest yield was obtained at zero dosage of cattle manure and inorganic NP application. Increasing the application rates of cattle manure and inorganic NP from zero to 7.5 t CM+75% NP ha^{-1} increased total tuber yield by 55.9%, 42.90% and 51.19%, 36.64% in both Belg and Meher season as compared to zero and 100% inorganic NP application of fertilizers, respectively. This show there is an opportunity for additional gain in tuber yield through the further application of more rates of combined cattle manure with inorganic NP fertilizers above 7.5 t ha^{-1} CM+75% of recommended NP ha^{-1}. This result is partly in line with the finding of and Najm [39] reported that combined application of cattle manure and inorganic fertilizers increased the total tuber yield. In his study highest tuber yield (36.8 tha^{-1}) was obtained by application of 20 $tons^{-1}$ Cattle manure+150 kg N ha^{-1}. on clay loam soils of Islamic Azad University, Roudehen Branch, Tehran,

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Iran, similarly Alemi [40] reported the maximum tuber yield (53.4 and 67 t ha^{-1}) and (51 and 63.1 t ha^{-1}) in 2003 and 2004 cropping season in Nitosol and Vertisol, soils of in addition maximum tuber dry weight (632.38 g·m-2) was obtained by integrated use of One third of Crop residue + one third of CM + Bio-fertilizer +150% RDF. In 2012 2013 cropping season the gangetic alluvium belt of West Bengal Shubhadip [41] and also Kabira [42] integrated the use of cattle manure at rate 2.47 t ha^{-1} with mineral NPK (23:23:0) at 77kg ha^{-1}and Desiree and Kenya Mavuno potato varieties.in the second season April 2014 to August 2014 at kalro Tigoni. station Nairobi Kenya provide better yield (26.24 t ha^{-1}).

Results have shown that all the treatments increased total tuber yield in both Belg and Meher season as compared to control, but the increment in total tuber yield is higher in belg season. This may be due to rainfall and temperature variability in each season causes soil fertility dynamics by facilitating more soil organic matter and manure decomposition this may favor higher nutrient availability in Belg season as compared to Meher season. in addition, compatibility of essential nutrient availability with growing phases that is maximum demand at tuber bulking phase and low in early and maturity phase (Table 5).

Table 5: Tuber yield (t ha-1) and percent yield change (%) as influenced by the combined application of organic fertilizer and mineral NP in Belg and Meher seasons, in Masha district, south-western Ethiopia.

Treatment*	Belg		Meher	
	Total tuber yield (t ha^{-1})	% change over 100% NP	Total tuber yield (t ha^{-1})	% change over 100% NP
2.5 t ha^{-1} CM+25% NP	29.3d^{e}	4.13	26.54d^{e}	5.31
2.5 t ha^{-1} CM+50% NP	29.9^{d}	6.26	27.98^{d}	10.43
2.5t ha^{-1} CM+75% NP	30.29^{d}	7.65	28.25^{d}	11.39
5 t ha^{-1} CM+25% NP	30.98^{d}	10.10	28.31^{d}	11.60
5 t ha^{-1} CM+50% NP	35.06^{c}	24.60	28.73^{cd}	13.10
5 t ha^{-1} CM+75% NP	35.99^{bc}	27.90	30.88^{bc}	20.74
7.5 t ha^{-1} CM+25% NP	36.77^{abc}	30.68	31.13^{b}	21.63
7.5 t ha^{-1} CM+50% NP	39.6^{ab}	40.73	32.46^{ab}	26.35
7.5 t ha^{-1} CM+75% NP	40.2^{a}	42.87	34.22^{a}	32.61
100% NP	28.14^{de}	0	25.04^{e}	0
Control	25.78^{e}	-8.37	22.63^{f}	-8.57
LSD (5 %)	3.78		2.26	
Significance	**		**	
CV (%)	8.77		4.62	

Means followed by the same letter within a column are non-significantly different to each other at * Significant at 5% level of significance ($P < 0.05$) and ** highly Significant at 1% level of significance. ($P < 0.01$) as established by LSD test; * CM = Cattle manure in t ha^{-1}.

Soil Physical Characteristics

Table 6: Bulk density (g cm^{-3}), particle density (g cm^{-3}), and total porosity (%) of soil after crop harvest as influenced by the combined application of cattle manure and mineral NP in Belg and Meher seasons, in Masha district, South-western Ethiopia.

	Belg			Meher		
	Bulk Density	Particle Density	Total Porosity	Bulk Density	Particle density	Total Porosity
T3	1.37^{ab}	2.66	48.55^{ef}	1.37^{ab}	2.67	48.57^{e}
T4	1.36^{bc}	2.65	48.62^{ef}	1.36^{bc}	2.67	48.49^{e}
T5	1.35^{cd}	2.65	49.11^{de}	1.35^{cd}	2.67	48.86^{de}
T6	1.35^{cd}	2.64	49.12^{de}	1.34^{d}	2.67	48.94^{de}
T7	1.33^{e}	2.65	49.63^{d}	1.33^{e}	2.67	49.38^{d}
T8	1.31^{f}	2.65	50.39^{c}	1.31^{f}	2.67	50.06^{c}
T9	1.3^{fg}	2.63	50.58^{bc}	1.30^{fg}	2.62	50.33^{bc}
T10	1.29^{gh}	2.64	51.11^{ab}	1.29^{gh}	2.63	50.85^{ab}
T11	1.28^{h}	2.65	51.79^{a}	1.30^{h}	2.61	51.10^{a}
T2	1.37^{ab}	2.66	48.49^{ef}	1.37^{ab}	2.67	48.64^{e}

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T1	1.38[a]	2.66	48.04[f]	1.38[a]	2.68	48.43[e]
LSD (5 %)	0.014	0.019	0.696	0.014	0.012	0.606
Significance	**	**	**	**	**	**
CV (%)	0.62	0.42	0.82	0.62	0.26	0.72

Means followed by the same letter within a column are non-significantly different to each other at * Significant at 5% level of significance (P < 0.05) and ** highly Significant at 1% level of significance. (P < 0.01) as established by LSD test; * CM = Cattle manure in t ha^{-1}, RDF = Recommended Dose of inorganic NP Fertilizer.

The combined application of cattle manure and inorganic N and P fertilizers had highly significant (P<0.01) effect on the bulk density and porosity of the soil both in Belg and Meher season (Table 6).The lowest bulk density (1.28g cm^{-3}) was obtained from the application rate of 7.5 tha^{-1} CM in combination with 75% inorganic N and P in Belg season which is stastically the same as application 7.5 t ha^{-1} CM with 50% inorganic N and P, 7.5 t ha^{-1} CM with 25% inorganic N and Pand5t ha^{-1} CM in combination with 75% inorganic N and P and 5 t ha^{-1} CM in combination with 50% inorganic N and P in Belg season Similarly, the lowest bulk density (1.30g cm-3) in Meher was obtained from the application rate of 7.5 t ha^{-1} CM in combination with 75% inorganic N and P which is statistically at par with application of 7.5 t ha^{-1} CM in combination with 75% inorganic N and P while highest bulk densities (1.25g cm-3) in Belg and (1.38g cm^{-3}) in Meher seasons were from the control, application of 100% NP and 2.5 t ha^{-1} CM with 25% NP in both Belg and Meher season respectively (Table 4). The lowest bulk density of 7.5 t ha^{-1} CM applied plots was due to the availability of organic matter to the soil at the proper time and in the proper proportions and this improves soil physical and chemical properties due to increased soil organic matter. These results corroborate with the findings of Paul [43] reported that cattle manure at 10 t ha^{-1} with 100% RDF (N150P75K75) has advantages in improving the soil organic matter and water holding capacity, with an associated decrease in bulk density and increasing infiltration rate of water. Similarly, Fekadu [12]; and Saha [44] reported that the use of cattle manure with mineral fertilizer significantly increased soil organic carbon (SOC) and decreased bulk density over time (Table 6). Several studies have reported that CM plus mineral nutrient application resulted in reduced bulk density, higher soil organic carbon and hydraulic conductivity and improved soil structure and microbial communities Andargachew,2014; Shiferaw [22], Yadav [17]; Kumar [45].

Bulk density normally decreases, as mineral soils become finer in texture. Therefore, the combined application of mineral NP and cattle manure decreased bulk density with increase in total pore space present in the soil and gives a good estimate of the porosity of the soil. Bulk density is of greater importance than particle density in understanding the physical behavior of the soil. Generally, soils with low bulk densities have favorable physical conditions. Similarly, Song [46] reported that the decrease in bulk density obtained with manure treated soil was directly related to the increased organic matter, which played a significant role in reducing compaction of soil. The organic amendments promote the activity of soil fauna and play a major role in the buildup and stabilization of soil structure. In view of this, bulk density values of the soils in the study areas were not too compact after crop harvest to limit root penetration and restrict movement of water and air.

Accordingly, the highest total porosity (51.78%) in Belg and (51.10%) in Meher was obtained from the application of 7.5 t ha^{-1} CM in combination with 75% inorganic N and P and 50% inorganic N and P in which is statistically the same as application of 7.5 t ha^{-1} CM in combination with 50% inorganic N and P in both Belg and Meher season This increased porosity with the application of CM might be due to low soil compaction increase in organic matter leading to increased rapid multiplication of soil microorganisms, fastens the mineralization of plant nutrients in the soil Similarly, Poeplau [47] reported that soil with good organic matter content have higher porosity, and plays a critical role in establishing and maintaining soil fertility. on the other hand, the lowest total porosity of 48.04 % in Belg and 48.43 in Meher season were obtained from the control (Table 6).

Soil Chemical Characteristics after Crop Harvest

A comparison of soil fertility status prior to planting and after harvesting of potato shown that incorporation of cattle manure and mineral NP highly significantly(P<0.01) affects organic carbon content, total N, available P, soil pH, CEC, exchangeable acidity, exchangeable aluminum, exchangeable calcium, exchangeable magnesium, exchangeable potassium percent bases saturation, However, there was non-significant(P>0.05) effect on exchangeable sodium both in Belg and Meher seasons. Table 4 indicating that there was an improvement of the fertility status of the soil due to an integrated nutrient management.

Soil pH

Soil pH in pre-sowing soil was 5.01 in Belg and 4.8 in Meher season (Table 2) Soil pH value after crop harvest ranged from a minimum of 4.95 to a maximum of 5.15 in Belg and a minimum of 4.79 to a maximum of 4.94 in Meher season The highest soil pH of 5.15 in Belg and 4.94 in Meher season after harvest was recorded at application 7.5 t ha^{-1} CM, with 75% inorganic N and P. which is stasticalley at par with application of 7.5 t ha^{-1} CM, with 50% inorganic N and P. and 7.5 t ha^{-1} CM, with 25% inorganic N and P. which might be due to lime like materials such as calcium and magnesium present in manure increases soil pH In line with this result, Suh et [48] showed an increase in soil pH in plots applied with cattle manure following potato production.

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Similarly, Ahmed [49] also found that using of animal manure such as cattle manure has positively beneficial effects on changes the soil pH where increases or decreases in the pH, depending on the type of soil and properties of organic fertilizer while the lowest soil pH(4.95) in Belg and (4.79)in Meher season was obtained at zero application of nutrients which is the same as application of 100% NP, 2.5 t ha^{-1} CM 25% NP, 2.5 t ha^{-1} CM +50% NP in Belg season and 100% NP, 2.5 t ha^{-1} CM+25% NP in Meher season. non-amendment of cattle manure and mineral NP removal of organic amendments can increase reduced pH, of soil this is because organic amendments can increase Al availability to plants by increasing the H+ release of soils. The observed reduced following non-application of treatments with organic amendments (e.g. cattle manure) and inorganic is understood to reduce decomposition (less negative charge of adsorption sites) and complexation of soluble Al and Fe by organic molecules. Therefore, the lesser the organic and inorganic amendments the greater the decrease in Al adsorption capacity of soil this increase the release of more H+1 and decline in soil pH. similar results were also reported by Haynes and Mokolobate [50] reduction in the decomposition of organic residues causes a reduction in soil pH (Table 7).

Table 7: pH of soil after harvest of potato as influenced by the application of cattle manure and inorganic NP in Belg and Meher season at Masha district, south-western Ethiopia.

Treatment*	Belg	Meher
	pH (1:2.5 H_2O)	pH (1:2.5 H_2O)
2.5 t ha^{-1} CM+25% NP	4.98^{fg}	4.82^{h}
2.5 t ha^{-1} CM+50% NP	4.99^{efg}	4.83^{efg}
2.5 t ha^{-1} CM+75% NP	5.00^{def}	4.84^{ef}
5 t ha^{-1} CM+25% NP	5.02^{def}	4.86^{de}
5 t ha^{-1} CM+50% NP	5.03^{bcde}	4.87^{cde}
5 t ha^{-1} CM+75%NP	5.04^{bcd}	4.89^{bcd}
7.5 t ha^{-1} CM+25% NP	5.06^{bc}	4.90^{abc}
7.5 t ha^{-1} CM+50% NP	5.07^{b}	4.90^{abc}
7.5 t ha^{-1}CM+75% NP	5.15^{a}	4.94^{a}
100% NP	4.96^{g}	4.80^{gh}
Control	4.95^{g}	4.79^{h}
LSD (5 %)	0.544	0.037
Significance	**	**
CV (%)	0.046	0.453

Means followed by the same letter within a column are non-significantly different to each other at * Significant at 5% level of significance ($P < 0.05$) and ** highly Significant at 1% level of significance. ($P < 0.01$) as established by LSD test; * CM = Cattle manure in t ha-1.

Organic Carbon

Total organic carbon before planting was 1.2% in Belg and 1.02% in Meher (Table 2). After harvesting, it ranged from a minimum of 18.8 to a maximum of 21.1g kg^{-1} in Belg season and from a minimum of 10.36 to a maximum of 12.72 g kg^{-1} in Meher season (Table 8). The highest values at 7.5 t ha^{-1} CM +75% RDF in both Belg and Meher season followed by 7.5 t ha^{-1} CM +50% RDF. After harvesting, application of 7.5 t ha^{-1} CM with75% RDF improved the soil organic carbon by 12.23% and 22.78% as compared to zero application of treatments in Belg and Meher seasons respectively. indicating that these amendments positively affected the organic matter

Increasing levels of cattle manure are linked to greater increased in soil organic matter due to enhanced soil microbial action increase soil moisture, soil structure, nutrient retention, aeration, water holding capacity of amended soil This indicated that the integrated application of 7.5 t ha^{-1} CM with 75% recommended rates of inorganic NP had the capacity of improving the soil carbon content, both in Belg and Meher seasons.

Kumar [45] reported that the combined application of CM from 12.5 to 25 t ha^{-1} with (75% and 100%) recommended doses of NPK (150:60:100) fertilizers in potato has increased the soil carbon content from (5.4-5.8 g kg^{-1}) and (5.3 to 5.7 g kg^{-1}) after potato harvest. In addition, Kumar [51] described that application of 50 % recommended dose of NPK (60:60:30) through inorganic fertilizers and remaining 50% recommended dose of N (60 kg N ha^{-1}) from cattle manure manures gave higher organic carbon pool (12.61 g kg^{-1}) as compared to 100% recommended dose of NPK through fertilizers after three years of potato cultivation. Similarly, Wang [52] reported that combined use mineral fertilizers and organic amendments had greater soil organic carbon content than those receiving only mineral fertilizers in paddy soil. In addition (Table 8).

Total Nitrogen

Total nitrogen in pre-sowing soil was 0.1% in Belg and 0.08% in Meher season (Table 2). soil total nitrogen after harvest ranged from a minimum of 1.24 to a maximum of 1.71g kg^{-1}in Belg and a minimum 0.92 to a maximum of 1.51 g kg^{-1} in Meher season from zero application of nutrients to the application of 7.5 t ha^{-1} CM with 75% recommended rate of mineral NP which resulted in improvement of soil nitrogen after harvest by 37.45% and 63.85%over zero application of nutrients (Table 8). This shows cattle manure prevents loss of mineral nitrogen into the environment. by gradually releases essential nutrients over a period through regulating the rate of conversion of cattle manure to total nitrogen in addition, to release of nutrients into the soil after decomposition. This result was in concomitant with the finding of Lemanowicz [15] reported that increasing the application CM from zero to 20, 40, and 80 t ha^{-1} and mineral nitrogen from 0, 40, 80 and 120 kg ha^{-1} increased the total nitrogen content of soil as compared to the soil sampled from the treatments fertilized with the zero CM and mineral NP rate. In addition, Girma et al. (2017) reported that application of 14 t ha^{-1} CM combines with 55kgha^{-1} and 20 t ha^{-1} mineral NP fertilizers improve soil total nitrogen supply by 48%. Similarly, Biruk [23] reported that the treatment receiving CM at 30 t ha^{-1} + N at 120kg ha^{-1} + 92kg P_2O_5 ha^{-1}. Improves total N by 67 % in the soil after harvest of potato as compared to zero application of mineral and cattle manure. In

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lined with this Kumar [53] also stated that the total soil nitrogen content after harvest of potato increased in response to the application of CM and mineral fertilizer than 100% inorganic fertilization. from the present result, the increasing levels of cattle manure and mineral NP application increase the total nitrogen content of soil after harvest.

Table 8: Organic carbon (g kg-1), total nitrogen (g kg-1) and available phosphorus (mg kg-1) content of soil after potato harvest as influenced by the application of cattle manure and mineral NP in Belg and Meher seasons in Masha district, south-western Ethiopia.

Treatmen^{t*}	Belg			Meher		
	Organiccarbon ($g\ kg^{-1}$)	Total nitrogen ($g\ kg^{-1}$)	Available phosphorus ($mg\ kg^{-1}$)	Organic carbon ($g\ kg^{-1}$)	Total nitrogen ($g\ kg^{-1}$)	Available phosphorus ($mg\ kg^{-1}$)
2.5t ha^{-1} CM+25% NP	18.9^{c}	13.7^{bcd}	6.24^{bcd}	10.4^{b}	0.98^{gf}	5.55^{cd}
2.5t ha^{-1} CM+50% NP	19.1^{c}	13.7^{bcd}	6.24^{bcd}	10.7^{b}	1.06^{ef}	5.57^{bcd}
2.5t ha^{-1} CM+75% NP	19.2^{c}	13.7^{bcd}	6.24^{bcd}	10.7^{b}	1.12^{de}	5.64^{bcd}
5t ha^{-1} CM+25%NP	19.3^{c}	13.7^{bc}	6.24^{bcd}	10.94^{b}	1.15^{cde}	5.71^{bcd}
5t ha^{-1} CM+50% NP	19.3c	14.8^{bc}	6.77^{abc}	10.96^{b}	1.164^{cd}	5.77^{bc}
5t ha^{-1} CM+75%NP	19.4^{c}	15.1^{abc}	6.95^{ab}	11.00^{b}	1.24^{c}	5.78^{bc}
7.5t ha-1 CM+25%NP	20^{bc}	15.4^{ab}	7.12^{ab}	11.13^{b}	1.38^{b}	5.82^{bc}
7.5t ha-1CM+50% NP	20.8^{ab}	15.8^{ab}	7.30^{a}	12.33^{a}	1.46^{ab}	5.94^{ab}
7.5 t ha-1 CM+75% NP	21.1^{a}	$17.^{1}$a	7.5^{5}a	12.72^{a}	1.5^{1}a	6.2^{7}a
100% NP	18.83^{cd}	13.1^{cd}	5.88^{cd}	10.42^{b}	0.96^{g}	5.37^{de}
Control	18.78^{d}	$12.^{4}$d	5.5^{3}d	10.36^{b}	0.9^{2}g	5.00^{3}e
LSD (5 %)	0.144	2.14	0.96	0.98	0.09	0.38
Significance	**	**	**	**	**	**
CV (%)	4.33	8.67	8.61	5.21	4.92	3.92

Available P

Available P in pre-sowing soil was 5.5 mg kg^{-1} in Belg and 5 mg kg^{-1}in Meher season (Table 2) while soil available P after harvest ranged from minimum of 5.53 mg kg^{-1} to maximum of 7.55 mg kg^{-1} in Belg and minimum of 5 to maximum of 6.27 mg kg^{-1} in Meher seasons compared to the initial soil content of available P and the control (Table 8). The highest available P in Belg (7.55 mg kg^{-1}) and in Meher (6.27 mg kg^{-1}) season were obtained from the application of 7.5 t ha−1CM in combination with 50 and 75% mineral NP fertilizers, respectively. The increase in available P with increased level of CM and mineral NP application was probably related to the addition of various organic sources improve the soil physio-chemical properties that created the favorable condition in rhizosphere, also the secretion of certain enzymes and auxins and other growth-promoting substances and manure also helps in producing intermediate compounds that interact with phosphorus-fixing cations such as aluminum, iron, etc. Thereby reducing P adsorption capacity.

This result was in agreement with the investigation of Balemi [40] where they reported the increase in available P with the application of cattle manure which might have helped in releasing a higher amount of P from the soil. Similarly, Kesarwani [54] reported that application of 5t ha^{-1} CM with 120:60:40 NPK kg ha^{-1} enhanced P availability, increased overall treatments than sole use of mineral fertilizer as well. In addition, Shethet [55] showed that integrated use of 15 t ha^{-1} cattle manure combined with 100% recommended dose of inorganic fertilizers (75: 50: 75 NPK kg ha^{-1}) is efficient than application of inorganic fertilizers alone in improving growth and yield in sweet potato cultivation The present result was also in agreement with the findings of Singh [56] reported that the increased available P content of soil with the application of cattle manure might be due to release of organic acids during decomposition which in turn helped in releasing phosphorus. Generally, the available P status of the soils in the control at both study seasons was very low, even below the critical level (10ppm) Isreal [6] which indicates that the low soil P was among the factors highly limiting the productivity of the soils in the study area. This result was in agreement with the investigation of Song [57] where they reported that continuous use of organic manure and chemical fertilizer on soil improves the available phosphorus status of the soil (Table 9). On the other hand, the lowest exchangeable acidity of 2.32cmol (+) kg^{-1} soil in Belg and 2.08cmol (+) kg^{-1} soil in Meher season was recorded at application of 7.5 t ha^{-1} cattle manure with 75% inorganic N and P which is statistically at par with application of 7.5 t ha^{-1} cattle manure with 50%inorganic N and P and 7.5 t ha^{-1} cattle manure with 25% inorganic N and P which might be that the addition of cattle manures, can increase perception of exchangeable Al which might have decrease exchangeable acidity and aluminum Similarly Narambuye and Haynes [58] reported that an increase in soil pH leads to reduction of soluble exchangeable Al which, in turn, decreases exchangeable acidity.

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Table 9: The combined effect of cattle manure and inorganic NP fertilizer on exchangeable acidity (cmol(+) kg^{-1}soil)and exchangeable aluminum(cmol(+) kg^{-1}soil) in Masha district in Belg and Meher seasons, south-western Ethiopia.

Treatment*	Belg		Meher	
	Exchangeable acidity	Exchangeable aluminum	Exchangeable acidity	Exchangeable aluminum
2.5 t ha^{-1} CM+25% NP	3.12^{c}	2.19^{ab}	2.91^{ab}	1.98^{ab}
2.5 t ha^{-1} CM+50% NP	2.87^{d}	2.16^{ab}	2.79^{b}	1.90^{b}
2.5t ha^{-1} CM+75% NP	2.79^{d}	2.15^{ab}	2.52^{c}	1.71^{c}
5 t ha^{-1} CM+25% NP	2.78^{d}	2.10^{ab}	2.44^{cd}	1.66^{cd}
5 t ha^{-1} CM+50% NP	2.60^{e}	1.99^{bc}	2.34^{cde}	1.59^{cde}
5 t ha^{-1} CM+75% NP	2.48^{ef}	1.81^{c}	2.25^{def}	1.53^{def}
7.5 t ha^{-1} CM+25% NP	2.36^{f}	1.54^{d}	2.20^{ef}	1.50^{ef}
7.5 t ha^{-1} CM+50% NP	2.34^{f}	1.52^{d}	2.17^{ef}	1.47^{ef}
7.5 t ha^{-1} CM+75% NP	2.3^{2}f	1.4^{6}d	2.0^{8}f	1.4^{1}f
100% NP	3.41^{b}	2.21^{a}	3.10^{a}	2.11^{a}
Control	3.7^{2}a	2.2^{6}a	3.0^{9}a	2.1^{0}a
LSD (5 %)	0.173	0.196	0.227	0.154
Significance	**	**	**	**
CV (%)	3.63	5.93	5.25	5.25

Means followed by the same letter within a column are non-significantly different to each other at * Significant at 5% level of significance ($P < 0.05$) and ** highly Significant at 1% level of significance. ($P < 0.01$) as established by LSD test; * CM = Cattle manure in t ha^{-1}.

Exchangeable Aluminum

The exchangeable aluminum pre-sowing soil was 2.01cmol (+) kg^{-1} soil in Belg 2.46cmol (+) kg^{-1} soil in Meher season (Table 2) while, soil total nitrogen after harvest ranged from 2.26 to 1.46cmol (+) kg^{-1} in Belg and to 2.10 to 1.41cmol (+) kg^{-1} in Meher season (Table 9). The highest exchangeable aluminum in Belg (2.26cmol (+) kg^{-1} soil) and Meher (2.10cmol (+) kg^{-1} soil) was recorded at control which might be due to a low organic matter reduces the affinity for Al+3 leads to increases the solubility and availability of aluminum. Similarly, Ayalew and Dejene [59] indicated that treatments with no fertilizer application be it inorganic N and Por organic gave highest exchangeable acidity and Al while the lowest exchangeable Al and acidity was obtained at the combined application of 46kg N + 40kg P + 50kg K + 20 t ha^{-1} CM, However, the lowest exchangeable Al+3in Belg(1.465cmol (+) kg^{-1}) and Meher (1.475cmol (+) kg^{-1}) were recorded at combined application 7.5 t ha^{-1} CM with 75% inorganic N and P 7.5 t ha^{-1} CM with50% inorganic N and P and 7.5 t ha^{-1} CM with 25% inorganic N and P which could be due to decomposition of cattle manure may add more Ca and Mg that may increase the affinity of aluminum, might result in a reduction of soluble and exchangeable aluminum. This result is in agreement with the work of Wong and Swift [60] reported decreased Al solubility because of the exchange between soil and organic matter with high cattle manure increases the soil pH this will decrease the solubility of Al. Similarly, Mccauley [61] stated that the reduction in exchangeable Ac and Al partly relates to the increase in soil pH because the increase in pH resulted in precipitation of exchangeable and soluble Al as insoluble Al hydroxides, thus reducing concentrations of Al in the soil solution

Effects of Treatments on Cation Exchange Capacity and Exchangeable Bases

Cation exchange capacity (CEC): Cation exchange capacity in pre-sowing soil was 20cmol (+) kg^{-1} in Belg and 19.3cmol (+) kg^{-1}inMeher. While (Table 2). Cation exchange capacity after harvest ranged from 16.35cmol (+) kg^{-1} to 22.04cmol (+) kg^{-1} in Belg and from 19.09cmol (+) kg^{-1}to23.96cmol (+) kg^{-1} in Meher season (Table 9). Accordingly, the highest CEC of 22.04cmol (+) kg^{-1} in Belg and 23.96cmol (+) kg^{-1} in Meher season were obtained from the combined application of 7.5 t ha^{-1} CM with 75% inorganic N and P and 7.5 t ha^{-1} CM with 50% inorganic N and P fertilizers in Belg and 7.5 t ha^{-1} CM with 75% inorganic N and P, 7.5 t ha^{-1} CM with 50% inorganic N and P and 7.5 t ha^{-1} CM with 25% inorganic N and P fertilizers in Meher season (Table 9). On the other hand, the lowest CEC observed in the control plots which could be attributed to the leaching of bases from the soil due to the high rainfall of the study areas, which were not replenished since there was no fertilizer provided to these plots thus decrease in organic matter content reduces site for carbon storage and sequestration, lowered microbial biomass in the soil and reduced nutrient reserves. The application of 7.5 t ha^{-1} CM in combination with 75% minral NP both in Belg and Meher could be due to the contribution of organic matter from CM to the high organic matter content in the plots than the other treatments.

In line with this result, Tolanur [62] reported that cation exchange capacity significantly increased with increase in organic manure in conjunction with inorganic fertilizer the mineral fertilizers which are readily taken up by the crop is subsisted by the use of organic amendments such as cattle manure has been

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recognized generally as an effective means for improving soil aggregation, structure and fertility causes increasing microbial diversity and populations, results in increasing surface charges, thus in turn leads to improvement in cation exchange capacity of soil. Similarly, Dorneles reported the highest CEC from the non-tillage system because of high organic matter as compared to another tillage system. Cation exchange capacity (CEC) of the soil is one of the most important components of soil fertility evaluation to supply nutrient cations to the soil solution and possible response to fertilizer application Sonon This indicates basic cations existing in a given soil and the natural and/or anthropogenic activities, acting upon these cations, thereby influencing the CEC of the soil. Xavier [63] (Table 10).

Table 10: Effect of application of inorganic NP and cattle manure on CEC (cmol (+) kg^{-1} soil, Ca+2(cmol (+) kg^{-1} soil, Mg^{+2} (cmol (+) kg^{-1}soil) of soil after crop harvest in Belg and Meher season in Masha district, south-western Ethiopia.

Treatment*	Belg			Meher		
	CEC	Ca^{+2}	Mg^{+2}	CEC	Ca^{+2}	Mg^{+2}
2.5 t ha^{-1} CM+25% NP	17.41^{efg}	6.39^{efg}	2.76^{bcde}	21.33^{bcde}	7.19^{bcde}	1.40^{efg}
2.5 t ha^{-1} CM+50% NP	17.01^{efg}	6.22^{efg}	2.70^{cde}	20.88^{cde}	6.98^{cde}	1.34^{fg}
2.5 t ha^{-1} CM+75% NP	17.98^{def}	6.63^{def}	2.76^{bcde}	21.35^{bcde}	7.18^{bcde}	1.48^{def}
5 t ha^{-1} CM+25% NP	18.3^{6d}e	6.7^{9d}e	2.89^{abcd}	22.20^{abcd}	7.54^{abcd}	1.54^{de}
5 t ha^{-1} CM+50% NP	18.86^{cd}	7.00^{cd}	2.98^{abc}	22.84^{abc}	7.80^{abc}	1.61^{cd}
5 t ha^{-1} CM+75% NP	19.2^{8c}d	7.1^{8c}d	2.99^{abc}	22.96^{abc}	7.86^{abc}	1.67^{cd}
7.5 t ha^{-1} CM+25% NP	20.01^{bc}	7.49^{bc}	3.07^{ab}	23.49^{ab}	8.09^{ab}	1.77^{bc}
7.5 t ha^{-1} CM+50% NP	20.88^{a}	7.86^{ab}	3.13^{a}	23.91^{a}	8.26^{a}	1.90^{ab}
7.5 t ha^{-1} CM+75% NP	22.04^{a}	8.36^{a}	3.14^{a}	23.96^{a}	8.28^{a}	2.06^{a}
100% NP	16.68^{fg}	6.08^{fg}	2.59^{de}	20.16^{de}	6.67^{cde}	1.23^{fg}
Control	16.35^{fg}	5.95^{g}	2.44^{e}	19.09^{e}	6.22^{de}	1.27^{g}
LSD (5 %)	1.36	0.57	0.33	2.31	0.98	0.19
Significance	**	**	**	**	**	**
CV (%)	4.29	4.86	6.78	6.17	7.71	7.09

Means followed by the same letter within a column are non-significantly different to each other at * Significant at 5% level of significance ($P < 0.05$) and ** highly Significant at 1% level of significance. ($P < 0.01$) as established by LSD test; * CM = Cattle manure in t ha^{-1}.

Exchangeable Calcium

Exchangeable calcium in pre-sowing soil was 6.5cmol (+) kg^{-1} soil in Belg 6.3cmol (+) kg^{-1} soil in Meher season (Table 2) while, soil exchangeable calcium after harvest ranged from 5.95to 8.36cmol (+) kg^{-1}in Belg and from 6.22 to 8.28cmol (+) kg^{-1}in Meher season (Table 10). The highest exchangeable ca^{+2} (8.36cmol (+) kg^{-1} soil) in Belg and (8.28cmol (+) kg^{-1} soil) in Meher season was recorded in the combined application, of a high dose of cattle manure(7.5 t ha^{-1}) with 75% inorganic N and P fertilizers that showed an increase of 40.36% and 33% in Belg and Meher season, respectively, as compared to zero application of nutrients. The elevated calcium levels were associated with decreasing exchangeable aluminum in this soil. with a dramatic increase in pH causes improvement in Exchangeable Calciumin conformity with this result, Shivan and Tolanur [62] reported that application of cattle manure in combination with inorganic fertilizers improved significantly exchangeable calcium when organic materials combine together with inorganic materials. On the other hand the lowest Exchangeable calcium (5.95cmol (+) kg^{-1} soil) in Belg and (6.22cmol (+) kg^{-1}) in Meher was obtained at zero application of nutrients which is statistically the same as application of 100% NP, 2.5t ha^{-1} CM + 25% NP, 2.5 t ha^{-1} CM+50% NP in Belg season and 100% NP, 2.5 t ha^{-1} CM+25% NP, 2.5 t ha^{-1} CM + 50% NP and 2.5 t ha^{-1} CM+75% NP in Meher season .

Exchangeable Magnesium

Exchangeable magnesium in pre-sowing soil was 2.1cmol (+) kg^{-1} in Belg 1.4cmol (+) kg^{-1} in Meher season while soil Exchangeable magnesium after harvest ranged from 2.44 to3.14 in Belg and 1.27 to 2.07 in Meher season (Table 2). The highest exchangeable magnesium content of soil after harvest (3.14cmol (+) kg^{-1} soil) in Belg and (2.07cmol (+) kg^{-1} soil) in Meher were recorded at combined application of cattle manure with 75% inorganic N and P (Table 9) This may be due to amending soil with cattle manure raises soil organic matter which increases the soil pH leads to greater activities of soil bacteria, which in turn improves availability of soil nutrients and the application of magnesium from any external sources improves the soil exchangeable magnesium. This result is partly in line with work of Daniel and Nigussie [21] reported that amending the soil with cow dung improves the soil exchangeable magnesium content of soil after harvest. In contrast, the lowest exchangeable magnesium content of the soil after harvest (2.44cmol (+) kg^{-1} soil) in Belg and (1.275 gcmol(+) kg^{-1} soil) in Meher were obtained at the zero application of nutrients (Table 11).

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Table 11: Exchangeable K+, Na+ and Pbs of soil after crop harvest as influenced by the combined application of cattle manure and inorganic NP in Belg and Meher seasons, in Masha district, south-western Ethiopia.

Treatmen[t*]	Belg			Meher		
	Exchangeable K^{+1} cmol (+) kg^{-1} soil	Exchangeable Na^{+1} cmol (+) kg^{-1} soil	Percent base saturation (%)	Exchangeable K^{+1}c-mol (+) kg^{-1} soil	Exchangeable Na^{+1} cmol (+) kg^{-1} soil	Percent base saturation (%)
2.5t ha^{-1} CM+25% NP	0.36^{de}	0.02	46.73^{ghi}	0.28^{cde}	0.20	48.73^{bcd}
2.5t ha^{-1} CM+50% NP	0.36^{de}	0.02	47.03^{fgh}	0.29^{bcde}	0.21	48.95^{abc}
2.5t ha^{-1} CM+75% NP	0.37^{cd}	0.03	47.40^{efg}	0.29^{bcde}	0.21	48.95^{abc}
5t ha^{-1} CM+25% NP	0.38^{bcd}	0.03	47.65^{def}	0.31^{abcd}	0.22	49.34^{abc}
5t ha^{-1} CM+50% NP	0.38^{bcd}	0.04	47.95^{cde}	0.30^{abc}	0.23	49.60^{ab}
5t ha^{-1} CM+75% NP	0.39^{bd}	0.04	48.20^{cd}	0.32^{abc}	0.23	49.65^{ab}
7.5t ha^{-1} CM+25% NP	0.40^{abc}	0.05	48.57^{cd}	0.33^{ab}	0.23	49.84^{ab}
7.5t ha^{-1} CM+50% NP	0.42^{ab}	0.06	49.01^{ab}	0.33^{a}	0.24	49.99^{a}
7.5t ha^{-1} CM+75% NP	0.43^{a}	0.07	49.54^{a}	0.34^{a}	0.24	50.0^{8}a
100%NP	0.35^{de}	0.01	46.48^{hi}	0.28^{de}	0.20	48.33^{cd}
Control	0.3^{1}e	0.01	46.20^{2}i	0.26^{e}	0.19	47.6^{5}d
LSD (5 %)	0.04	0.01	0.73	0.035		1.13
Significance	**	Ns	**	**	Ns	*
CV (%)	6.17	23.12	0.90	6.78	7.04	1.35

Means followed by the same letter within a column are non-significantly different to each other at * Significant at 5% level of significance ($P < 0.05$) and ** highly Significant at 1% level of significance. ($P < 0.01$) as established by LSD test; * CM = Cattle manure in t ha^{-1}.

Exchangeable Potassium

Exchangeable potassium in pre-sowing soil was 0.42cmol (+) kg^{-1} soil in Belg 0.36cmol (+) kg^{-1} soil in Meher (Table 2) while, soil Exchangeable potassium after harvest ranged from 0.31cmol (+) kg^{-1} soil to 0.43cmol (+) kg^{-1} soil in Belg and to 0.26 to 0.34cmol (+) kg^{-1} in Meher season. The highest exchangeable potassium of 0.43cmol (+) kg^{-1} soil in Belg and 0.34cmol (+) kg^{-1} soil in Meher was obtained at the combined application of 7.5 t ha^{-1} CM, with 75% inorganic N (165 kg N ha^{-1}) and P (137 kg P_2O_5 ha^{-1}) (Table 11). Which is statistically the same as 7.5 t ha^{-1} CM with 50% recommended dose of inorganic N (165 kg N ha^{-1}) and P (137 kg P2O5 ha^{-1}) and 7.5 t ha^{-1} CM with 25% recommended dose of inorganic N (165 kg N ha^{-1}) and P (137 kg P_2O_5 ha^{-1}) while the lowest exchangeable potassium in both seasons was recorded at zero rates organic and inorganic fertilizer (Table 10). The higher status of exchangeable potassium both in Belg and Meher seasons of higher dosage plots indicates amendment of soil with external fertilizers increases exchangeable K with an increase in nutrient dosage similarly Abay and Sheleme [59] reported that periodic assessments for potassium status of the soil and the effect of the crop to potassium are essential and as potato is a highly K demanding crop.

Percent Bases Saturation:

percent bases saturation: percent bases saturation in pre-sowing soil was 45.4% in Belg and 41.7% in Meher (Table 2) while, soil percent bases saturation after harvest ranged from 46.202%to 49.54% in Belg and to 47.65% to 50.08 % in Meher season. The highest percent bases saturation of 49.54(%) in Belg and 50.08(%) in Meher seasons) was obtained at the combined application of 7.5 t ha^{-1} CM with 75% and 50% (RDF) and 50.08(%) was obtained at 7.5 t ha^{-1} CM, with 75% (RDF) which is statically the same as all rates except Control, 100% NP,2.5 t ha^{-1} CM+25% NP, 2.5 t ha^{-1} CM+50% While the lowest percent bases saturation in both seasons was recorded at zero rates of either organic or inorganic fertilizer which is statistically the same as application of 100% NP and 2.5 t ha^{-1} CM+25% NP in Belg and Meher seasons (Table 11). The higher status percent bases saturation both in Belg and Meher seasons may be due to the addition of organic and inorganic amendment together increases organic matter, surface area for exchange site and this causes favorable environment for plant growth by reducing leaching, enhancing growth in density and length of root hairs Similarly Wasihun [64] reported that treatments with high organic matter have high PBS.

Conclusion

The soil test results after potato harvest revealed significant increase in soil, pH, EC, TN, available P, CEC, exchangeable calcium, exchangeable magnesium, exchangeable potassium, porosity and tuber yield of potato, on the other hand, significant in reducing soil bulk and particle density, exchangeable acidity and Al when CM was applied in combination with inorganic NP than the use of either zero application of NP or 100% recommended rate of NP at both seasons. Among the treatments, the combined application of 7.5 t CM with 75% inorganic NP fertilizer was superior. Hence, the use of CM (7.5 t ha^{-1}) with 75% recommended rate of N (123.75 kg N ha^{-1}) and P (103.05 kg P_2O_5 ha^{-1}) was found to be appropriate to improve the physico-chemical properties of the soil and to

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increase the productivity of potato in the study areas as compared to the 100% recommended rate of NP(165 kg N ha^{-1} and 137 kg P_2O_5 ha^{-1}) alone [65-75].

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