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Original Research Article

Effect of Blended NPS Fertilizer Application in Conjunction with Filter Cake and its Compost on Selected Soil Physicochemical Properties and Yield of Onion (*Allium cepa* L.*)* at Melkassa Research Center, Ethiopia

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Abstract

Low soil fertility is one of the identified factors limiting agricultural productivity of onion crop on smallholder farmers in central rift valley of Ethiopia. Inorganic fertilizers are used mostly to improve these conditions of soil. However, the use of sugarcane filter cake and its compost with NPS fertilizers as media for onion crop growth is not documented. With this context, field experiment was conducted in 2020/2021 cropping season at Melkassa Research Center to evaluate the effect of integrated application of sugarcane filter cake and its compost with NPS fertilizer on selected soil physicochemical properties and yield of onion. The treatments were laid down in randomized complete block design and replicated three times. The results of this study revealed that the bulk density of the study area with loam textural class was ideal for onion crop growth, while, soil total porosity and moisture content were in a minimum range of acceptable for crop production. The pH of the experimental soil was out of suitable range for onion production in which there is possibility of deficiency of most essential nutrients. The pre planting soil analysis exhibited that soils of study area were low in fertility status. This calls for the use of integrated soil fertility management practices that can improve soil fertility and enhance sustainable agricultural crop production. In response to this situation, integrated application of sugarcane filter cake and its compost with NPS fertilizers were evaluated. It has been found that the combined application of the organic and inorganic fertilizers improved physicochemical parameters of the soil and onion crop production. The estimated average marketable bulb yield of onion crop for current study was 39.27 t ha^{-1} at combination of 7.5 t ha^{-1} of composted sugarcane filter cake with 50% recommended NPS fertilizers. Therefore, application of 7.5t ha^{-1} filter cake compost with 50% recommended NPS fertilizers could be one option to solve the soil fertility problems of the soils of study area.

Keywords: Compost, Filter cake, Fertility management, NPS fertilizer, Onion, Yield

INTRODUCTION

Soil nutrient depletion and low soil organic matter contents are considered to be major constraints of crop production in central parts of Ethiopia [1]. The problem is more serious in Ethiopian central rift valley region of the country [2]. Moreover, this area has great economic importance to the national food security and foreign exchange earnings of the country through production of export crops [3]. In order to improve these conditions, soil nutrient replenishment should be done. This has been done by applying chemical fertilizers. However, high cost of chemical fertilizers coupled with the low affordability of small holder farmers was the biggest obstacle for chemical fertilizer use. In addition to this, inadequate supply or even unavailability of fertilizer at the time of need, the potential polluting effect of chemical fertilizer on the environment, becoming very costly for farmers to apply the full recommended rates [4].

Moreover, the current energy crisis prevailing higher prices and lack of proper supply system of inorganic fertilizers calls for more efficient use of organic residues such as sugar industry wastes [5]. Sugar industry wastes include by products (e.g. bagasse, filter cake, and molasses) during the processing of sugarcane and by product from ethanol processing such as vinasse [6]. For every 100 tons of sugar cane crushing on an average 4.5 tons of molasses, 3.3 tons of bagasse and 2.5 tons of filter cake are given out [7]. The sugarcane industry in Ethiopia, in combined form, produced a large amount of sugarcane by-products, amounting to about 7 x 10^4 tons of filter cake, 9.8 x 10^4 tons of molasses and 3.3 x 10^6 m^3 of vinasse, in the year 2012/2013 [8].

Integrated soil fertility management (ISFM) is the combined use of mineral fertilizers with organic resources such as filter cake waste and filter cake waste compost [9]. An integrated use of chemical fertilizers and filter cake as well as its compost has been confirmed to be highly beneficial for sustainable growing of horticultural crops such as onion production to smallholder farmers [10]. The potential of

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Ethiopia for onion production, for local consumption and export is immense. Onion crop is the major agricultural commodity on which Ethiopians are depending on their daily food. Onion can be well adapted to highland and low land soils of the country. In Ethiopia about 293,927.4 tons of bulbs were produced from 31,673.21 ha of land with an average yield of 9.28 t ha^{-1} [11].

The use of chemical fertilizers alone in blended form are unable to maintain and sustain long-term soil health and crop productivity because they are unable to improve soil physicochemical properties [12]. Gelaw [13] also indicated that Ethiopia faces a wider set of soil fertility issues beyond inorganic fertilizer use which has historically been the major focus for researchers include loss of soil organic matter, deficiency of trace elements and deterioration of soil physical properties. On other hand, sole application of organic fertilizer is also constrained by access to sufficient organic inputs, slow nutrients release and low nutrient content. The recent pattern of soil fertility management intervention that involves the use of the eco-friendly; cost effective and adaptive soil fertility management techniques that enable smallholder farmers to overcome the many limitations of chemical fertilizer uses [14].

Thus, integrated use of organic and mineral fertilizers is the best alternative technology used for tackling soil fertility depletion and sustainably increasing crop yields. Although, large amount of filter cake is produced from the Ethiopian sugar factory, the use of filter cakes and its compost as a fertilizer source is very limited in Ethiopia due to lack of awareness regarding to the effects of filter cake on soil physicochemical characteristics and onion yield. Thus, INM approaches involving filter cake and its compost with NPS blended fertilizers for onion production need to be investigated as little information is available in the country. Such information is particularly important input for onion producing community at study area. Moreover, there is a need to undertake research to identify the optimum rate of filter cake and filter cake compost with NPS mineral fertilizer for maximum onion production which can solve location-specific nutrient problems. Therefore, the main purpose of this study was to examine the effectiveness of integrated application of filter cake and filter cake compost with NPS fertilizer in improving soil physicochemical properties and onion yield.

MATERIALS AND METHODS

Description of the Study Area

Geographical Location and Area coverage

The study was conducted at Melkassa Agricultural Research Centre (MARC) which is found in Adama district during the cropping season of 2020/2021. It is located at a distance of 117 km from Addis Ababa and 17 km from Adama city on the street to Assela town within the Oromia National Regional State (ONRS) in the great Central Rift Valley of Ethiopia. Adama district is found in East Shewa Zone and geographically located between 8°33'35"-8°38'46"N latitudes and 39°10'57"-39°30'15"E longitudes [15] **(Figure 1)**. Total area of Adama district is estimated that 96,020 ha, while, the total area of Melkassa Agricultural Research Centre is 275 ha [16].

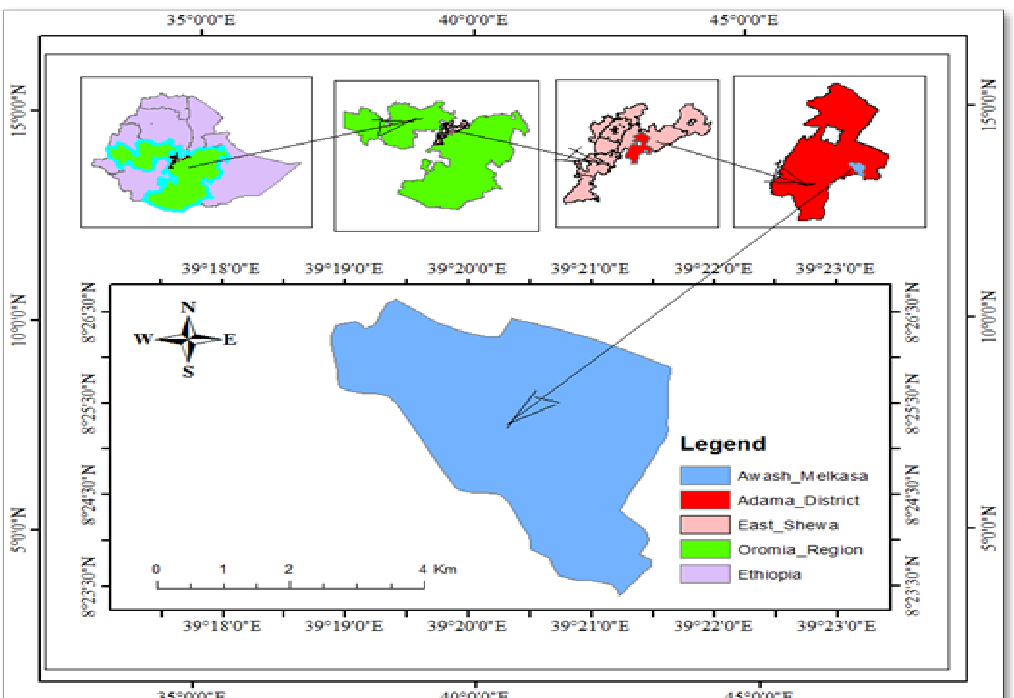

Figure 1. Location map of the study area (MARC).

Climate and topography

According to the classification of Agro-ecological zones by Ministry of Agriculture and Rural Development (MoARD) [17], the area is classified as semi-arid (67%), arid (7%) and sub-humid (26%). Melkassa Agricultural Research Centre is characterized by plain (50%), moderately plain (35%) and mountains (15%), respectively. It has tepid to cool sub-moist mid high lands agro-ecological zones, constrained by moisture stress, unreliable rainfall. The area is characterized by bimodal rainfall. The long-term meteorological data (1978-2021) reveals weather parameters that average annual rainfall in the area is 825.9 mm and more than 67% of the total rainfall of the area occurs from mid-June to mid-September, with its peak in the month of July and followed by August **(Figure 2)**. The mean minimum (Tmin) and maximum temperature (Tmax) was 14.04 and 28.81°C, respectively, while the elevation of study area was 1550 m.a.s.l.

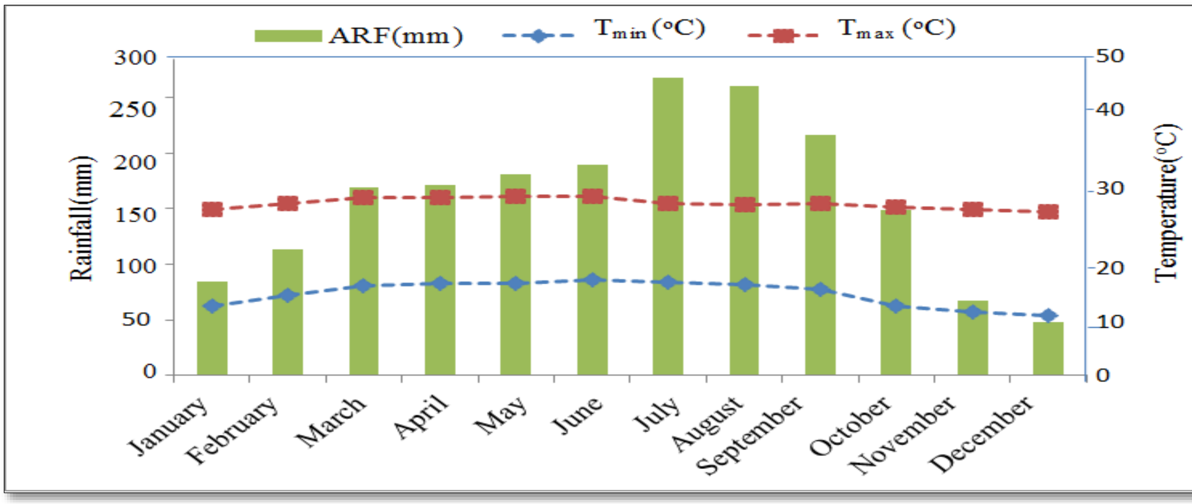

Figure 2. Long-term years (1978-2021) mean monthly annual rainfall (mm), minimum temperature (T_{min}) and maximum temperature (T_{max}) of the study area.

Soil types and parent materials

The soil of Melkasa Agricultural Research Center is classified as Haplic Andosol with a characteristic feature of deep pumice or volcanic according to FAO/ UNESCO Soil Classification System. The district soil textural class mainly varies from clay to clay loam. The area has organic matter less than 1% and soil pH ranges from neutral to mildly alkaline [18,19]. Soil of the study area formed from Sedimentary rock (unconsolidated) parent materials which have volcanic lacustrine terraces formed in quaternary lacustrine silt stone, sand stone, inter-bedded pumice and stuffs. It also has quaternary alluvial landforms, mostly bordering the main river valley or located at the foot of the higher plateaus, as alluvial colluvial cones [20].

Population, Land use and Farming System

The total population of Adama district estimated to be 155, 321 from this total population about 78, 997 are males and 76, 324 are females. The total land area of the district is about 96, 020 hectare, which the total arable land accounts 59, 220 ha (61.7%) while a very small forest cover 5,196 ha (5.4%) has aggravated and contributed to the effects of the climate change through the less tree cover that can assimilate the ever carbon concentration. Similarly, the total grazing land covers 1000 ha (1.04%) of the total land, about 15% of the district's land is found to be mountainous [21] and the others 16,201 ha (16.87%) account for construction area.

The district is characterized by a mixed-farming system that combines agro-pastoralism and cultivation of crops. Farmers in the study area grow crops three times per year in which September to January using traditional furrow irrigation, February to May using traditional furrow irrigation again and June to September using rainfall and irrigation as a supplementary. The dominant crops grown around the study area in response to the climatic variability are short season varieties of maize, sorghum, and tef, which are tolerant to the prevalent drought and resistant to disease and insect attack.

According to Admassu [22], Fruits, vegetables and sugarcane are important cash crops. The farmers also cultivate market valued crops such as pepper, tomato, onion, potato, shallot, haricot beans, sweet potato, and papaya using irrigation water particularly from Awash River source that serves 27% of the total irrigated agriculture of the country [23]. The major livestock reared are cattle, sheep, goat, donkey, poultry, and camel. Agricultural production at the study area (by farmers) is mainly depending on irrigation supported rainfall and oxen plough farming system.

METHODS OF STUDY

Compost materials and preparation procedures

Sugarcane industrial byproducts filter cake samples were collected from Wonji sugar factory and filter cake compost was prepared from filter cake and vinasse based on composting procedures established by Mahamuni and Patil [24].

Treatments and Experimental Design

The experiment was laid out in randomized Complete Block Design (RCBD) with three replications. The treatments consist of a combination of two rates of filter cake (5 and 7.5 t ha^{-1}), two rates of composted filter cake (5 and 7.5 t ha^{-1}) and three rates of NPS fertilizer (25, 50 and 75%) from recommended rate of NPS fertilizers (200 kg ha^{-1}) for the production of onion under irrigated production system as described by Nigatu [25]. Additionally, farmers practiced (2.5t FYM + 75% ha^{-1} NPS) and control was included as treatments. The treatment combinations were showed in **Table 1** below. The experiment was consisted of 15 treatment combinations and 45 experimental units (plots). The following 15 treatment combinations were evaluated as follows:

Table 1. Treatment combinations.

Tr.	Treatment combinations
1	Control
2	5 t ha^{-1} FC + 25% NPS
3	5 t ha^{-1} FC + 50% NPS
4	5 t ha^{-1} FC + 75% NPS
5	7.5 t ha^{-1} FC+ 25% NPS
6	7.5 t ha^{-1} FC+ 50% NPS
7	7.5 t ha^{-1} FC+ 75% NPS
8	5 t ha^{-1}FCC +25% NPS
9	5 t ha^{-1} FCC +50% NPS
10	5 t ha^{-1} FCC +75% NPS
11	7.5 t ha^{-1} FCC + 25% NPS
12	7.5 t ha^{-1} FCC + 50% NPS
13	7.5 t ha^{-1} FCC + 75% NPS
14	100% RR NPS
15	Farmers practices (2.5t FYM+75% NPS ha^{-1})

Tr.: Treatments; t ha^{-1}: Ton per hectare; FC: Filter cake; NPS: Nitrogen, Phosphorus and Sulfur; FCC: Filter cake compost; RR: Recommended rate; FYM: Farm yard manure

Experimental procedures and field management

The experiment was conducted at Melkassa Agricultural Research Center under furrow irrigation during hot seasons of November 2020 to June 2021. After test field selection the experimental field was cleared and prepared for sowing using standard land preparation practices of the center; tractor-mounted disk plowing and disk harrowing was carried to prepare fine experimental field starting from November 15/2020 to January 05/2021 seasons as described by Abebe [23]. The whole field was divided in to three blocks each containing fifteen plots. Then, the experiment was laid out in RCBD with three replications. An onion variety named Nafis, which is recently cultivated in the region with 90-100 maturity days and high yielding was used as test crop for this study [26].

The seeds were sown on well-prepared seed-bed of 1 m x 5 m double at seed rate of 90 g per bed on Nevember 28, 2020 at Melkassa Agricultural Research Center nursery site. It was sown in line 3cm deep with finger at spacing of 7cm between two seeds row and the bed was slightly watered. The seedlings management practice was made as per the MARC recommendation until seedlings reached stage of transplanting. Sugarcane filter cake and composted sugarcane filter cake were added and mixed thoroughly with top soil to experimental field about one month before transplanting. Then February 23/2021, after 55 days of sowing onion seedling transplanting was done to the experimental field when they were attains a 3 to 4 leaf stage and one-time application of NPS at transplanting was done by hand placement at desired rates.

The total area for test field and plot are 292.4 m^2 and 3.96 m^2 respectively. The spacing of 0.2, 0.5 and 1m was used between rows, plots and blocks, respectively. The study was done on ridges of about 25cm high, adopting the recommended spacing of 40cm between water furrows, 20cm between rows on the bed [27,28]. Each plot has three ridges and consisting of about 22 double plants per ridge and 132 plants per plot. The middle ridge was used for recording agronomic data. Onion is usually planted in flat ridges; after field transplanting of onion seedlings all agronomic practice such as cultivation, weeding, insect control and irrigation water application was done by adopting the recommended agronomic practices of onion production commonly in use at melkassa agricultural research center until seedlings reach stage of harvesting.

The field irrigation water was applied to each experimental plot was measured by 3-inch Parshall flume (PF) made from metal sheet and installed 10 m away from the nearest plot along main canal and prevents mixing of treatments between plots; each plot was irrigated separately by closing furrow ends (Dike). The total duration of the onion under treatment application was 113 days up to June 16/2021 after establishment and two more weeks before harvesting.

Soil sampling and sample preparation

Soil samples were collected both before and after planting from experimental field. Composite (using auger) composited by thoroughly mixing and core samples using core sampler of soil samples were collected. Before planting, samples were randomly taken from five different spots across each block from a depth of 0-20 cm to make one composite sample and one core sample per each block from a depth of 0-20 cm was collected. After harvesting, both core and composite soil samples were collected from each plot at a depth of 0-20 cm. Core samples and about 1kg of the collected composite samples from each was bagged, labeled and submitted to Melkassa Agricultural Research

Laboratory. In the laboratory sufficient amount of composite soil samples were air dried and ground to pass a 2 mm sieve except for organic carbon and total N in which 0.5 mm sieve was used. Then, soil samples were analyzed for physicochemical properties following standard laboratory procedures.

Soil Laboratory Analysis

Soil Physical Analysis

Soil particle size distribution was determined using hydrometer method [29]. After determining sand, silt, and clay separates; the soil was assigned to textural classes using the USDA soil textural triangle [30]. Bulk density was determined using the core method as described by Jamison [31]. Particle density was determined using pycnometer method following procedures described in Rao [32]. Total porosity was calculated from the value of bulk density and particle density using the formula described by Rowell [33]. Soil moisture content was determined using gravimetric method as described by Reynolds [34].

Soil Chemical Analysis

Soil pH was measured from soil suspension of 1:2.5 (w/v) soils to water ratio using a glass electrode attached to digital pH meter [35]. Soil electric conductivity was measured from soil suspension of 1:2.5 (w/v) soils to water ratio using digital conductivity meter [35]. Organic carbon was determined following the wet digestion method as described by Walkley and Black [36]. Soil organic matter was calculated from organic carbon using the formula described by Nelson and Sommers [37].

$$\text{Organic matter} = 1.724 * \text{Organic Carbon} \quad (1)$$

Total N was determined by the Kjeldahl procedure as described by Jackson [38]. Available phosphorus was extracted by using the Olsen method [39]. The P extracted with this method was measured by spectrophotometer following the procedures described by Murphy and Riley [40]. Available sulfur was determined using gravimetric determination following extraction with ammonium acetate (NH_4OAC) [41]. Cation exchange capacity (CEC) and exchangeable bases (Ca, Mg, K and Na) were determined from soil samples extracted by ammonium acetate (NH_4OAC) at pH 7.0. CEC was determined from the extract using ammonium acetate method described by Chapman [42]. Exchangeable Ca and Mg in the extracts was determined using atomic absorption spectrophotometer, while Na and K will be measured by flame photometer [33,42]. Percent base saturation of the soil samples was calculated by taking the ratio of the sum of the basic exchangeable cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) to CEC as percentage [43]. The result of soil analysis for prior to planting is presented in **Table 2** below.

Table 2. Soil physicochemical properties of the experimental site before planting.

Soil Chemical properties	Mean value
pH (H_20)	8.14
Electrical Conductivity (dSm^{-1})	0.242
Organic Carbon (%)	1.15
Total Nitrogen (%)	0.13
C:N ratio	8.85
Available Phosphorus (ppm)	11.78
Available Sulfur (ppm)	18.40
Exchangeable Na^+(cmol (+) kg^{-1})	0.45
Exchangeable K^+(cmol (+) kg^{-1})	1.74
Exchangeable Mg^{2+}(cmol (+) kg^{-1})	2.35
Exchangeable Ca^{2+}(cmol (+) kg^{-1})	19.43
CEC (cmol (+) kg^{-1})	24.96
PBS (%)	96.03
Sand (%)	46
Silt (%)	38
Clay (%)	16
Textural class	Loam
Bulk Density (gcm^{-3})	1.31
Particle Density (gcm^{-3})	2.59
Total porosity (%)	49.42
Soil Moisture Content (%)	18.66

FYM, Sugarcane Filter Cake and Its Compost Analysis

Available sulfur was determined using gravimetric determination following extraction with ammonium acetate (NH_4OAC) [41]. Calcium (Ca) and magnesium (Mg) was determined using Atomic Absorption Spectrophotometer (Hesse, 1971), while potassium (K) and sodium (Na) was measured using a flame photometer [42]. CEC was determined in ammonium acetate (NH_4OAc) solution at pH 7 and NH_4 concentration in the Representative samples of 10g were collected from FYM, raw filter cake and its matured compost separately from each for laboratory analysis. The physical (moisture content and temperature) and chemical (pH, OC, N, P, S, Ca, Mg, K, Na and CEC) parameters were determined. The percentage of moisture content of filter cake and its compost was calculated in the laboratory by oven dry method and the temperature was measured every week at a depth of 50 cm at different positions inside the pile of compost to analyze activities of the microbe with bi-metal dial thermometer method.

The pH of both filter cake and its compost was measured using pH meter glass electrode from the extract of the saturated filter cake and vermicompost [35]. Organic carbon content was determined following Walkley and Black [36] method. Total Nitrogen content was analyzed using the

Kjeldahl digestion, distillation and titration method as described by Nelson and Sommers [44]. Phosphorus content was analyzed by Vanadomolybdic calorimetric method according to Chaudhuri [45].

Solution determined by Kjeldhal distillation followed by titration with hydrochloric acid as described by Chapman [42]. The result of analysis is presented in **Table 3** below.

Table 3. Chemical characteristics of filter cake and its compost before application.

Chemical properties	Unit	FC	FCC	FYM
pH (H_2O)		6.61	7.82	7.54
Moisture Content	(%)	42.25	41.56	38.21
Organic Carbon	(%)	25.27	23.97	24.98
Total Nitrogen	(%)	1.15	2.59	1.17
C:N ratio	(%)	21.97	9.25	21.35
Available Phosphorus	(ppm)	1.41	2.19	1.98
Available Sulfur	(ppm)	0.51	1.25	1.06
Exchangeable Na^+	(cmol (+) kg^{-1}) (([+]/kg)	0.22	0.13	0.13
Exchangeable K^+	(cmol (+) kg^{-1})	0.67	3.89	1.11
Exchangeable Mg^{2+}	(cmol (+) kg^{-1})	2.02	4.25	1.92
Exchangeable Ca^{2+}	(cmol (+) kg^{-1})	2.11	5.77	2.03
CEC	(cmol (+) kg^{-1})	32.98	42.23	29.63

CEC: Cation Exchange Capacity; C:N: Carbon to Nitrogen Ratio; pH: Power of Hydrogen; FC: Filter Cake; FCC: Filter Cake Compost; FYM: Farm Yard Manure

Marketable bulb yield (t ha^{-1})

Marketable yield further categorized by weight in to large (100-160 g), medium (50-100g) and small (21-50g) and expressed as kg per plot and converted into t ha^{-1}. Total weight of clean, disease and damage free bulbs with greater than 21g in weight was considered as marketable bulb yield [46]. The total yield of single bulbs per plot was recorded and the yield per hectare calculated as equation 2 for total yield.

$$\text{Marketable Yield (t ha} - 1) = \frac{\text{marketable plot yeild (kg)}}{\text{plot area}} * \frac{10000}{1000} \quad (2)$$

Data analysis

Soil physicochemical properties and yield data collected were subjected to analysis of variance using GLM procedures of the statistical analysis system (SAS) soft-ware Version 9.2 [47]. Whenever the ANOVA detects significant differences (P<0.05) between treatments, mean separation was conducted using fisher's least significant difference test [48]. Simple correlation analysis was also performed to identify useful associations among key soil chemical parameters and onion plant variables.

RESULTS AND DISCUSSION

Effect of filter cake, its compost and NPS fertilizer on soil physico-chemical properties after planting

Effect of filter cake and its compost with NPS fertilizer on soil physical properties

Mean value results of soil bulk density, total porosity and moisture content of the after harvest soil analysis made at MARC in 2020/2021 is presented in **Table 4**.

Table 4. Effect of NPS with filter cake and its compost on soil physical properties.

Treatments	Bulk Density (g cm^{-3})	Total Porosity (%)	Moisture Content (%)
Control	1.30^{a}	49.81^{e}	18.68^{e}
5 t ha^{-1} FC + 25% NPS	1.25^{abc}	51.74^{cde}	39.01^{cd}
5 t ha^{-1} FC + 50% NPS	1.25^{abc}	51.74^{cde}	39.01^{cd}
5 t ha^{-1} FC + 75% NPS	1.21^{cde}	53.28^{abcd}	39.74^{bcd}
7.5 t ha^{-1} FC + 25% NPS	1.19^{edf}	54.05^{abc}	40.50^{abc}
7.5 t ha^{-1} FC + 50% NPS	1.18^{ef}	54.44^{ab}	40.79^{abc}
7.5 t ha^{-1} FC + 75% NPS	1.17^{ef}	54.83^{a}	41.08^{ab}
5 t ha^{-1} FCC + 25% NPS	1.24^{bcd}	52.12^{bcde}	39.06^{cd}
5 t ha^{-1} FCC + 50% NPS	1.24^{bcd}	52.12^{bcde}	39.06^{cd}
5 t ha^{-1} FCC + 75% NPS	1.19^{edf}	54.05^{abc}	40.50^{abc}
7.5 t ha^{-1} FCC + 25% NPS	1.18^{ef}	54.44^{ab}	40.79^{abc}
7.5 t ha^{-1} FCC + 50% NPS	1.16^{ef}	55.21^{a}	41.37^{ab}
7.5 t ha^{-1} FCC + 75% NPS	1.15^{f}	55.60^{a}	41.66^{a}
100 % NPS RR	1.26^{abc}	51.74^{cde}	38.48^{d}

FC: Filter cake; FCC: Filter cake compost; RR: Recommended rate; FP: Farmers practices; LSD: Least significant difference; CV: Coefficient of variation, numbers followed by the same letter in the same column are not significantly different at 5% probability level

Bulk density

Bulk density is an important parameter in soil fertility studies since it influences the transport as well as utilization rate of nutrients directly [49]. The mean value of soil bulk density showed significant ($P < 0.05$) variation among the different treatments applied **(Table 5)**. The bulk density ranged from 1.15g cm^{-3} (lowest) recorded from application of 7.5t ha^{-1} of filter cake compost with 50% recommended NPS fertilizer to 1.3g cm^{-3} (highest) from control. The lowest bulk density recorded from plots treated with 7.5t ha^{-1} of filter cake compost with 75% of recommended NPS fertilizer might be due to organic matter effect which can be evidenced by negative correlation ($r = -0.75$) between bulk density and organic carbon **(Tables 4 & 7)**. Inconsistent with this, Tesfaye [20]; Negessa and Tesfaye [51] reported that the inverse relationship between soil bulk density and organic matter content.

Total Porosity

Soil porosity is derived from dry bulk density and particle density which is important to conduct water, air and nutrients into the soil that are indirectly support crop production [52]. The combined application of organic and inorganic fertilizers significantly ($p < 0.05$) affected total porosity of the soil. The maximum total porosity (55.60%) was obtained from application of 7.5t ha^{-1} of filter cake compost with 75% of recommended NPS fertilizers and the lowest total porosity (49.81%) of the soil was recorded from control plot **(Table 4)**. The positive result for this finding might be due to corresponded higher organic matter contents and lower bulk density values of this treatment.

This could be supported by the correlation of total porosity ($r = -0.99^{**}$, $r = 0.71^{**}$) with bulk density and organic carbon, respectively **(Table 8)**. In line with this finding, Tesfaye [49] reported that the negative and positive correlation of total porosity, with bulk density and organic carbon respectively. Similarly, Fantaye [53] also reported that addition of filter cake compost improved the core index of the soil followed by increase in total porosity.

Soil moisture content

The soil moisture content is an indicator of the quantity of water existing and transport process in the soil [54]. Soil moisture content was significantly ($P < 0.05$) affected by the different treatments applied.

The maximum value of soil moisture content (41.66%) was obtained from application of 7.5 t ha^{-1} filter cake compost with 75% recommended NPS fertilizers, while, the lowest soil moisture content (18.68%) was recorded from control plots **(Table 4)**. The highest value of soil moisture content might be due to the presence of higher organic matter contents of this plot. In consistent with this finding, Tolera and Tesfaye [55] reported that the integrated application of organic and inorganic fertilizers were improved soil moisture over control might be due to enrichment of soil with organic matter sourced from filter cake compost which have high surface area. Similarly, Dotaniya [56]; Shehzadi [57] reported increment in soil water content as a result of application of filter cake compost.

From the effect of integrated application of filter cake and its compost with NPS fertilizer rates on soil physical properties, the application rate of filter cake compost with NPS fertilizer gave the highest value when compared with similar application rate of raw filter cake with NPS fertilizer.

The application of filter cake and its compost with NPS fertilizer rates gave highest value when compared with control, 100% NPS recommended rate and farmers practice of the study area. From the different rates of organic and inorganic fertilizers, the application of 7.5 t ha^{-1} filter cake compost with 75% recommended NPS fertilizers reduced the value of bulk density by (11.53, 3.08 and 2.31%), enhanced the value of total porosity by (10.41, 3.74 and 2.56%) and improved soil moisture content by (55.16, 51.46 and 51.39%) with respect to control, 100% NPS recommended rate and farmers practice as indicated in **Table 5**. This indicates that soil physical properties could be improved with enhanced integrated application of filter cake compost and inorganic fertilizers than the sole application of inorganic fertilizers to the soil.

Table 5. Effect of NPS with filter cake and its compost on soil chemical properties (pH, EC, OM).

Treatments	pH(H_2O)	EC(dSm^{-1})	OM (%)
Control	8.15^{a}	0.243^{a}	1.97^{g}
5t ha^{-1} FC + 25% NPS	7.85^{bc}	0.239^{abc}	2.76^{def}
5 t ha^{-1} FC + 50% NPS	7.80^{bcd}	0.234^{cde}	2.77^{cdef}
5 t ha^{-1} FC + 75% NPS	7.79^{cbde}	0.233^{def}	2.87^{bc}
7.5 t ha^{-1} FC + 25% NPS	7.77^{bcdef}	0.232^{defg}	2.88^{b}
7.5 t ha^{-1} FC + 50% NPS	7.75^{bcde}	0.231^{defg}	3.20^{a}
7.5t ha^{-1} FC + 75% NPS	7.70^{bcdef}	0.229^{efg}	3.22^{a}
5 t ha^{-1} FCC + 25% NPS	7.68^{bcdef}	0.235^{bcd}	2.86^{cbd}
5 t ha^{-1} FCC + 50% NPS	7.60^{cdef}	0.233^{def}	2.85^{bcde}
5 t ha^{-1} FCC + 75% NPS	7.55^{def}	0.232^{defg}	3.21^{a}
7.5 t ha^{-1} FCC + 25% NPS	7.53^{def}	0.230^{defg}	2.89^{b}
7.5 t ha^{-1} FCC + 50% NPS	7.51^{ef}	0.228^{fg}	3.23^{a}
7.5 t ha^{-1} FCC + 75% NPS	7.50^{f}	0.227^{g}	3.24^{a}
100 % NPS RR	7.93^{ab}	0.240^{ab}	2.75^{ef}
2.5t FYM +75 % NPS FP	7.96^{ab}	0.241^{a}	2.74^{f}
LSD (0.05)	0.28	0.01	0.1
CV %	2.17	1.44	2.12

pH: Power of Hydrogen; EC: Electrical Conductivity; OM: Organic Matte; FC: Filter cake; FCC: Filter cake compost; RR: Recommended rate; FP: Farmers practices; LSD: Least significant difference; CV: Coefficient of variation, numbers followed by the same letter in the same column are not significantly different at 5% probability level

Effect of filter cake and its compost with NPS fertilizer on soil chemical properties

The Post-harvest laboratory soil analysis mean values of pH, EC, OM, Nt, AvP, AvS, C: N, Exchangeable bases (Na, K, Mg, Ca), CEC and PBS were presented in **Tables 6-8**.

Table 6. Effect of NPS with filter cake and its compost on soil chemical properties (TN, Av. P, S, and C: N).

Treatments	**TN (%)**	**Av.P (ppm)**	**Av.S (ppm)**	**C:N**
Control	0.12^{i}	11.80^{h}	18.39^{e}	9.50^{f}
5t ha^{-1} FC + 25% NPS	0.25^{gh}	13.76^{ef}	19.85^{bcd}	9.92^{e}
5 t ha^{-1} FC + 50% NPS	0.27^{f}	13.78^{ef}	19.88^{bcd}	10.32^{d}
5 t ha^{-1} FC + 75% NPS	0.31^{e}	13.87^{def}	19.95^{bcd}	10.33^{d}
7.5 t ha^{-1} FC + 25% NPS	0.33^{d}	14.10^{bcd}	19.98^{bc}	10.50^{cd}
7.5 t ha^{-1} FC + 50% NPS	0.34^{cd}	14.20^{bc}	19.98^{bc}	10.57^{bc}
7.5t ha^{-1} FC + 75% NPS	0.35^{bc}	14.34^{b}	20.00^{bc}	10.67^{abc}
5 t ha^{-1} FCC + 25% NPS	0.26^{fg}	13.80^{ef}	19.88^{bcd}	10.50^{cd}
5 t ha^{-1} FCC + 50% NPS	0.31^{e}	13.82^{ef}	19.96^{bcd}	10.33^{d}
5 t ha^{-1} FCC + 75% NPS	0.33^{d}	14.00^{cde}	19.99^{bc}	10.50^{cd}
7.5 t ha^{-1} FCC + 25% NPS	0.35^{bc}	14.20^{bc}	19.98^{bc}	10.58^{bc}
7.5 t ha^{-1} FCC + 50% NPS	0.36^{ab}	15.26^{a}	20.40^{ab}	10.75^{ab}
7.5 t ha^{-1} FCC + 75% NPS	0.37^{a}	15.40^{a}	21.36^{a}	10.83^{a}
100 % NPS RR	0.24^{h}	13.70^{f}	18.96^{cde}	9.91^{e}
2.5t FYM +75 % NPS FP	0.24^{h}	12.40^{g}	18.89^{ed}	9.83^{e}
LSD (0.05)	0.02	0.25	1.1	0.19
CV %	3.43	1.06	3.32	1.12

TN: Total Nitrogen; Av.P: Available Phosphorus; Av.S: Available Sulfur; C: N: Carbon to Nitrogen Ratio; FC: Filter cake; FCC: Filter cake compost; FP: Farmer practiced; LSD: Least significant difference; CV: Coefficient of variation, numbers followed by the same letter in the same column are not significantly different at 5% probability level

Table 7. Effect of NPS with filter cake and its compost on soil CEC, Exchangeable bases and PBS.

Treatments	Exchangeable bases (cmol (+) kg^{-1})					PBS
	Na^+	K^+	Mg^{2+}	Ca^{2+}	CEC	%
Control	0.44^{a}	1.75^{j}	2.36^{g}	19.42^{f}	24.97^{g}	95.99^{f}
5 t ha^{-1} FC + 25% NPS	0.40^{c}	2.88^{g}	2.88^{fg}	27.78^{e}	34.94^{e}	97.14^{cdef}
5 t ha^{-1} FC + 50% NPS	0.37^{d}	2.90^{e}	2.91^{fg}	27.93^{e}	34.95^{e}	97.60 ^{bcdef}
5 t ha^{-1} FC + 75% NPS	0.33^{f}	3.14^{ef}	3.65^{de}	33.47^{d}	42.20^{d}	96.18^{ef}
7.5 t ha^{-1} FC + 25% NPS	0.31^{g}	3.88^{cd}	3.81^{d}	34.05^{cd}	42.67^{d}	98.55^{abcd}
7.5 t ha^{-1} FC + 50% NPS	0.29^{hi}	4.11^{abc}	4.50^{bc}	34.22^{bcd}	43.23^{cd}	99. 75^{ab}
7.5 t ha^{-1} FC + 75% NPS	0.27^{j}	4.17^{ab}	4.75^{ab}	34.86^{b}	44.36^{cd}	99. 30^{abc}
5 t ha^{-1} FCC + 25% NPS	0.36^{de}	2.95^{fg}	3.01^{f}	27.94^{e}	35.12^{e}	97.55^{cdef}
5 t ha^{-1} FCC + 50% NPS	0.35^{e}	3.24^{e}	3.09^{ef}	27.96^{e}	35.13^{e}	98.61^{abcd}
5 t ha^{-1} FCC + 75% NPS	0.28^{ij}	3.75^{d}	4.02^{cd}	34.42^{cb}	42.88^{d}	99.04^{abc}
7.5 t ha^{-1} FCC + 25% NPS	0.30^{gh}	3.98^{bcd}	4.50^{bc}	34.15^{bcd}	44.35^{bc}	96.80^{def}
7.5 t ha^{-1} FCC + 50% NPS	0.27^{j}	4.15^{ab}	5.02^{ab}	35.85^{a}	45.37^{ab}	99.82^{a}
7.5 t ha^{-1} FCC + 75% NPS	0.25^{k}	4.21^{ab}	5.14^{a}	35.94^{a}	46.38^{a}	98.19^{abcde}
100 % NPS RR	0.42^{b}	2.45^{h}	2.74^{fg}	27.49^{e}	34.07^{ef}	97.15^{cdef}
2.5t FYM +75 % NPS FP	0.43^{ab}	2.18i	2.60^{fg}	27.48^{e}	33.09^{f}	98.79^{abcd}
LSD (0.05)	0.02	0.25	0.59	0.81	1.15	2.19
CV %	2.92	4.39	9.62	1.56	1.77	1.34

FP: Farmers practice; CEC: Cation exchange capacity; Ca: Calcium; Mg: Magnesium; K: Potassium; Na: Sodium; PBS: Percent of Base Saturation, Numbers followed by same letter in the same column are not significantly different at 5 % probability level

Table 8. Correlation among selected soil physicochemical properties.

	BD	TP	SMC	pH	EC	OM	TN	Av.P	AvS	Na	K	Mg	Ca	CEC	PBS
BD	1														
TP	-0.99**	1													
SMC	-0.54**	0.50*	1												
pH	0.44*	-0.43*	-0.46*	1											
EC	0.58**	-0.54**	-0.54**	0.55*	1										
OM	-0.75**	0.71**	0.68**	-0.53*	-0.71**	1									
TN	-0.72**	0.68**	0.84**	-0.59**	-0.77**	0.92**	1								
AvP	-0.64**	0.59**	0.73**	-0.61**	-0.79**	0.84**	0.88**	1							
AvS	-0.51*	0.48*	0.55**	-0.36*	-0.57**	0.60**	0.66**	0.71**	1						
Na	0.70**	-0.65**	-0.59**	0.54**	0.83**	-0.83**	0.89**	-0.84**	-0.63**	1					
K	-0.72**	0.70**	0.67**	-0.55**	-0.80**	0.84**	0.92**	0.84**	0.64**	-0.96**	1				
Mg	-0.69**	0.65**	0.52*	-0.53*	-0.73**	0.80**	0.82**	0.77**	0.49*	-0.91**	0.87**	1			
Ca	-0.70**	0.66**	0.78**	-0.56**	-0.78**	0.89**	0.95**	0.84**	0.60**	-0.90**	0.94**	0.86**	1		
CEC	-0.73**	0.69**	0.74**	-0.58**	-0.78**	0.89**	0.94**	0.85**	0.63**	-0.93**	0.95**	0.89**	0.99**	1	
PBS	-0.22ns	0.19ns	0.50*	-0.18^{ns}	-0.39*	0.45*	0.47*	0.33*	0.37*	-0.36*	0.35*	0.23*	0.44^{ns}	0.37*	1

*Bd: Bulk density; TP: Total porosity; SMC: Soil moisture content; PH: Power of hydrogen; OM: Organic matter; AvP: Available phosphorus; AvS: Available sulfur; K: Potassium; TN: Total nitrogen; CEC: Cation exchange capacity; PBS: Percent base saturation; Mg: Magnesium; Ca: Calcium, Na: Sodium, *, ** and ns: significant, highly significant, and non-significant at 0.05 and 0.01 respectively*

Soil pH

Soil pH is a master key parameter that regulates most of the chemical reactions and microbial activities in the soil as well as availability of essential nutrients for plants [58,59]. Soil pH was significantly ($P < 0.05$) and highly affected by applied organic and inorganic fertilizers **(Table 6)**. The lowest soil pH (7.50) value was obtained from application of 7.5 t ha^{-1} filter cake compost with 75% recommended NPS fertilizer followed by the application of 7.5 t ha^{-1} filter cake compost with 50% recommended NPS fertilizer. While, the highest soil pH (8.15) was obtained from control plot **(Table 5)**.

The lowest soil pH (7.50) obtained from application of 7.5 t ha^{-1} filter cake compost with 75% recommended NPS fertilizer might be due to acidifying effect of inorganic fertilizer and acids produced during the process of decomposition of organic amendments. Due to enough organic matter available in filter cake compost soil pH reduced from 8.15 to 7.50 (by 7.98%) **(Table 5)**. This can be confirmed by negative correlation (r=-0.53**) between soil pH and organic matter **(Table 8)**. In line with this finding, Ghulam [60] and Bahadur [61] reported that addition of filter cake compost decreased pH of the soil. Similarly, Bashir [62] indicated that the addition of compost could reduce the soil pH due to the humification nature of compost.

Electrical conductivity (dSm^{-1})

Electrical conductivity can serve as a measurement of soluble salts in soil [63]. Soil Electrical conductivity was significantly (*P* < 0.05) affected by application of filter cake and filter cake compost with NPS fertilizer **(Table 5)**. The results clearly indicated that application of 7.5 t ha^{-1} filter cake compost with 75% of recommended NPS fertilizer reduced the EC from 0.243 to 0.227 dS m^{-1} (by 6.58%) with respect to the control. The reduction of EC might be due to organic matter provided to soil by filter cake compost which can be confirmed by negative correlation (r=-0.71**) between electrical conductivity and organic matter **(Table 8)**. Similar to this finding, Ghulam [60] suggested that addition of filter cake compost decreases EC of the soil. Correspondingly, Tazeh [64] also reported that application of manure and compost decreased soil EC.

Soil organic carbon (%)

Soil organic carbon is a reservoir of nutrients for crops, provides soil aggregation, increases nutrient exchange, reduces soil compaction, and retains moisture [65]. Soil organic matter was significantly ($P < 0.05$) affected by application of organic and inorganic fertilizers **(Table 5)**. The application of amendment filter cake and its compost with various levels increased soil organic matter over the control treatment **(Table 5)**. The highest soil organic matter (3.24%) was recorded from application of 75% recommended NPS and 7.5 t ha^{-1} filter cake compost, whereas, the lowest soil organic matter (1.97%) was recorded from control plots.

The increase in soil organic matter by 39.20% (1.97 to 3.24) following application of compost might be attributed to the high content of organic matter in the filter cake compost **(Table 3)**. This finding is in agreement with Lucelia [66] who reported that the addition of sugarcane industry byproduct increased organic matter content of the soil in comparison with mineral fertilizers. Similarly, Tesfaye [8] also reported increase in soil organic matter following application of filter cake compost, filter cake and vinasse to soils.

Soil total nitrogen (%)

Soil total Nitrogen is the most limiting element mostly obtained by plants from the soil [67]. Total soil nitrogen was significantly ($P < 0.05$) affected by application of organic and inorganic fertilizers to soil **(Table 6)**. The highest soil total nitrogen (0.37%) was recorded from application of 7.5t ha^{-1} filter cake compost with 75% recommended NPS fertilizer. The lowest soil total nitrogen (0.12%) was obtained from the control plots. The highest soil total nitrogen recorded from 7.5t ha^{-1} filter cake compost with 75% recommended NPS fertilizer might be related to the release of mineralized nitrogen from filter cake compost and N supplied to soil from the blended NPS fertilizer. This can be confirmed from highly significant positive correlation (r = 0.92**) between total nitrogen and organic matter **(Table 8)**. In line with this finding, Septyani [68] reported that addition of filter cake compost increase percentage of total nitrogen.

Soil available phosphorus (ppm)

Phosphorus (P) is the second limiting element in agricultural production of crops [33]. Soil available phosphorus was significantly ($P < 0.05$) affected by application of organic and inorganic fertilizers **(Table 6)**. Application of 7.5 t ha^{-1} filter cake compost and 75% recommended NPS fertilizer gave highest available phosphorus (15.40 ppm), while, the lowest soil available phosphorus (11.80 ppm) was obtained from the control plot **(Table 6)**.

The highest available phosphorus obtained from the plots treated with 7.5t ha^{-1} filter cake compost and 75% recommended NPS fertilizer might be due to relatively highest phosphorus released from filter cake compost and supplied from blended NPS fertilizer to soils of this plot. This can be confirmed by positive correlation (r=0.84**) between available P and organic matter **(Table 8)**. This finding is in agreement with Lucelia [66] who reported that addition of sugarcane industrial by product could increase soil available phosphorus. Similar study by Nduka [69] also reported that filter cake compost could release organic substances that can form complex with ions of Fe and Al in soil solution consequently can release fixed p.

Soil available sulfur (ppm)

Sulfur is one of the essential nutrients that is required for the adequate growth and development of plants; about 90% of sulfur in soil is found in organic matter and released through mineralization [70]. Soil available sulfur was significantly ($P < 0.05$) affected by application of filter cake and its compost with NPS fertilizer **(Table 6)**. Application of 7.5 t ha^{-1} filter cake compost with 75% recommended NPS fertilizer gave highest available sulfur (21.26 ppm) followed by 20.4 ppm from 7.5 t ha^{-1} filter cake compost with 50% of recommended NPS **(Table 6)**. While, the lowest value (18.39 ppm) was recorded for control plots.

The highest available S for 7.5t ha^{-1} filter cake compost with 75% recommended NPS fertilizer might be due to the sulfur released from compost and supplied from NPS fertilizers. This can be confirmed by positive correlation (r=0.60**) between available sulfur and organic matter **(Table 8)**. This finding is consistent with study reported by Prabhavathi and Ramakrishna [71] that the application of filter cake compost significantly improved availability of sulfur in soil. Similarly, Sinha [72] also reported that filter cake compost addition resulted in increase in available S might be due to S released from the filter cake compost.

C: N ratio

C: N ratio *is the intimate relationship between organic carbon and nitrogen contents in organic residues or soil* which controls N availability in soils to plants [73]. Soil C: N ratio was significantly ($P < 0.05$) affected by the application of filter cake and its compost with NPS fertilizer **(Table 6)**. Application of 7.5 t ha^{-1} filter cake compost with

75% of recommended NPS fertilizer gave highest C: N ratio (10.83) followed by 7.5 t ha^{-1} filter cake compost with 50 % recommended NPS fertilizer (10.75) **(Table 6)**, while, the lowest value (9.5) was recorded from control plots.

Relatively the lowest total carbon to nitrogen ratio after amendment indicates low organic residues as a result of rapid decomposition (organic residue is well decomposed), high microbial activity and mineral N can be released for onion plant use. This finding is in agreement with Tesfaye [74] who reported that C: N ratio less than 20:1 can release mineral N. Similarly, Yang [75] also reported that, lower C: N ratios in the amended soils indicate higher N mineralization by microbial activities.

Cation exchange capacity (cmol (+) kg-1)

CEC measures soil's ability to hold exchangeable cations and it is important for the overall nutrient dynamics in the soil [76,77]. The cation exchangeable capacity of the soil was showed significant ($P < 0.05$) difference with the application of filter cake and its compost with NPS fertilizer **(Table 7)**. The highest CEC (46.38) cmol (+) kg^{-1}) was obtained from application of 7.5 t ha^{-1} filter cake compost with 75% recommended NPS fertilizer **(Table 7)**. While, the lowest CEC (24.97 cmol (+) kg^{-1}) of soil was gained from control plots **(Table 7)**. The increase in CEC over the untreated plots might be attributed to the increase in soil organic matter content as a result of application filter cake compost. This can be evidenced with positive and significant correlation ($r = 0.89$**) between CEC and organic carbon **(Table 8)**. In line with this finding, Alemayehu and Sheleme [78] reported that CEC was positively correlated with organic carbon for surface soils. Similarly, Shi [79] reported that application of filter cake compost improves CEC value.

Exchangeable bases (Cmol (+) kg^{-1})

Exchangeable bases are important properties of soils indicate the existing nutrient status, and can also be used to assess the balances amongst cations [80]. Exchangeable calcium showed highly significant ($P < 0.05$) difference among the applied filter cake and its compost with NPS fertilizer **(Table 7)**. The highest (35.94 cmol (+) kg^{-1}) and the lowest value of exchangeable calcium (19.42 cmol (+) kg^{-1}) were recorded from the application of 7.5 t ha^{-1} filter cake compost with NPS fertilizer and control plots, respectively **(Table 7)**. The increment in exchangeable calcium above the control might be due to Ca^{2+} availability from organic matter from compost applied to soil. This can be confirmed by positive correlation ($r=0.89$**) between exchangeable Ca^{2+} and organic matter **(Table 8)**.

In agreement with this, Jufri [81] reported higher exchangeable Ca^{2+} content supplied to soil as a result of releasing from mineralization of the organic matter sourced from compost. Similarly, Prabhavathi and Ramakrishna [71] also reported that significant increase in the content of exchangeable calcium was observed due to application of filter cake and filter cake compost. Exchangeable magnesium also showed significant ($P < 0.05$) difference with the different treatments applied **(Table 7)**. The maximum mean soil exchangeable Mg^{2+} (5.14 cmol (+) kg^{-1}) was recorded from the application of 7.5t ha^{-1} filter cake compost with 75% NPS fertilizer, while the lowest exchangeable Mg^{2+} value (2.36 cmol (+) kg^{-1}) was obtained from control plots **(Table 7)**.

This increment in exchangeable magnesium might be due to increase in Mg^{2+} availability as a result of applied compost and through declining of pH as a result of the low pH of filter cake compost. This finding is in agreement with Samake [82] who reported increase in Mg^{2+} in the soil as a result of applied manure and improved soil pH.

Exchangeable K^+ also showed significant ($P < 0.05$) difference with the application of organic and inorganic fertilizer to soil **(Table 8)**. The maximum mean soil exchangeable K^+ (4.25%) was recorded from the application of 7.5 t ha^{-1} filter cake compost with 75% of recommended NPS fertilizer. The lowest exchangeable K^+ value (1.75%) was obtained from control plots **(Table 7)**. The increase in exchangeable K^+ over the control might be due to exchangeable K^+ released to soil through mineralization of organic matter sourced from filter cake compost. This result could be confirmed by positive correlation ($r=0.84$**) between exchangeable K^+ and organic matter **(Table 8)**. In line with this finding, Lakshmi [83] was reported that application of filter cake and its compost increased availability of K.

Exchangeable sodium showed significant ($P < 0.05$) difference with the application of filter cake and its compost with NPS fertilizer **(Table 7)**. The highest soil exchangeable sodium value (0.44 cmol (+) kg^{-1}) was recorded from control plots while the lowest soil exchangeable sodium (0.25 cmol (+) kg^{-1}) was obtained from 7.5 t ha^{-1} filter cake compost with 75% recommended NPS ha^{-1} fertilizer. The exchangeable Na^+ was decreased with application of organic and inorganic fertilizers to soil might be because of replacement of exchangeable sodium by Ca^{2+} that released from dissolution of the native calcium carbonate.

This result could be confirmed by negative correlation ($r=-0.83$**) between exchangeable Na^+ and organic matter **(Table 8)**. In line with this finding, Negim [84] reported that the reduction of exchangeable Na due to the effect of organic acids which produced during the process of decomposition of the amendments in which replacement Na by Ca occurred. This result was also in agreement with Nekir [85] who reported that exchangeable Na^+ was decreased with increasing application of filter cake compost.

Percent base saturation (%)

Percent base saturation (BS) is the percentage of the Cation-Exchange Capacity occupied by the basic cations (Calcium, Magnesium, Potassium and sodium) used to indicate the degree of leaching and evaporation of exchangeable bases from surface and sub-surface of soil [86]. The percent base saturation for this study was significantly ($P < 0.05$) affected by the application of organic and inorganic fertilizers **(Table 7)**.

The highest soil PBS (99.82%) was recorded from application of 7.5 t ha^{-1} filter cake compost with 50% recommended NPS fertilizers while, the relatively lowest mean value (95.99%) was obtained from control plots. This highest soil PBS finding could be attributed to relatively high content of organic matter possessed by filter cake compost which can release more basic cations to soil **(Table 3)**. This result could be confirmed by positive correlation (r=0.45*) between PBS and organic matter **(Table 8)**. This result was also similar with Zebire [87] who reported that the highest soil PBS recorded from plots treated with the highest organic matter with inorganic fertilizer.

From this result it could be summarized that the application of filter cake compost with NPS fertilizer gave the highest value when compared with similar application rate of raw filter cake with NPS fertilizer. Also the application of filter cake and its compost with NPS fertilizer rates gave highest value when compared with control, 100% NPS recommended rate and farmer practiced of the study area.

From the rates of filter cake compost, the application of 7.5 t ha^{-1} filter cake compost with 75% recommended NPS fertilizers reduced the value of pH by (7.98, 2.70 and 2.33%), EC (6.58, 1.23 and 0.82%), exchangeable Na (43.18, 4.55 and 2.27%) and enhanced the value of organic matter (39.01, 28.36 and 28.10%), total N (67.57, 50 and 50%), available P (23.38, 13.87 and 4.84%), available S (13.90, 3.01 and 2.65%), exchangeable K (58.43, 28.57 and 19.72%), Mg (54.09, 13.87 and 9.23%), Ca (45.97, 29.36 and 29.33%), CEC (46.16, 26.71 and 24.54%), PBS (3.84, 1.19 and 2.83%) compared with control, 100% NPS recommended rate and 75% NPS ha^{-1} farmers practice, respectively **(Tables 5-7)**. This result indicates that soil chemical properties were improved due to integrated application of filter cake compost and inorganic fertilizers than the sole application of inorganic fertilizers and integrated application of raw filter cake to the soil.

Pearson correlation among selected soil physicochemical properties

The correlation analysis among soil physicochemical properties was indicated in Table 9. The correlation analysis showed that bulk density of the soil was significantly and negatively correlated with total porosity (r = -99**), soil moisture content (r = -0.54**), organic matter (r = -0.63**), total N (r = -0.72**), available P (r = -0.64**), available S (r = -0.51**). In contrary, soil organic matter was significantly and positively correlated with SMC (r = 0.86**), total N (r = 0.92**), available P (r = 0.84**), available S (r = 0.60**), CEC (r = 0.89**), PBS (r = 0.45**), exchangeable K (r = 0.84**), Mg (r = 0.80**) and Ca (r = 0.89**) as shown in **Table 8**.

Marketable bulb yield (t ha-1)

The mean values of marketable bulb yield of nafis onion was significantly ($p < 0.05$) affected by different rates of application of filter cake and its compost with NPS fertilizer **(Table 9)**. The highest values of marketable bulb yield (39.27 t ha^{-1}) was obtained from application of 7.5 t ha^{-1} of filter cake compost with 50% recommended NPS fertilizers followed by 7.5 t ha^{-1} filter cake compost with 75% recommended NPS fertilizer (37.95 t ha^{-1}); while the lowest values of marketable bulb yield (28.62 t ha^{-1}) was recorded from control plots **(Table 9)**.

Table 9. Main effects of filter cake and its compost with NPS fertilizers on yield of nafis onion.

Treatments	MBY (t ha^{-1})	Onion yields	
		UnMBY (t ha^{-1})	TBY (t ha^{-1})
Control	28.62^{e}	0.55^{a}	29.17^{f}
5 t ha^{-1} FC + 25% NPS	33.29^{d}	0.52^{c}	33.81^{de}
5 t ha^{-1} FC + 50% NPS	33.31^{d}	0.48^{d}	33.79^{e}
5 t ha^{-1} FC + 75% NPS	35.87^{c}	0.44^{ef}	36.31^{bcd}
7.5 t ha^{-1} FC + 25% NPS	35.94^{c}	0.43^{f}	36.37^{b}
7.5 t ha^{-1} FC + 50% NPS	37.88^{b}	0.35^{gh}	38.23^{ab}
7.5 t ha^{-1} FC + 75% NPS	37.92^{ab}	0.33^{i}	38.25^{ab}
5 t ha^{-1} FCC + 25% NPS	33.86^{d}	0.47^{d}	34.33^{cd}
5 t ha^{-1} FCC + 50% NPS	35.98^{c}	0.45^{e}	36.43^{b}
5 t ha^{-1} FCC + 75% NPS	37.90^{b}	0.34^{hi}	38.24^{ab}
7.5 t ha^{-1} FCC + 25% NPS	35.96^{c}	0.36^{g}	36.32^{bc}
7.5 t ha^{-1} FCC + 50% NPS	39.27^{a}	0.27^{k}	39.54^{a}
7.5 t ha^{-1} FCC + 75% NPS	37.95^{ab}	0.29^{j}	38.24^{ab}
100 % NPS RR	33.27^{d}	0.53^{bc}	33.80^{de}
75 % NPS FP	33.24^{d}	0.54^{ab}	33.78^{e}
LSD (0.05)	1.36	0.02	2.49
CV %	2.30	2.40	4.15

MBY: Marketable Bulb Yield; UnMBY: Un Marketable Bulb Yield; TBY: Total Bulb Yield; Numbers followed by same letter in the same column is not significantly different at 5 % probability level

The application of 7.5t ha^{-1} filter cake compost with 50% recommended NPS fertilizers increased marketable bulb yield by about 27.12, 15.23, 15.4 and 3.54% over the control, RR of NPS, farmers practiced, similar rate of filter cake with NPS, respectively. This might be due to the synergetic effects of many factors such as increase in bulb size, bulb weight, photosynthesis activities and in turn enhanced growth as well as expansion of vegetative growth as a whole of bulbs at maturity. Beside this, the complementary effects of plant nutrients available in NPS and filter cake compost improved soil conditions, bulb weight, bulb diameter, and total bulb yield. Similarly, as suggested by Miruts [88] the estimated average marketable bulb yield of onion crop for experimental plots is 40t ha^{-1}, which is much higher than the yield recorded under smallholder farmers at study area of 27.12 t ha^{-1}. However, the experimental yield for this study was 39.27t ha^{-1} at combination of 7.5 t ha^{-1} filter cake compost with 50% recommended NPS fertilizers.

Moreover, increase in essential nutrients and organic matter promotes microbial population, which ultimately enhances the plant growth and production at sustainable basis. This could be confirmed by significant and positive correlation (r = 0.90**, 0.91**, 0.82**, 0.60**, 0.92**) of marketable bulb yield with OM, TN, Available P, S and CEC, respectively. Similarly, Bagali [89]; Gessesew [90] and Alpona [91] reported that application of inorganic and organic fertilizers resulted in higher marketable bulb yields of onion. In line with this finding, Gebremichael [92] reported that application of vermicompost and N mineral fertilizer gave the highest marketable onion bulb yield compared to control plots.

Pearson correlation among some soil properties, growth and yield parameters

The highest yield from compost integrated with NPS fertilizer plot over the control might be attributed to extraction of large quantity of mineral nutrients by onion crop from sufficient available nutrients supplied to soil by compost and blended fertilizers. Similarly, Rai [91] stated that incorporation of organic and inorganic fertilizers improved soil physical property and nutrient availability that may have a direct effect on onion crop growth and yield attributes. Combined applications of filter cake compost with NPS chemical fertilizers are more effective than sole application of filter cake compost or NPS blended fertilizers for sustainable onion productivity enhancement.

Moreover, there were significantly positive correlation (r = 0.90**, 0.91**, 0.82**, 0.60**, 0.92**) between onion marketable bulb yield and soil OM, total N, available P, S contents and CEC, respectively. The positive correlations among onion MBY and soil total N, available P, S, CEC and OM status indicates that the soil nutrient status may affects onion yield and yield components directly. However, soil bulk density decreased due to application of organic fertilizer and showed a negative correlation (r = -0.68**) with onion MBY **(Table 10)**.

This also indicated that incorporating combination of filter cake and its compost with blended NPS fertilizers in the soil not only improved the nutrient status, but also resulted in good physical conditions of the topsoil and thus significantly favored optimum shoot and root growth parameters and enhanced nutrient use efficiency by the onion crop with ultimate increased marketable yield and onion crop productions. Similarly, Wairegi [92] also reported that onion MBY could be enhanced and sustained by the addition of integrated form of compost and mineral fertilizers.

Table 10. Correlation among some soil physicochemical properties and agronomic traits.

	BD	pH	OM	Nt	AvP	AvS	CEC	MBY	TBY
BD	1								
pH	0.43*	1							
OM	-0.63**	-0.53*	1						
TN	-0.72**	-0.59**	0.92**	1					
AvP	-0.64**	-0.61**	0.84**	0.88**	1				
AvS	-0.51*	-0.36*	0.6**	0.66**	0.71**	1			
CEC	-0.73**	-0.58**	0.89**	0.94**	0.85**	0.63**	1		
MBY	-0.68**	-0.65**	0.90**	0.91**	0.82**	0.60**	0.92**	1	
TBY	-0.48*	-0.52*	0.82**	0.80**	0.75**	0.41**	0.79**	0.78**	1

*BD: Bulk Density; OM: Organic Matter; TN: Total nitrogen; Av. P: Available phosphorus; Av.S: Available sulfur; CEC: Cation exchangeable capacity; MBY: Marketable bulb yield; TBY: Total bulb yield; *: significant at $p \leq 0.05$; **: Highly Significant at $p \leq 0.01$*

CONCLUSIONS AND RECOMMENDATIONS

The results of this study showed that the bulk density of the study area with loam textural class was ideal for onion crop growth; whereas soil total porosity and moisture content were in a minimum range of acceptable for crop production. In contrary to this, the pH of the experimental soil was out of suitable range for onion production in which there is possibility of deficiency of most essential nutrients. Continuous cultivation and lack of incorporation of enough organic materials to the soils made the soil low in total nitrogen, available phosphorus, available sulphur and organic matter. The low values of these soil chemical properties recorded from pre planting soil analysis exhibited that soils of study area were low in fertility status. This calls for the use of integrated soil fertility management practices that can improve soil fertility and enhance sustainable agricultural crop production. In response to this situation, integrated application of filter cake and its compost with NPS fertilizers were evaluated. It has been found that the combined application of the organic and inorganic fertilizers increased physical parameters of soils (total porosity, moisture content) and chemical parameters (Om, TN, av.P, av.S, CEC, basic cations (Ca, Mg, K).

Similarly, agronomic parameters (plant height, bulb weight, marketable bulb yield and total bulb yield) were also improved by the combined application of the organic and inorganic fertilizers. In contrary to this, bulk density, pH and exchangeable sodium were reduced in response to these applied organic and inorganic fertilizers. Application of higher dose of filter cake compost with NPS fertilizers was increased marketable bulb yield by about 27.12, 15.23, 15.4 and 3.54% over the control, recommended rate of NPS, farmers practiced, and the same rate of filter cake with NPS, respectively. The estimated average marketable bulb yield of onion crop for experimental plots is 40t ha^{-1}, which is much higher than the yield recorded under smallholder farmers at study area of 27.12t ha^{-1}. However, the experimental yield for this study was 39.27t ha^{-1} at combination of 7.5 t ha^{-1} filter cake compost with 50% recommended NPS fertilizers.

From this finding it can be concluded that low soil fertility is major factors hampering the production and productivity of onion crop at Melkasa area which require an urgent attention to resolve the situation. In response to this, application of integrated NPS fertilizer and filter cake compost with different rates improved soil physicochemical properties and yield of onion crop. Moreover, combined applications of filter cake compost with NPS chemical fertilizers are more effective than application of filter cake of the same rate, recommended rate of NPS and farmers practiced for sustainable onion productivity. Therefore, application of 7.5 t ha^{-1} filter cake compost with 50% recommended NPS fertilizers could be one option to solve the soil fertility problems of the soils of study area in turn to reduce the yield gap seen between smallholder farmers and experimental fields.

Based on the findings and conclusions of this study the recommendations are; soil management practices that can increase low soil fertility status and reduce soil pH are important at Melkasa area. Based on the highest marketable bulb yield obtained, combined application of integrated filter cake compost at 7.5t ha^{-1} and 50% recommended NPS fertilizer can be recommended as the most suitable combination and dose for maximum growth and yield of onion and suggested for onion growing farmers in central rift valley of Ethiopia. Likewise, since this result is based on one season and location work, further study is suggested to repeat the experiment at the study district, different locations, and seasons by including other onion varieties. Furthermore, inclusion of cost-benefit analysis also suggested as a future line of work to make a generalized recommendation.

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