

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 Ca²⁺ availability from organic matter from compost applied to soil. This can be confirmed by positive correlation ($r=0.89^{**}$) between exchangeable Ca²⁺ and organic matter (**Table 8**).

In agreement with this, Jufri [81] reported higher exchangeable Ca²⁺ 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 Mg²⁺ (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 Mg²⁺ value (2.36 cmol (+) kg⁻¹) was obtained from control plots (**Table 7**).

This increment in exchangeable magnesium might be due to increase in Mg²⁺ 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 Mg²⁺ 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 Ca²⁺ 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 ($r = -0.99^{**}$), 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 ≤ 0.05; **: Highly Significant at p ≤ 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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