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ORIGINAL RESEARCH

Effect of bagasse ash and filter cake amendments on wheat (*Triticum turgidum* L.var. *durum*) yield and yield components in nitisol

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Abstract
Purpose This experiment was initiated to evaluate the effect of filter cake and bagasse ash on the productivity of wheat under greenhouse conditions.
Methods Six levels of filter cake and bagasse ash each separately and control check were arranged in a completely randomized design with three replications.
Results At 100 tons/ha, both inputs resulted in the highest values of all the investigated traits. It was also found that yield and yield components that were obtained from bagasse ash overwhelmed those from filter cake treatments, except in tillers, dry biomass, and straw yield. Linear regression analysis revealed a significant and positive relationship between grain yield with that of total N, P, K, S, Ca, Mg, Cu, and Zn uptake. A linear relationship between the grain yield with that of N and Zn uptake was found, while the association between grain yield with total P, K, S, Ca, Mg and Cu uptake was quadratic.
Conclusion It can be concluded that filter cake and bagasse ash are good sources of nutrients to enhance wheat yield in acidic soil. To give a conclusive result, these inputs should be tested in field trials in different soil types.

Keywords Bagasse · Ethiopia · Filter cake · Soil acidity · Subsistence farmers

Introduction

Durum wheat (*Triticum turgidum* L var. durum) is the most important cereal crop grown in Ethiopia. Ethiopia is believed to be the center of genetic diversity for wheat (Tesfaye and Getachew 1991). It is primarily produced by the smallholder farmers under rainfed conditions at altitudes ranging from 1800 to 2800 meters above sea level (Tesfaye 1987). Prior to 1954, Ethiopia was an exporter of durum wheat grain and flour (Pinto 1971). However, consumer demand presently far exceeds domestic production and the country is even importing wheat products for the pasta industry.

Although many efforts have been made to develop high-yielding variety of wheat in Ethiopia, the productivity of wheat is still far below the potential yield reported elsewhere as a result of soil quality depletion and low soil fertility (Harden 2001; Lal 2001). The deficiency of some micronutrient besides widespread N and P (and localized K) deficiencies in major wheat-growing areas of Ethiopian has been recently reported (Hailu et al. 2015). These problems are aggravated by continuous nutrient depletion due to the complete harvest of whole plant biomass and losses in runoff and soil erosion (Vlek 1993; Sanchez et al. 1997), which have led to negative nutrient balances (Stoorvogel and Smaling 1990). Crop yield per hectare has eventually decreased (Vierich and Stoop 1990). As a result, most of the soil in eastern Africa is less responsive as well as non-responsive to macronutrients like N (Bationo et al. 1986).

Agro-ecology-based production systems have promoted sustainable agricultural production systems (Altieri 1995; Gliessman 1998). Agricultural practices based on organic amendments are strongly recommended for tropical agro-ecosystems. The application of organic inputs to the soil is increasing as both an environmentally favorable and as a means of improving soil organic matter (SOM) content in low-fertility soils. Organic leftovers, namely, plant biomass, manure, and waste from urban, industrial, and agricultural activity are identified as valuable natural resources that can

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be effectively used for sustainable production and ecosystem restoration. Such organic inputs are useful inputs for the potential restoration of soil organic matter and increase inherent soil nutrient supply capacity (Fernandez-Luqueno et al. 2009; Nurhidayati et al. 2018) since manures are often scarce like in Ethiopia (Lupwayi et al. 2000). Organic by-products originating from industrial processes represent an important source of nutrients for integrated soil fertility management.

Organic amendment could increase the soil P supplying capacity in acidic soils through increasing P mobility in the soil by chelating the soil Al and Fe, thereby enhancing P acquisition by stimulation of root growth achieved by organic amendment (Kretzschmar et al. 1991). The organic amendment may also increase the soil pH, the contents of exchangeable cations (K, Ca, Mg) and the base saturation (Kretzschmar et al. 1991; Geiger et al. 1992). Maize grain yields tended to increase with increasing contents of soil C, total N, extractable P, and exchangeable bases as result of organic input application (Tittonell et al. 2007).

After combustion, most of the inorganic nutrients in biomass ash could be a significant source of P, K, Mg and Ca (Bougnom and Insam 2009; Bougnom et al. 2009). Biomass ash application could increase soil pH and stimulated bacterial activities that in turn increase decomposition rate of the humus layer, N mineralization, and N availability to plants (Fritze et al. 1994; Kreutzer 1995; Haimi et al. 2000). A significant increase in growth and yield of different crops due to biomass ash application has been reported (Odiete et al. 2005; Adekayode and Olojugba 2010; Gupta et al. 2010). For instance, biomass ash application resulted in a better increase in grain yields of barley (*Hordeum vulgare* L.), canola (*Brassica rapa* L.), and pea (*Pisum sativum* L.) when compared to the effect of agricultural lime have been reported (Arshad et al. 2012). However, the comparative advantage of filter cake and bagasse ash application on the productivity of wheat in acidic nitisol soil is not well known. Hence, the aim of this work was to evaluate the effect of filter cake and bagasse ash application on yield of wheat and to evaluate the relationship between the nutrients uptake with grain yield of wheat.

Materials and methods

A greenhouse experiment was performed on a silty clay soil classified as Eutric Nitisols, collected from the Endibir area (Central Ethiopia). For soil collection, the fields of 20 farmers were purposely selected based on the extent of soil acidity. Soil samples were collected from 0 to 20 cm depth at random from the fields of these 20 farmers and mixed well. The dried soil sample was passed through a 4-mm sieve to eliminate coarse rock and plant material and thoroughly mixed to ensure uniformity. A subsoil sample of about 1 kg was taken, air dried, and passed through a 2-mm sieve and used for the determination of physical and chemical characteristics. A part of the homogenized soil sample was ground to pass through a 0.5-mm sieve for the analysis of N, organic matter (OM), Cu, Zn, Fe and Mn concentrations.

The soil was analyzed using standard procedure compiled by Sertsu and Bekele (2000). The soil had an average pH of 5.1 in a 1:2.5 soil-to-water ratio. The chemical composition of the soil before amendment contained 3.4% OM, 0.16% total N, 10 mg/kg available P, 35.18 mg/kg available sulfur; 0.54 meq/100 g soil of exchangeable acidity (Al + H); 44 mg/kg of Fe; 154 mg/kg of Mn; 0.56 mg/kg of Cu; 2.40 mg/kg of Zn, and 0.25, 1.89, 5.04 and 2.80 cmol (+)/kg exchangeable Na, K, Ca and Mg, respectively. The textural composition of the soil was 9% sand, 45.5% silt and 45.5% clay with the bulk density of 1.27 gm/cm^3. The volumetric soil water contents of the soil were 32 and 18% and 14% for field capacity, available water, and permanent wilting point, respectively.

Samples of both filter cake and bagasse ash were air dried and screened through a 2-mm sieve. Samples were sealed in polyethylene plastic containers until use for analysis or in the experiments. Triplicate samples from both filter cake and bagasse ash were analyzed for the selected chemical composition according to methods described for soil analysis. The chemical composition of both inputs is indicated in Table 1.

The pot experiments were conducted on wheat under greenhouse conditions using cleaned plastic pots of 24 cm height and 25 cm width. Each pot contained 4 kg of soil. There were 11 treatments comprising 5 levels of filter cake application (20, 40, 60, 80 and 100 tons/ha) and 5 levels of bagasse ash application (20, 40, 60, 80 and 100 tons/ha) separately, and the control check with 4 replications. Four replicates per treatment were established in a completely

Table 1 Chemical properties of filter cake and bagasse ash

Parameter	Filter cake	Bagasse ash
pH (H_2O)	8.0	10.2
EC (ds/m)	1.70	3.90
OM (%)	36.2	3.6
N (%)	1.77	0.17
Available P (mg/kg)	1.62	0.85
Available S (mg/kg)	1.67	1.29
K (%)	0.16	0.05
Ca (%)	1.3	1.45
Mg (%)	0.31	0.70
Fe (mg/kg)	3	3
Mn (mg/kg)	39	19
Cu (mg/kg)	1.24	0.40
Zn (mg/kg)	31.00	10.50

randomized design (CRD). A total of 44 experimental units were used during the experiment.

The pot plants were harvested when physiologically matured. Samples of grain and straw collected at harvesting were oven-dried in an oven at 65 °C till a constant weight was obtained and then ground and passed through a 0.5-mm screen for chemical analysis. The uptake of selected macronutrients and micronutrients was calculated by multiplying the concentration of each nutrient by the dry weight expressed in kg/plant.

Agronomic data were collected and assessed to evaluate the effect of filter cake and bagasse ash on durum wheat. The agronomic parameters and yield and yield components determined are number of tillers, grain yield (GY), above-ground biomass, harvest index (HI), spike length, number of kernels per spike, number of spikelet per spike, and 1000 kernel weights of durum wheat. Plant root length was also taken by flushing with tap water to assess the effect of filter cake and bagasse ash on root length as it was affected by soil acidity.

All analyses were carried out on the four replicates. Treatment effects were analyzed by one-way analysis of variance (ANOVA). Data analysis was performed with SAS version 9.0. Data on soil, yield and yield traits of the crop were compared at a significance level of 0.05. The means were separated by Tukey's test. Linear regression analysis of grain yields against nutrients uptake was performed to determine trends. The probability values of the slope indicated the level of significance of observed changes in yield.

Table 2 ANOVA data of filter cake treated agronomic parameters, yield and yield components

Parameters	*F* value	*P* value
PLH	159.27	< 0.0001
TIL	20.93	< 0.0001
SPL	18.93	< 0.0001
SPLS	2.78	< 0.0001
KPS	167.08	< 0.0001
TKW	34.48	< 0.0001
DBM	43.16	< 0.0001
SY	9.85	0.0003
GY	266.57	< 0.0001

PLH plant height; *TIL* tillers; *SPL* spike length; *SPLS* spikelet per spike; *KPS* kernels per spike; *TKW* thousand kernels weight; *DBM* dry biomass; *SY* straw yield; *GY* grain yield

Table 3 ANOVA data of bagasse ash treated durum wheat agronomic parameters and yield and yield components

Parameters	*F* value	*P* value
PLH	117.16	< 0.0001
TIL	11.16	< 0.0001
SPL	12.0	< 0.0001
SPLS	56.78	< 0.0001
KPS	5.79	0.0036
TKW	885.29	< 0.0001
DBM	85.1	< 0.0001
SY	10.01	0.0002
GY	1.58	0.0001

PLH plant height, *TIL* tillers, *SPL* spike length per spike, *SPLS* spikelet per spike, *KPS* kernels per spike, *TKW* thousand kernels per spike, *DBM* dry biomass, *SY* straw yield, *GY* grain yield

Results and discussion

Days of seedling emergence, heading, and physiological maturity

The ANOVA showed that filter cake and bagasse ash application did not significantly ($P > 0.05$) affect days to 50% seedling emergence but these amendments significantly influenced days to 50% heading and 90% physiological maturity (Tables 2 and 3). At early vegetative growth stage, when the rate of filter cake increased, the treatments which received high rates of filter cake (80 and 100 tons/ha) showed slowness in growth (Table 4). The delaying of wheat growth at early vegetative stage could be due to immobilization of nutrients (Butler et al. 2001). At high rates of filter cake application, filter cake enhances the microbial growth (Kaur et al. 2008) and favors immobilization (Tejada et al. 2006) though the C: N ratio < 15, as indicated in Table 1, should not occur immobilization (Powlson et al. 2001). In line with the present study, filter cake application enhanced N immobilization (Rasul et al. 2009). The rapid immobilization due to filter cake application might be due to the decomposition of an easily available carbohydrate fraction that may induce utilization of soil N by the soil microbial communities (Lentz and Ippolito 2012), thereby reducing the soil inorganic N (Khan et al. 2008). However, the plant that received high rates as well as low rates at 20 and 40 tons/ha of filter cake gradually showed good improvement over the control at a late stage of the plant.

Delaying in the days to 50% heading was also observed when the rates of filter cake increased. Likewise, days to physiological maturity was increased when filter cake application increased. The release of high N from the transiently immobilized N by the soil microbial biomass could be the cause of long days of 90% physiological maturity. Ellis and Cock (1992) found that excess N keeps vegetative growth, which results in delayed flowering and maturity. Bagasse ash treatments also recorded maximum days to 50% heading

Table 4 Effect of filter cake and bagasse ash application on durum wheat phenology

Treatment rates (t/ha)	Days to 50% emergence	Days to 50% heading	Days to 90% maturity
Filter cake			
0	4	60a	88e
20	4	54e	87e
40	4	55d	91d
60	4	56cd	95c
80	4	56cb	97b
100	4	57b	101a
LSD (0.05)	ns	1.02	1.15
CV (%)		1.20	0.82
Bagasse ash			
0	4	60a	88.0a
20	4	53b	85.5c
40	4	53b	86.0b
60	4	52d	86.5ba
80	4	51d	86.0b
100	4	48e	85.5c
LSD (0.05)	ns	0.98	0.54
CV (%)		1.23	0.44

Values along the column with the same letter are not significantly different at $\alpha = 0.05$

(Table 3). When compared with filter cake, bagasse ash received plants showed lesser days to heading and physiological maturity. This difference may be due to more availability of plant nutrients at a reasonable time for bagasse ash application and having low nitrogen contents.

Root length of durum wheat

The data indicated that root length of experimental durum wheat was significantly and positively affected by filter cake and bagasse ash application (Table 5). Increasing rate of both inputs resulted in an increase in the root length of durum wheat. The highest value (31.2 and 28 cm) was obtained at 100 and 60 tons/ha of filter cake and bagasse ash application, respectively. The lowest values were recorded at the control. From this, it could be concluded that filter cake application increased root length more than bagasse ash. This may be due to high Ca and OM content of filter cake that suppresses the availability of toxic elements such as (Al^{3+}) which affect root growth through precipitation and complex formation (Munoz et al. 1990). Calcium displaces Al from exchange sites and makes it form precipitation in the form of $Al(OH)_3$ (Dee et al. 2002). Besides this, the filter cake could improve the soil physical properties and this may, in turn, facilitate the root growth.

Effect of filter cake and bagasse ash application rates on agronomic parameters and yield and yield components of durum wheat

Yield and yield components are soil fertility indicators and their positive response indicates the soil fertility improvement. Analysis of variance indicated that filter cake and bagasse ash rates application significantly affected the yield and yield components of wheat (Tables 2 and 3).

Plant height, dry biomass, and number of tillers

All treatments had shown positive response over the control in increasing plant height (Table 6). Dry biomass was significantly increased due to filter cake and bagasse ash application (Table 5). The maximum value was obtained with filter cake and bagasse ash application at 100 and 60 tons/ha, respectively, while the minimum value was recorded at the control treatment. The finding corresponds to that of Jamil et al. (2004) that filter cake and bagasse application positively affected durum wheat dry biomass. In general, increasing the application rates of filter cake increased dry biomass. However, increasing bagasse ash rates did not bring significant differences among treatments in dry biomass except that all treatments brought higher values as compared to the control. These different effects on biomass production between two inputs investigated might be because of the presence of readily available nutrients in bagasse ash.

The numbers of tillers per plant were significantly increased due to filter cake application but inconsistently (Table 6). The lowest value was recorded at control. Due to high N and P content in filter cake, it induced a better number of tillers and dry biomass when compared with bagasse ash application.

Table 5 Effect of filter cake and bagasse ash on experimental wheat root length

Treatment (t/ha)	0	20	40	60	80	100	Mean	LSD (5%)	CV%
R. length, FC	16.5e	30c	29d	31bc	31.1ba	31.2a	28.08	0.72	1.70
R. length, BA	16.5d	22.3c	25b	28a	25b	25b	23.63	0.61	1.70

Values with the same letter are not significantly different, t/ha, ton per hectare

FC filter cake, *R. length* root length (cm), *FC* filter cake, *BA* bagasse ash

Table 6 Effect of filter cake and bagasse ash application on wheat yield and yield components

Treatment rates (t/ha)	PLH (cm)	TIL (No)	SPL (cm)	SPLS (No)	KPS (No)	TKW (g)	DBM (g)	SY (g)	GY (g)	HI
Filter cake										
0	54.0f	1.2c	3.1c	7.4c	3.1e	42.2c	6.8d	5.9b	0.9e	0.15d
20	60.9e	2.0b	3.8b	8.8b	10.1d	49.6ba	9.6c	6.5b	3.1d	0.37c
40	64.5d	2.8a	4.0ba	8.9a	13.2c	50.8a	10.5c	6.0b	4.6c	0.47a
60	68.6c	2.8a	4.1ba	8.9a	14.4b	48.7b	13.6b	8.7a	4.9c	0.41bc
80	72.5b	2.7a	4.1ba	8.8a	15.3b	48.8b	13.2b	8.0a	5.2b	0.45ba
100	75.0a	2.7a	4.4a	8.8a	17.2a	49.4ba	14.7a	8.9a	5.8a	0.45ba
Mean	66.0	2.34	3.89	8.46	12.18	48.3	11.39	7.32	4.09	0.38
LSD (0.05)	1.85	0.43	0.30	0.30	1.18	1.48	1.36	1.33	0.33	0.05
CV (%)	1.86	12.15	5.14	2.38	6.41	2.04	7.91	12.02	5.38	8.6
Bagasse ash										
0	54.0	1.2c	3.1d	7.4c	3.1d	42.6e	6.8b	5.9e	0.9d	0.15d
20	64.9e	2.5a	3.9c	9.13b	12.2c	50.15d	10.9a	7.1c	3.9c	0.41c
40	67.8d	2.6a	4.1bc	8.88b	14.1b	51.4c	12.1a	7.6a	4.6b	0.43bc
60	71.9c	1.7b	3.9c	9.08b	15.1ba	58.5b	12.4a	7.3b	5.1a	0.47ba
80	75.4b	1.45cb	4.5ba	9.53a	15.8a	60.7a	10.6a	5.4f	5.2a	0.50ba
100	79.5a	1.65b	4.6a	9.50a	16.7a	58.7b	11.7a	6.7d	5.3a	0.56a
Mean	68.95	1.84	4.00	8.85	12.81	53.7	10.79	6.52	4.17	0.42
LSD (0.05)	2.52	0.44	0.46	0.37	1.61	0.71	1.96	0.13	0.42	0.09
CV (%)	2.43	15.81	7.65	2.79	8.46	0.86	12.08	1.31	6.67	14.14

Values with the same letter are not significantly different at $\alpha = 0.05$

PLH plant height; *TIL* tillers; *SPL* spike length; *SPLS* spikelet per spike; *No* number; *KPS* kernels per spike; *TKW* thousand kernels weight; *DBM* dry biomass; *SY* straw yield; *GY* grain yield; *No* number/counting; *HI* harvest index

Spike length, spikelet per spike and kernels per spike

The spike length, spikelet per spike and kernels per spike of durum wheat significantly increased as both inputs increased (Table 6). The maximum values were found at 100 tons/ha with both inputs whereas the minimum at the control treatment. Bagasse ash application resulted in a better mean value of spike length, spikelet per spike and kernels per spike over filter cake applications though higher tiller number was obtained with plants treated filter cake than bagasse ash. This might have been related to the high availability of nutrients in bagasse ash treated plants besides maintaining soil pH at an acceptable level (Rautaray et al. 2003). These authors showed that high K, P, Ca and Mg nutrients uptake due to high available nutrients delivered through fly ash integrated with chemical and organic fertilizer leads to higher yield in rice. Other authors found the increase in grain yield of rice by ash application as result of enhancing the nutrient uptake (Mittra et al. 2005).

Thousand kernels weight and straw yield

Thousand kernels weight is an important yield-determining component, which is reported to be a genetic characteristic of a plant and influenced sparsely by the environmental factors (Ayoub et al. 1994). It was found that both inputs significantly increased 1000 kernels weight (Table 6). At 40 and 80 tons/ha, filter cake and bagasse ash application resulted in the highest kernel weight, respectively. The lowest value was recorded at control. The mean values for 1000 kernels weight of durum wheat, after the wheat treated with filter cake and bagasse ash application, were 48.3 and 53.7 g, respectively. However, relatively higher 1000 kernels weight was obtained with filter cake when compared with bagasse ash treatment. This could be related to aphid and powdery mildew infection on the plants that received high rates of filter cake at maturity stage. High incidence of disease in filter cake amended plants might be due to the high N in the soil that may cause the plant to be more succulent and thus lead to susceptibility of the plants for disease.

The straw yield is another input response as well as an indicator of soil fertility status. The straw yield was significantly increased by filter cake and bagasse ash application (Table 6). The maximum value was recorded at 100 and 40 tons/ha for filter cake and bagasse ash application, respectively. The straw yield increased consistently with increasing application rate of filter cake but this trend along bagasse ash application rate was inconsistent.

Grain yield and harvest index

The results of statistically analyzed data revealed that the filter cake and bagasse ash application regardless of the rates significantly increased the grain yield when compared to the control treatment (Table 6). The highest value was found at highest rates of application. The minimum values were recorded at the control treatment. The yield increment due to applying such input could be attributed to the increase in available nutrients and suitable soil condition to beneficial microbial proliferation and activities around the plant root zone (Demeyer et al. 2001; Rasul et al. 2008). Other studies showed that 60 tons/ha of filter cake application increased the yield of cassava by 50% over the mineral fertilization (Ossom 2010). Ossom and Dlamini (2012) found the comparable amount of maize grain yield by filter cake and recommended chemical fertilizer application. In general, wheat grain yield consistently increased as the rate of applied filter cake increased to the highest level but showed the tendency of stopping increment after 60 tons/ha for bagasse ash application. In previous studies, Thind et al. (2012) found that 10 tons/ha increased the yield of wheat by up to 43.7% over the unfertilized plants in the alkaline loamy sand.

Harvest index (HI) was significantly increased by filter cake and bagasse ash application (Table 6). The highest values (0.45 and 0.56) were recorded at 100 tons/ha with filter cake and bagasse ash application, respectively, while the lowest values were obtained from control treatment. The value we have obtained in the present study after treatments, when compared with Hussians and Pan (1993) reported on average 0.34 for local cultivars and 0.44 for improved new varieties are high. Therefore, the highest values of harvest index (HI) in this study coincide with improved new varieties that were reported by Hussians and Pan (1993) as the experimental wheat was variety released from Debre Zeit Agricultural Research Center (DZARC) with the name "Yerer". In general, it was found that plants that were treated bagasse ash application had better HI when compared those treated filter cake applications.

Regression analysis between grain yield of wheat and nutrients uptake

The regression analysis between the grain yield and total uptake of selected macronutrients and micronutrients were significant at $P < 0.05$ (Fig. 1a). Association between grain yield with N and Zn uptake was linear, implying that further increase in N and Zn uptake by applying inorganic fertilizer could improve the grain yield of wheat. This could be suggested that N and Zn the major limiting nutrients for wheat cultivation in the soil we used. This result indicates that organic fertilizer alone has not sufficiently supplied N to the plant (Herencia et al. 2007). With another nutrient uptake (P, S, Ca, Mg and Cu), grain yields exhibited quadratic relationship. This result could suggest that the rates below 100 tons/ha could be sufficient, although further investigations under field condition are needed.

A significant ($P < 0.05$, $r^2 = 0.95$) association between grain yield and total N uptake with higher slope (2.783) for bagasse ash amended soils than the soil amended filter cake was demonstrated, implying the better effect of bagasse ash application on the total N uptake of wheat. The result might have been related with immobilization of native N by the high rate of filter cake application (Rautaray et al. 2003) and increase in N uptake by correcting the soil nutrients constraints through bagasse ash application (Aulakh and Malhi 2005). Ash application could also increase the decomposition of native soil organic matter through improving the microbial proliferation (Kaur et al. 2008) and activity (Lal et al. 1996), thereby improving the N availability (Wong and Wong 1986).

The association between grain yield and total P uptake were quadratic and significant ($P < 0.05$, $r^2 = 0.96$) with both inputs (Fig. 1b). In case of total K uptake and grain yield was significant ($P < 0.05$, $r^2 = 0.94$) and quadratic with a greater coefficient of the *x*-axis and *y*-intercept in plants that was amended bagasse ash than those amended filter cake (Fig. 1c). This result may indicate that bagasse ash could be a good source K for plants. Similar studies have shown that a strong association between K uptake and grain yield of wheat (Thind et al. 2012). Ash application increased the K availability in sandy loam acid lateritic soil (Rautaray et al. 2003). It was also found a significant ($P > 0.05$, $r^2 = 0.96$) and the quadratic relationship between grain yield and total S uptake (Fig. 1d).

In bagasse ash and filter cake amended soils, a linear and quadratic relationship between grain yield and total Ca uptake were found, respectively (Fig. 1e). This figure also indicated that the higher y-intercept was recorded in filter cake amended soil than bagasse ash amended soils. This result could be related to the presence of high Ca in filter cake compared to bagasse ash. Quadratic association ($P > 0.05$, $r^2 = 0.97$) between grain yield and total Mg uptake with a greater coefficient of *x*-axis and *y*-intercept was recorded when plants were treated with bagasse ash as compared with those treated with filter cake (Fig. 1f). This suggests that bagasse ash could be the good source of Mg when compared to the filter cake.

The relationship between grain yield and total Cu uptake was quadratic with a higher coefficient of the *x*-axis and *y*-intercept with plants treated bagasse ash than those with filter cake (Fig. 1g). Grain yield and total Zn uptake showed the linear association with higher *y*-intercept with bagasse ash amended plants than the filter cake amended plants (Fig. 1h), implying that bagasse ash is a good source of Zn and Cu when compared to the filter cake. Similar

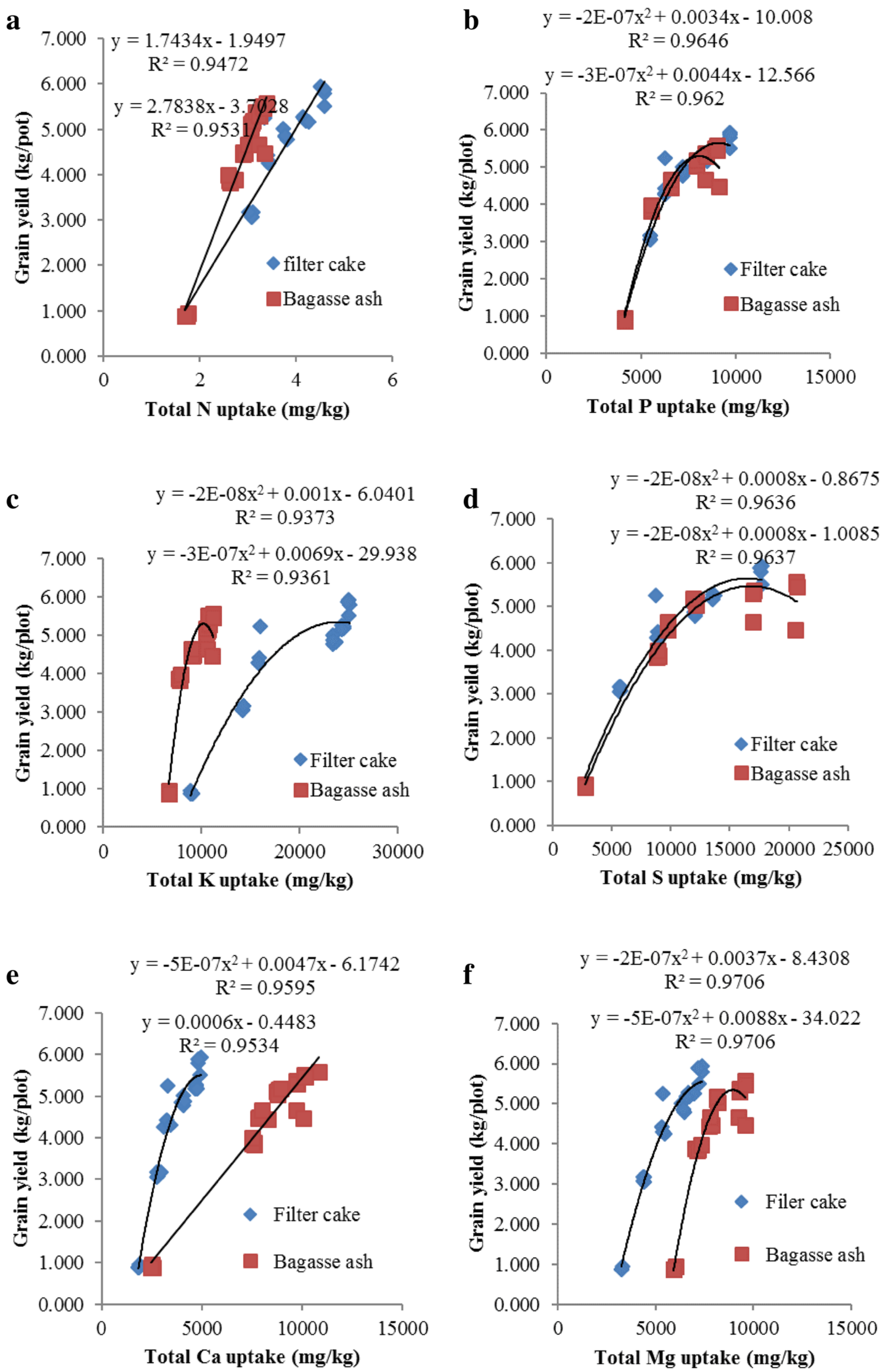


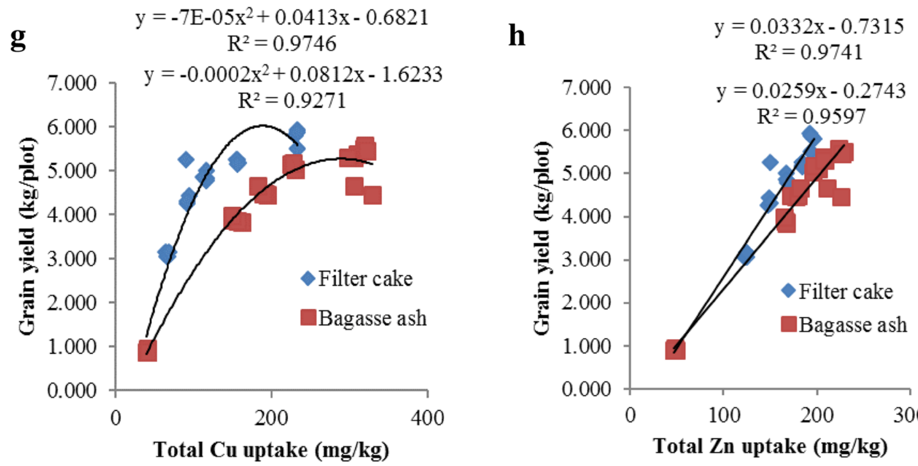
Fig. 1 Effect of filter cake and bagasse ash application rates on **a** Total N uptake, **b** Total P uptake, **c** Total K uptake, **d** Total S uptake, **e** Total Ca uptake, **f** Total Mg uptake, **g** Total Cu uptake and **h** Total Zn uptake of wheat under greenhouse condition

findings have been reported by Lentz and Ippolito (2012) who demonstrated that organic fertilizer with high nutrients content increased Cu, Zn, S, Mg, K, and N concentration of silage corn by 1.3 fold when compared to the control.

Conclusion

In general, due to immobilization of nutrient when the applied high rate of the filter cake, incorporating filter

Fig. 1 (continued)



cake to the soil 1–2 months before sowing and undertaking decomposition before application to the soil is recommended. The result also found the need for relatively lower rate of bagasse ash when compared with filter cake to enhance wheat production in acidic and low fertile soils. To give a conclusive result for the end user and to fine-tune the rate for practical implementation, further research work under field conditions is needed. In general, the awareness of amending the acidic soil with filter cake and bagasse ash application, besides lime application, could correct the soil pH into acceptable range and improve the soil nutrients as well.

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