INT. J. BIOL. BIOTECH., 16 (2): 433-441, 2019.

GROWTH RESPONSE OF *CICER ARIETINUM* L. TO SOIL APPLIED SUGAR CANE RESIDUE ASH

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ABSTRACT

The huge amounts of crop residue, produced by the harvesting of sugarcane, are discarded by burning in the field. The ash produced by this phenomenon enters the soil and become available for next crop. Thus, it was hypothesized that whether or not this ash affects plant growth and soil properties positively? The pot experiments were conducted in net house using two factor RCBD design with four replications. The type of ash at two levels (P1=Pyrolyzed and P2=Non-Pyrolyzed) was a main factor arranged in main blocks while sub block factor included three levels of ash doses (0, 5, and 15 g kg^{-1} of soil). The ash was mixed thoroughly in soil prior to sowing of seeds. The data were recorded for Germination %, shoot length, leaf number, root Length, shoot fresh and dry weight, and whole plant biomass. The soil was analyzed for pH, organic matter, Total organic carbon, Na^+ and K^+. The results suggested that ash of sugarcane, produced either by pyrolysis or by non-pyrolysis, has significant positive growth and germination effects on *Cicer arietinum* L. than control. The effects were highly dose dependent i.e. as the dose increased the growth increased. It can be concluded therefore, that the sugarcane ash can be good alternative to inorganic fertilizers in agriculture fields.

Key Words: Ash, Sugarcane, Banana, Pyrolyzed and non-pyrolyzed, *Cicer arientinum* L

INTRODUCTION

Ash is charcoal made from plant residue, leftover biomass waste, (stems, leaves and roots) burned during conditions with low oxygen level (Antal and Gronli, 2003; Alvum-Toll *et al*., 2011; Akhtar *et al*., 2014; Saxena *et al*., 2014). There are two types of Ash pyrolyzed, the thermal production of ash in which air is not involved and Non-pyrolyzed, burning of residue in presence of air (Oxygen). Ash cannot be considered as a pure carbon (C) but it also contains ash, Oxygen, hydrogen, sulfur, phosphorus and nitrogen (Duku *et al*., 2011; Lehmann and Joseph, 2015). During previous decade, the application of ash in agriculture lands has gained great importance because it affects crops and environment positively (Liu *et al*., 2013; Stavi and Lal 2013). Worldwide crop residue production of cereal crops amounts 2802x10 Mg/Year, Cereal and Legumes $317x10^6$ Mg/Year, food crops $3587x10^6$ Mg/Year (Lal, 2004). Amount of Sugarcane residue produced in Pakistan ranges up to $2765x10^6$ Ton/year (Saeed *et al*., 2015). The huge amounts of sugarcane crop residue, in Pakistan are either used for cattle fodder or left in the field and burned. The burning of crop residue incorporates huge amounts of ash in the top soil. The production of ash may show negative as well as positive effects on both soil quality and crop growth in following seasons.

The properties of ash resemble clay aggregates and, therefore, give soil a more clayish feature, providing some of the benefits for plant growth (Alvum-Toll *et al.*, 2011). Ash contains important nutrients; make them more available for plant uptake by enhancing the decomposition of organic material (Alvum-Toll *et al.*, 2011; Lehmann and Joseph, 2015). It contains potassium and brings great increase in soil organic carbon (Liu *et al*., 2014). In general ash has a high C/N ratio which indicates that immobilization (conversion of inorganic compounds to organic compounds by micro-organisms or plants) of nitrogen can occur when applied to soil (Alvum-Toll *et al*., 2011). Ash has several beneficial effects on soil physical properties, such as increased water holding capacity, water retention and porosity (Karhu *et al*., 2011; Alvum-Toll *et al*., 2011).

The water soluble carbon nano particles (wsCNPs) of ash in solution enhance the growth rate of wheat plants (Saxena *et al*., 2014). Incorporation of ash may, therefore, give higher yield with the same amount of fertilizers (Alvum-Toll *et al*., 2011). Ash can contain organic compounds that may impact plant germination and growth (Rogovska, 2010) positively. The traditional use of ash for the healthy growth of plants is due to its retention capability of nutrients for need-based slow release (Saxena *et al*., 2014). Nutrient uptake and availability can also be affected by change in pH as a result of ash addition (Lehmann and Joseph, 2015). The total nutrient concentration in ash can be high, however the proportion of plant available nutrients can vary depending on which kind of feedstock is being used for ash production (Alvum-Toll *et al*., 2011).

Ash improve plant uptake of Potassium, Phosphorus and Calcium (Alvum-Toll *et al*., 2011). Ash is also well known to increase the colonization of mycorrhizal rhizobia (Solaiman *et al*., 2010). Plant waste residue amendment in the form of ash is used for enhancing soil fertility, which may increase plant growth. Due to high variability in the quality and quantity of ash, its effects on soil and plant are likely to differ.

Present study was carried out to investigate effects of sugarcane residue ash, either Pyrolyzed or Non-Pyrolyzed, on Plant growth of *Cicer arientinum* L and soil quality improvement.

MATERIALS AND METHODS

Production of Ash

The dried residue of sugarcane was collected from farmer's field and dumped in 3 feet deep ditch made in earth. The residue was set fired after covering the ditch with bricks and soil. In this way pyrolyzed ash (ash made in the absence of air/oxygen) was produced. The Non-pyrolyzed ash of sugarcane was collected from the original field where peasants burned it under open air. Ash of sugarcane was crushed and passed through 0.5 mm sieve. The ash was mixed in river sand collected from the bed of river Indus in different concentrations.

Experimental design

The experiment was conducted in the net house of Institute of Plant Sciences, University of Sindh, Jamshoro, in earthen pots of 8″ diameter during March 2016. The experiments were conducted using RCBD design with following two factors: 1. Type of ash at two levels (Pyrolyzed and non-pyrolyzed ash) in main blocks and 2. Dose of ash at three levels (0, 5 and 15 g Kg^{-1} soil) in sub-blocks. All factors were replicated four times and this produced a set of total 48 observations.

Bioassay Plant

To analyze the effects of ash on plant growth common chick pea *Cicer arietinum* L. was sown in each pot. Before sowing, the seeds were hydroprimed for 10 hours and surface dried by spreading on a paper towel for 30 minutes. About five seeds per pot were sown at the depth of 6 inches.

The data for shoot and root length were recorded at the time of harvest after 2 months of experimentation. The root length, fresh and dry weights of shoot were calculated at harvest of crop. The plants were uprooted and dried at 60 $^{\circ}$C for 24 hours to record whole plant biomass.

Soil Analysis

At the termination of experiment soil samples were taken from each observation and brought to laboratory for further analysis. The soil extracts from soil saturation paste were obtained to analyze pH and EC. The total organic carbon and organic matter was determined by modified Walkely and Blake method (Bremner and Jenkinson, 1960) using oxidation with potassium dichromate. The Na^+ and K^+ were analyzed on flame photometer (FP 640 Gold China) by the method described by Estefan *et al.* (2014).

Statistical analysis

The data were statistically analyzed for normality and ANOVA to compare means of two factors by using general linear model. The advantage of general linear model is that it compares many factors at a time with interaction therefore; a model can be tested accurately. The R^2 (percent variability) generated by GLM was used to describe results. The Pearson correlation coefficients were calculated with their corresponding p values. The individual mean comparisons were computed through Tuckey's pairwise comparison test at 95% confidence interval and 5% Tuckey's family error rate. All the hypothesis were tested using α =0.05. All the statistical analysis was done using Minitab® V. 17 and the graphs were produced by Microsoft® Excel® 2007.

RESULTS AND DISCUSSION

Plant growth

The results for various plant growth parameters are presented in Table 1. Taking the shoot length (cm) as first parameter it was observed that pyrolyzed ash produced significantly higher shoot length than non-pyrolyzed ash. Similarly, the ash doses have shown significantly high shoot length than non-ash control (Table 1). The highest shoot length was observed under 15 g pyrolyzed ash kg^{-1} soil while control (no-ash) produced lowest results. The corresponding F static and P values presented in Table 2 show the significance level of process and doses. Both the process and dose produced significant levels $p<0.001$. The R^2 (94.72%) suggests that the effects show highly linear pattern i.e. as the factor (dose) increases the shoot length increases. The interactions, however, does not show the significant results indicating that both the factors remained independent in their effects (Table 2).

Table 1. The effects of process and dose of ash produced from Sugarcane on different growth parameters of the *Cicer arientinum* L. The processes x dose interaction means are presented to assess the interaction of two factors with each other.

Parameter	Dose	Process		Mean
		Pyrolyzed	Non-Pyrolyzed	
Shoot Length (cm)	0 g (No Ash)	22.08D	20.58E	21.32c
	5 g kg^{-1} soil	24.58AB	23.23C	23.90b
	15 g kg^{-1} soil	25.27A	23.98BC	24.63a
	Mean	23.98a	22.59b	
Root length (cm)	0 g (No Ash)	21.60D	22.00D	21.80c
	5 g kg^{-1} soil	29.00C	36.00B	32.50b
	15 g kg^{-1} soil	45.00B	29.37B	37.19a
	Mean	31.87a	29.12b	
Shoot Fresh weight (g)	0 g (No Ash)	2.65D	2.65D	2.65c
	5 g kg^{-1} soil	5.05C	6.08B	5.55b
	15 g kg^{-1} soil	8.50A	4.48C	6.49a
	Mean	5.39a	4.40b	
Shoot Dry weight (g)	0 g (No Ash)	0.700C	0.700C	0.70b
	5 g kg^{-1} soil	1.47B	1.22B	1.19a
	15 g kg^{-1} soil	1.57A	0.92C	1.25a
	Mean	1.14a	0.95b	
Whole plant dry Biomass	0 g (No Ash)	1.95D	1.95D	1.95c
	5 g kg^{-1} soil	3.87C	4.85B	4.36b
	15 g kg^{-1} soil	6.93A	3.55C	5.24a
	Mean	4.25a	3.45b	

The means are compared at $\alpha=0.05$
The means that share same capital letter are non-significant.
The overall means are distinguished by using small letters. The different small letters show significant differences among overall means at $\alpha=0.05$

Table 2. The ANOVA table showing F static and P value for process, dose and process x dose interaction of various plant parameters of *Cicer arietinum* L as affected by sugarcane ash. The last column shows general linear model (GLM) % variance.

Parameter		ANOVA		Dose x Process Interaction	GLM R^2%
		Process	Dose		
Shoot Length (cm)	*F-static*	62.16	130.26	0.12	94.72
	P value	0.000	0.000	0.890	
Root length (cm)	*F-static*	26.18	288.89	157.17	98.08
	P value	0.000	0.000	0.000	
Shoot Fresh weight (g)	*F-static*	42.78	232.17	104.07	97.55
	P value	0.000	0.000	0.000	
Shoot Dry weight (g)	*F-static*	23.53	75.33	34.22	93.09
	P value	0.000	0.000	0.000	
Whole plant dry Biomass	*F-static*	26.88	163.33	72.91	96.52
	P value	0.000	0.000	0.000	

The similar pattern of results is observed in root length (cm) (Table 1). The overall mean results suggest that the highest root length was observed in pyrolyzed ash as compared to non-pyrolyzed (Table 1). The root length increased significantly with increasing the ash dose. However, the ash applied at the rate of 5 g kg^{-1} soil produced lower results in pyrolyzed than the non-pyrolyzed ash while at highest dose of pyrolyzed ash resulted in the production of significantly higher root length than non-pyrolyzed ash. All the differences are highly significant $p<0.001$ as evident from the F static and p values presented in Table 2. Unlike shoot length, the root length showed highly significant interaction between process and dose clearly indicating that both the factors are interdependent. The 98.08 % R^2 shows linear pattern of effects of both the factors. The correlation analysis of shoot and root length with dose (Fig 1 A) is highly significant (p<0.00) while both the variables showed negative correlation with process. However, the negative correlation was non-significant (p>0.05).

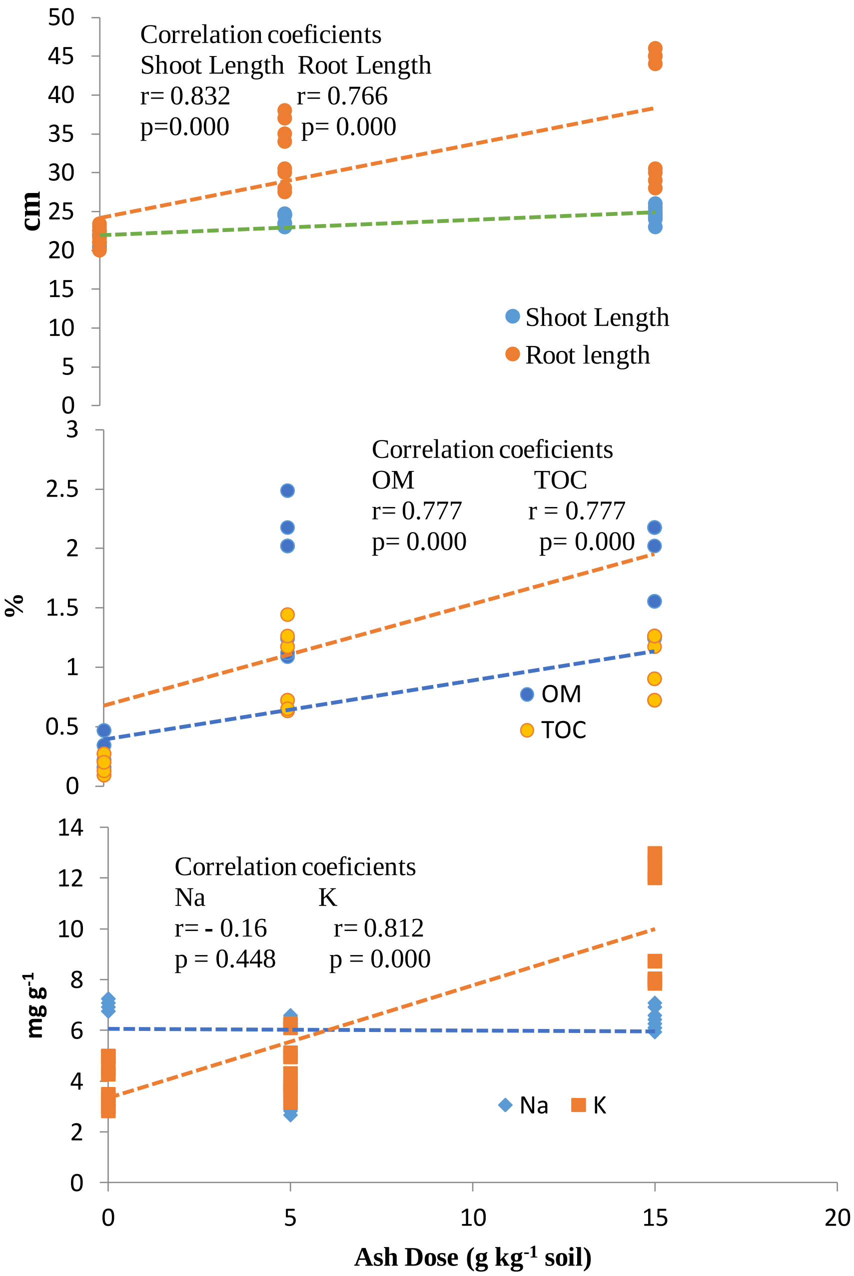

Fig. 1. The correlations scatter plots of shoot and root length (cm) of *Cicer arientinum* L (A), soil organic matter and total organic carbon (B) and soil Na and K levels (C) with dose. The Pearson correlation coefficients and p values are produced to make graph readings more clear.

The fresh and dry weights of shoot (g) also showed significantly different results. The overall mean results showed that highest fresh and dry weights (g) were produced under pyrolyzed ash while 15 g kg^{-1} soil (highest dose) produced highest fresh and dry weights (Table 1). When analyzing individually, however, the lower dose of pyrolyzed ash i.e. 5 g kg^{-1} soil showed significantly lower fresh and dry weights than non-pyrolyzed. But at higher dose (15 g kg^{-1} soil) the pyrolyzed ash produced significantly higher shoot fresh and dry weights than non-pyrolyzed ash. The effects were highly significant with $p<0.001$ (Table 2). The process x dose interaction was found highly significant (Table 2) showing that fresh and dry weight was highly dependent on both process and dose. The R^2 97.55 % and 93.05% (Table 2) for fresh and dry weights respectively, shows the highest linearity of the effect of both factors. The whole plant biomass was significantly affected by both process and dose of ash. The highest mean whole plant biomass was found in pyrolyzed ash than non-pyrolyzed (Table 1). While the highest overall mean biomass was found in highest dose i.e. 15 g kg^{-1} soil when compared to control and low ash dose. The pyrolyzed ash showed significantly higher whole plant biomass than non-pyrolyzed ash. The effects of individual factors i.e. process and dose are highly significant ($p<0.001$) including process x dose interactions. The high GLM R^2 value (96.52%) shows that the effects show linear trends (Table 2).

Table 3. The effects of process and dose of ash produced from Sugarcane on different soil chemical parameters. The processes x dose interaction means are presented to assess the interaction of two factors with each other.

Parameter	Dose	Process		Mean
		Pyrolyzed	Non-Pyrolyzed	
pH	0 g (No Ash)	8.17B	7.95B	8.06b
	5 g kg^{-1} soil	9.00A	9.20A	9.10a
	15 g kg^{-1} soil	9.20A	9.17A	9.18a
	Mean	8.79a	8.77a	
Organic matter (%)	0 g (No Ash)	0.29C	0.29C	0.29b
	5 g kg^{-1} soil	2.17A	1.17B	1.67a
	15 g kg^{-1} soil	2.13A	1.39B	1.76a
	Mean	1.53a	0.95b	
Total organic carbon (%)	0 g (No Ash)	0.17C	0.16C	0.17b
	5 g kg^{-1} soil	1.26A	0.68B	0.97a
	15 g kg^{-1} soil	1.23A	0.81B	1.02a
	Mean	0.89a	0.55b	
Na^+ (mg g^{-1})	0 g (No Ash)	7.00A	7.00A	7.00a
	5 g kg^{-1} soil	6.10C	6.79AB	4.59c
	15 g kg^{-1} soil	6.10C	6.75AB	6.43b
	Mean	6.45a	5.56b	
K^+ (mg g^{-1})	0 g (No Ash)	4.68CD	3.16E	3.92c
	5 g kg^{-1} soil	5.61C	3.73DE	4.67b
	15 g kg^{-1} soil	12.44A	8.14B	10.29a
	Mean	7.58a	5.01b	

The means are compared at α=0.05
The mean that share same capital letter are non-significant.
The overall means are distinguished by using small letters. The different small letters show significant differences among overall means at α=0.05

The positive effects of ash have been investigated on various crop plants by many authors. The effects are both type and dose specific. For example, ash applied at 68 t ha^{-1} significantly increased rice and cowpea biomass by 20 and 50%, respectively, and at 36.75 t ha^{-1} increased cowpea biomass by 100% (Glaser *et al.*, 2002). This confirms our finding that increasing dose of ash increases plant growth and biomass. In addition, ash has been found effective in improving biological and grain yields up to 30 % in durum wheat (*Triticum durum* L.) (Vaccari *et al.*, 2011). These and many other studies confirm the results of our findings that ash in higher doses improve both plant biomass and yield. The positive effects of ash on crop productivity are related to improvement in soil physical and chemical properties. It has been reported that ash increases surface area in soil for biological activities, improves cation exchange capacity, porosity (Thies and Rillig, 2009), water holding capacity, nutrient maintenance (Glaser *et al.*, 2002; Lehmann and Rondon, 2006).

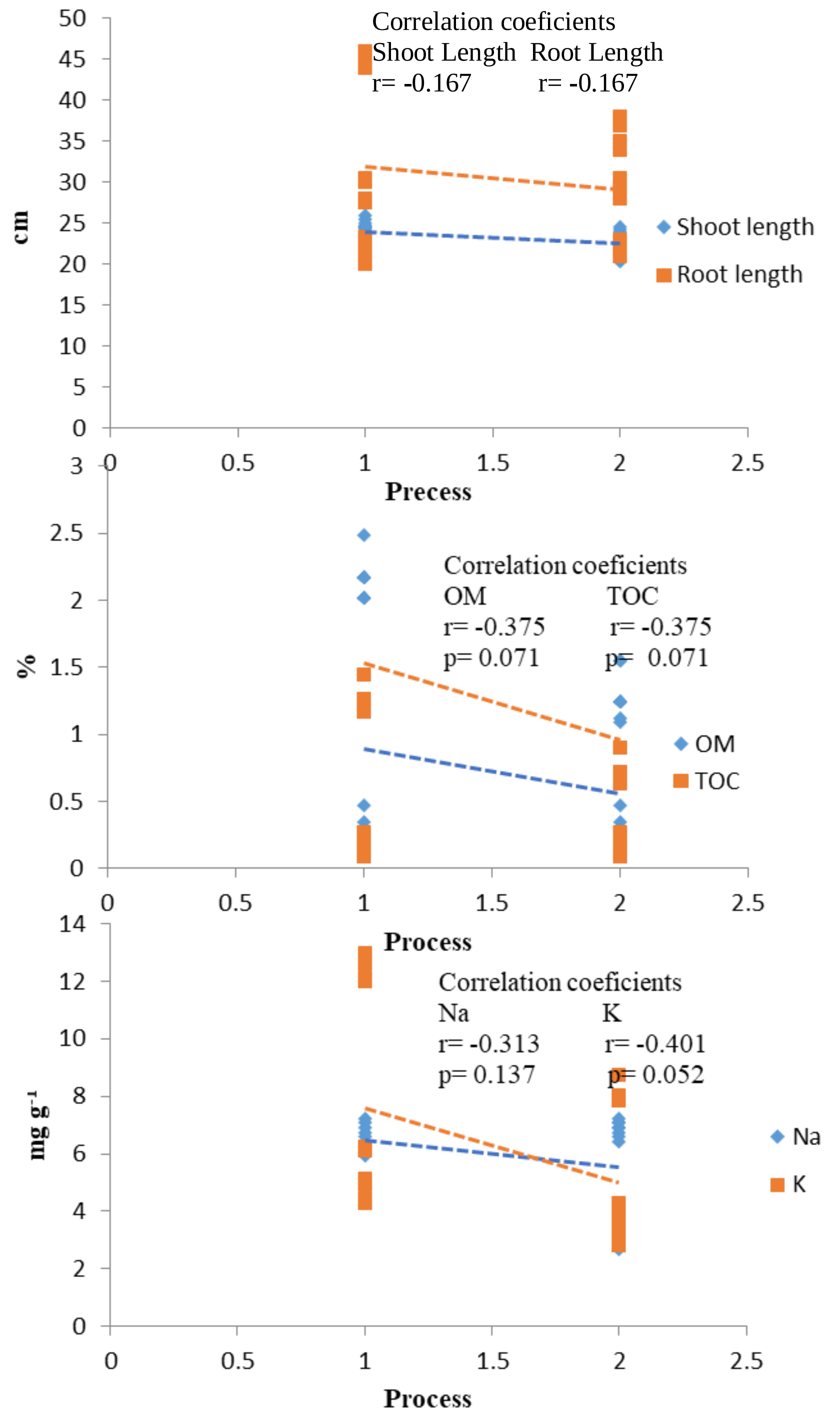

Fig. 2. The correlations scatter plots of shoot and root length (cm) of *Cicer arietinum* L (top), soil organic matter and total organic carbon (middle) and soil Na and K levels (bottom) with process. The Pearson correlation coefficients and p values are produced to make graph readings more clear.

Table 4. The ANOVA table showing F static and P value for process, dose and process x dose interaction of various soil chemical parameters as affected by sugarcane ash. The last column shows general linear model (GLM) % variance.

Parameter		ANOVA		Dose x Process Interaction	GLM R^2%
		Process	Dose		
pH	*F-static*	0.03	51.03	1.47	85.37
	P value	0.871	0.000	0.256	
Organic matter (%)	*F-static*	92.35	248.69	24.68	97.26
	P value	0.000	0.000	0.000	
Total Organic Carbon (%)	*F-static*	92.35	248.69	24.68	97.26
	P value	0.000	0.000	0.000	
Na (mg g^{-1})	*F-static*	99.00	259.18	188.45	98.20
	P value	0.000	0.000	0.000	
K (mg g^{-1})	*F-static*	190.15	466.68	21.97	98.84
	P value	0.000	0.000	0.000	

Soil properties

Table 3 shows mean values for soil pH, organic matter, total organic carbon, Na^+ and K^+ concentrations analyzed after the harvest of crop. A significant increase in pH has been monitored under the treatments containing ash. The process does not affected pH significantly but ash dose has higher effects on pH increase. The pH of soils with 5 and 15 g kg^{-1} soil ash increased above 9 showing highly alkaline reaction. Only the dose produced significant results ($p<0.001$) (Table 4) while process and process x dose interaction was non-significant. Our findings are in confirmation with the observations of Castaldi *et al*. (2011) and Vaccari *et al.* (2011) who reported that when ash was applied on acid soils it increases pH from 5.1 to 6.7. In addition, Novak *et al*., (2009) found that application of biochar significantly increases the soil fertility by increasing pH, organic matter, organic carbon, Ca, Mg, Mn and P is acidic soils.

The percent organic matter and total organic carbon levels increased significantly in ash applied soils as compared to non-ash applied soils (Table 3). It has been observed that the pyrolyzed ash increased organic matter and total organic carbon significantly than the non-pyrolyzed ash. While the effects of dose were more significant i.e. the increased dose produced increased organic matter and total organic carbon in soil. The overall means (Table 3) show that increase in organic matter and total organic carbon is highly dose dependent while process from pyrolysis to non-pyrolysis reduced the organic matter and total organic carbon significantly (Table 4). The process x dose interaction was highly significant showing that both the factors interacted with each other and none of the factors was independent in their effects. The R^2 values 97.26 % were very high and showed high variability. This also suggests that linear model fits the observations thus pattern of organic matter increment is highly linear (Table 4). The organic matter and total organic carbon showed significantly positive correlation with ash dose (Fig. 1) while they produced a negative correlation with process (Fig. 2). This suggests that the pyrolyzed ash is more effective in increasing the organic matter and total organic carbon levels in the soil. The improvement in soil organic matter and organic carbon has been reported extensively. The ash has dual effects i.e. it improves the structure of soil organic matter as well as its function (Cheng *et al*., 2008). In a study Laird *et al*. (2010) reported a 69% increase in soil organic carbon after 500 days of ash application on loam soil with 2.0% soil organic carbon. Although the decomposition rates of ash in soil are very slow (Nguyen and Lehmann, 2009), but however, it is beneficial for soil due to its aggregation and nutrient retention properties (Downie *et al*., 2009; Atkinson *et al*., 2010) which, help soil biota to develop and enhance microbial biomass in soil system.

Among the cations the concentrations of K^+ significantly increased than Na^+ in both pyrolyzed and non-pyrolyzed ash applied soils as compared to control (Table 3). The Na^+ content of soils with non-pyrolyzed ash was non-significant to its control but it was significantly low in pyrolyzed ash applied soils (Table 3). Interestingly, the amount of Na^+ was found lower than control, which suggests ash helped in desorption of Na^+ from cation exchange sites and mobilized the Na^+ in soil system. Increase in K^+ highly affects the soil fertility as well as plant growth (Verheijen *et al*., 2010). The K^+ levels significantly increased in soil applied with 15 g kg^{-1} soil (Table 3). The increase in levels of Na^+ and K^+ were highly dose and process dependent as process x dose interaction is significant. The R^2 of 98.20 and 98.84 for Na^+ and K^+ respectively fits the linear model of increase in K^+ and decrease in Na^+ (Table 4).

Conclusion

The results of present findings reveal that the ash of sugarcane, produced either by pyrolysis or non-pyrolysis have significant effects on the growth and biomass production of *Cicer arietinum* L. The most growth parameters were affected positively by ash dose rather than ash type. While between ash types pyrolyzed ash was found more effective than non-pyrolyzed. The soil pH, organic matter, total organic carbon and soil K^+ content increased significantly while Na^+ concentrations decreased in ash applied soil as compared to control. The GLM produced significant results that the pattern of change in significantly different variables was linear. Therefore, a linear regression model can be developed to fit the data for the observations.

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(*Accepted for publication February 2019*)