



ISSN Print: 2618-060X
 ISSN Online: 2618-0618
 NAAS Rating (2026): 5.20
 IJRA 2026; 9(9): 1592-1596
www.agronomyjournals.com
 Received: 10-07-2026
 Accepted: 15-08-2026
 Published: 30-09-2026

The names and affiliations of all authors are provided below, following the references.

Correlation of soil chemical properties with sugarcane yield and CCS under different trash management practices

RB Zodge¹, DH Phalke², BM Kamble³, MC Manna⁴, SR Patil⁵, SS Bachhav⁶, CA Nimbalkar⁷

DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i9u.6737>

ABSTRACT

The correlation analysis revealed that *N*, *P* and *K* were the nutrients most consistently associated with sugarcane Yield and CCS under both trash management and trash burning practices across the different sugar recovery zones. Yield showed strong positive relationships with *N*, *P* and *K* ($r = 0.702-0.989$), while CCS also showed positive correlations with these nutrients ($r = 0.542-0.985$). Yield and CCS exhibited a strong positive association ($r = 0.861-0.982$), indicating that increased cane yield was generally accompanied by improved sugar recovery. Under trash management, *P* and *K* showed particularly strong associations with Yield and CCS, while similar trends were observed under trash burning. The findings indicate that *P* and *K* showed the strongest and most consistent relationships with Yield and CCS, whereas the other soil chemical properties displayed comparatively weak to moderate associations. These results emphasize the importance of balanced nutrient availability, particularly *N*, *P* and *K*, for maintaining higher sugarcane productivity and sugar recovery under different trash management practices.

Keywords: Trash retention, Trash burning, Yield and CCS%, Correlations matrix

Introduction

Sugarcane is one of the important commercial cash crops, grown in India (Solomon, 2016; Chauhan *et al.*, 2022) [2, 1]. Sugarcane production depends greatly on soil fertility, nutrient availability, and proper crop management. Cane yield and Commercial Cane Sugar (CCS) are commonly used to assess crop performance because they indicate both the amount of cane produced and the potential sugar that can be recovered from it. Maintaining healthy soil and providing nutrients in the right balance are therefore important for improving cane yield as well as sugar recovery.

Crop residues are a valuable source of biomass, but a large quantity around 93 Mt is still burned in the fields each year. In India, sugarcane generates about 12 Mt of residues annually, mainly in the form of tops and leaves, which account for nearly 2% of the total crop residues Bairwa *et al.* (2020) [3]. The regular burning of these residues results in the loss of valuable nutrients and organic matter that could otherwise be returned to the soil and help maintain soil fertility Ravish *et al.* (2025) [4], Tandon *et al.* (2025) [5]. In India, a considerable amount of crop residue is left unused each year. Estimates show that about 140.84 Mt of crop residues are surplus, while nearly 92.81 Mt are burned in the fields annually (Pandey, 2018) [6]. Burning these residues causes significant losses, with more than 70 % of their organic matter and nutrients being released into the atmosphere (Mitchell *et al.*, 2000) [7]. On the other hand, leaving the residues in the field allows these nutrients and organic matter to return to the soil. Research from northern Australia has also shown that retaining green cane trash can improve soil nitrogen, organic carbon, and nitrogen mineralization (Wood *et al.*, 1991; Sutton *et al.*, 1996) [9, 8].

After crop harvesting, the leftover residues are sometimes burned directly in the field to clear the land for the next crop and short time. However, this practice can cause considerable losses of valuable plant nutrients, with as much as 44 kg of nitrogen, 5.4 kg of phosphorus, and 31 kg of potassium per hectare being lost during burning (Bhattacharjya *et al.*, 2021) [10]. The study, conducted in sugarcane fields in Maharashtra, found that burning sugarcane trash resulted in higher soil pH and electrical conductivity (EC) compared with fields where the trash was trash retention Bramhe *et al.* (2024) [11].

Burning sugarcane trash can lead to significant nitrogen losses, mainly through volatilization during combustion. In contrast, retaining the trash in the field allows nitrogen to be recycled as the residues gradually decompose, thereby contributing to soil nitrogen availability and improving nutrient cycling (Basanta *et al.*, 2003; Yadav *et al.*, 1994; Graham *et al.*, 2002) [12, 13, 14].

Nitrogen (*N*), phosphorus (*P*), and potassium (*K*) are key nutrients required for the healthy growth and development of sugarcane. Along with these nutrients, soil characteristics such as pH, electrical conductivity (EC) and the availability of micronutrients iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) also influ

Corresponding Author:

RB Zodge

Department of Soil Science,
 Post Graduate Institute,
 Mahatma Phule Krishi
 Vidyapeeth, Rahuri,
 Ahilyanagar, Maharashtra,
 India

ence nutrient availability and overall crop performance. Understanding the relationship between these soil properties and sugarcane yield and sugar recovery can help in developing more effective and efficient crop management practices.

Correlation analysis is useful for understanding the strength and direction of relationships among soil chemical properties, sugarcane yield and Commercial Cane Sugar (CCS) [Mavchi et al. \(2015\) \[15\]](#). These relationships may vary depending on the method of trash management, particularly between trash retention and trash burning, as well as among areas with different levels of sugar recovery. Therefore, the present study was undertaken to examine the relationships between soil chemical properties, sugarcane yield and CCS under trash retention and trash burning practices across high, medium and low sugar recovery zones.

Statistical analysis

The two treatments were compared using a paired *t*-test, the same samples were used for both treatments. The association between the different measured variables was examined using a correlation matrix.

Results

sugarcane trash management practices in high sugar recovery zone
As shown in [Table 1](#), *N*, *P* and *K* showed strong positive correlations with yield ($r = 0.932$, 0.935 and 0.948 , respectively) and CCS ($r = 0.727$, 0.880 and 0.877 , respectively). Yield also had a strong positive relationship with CCS ($r = 0.893$). In contrast, pH and EC showed negative correlations with yield ($r = -0.348$ and -0.302) and CCS ($r = -0.217$ and -0.373). The relationships of Fe, Mn, Zn and Cu with yield and CCS were generally weak ([Cerri et al., 2012](#)) [16].

Table 1. Correlation between soil chemical properties and yield, CCS % as influenced by

	pH	Ec	N	P	K	Fe	Mn	Zn	Cu	Yield	CCS
pH	1.000										
Ec	0.254	1.000									
N	-0.369	-0.236	1.000								
P	-0.298	-0.343	0.768	1.000							
K	-0.327	-0.332	0.794	0.986	1.000						
Fe	0.026	0.181	0.159	0.082	0.092	1.000					
Mn	0.204	0.292	0.219	0.218	0.181	0.508	1.000				
Zn	-0.008	0.051	-0.135	-0.116	-0.062	0.021	-0.071	1.000			
Cu	-0.170	-0.045	0.206	0.200	0.202	0.626	0.407	0.146	1.000		
Yield	-0.348	-0.302	0.932	0.935	0.948	0.137	0.223	-0.116	0.194	1.000	
CCS	-0.217	-0.373	0.727	0.880	0.877	0.062	0.188	-0.145	0.126	0.893	1.000

by sugarcane trash management practices in medium sugar recovery zone

Table 2. Correlation between soil chemical properties and yield, CCS % as influenced

	pH	Ec	N	P	K	Fe	Mn	Zn	Cu	Yield	CCS
pH	1.000										
Ec	-0.361	1.000									
N	-0.037	-0.002	1.000								
P	-0.094	0.059	0.906	1.000							
K	-0.077	0.046	0.885	0.957	1.000						
Fe	0.073	0.124	-0.093	-0.095	-0.046	1.000					
Mn	-0.036	-0.106	-0.001	-0.028	0.006	0.585	1.000				
Zn	0.036	-0.195	-0.085	-0.275	-0.332	-0.091	-0.034	1.000			
Cu	0.021	-0.267	0.080	0.023	0.023	0.269	0.281	0.215	1.000		
Yield	-0.129	0.071	0.872	0.974	0.978	-0.112	-0.006	-0.297	-0.001	1.000	
CCS	-0.116	0.087	0.874	0.977	0.969	-0.094	-0.029	-0.306	0.059	0.982	1.000

As shown in [Table 2](#), under trash management in the medium sugar recovery zone, *N*, *P* and *K* showed strong positive correlations with both yield and CCS. Yield was strongly correlated with *N* ($r = 0.872$), *P* ($r = 0.974$) and *K* ($r = 0.978$), while CCS showed similar positive relationships with *N* ($r = 0.874$), *P* ($r = 0.977$) and *K* ($r = 0.969$).

Yield and CCS also had a very strong positive correlation ($r = 0.982$). Fe and Mn showed a moderate positive relationship ($r = 0.585$), whereas Zn had weak negative correlations with yield ($r = -0.297$) and CCS ($r = -0.306$).

by sugarcane trash management practices in low sugar recovery zone

Table 3. Correlation between soil chemical properties and yield, CCS % as influenced

	pH	Ec	N	P	K	Fe	Mn	Zn	Cu	Yield	CCS
pH	1.000										
Ec	-0.073	1.000									
N	0.244	-0.012	1.000								
P	0.300	-0.210	0.871	1.000							

(continued on next page)

	pH	Ec	N	P	K	Fe	Mn	Zn	Cu	Yield	CCS
K	0.222	-0.135	0.932	0.966	1.000						
Fe	-0.143	0.299	-0.026	-0.129	-0.064	1.000					
Mn	-0.372	0.536	-0.176	-0.413	-0.335	0.509	1.000				
Zn	0.099	0.226	0.278	0.319	0.330	0.105	0.191	1.000			
Cu	0.080	0.336	0.432	0.170	0.269	0.274	0.364	0.223	1.000		
Yield	0.307	-0.113	0.965	0.919	0.931	-0.161	-0.291	0.238	0.332	1.000	
CCS	0.231	-0.272	0.830	0.966	0.932	-0.033	-0.357	0.294	0.168	0.861	1.000

As shown in Table 3, under trash management in the low sugar recovery zone, N, P, and K showed strong positive relationships with both yield and CCS. Yield was strongly correlated with N ($r = 0.965$), P ($r = 0.919$) and K ($r = 0.931$), while CCS showed positive correlations with N ($r = 0.830$), P ($r = 0.966$) and K ($r = 0.932$). Yield and CCS were also strongly correlated ($r = 0.861$), indicating that higher cane yield was generally associated with better sugar recovery. While EC was moderately correlated with Mn ($r = 0.536$). Mn showed weak negative correlations with yield ($r = -0.291$) and CCS ($r = -0.357$), whereas the remaining soil properties showed weak or negligible relationships with yield and CCS.

sugarcane trash burning practices in high sugar recovery zone

As shown in Table 4, under sugarcane trash burning in the high sugar recovery zone, N, P and K showed strong positive relationships with both yield and CCS. Yield was strongly correlated with N ($r = 0.891$), P ($r = 0.956$), and K ($r = 0.965$), while CCS showed similar positive correlations with N ($r = 0.879$), P ($r = 0.950$), and K ($r = 0.916$). Yield and CCS also had a strong positive correlation ($r = 0.939$), indicating that higher cane yield was generally associated with better sugar recovery. Fe and Mn showed a moderate positive relationship ($r = 0.641$), while Mn and Cu were strongly correlated ($r = 0.770$). In contrast, soil pH showed negative relationships with N ($r = -0.527$), P ($r = -0.456$), yield ($r = -0.445$), and CCS ($r = -0.386$).

Table 4. Correlation between soil chemical properties and yield, CCS % as influenced by

	pH	Ec	N	P	K	Fe	Mn	Zn	Cu	Yield	CCS
pH	1.000										
Ec	0.017	1.000									
N	-0.527	0.226	1.000								
P	-0.456	0.274	0.953	1.000							
K	-0.352	0.367	0.860	0.947	1.000						
Fe	-0.204	0.098	0.222	0.191	0.159	1.000					
Mn	0.077	0.224	-0.160	-0.188	-0.198	0.641	1.000				
Zn	-0.208	-0.236	0.012	-0.066	-0.128	0.143	0.075	1.000			
Cu	0.105	0.190	-0.169	-0.157	-0.175	0.471	0.770	-0.147	1.000		
Yield	-0.445	0.295	0.891	0.956	0.965	0.148	-0.268	-0.100	-0.216	1.000	
CCS	-0.386	0.286	0.879	0.950	0.916	0.184	-0.146	-0.036	-0.131	0.939	1.000

sugarcane trash burning practices in medium sugar recovery zone

Table 5. Correlation between soil chemical properties and yield, CCS % as influenced by

	pH	Ec	N	P	K	Fe	Mn	Zn	Cu	Yield	CCS
pH	1.000										
Ec	-0.144	1.000									
N	0.192	0.208	1.000								
P	0.226	0.181	0.983	1.000							
K	0.118	0.197	0.938	0.897	1.000						
Fe	0.230	0.122	0.528	0.580	0.379	1.000					
Mn	0.236	0.001	0.348	0.392	0.244	0.653	1.000				
Zn	0.312	-0.112	0.084	0.117	0.123	0.299	0.482	1.000			
Cu	-0.033	0.058	0.145	0.155	0.175	0.269	-0.037	-0.110	1.000		
Yield	0.152	0.163	0.989	0.967	0.941	0.496	0.369	0.087	0.124	1.000	
CCS	0.240	0.152	0.969	0.985	0.873	0.563	0.373	0.074	0.145	0.950	1.000

As shown in Table 5, under trash burning in the medium sugar recovery zone, N, P and K were strongly and positively related to both yield and CCS. Yield showed very strong correlations with N ($r = 0.989$), P ($r = 0.967$), and K ($r = 0.941$), while CCS was also strongly correlated with N ($r = 0.969$), P ($r = 0.985$) and K ($r = 0.873$). Yield and CCS were strongly related to each other ($r = 0.950$), suggesting that higher cane yield was generally associated with better sugar re-

covery. Among the other soil properties, Fe showed moderate positive correlations with P ($r = 0.580$) and CCS ($r = 0.563$) and a strong positive relationship was observed between Fe and Mn ($r = 0.653$). Mg also showed moderate positive relationships with K ($r = 0.526$) and yield ($r = 0.404$).

sugarcane trash burning practices in low sugar recovery zone

Table 6. Correlation between soil chemical properties and yield, CCS % as influenced by

	pH	Ec	N	P	K	Fe	Mn	Zn	Cu	Yield	CCS
pH	1.000										
Ec	0.099	1.000									
N	0.217	-0.079	1.000								
P	0.235	0.112	0.876	1.000							
K	0.115	-0.107	0.748	0.712	1.000						
Fe	-0.299	-0.108	0.006	0.056	0.054	1.000					
Mn	-0.151	0.344	0.308	0.531	0.341	0.206	1.000				
Zn	0.313	0.353	0.177	0.244	-0.010	-0.080	0.176	1.000			
Cu	-0.246	0.263	0.108	0.180	0.068	0.392	0.450	-0.186	1.000		
Yield	-0.023	0.051	0.809	0.864	0.702	0.165	0.553	0.055	0.279	1.000	
CCS	0.064	0.049	0.819	0.790	0.542	0.052	0.358	0.119	0.238	0.888	1.000

As shown in Table 6, under trash burning in the low sugar recovery zone, N, P and K showed positive associations with both yield and CCS. Yield was strongly correlated with N ($r = 0.809$) and P ($r = 0.864$), while K also showed a positive relationship ($r = 0.702$). Similarly, CCS was strongly associated with N ($r = 0.819$) and P ($r = 0.790$), whereas its relationship with K was moderate ($r = 0.542$). A strong positive correlation was also observed between yield and CCS ($r = 0.888$), indicating that higher cane yield was generally linked with better sugar recovery. Among the other soil properties, while Mn had moderate positive correlations with yield ($r = 0.553$).

Conclusions

- The correlation analysis indicated that N, P and K had the strongest and most consistent relationships with sugarcane yield and CCS under both trash retention and trash burning practices across the different sugar recovery zones. A strong positive relationship was also observed between yield and CCS, suggesting that higher cane production was generally associated with better sugar recovery. In comparison, soil pH and EC showed weak to moderate negative relationships with yield and CCS, while the associations of most secondary and micronutrients were relatively weak and varied across the treatments. Collectively these results indicate that maintaining adequate nutrient availability and implementing effective trash management practices are essential for improving sugarcane yield and sugar recovery.

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How to cite this article: Zodge R, Phalke D, Kamble B, Manna M, Patil S, Bachhav S, et al. Correlation of soil chemical properties with sugarcane yield and CCS under different trash management practices. *International Journal of Research in Agronomy*. 2026;9(9):1592-1596. doi: <https://www.doi.org/10.33545/2618060X.2026.v9.i9u.6737>

Authors

RB Zodge

Department of Soil Science, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahilyanagar, Maharashtra, India

DH Phalke

Department of Soil Science, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahilyanagar, Maharashtra, India

BM Kamble

Department of Soil Science, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahilyanagar, Maharashtra, India

MC Manna

Department of Soil Science, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahilyanagar, Maharashtra, India

SR Patil

Department of Soil Science, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahilyanagar, Maharashtra, India

SS Bachhav

Department of Soil Science, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahilyanagar, Maharashtra, India

CA Nimbalkar

Department of Soil Science, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahilyanagar, Maharashtra, India