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Soil chemical properties as influenced by pre and post emergence herbicide in sweet corn grown in Vertisols

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Abstract
Field experiment was conducted at Department of Agronomy, College of Agriculture, Dhule during *Kharif* 2019 to study the effect of pre and post emergence herbicides on soil chemical properties in sweet corn. The treatment of weedy check (T_1) recorded significantly higher soil organic carbon of 5.51 g kg^{-1}. There was no variation in the soil organic carbon content among the treatments of pre and post emergence application of herbicides. The soil organic carbon in all these treatments of pre and post emergence application of herbicides was in the range of 5.43 to 5.45 g kg^{-1}. The periodical soil available N was significantly influenced at 7, 15, 21, 30 and 45 days after application due to application of pre and post emergence herbicides to sweet corn. At harvest of sweet corn, the application of halosulfuron-methyl @ 90 g ha^{-1} as post emergence recorded significantly higher soil available N (208 kg ha^{-1}), available P (17.11 kg ha^{-1}) and available K (333.33 kg ha^{-1}). The treatment of weedy check (T_1) recorded significantly lower soil available N (195.33 kg ha^{-1}), available P (15.33 kg ha^{-1}) and available K (306.44 kg ha^{-1}).

Keywords: Soil pH, electrical conductivity, soil available N, P and K

Introduction

Sweet corn is gaining popularity among the urban masses in terms of nutrition and health consciousness in India. Heavy weed infestation is one of the major constraints that limit the productivity of sweet corn crop. In the modern era of urbanization, labour component in agriculture is becoming scarce, not available at time and prohibitive cost. Chemical weed control is a better supplement to conventional methods and forms an integral part of the modern crop production. Herbicides are toxic agrochemicals, which have being used to control the weeds in the agricultural farms and gardens. After application of herbicide in soil it is said to be persistent if it is present in the soil in its original or closely related to its phytotoxic forms (Sondhia 2014) [20]. The remaining quantity of herbicide after weed control is referred to as its residue while its soil persistence is often described as its "half-life" which is the amount of time it takes to decompose fifty percent of the applied chemical to an herbicidal inactive form.

Soil physical, chemical and microbial properties are playing important role in the persistence of herbicides in the soil (Hager *et al*. 2000) [9]. These soil factors affects herbicide persistence through adsorption, leaching and volatilization. Generally, soils that are high in clay/organic matter or both, have greater potential for herbicide carryover because there is increased adsorption to soil colloids with a corresponding decrease in leaching and loss through volatilization. Chemical properties of a soil which include the pH, electrical conductivity, organic carbon, soil available nitrogen, available phosphorus, available potassium indicate its nutrient status. Some herbicides are particularly affected by soil pH such that lesser amounts of these herbicides are adsorbed or adhered to soil colloids at higher soil pH, so they remain in the soil solution. Herbicides in the soil solution are available for plant uptake. Various nutrients and cations in the soil have been observed to affect both herbicide activity and degradation (Bulu *et al.* 2019) [5]. In recent times, the rate at which herbicides are applied to control weeds at residential areas in urban environment has increased rapidly. The increasing use of herbicides with high potential mobility may pose serious environmental problems through offsite transport. This research was therefore done with a view to assessing the effects of pre and post emergence herbicides on soil chemical properties in sweet corn.

Material and Methods

Field experiment was conducted at Department of Agronomy, College of Agriculture, Dhule during *Kharif* 2019 to study the effect of pre and post emergence herbicides on soil enzymes in sweet corn. The experiment was laid out in randomized block design with ten treatments replicated three times. Treatments composed of T_1: weedy check, T_2: weed free (two hand weeding), T_3: atrazine @ 1000 g ha^{-1} (PE) *fb* halosulfuron methyl @ 90 g ha^{-1} (PoE), T_4: atrazine @ 1000 g ha^{-1} (PE) *fb* 2,4 D ethyl ester @ 1000 g ha^{-1} (PoE), T_5: pendimethalin @ 1000 g ha^{-1} (PE) *fb* halosulfuron-methyl @ 90 g ha^{-1} (PoE), T_6: pendimethalin @ 1000 g ha^{-1} (PE) *fb* tembotrione @ 120 g ha^{-1} (PoE), T_7: pendimethalin @ 1000 g ha^{-1} (PE) *fb* 2,4 D ethyl ester @ 1000 g ha^{-1} (PoE), T_8: halosulfuron-methyl @ 90 g ha^{-1} (PoE), T_9: tembotrione @ 120 g ha^{-1} (PoE) and T_{10}: 2,4 D ethyl ester @ 1000 g ha^{-1} (PoE). The pre emergence (PE) herbicides were applied on next day after sowing of sweet corn, however, the post emergence (PoE) hebicides were applied 30 days after sowing of sweet corn. The soil of experimental site was medium black with the following chemical properties: pH 8.01, electrical conductivity (EC) 0.32 dS m^{-1}, organic carbon (5.60 g kg^{-1}), calcium carbonate (49 g kg^{-1}), available N (202.34 kg ha^{-1}), available (Olsen-P) P (17.32 kg ha^{-1}), available (NH_4OAc-K) K (402.25 kg ha^{-1}).

For assessment of physio-chemical properties of soil, surface representative and composite soil samples from each treatment were collected replication wise and dried in shade, pounded in wooden mortar and pestle and passed through 2 mm sieve and used for chemical analysis. Soil pH (1:2.5) was determined by potentiometric method and electrical conductivity (1:2.5) was determined by conductometric method (Jackson 1973) [10]. Organic carbon in soil was determined by wet oxidation method (Nelson and Sommer 1982) [15]. $CaCO_3$ content was determined by acid neutralization method (Allison and Moodie 1965) [2]. Available N in soil was determined by alkaline permanganate method (Subbiah and Asija 1956) [21]. Available P in soil was determined by $NaHCO_3$ (0.5 *M*) method (Olsen *et al.* 1954) [16]. Available K in soil was determined by N *N* NH_4OAc method (Knudsen *et al.* 1982) [12].

Result and Discussion

Soil organic carbon

The effect of pre and post emergence herbicides *viz*., atrazine, halosulfuron methyl, 2-4-D ethyl ester, pendimethalin and tembotrione on periodical soil organic carbon is presented in Table 1. The periodical soil organic carbon was statistically non significant at 7, 15, 21 and 30 DAS due to application of pre and post emergence herbicides for sweet corn. At 45 DAS, the weedy check treatment (T_1) recorded significantly higher soil organic carbon (5.54 g kg^{-1}). The treatments of pre and post emergence of herbicide application (T_3 to T_{10}) recorded the organic carbon content of 5.48 to 5.49 g kg^{-1} at 45 DAS. All the treatments of pre and post emergence of herbicide application (T_3 to T_{10}) were statistically at par with each other at 45 DAS. The weed free (two hand weeding) treatment (T_2) recorded significantly lower soil organic carbon (5.42 g kg^{-1}) at 45 DAS. At harvest of sweet corn, the treatment of weedy check (T_1) recorded significantly higher soil organic carbon of 5.51 g kg^{-1}, which might be due to addition of weed root biomass in the soil. The results revealed that there was no variation in the soil organic carbon content among the treatments of pre and post emergence application of herbicides. The soil organic carbon in all these treatments of pre and post emergence application of herbicides was in the range of 5.43 to 5.45 g kg^{-1} and the treatments T_3 to T_{10} were statistically at par with each other. The weed free treatment (two hand weeding) recorded significantly lower soil organic carbon of 5.39 g kg^{-1}, however, this treatment was statistically at par with the treatment halosulfuron-methyl @ 90 g ha^{-1} (PoE). Mayeetreyee *et al.* (2013) [14] and Abbas *et al*. (2014) [1] also reported the decrease in total organic carbon with application of pre and post emergence herbicides.

Soil available N

The periodical soil available nitrogen in soil was significantly influenced at 7, 15, 21, 30 and 45 days after application by pre and post emergence herbicides during the field experiment (Table 2). The results revealed that the availability of the nitrogen was higher at initial stage of sweet corn (7 DAS) which might be due to basal application of nitrogenous fertilizer and at 30 DAS, which might be due to top dressing of nitrogenous fertilizer to sweet corn.

The soil nitrogen content in the treatments of application of pre and post emergence herbicides (T_3 to T_{10}) at all the stages was higher as compared to the treatments of weed free (two hand weeding) (T_2) and weedy check (T_1). This might be associated with the mineralization processes, the bacteria responsible for oxidation in the soil system were affected by higher concentration of herbicide in soil. Since microbe plays a crucial role in nutrient transformation, any change in their population and activity may affect cycling of nutrients as well as availability of nutrients. Thus, indirectly affecting plant growth and other soil functions. The results revealed that the application of herbicides may involve a risk of reduced or altered soil microbial activities and microbial diversity, soil chemical processes and mineralization rates. These in turn resulted in reduced uptake of nitrogen by sweet corn (Duhan *et al.* 2005) [8]. At 45 DAS, significantly higher soil available nitrogen (221.05 kg ha^{-1}) was recorded in application of halosulfuron-methyl @ 90 g ha^{-1} (PoE). However, this treatment was statistically at par with the treatments of 2,4 D ethyl ester @ 1000 g ha^{-1} (PoE) and pendimethalin @ 1000 g ha^{-1} as (PE) *fb* halosulfuron-methyl @ 90 g ha^{-1} (PoE). The significantly lower value (208.76 kg ha^{-1}) of soil nitrogen was recorded in the treatment of weedy check (T_1) at 45 DAS, however, this treatment was at par with the treatments of T_2, T_3, T_4, T_6 and T_7. At harvest of sweet corn, application of halosulfuron-methyl @ 90 g ha^{-1} (PoE) recorded significantly higher soil available N (208 kg ha^{-1}). However, this treatment was statistically at par with the treatment of pendimethalin @ 1000 g ha^{-1} (PE) *fb* halosulfuron-methyl @ 90 g ha^{-1} (PoE) which recorded the soil available N of 206 kg ha^{-1}. The treatment of weedy check (T_1) recorded significantly lower soil available N of 195.33 kg ha^{-1}. However, this treatment was at par with application of pendimethalin @ 1000 g ha^{-1} (PE) *fb* 2,4 D ethyl ester @ 1000 g ha^{-1} (PoE), pendimethalin @ 1000 g ha^{-1} (PE) *fb* tembotrione @ 120 g ha^{-1} (PoE) and weed free treatment (two hand weeding). The decrease in soil available nitrogen might be due to inhibition of proliferation of soil microbial population and the active sites of enzymes substituted by functional groups of herbicides. Similar results regarding soil avialbale nitrogen due to application of pre and post emergence herbicides were also reported by Parlda *et al*. (2010) [17] and Jha *et al.* (2014) [11].

Soil available P

The periodical soil available phosphorus was statistically non significant at 7 and 15 DAS due to application of pre and post emergence herbicides for sweet corn (Table 3). Similar results were also reported by Bera and Ghosh (2013) [4]. However, at 21, 30 and 45 DAS, the soil available phosphorus was significantly influenced due to the application of pre and post emergence herbicides to the sweet corn. At 45 DAS, application of tembotrione @ 120 g ha^{-1} (PoE) recorded significantly higher soil available phosphorus (17.65 kg ha^{-1}). However, this treatment was statistically at par with treatments, halosulfuron-methyl @ 90 g ha^{-1} (PoE), pendimethalin @ 1000 g ha^{-1} (PE) *fb* tembotrione @ 120 g ha^{-1} (PoE) and atrazine @ 1000 g ha^{-1} (PE) *fb* halosulfuron methyl @ 90 g ha^{-1} (PoE). These results are in conformity with the results reported by Das *et al*. (2003) [7] and Patel *et al* (2019) [18]. The treatment of weedy check (T_1) recorded significantly lower soil phosphorus content (16.09 kg ha^{-1}), which might be due to higher uptake of soil P by weed biomass. The treatment T_1 was statistically at par with the treatments weed free (T_2), atrazine @ 1000 g ha^{-1} (PE) *fb* 2,4 D ethyl ester @ 1000 g ha^{-1} (PoE) and pendimethalin @ 1000 g ha^{-1} (PE) *fb* 2,4 D ethyl ester @ 1000 g ha^{-1} (PoE).

At harvest of sweet corn, application of halosulfuron-methyl @ 90 g ha^{-1} (PoE) recorded significantly higher soil available P (17.11 kg ha^{-1}). However, this treatment was statistically at par with application of tembotrione @ 120 g ha^{-1} (PoE), atrazine @ 1000 g ha^{-1} (PE) *fb* halosulfuron methyl @ 90 g ha^{-1} (PoE), pendimethalin @ 1000 g ha^{-1} (PE) *fb* halosulfuron-methyl @ 90 g ha^{-1} (PoE), pendimethalin @ 1000 g ha^{-1} (PE) *fb* tembotrione @ 120 g ha^{-1} (PoE), pendimethalin @ 1000 g ha^{-1} (PE) *fb* 2,4 D ethyl ester @ 1000 g ha^{-1} (PoE) and 2,4 D ethyl ester @ 1000 g ha^{-1} (PoE). The weed free treatment (two hand weeding) recorded 16.11 kg ha^{-1} soil available P, however, this treatment was at par with T_4, T_5, T_6, T_7 and T_{10}. The treatment of weedy check (T_1) recorded significantly lower soil available P of 15.33 kg ha^{-1}. The decrease in soil available phosphorus might be associated with the decrease in permeability of cells of soil microbes from which the enzymes exudate. The exudated enzymes enhance the availability of phosphorus. The results are in conformity of the observations of Das *et al.* (2012) [6], Sinodiya and Jha (2014) [11].

Soil available K

The periodical soil available potassium was statistically non significant at 7 and 15 DAS due to application of pre and post emergence herbicides for sweet corn (Table 4). However, at 21, 30 and 45 DAS, the soil available potassium was significantly influenced due to the application of pre and post emergence herbicides to the sweet corn. At 45 DAS, application of halosulfuron-methyl @ 90 g ha^{-1} (PoE) recorded significantly higher soil available potassium (440.89 kg ha^{-1}). However, this treatment was statistically at par with treatments 2, 4 D ethyl ester @ 1000 g ha^{-1} (PoE) and pendimethalin @ 1000 g ha^{-1} (PE) *fb* halosulfuron-methyl @ 90 g ha^{-1} (PoE). The treatment of weedy check (T_1) recorded significantly lower soil potassium content (414 kg ha^{-1}), however, this treatment was statistically at par with the weed free treatment (T_2). The soil available potassium was increased in the treatments of pre and post emergence herbicide application by 16.34 to 21.70% at 45 DAS over the initial value of soil K (362.25 kg ha^{-1}). These results are in conformity with the results reported by Alksyants *et al.* (1986) [3] and Lane *et al.* (2012) [13].

At harvest of sweet corn, the treatment of halosulfuron-methyl @ 90 g ha^{-1} (PoE) recorded significantly higher soil available K (333.33 kg ha^{-1}). However, this treatment was statistically at par with 2,4 D ethyl ester @ 1000 g ha^{-1} (PoE) and pendimethalin @ 1000 g ha^{-1} (PE) *fb* halosulfuron-methyl @ 90 g ha^{-1} (PoE). The treatment of weedy check (T_1) recorded significantly lower soil available K of 306.44 kg ha^{-1}. The soil available potassium was decreased with an advanced age of crop. It was reduced consistently from 15 DAS to 45 DAS and at harvest in all the treatments. This might be because of sweet corn crop taken the potassium from soil for metabolic activities as well as growth and development of crop. Similarly, there might be fixation of potassium in lattice layer of clay minerals. The results are in conformity of the observations of Sinodiya and Jha (2014) [11].

Table 1: Soil organic carbon as influenced by application of herbicides

Sr. No.	Treatments	Soil organic carbon (g kg^{-1})					
		7 DAS	15 DAS	21 DAS	30 DAS	45 DAS	At harvest
1.	Weedy	5.60	5.59	5.57	5.56	5.54^{a}	5.51^{a}
2.	Weed free (two hand weedings)	5.60	5.58	5.57	5.48	5.42^{c}	5.39^{c}
3.	Atrazine @ 1000 g ha^{-1} (PE) *fb* halosulfuron methyl @ 90 g ha^{-1} (PoE)	5.59	5.59	5.57	5.52	5.48^{b}	5.45^{b}
4.	Atrazine @ 1000 g ha^{-1} (PE) *fb* 2,4 D ethyl ester @ 1000 g ha^{-1} (PoE)	5.60	5.59	5.58	5.52	5.49^{b}	5.44^{b}
5.	Pendimethalin @ 1000 g ha^{-1} (PE) *fb* halosulfuron-methyl @ 90 g ha^{-1} (PoE)	5.59	5.59	5.58	5.52	5.49^{b}	5.44^{b}
6.	Pendimethalin @ 1000 g ha^{-1} (PE) *fb* tembotrione @ 120 g ha^{-1} (PoE)	5.60	5.58	5.56	5.52	5.48^{b}	5.45^{b}
7.	Pendimethalin @ 1000 g ha^{-1} (PE) *fb* 2,4 D ethyl ester @ 1000 g ha^{-1} (PoE)	5.60	5.59	5.57	5.51	5.49^{b}	5.44^{b}
8.	Halosulfuron-methyl @ 90 g ha^{-1} (PoE)	5.59	5.59	5.57	5.51	5.48^{b}	5.43^{bc}
9.	Tembotrione @ 120 g ha^{-1} (PoE)	5.59	5.58	5.56	5.51	5.48^{b}	5.44^{b}
10.	2,4 D ethyl ester @ 1000 g ha^{-1} (PoE)	5.58	5.58	5.56	5.51	5.48^{b}	5.44^{b}
	SE(m)+	0.013	0.011	0.009	0.007	0.006	0.010
	CD at 5%	NS	NS	NS	NS	0.019	0.032

Table 2: Available N in soil as influenced by application of herbicides

Sr. No	Treatments	Soil available N (kg ha^{-1})					
		7 DAS	15 DAS	21 DAS	30 DAS	45 DAS	At harvest
1.	Weedy	210.86^{b}	205.14^{b}	201.16^{b}	209.72^{b}	208.76^{c}	195.33^{c}
2.	Weed free (two hand weedings)	209.58^{b}	206.05^{b}	202.76^{b}	212.15^{b}	211.12^{c}	196.67^{c}
3.	Atrazine @ 1000 g ha^{-1} (PE) *fb* halosulfuron methyl @ 90 g ha^{-1} (PoE)	216.91^{ab}	211.46^{a}	208.18^{a}	217.95^{a}	216.06^{bc}	202.67^{b}
4.	Atrazine @ 1000 g ha^{-1} (PE) *fb* 2,4 D ethyl ester @ 1000 g ha^{-1} (PoE)	213.87^{ab}	209.11^{b}	205.89^{b}	214.70^{b}	213.21^{bc}	200.00^{bc}
5.	Pendimethalin @ 1000 g ha^{-1} (PE) *fb* halosulfuron-methyl @ 90 g ha^{-1} (PoE)	218.60^{ab}	213.47^{ab}	209.94^{ab}	220.34^{a}	219.00^{ab}	206.00^{a}
6.	Pendimethalin @ 1000 g ha^{-1} (PE) *fb* tembotrione @ 120 g ha^{-1} (PoE)	212.48^{b}	207.14^{b}	203.20^{b}	213.72^{b}	212.22^{bc}	198.67^{bc}

7.	Pendimethalin @ 1000 g ha-1 (PE) *fb* 2,4 D ethyl ester @ 1000 g ha-1 (PoE)	213.15b	207.09b	202.92b	212.38b	211.66c	198.67bc
8.	Halosulfuron-methyl @ 90 g ha-1 (PoE)	221.57a	215.80a	212.11a	222.23a	221.05a	208.00a
9.	Tembotrione @ 120 g ha-1 (PoE)	216.90ab	210.77ab	207.44ab	217.91ab	216.24b	202.67b
10.	2,4 D ethyl ester @ 1000 g ha-1 (PoE)	220.19ab	214.72a	210.54ab	220.12a	219.06a	206.33a
	SE(m)+	2.54	1.68	1.92	1.74	1.39	1.73
	CD at 5%	8.15	5.09	5.71	5.19	4.13	5.16

Table 3: Available P in soil as influenced by application of herbicides

Sr. No	Treatments	Soil available P (kg ha-1)					
		7 DAS	15 DAS	21 DAS	30 DAS	45 DAS	At harvest
1.	Weedy	17.28	17.32	16.68c	16.45c	16.09c	15.33c
2.	Weed free (two hand weedings)	17.29	17.32	17.18bc	16.94c	16.58c	16.11b
3.	Atrazine @ 1000 g ha-1 (PE) *fb* halosulfuron methyl @ 90 g ha-1 (PoE)	17.27	17.29	17.99ab	17.77ab	17.36ab	16.89a
4.	Atrazine @ 1000 g ha-1 (PE) *fb* 2,4 D ethyl ester @ 1000 g ha-1 (PoE)	17.29	17.31	17.57b	17.34bc	16.98bc	16.22b
5.	Pendimethalin @ 1000 g ha-1 (PE) *fb* halosulfuron-methyl @ 90 g ha-1 (PoE)	17.26	17.28	17.79ab	17.56ab	17.14b	16.67ab
6.	Pendimethalin @ 1000 g ha-1 (PE) *fb* tembotrione @ 120 g ha-1 (PoE)	17.27	17.30	17.95ab	17.73ab	17.32ab	16.56ab
7.	Pendimethalin @ 1000 g ha-1 (PE) *fb* 2,4 D ethyl ester @ 1000 g ha-1 (PoE)	17.28	17.30	17.62b	17.39b	17.03bc	16.56ab
8.	Halosulfuron-methyl @ 90 g ha-1 (PoE)	17.27	17.29	18.16ab	17.94ab	17.58ab	17.11a
9.	Tembotrione @ 120 g ha-1 (PoE)	17.28	17.31	18.30a	18.06a	17.65a	16.89a
10.	2,4 D ethyl ester @ 1000 g ha-1 (PoE)	17.28	17.30	17.73ab	17.50b	17.14b	16.67ab
	SE(m)+	0.049	0.047	0.19	0.17	0.16	0.20
	CD at 5%	NS	NS	0.58	0.52	0.49	0.61

Table 4: Available K in soil as influenced by application of herbicides

Sr. No	Treatments	Soil available K (kg ha-1)					
		7 DAS	15 DAS	21 DAS	30 DAS	45 DAS	At harvest
1.	Weedy	402.23	468.71	451.96e	431.87e	414.00d	306.44e
2.	Weed free (two hand weedings)	404.96	471.92	456.53e	437.54d	419.17cd	311.11d
3.	Atrazine @ 1000 g ha-1 (PE) *fb* halosulfuron methyl @ 90 g ha-1 (PoE)	403.55	470.73	467.74c	448.65c	430.51b	322.22bc
4.	Atrazine @ 1000 g ha-1 (PE) *fb* 2,4 D ethyl ester @ 1000 g ha-1 (PoE)	406.66a	473.22	459.31de	439.32d	421.45c	313.89d
5.	Pendimethalin @ 1000 g ha-1 (PE) *fb* halosulfuron-methyl @ 90 g ha-1 (PoE)	402.63	469.59	473.3b	454.21b	435.84ab	327.78ab
6.	Pendimethalin @ 1000 g ha-1 (PE) *fb* tembotrione @ 120 g ha-1 (PoE)	403.06	470.23	459.31de	440.32d	422.06c	313.89d
7.	Pendimethalin @ 1000 g ha-1 (PE) *fb* 2,4 D ethyl ester @ 1000 g ha-1 (PoE)	404.11	470.59	462.09d	442.1d	424.23c	316.67cd
8.	Halosulfuron-methyl @ 90 g ha-1 (PoE)	403.07	470.02	478.75a	459.76a	440.89a	333.33a
9.	Tembotrione @ 120 g ha-1 (PoE)	402.61	469.79	467.74c	448.65c	430.28b	322.22bc
10.	2,4 D ethyl ester @ 1000 g ha-1 (PoE)	405.63	472.12a	475.98ab	455.99ab	438.12a	330.56a
	SE(m)+	1.38	1.96	1.67	1.73	1.79	1.87
	CD at 5%	NS	NS	4.97	5.15	5.33	5.58

Conclusion

It is concluded that there was no variation in the soil organic carbon content among the treatments of pre and post emergence application of herbicides. The periodical soil available N was significantly influenced at 7, 15, 21, 30 and 45 days after application due to application of pre and post emergence herbicides to sweet corn. At harvest of sweet corn, the application of halosulfuron-methyl @ 90 g ha^{-1} as post emergence recorded significantly higher soil available N (208 kg ha^{-1}), available P (17.11 kg ha^{-1}) and available K (333.33 kg ha^{-1}). The treatment of weedy check (T_1) recorded significantly lower soil available N (195.33 kg ha^{-1}), available P (15.33 kg ha^{-1}) and available K (306.44 kg ha^{-1}).

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