Research Article
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Comparison between incorporation and stubble burning in an Humic Haploxerands Soil, Central Southern, Chile

Abstract

Stubble burning in Chile is a common practice used for the farmers but it causes nutrient losses , erosion and environmental pollution. An alternative to change this situation is the incorporation of crop residue to improve the soil quality. The objective of this research was to compare the effects of the incorporation of oat stubble and stubble burning on the chemical and physical properties in an Humic Haploxerands soil with crop rotation oat-wheat. A completely randomized experimental design was used by two treatments of incorporation and stubble burning with soil sampling at depths of 0-5, 5-10 and 10-20cm, with three replicates. The results showed that stubble incorporationrepresents an sustainable management alternative for the ash volcanic soils, that improve the soil pH, organic matter , potassium exchangeable , aggregates stability and soil porosity.

Keywords: soil quality, macroaggregate, organic matter, C:N ratio

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Introduction

The stubble incorporation is a beneficial practice to avoid soil degradation, maintain fertility, increase crop yield, improve soil physical properties,and enrich the microbiota.[1,2] Stubble burning is the physical removal of crop residue that it is easier for the farmer to burn the stubble after harvest and prepare the soil quickly for the next sowing, but emitting a large amount of dangerous pollutants,[3,4] causing serious damage to human health and the environment.[5-7] Besides, it affects the productivity of the soil by eliminating essential macronutrients such as N, P, K and micronutrients,[8] raises the soil temperature up to 42°C and eliminates soil microorganisms until 2.5cm soil depth.[9] In Chile, the stubble burning is aused by farmers, to control diseases and weeds, eliminate the high volumes of straw produced by cereals, and to facilitate the sowing of the next crop.[10] It has been used for centuries by farmers to clear agricultural land, but it is necessary to strengthen policies to limit the stubble burning.[11,12]

This practice is not sustainable in the next years and the pressure to eliminate it will become evident, as it happened in developed countries. In this regard, in the Kingdom United, the law states that no person engaged in agriculture shall, on agricultural land,burn any crop residues, unless the burning is for the purposes of education or research, disease control or the elimination of plant pests.[13] Therefore, it is necessary to implement stubble incorporation , as a sustainable practice to improve soil quality, since it generates positive effects on infiltration, water holding capacity , less weed germination, protection against erosion, improving the structure and stability of soil aggregates.[14]

The aim of this research was a comparison between the effects of the incorporation and stubble burning on the chemical and physical properties of an Andisol in the Andean foothills of Ñuble Region, Chile.

Materials and methods

The experiment was conducted in the El Carmen commune (18.36 °54'43"S, 71 °54'13" W, altitude 314m.), Ñuble Region, Chile. The soil is classifiedas Humic Haploxerands (Mayulermo Series). The climate is warm mediterranean, maximum temperature of 28.7°C in January, and minimum in July of 3.4°C, average annual temperature was 12.7°C, average annual rainfall was 1,393mm, the annual mean evaporation was 1,386mm, the annual relative humidity was 72%, with a frost-free period of 196days and a dry period of 5months with a water deficit of 693.3 mm between October and March.[15]

The field experiment was carried out during 2016-2017 growing season using a completely randomized design with two treatments of 1ha (10,000m^2) each one. These were: T1: sowing of 'Pantera' wheat on incorporated oat stubble (10t ha^{-1}); T 2: sowing 'Lleuque' wheat on burnt oat stubble. Soil samples were collected at three depths, 0-5cm, 5-10cm and 10-20cm, for each treatment. Soil samples were dried at room temperature and sieved <2mm, determining : pH, organic matter (OM), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sodium (Na) by analytical techniques.[16]

The physical soil properties determined were: bulk density by the cylinder method,[17] water availability by the water chamber method,[18] hydraulic conductivity by the constant height permeameter method[19] and soil aggregate stability.[20] In addition, it was determined total porosity macroaggregates, microaggregates and mean weight diameter (MWD).[17] The analysis was carried out in the Soil Laboratory of the University of Concepción, Chillán (Chile).

The results of the chemical and soil physical properties were subjected to an analysis of variance (ANOVA). The assumption of normality was verified with the Shapiro-Wilks test. Differences between means were verified by test LCD with a confidence level $\alpha<0.05\%$. Data analysis was performed using SAS software (Statiscal Analysis System).[21]

Results and discussion

The chemical evaluation of the different treatments (Table 1) shows that OM content in the stubble incorporation for depth 0-5cm (T1.5) was higher ($P\leq0.05$) in the OM content, as compared with other treatments. This is due to the straw decomposing more quickly if it is kept in contact with the surface layer of the soil depth 5cm, where aerobic bacteria are more active and promote the activity of soil enzymes[22]. Therefore, the mixture of straw with the soil and other crop residues in the upper part of the soil, immediately after harvest, produces the release of nutrients in the soil.[11]

The OM contents in the three depths were always higher in the treatment with stubble incorporation, especially in 0-5 cm soil depth, which improves the quality of the soil and its productivity, increasing the soil sustainability and productive process. The straw, decomposed by soil microorganisms, improves the availability of nutrients, on the other hand, with burning important amounts of nutrients are lost to the atmosphere, almost all of the carbon, sulfur and organic nitrogen, and part of the phosphorus and potassium remains in the ashes, that is carried by the wind or water runoff.[11] In this regard,[10] established that with the stubble burning, all the organic carbon, 90% N, 25% K and 50% S, is lost in the form of various gases and particulate matter.

The soil shows normal acidity for soils derived from volcanic ash, however, the treatment with stubble incorporation in the first 10cm was significantly (P≤0.05) more basic than the treatment with stubble burning (Figure 1), highlighting the increase in pH by 0.24units in the first 5cm, this would be equivalent to an application of 2.18t ha^{-1} of calcium,[23] a situation that is reversed at 20cm soil depth. Some of the factors that influence soil acidity are the decomposition of OM, however, the most significant source of acidification is the use of N ammoniacal sources, mainly urea,[11] which is applied by farmers with a dose of 200kg ha^{-1}.

The levels of N, P and K (Table 1) for both treatments with burning and stubble incorporation were high to medium in all depths analyzed, however, phosphorus in the 10-20cm soil layer reduced its concentration significantly (P≤0.05) in the burning treatment. In relation to inorganic nitrogen, the burning treatment presented higher values (P≤0.05) than the treatment with incorporation of stubble, especially in the depth 0-5cm with 85.05mg kg^{-1}, which is considered high if is greater than 60mg kg^{-1}, probably due to the fertilization of 200kg ha^{-1} of urea carried out by farmers in the treatment with burning, hence the levels found in this treatment may favor losses and decrease the N use efficiency , with environmental and economic negative consequences.[24] Treatment withstubble incorporation presents lower nitrogen levels, 43.07mg kg^{-1}at 0-5cm: 35.83mg kg^{-1}at 5 -10cm and 27.43mg kg^{-1} at 10-20cm soil layer, but with ahomogeneous distribution in depth, which would reduce losses and improve the use nitrogen efficiency.

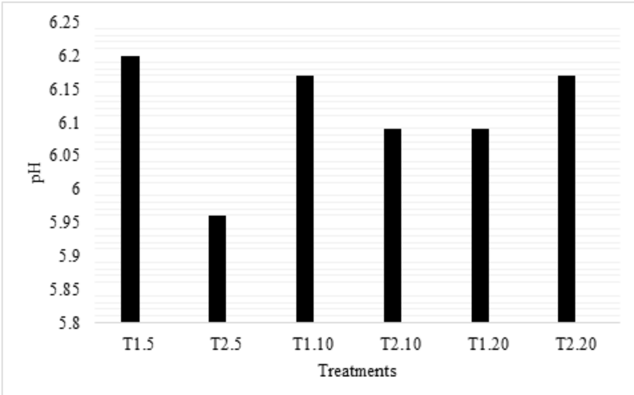

Figure 1 Effect of incorporation and stubble burning on the soil pH at three depths in an HumicHaploxerands of Andean foothills at the Ñuble Region, Chile. T1.5: Incorporation 0-5 cm; T2.5: Burning 0 -5 cm; T1.10: Incorporation 5-10 cm; T2.10: Burning 5-10 cm; T1.20: Incorporation 10-20cm; T2.20: Burning 10- 20 cm.

Table 1 Soil chemical properties of an HumicHaploxerands with incorporating vs stubble burning at Andean Ñuble foothills, Chile

T	OM	pH	N	P	K	Ca	Mg	Na	C:N
T1.5	16,03a	6,2 a	43,07b	29,07b	457 a	7,99b	0,81ab	0,24b	11,67b
T2.5	13,97b	5,96c	85,05a	34,43a	391 b	8,44a	0,59c	0,17c	9,73 f
T1.10	13,72b	6,17a	35,83c	29,1 b	237,7c	5,63e	0,8 b	0,31a	12,53a
T2.10	12,77c	6,09b	35,3 c	22,2 c	233,3c	7,46c	0,57c	0,24b	10,63d
T1.20	11,22d	6,09b	27,43e	12,17d	110,3e	4,88f	0,81ab	0,3 a	11,03c
T2.20	10,27e	6,17a	29,33d	8,57 e	127,7d	6,28d	0,84a	0,17c	10,23e
CV	1,60	0,43	2,05	1,13	1,22	2,43	2,70	7,31	1.31
LSD	0,39	0,04	1,59	0,46	5,00	0,3	0,04	0,03	0,26

T: treatment; OM: organic matter (%); N: nitrógen (mg kg -1); P: phosporus (mg kg-1); K: potassium (mg kg-1); Ca: calcium (cmol(c) kg-1); Mg: magnesium (cmol(c) kg-1); Na: sodio (cmol(c) kg-1); C/N: Carbon/Nitrogen ratio. T1.5: Incorporation 0 a 5 cm; T2.5: Burning 0 a 5 cm; T1.10: Incorporaction 5-10cm; T2.10: Burning 5-10 cm; T1.20: Incorporation 10-20cm; T2.20: Burning 10 a 20cm. CV (%): Variation coefficient. LSD: least significative difference. Different letters in the same column indicate significative according Student test (P≤0,05).

The phosphorus levels in the soil for both treatments presented high to medium levels. In the 0-5 cm soil depth, the treatment with stubble burning presented a significantly higher phosphorus content (P≤0.05) than the treatment with stubble incorporation, this situation is reversed from 10-20cm soil depth, a fact that results favorable since it has a medium and homogeneous concentration at 20 cm depth. Potassium presented average levels for both treatments, favoring significantly (P≤0.05) the levels of the treatment with incorporation of residues in the first 10cm of depth (Table 1).

The levels of Ca, Mg and Nawere adequate, calcium in both treatments presented high levels for the first 5 cm, and then moderate at a greater depth; the magnesium, levels were medium. Regarding sodium, the levels were low for both treatments and all the depths analyzed.

The C: N ratio was low, which favors the OM mineralization, however, the treatment with stubble incorporation always significantly (P≤0.05) greater than the treatment with burning in all the depths studied, since is incorporated organic matter with high ratio C:N. In this regard[25], determined that a C:N = 18 ratio is optimal for the decomposition of stubble, and in this research they varied in the range of 9.73 (T2.5) to 12.53 (T1.10).

The soil physical properties showed low values of bulk density (Bd) (Table 2). In both treatments at 20 cm depth the bulk density values were significantly (P≤0.05) higher than the other depths, and this coincides with the lower OM contents, that another researchers found that by increasing the OM of the soil, Bd should decrease and thereby increase porosity and decrease resistance to penetration, improving soil structure, aggregate stability and significantly increasing the soil quality index.[26]

Regarding aggregation, this was lower, similar to the stability of the aggregates. The MWD at 10cm depth, presented greater stability for the treatment with stubble incorporation (Figure 2), resulting significantly (P≤0.05) better than the rest of the treatments with 0.89mm that indicates a better stability of the aggregates at this depth, unlike the rest of the depths and treatments that showed low values <0.4mm, which would correspond to a very unstable structural state,[27] that the stubble incorporation is an effective practice to improve the content of aggregates >0.25mm and its stability.[14]

Table 2 Physical parameters with stubble incorporationvs stubble burning at three depths in an HumicHaplerands of Andean foothills at the Ñuble Region, Chile

T	OM		Bd		Macro.		Micro.		MWD		Ks		WA	
T1.5	16,03	a	0,73	c	26,77	f	0,57	e	0,23	c	7,8	b	5,77	dc
T2.5	13,97	b	0,74	c	15,36	b	3,14	b	0,33	b	13,25	d	5,48	e
T1.10	13,72	b	0,81	b	52,07	a	1,02	d	0,89	a	9,66	a	2,98	b
T2.10	12,77	c	0,83	b	18,74	e	3,17	b	0,15	e	4,22	c	2,87	d
T1.20	11,22	d	0,89	a	20,36	d	2,48	c	0,20	d	4,35	dc	1,63	a
T2.20	10,27	e	0,88	a	23,15	c	3,63	a	0,24	dc	4,3	dc	1,45	c
CV(%)	1,68		2,02		0,525		2,51		6,91		4,71		0,29	
LSD	0,28		0,02		0,17		0,07		0,03		0,00		0,11	

T: tratamiento; OM: organic matter(%); Bd: bulk density(g cm-3); Macro: macroaggregates (%); Micro:micoaggregates (%); MWD: mean weight diameter (mm); Ks: hydraulic conductivity (cm h-1); WA: water availability (cm); T1.5: Stubble incorporation 0-5 cm; T2.5: Burning 0-5 cm; T1.10: Incorporation 5-10 cm; T2.10: Burning 5-10 cm; T1.20: Stubble incorporation 10-20cm; T2.20: Burning.

The effects of the stubble management treatments were limited mainly in the depth of 0-5cm, and the indicator of water retention was lower with stubble burning , due to the increase in water repellency on the soil surface[9].

The indicators of the porous soil matrix (drainage, water-holding capacity, total porosity, bulk density) it were adequate, on the contrary, the soil structural characteristicsshowed low stability (macroaggregate and MWD), due to the hierarchical organization of the soil system is in a very active and variable dynamic evolution over time, which makes the system susceptible to degradation.[28] This is consistent with another researchers[29] who determined changes in soil quality associated with stubble burning associated with a reduction in the stability of macroaggregates and an increase in pH and exchangeable K.Our results suggest that stubble incorporating is an effective practice to improve the soil aggregate structural and stability, especially in the 5-10cm soil depth where it obtained the best MWD value with 0.89mm (Figure 2).

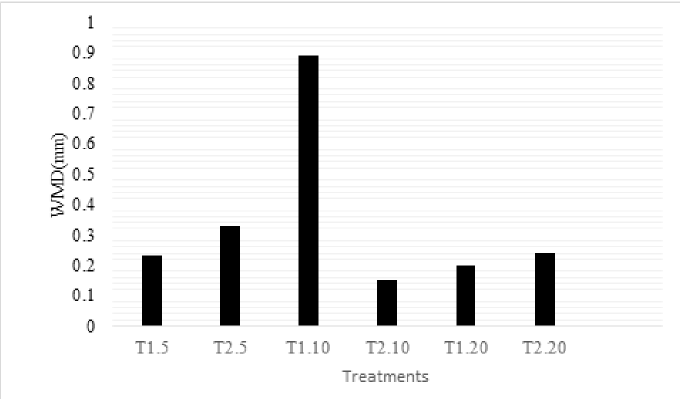

Figure2 Effect of incorporation and stubble burning on the average weight diameter at three depths at three depths in anHumicHaplerands of Andean foothills at the Ñuble Region, Chile. T1.5: Stubble incorporation 0-5cm; T2.5: Burning 0 -5cm; T1.10: Incorporatipn 5-10cm; T2.10:Burning 5-10cm; T1.20: Incorporation 10-20cm; T2.20: Burning 10- 20cm.

Conclusion

The stubble incorporation is the best management strategy for volcanic soils, improving the levels of organic matter, bulk density, macroaggregate, moisture availability, stability of aggregates, levels of exchangeable K, nitrogen content and the soil pH in the 0- 5cm depth.

Acknowledgments

None.

Conflicts of interest

The authors declare no conflicts of interest regarding the publication of this paper.

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