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Evaluation of Tillage Reduction for Potato Production in Slope Areas of Los Andes Mointains in Colombia

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In Colombia, the potato is grown in mountain areas above 2800 masl. In general, tillage and subsequent agricultural practices lead to a soil degradation by erosion, compaction of deep soil layers and loss of productive capacity. In addition, the mechanization and inputs costs are high. In order to find a more conservationist alternative, a research on a potato growing area of the municipality of Fúquene -Cundinamarca at an altitude of 2930 masl, was conducted. Three production systems: Conventional, minimum and zero tillage; were contrasted. In all treatments as green manures, crop rotation and plant cover; Caldas Oats (Avena sativa L.) and Turnip (Raphanus sativus L.) were implemented. During 8 months counted from before planting the green manure to just before the deposing of the second rotation of green manure, the performance of some physic and hydraulic soil properties, namely Infiltration, bulk density, moisture content and cone index as well as the change of the chemical analysis of soil were evaluated. The yield of the potato crop was also measured.
Caldas oats had a production of 4506 kg dm / ha despite having a lower seeding density than turnip. By the action of green manure, soil pH did not change; the greatest contributions of organic matter were obtained with the reduced tillage. Because of the destruction of the topsoil, the basic infiltration suffered a high reduction in the conventional tillage. The best performance of infiltration was found in the zero tillage. Thanks to the vegetal cover along the development of the crop, the moisture content was higher in zero and minimum tillage. In the lower soil layers, the effect of machinery, promoted an increase in bulk density and cone index in the conventional tillage. The results showed that the best treatment was the minimum tillage with turnip as green cover because it allowed 16.250 kg potatoes/ha, which was the best

Introduction

Tillage could be defined as the action of an agricultural implement over the ground in order to provide suitable conditions for the production of crops, (5). The resulting condition should meet the requirements for a suitable seedbed and roots and adequate availability of nutrients to grow without limitations. (8), (7). Then the main objectives of tillage are weeding, preparing the seedbed and conditioning of soil properties, (6).
According to the intensity of tillage, it can be classified into: conventional, minimum and zero. Waste management could differentiate tillage between a "in clean" of a tillage with coverage of protection, according to the intensity of soil movement, the amount of operations and the coverage. (10), (9), (1).

Bulk density and porosity vary with tillage intensity and time and are good indicators of the degree of compaction. Values of 1.20 to 1.80 g cm^{-3} in sandy soils and of 1.0 to 1.6 g cm^{-3} in clay soils have been reported, (4).
The moisture content of the soil, at the time of preparing, conditions the level of disintegration or compaction. The effect of the weight of the implements under unfavourable humidity is cumulative.
By modifying the surface roughness, structure, density, porosity and surface coverage, tillage modifies the infiltration rate. So that after some level of removal, the infiltration rate increases, but after time, with the degradation of the structure, this is reduced.
Cone index changes with the moisture content, so that this increases with soil drying, (2). With Moisture Content in a range of 30 to 50%, the Cone Index varies widely, and above 50%, it does not vary much and oscillates around 1 MPa.
Green manures are plants in rotation, following or associated with commercial crops, with whose incorporation or deposition on the surface provides protection, maintenance and / or recovery of the physical, chemical and biological soil properties, (3). They protect the topsoil against high intensity rains, the sun and wind; maintain high rates of water infiltration through the combined effect of the root system and the plant cover; prevent the breakdown and surface sealing.

Materials and Methods
The test was allocated in 1 ha in the town of Fúquene- Cundinamarca, at 2930 m asl. The soil belongs to the mapping unit association Frentepino. Black soils, with medium and fine textures; deep, well drained, highly acidic, high carbon and exchangeable aluminum, low and very low fertility, classified as slopes of cold wet weather, with rainfall of 1000-1500 mm - year, well distributed and corresponds to the living area of lower mountain rain forest, (11).
The experiment had 6 factors corresponding to 2 green manures and 3 tillage systems. Bulk density, gravimetric moisture content and penetration resistance analysis of variance was made. 1 ha was divided into two equal parts of 0.5 ha, in each of which one green manuere was seeded. 90 days later the plants were deposed over the soil using a roller cutter and then 3 tillage treatments on each deposed manure were implemented. The test was developed along 8 month, from one month before the deposition until a month after the second deposition of the second rotation with green manure. The green manures were Avena sativa L. (A) and Raphanus sativus L (N)., with seeding density of 110 kg ha-1 and 25 kg ha-1 respectively, according with (12)
Tillage treatments, randomly distributed within the lot, were subdivided into three replications. Tillage were: Conventional (C): 1Roller, 1 Chisel, 3 disk harrow, 1 furrower. Minimum (M): 1 Roller, 1 Chisel, 1 disk harrow, 1 furrower. Direct Seeding (0): 1 Roller, 1 furrower.
Soil samples were collected at times: T0: one month before the deposition of the first green manure. T1: Deposition of the first green manure. T2: Tillage and seeding. T3 - T5: Data collection every 15 days. T6: Potato Harvest. T7: One month before the deposition of the second green manure.
The soils characteristic evaluated were: Cone Index between T1 and T7, three replications and 5 readings per replication. Bulk Density, at T1 and T7, sampled at 0 to 15 cm and 15 to 30 cm in three replicates. Moisture content, between T1 and T7 at the same two depths. Basic infiltration with concentric rings, at T1 and T7, three replicates.

Results and Discussion
Infiltration Rate: Basic Infiltration (IB)

In T0 an average BI was of 48 mm h^{-1} (fast as Mazurzk). At T7 in conventional tillage BI was markedly reduced because the destruction of the porous continuity by the effect of tillage, decreasing 25 and 75% for Avena and Raphanus, respectively. In no-till treatments, BI increased from baseline in 37.5% and 87.5% for Avena and Raphanus respectively. The prominent rise in

Raphanus was due to the influence of the root system in the soil. In minimum tillage, while for Raphanus BI increased 12.5% in Avena it decreased 25%.
Figure 1 shows cumulative infiltration curves of the treatments at T7. There was a better performance in no-tillage treatments. Also it was better performance in Raphanus than in Avena.

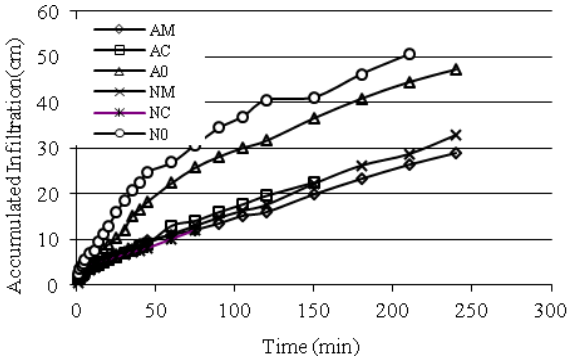

Figure 1. Accumulated Infiltration

Soil Moisture Content (MC)
Treatments of minimum and zero tillage showed a significantly higher humidity than conventional tillage treatments, there were no differences between the first two. This was due to the less soil removal, the use of chisels in minimum tillage and mainly to the presence of mulch.
For Avena, MC was significantly higher in minimum and zero tillage than in conventional at both depths, being the highest with minimum tillage. Regarding Raphanus, no significant differences between tillage systems were found, but there was a trend to greater MC in no-tillage.
During the first 15 to 30 days Avena enabled a significantly higher MC than Raphanus. This effect was lost from the half time of the crop, because after that, the mulch has gone.

Bulk Density. (BD)
In all treatments and both depths an increase in BD was found, due to the soil settlement, rearrangement of particles, clamping effect of the roots of the crop, etc., (13), and to the compressible nature of this soil.
At T1, B.D. was significantly higher in Raphanus than in Avena, because of the Raphanus root system, while the end of the test there were not differences.
At T7 BD was significantly higher in Avena and no-tillage, than in minimum and conventional. In other hand, no significantly differences where found between treatments for Rapahnus, although the bulk density was higher at both soil depths for all the conventional tillage.
For the surface soil, BD increased in the conventional tillage 86% and 50% in Avena and Rapahnus respectively, while in no-tillage the increase was 62% and 34% respectively; because, after a tillage, the pulverized soil tends to re-densificate and create scabs over time.
Between 0.15 and 0.30 m, with no-tillage, BD was in general higher than with minimal because of the effect of chisels. On the other hand the biggest increases in BD were found in conventional tillage, due to compaction.
For Avena, BD was significantly higher in no tillage than in minimum, although in both cases the increase was around 40%. The largest increase occurred with conventional tillage, which was 50%. For Raphanus no significant differences between tillage systems were found, although higher values were achieved in no-till. Likewise the greatest increases were found in no and conventional tillage, about 40% while in minimum was 30%.

Cone Index (CI)
In depth 1 only Raphanus with no-tillage and Avena in minimum tillage reduced the CI. Both fertilizers in the conventional tillage showed a large increase in CI of 60 and 70% for Raphanus and Avena respectively. It is remarkable the increase of more than 120% of IC for Avena in no-

tillage. There was a tendency to decrease CI with reduced tillage. At T0 there were very high values of CI, between 1.8 and 3.9 MPa, which after treatments did not reach favourable values. Between 0.15 and 0.30 m, all treatments reduced their CI values except Raphanus with minimum tillage, but it only increased 10%.

Conclusions

• The basic infiltration responds well to tillage treatments and the mulch used, in the sense that it increases in treatments of no-tillage and decreases in conventional tillage.
• The presence of vegetative cover by green manure keeps higher moisture content of the soil than in bare soils, while it remains in the soil, ie the first 20 days.
• The coverage of Avena is more efficient retaining the moisture with content than those of Raphanus.
• In this ground any soil preparation tends to increase the bulk density, which is due to the compressibility given by the presence of clays, however the biggest densification in the first 0.15 m of the soil are present in treatments with more soil remotion.
• With Raphanus there were a greater penetration resistance throughout the culture than with Avena. However Raphanus and no-tillage decreases the CI in the first IC 0.15 m.
• Between 0.15 and 0.30 m seems to be better the use of green manure and any tillage to reduce penetration resistance. In this case the best option is to use minimum tillage and Avena.
• Whereas the coverage improves moisture conservation and influences the resistance to root penetration, the best performances was provided by the combination of Avena and chisels in the deeper layers of soil.
• It seems that the best treatment is the minimum tillage with Raphanus as cover.

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