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IMPACT OF DIFFERENT TILLAGE SYSTEMS ON THE NUTRITIONAL PHYSIOLOGY OF WHEAT CROP (*Triticum durum* L.)

Impacto de diferentes sistemas de laboreo en la fisiología de la nutrición del trigo (*Triticum durum* L.)

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ABSTRACT. This work was conducted in "La Hampa" experimental farm, belonging to the Institute of Natural Resources and Agrobiology of Seville (CSIC), Spain, in order to evaluate the physiological responses elicited by traditional (LT) and conservation tillage (LC) on the nutritional status of wheat crop (*Triticum durum* L.) in long-term experiments on a sandy clay loam Xerofluvent soil. The experimental area has an agrometeorological station to record the minimum, average and maximum values of different variables, considering temperatures and rainfall in this work. A randomized block design with three replicates per treatment was used for the study; each block had a surface area of 240 m^2. At the experimental stage, crop nutrient extraction was assessed on the grains and leaf mass of 10 randomly selected plants per treatment. Nitrogen was determined by Kjeldahl method whereas the other elements by plasma atomic emission spectroscopy (ICP). From the physiological point of view, there are significant differences on the extraction of nutrients absorbed by the crop, ensuring that plants had no nutritional problems at the conservation tillage, with an increased total dry mass production. No significant differences were detected between both treatments with respect to yield, so that conservation tillage is more appropriate when taking into account its environmental benefits.

Key words: tillage, nutrition, yield, physiological response, wheat

RESUMEN. El trabajo se desarrolló en la finca experimental "La Hampa", perteneciente al Instituto de Recursos Naturales y Agrobiología de Sevilla (CSIC), España, con el objetivo de evaluar las respuestas fisiológicas provocadas por el laboreo tradicional (LT) y el laboreo de conservación (LC) en el estado nutricional del cultivo del trigo (*Triticum durum* L.), en experimentos de larga duración, en un suelo Xerofluvent, franco arcillo arenoso. El área experimental cuenta con una estación agrometeorológica que registra valores mínimos, medios y máximos de diferentes variables, considerándose para este trabajo las temperaturas y las precipitaciones. Para el estudio se utilizó un diseño de Bloques al Azar con tres réplicas por tratamiento; cada bloque contó con una superficie de 240 m^2. En la fase experimental se evaluó la extracción de nutrientes por el cultivo en la masa foliar y en los granos, para lo cual se emplearon 10 plantas al azar por tratamiento. Las determinaciones de nitrógeno se realizaron por el método Kjeldahl y el resto de los elementos mediante espectroscopia de emisión atómica de plasma (ICP). Desde el punto de vista fisiológico, hay diferencias significativas en la extracción de nutrientes absorbidos por el cultivo, lo que asegura que en el laboreo de conservación las plantas no tuvieron problemas nutricionales, con una mayor producción de masa seca total. Tampoco se detectaron diferencias significativas entre ambos tratamientos, en lo que respecta al rendimiento, por lo que el laboreo de conservación resulta el más adecuado, teniendo en cuenta los beneficios medioambientales que conlleva.

Palabras clave: labranza, nutrición, rendimiento, respuesta fisiológica, trigo

INTRODUCTION

Wheat is one of the three most produced globally cereals, along with corn and rice, is the most widely consumed by man; is the power base of more than 96,4 % of the world population (1). Moreover, the

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correct application of fertilizer, particularly nitrogen, is very important to achieve high yields and good grain quality wheat, in addition to regular plant nutrition (2).

The effectiveness of conservation tillage to reduce soil erosion and provide water storage is a universally accepted reality. However, there have been relatively frequent decreases in crop to implement this system, especially under the form of non-tillage (3). This does not mean that always losses are recorded when the traditional tillage (TT) is changed to no-till or other form of conservation tillage (CT). In suitable soils would not necessarily these losses (3) occur, resulting in even higher yields under conservation tillage in specific circumstances.

When losses occur, varied reasons could explain this fact, such as lower soil temperature, together with increased water content; limiting physical properties in the seedbed; phytotoxicity of plant residues from the previous crop; increased soil pathogens and weeds and less efficient fertilizers use (4, 5). Depending on the soil and climatic characteristics of each area in particular, one or the others could prevail.

Regarding the efficient use of nutrients, there are very numerous works that highlight the increased availability of N which can cause the TT, as a result of greater availability of organic matter to microbial activity (3). Moreover, the presence of residues in the CT could enhance immobilization of N more or less pronounced. However, this unique aspect is often insufficient to explain the differences in growth or harvest, observed at times between the two tillage systems, although other types of experiments that have not used chemical fertilizers in some of its treatments and other work soil preparation, yields have been greater under these conditions (6).

It is also important to note that differences have been found in the soil nitrate concentration in areas with temperate climates under no-till and TT (7). In addition, slower growth of a seedling under no-till, not always corrected with the addition of N. Numerous authors think that there are more important aspects in the CT that the availability of water and nutrients (generally not limiting factors) for seedling growth. For many authors the physical properties of seedbed are especially relevant; yet the response of seedlings usually interpreted better when considering the interactions between the different variables of soil, that when certain physical properties (5) are considered in isolation. These interactions can vary substantially from one area to another.

In this paper the physiological responses caused by different tillage systems, conventional tillage (TT) and conservation tillage (CT) in the nutritional status of growing wheat (*Triticum durum* L.) established under rainfed conditions were evaluated. Referring to nutritional crop extraction performance it is also made.

MATERIALS AND METHODS

The work was developed in the “La Hampa” farm, from the Institute of Natural Resources and Agrobiology of Seville (CSIC), Spain. Plots with two tillage techniques were used: TT, which basically consisted of turning the soil by moldboard, up to 30 cm deep, after burning the stubble of the previous crop, field pea (*Pisum sativum* L.) and CT, which were left on the ground the remains of the previous crop, as a ground cover and not turned in long-term experiments in which the cultivation of wheat (*Tricticum durum* L.) was used in a sandy clay loam Xerofluvent soil (8) or Fluvisol (9). The table lists some properties of this soil.

Sowing was done mechanically, for which a drill with a space between lines of 16 cm and the variety of seed used was “Euroduro” of medium-long cycle with a purity of 98 % and a germination of 85 % was used. The seeding density was 240 kg ha^{-1} and no type of chemical fertilizer was applied, except provided by the preceding crop (a legume). When weed plants were presented, these were controlled with herbicide in the CT. No herbicides are usually applied in the TT, except in exceptional cases, admitting that destroys soil tumbling almost all weeds.

During the development of the experimental phase, the behavior of the minimum, mean and maximum temperatures and rainfall was determined, processed two variables in decennial way.

Main characteristics of the soil in the studied area (0-10 cm depth)

Indicators	Values
PH (extract of soil: water 1/2,5)	8,2
CE (extract of soil: water 1/5)	153 µS cm^{-1}
COT (Walkley and Black, 1934)	1,54 %
$CaCO_3$ (calcimeter Barnad)	26,5 %
N (extraction with H_2SO_4 conc.)	0,095 %
P_{Olsen} (extraction with HCO_3Na)	26 mg kg^{-1}
K (extraction with NH_4CH_3COO)	1,2 cmol kg^{-1}
Fine sand	12,2 %
Coarse sand	29,6 %
Limo	24,8 %
Clay	33,4 %

At the time harvest extraction of nutrients by crop in the grain and the aerial part was evaluated, where the contents of N, P, K, Ca, Mg and S expressed in kg ha^{-1} and Cu, Fe, Mn, Zn and Ni, expressed in g ha^{-1} were determined. The N was determined by the Kjeldahl method and the remaining elements were treated with the sample under pressure with concentrated HNO_3 in microwave (BERGHOF, Speedwave Two, 2004, Germany) and the subsequent reading was performed by optical spectrometry with inductively coupled plasma in ICP-OES (Radial Simultaneous Varian 725-ES). For the study three samples were taken randomly for each treatment, cutting all aboveground biomass at 1 cm from the ground.

Samples were decontaminated by brief washes with deionized water. Immediately after washing, drying proceeded in an oven at 70 °C and once dry, samples were ground and stored in cold storage until analysis in the laboratory.

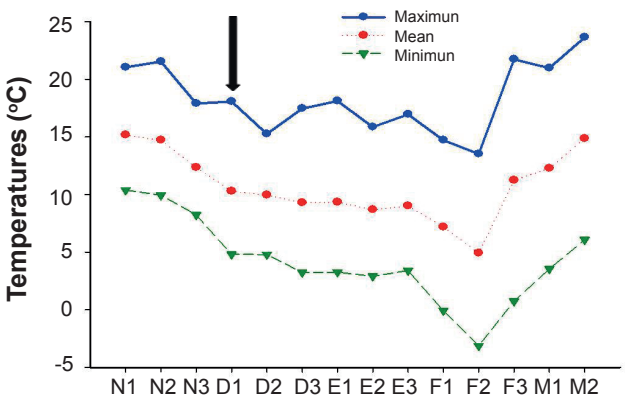
Statistical analysis was performed using the Statgraphics version 5.1 programs (10) and graphics were performed through Sigmaplot 11.0. To assess the significant differences in the treatments studied, the T-Student test was used at a level of $p<0,05$.

RESULTS AND DISCUSSION

In Figure 1 the behavior of the maximum, minimum and mean temperature occurs during the development of research; as the thermometric place shown regime is characterized by belonging to a temperate zone. The lowest temperatures were recorded in the months of December to February, with an average minimum of 5,2 °C, characteristic parameter of a Mediterranean climate (8).

The temperature usually affects the development of plants through its influence on the different growth stages of these, which is reflected in the production of leaves, stems and other components. All physiological processes in plants occur more rapidly as the temperature increases, but if these are sufficiently low, severe damage occurs in young tissues, a situation that was not presented during planting and early stages of crop development (December-January), so that the damages did not cause significant damages, other cultivar used is a variety obtained for these conditions.

Because the experiment was carried out under dry conditions, decennial rainfall that occurred during that period were also recorded (Figure 2).



The arrow on the graph indicates the date of crop sowing

Figure 1. Behavior of high, medium and minimum temperatures during the development of research

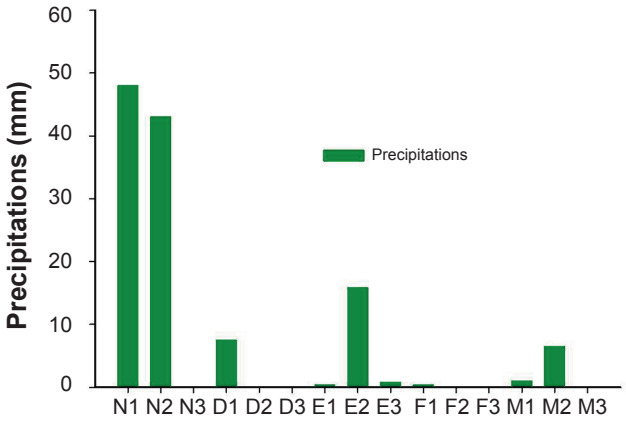


Figure 2. Behavior of decennial accumulated rainfalls during the research development

Given the characteristics of the area climate in terms of rainfall, there have been abnormally dry years with no rainfall exceeded 250 mm and other extremely wet 1200 mm, reflecting a great variability in the rainfall parameter. During the months of crop establishment, December 2011-March 2012, a total of 179,2 mm was recorded.

Given the distribution of rainfall, planting was carried out with appropriate content for good germination moisture, as there was rainfall in the tens preceding crop planting. In the recommendations for crop management (11), it is also important to ensure that water is not a limiting factor in the planting time, as in the phase of anthesis. Moisture in both treatments was not a limiting factor, since the development of plants in those moments was favored. In this regard, rainfall and temperatures are some of the main climatic variables that drive agricultural production worldwide (12).

An important element in wheat production constitute the work done on the ground in preparation for seeding, of which also depends on their fertility, because the fact of not making application of mineral fertilizers affects the nutrients availability for plant development, which is necessary to achieve an adequate tillage where soil properties are not affected. Following extraction of nutrients that plants have made is analyzed, taking into account the two tillage systems used.

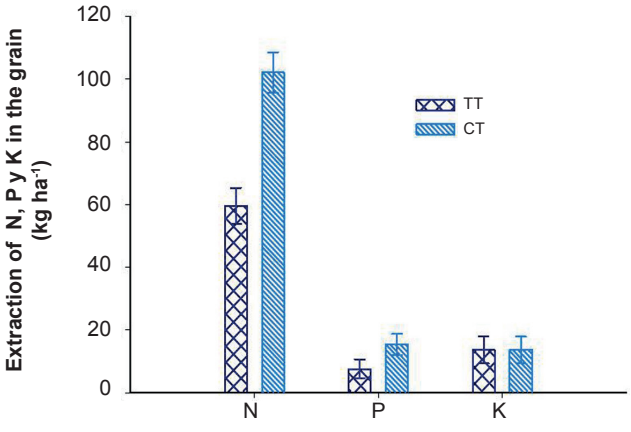
Assuming that the N and P are essential for the growth and development of grasses (13), in Figure 3 (A and B) extraction of nutrients N, P and K is shown in the grain and the aerial part. When analyzing the removal of N in different evaluated parts, significant differences, with higher values, generally, in conservation tillage, were found even in the case of extraction by the grain, much higher values were found in the aerial part. Keep in mind that this evaluation was conducted at the end of the crop cycle, which was greater mobilization of assimilates from the leaves to the grain.

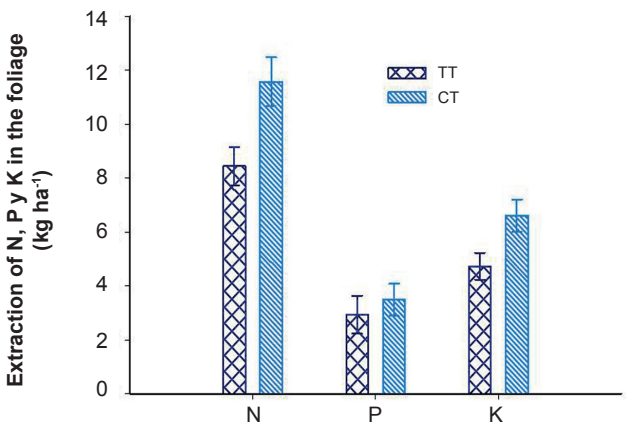
However, studies demonstrated that CT provides effective means for preserving soil fertility and improve the needs of nitrogen (14), which implies a better absorption of this element by the grain, as shown in the results. Regardless that no applications were made chemical fertilizers, nitrogen fertilization affects yield and its components in wheat cultivation, something that has been documented in the last 20 years (15, 16, 17). Recent work has shown the great relationship between the extraction of N by the crop and their arrangement on the ground, which depends on grain quality and yield of the crop (17).

In the case of P and K nutrients, no significant differences among treatments were observed when evaluated in both considered sides. There is concern that the accumulation of P and K near the surface, as often occurs in the CT may result in less available to plants if moisture conditions are not right on the surface. The occurrence of water deficit in the first few centimeters of soil depend not only on weather conditions, but also greatly and the amount and type of surface residues in affecting the rate of evaporation (18).

These results demonstrate that CT techniques, despite increases in favor biochemical soil properties, experience slight increases of soil organic carbon as well as the N, P and K concentrations on the surface (19). Wheat needs many nutrients to achieve good growth, especially macronutrients, including not analyzed, Ca, Mg and S play an important role, considering the functions they perform in plants: the Ca is responsible for integrity and functionality of the membranes, the Mg actives important enzymes for the photosynthetic process as Rubisco and carboxylase phosphoenol-pyruvate and S participates in many enzymatic processes, among others (20).

In Figure 4 (A and B) the analysis of the extraction of these elements is performed by plants; generally, greater extraction by the different organs analyzed in CT with respect to TT is presented. In the case of Mg and S behaved similarly in both, in the grain and the aerial part, not so for the Ca, as there was a greater extraction in the aerial part.





Bars means the confidence interval for the mean at p<0,05
Traditional tillage (TT) and Conservation tillage (CT)

Figure 3. Removal of N, P and K for the grain (A) and the aerial part (B), expressed in kg ha^{-1}

Moreover, in Figure 5 (A and B) the removal behavior of some microelements that are also important for cultivation is analyzed, in which the Fe and Zn extraction was higher in both organs in the CT. For the Mn was greater in the extraction by grain and higher under conservation tillage. Moreover, extractions B and Cu were minimal in both organs. Comparing the two tillage systems, in general, the elements extracted from the grain and the aerial part showed a higher extraction in the CT.

However, these microelements no longer important for plant growth, but are required in smaller amounts than analyzed macronutrients. According to several authors (21, 22), conservation tillage increases the availability of most of these nutrients in the topsoil.

Also, if you consider that the N and S have proven nutrients that most often influence the production of gluten high levels and protein in wheat grains[A], a situation that was presented in the system of conservation tillage, the grains obtained in this system have a higher quality according to the results.

CONCLUSIONS

The results show that not only CT potentiated development (greater production of aerial biomass) but also the absorption of nutrients by the plant. It is an advisable tilling technique for its influence on soil quality, especially during years of marked drought.

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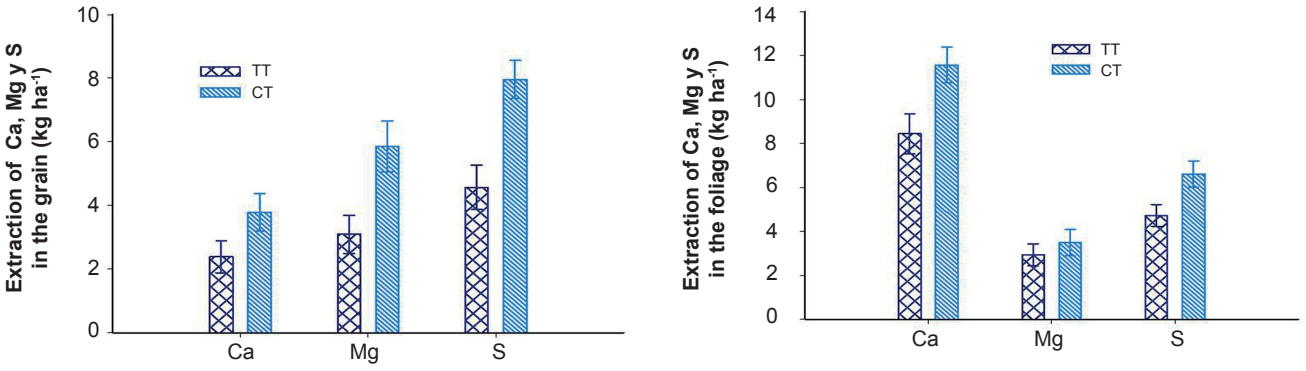
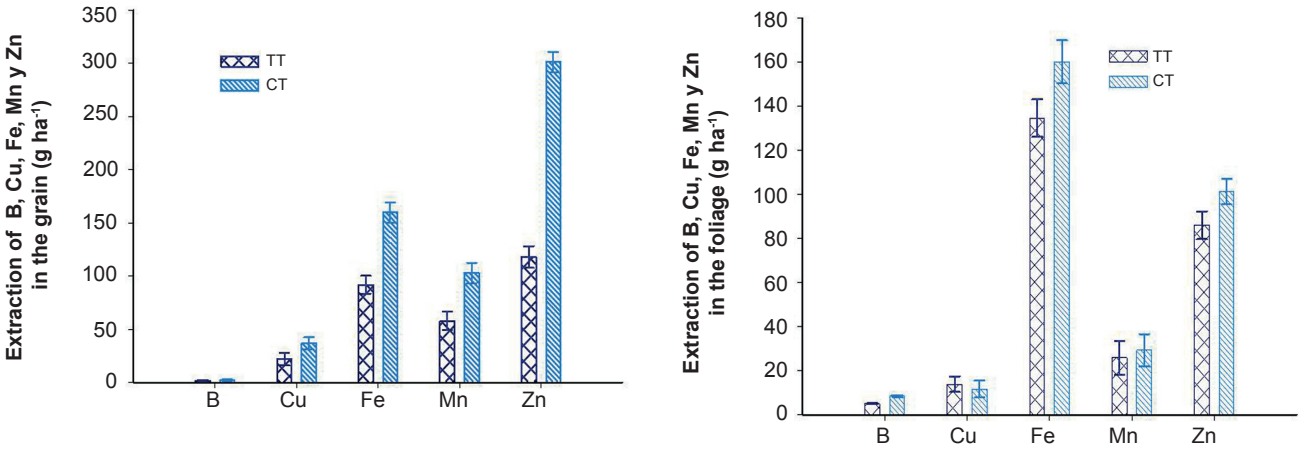


Bars means the confidence interval for the mean at p<0,05
Traditional tillage (TT) and Conservation tillage (CT)

Figure 4. Removing of Ca, Mg and S for the grain (A) and the aerial part (B), expressed in kg ha^{-1}



Bars means the confidence interval for the mean at p<0,05
Traditional tillage (TT) and Conservation tillage (CT)

Figure 5. Removing of B, Cu, Fe, Mn and Zn for the grain (A) and the aerial part (B), expressed in g ha^{-1}

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