DEVELOPMENT OF SOY PLANTS *(Glycine max* L. Merril*)* ACCORDING TO THE TRAFFIC OF HARVESTERS WITH TWO TYPES OF WHEELERS

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DOI: 10.29322/IJSRP.8.10.2018.p8259
http://dx.doi.org/10.29322/IJSRP.8.10.2018.p8259

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Abstract- The use of machinery with unsuitable tires and in unsuitable climatic conditions, can affect the development of the plants and consequently the productivity. Soil compaction is one of the factors that most affect the crop, since it can decrease the ability of the roots to penetrate the soil profile in search of water and nutrients. The objective of the present work was to evaluate the development of soybean based on the traffic of harvesters with two types of wheelers. The work was carried out in the Marangatú neighborhood, Nueva Esperanza district, in the agricultural year 2017. The experimental design used was randomized complete blocks with trifactorial arrangement. The factors were load of the hopper with and without load, two types of rolled and two levels of humidity of the ground, with 8 treatments and two witnesses. The greater resistance to penetration was caused by conventional rolling, the height of the plant was influenced by the humidity level and the combination of load with rolling, where the highest height was observed with the track rolled and without load. The highest number of pods per plant was obtained with the combination of wheeled to caterpillar and moisture level 1. In relation to the number of grains per plant, significant differences were observed between the rovings, independently of the other factors where the caterpillar rounds obtained the greatest amount of grains. In the variables studied, the best results were obtained with the caterpillar rolling and less damage to the development of the plant and soil.

Keywords: soybean, wheeled, load, compaction, soil

I. Introduction

Food production has been in great demand in recent times for this reason is constantly seeking to find techniques to improve and where soil is an important factor, so it is necessary to conserve and implement a system of greater operational efficiency for production agricultural. One of them is the soybean which is a legume of the leguminous family (fabaceae) cultivated for its seeds of medium content in oil and high in protein; it is a crop that is sown in the months of October to January, from which oils and flours are obtained that are used in food products; Its introduction in Paraguay dates back to 1921, beginning its expansion only in 1960 (M.A.G, 2010).

The production of soy represents a very important fraction in the GDP of any country of the Mercosur, its importance not only derives from the production figures but also from the production chain; in Paraguay it represents 40% of agricultural production (Melgar, Vitti and De Melo, 2011); However, this production is affected to a large extent in the use of machinery with increasing size and size, more powerful tractors, seeders with high sowing capacity, harvesters covering more lines per pass and with hoppers each time greater; These machines, due to their high weight and bad use in inadequate conditions, can have negative consequences on the physical structure of the soil.

The agricultural soils have been suffering great disturbances, the compaction is indicated as the main cause of these changes by virtue of the traffic of agricultural machines in inadequate handling conditions; that can modify the physical structure of the soil, ranging from resistance to penetration, reduction of macroporosity, as a consequence there is less accumulation of water, which compromises its infiltration and the penetration of the roots in the soil profile (Richart *et al*., 2005).

According to Da Veiga, Reichert and Reinert (2009), compaction is one of the main causes of the reduction of productivity in agricultural areas because it restricts the growth of the root system and reduces the infiltration of water and the gas exchange between soil and soil. atmosphere. And De Moura, Bezerra, Rodrigues and Barreto (2008) mentions that when the soil is under inadequate humidity conditions, the traffic of machinery is one of the main causes of the compaction observed in many fields and that it results in a decrease in production with the use of machinery with unsuitable tires and in unsuitable conditions of soil moisture, can affect the development of subsequent crops and consequently their productivity, one of the factors that most affect the cultivation of soybeans is the compaction of the soil, since could decrease the ability of the roots to penetrate the soil profile in search of water and nutrients, which would lead to plants with less root development, lower height and therefore could affect the production capacity of grains.

Due to the great problem, it is necessary to search for solutions to optimize production and identify the effects that the incorrect use of agricultural machinery causes at the time of harvest, which is why this work had an impact on the development of the following crops. As objective to evaluate the development of soybean plants based on the traffic of combines with two types of wheeled.

II. MATERIAL AND METHODS

The experiment was installed in the agricultural field of the agricultural farm of the Paraná, located in the Marangatú district of Nueva Esperanza in the department of Canindeyú whose coordinates are 24 ° 28'10 "S; 54 ° 30'26 " O, The average annual rainfall ranges between 1,300 mm and 1,900 mm, and the average monthly temperature between 17 ºC and 27 ºC, although the average minimum annual temperatures reach 15 ºC and the maximum annual averages reach 30 ºC. In the sunny summer months, temperatures occasionally exceed 40ºC, and in the winter months with little sun, important frosts can be registered in most of the territory, since temperatures can drop to -2ºC (DINAC, 2016). The area of the experiment has a soil characteristic of the northern region of Canindeyú Paraguay department, which belongs to the Oxisol order, large Rhodic group and Kandiudiox subgroup - Rhodic Kandiudox (López, 1995). For the installation of the plot, 10 sub samples from 0 to 0.20m of the surface were collected for the determination of the chemical characteristics and granulometry of the soil, the result of which are as follows: pH ($CaCl_2$) = 5,5; M.O = 25,5 g dm^{-3}; P (Mehlich I) = 8,01 mg dm^{-3}; K^+ = 0,25 cmol dm^{-3}; Ca^{++}= 3,2 cmolc dm^{-3}; Mg^{++}= 0,34 cmolc dm^{-3} ; V= 32,76%, Sand = 35.5% granulometry; Silt = 10.4% and Clay = 54.1% respectively.

The plots installed were 3 blocks and 10 treatments totaling 30 experimental units with 6 meters long and 5 meters wide that started in a field with corn crops at harvest time where a rainfall was simulated, with the help of a uniport sprayer, with two 15 mm and 30 mm humidity levels. After 36 hours of moistening the plots, the harvesters were trafficked in each experimental unit, where harvesters with two types of wheeled were used: equipped with caterpillar wheels (Claas lexion 750) with a total weight of 22930 kg without load and with conventional double wheels (John Deere S680) with a weight of 23490 kg without load;both with two load levels: with load and without load of the hopper with grains.

The variety of planted soybean was Syngenta 9070 with a degree of maturity 7.0 of indeterminate growth habit, with light brown yarn and with white flowers with an average cycle of between 130-135 days approximately, and was carried out one week after the traffic of the harvesters in the corn plot, was carried out with the help of a seeder with furrower, with a fertilization NPK of formulation 4-30-10 of 300 kg ha-1 and a distance of 0.45m between rows and 12 seeds per linear meter, it was cross-seeded traffic in such a way that the plants cover the trail of the harvesters.

The design of the experimental plot was randomized complete blocks with factorial arrangement of the treatments (T) with three repetitions. The factors studied were: types of wheels, conventional wheel (Cw) and wheel to caterpillar (Wtc); load level, hopper with load (Hwl) and hopper without load (Hw) in two conditions of humidity (Hm) of the ground 15 mm and 30 mm; they were combined in a factorial arrangement of 2x2x2, which results in 8 treatments and 2 additional controls.

The variables evaluated were: The resistance to penetration was determined through a digital penetrometer model Falker, in each experimental unit two points were made on the right side of the trail of the road before the symmetry in depths of 0 to 0.40 m. To determine the root volume was extracted 10 plants with their roots of each experimental unit in R6 state, for it was used a metal cylinder of 0.3 m in height and 0.2 m in diameter, with 8 mm in thickness adapted to be manipulated by the loader of a tractor and was measured by placing a sample of green radicular mass in a graduated cylinder with water, where the samples were submerged and the volume evicted was noted. For the determination of the diameter of the main root ten plants were extracted from the useful area, the roots were cleaned to later measure the diameter of each main root, with the use of a digital pachymeter. Regarding the length of the main root, the roots of the 10 extracted plants were used where it was measured from the base of the stem to the tip of the main root with the help of a tape measure. To determine the height of the plants, the aerial part of the root of the 10 extracted plants was separated, it was measured using a tape measure from the base of the stem until the last outbreak of the plant, according to the methodology of (Ozuna, 2013). For the number of pods per plant, the manual counting of the 10 plants extracted from each experimental unit in R6 state was carried out before full ripening, according to the methodology of Braccini, Mariucci, Suzukawa, Lima, and Piccinin, (2016). And finally grain numbers per pod was made to count the grains that were in the pods of 10 plants of each experimental unit in the R6 state before full maturation. The results were subjected to the analysis of variance, the variables that presented significant differences, their averages were submitted to the Tukey test, to process the data the statistical software AgroEstat was used.

III. RESULTS AND DISCUSSION

For the variable resistance to penetration, a highly significant effect was observed (p <0.05), the studied factors showed an effect of high significance and an interaction between the factors A and B, which are moisture per hopper load, was observed factor A inside B1 (with load) statistically differ from each other, being A2 (humidity 30 mm) was of the highest resistance to penetration. Like A inside B2 (no load) that statistically differ from each other. However, the B factor within A2 are similar while B within A1 show statistical differences; in terms of the treatment that showed the greatest resistance to penetration, it was T7 where 30 mm humidity was combined with loading of the hopper and machinery with crawler track, followed by the T8 humidity 30 mm without load of the hopper and the same type of rolling is the conventional. However, the treatment that had the least resistance was the additional T1 (Control) with humidity of 15mm, in this experimental unit the traffic of the machinery was not carried out, reason for which a lower degree of soil compaction was obtained as observed in the (Table 1). Similar results were obtained by De Olveira (2007) that comparing two types of rolling could verify that the roll of conventional type both wide and fine caused greater degree of soil compaction measured through the RP method, because this type of roll has lower capacity for weight distribution. It is also related to the experiment conducted by Castro (2001) where he found that the RP decreased in relation to the days that were expected to return to traffic with machinery because the more days they spend the lower is the moisture content of the soil, as that this experiment, since the PR values were lower for the experimental units with lower humidity level; so it could be determined that the less humidity the soil contained, the effects of the machinery on the physical properties of the soil also decreased. Unlike this work, where soil resistance to penetration is observed with the highest level of soil moisture, Unger and Kaspar (1994) verified that the same level of resistance to penetration the effects of this resistance are less pronounced in a soil with a higher moisture content.

Table 1. Comparison of average resistance to penetration (Kpa).
Katueté Canindeyú, 2018

Comparison between the means of A (humidity) x B (hopper load)			
	Factor A	B1(with load)	B2 (without charge)
	Hm 2	2548 a	2598 a
	Hm 1	2143 b B	2427 b A
Treatments of penetration resistance stockings		(Kpa)	
T7	Hm (A2) Hwl (B1) Cw (C1)	3314 a	
T8	Hm (A2) Hw (B2), Cw (C1)	3218 b	
T3	Hm (A1) Hw (B2) Cw (C1)	3105 c	
T2	Hm (A1) Hwl (B1) Cw (C1)	2258 d	
T4	Hm (A1) Hwl (B1) Wtc (C2)	2027 e	
T10	Hm (A2) Hw (B2) Wtc (C2)	1979 e	
T9	Hm (A2) Hw (B2) Wtc (C2)	1782 f	
T5	Hm (A1) Hw (B2) Wtc (C2)	1749 f	
T6	Hm (A2) Witness 2	1155 g	
T1	Hm (A1) Witness 1	1130 g	
CV:	3,10 %		
DMS:	81,14		

* Equal means by the same lowercase letter in the column and uppercase in the line are not deferred to each other, to 5% of probabilities, by the Tukey test

For the root volume, a highly significant effect between the treatments was also observed (p <0.05), the humidity factor A, also showed highly significant differences between the two moisture levels, A1: 15 mm and A2: 30 mm; where the level of humidity that presented the highest root volume was A2, the humidity level A1 had lower root volume and a highly significant interaction between factors A (humidity) and B (load of the hopper) where with Factor A within factor B1 (with load) obtained greater root volume with the humidity level A2: 30 mm and with the loading the hopper; the data obtained by the Tukey test, treatment 7, showed greater root volume, with the lowest root volume being Treatment 4, as shown in Table 2. These factors could have favored the greater compaction of the soil causing the roots to grow in thickness, resulting in higher root volume, as well as the work done by Beulter and Centurion (2004), where they observed that the highest level of RP occurred changes in the distribution of the root system as an increase in the thickness of the root system, on the other hand Borges et al., (1988), Benghough and Mullins (1990) affirm that soybean roots develop better in points of lower resistance to penetration , reason for which, to a greater degree of compaction, morphological modifications in the root occur, such as reduction in root length and an increase in thickness due to mechanical impediment, these factors cause the obtainment of greater root volume.

Table 2. Comparison of means between root volume treatments in cm3. Katueté Canindeyú, 2018.

Comparison between the means of the factor A (Humidity)	
Factor A Humidity	Volume
Humidity 2	10,47 a
Humidity 1	9,19 b

Comparison between the means the interaction of B (charge) inside A2 (Humidity 2: 30 mm)	
Load	Volume
Load 1	11,63 a
Load 2	9,31 b

	Root volume stockings	(cm3)
T7	Hm (A2) Hwl (B1) Cw (C1)	12,17 a
T6	Hm (A2) Testigo (2)	11,33 a
T9	Hm (A2) Hwl (B1) Wtc (C2)	11,10 a
T1	Hm (A1) Testigo (1)	10,93 a
T10	Hm (A2) Hw (B2) Wtc (C2)	9,80 b
T5	Hm (A1) Hw (B2) Wtc (C2)	9,53 b
T2	Hm (A1) Hwl (B1) Cw (C1)	9,53 b
T3	Hm (A1) Hwl (B2) Cw (C1)	9,44 b
T8	Hm (A2)	8,83 b
T4	Hm (A1) Hwl (B1) Wtc (C2)	8,27 d
CV:	10,70 %	
DMS:	1,30	

* Equal means by the same lowercase letter in the column do not differ from each other, at 5% probability, by the test Tukey

In the variable diameter of the main root according to the results of the ANOVA table, no significant differences were found between treatments, but Factor B (load) presented significant differences. In Table 3, the results of the significance of factor B are explained, where the largest diameter of soybean root was obtained with the B1 load (with loading of the hopper) unlike the no-load harvester with the smaller diameter, these results could be related to the RP (resistance to penetration), since the harvester with load caused higher RP which could have caused greater compaction, this condition causes greater increase in the diameter of the root as it prevents its growth in length, this The result coincides with another experiment where compaction contributed to the increase in soybean root diameter, as can be seen in the graph that the largest diameter was obtained with the harvester under load, which ensures that the loading condition caused a greater degree of soil compaction and consequently the increase of the diameter of the root. On the other hand Oliveira et al., (2012) found that the greater the degree of soil compaction, consequently there is an increase in the diameter of the roots of soybeans, which inhibits root development in compacted soils. Like this experiment, Beulter and Centurion (2004) also did not obtain significant differences regarding the increase of the diameter of soybean roots in relation to the levels of soil compaction.

Table 3. Comparison between the means of factor B for the variable Diameter of the main root. Katueté Canindeyú, 2018

Comparison of means B (load of the hopper)	
load 1: with load	10,68 a
load 2: without charge	9,87 b
CV: 8,89%	

* Average, at 5% probability, by the Tukey test

For the length of the main root, the analysis of the variance, no significant differences were observed between the treatments performed ($p > 0.05$). The factors studied in the experiment: Humidity, hopper load, type of roll, did not show significant differences, no interaction between the factors was observed, and coincides with the work done by Da Silva and Rosolem, (2002) on the development of the soybean in relation to the compaction did not find significant differences between the treatments regarding the root length of the soya plants. Similar results were also obtained by (Queiroz, Nogueira, & Coelho, 2000) where they also did not observe significant differences in the root length of soybean plants. On the other hand, Lipiec et al. (1993) proved that compacted soils cause morphological alterations in the roots of vegetables and one of them is the decrease in the length of the root and due to the resistance offered by the soil there is an increase in the diameter, therefore, it coincides with this experiment since differences in diameter were observed, but not with the length.

For the plant height variable, highly significant differences were observed between the treatments ($p < 0.05$), according to the analysis of variance. The factor A (humidity) was also highly significant for its two levels of 15 mm and 30 mm of humidity, as well as the additional treatments, and an interaction between the factors A by B that belongs to the hopper load, the interaction between the factors B x C (Load x wheel) was obtained better result of height of plants with the level of load B1 (empty) and the rolled C2 (caterpillar) in comparison with the rolled C1 (conventional) that contained the same level of load B1 (empty) as shown in table 4. In general lines it can be highlighted that the highest height of plants was obtained with the humidity of 15 mm, between the additional controls, better results were observed with Control 2 and in terms of the interaction Rolled by Load of hopper B1 (without load)) the height was greater with the combination of the no-load harvester and the caterpillar wheels, so it can be said that the soil was not subjected to a very severe compaction since the harvester was empty and with the wheel that distributed better the weight of the machine so the plant did not have many impediments to its proper development; while work done by Queiroz, Nogueira and Miranda, (2000) where they simulated a compaction in pots, the height of plants decreased with the increase in soil compaction, while increasing root growth; that coincides with the present work, since the highest height we obtained without load of the hopper and with the rolled to caterpillar, because this rolled offers better weight distribution and therefore compacts less the ground in comparison to the other rolled (conventional). However, the results differ with the work done by Beutler et al., (2006) where plant height was decreasing with the increase in the number of passes of the machinery, being that in this work the lowest height of soybean plants was obtained in the place where there was no traffic of machinery; they also differ with the work done in the corn crop by (Gonzales, Bobadilla, Rivas, and Osorio, 2017) where no significant differences were found in the height of corn plants according to the levels of soil compaction.

Table 4. Average of the plant height variable in centimeters.
Katueté Canindeyú, 2018

Comparison between the means of A (Humidity)	
Humidity	Height
Humidity 1: 15 mm	118,04 a
Humidity 2: 30 mm	110,41 b
Comparison between the means of additional treatments	
Witnesses	Height
Witness 2: Hm 30mm	117,66 a
Witness 1: Hm 15mm	98,50 b
Comparison between the means of C (wheels) within B2 (without load)	
wheels	Height
wheel 2: to caterpillar	119,66 a
wheel 1: Conventional	108,41 b
CV: 5,47 %	

* Average, at 5% probability, by the Tukey test

For the variable number of pods per plant, significant differences were observed ($p < 0.05$), between the two levels of Factor C (wheel to caterpillar and conventional wheel); and an interaction between factors A (humidity) and B (hopper load); the use of the harvester equipped with caterpillar wheels was obtained more pods per plant, than with the use of conventional wheel. In contrast, in the significant interaction between the factors A x C (Humidity x Load) and as observed in table 5; the highest number of pods was obtained using the combine equipped with the caterpillar roll combined with the humidity level A2 (15mm). It can be said that this result is due to the fact that the harvester equipped with caterpillar wheels distributes the weight better and even with the moisture content there was no suitable environment for the compaction, reason why it is assumed that the plant had no physical impediments for its normal development, which stands out in the good production of pods that was observed in the experiment, however Queiroz et al., (2000) observed that as soil compaction increased the number of pods per plant decreased, which coincides with this work since the number of pods decreases with the use of the conventional wheel, since this rolling exerts more pressure on the ground. Similarly

Centurion et al., (2005) found significant differences, where the number of pods per plant was affected with the increase in soil compaction and as shown in this work, fewer pods were obtained with the use of rolled that causes greater soil compaction.

Table 5. Comparison of means of the variable number of pods for Factor C (wheels) and the interaction between humidity and wheels. Katueté Canindeyú, 2018.

Comparison between the means of C (wheels)	
wheels	Number of Pods
wheel 2: to caterpillar	59,66 a
wheel 1: conventional	50,75 b
Comparison between the means of C (wheels) inside A2 (humidity: 30mm)	
wheels	Number of Pods
wheel 2 inside A2	63, 66 a
wheel 1 inside A2	47,33 b
CV: 13,74 %	

* Average, at 5% probability, by the Tukey test

In the variable number of grains per pod, no significant differences were observed ($p > 0.05$) between the treatments, but the C factor (wheels) presented significant differences ($p < 0.05$) between its two levels, which are: caterpillar and conventional wheel, however the other factors (humidity and load) did not present significant differences as observed in table 6, of comparison of means by the Tukey test; the greater amount of grains per plant was obtained with the use of the combine equipped with the wheel 2 (caterpillar), in comparison with the wheel 1 (conventional) that had smaller amount of grains, since the harvester with caterpillar wheels causes minor soil compaction which favored the production of grains, compared to the other harvester that was equipped with the conventional wheel that has a lower capacity to distribute the weight, which could have caused greater compaction and consequently lower grain production. This coincides with the work of Terminiello et al., (2004) where they state that the use of machinery with a high soil compaction index has a negative effect on the production of grains, as observed in this experiment that the amount of grains visibly decreased with the use of the conventional wheel, also relates to the work carried out by Cardoso et al., (2006) where no significant differences were found between the treatments as a function of soil compaction; According to the author, the availability of water in grain production may have interfered.

Table 6. Comparison between the means of the factor C. katueté, Canindeyú, 2018.

Comparison between the means of C (Wheels)	
Wheels	Amount of grains
Wheel 2 : to caterpillar	144,58 a
Wheel 1: Conventional	123, 58 b
CV: 14,85 %	

* Average, at 5% probability, by the Tukey test

IV. CONCLUSION

The highest resistance to penetration was obtained with the conventional wheel, the humidity of 30mm and without load of the hopper; the root volume was greater when combined the humidity of 30mm with conventional wheel and with load of the hopper; the diameter of the main root increased with the load of the hopper, said variable was not affected by the other factors; the root length did not present significant differences between the treatments nor for any of the factors; plant height showed significant differences between treatments; it was greater with the humidity level of 30mm, without load of the hopper and with the wheel to caterpillar; As for the number of pods per plant, more was obtained with the track wheel and with the combination of this with the humidity of 15 mm, the load factor did not present significant differences and in number of grains per plant was greater with the use of machinery equipped with track wheels, the other factors did not show significant differences.

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