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COMPARATIVE ANALYSIS OF YIELD AND STARCH CONTENT FOR ENERGY PURPOSES IN MAIZE HYBRIDS IN THE PROVINCE OF CHACO

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ABSTRACT

The development of a region is a central concern of the main productive actors and the community as a whole. From its conceptual premises related to economic development to its more recent conceptions such as sustainable development, there is a certain consensus that economic development is the ability to create wealth to increase the economic and social well-being of people. The Province of Chaco, Argentina, presents a diversity of environmental environments where significant extensions of corn cultivation are cultivated. This is a merely primarized productive sector, with a high transfer of minerals. Using part of

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the corn production in the generation of renewable energy would be an excellent option for the transformation of this resource since it would favor the regional economy, the environment, and the profitability of the production system through the addition of value. This work aims to analyze the behavior of the different corn hybrids by comparing their grain yield and starch content for energy purposes, influenced by environmental factors. A statistical study was carried out that correlates dependent variables (yield and starch) with independent variables such as environment and soil, which allowed analyzing the behavior of different hybrids grown in various test areas and environmental conditions within the provincial territory, comparing the effects they generate on the variables considered. The results showed significant differences based on environmental and soil conditions, highlighting, due to its better performance, the hybrid of temperate maize with an average yield of 82.20 qq/ha, compared to the general average yield of the different materials under study, which is 75.76 qq/ha. Regarding the starch content in corn kernels, temperate hybrids exhibited a remarkable performance with low dispersion of values, presenting an average starch content of 74.48%, compared to the general average (73.01%) and significantly higher than the control or control materials (70.46%). From the analysis, it emerges that the percentage of starch content of the hybrids analyzed does not show a correlation with grain yield, environment, and soil type, and variations in starch composition were also observed for the same type of hybrid developed in different locations of the province. It is concluded that the different maize hybrids exhibited significant yields in the production of maize grains and starch content, the latter being of considerable relevance due to its potential conversion into bioenergy, as well as in the production of food for humans and animals, highlighting the high potential of the productive area analyzed.

Keywords: Starch. Corn. Environment. Bioenergies.

INTRODUCTION

Argentina's challenge is to take advantage of the opportunity to supply the world with food and renewable energy, improve the standard of living of our population, create opportunities for education and decent work for all, ensure that public and private objectives coincide to achieve that future and develop the coordination mechanisms that each chain needs to achieve its maximum development.

The main primary business of Argentine agriculture is the production of soybeans, but this crop, to be sustainable from the point of view of natural resources (soil), must produce rotation with grass crops and corn is the crop with the largest root system and with an important contribution of organic material at the surface level. Therefore, the logical trend in Argentine agricultural production implies a significant increase in the area planted with corn or other grasses [1].

Chaco is one of the provinces outside the Pampas with the largest area cultivated with cereals and oilseeds. In recent years, maize has shown significant growth, occupying increasing areas among the province's crops [2].

The planting area and production level were affected by climatic factors in recent campaigns, as can be seen in Table 1 and Table 2, which shows the relationship between the area cultivated with corn and its production in the Province of Chaco and the total of the country for the 2018/2019 campaigns. 2019/2020 and 2020/2021. [3]

Table 1: *Relationship of Cultivated Areas*

Campaign	Planted Area (ha)		
	Country Total	Total Chaco	%
2018 /2019	9039594	281867	3,11
2019 /2020	9504473	279602	2,94
2020 /2021	9742230	228250	2,34

Table 2: *Relationship of the Production Level*

Campaign	Harvest (tn)		
	Country Total	Total Chaco	%
2018 /2019	56860703	1188223	2,08
2019 /2020	58395811	1306732	2,23
2020 /2021	60525805	892515	1,47

Considering the production in the province, it is intended to achieve materials that improve their resistance and performance. To achieve these objectives, so-called hybridization is used, which improves genetic characteristics to obtain higher yields and also has resistance to diseases and adverse developmental conditions [4], [5].

To obtain hybrids with superior genetic characteristics, improvements were made in maize, using materials resistant to biological [6] and environmental factors, mainly water [7].

In addition, in vitro genetic modifications have been carried out, developing herbicide-resistant genotypes [8].

Both the yield and the quality of the corn kernel can be influenced by its characteristics (genotype), and the environment in which it develops (phenotype) or by the action between the two [9]. The interaction between genotype and environment is considered as the response of genotypes to changes in the environment [10].

The environment may be subject to a factor or set of factors that impact crop growth. Temperature [11] and sunlight incidence time [12] are some of the variables that act on the growth of the maize crop.

The growth of corn depends mainly on temperature as long as the values are not too high or low so that they do not affect the development of the plants and sunlight. The most conducive conditions for high yields occur in climates with high solar radiation and high daytime temperatures between 20 and 28°C [13].

The conditions of maize crop development modify the starch structure of the grains and the amylose/starch ratio decreases as the ambient temperature drops. The amount of amylose in the endosperm of grains increases when the parameters for development are optimal during the grain filling time. [14]

The composition of the grain is determined by the genes of the hybrid, but the environmental conditions act notably in this aspect, mainly with the temperature. [15]

The quality of the corn kernel is a comprehensive attribute that reflects its chemical constitution, variable in terms of content and/or quality of proteins, starch, or oil, and determinant of texture, nutritional value, and technological properties. The chemical composition can be modified by the action of multiple factors, some imponderables such as climate and soil, while others such as genotype, cultivation techniques, transport, and post-harvest handling can be altered to conserve or improve grain quality levels [17].

Those varieties of corn hybrids that have a high percentage of their chemical parameters (starch, protein, and oil) favor the transformation into products that are used in the industry. [16]

Regional development is a central concern of the main productive actors and the entire community, from its first concepts related to economic development to its most recent conceptions such as sustainable development. There is a certain consensus that economic development is the ability to create wealth to increase the economic and social well-being of the population of a given geographical area.

The use of a resource with commercial and energy value constitutes an opportunity for sustainable development for the sector, as it brings economic benefits and a favorable

impact on the environment, characterized mainly by the existence of a primarized production system [19].

Through the search for new alternatives focused on promoting the development of the northern region of the country, the cultivation of corn and its value chain is proposed as an option, conceived as a development model due to its capacity to collaborate with the sustainability of the production system, increase primary production, and create genuine employment, fundamentally through the addition of value in the process of converting this crop into food and energy [19].

Many of these issues require national policies, however, the provinces have primary responsibility in certain aspects and, due to proximity, it is perhaps the level of the State most apt to individualize large productive projects [20].

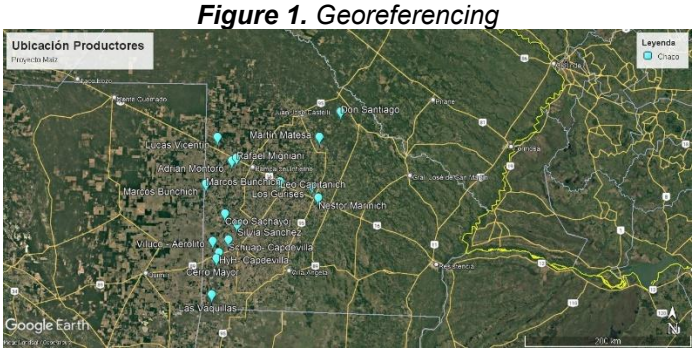
The objective of this work was to analyze the behavior of different maize hybrids, comparing their grain yield and starch content for energy purposes, and considering the influence of environmental factors.

DEVELOPMENT

To know the relationship between the environment and the amount of starch in the corn grain, samples from agricultural farms in localities of the province of Chaco, where this crop has a relevant and constant importance over time, are analyzed.

The establishments participating in the development of the work are located between Latitude 26° 00' 46.4" S, and 27° 57' 45.72" S, and Longitude 60° 08' 36.76" W and 61° 41' 19.28" W for the province of Chaco.

Figure 1. *Georeferencing*



Source: Authors.

In each of the establishments, plots were selected for the execution of the trials, planting blocks with the following series of genetic material lines, such as Temperate, Temperate x Tropical, and Tropical, carrying out the corresponding monitoring and control during the crop cycle, data that are found in Table 3.

The hybrids shown in Table 4 were used as a control for the evaluation of performance in starch production.

Table 3: *Types of Materials Used*

Tropical	Temperate x Tropical	Temperate
DK390VT3P	DK7910VT3P	DK7210VT3P
NK139VIP3	LT795VT3P	DK7310VT3P
P30F53HXRR2	2A120PW	2M510PW

Source: Authors.

Table 4: *Control Materials*

Germplasm Lines	Hybrids
Tropical	474V13
	B67049
	INTA2012
	P30B39
	DM1820
Temperate x Tropical	DKB299
	SY138
Temperate	DKC6345
	P1548

Source: Authors.

During the evolutionary cycle of the crop, meteorological data was collected, such as average temperature, precipitation and intercepted radiation corresponding to each locality of the province. Table 5.

Table 5: *Meteorological Data of Localities of the Province of Chaco*

Locations	Average Temperature (°C)	Rainfall (mm)	Effective Heliophany (hs)
Los Frentones (AM)	22,64	308	7,367
Long Camp (LC)	24,40	353	7,367
Dead River (LV)	22,64	707	7,367
Pampa del Infierno (MG)	23,48	360	6,873
Pampa del Infierno (LG)	23,48	360	6,873
Las Breñas (MB)	24,4	413	7,367
Tres Isletas (Ma)	24,02	642	6,873
Tres Isletas (DS)	24,02	820	6,873
P. R. Sáenz Peña (NM)	24,03	433	6,873
Beautiful Field (CM)	23,67	441	7,367
Charata (SS)	24,4	336	7,367
Gen. Capdevila (Sch)	24,35	384	7,367
General Capdevila (HyH)	24,35	447	7,367
General Capdevila (VL)	24,35	420	7,367

Source: Authors.

In addition, data on the soil conditions of the different plots used for the trials were analyzed, including pH, amount of organic matter present, amount of Nitrogen (N) and Phosphorus (P) (Table 6). The data are discriminated by locality.

Table 6: *Soil Data*

Locality	Producer	Soil Factors			
		Mat. Organic [%]	Nitrogen [ppm]	Phosphorus [ppm]	pH
The Frentones	AM	0,40	0,07	77,00	7,30
Long Camp	LC	0,42	0,07	13,10	7,00
Dead River	LV	0,56	0,08	63,50	6,70
Pampa del Infierno	LG	1,27	0,15	67,10	7,50
Pampa del Infierno	MG	0,40	0,07	77,00	7,30
Las Breñas	MB	1,00	0,12	58,55	6,45
Three Islets	Ma	0,56	0,08	63,50	6,70
Three Islets	DS	0,58	0,09	65,50	6,70
P. R. Sáenz Peña	NM	1,50	0,12	55,80	7,60
Beautiful Countryside	C M	0,83	0,08	49,00	7,30
Charata	Sa	0,77	0,10	74.20	6,50
General Capdevila	Sch	1,07	0,09	64,34	7,04
General Capdevila	HyH	1,29	0,13	59,90	7,60
General Capdevila	VL	1,12	0,13	46,40	6,90

Source: Own elaboration

During the collection process, mechanical harvesting, samples were extracted directly from the unloading system, which was conditioned, stored, and preserved in a dry environment until subsequent analysis.

Subsequently, the average yield of maize by locality was determined in quintals per hectare (Table 7). The materials used as a control had an average yield for the same period of 65 qq/ha [18].

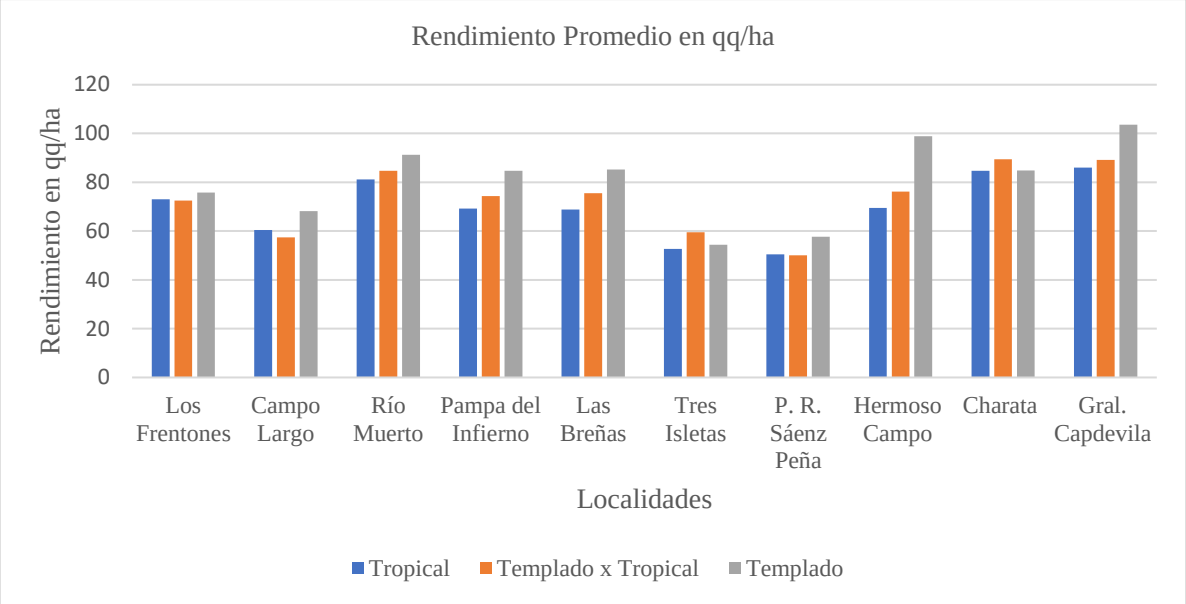
As well as the analytical determination of the percentage of starch present in the grains (Tables 8 and 9).

Table 7: *Average Yield in qq/ha by Localities*

Locations	Average Yield (qq/ha)			Average
	Tropical	Temperate x Tropical	Temperate	
Los Frentones (AM)	73,07	72,51	75,76	73,78
Long Camp (LC)	60,44	57,43	68,16	62,01
Dead River (LV)	81,23	84,76	91,28	85,76
Pampa del Infierno (LG)	72,23	86,99	94,35	84,52
Pampa del Infierno (MG)	66,17	61,73	75,03	67,64
Las Breñas (MB)	68,78	75,55	85,3	76,54
Tres Isletas (Ma)	36,81	56,37	46,84	46,67
Tres Isletas (DS)	68,50	62,72	61,92	64,38
P. R. Sáenz Peña	50,49	50,10	57,73	52,77
Beautiful Field (C M)	69,5	76,17	98,94	81,54
Charata (SS)	84,69	89,42	84,85	86,32
Gen. Capdevila (Sch)	90,09	87,78	107,05	94,97
General Capdevila (HyH)	86,37	94,77	103,64	94,93
General Capdevila (VL)	81,51	85,01	100,00	88,84
Average	**70,71**	**74,38**	**82,20**	**75,76**

Source: Authors

Graph 1: *Average Yield in qq/ha of the Hybrids/Localities*



Source: Authors

Table 8: *Starch Content of Control Hybrids*

Germplasm Lines	Hybrids	Starch (%)	Average
Tropical	474V13	72,01	69,77
	B67049	68,13	
	INTA2012	66,72	
	P30B39	69,03	
	DM1820	73,00	
Temperate x Tropical	DKB299	68,92	69,46
	SY138	70,00	
Temperate	DKC6345	71,45	72,15
	P1548	72,85	
Average			**70,46**

Source: Own elaboration

Table 9: *Average Starch Content of the Analyzed Hybrids*

Locations	Tropical	Temperate x Tropical	Temperate	Average
The Frentones	74,28	73,27	74,32	73,96
Long Camp	75,48	74,53	73,44	74,48
Dead River	69,57	70,57	73,10	71,08
Pampa del Infierno	71,22	73,05	73,65	72,64
Las Breñas	73,53	73,69	73,18	73,47
Three Islets	75,21	74,43	73,75	74,46
Sáenz Peña	74,56	73,75	73,22	73,84
Beautiful Countryside	72,39	72,32	74,66	73,12
Charata	69,99	71,05	72,52	71,19
General Capdevila	71,84	70,73	72,95	71,84
Average	72,81	72,74	73,48	**73,01**

Source: Authors

RESULTS

AGRONOMIC PERFORMANCE

The results obtained in corn grain yield, for the tested hybrids, in each test block, showed significant differences depending on the environmental and soil conditions. A relevant characteristic can be distinguished between the temperate maize hybrid and the highest average yield of 82.20 qq/ha, managing to surpass the temperate x tropical (74.38 qq/ha) and the tropical (70.71 qq/ha) in comparison, demonstrating its best performance in the study area considered.

The localities of Río Muerto, Charata and Gral. Capdevila shows consistent and high yields in the three categories, which indicates a significant productive potential, likewise, we can highlight that Río Muerto, Pampa del Infierno (LG), Hermoso Campo, and Gral. Capdevila, presents superior yields, especially in the temperate category.

Towns such as Río Muerto, Charata, and General Capdevila are examples to follow, showing how certain practices and conditions can result in high levels of production.

Low-yielding localities, such as Tres Isletas, require special attention to identify and address constraints that affect their production.

Taking into account that the overall average total yield stands at 75.76 qq/ha, it reveals, for the region considered, in general, an acceptable yield, but with room for improvement in certain localities, especially in those that are below the average.

STARCH CONTENT

The starch content in the samples analyzed is of important relevance, as a potential source of renewable energy (bioethanol) and, in addition, its nutritional value, which makes it an essential component in the agri-food chain.

From the analysis of starch content in the selected localities, Campo Largo stands out as the locality with the highest average starch content (74.48%), also highlighting that the tropical germplasm line was the one with the highest value (75.48%).

Taking into account that the general average starch content is 73.01%, localities such as Tres Isletas, Los Frentones, and Sáenz Peña presented remarkable starch contents, above the average (74.46%, 73.96%, and 73.84%, respectively) and remarkable values compared to the average of the control materials (70.46%).

CORRELATION BETWEEN YIELD AND STARCH

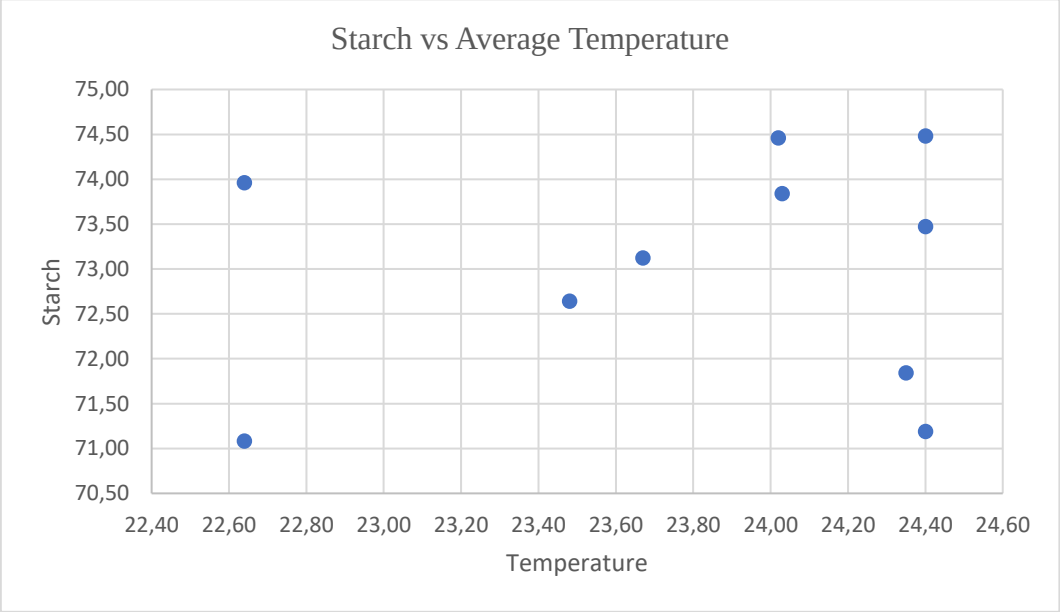
The most relevant, with an interesting relationship, is the one presented by the town of Campo Largo with an average yield in corn grains (61.01 qq/ha), below the general

average (75.76 qq/ha), but with a significant average starch content (74.48%), with peaks of (75.48%).

From the general analysis of data, it emerges that there is no correlation between corn grain yield and starch content, for example, some localities with important yields, such as Río Muerto (85.76 qq/ha), Charata (86.32 qq/ha) and General Capdevila (92.91 qq/ha), have a starch content (71.08%, 71.19% and 71.84%, respectively) below the general average (73.01%).

Below, dispersion graphs are shown between the percentage of starch content present in corn grains as a function of climatic and soil factors, for the study test areas considered.

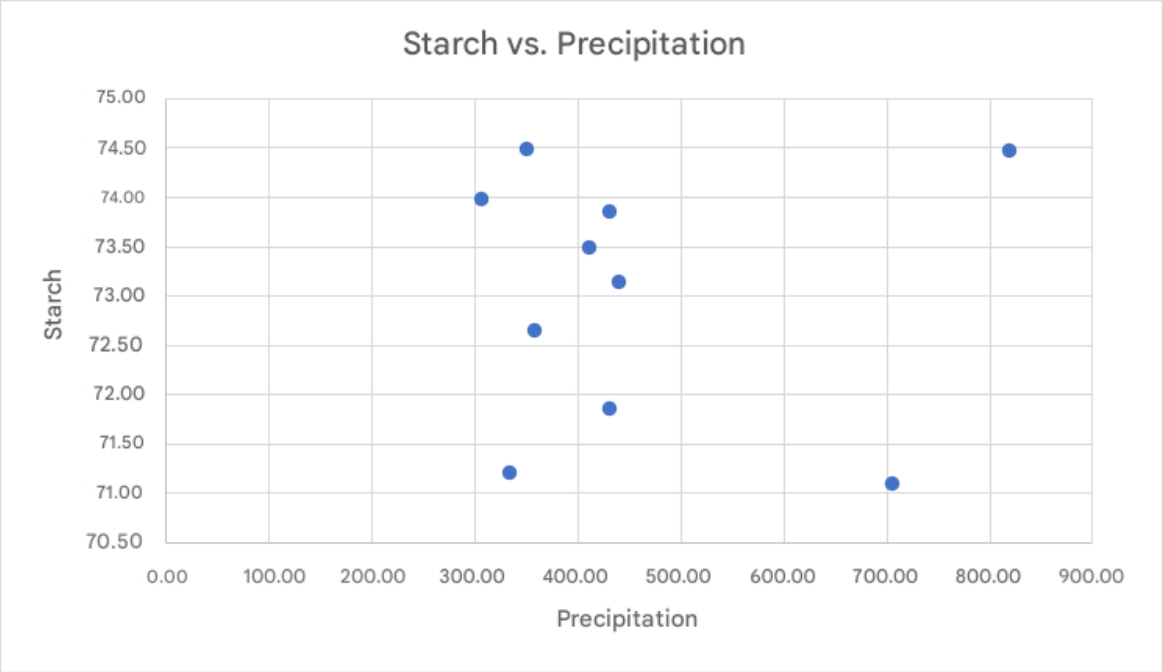
Graph 2: *Dispersion of Starch Content vs. Average Temperatures*



Source: Authors.

Graph 2 shows the average temperatures of the different study areas in the Province of Chaco, which range between 22.7 and 24.4 °C, and the starch content values that vary between 71.08 and 74.48 %. If the percentages of starch content are analyzed, it can be seen that there are hybrids whose values are higher than the average (73.01%) at different temperatures.

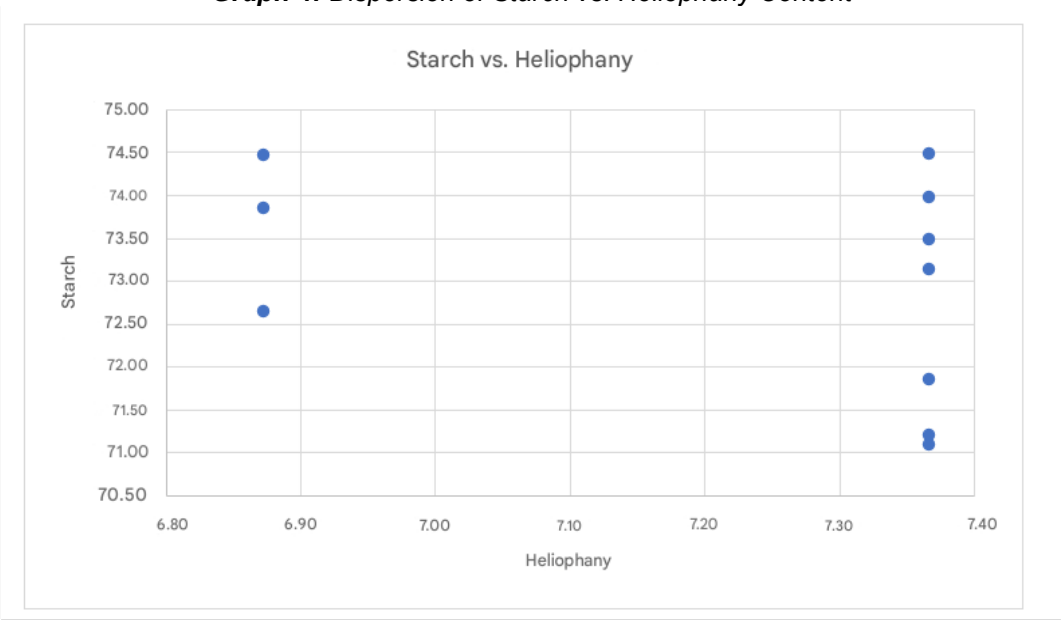
Graph 3: *Dispersion of Starch Content vs. Precipitation*



Source: Authors

Graph 3 shows variations in the percentage of starch content above the average (73.01 %) for different rainfall values ranging from 308 mm to 820 mm.

Graph 4: *Dispersion of Starch vs. Heliophany Content*

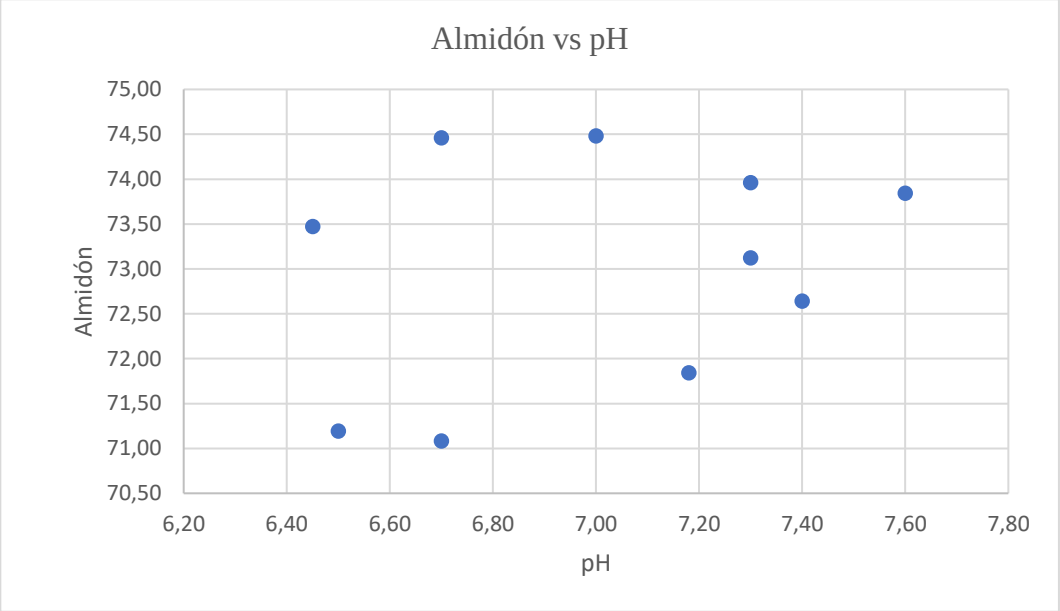


Source: Authors

In Graph 4, the incidence of cellophane is analyzed with the percentage of starch content, where cellophane values vary between 6.873 and 7.367 hours of sun exposure. A relevant aspect is that those materials that exceed the average percentage of starch

content are grouped in a greater proportion in those localities with a cellophane value of 7.367 hours.

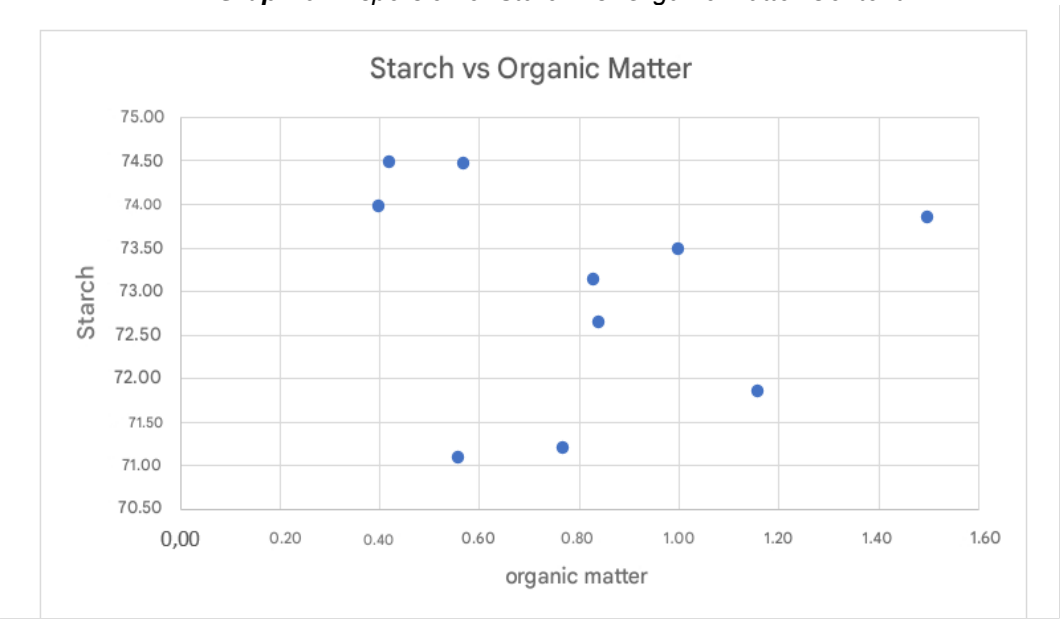
Graph 5: *Dispersion of Starch Content vs. pH*



Source: Authors

Graph 5 analyzes the starch content as a percentage of the soil pH values in the different areas of analysis in the province, with a range ranging from 6.45 to 7.60. Six test areas are found to exceed the average of 73.01% in starch content. In particular, pH values 6.7 and 7 stand out, where significant increases in starch content are recorded.

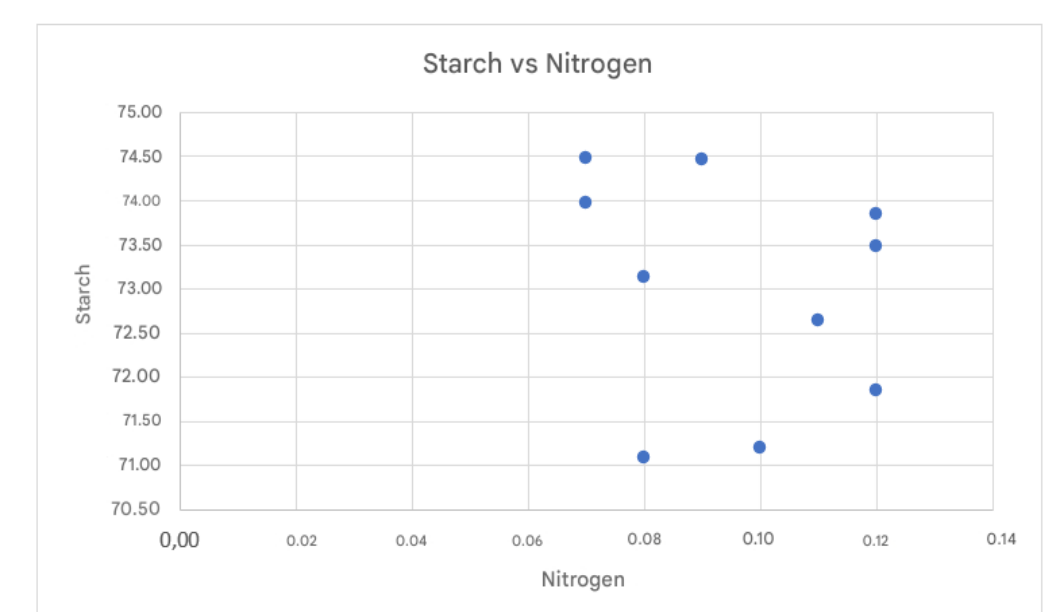
Graph 6: *Dispersion of Starch vs. Organic Matter Content*



Source: Authors

Figure 6 analyzes the starch content of the organic matter content present in the soil, which ranges from 0.40 % to 1.50 %. The results obtained are significant throughout the entire range considered of organic matter. Especially, the areas with organic content of 0.42% and 0.57% stand out, where notoriously high values in starch content are observed.

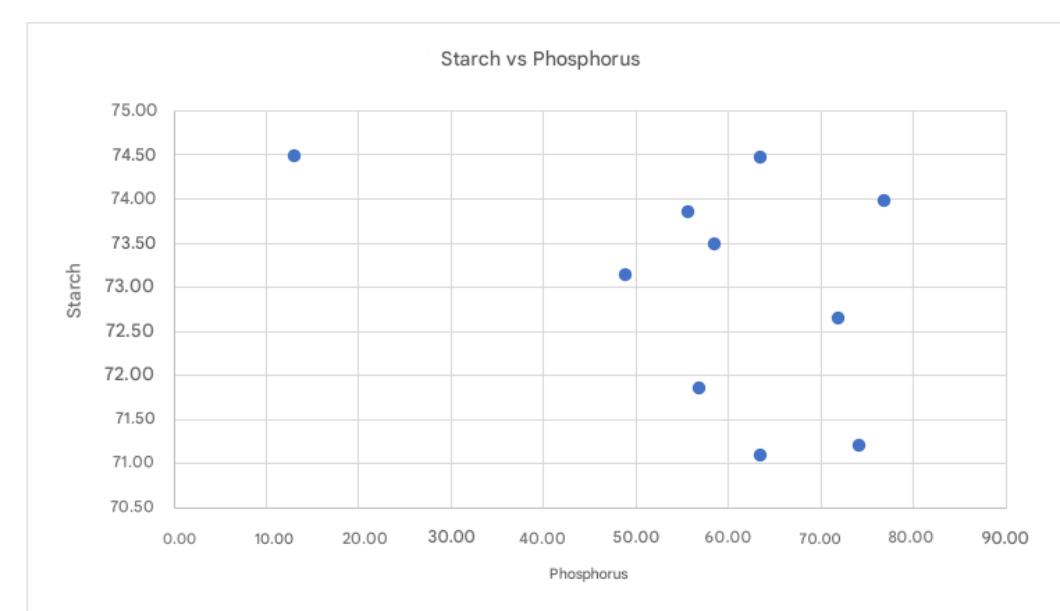
Figure 7: *Dispersion of Starch vs. Nitrogen Content*



Source: Authors

Figure 7 analyzes the variation in the percentage of starch content about the nitrogen content present in the soil, which fluctuates between 0.07 and 0.12 ppm. It is observed that significant starch content percentages are concentrated in nitrogen values between 0.07 and 0.09 ppm.

Graph 8: *Dispersion of Starch Content* vs. Starch *Phosphorus*



Source: Authors

Figure 8 analyzes the variation in the percentage of starch content about the phosphorus content present in the soil, which fluctuates between 13 and 77 ppm. It is observed that the most relevant starch content percentages are concentrated specifically for phosphorus content values of 13.10 and 65.50 ppm respectively.

CONCLUSIONS

The analysis shows that genetically modified corn hybrids for energy purposes showed good performance in both grain production and starch content, which highlights their high productive potential in the province of Chaco. In addition, it is highlighted that the localities of Río Muerto, Charata, and General Capdevila have excellent agronomic conditions for the development of corn cultivation, especially in terms of their productive capacity measured in qq/ha.

About the materials used in the trial and their productive capacity, it is observed that the general average grain yield of the maize hybrids used was 75.76 qq/ha. Compared to the average yield of the campaign for the same period in the aforementioned region, which was 65 qq/ha [18], there is an increase in yield of 16.55%. In addition, when contrasting this yield with the average of the temperate hybrids that showed better performance (82.20 qq/ha), an increase of 26.46% stands out.

On the other hand, it can be seen that the starch content values of the tested hybrids are higher than those of the control materials used. The overall average starch content for the reference materials was 70.46%, while that of the hybrids tested reached 73.01%, representing an increase of 3.62%.

The path of development through the transformation of resources is the answer to remedy the difficulties that currently afflict the sector, such as poverty, marginalization, and social exclusion, where the state, as a relevant actor, must actively promote it, through the implementation of public policies that encourage production and promote an inclusive and sustainable environment.

The realization of the objectives is a task that requires synergy between all the actors of the productive sector and a state that acts as a motor of private initiatives, with public policies that encourage the production and transformation of resources.

In summary, incorporating new links in the maize value chain will improve the profitability of agricultural producers, also conceiving an increase in planting areas and a greater diversification of agricultural production to the detriment of monoculture.

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