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Fertilization in potato (*Solanum tuberosum* L. group Phureja)

Fertilización en papa (*Solanum tuberosum* L. grupo Phureja)

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ARTICLE DATA

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ABSTRACT

Potato fertilization is an important and pricey task, especially when soil analysis is not considered to define fertilization according to its nutritional requirements. The objective of this study was to evaluate genotypes of *Solanum tuberosum* group Phureja at different levels of fertilization (LF) in four localities in the department of Nariño. The LF were 0, 60, 70, and 80% of the dose used in the traditional fertilization of the area (900Kg ha^{-1} of 10-30-10). The split-plot design was used. The LF was located in the main plot, and the genotypes were in the subplots. The genotypes with the best performance in Botana were UdenarStCr10 with 60%, 70%, and 80% LF, UdenarStCr42 with 60% and 80% LF, and UdenarStCr42 with 80% LF with yields between 29.92 and 38.22t ha^{-1}. In the locality of Gualmatán, the best genotype with a LF of 60% was UdenarStCr10, with 70% were UdenarStCr10, UdenarStC42 and UdenarStCr54, and with 80% were UdenarStCr1, UdenarStCr42 and UdenarStCr54 whose yields ranged between 43.58 and 52.91t ha^{-1}. In San Juan, they were UdenarStCr10 with 60% and 80% LF, UdenarStCr42 and UdenarStCr54 with 70% LF with yields between 9.53 and 18.85t ha^{-1}. UdenarStCr1, UdenarStCr10, UdenarStCr42, and UdenarStCr45 responded well to low fertilization levels in all locations. As a result, evaluating them in other environments is recommended to use them as commercial crops or as parents in plant breeding.

Keywords: Behavior; creole; genotypes; locations; yield.

RESUMEN

La fertilización en papa es una labor importante y costosa, especialmente, cuando no se tiene en cuenta el análisis de suelo para definir la fertilización según sus requerimientos nutricionales. El objetivo fue evaluar genotipos de *Solanum tuberosum* grupo Phureja a diferentes niveles de fertilización (NF) en cuatro localidades del departamento de Nariño. Los NF fueron 0, 60, 70 y 80% de la dosis utilizada en la fertilización tradicional de la zona (900Kg ha^{-1} de 10-30-10). Se utilizó el diseño de parcelas divididas. En la parcela principal se ubicaron los LF y en las subparcelas los genotipos. Los genotipos con mejor desempeño en Botana fueron UdenarStCr10 con 60, 70 y 80% de NF, UdenarStCr42 con 60 y 80% de NF y UdenarStCr42 con 80% de NF con rendimientos entre 29,92 y 38,22t ha^{-1}. En la localidad de Gualmatán con un NF de 60% el mejor genotipo fue UdenarStCr10, con 70% fueron UdenarStCr10, UdenarStC42 y UdenarStCr54, con 80% fueron UdenarStCr1, UdenarStCr42 y UdenarStCr54 cuyos rendimientos oscilaron entre 43,58 y 52,91t ha^{-1}. En San Juan fueron UdenarStCr10 con 60 y 80% NF, UdenarStCr42 y UdenarStCr54 con 70% NF con rendimientos entre 9.53 y 18.85t ha^{-1}. UdenarStCr1, UdenarStCr10, UdenarStCr42, UdenarStCr45 y UdenarStCr45 respondieron bien a niveles bajos de fertilización en todas las localidades, por lo tanto, se recomienda evaluarlos en otros ambientes para utilizarlos como cultivos comerciales o como progenitores en fitomejoramiento.

Palabras clave: Comportamiento; criolla; localidades; genotipos; rendimiento.

INTRODUCTION

The potato (*Solanum tuberosum*) represents the fourth most consumed food globally after wheat, rice, and corn, and is a major non-cereal food crop worldwide (FAOSTAT, 2016). The potato contains high carbohydrates, which makes it a food with a high-energy value and a rich source of vitamin C (Ortiz & Mares, 2017). It is grown in more than a hundred countries. In 2019, the world potato harvest was 371 million tons (Anning *et al.*, 2021).

In Colombia, potato production in 2019 reached 2,701,062t in 128,622ha, averaging 21t ha^{-1}. In the department of Nariño, potato cultivation is one of the vital economic sources; in 2019, its production reached 569.16t in 24,906ha planted, averaging 21.5 t ha^{-1} (MADR, 2020).

Potato is a fundamental crop to provide food security to developing regions and is also a highly nutritious food that provides more calories, vitamins, and nutrients per area of cultivated land than any other primary crop (Zaheer & Akhtar, 2016). As it is known in Colombia, the yellow potato has nutritional value, and one hectare of it doubles one hectare of wheat in terms of protein yield. In addition, it contains high-quality protein (2%), essential amino acids, and vitamin C or ascorbic acid (Román & Hurtado, 2002).

The yellow potato shares 10% of the total potato yield in Colombia. Antioquia, Boyacá, Cundinamarca, and Nariño are the leading potato-producing departments in Colombia, which by 2018 registered 8460 hectares planted with yellow potatoes (Agronet, 2018).

Fertilization plays an essential role in potato crops' performance, directed at obtaining adequate nutrition to attain the maximum yields per unit area (Murillo *et al.*, 2016). It is necessary to ensure the expression of the genetic potential since it provides the crops with the necessary quantities of elements to fulfill critical physiological functions for food production and crop quality; nevertheless, fertilizers can represent between 20-35% of production costs (Sifuentes *et al.*, 2015).

In general, the fertilization of potato crops in Colombia is not based on soil analysis and the requirements of the species. In general, high doses of chemical fertilizers are used. Compound fertilizers that contain nitrogen, phosphorus, and potassium in a ratio of 1:3:1 are used in doses established by the farmers' empiric; thus, fertilization in yellow potatoes is deficient (Torres & Suarez, 2014).

In such context, the objective of this work was to test the response of nine native potato genotypes at different levels of fertilization in four localities of the department of Nariño.

MATERIALS AND METHODS

Location. The present work was developed in four municipalities of the department of Nariño, whose location and general climate conditions are shown in Table 1.

Table 1. Passport data of the four localities where the fertilization trials were carried out.

Municipality	Altitude (m a.s.l.)	Average temperature (°C)	Relative humidity (%)	Average rainfall (mm)	Coordinates
Botana	2.863	12	73	900	01° 09' 19"N 77° 16' 33.1"W
Tangua	3.000	19	85	860	1° 07 '19.9"N 77° 22' 03.1"W
Gualmatán	2.820	11	81	730	1° 09' 28.3"N 77° 26' 29.5"W
San Juan	2.820	11	81	730	0° 53' 36.7"N 77° 32' 54.3"W

Plant material. Nine Creole potato genotypes (*Solanum tuberosum* group Phureja) were used from the work collection of the Colombian Central Collection and the University of Nariño. The general traits of the tested genotypes are in Table 2.

Experimental design. Four trials were carried out in different localities of the Andean region of the department of Nariño, southern Colombia. Each trial was established under a Split Plot Design with four replicates with four chemical fertilizers. The replications corresponded to four planting distances. Four fertilization levels were located in the main plot, and nine genotypes of Creole potato were located in the subplots (Table 3).

Table 2. Yellow potato genotypes (*Solanum tuberosum* Phureja group) evaluated under different fertilization levels and planting distances.

Introduction	Origin	m a.s.l.	Municipality	District
UdenarStcr10	AGROSAVIA	2718	Pasto	Obonuco
UdenarStcr46	UDENAR	3109	Cumbal	La Laguna
UdenarStcr42	UDENAR	2806	Pasto	Jurado
UdenarStcr140	AGROSAVIA	3300	Chitaga	Does not have
UdenarStcr1	UDENAR	3089	Cumbal	Panam
UdenarStcr54	UDENAR	2840	Pasto	El Encano
UdenarStcr45	UDENAR	2897	Córdoba	El Salado
UdenarStcr63	UDENAR	2905	Córdoba	Tandaup
UdenarStcr40	UDENAR	3090	Cumbal	Panam

Table 3. Dose of chemical fertilizer and planting distance between plants evaluated in nine genotypes of Creole potato.

Blocks PD (m)	**10-30-10 dose (g/plant) for each LF**			
	80%	70%	60%	0%
0.20 x 1.2	14.4	12.6	10.8	0
0.30 x 1.2	21.6	18.9	16.2	0
0.35 x 1.2	25.2	22.05	18.9	0
0.40 x 1.2	28.8	25.2	21.6	0

PD= planting distance between plants and furrows; LF = level of fertilization (%).

The dose of fertilizer used for each locality was calculated according to the traditional fertilization system of the area, which corresponds to 900Kg ha^{-1} of the chemical formula 10-30-10 fertilizer (Muñoz & Lucero, 2008). The fertilization levels are described in Table 3. The application was carried out in two cultivation stages, first when most plants had already emerged and second 45 days after sowing.

Traits evaluated. The tubers were evaluated by diameter and weight to be classified into three categories: first, second, and rejection (Vega, 2015; Table 4). The number of tubers per plant of the first category was identified with the nomenclature NTuIC; for the second category NTuIIC, the weight of the tuber of the first category used the WTuIC nomenclature, and for the weight of the second, the WTuIIC nomenclature. The yield was calculated considering the weight of first category tubers per plant (WTuIC), the weight of second category tubers per plant (WTuIIC), and the number of harvested plants. This information was expressed in t ha^{-1}.

Analysis of the information. The data of the evaluated traits were analyzed under ANOVA of the statistical model of the Split Plot Design described below:

$$Y_{ijk} = \mu + \alpha_i + n_{k(i)} + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk}$$

Where Y_{ijk} is the response trait, μ is the mean of all the data, α_i is the fixed effect of fertilization, β_j is the fixed effect of the genotype and $(\alpha\beta)$ ij is the interaction between both factors, $\eta_{k(i)}$ is the total plot factor random error (planting distance) and ε_{ijk} is the total error. The distribution of both error terms was normal.

Table 4. Classification of the size of tubers harvested for Creole potatoes.

Classification	Approximate Diameter (cm)	Approximate weight (g)
First (TulC)	>2.5	>20
Second (TullC)	Between 1.6 y 2.4	Between 11 y 19
Rejection (TulllC)	<1.5	<10

The assumptions of normality, homogeneity, and independence of residuals were evaluated by visual inspection of their distribution based on the adjusted values, the normal distribution quantiles, and their respective histogram.

When significant differences were found in the ANOVA for the traits evaluated, the LSD test ($P \leq 0.05$) was performed between the trials' treatments. The analysis was performed using the SAS package.

RESULTS AND DISCUSSION

ANOVA results for the Botana location (Table 5) showed a significant effect for LF and genotypes for NTuIIC, NTuIC, WTuIC, and yield. For planting distances (PD), only yield presented essential differences. The genotype by fertilization level (GxFL) interaction was substantial for all traits except WTuIIC (Figure 1).

In Botana, the highest values in terms of the number of tubers per plant, both first and second category, corresponded to the combinations UdenarStCr10-FL 60, 70 and 80%, UdenarStCr40-FL 70%, UdenarStCr42-FL 60 and 80%, UdenarStCr46-FL 60, 70 and 80% and UdenarStCr54-FL 80%. In the WTuIC trait, the combinations that presented significant differences were UdenarStCr1-FL 60 and 80%, UdenarStCr10-FL 80% and UdenarStCr42-FL 70 and 80% (Figure 1).

Table 5. ANOVA for the traits of the creole potato genotypes evaluated under different levels of fertilization in Botana.

FV	*GL*	*NTuIIC*	*NTuIC*	*WTuIIC*	*WTuIC*	*Yield*
Blocks (PD)	3	5.72ns	1.66ns	0.019ns	0.08ns	1165.03**
FL	3	37.41*	60.10**	0.13**	0.98**	2130.59**
Error a	9	8.07	4.33	0.006	0.05	132.11
Genotype (G)	8	11.07**	19.37**	0.019**	0.23**	293.16**
GxFL	24	3.39**	2.66**	0.004ns	0.032**	46.53*
Error b	72	1.50	1.32	0.0033	0.012	24.32
Average		5.52	5.06	0.21	0.42	21.11
CV		22.21	22.69	27.85	26.27	23.36
R^2		0.72	0.78	0.69	0.84	0.86

ns = not significant; *= significant at α=0.05; **= significant at α=0.01 PD= planting distances; FL= fertilization levels; NTuIIC= number of tubers/plant of commercial category II; NTuIC= number of tubers/plant of commercial category I; WTuIIC= weight of tubers/plant of commercial category II; WTuIC= weight of tubers/plant of commercial category I; R^2= coefficient of determination; CV= coefficient of variation.

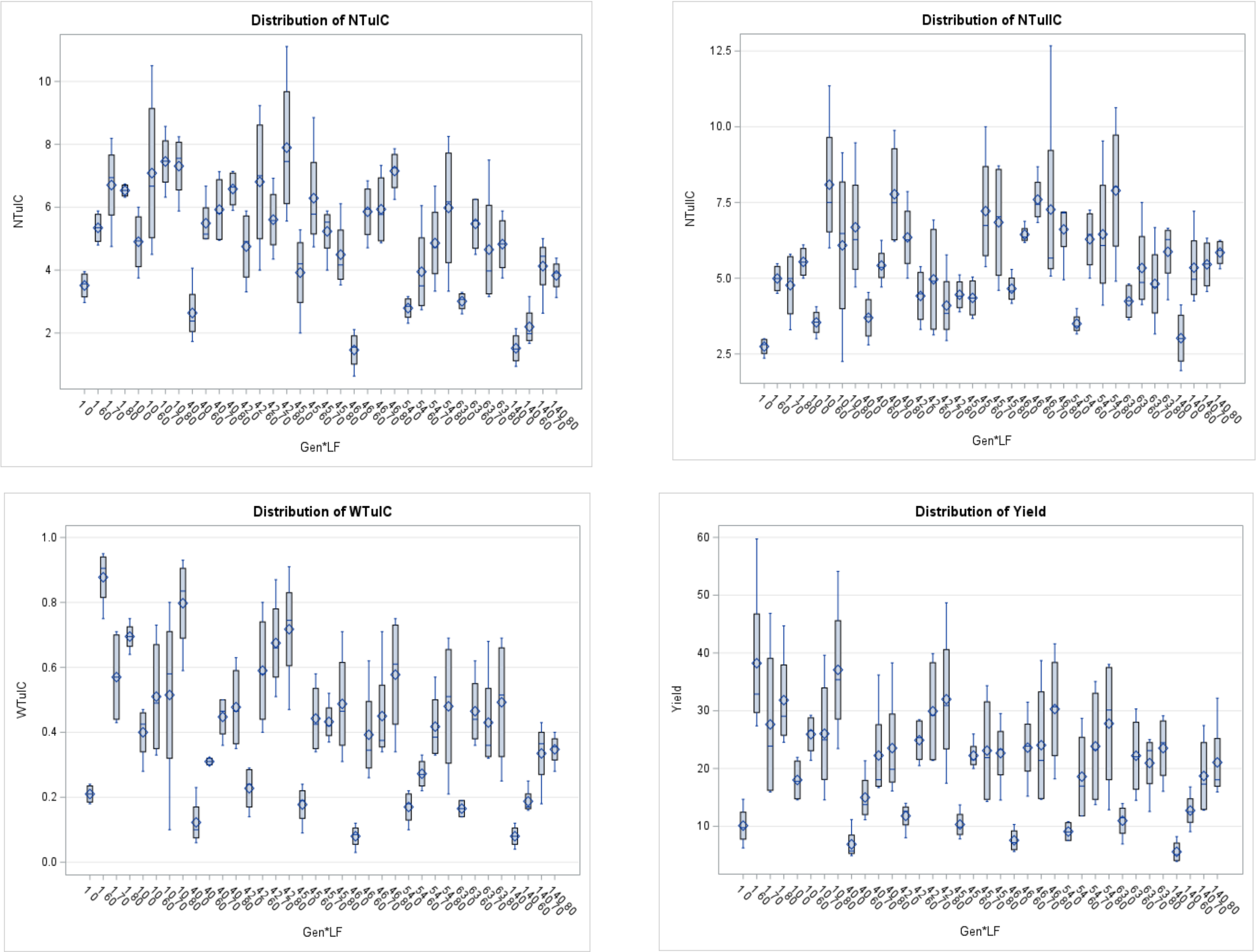

Figure 1. Box plots for the creole potato genotypes evaluated under different levels of fertilization (GxFL interaction) of the Botana locality in the NTuIIC, NTuIC, WTuIC, and yield traits.

The genotypes with the highest yields were UdenarStCr1, UdenarStCr10, UdenarStCr42 and UdenarStCr46 at FL 60, 70 and 80%. UdenarStCr, with an FL of 60%, is the genotype with the best performance with 38.22t ha^{-1}. As mentioned earlier, the other yields of the treatments ranged between 29.92 and 37.08t ha^{-1}. It should be noted that these combinations of genotypes by FL are the ones with the best performance in the NTuIC, WTuIC, and yield traits (Figure 1). The results suggest that these combinations can be used in crops to reduce the use of chemical fertilizers.

The ANOVA of the Gualmatán locality (Table 6) shows key differences in all the traits between the FL and the genotypes. The GxFL interaction was only significant in WTuIIC and yield, which establishes that the genotypes change their behavior through the FL. For WTuIIC, the combinations with larger tubers were UdenarStCr42 with FL 0, 70 and 80%, UdenarStCr45 with FL 80% and UdenarStCr45 with FL 60 and 70%, whose weights ranged between 0.47 and 0.61g (Figure 2).

Table 6. ANOVA for the traits of the creole potato genotypes evaluated under different levels of fertilization in Gualmatán.

FV	*GL*	*NTuIIC*	*NTuIC*	*WTuIIC*	*WTuIC*	*Yield*
Blocks (PD)	3	11.87ns	40.77**	0.02ns	0.15ns	3258.02**
FL	3	43.85*	51.71**	0.09*	0.88**	1836.16**
Error a	9	7.32	3.91	0.019	0.054	177.78
Genotype (G)	8	39.51**	25.08**	0.10**	0.42**	649.84**
GxFL	24	7.09ns	5.73ns	0.02*	0.05ns	111.05*
Error b	72	5.50	4.17	0.011	0.035	62.09
Average		7.46	6.25	0.35	0.63	33.14
CV		31.42	32.64	30.52	29.94	23.77
R^2		0.59	0.62	0.62	0.71	0.81

ns = not significant; *= significant at α=0.05; **= significant at α=0.01 PD= planting distances; FL= fertilization levels; NTuIIC= number of tubers/plant of commercial category II; NTuIC= number of tubers/plant of commercial category I; WTuIIC= weight of tubers/plant of commercial category II; WTuIC= weight of tubers/plant of commercial category I; R^2= coefficient of determination; CV= coefficient of variation.

In terms of yield, the best treatment in Gualmatán was UdenarStCr10-FL 60%, which reached 52.91t ha^{-1}. This treatment was followed by UdenarStCr54-FL 80% (49.36t ha^{-1}) and the combinations UdenarStCr42-FL 80%, UdenarStCr10-FL 70%, UdenarStCr1-FL 80%, UdenarStCr54-FL 80% and UdenarStCr42-FL 70%, whose yields ranged between 43.59 and 47.96t ha^{-1} (Figure 2). The good behavior of the clones UdenarStCr10, UdenarStCr42, and UdenarStCr54 stand out at fertilization levels below 80% of the traditional fertilization done in Creole potatoes in the department of Nariño.

The data obtained in the San Juan locality showed a major effect on fertilization level and genotype for all traits. The GxFL interaction was considerable for WTulC and yield (Table 7). Consequently, the discussion will center on these two traits.

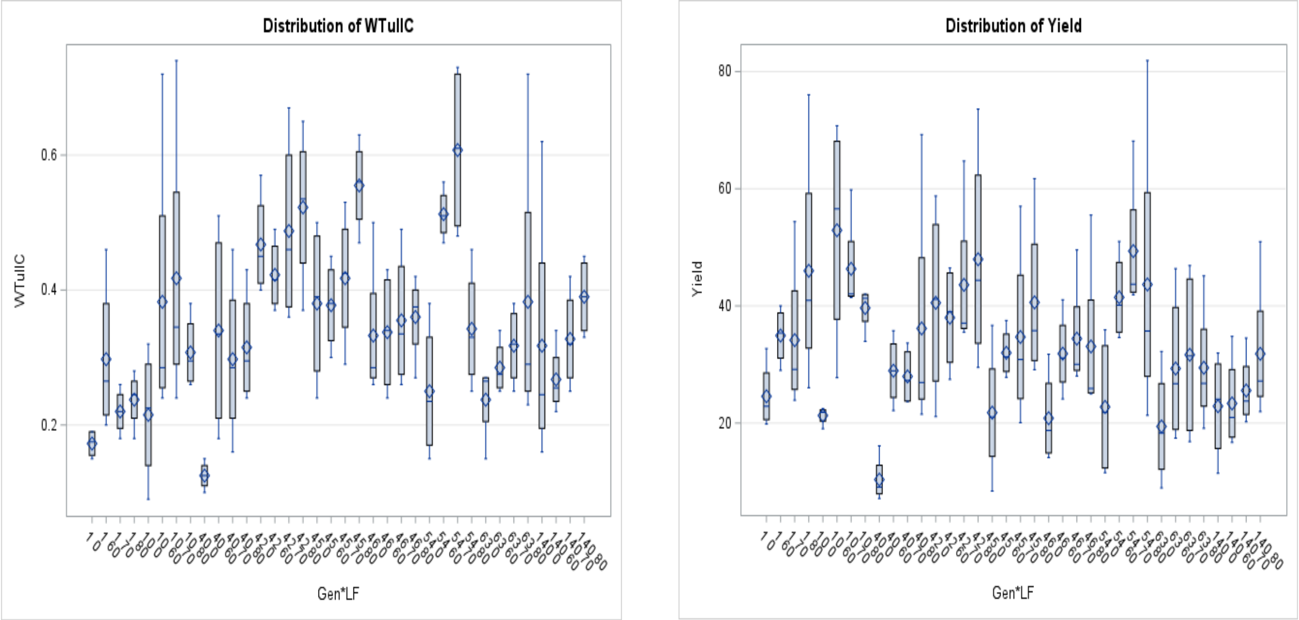

Figure 2. Box plots for the creole potato genotypes evaluated under different levels of fertilization (GxFL interaction) of the Gualmatán locality in the WTuIIC and yield traits.

Table 7. ANOVA for the traits of the creole potato genotypes evaluated under different fertilization levels in San Juan.

FV	*GL*	*NTuIIC*	*NTuIC*	*WTuIIC*	*WTuIC*	*Yield*
Blocks (PD)	3	2.88ns	51.80ns	0.027*	0.062**	2684.93**
FL	3	25.40*	187.94**	0.18**	0.067**	550.55**
Error a	9	3.67	24.98	0.004	0.006	30.69
Genotype (G)	8	35.26**	88.17**	0.07**	0.015**	147.43**
GxFL	24	6.07ns	9.07ns	0.014	0.005*	33.16*
Error b	72	4.39	6.87	0.009	0.003	20.25
Average		6.64	9.07	0.35	0.20	19.13
CV		31.59	28.90	27.02	27.36	23.52
R^2		0.56	0.74	0.65	0.71	0.86

ns = not significant; *= significant at α=0.05; **= significant at α=0.01 PD= planting distances; FL= fertilization levels; NTuIIC= number of tubers/plant of commercial category II; NTuIC= number of tubers/plant of commercial category I; WTuIIC= weight of tubers/plant of commercial category II; WTuIC= weight of tubers/plant of commercial category I; R^2= coefficient of determination; CV= coefficient of variation.

The treatments with the WTuIC highest values for San Juan locality were UdenarStCr40-FL 60 and 80%, UdenarStCr42-FL 80%, UdenarStCr45-FL 60 and 80%, UdenarStCr54-FL 70%, and UdenarStCr140-FL 60, with averages between 0.26 and 0.34g/plant. The best combinations with statistical differences concerning the others were UdenarStCr10-FL 60 and 80%, UdenarStCr42-FL 70%, and UdenarStCr54-FL 70%, whose yields were above the mean plus one standard deviation and ranged from 25.44 and 31.31t ha^{-1} (Figure 3).

The Tangua ANOVA (Table 8) shows significant differences between FL and genotypes for all traits. The GxFL interaction was statistically notable for NTulC, WTuIC, and yield. It means that for these three traits, a differential behavior of the Creole potato genotypes was evidenced at the different levels of fertilization.

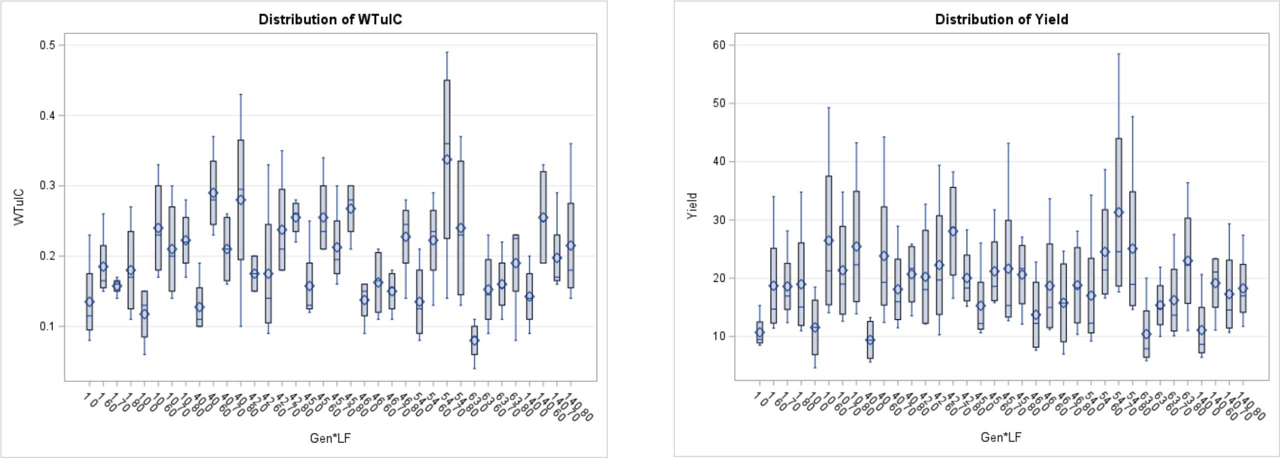

Figure 3. Box plots for the creole potato genotypes evaluated under different levels of fertilization (GxFL interaction) of the San Juan locality in the WTuIC and yield traits.

Table 8. ANOVA for the traits of the creole potato genotypes evaluated under different levels of fertilization Tangua.

FV	*GL*	*NTuIIC*	*NTuIC*	*WTuIIC*	*WTuIC*	*Yield*
Blocks (PD)	3	28.61*	1.43ns	0.006ns	0.05*	2029.67**
FL	3	119.38**	89.23**	0.22**	0.65**	1877.08**
Error a	9	4.58	5.07	0.006	0.008	89.33
Genotype (G)	8	49.72**	41.05**	0.048**	0.28**	294.03**
GxFL	24	7.26ns	10.40**	0.009ns	0.022**	27.45**
Error b	72	6.52	6.01	0.008	0.008	15.45
Average		7.75	6.01	0.27	0.43	23.90
CV		32.94	30.28	32.16	20.23	16.44
R^2		0.63	0.74	0.65	0.87	0.92

ns = not significant; *= significant at α=0.05; **= significant at α=0.01 PD= planting distances; FL= fertilization levels; NTuIIC= number of tubers/plant of commercial category II; NTuIC= number of tubers/plant of commercial category I; WTuIIC= weight of tubers/plant of commercial category II; WTuIC= weight of tubers/plant of commercial category I; R^2= coefficient of determination; CV= coefficient of variation.

The Tangua treatments with the highest NTuIC values were UdenarStCr1-FL 70%, UdenarStCr10-FL 60 and 80%, and UdenarStCr40-FL 80%, which showed weighty differences with the other combinations; this NTuIC ranged between 9.19 and 14.84. UdenarStCr1 and UdenarStCr10 in all FL except 0%, together with the genotypes UdenarStCr40-FL 80% and UdenarStCr42-FL 80%, exhibited major differences with the rest of the treatment combinations in WTuIC with weights between 0.62 and 0.80g/plant (Figure 4).

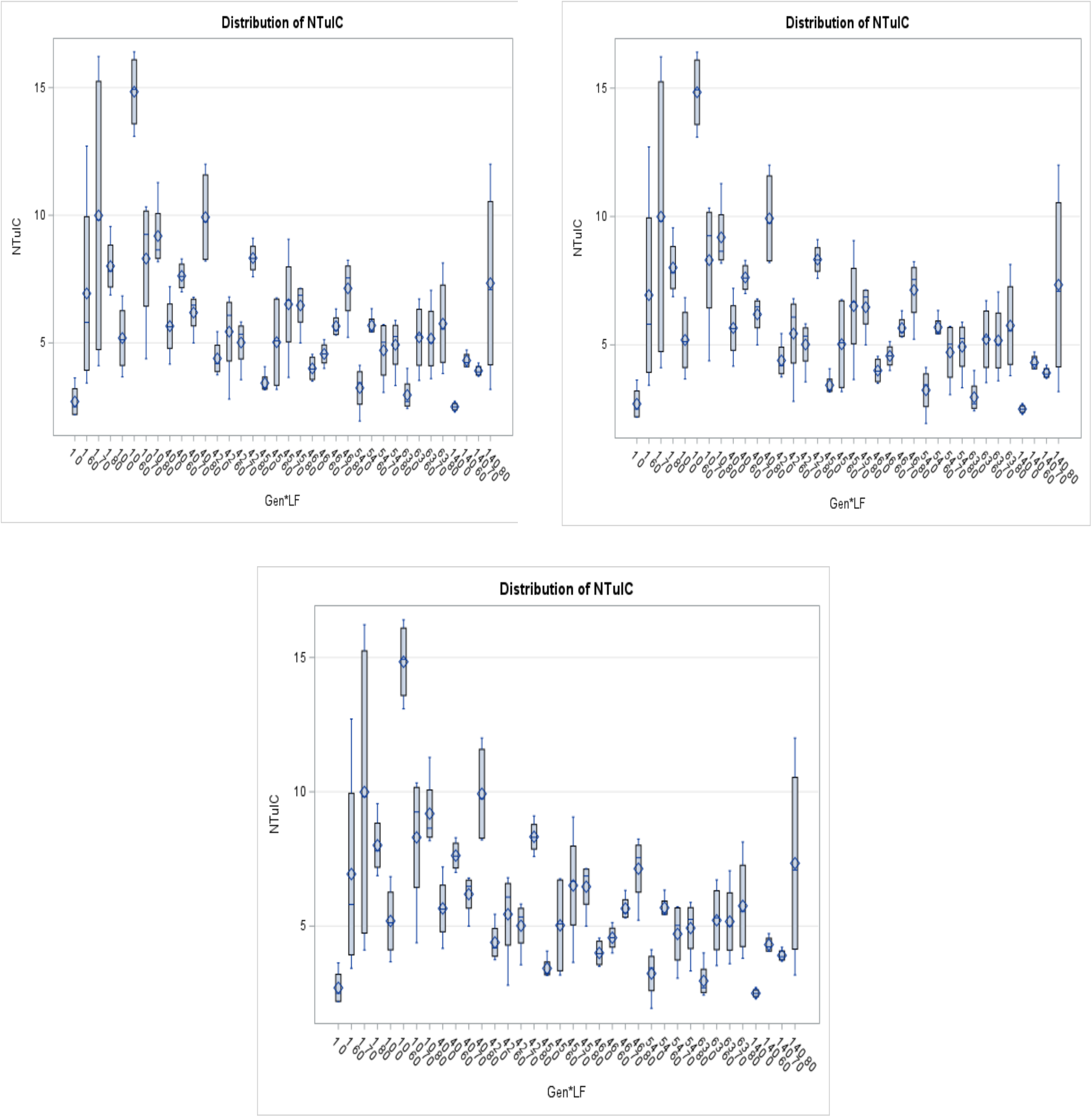

Figure 4. Box plots for the creole potato genotypes evaluated under different levels of fertilization (GxFL interaction) of the Tangua locality in the NTuIC, WTuIC, and yield traits.

Regarding the yield in Tangua, as in the other locations, the combinations that showed greater differences with the other treatments were UdenarStCr1-FL with 70 and 80%, UdenarStCr10-FL with 60, 70, and 80%, UdenarStCr42-FL with 80% and UdenarStCr45-FL with 80%, whose yields ranged between 31.87 and 38.89t ha^{-1}.

Considering that the purpose of this research is to choose genotypes with the best performance under low levels of fertilization, these genotypes can be used as parents in potato breeding programs or directly by producers to improve the efficiency of their crops. It should be considered that potato cultivation is one of the most profitable vegetables, but with high production costs due to its frequent use of inputs. It requires a great variety of nutrients, among which the most prominent ones are potassium (K), Phosphorus (P), and Nitrogen (N) (Keiluweit *et al*., 2015). These supplements are applied under strict conditions, for example, when the soil is poor (Ierna *et al*., 2011; Prunell, 2019).

For the Botana locality, the UdenarStCr10, UdenarStCr42, and UdenarStCr46 genotypes recorded the highest values in the different traits, even compared to the control genotype (UdenarStCr40). Statistically significant differences are evident in favor of these genotypes; thus, they are promising candidates that exhibit a positive GxFL interaction response. These genotypes also stood out in the other locations, along with UdenarStCr54.

Besides being directly related to yield, it is known that fertilization influences the quality of the tuber as well (Talburt & Smith, 1967; Murillo *et al*., 2016). In this sense, Ozturk *et al*. (2010) mention that the Protein content of sour potato in Erzurum (Turkey) is increased if Nitrogen (N) levels are increased, while the phosphorus dose is directly related to the oil absorption rate (FAO, 2012). The finding coincides with the study by Zelalem *et al*. (2009), who report similar effects of N and P doses on dry matter content and specific gravity of potatoes in Ethiopia. Similarly, after a long series of field experiments in the United States of America, Kunkel and Holstad (1972) also concluded that potato specific gravity often decreased with increasing levels of N, P, and K. This is consistent with what happened in Botana, Gualmatán, and Tangua, where the UdenarStCr10 genotype was the one that reported the highest number of category I commercial tubers. Probably, in these areas, fertilization supplied low levels of nutrients, and a higher production was achieved. It is worth highlighting what was stated by Porras (2015), who suggests that the yield of the crops depends on various factors. One of them is fertilization, but it is not the only one. Plant material, properties and use of the soil, climate, seed quality, and planting distances were precisely considered as the explanatory factors in this research. Oddly, there are different values as optimal, very probably explained by those mentioned above.

Studies developed by Levallois *et al*. (1998) and Bernal (2018) reveal that if the fertilization percentages do not show a statistically relevant difference, the optimal fertilization is the functional minimum, for this research, the lowest value that yielded results. The most prominent one was the percentage of 60, which suggests that it is enough to achieve differential yields. Additionally, it must be considered that the excessive application of fertilizer does not ensure a better yield. On the contrary, in many cases, the plant is unable to fully assimilate it, leading to an unnecessary increase in production costs. What is more, it would contribute to environmental contamination in groundwater (Levallois *et al*., 1998; López *et al*., 2020).

For the locality of Tangua, the genotypes UdenarStCr1, UdenarstCr10, UdenarstCr42, and UdenarstCr45 are again reported as the ones with the best performance at FL 60, 70, and 80%, much higher than the combinations without fertilization and with good yields at fertilization levels lower than the traditional doses used by farmers in the area. These results are in keeping with Tekalign and Nigussie (2012), who found higher tuber production in Ethiopia at a planting distance of 40cm with a fertilization percentage of 75%.

For the yield in the Gualmatán locality, besides UdenarStCr10, the best genotypes were UdenarStCr1, UdenarStCr42, and UdenarStCr54, mainly with FLs 70 and 80%, which registered a high yield compared to the control (UdenarStCr40) in all FLs. A similar situation was observed in San Juan except for the UdenarStCr01 genotype. The peculiar thing is that for the latter in both localities, an acceptable weight in category 1 tubers is reported but at a fertilization level of 0%. This situation is reported in the literature, and although it is known that fertilization is not the only factor that influences production, it is recognized that a certain degree of fertilization is required to accelerate production (Porras, 2015).

The findings above suggest that it is interesting to continue studying the genotypes that under 0% fertilization conditions exhibit excellent potential for assimilation and/or absorption of the existing nutrients in the soils of each of the localities. This characteristic is consistent with what Saravia *et al*. (2016) state when affirming that one of the biggest challenges in potato production is obtaining genotypes with a satisfactory performance at low fertilization of N.

It is also remarkable that each species' genetics is essential to achieving better production results. Martinez and Ligarreto (2005), and Aguilar *et al*. (2020), mention that "the accumulation rate of reducing sugars and the dry matter is genetically determined and exhibits high heritability. It is considered as a trait of low genotype-by-environment interaction". Although there are essential factors in producing commercial tubers of different types, genetics plays a vital role in the productive capacity when contrasting with the results obtained. Additionally, it should be noted that nine different genotypes were used for the experimental design, leaving a precedent that each genotype can behave differently in the face of external factors or respond differently to different variables.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interest.

CONCLUSIONS

The genotypes with the best performance in Botana were UdenarStCr10 with 60, 70 and 80% chemical fertilization (FL), UdenarStCr42 with 60% and 80% FL, and UdenarStCr42 with 80% FL. In the locality of Gualmatán, with a FL of 60%, the best genotype was UdenarStCr10; with 70% were UdenarStCr10, UdenarStC42, and UdenarStCr54, and with 80% were UdenarStCr1, UdenarStCr42 and UdenarStCr54. In San Juan, UdenarStCr10 with 60 and 80% FL, UdenarStCr42 and UdenarStCr54 with 70% FL were the genotypes with the best performance. In Tangua, the best combinations were 60% FL UdenarStCr10, 70% UdenarStCr1 and UdenarStCr10 and 80% UdenarStCr1, UdenarStCr10, UdenarStCr42 and UdenarStCr45. The UdenarStCr1, UdenarStCr10, UdenarStCr42, UdenarStCr45, and UdenarStCr45 genotypes have the potential to be used in crops or breeding programs aimed at reducing the use of chemical fertilizers.

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