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Research Article

Effect of Floral Decapitation on the Yield of Two Potato Varieties (Huaych'a and Desiree)

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Abstract: Floral decapitation is performed in order to favor the translocation of dry matter to the tubers, to obtain positive results in the yield of the potato tuber. The research was carried out in a plot of land in the southern Bolivian highlands, with the aim of evaluating the effect of decapitation on two potato varieties: Huaych'a (*Solanum tuberosum spp. andigenum*), which is late, and Desiree (*Solanum tuberosum spp. tuberosum*), early variety. The trial was established under an experimental design of randomized blocks with a divided plot arrangement with two study factors: Factor A: Varieties (Huaych'a – Desiree) and Factor B: Floral decapitation (with decapitation – without decapitation). Having four treatments with three replications, the variables evaluated were: percentage of emergence, plant height, stem diameter, number of stems, leaf cover, dry matter, number of tubers, tuber weight (kg), tuber classification, yield (EU and t $^{ha-1}$) and benefit/cost.

The results show that the climatic conditions recorded in the production cycle were favorable in the development of the tuber with a rainfall 52% higher than the average of 8 years. Plant height showed significant differences in factor A at 36, 49, 92 and 118 DDS. For the weight of the root and leaf dry matter, there were significant differences in factor A, with the Huaych'a variety being the one with a higher weight. The yield did not present statistically significant differences, but when the tuber was classified, the floral decapitation had an effect on the quality of the tubers, obtaining a higher proportion of first category in both varieties, which makes the cost benefit more than 1.98 to 2.25 in the Desiree and Huaych'a varieties.

Keywords: Floral decapitation, Huaych'a and Desiree varieties, Random blocks with divided plot arrangements, tuber quality.

Introduction

The potato (*Solanum tuberosum L.*) plays a key role in global food security and contributes to poverty reduction through income generation and job creation. Despite its importance, the potato sector is affected by numerous problems, such as a lack of clean seeds, a lack of proper pest and disease management, a disorganized marketing system, and a lack of clear policies on packaging [1].

In Bolivia, 2423 types of varieties have been registered according to the INIAF by 2025 [2], with the production of approximately 230 varieties of the 4500 existing in the world. According to Flores [3], in the 2020–2021 agricultural season, according to INE data, Bolivia reached a potato production of 1,272,649 t in a total area of 191,321 hectares, achieving an average yield of 6.65 t ha-1, while in the 2019–2020 agricultural season the total produced reached 1,317,923 t with a yield of 7.2 t $^{ha-1}$.

The potato is one of the most important foods in Bolivia because it is the basis of the population's diet. On average, in urban areas each inhabitant consumes 80 kg of potatoes per year and in rural areas 140 kg, providing more than 60 percent of daily calories [4]. According to a report by the PROINPA Foundation, more than 200,000 Bolivian families live from this crop and produce an average of 652,000 tons per year. The potato occupies a key place in the farmer's economy [5].

According to Terrazas et al. [6], potatoes are the main food for children, adolescents and adults in the northern communities of Potosi and Oruro, contributing significantly to caloric and energy requirements. The abundant and diversified consumption in the North of Potosí is possible thanks to the variety they grow on their plots.

For Fitsum et al. [7], the main factors contributing to low production are the lack of high-yielding and disease-tolerant varieties, the scarcity of quality seeds, and poor agronomic practices, such as nutrition, irrigation, improper hilling, and the removal of flowers at the correct stage. In the northern region of Potosi, the crops are concentrated in the provinces of Bilbao, Ibanez, Charcas, Bustillos, Chayanta, Tomas Frias, Saavedra and Linares. Despite poor soil management, the Lequezana and Sacaca pampas still produce significant volumes, although there is a reduced production with yields of 5.47 t/ha [4].

The literature indicates that there is often an inverse relationship between the growth of floral parts and vegetative organs, where fruit and seed production inhibits vegetative growth [8]. According to Midmore [9], tuber production depends on intercepted solar energy, dry matter conversion efficiency, and translocation efficiency to tubers. Floral decapitation would affect this efficiency in favor of the tubers. Flowers and tubers compete for assimilates, and pruning increases their transfer to underground structures and increases yield [10].

In the municipality of Sacaca, rainfed production has low yields. Floral decapitation is proposed as an alternative to improve production. This research aims to evaluate the effect of floral decapitation on the yield of two potato varieties, Huaych'a (*Solanum tuberosum spp. andigenum*) and Desiree (*Solanum tuberosum spp. tuberosum*), in the Totoroco community.

Methodological Design

Location of the study area

The work was carried out in the Totoroco community, Alonso de Ibanez Province, Sacaca Municipality, Potosi Department (X:777239.68 Y:8000892.33, altitude 3,720 meters above sea level). According to historical data (2014-2023), the area has an average annual temperature of 12.19°C, average maximum of 22.65°C, average minimum of 1.67°C and annual rainfall of 449 mm [11].

Methodology

The research has a quantitative approach. The study factors were:

- Factor A: Potato varieties (Huaych'a and Desiree).
- Factor B: Floral decapitation (With decapitation and without decapitation).

Four treatments were established:

- (V1 SD): Huaych'a variety without decapitation.
- (V1 CD): Huaych'a variety with decapitation.
- (V2 SD): Desiree variety without decapitation.
- (V2 CD): Desiree variety with decapitation.

The statistical model was randomized blocks arranged in divided plots [12], shown in equation 1:

$$Yijk = \mu + \beta j + \alpha i + Eij + \gamma ijk + (\alpha\gamma)ik + \varepsilon ijk \qquad (1)$$

Where: Yijk = variable of the response measured in the ijk – th experimental unit ; μ = general mean; βj = effect of the j-th block; αi = effect of the i-th level of the factor applied to the main plot; εij = experimental error of the main plot; γijk = effect of the j-th level of the factor associated with the sub-plot within the i-th main plot of the j-th block; (αγ)ik = interaction of the principal factor with the factor applied to the subplots; εijk = experimental error at the subplot level (error b).

Soil preparation was mechanical 60 days before planting. Certified ASPROSEMI seed was used. Sowing began on November 4, 2023 (density 70x30 cm). Floral decapitation was performed every four days from the appearance of flower buds to flowering with pruning shears. The Desiree variety matured at 121 DDS and the Huaych'a at 153 DDS.

The classification of the Huaych'a tuber was based on PROINPA [13], and for Desiree according to weight parameters [14]. Dry weight was obtained by drying samples at 105 °C for 24 hours. The data were processed in InfoStat with analysis of variance at 5%.

Table 1: Tuber classification parameters according to diameter and weight

Size	Diameter (*)	Weight (**)
I	Mayor a 55 mm	Mayor a 101 g
II	45 a 55 mm	81 a 100 g
III	30 a 45 mm	61 to 80 g
SAW	20 to 30 mm	40 to 60 g
V	Less than 20 mm	Less than 40 g
Note: PROINPA (13)*; SEPA (14)**		

Results and Discussion

Weather conditions

During the cycle (2023-2024), low temperatures were recorded (minimum 3°C, average maximum 22.6°C). Rainfall was 654.7 mm, concentrated in February (219.4 mm). This represents 52.2% more precipitation compared to the historical average [11] as shown in Figure 1. According to Egusquiza [15], the climate must be cold for adequate production. Condori et al. [16] point out that the crop develops between 2800 and 4200 meters above sea level with rainfall of 400 to 900 mm. Canqui and Morales [17] confirm that the potato adapts to cold areas with rainfall of 600 to 800 mm.

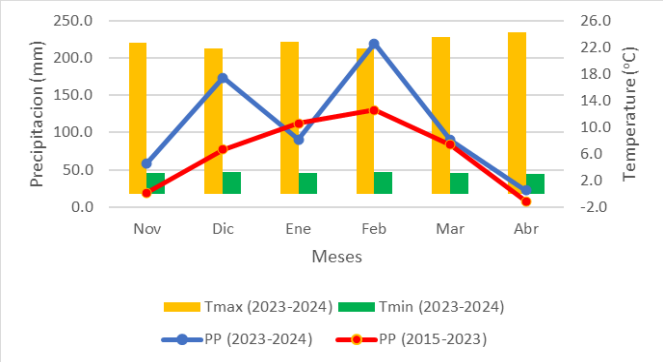

Figure 1: Climate Graph during the average research period of 2015-2023 and 2023-2024

Note. SENAMHI (Sacaca Meteorological Station).

Physicochemical characteristics of the soil

Through the physical-chemical analysis of the soil in the soil laboratory of the Faculty of Agronomy of the Universidad Mayor de San Simon, the following results were obtained (table 2).

The soil texture of the research plot belongs to the sandy loam (PA) soil type, with a bulk density of 1.47 g $^{cm-3}$, with a neutral pH of 6.5, with a non-saline electrical conductivity, as well as with a low cation exchange capacity (0.22 meq 100g-1), with a low organic matter of 0.58%, with a low total nitrogen (0.031%) and with low available phosphorus of 7 ppm.

Table 2: Result of physical-chemical analysis of the soil

Parameters	Results	Interpretation
Texture	AF	Moderately thick
Clay	9 %	Casualty
Slime	18 %	Casualty
Sand	73 %	Loud
Bulk density	1.47 g $^{cm-3}$	Middle
pH	6,5	Neutral
C.E	0.076 dS $^{m-1}$	No salino
Potassium	0.22 meq 100 $^{g-1}$	Casualty
Organic matter	0,58 %	Casualty
Total Nitrogen	0,031 %	Casualty
Phosphorus available	7 ppm	Casualty

Note: Soil analysis carried out in the soil laboratory of the Faculty of Agronomy of the Universidad Mayor de San Simon (UMSS).

Montaldo [18] and INTAGRI [19] suggest that the best soils have a pH between 4.8 and 7.0, an electrical conductivity of less than 4 dS $^{m-1}$ and organic matter greater than 3.5%, which indicates deficiencies in the studied plot.

Emergency Percentage

At 26 DDS, the Desiree variety without decapitation obtained 98.5% emergence (Figure 2). Cortez [20] reports 97% emergencies for Huaych'a, while Ruiz [21] indicates ranges of 65% to 70% for Desiree, surpassed in this study.

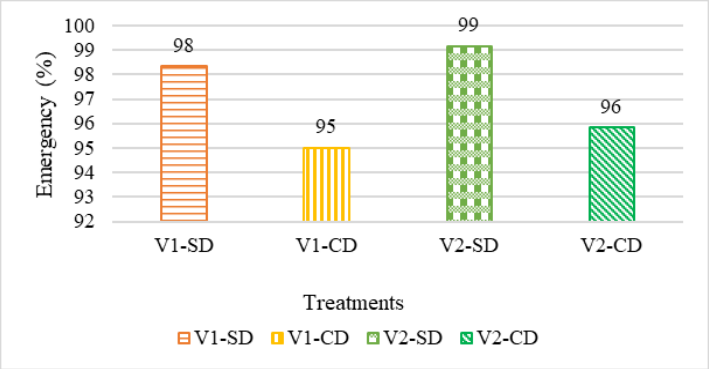

Figure 2: Percentage of emergency treatment at 26 DDS

Plant height

The interaction of floral decapitation and variety in the analysis of variance for plant height at 26, 36, 49, 92 and 118 DDS did not obtain significant differences, only for the variety factor there were significant differences at 36, 49, 92 and 118 DDS (Table 2). This difference in height is mainly due to the genetic characteristics of both varieties, with Desirée being earlier than Huaych'a.

Table 3: Mean squares of the analyses of variance for the plant height at 26, 36, 49, 92 and 118 DDS

F.V.	GL	CM				
		26 DDS	36 DDS	49 DDS	92 DDS	118 DDS
Block	2	5,93 ns	20,3 ns	37,45 ns	37,28 ns	14,19 ns
Variety	1	42,19 ns	319,71 *	422,81 *	3383,52 *	4333,52 *
Main Parcel Error	2	5,24	6,34	5,14	50,81	56,9
Floral decapitation	1	1,83 ns	7,05 ns	2,99 ns	12,77 ns	7,65 ns
Floral decapitation*Variety	1	2,18 ns	10,3 ns	16,12 ns	0,69 ns	0,31 ns
Error sub parcela	4	2,82	12,09	12,42	13,21	5,78
Total	11					
C.V. (%)		24,78	22,85	13,39	8,58	5,87

Note: F.V: Sources of variation. GL: Degrees of freedom. CM: Medium squares. C.V.: Coefficient of variation. ns: Not significant. *: Significance at 5%

The difference in height is due to genetic characteristics. According to Bethke & Jansky [22], late cultivars (such as Huaych'a) have greater shoot development. The Huaych'a is erect growing and Desiree semi-erect.

The analysis of third-degree polynomial regression in terms of height and days after planting (Figure 4), shows that the regression equations have a good fit to the data obtained, with a coefficient of determination R2: 0.99, evidencing the precocity of Desiree (29 days before Huaych'a).

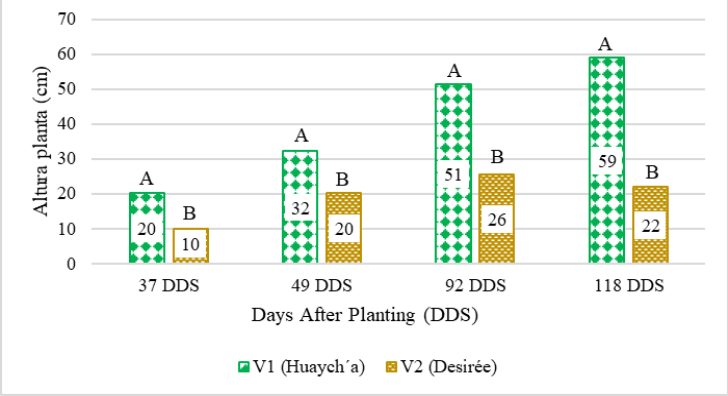

Figure 3: Average plant height by variety

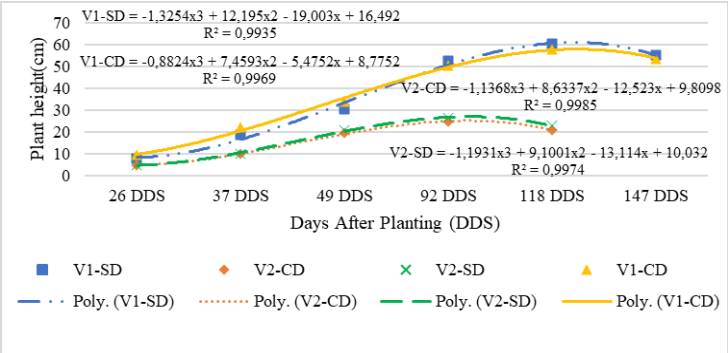

Figure 4: Plant height at different stages after sowing

Root and leaf dry matter

In table 4, the interaction of the variety by floral decapitation does not present statistically significant differences, however, the variety factor obtained a p-value of 0.017 highly significant to 0.01 of significance, these results can be attributed to the fact that V2 was in a dry state at the time of sample collection, with a coefficient of variation of 38.34% with high variability of the data.

Table 4: Analysis of root dry matter variance by plant

F.V.	SC	GL	CM	F	p-value
Block	4,54	2	2,27	0,55	0,6472
Variety	237,63	1	237,63	57,13	0,0171 **
Main Parcel Error	8,32	2	4,16		
Floral decapitation	0,47	1	0,47	0,08	0,7899 ns
Floral decapitation*Variety	1,39	1	1,39	0,24	0,6509 ns
Error sub parcela	23,27	4	5,82		
Total	275,61	11			
C.V. (%)	38,34				

Note: F.V: Sources of variation. GL: Degrees of freedom. CM: Medium squares. C.V.: Coefficient of variation. ns: Not significant. **: Significant at 1%

Bautista et al. [23] mention that in terms of the comparison of means, tubers such as black imilla, qhati señorita have a root weight per plant of 26.41 g., which is higher than the results obtained in the present research.

Foliar dry matter

Table 5 shows the analysis of variance for leaf dry matter, where the interaction between variety and floral decapitation did not obtain significant differences, however, the variety factor obtained a highly significant difference, with a coefficient of variation of 38.08% indicating a high variation of the data obtained, due to the difference in the ripening and harvest of the varieties.

Table 5: Foliar dry matter analysis of variance

F.V.	SC	GL	CM	F	p-value
Block	68,55	2	34,28	39,97	0,0244*
Variety	4168,09	1	4168,09	4859,96	0,0002**
Main Parcel Error	1,72	2	0,86		
Floral decapitation	838,09	1	838,09	6,91	0,0583 ns
Floral decapitation*Variety	687,28	1	687,28	5,67	0,076 ns
Error sub parcela	485,16	4	121,29		
Total	6248,89	11			
C.V. (%)	38,08				

Note: F.V: Sources of variation. SC: Sum of squares. GL: Degrees of freedom. CM: Medium squares. C.V.: Coefficient of variation. ns: Not significant. *: Significance at 5%. **: Significance at 1%

Saluzzo et al. [24] mention that nutrients such as N favor the development of the leaf area that allowed to increase the interception of biomass radiation, however, these positive effects can be counteracted by reducing the partition of dry matter to the tubers.

Yield

The analysis of variance showed no significant differences for the interaction or for individual factors (Table 6).

Table 6: Yield analysis of variance kg/EU

F.V.	SC	GL	CM	F	p-value
Block	135,11	2	67,56	0,61	0,6203 ns
Variety	28,9	1	28,9	0,26	0,6598 ns
Main Parcel Error	220,73	2	110,37		
Floral decapitation	27,99	1	27,99	1,78	0,2536 ns
Floral decapitation*Variety	9,85	1	9,85	0,62	0,4735 ns
Error sub parcela	63,08	4	15,77		
Total	485,67	11			
C.V. (%)	19,94				

Note: F.V: Sources of variation. GL: Degrees of freedom. CM: Medium squares. C.V.: Coefficient of variation. ns: Not significant.

Although the yield was not significant, the averages of the combination between variety and floral decapitation were obtained (Figure 5), where the Huaych'a variety without floral decapitation obtained a higher yield with 25.6 t $^{ha-1}$ followed by the Huaych'a variety with floral decapitation with 20.39 t $^{ha-1}$, likewise the Desiree variety presents an average of 19.6 t $^{ha-1}$. It was concluded that floral decapitation has no effect on the yield of the Huaych'a and Desiree varieties. In a study conducted in the northern highlands, [23] evaluated the effect of floral decapitation on native potato varieties and concluded that this practice did not have a significant impact on crop yield. Although in a study conducted in Africa, Ethiopian potato with flower buds removed and harvested 15 days after complete emergence showed better results in terms of all characteristics that contribute to yield and tuber yield [7].

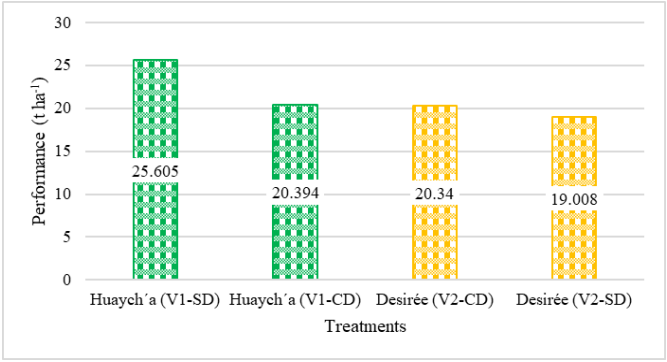

Figure 5: Yield per treatment (t ha^{-1})

It is concluded that floral decapitation had no significant effect on total yield, agreeing with Bautista et al. [23], although it differs from Fitsum et al. [7] in Ethiopia. The yields obtained exceed those reported by Cortez [20] for Huaych'a (12.79 t $^{ha-1}$) and are similar to those of Gabriel et al. [25] for Desirée (17 t $^{ha-1}$).

Tuber Classification

Table 7 shows the analysis of variance for the first, second, third, fourth and fifth categories, they do not present significant differences in interaction, the variety factor in the classification of third and fourth present significant differences.

Table 7: Mean squares of the analysis of variance in potato classification

F.V.	GL	First	Second	Third	Fourth	Fifth
Block	2	1240,75 ns	2284,01 ns	9,53 ns	3,17 ns	2,39 ns
Variety	1	3463,35 ns	757,91 ns	1396,3 *	1226,21 *	32 ns
Main Parcel Error	2	2797,09	935,93	16,01	15,88	5,2
Floral decapitation	1	271,23 ns	62,07 ns	5,24 ns	9,8 ns	9,62 ns
Floral decapitation*Variety	1	1795,53 ns	63,23 ns	3,73 ns	10,56 ns	5,5 ns
Error sub parcela	4	1157,97	66,06	33,17	38,59	13,94
Total	11					
C.V. %		30,58	15,41	14,16	30,53	42,12

Note: F.V: Sources of variation. GL: Degrees of freedom. CM: Medium squares. C.V.: Coefficient of variation. ns: Not significant.

Table 8 shows a higher percentage of the production belonging to the treatments operated with floral decapitation. The treatment (V2-CD) presented a higher yield in terms of weight with a total of 286.5 g $^{plant-1}$, of which 45% belongs to the first category, followed by 23% from the second category. on the other hand, the treatment (V2-SD) obtained a yield of 255.8 g $^{plant-1}$, of which 39% belongs to the first category. Likewise, the treatment (V1-CD) presented a yield equivalent to 245.4 g $^{plant-1}$, of which 59% belongs to the first category, the treatment (V1-SD) obtained a yield of 224.39 g $^{plant-1}$, being the lowest average of the treatments that obtained 49% of the first category, through which we can affirm that floral decapitation has an effect on the proportion in the first category in both varieties (Huaych'a and Desiree).

Table 8: Classification by treatment according to its categories

Category		Treatments			
		V1-SD	V1 CD	V2-SD	V2-CD
First	g pl-1	111,2	145,3	101,8	130,2
	%	49,6	59,2	39,8	45,4
Second	g pl-1	65,25	56,11	67,15	67,21
	%	29,1	22,9	26,2	23,5
Third	g pl-1	31,08	28,6	51,5	51,34
	%	13,9	11,7	20,1	17,9
Fourth	g pl-1	10,2	10,2	28,6	32,3
	%	4,6	4,2	11,2	11,3
Fifth	g pl-1	6,51	5,2	6,79	5,46
	%	2,9	2,1	2,7	1,9
Total	g pl-1	224,39	245,41	255,86	286,52
	%	100	100	100	100

Although the total yield did not vary significantly, the floral decapitation influenced the quality. This agrees with Gebregwergis et al. [26] on quality improvement. The lower flowering in early varieties suggests a greater direction of photoassimilates to the tuber [22].

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Benefit/Cost Ratio (B/A)

Table 9 indicates the net gains on the treatments where the treatment (V1-CD) presented greater expenditure due to the activity of floral decapitation, reaching an amount of Bs. 32,532.5 (thirty-two thousand five hundred thirty-two 05/100 bolivianos), as well as a higher income obtaining an amount of Bs. 64,446 (sixty-four thousand four hundred forty-six 00/100 bolivianos). with a cost benefit ratio of 1.98, that is to say that for every 1 boliviano invested, 0.98 bolivianos can be generated, the treatment (V2-CD) generated greater economic income with an amount of Bs. 72,028 (seventy-two thousand twenty-eight 00/100 bolivianos) with a cost benefit of 2.25 which indicates that for every 1 Bs invested, 1.25 Bs of profit is generated, being the treatments with floral decapitation with the greatest economic benefit.

Table 9: Income through the classification category

Detail	Treatments			
	V1-SD	V1 CD	V2-SD	V2-CD
Revenue	58652	64446	61433	72028
Expenses	31982,5	32532,5	31982,5	31982,5
B/C	1.83	1.98	1.92	2.25

Treatments with floral decapitation generated greater economic benefit due to the higher proportion of first-class tubers. Yanarico [27] reported a B/C of 1.71 for Huaych'a, lower than that obtained in this research.

Conclusions

1. The agronomic behavior showed that the Huaych'a variety surpassed the Desirée in plant height and dry matter (root and foliar), demonstrating a good adaptation to the area and to favorable climatic conditions (rainfall +52%).
2. Floral decapitation had no statistically significant effect on total yield (t/ha). Huaych'a yielded 25 t $^{ha-1}$ without decapitation and 20.3 t/ha with decapitation. Desirée yielded 20.34 t ha-1 with decapitation and 19 t $^{ha-1}$ without.
3. Floral decapitation positively influences the quality (size) of the tuber. Increases were achieved in the proportion of "First" category (59% in Huaych'a and 45% in Desirée for decapitated plants).
4. This cultural practice of floral decapitation improves economic profitability, reaching a benefit-cost ratio of 1.98 for Huaych'a and 2.25 for Desiree.

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