Research Article

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Adaptation of orange (*Citrus sinensis* L. Osbeck) to climatic conditions in Cusco as a response to climate change

Abstract

The Cusco Region, due to its geographical and climatic peculiarities, is prone to extreme climatic events, such as the increase in average temperature, intense rainfall, agronomic and meteorological droughts. Citrus fruits, like oranges, adapt to different climates; however, its growth, flowering phenology and fruit set are affected by changes in temperatures and lack of rain; therefore, these abiotic factors are detrimental to citrus production in usual scenarios and in tropical climates. The objective of the research was to develop an experiment to propose a mechanism of adaptation to climate change of the orange (*Citrus sinensis* L. Osbeck) in climatic conditions and altitude of Cusco, located at 3,302 m.a.s.l. evaluating the phenology and the characteristics of the fruit and production. The experiment constitutes a quantitative investigation, of a descriptive and correlational type, using non-probabilistic sampling called consecutive sampling. Management consisted of pruning, removing thorns and applying soil conditioner; the evaluation of the phenology consisted of the observation of the phases of sprouting, flowering, relative rest, fruiting and harvest period; for the conditions in Cusco, the phenological parameters presented two sprouting flows, first between January-May and second, between August-September; two flowering flows, the first between April-June and the second between September-November; the average production was: 229 fruits/tree/year; fruit diameter of 06,44 cm and a production of 26,44 kg/tree/year. The production of oranges at high altitudes shows an adaptation to climate change, constituting an action of economic interest, contributing to the Peruvian proposal, which is committed to the global response to climate change and considers it a priority to update its national contributions to incorporate the objectives adaptation to climate change.

Keywords: Adaptation, phenology, production, sprouting, water stress

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Introduction

Peru as an Andean country has an enormous diversity of ecosystems, altitudinal floors, climates, soils that show enormous biodiversity and is listed among the 10 megadiverse countries.[1] According to Ashby, cited by Earls,[2] for an adequate management of development and planning, he suggests that one of the mechanisms to manage diversity is with diversity, based on the principle that only diversity is capable of absorbing diversity; Consequently, any measure of adaptation to the climate change scenario under conditions of diversity, as is characteristic for the national territory that has tropical Andean mountain ecosystems, must, in turn, be diverse, considering the scenarios in the environment. Therefore, the adaptation measures to be proposed must refer to the actions to be implemented considering the vulnerabilities they present; without a doubt, this process has to be of a local nature, since the biophysical scenario of each territory is unique and the adaptation measures must also be specific for each territory.

According to the IPCC,[3] climate change, as a global phenomenon, is generated by various factors such as the increase in greenhouse gas emissions, causing the average temperature of the planet to increase; However, the consequences are not limited only to the increase in temperature, but other modifications occur, among the most conspicuous is the increase in extreme weather events that are detrimental to agriculture, in the case of the increase in intensity and frequency of heat waves, episodes of severe drought, or floods resulting from torrential rains. Therefore, in accordance with the IPCC guidelines, one of the adaptation measures to climate change must consist of reducing vulnerability and exposure to current climate variability.

According to MINAM,[4,5] Peru has international commitments, in addition, it has been a promoter and pioneer in the implementation of climate change adaptation mechanisms as part of the national contributions since COP20, held in Lima; therefore, Peru is committed to contributing to the global goal of adaptation to climate change established in Article 7 of the Paris Agreement,[6] which consists of increasing proper adaptation, strengthening resilience and reducing vulnerability to change with a view to contributing to sustainable development and achieving an adequate adaptation response in the context of the objective referring to limiting the increase in temperature mentioned in Article 2 of the same Agreement.

The various effects and impacts that climate change produces on the diversity of existing ecosystems in Peru, demand that the State, at its various levels of government, academia, private economic agents and civil society, implement effective measures to avoid or mitigate the damage in social, economic and environmental aspects and the current and future losses generated by climate change on the populations and their livelihoods, on the territories and on the infrastructure, goods and services of the country.

According to Makuvaro et al.,[7] agricultural activity is sensitive to climate change and the ability of small farmers to develop. Therefore, it is necessary to adapt current practices and develop new strategies for climate resistance in cropping systems;[8] on the other hand, Klocker et al.,[9] point out that climate change poses serious challenges for agriculture and adaptation to its impacts; therefore, producers and their production systems are increasingly vulnerable to its effects. According to Ibarrarán et al.,[10] the IPCC defines vulnerability to climate change as the: “degree of susceptibility or inability of a system to face the adverse effects of climate change and, in particular, climate variability and extreme events and that vulnerability it will depend on the character, magnitude and rate of climate change to which a system is exposed, and on its sensitivity and adaptive capacity”.

According to Ordaz et al.,[11] one of the economic activities most sensitive to the impact of global warming is agriculture, due to the consequences of high temperatures and the increase in atmospheric CO_2, the main impacts are thermal and water stress due to the increased demand for water for irrigation, greater presence of pests and diseases. Therefore, the result is decreased productivity of many crops. On the other hand, the BID[12] mentions that the impact of climate change on agriculture can be serious, since it would affect the production of most crops; in this context, and taking into account that subsistence agriculture predominates in our country, the decrease in productivity can cause imbalances in the life system of producers.

It is pertinent to consider what was indicated by MINAM[13] that the Peruvian Andes gather 71% of the world’s tropical glaciers (2 699 glaciers in total), the reduction of glaciers is one of the main evidence of climate change, in the in the last 30 years, Peru has lost 42% of the glacier surface. Likewise, Peru is a country with populations and ecosystems highly prone to the adverse consequences of climate change; this high vulnerability is due to various factors such as poverty, poor institutional articulation, and a productive base affected by climatic factors.

In the case of the Cusco Region, due to its geographical, physical and climatic characteristics, it is a territory prone to the presence of extreme climatic events, which is evidenced in the increase in average temperature, more intense rainfall, agronomic and meteorological droughts. The increase in average temperature is a clear example that the Cusco Region is affected by climate change and this influences agricultural production.[14]

Regarding the previously analyzed, there are different authors who propose different proposals; this is the case of Islam and Nursey-Bray;[15] Thornton et al.,[16] who argue that some strategies implemented to reorient agricultural development under the reality of climate change are climate-smart agriculture, conservation agriculture, varieties of improved species, among many others; aspects that are considered in the present study that aims to show the adaptation of the orange (*Citrus sinensis*) to the climatic conditions in Cusco, located at 3 340 meters above sea level.

According to Pereira et al.,[17] citrus vegetatively adapt well to different climates; however, its growth, flowering and fruiting phenology are limited by changes in temperatures and lack of rain; the increase in temperature due to climate change promotes greater evapotranspiration and a drought causes greater irrigation, considering that it is a crop that has a high demand for irrigation. On the other hand, Zandalinas et al.,[18] show that among the most harmful abiotic factors for citrus production are extreme temperature fluctuations, drought, floods or the salinity of irrigation water and soil, these factors are consequences of climate change.

Various authors have reported the effects of climate change on the cultivation of citrus; thus, Pereira et al.,[17], Zandalinas et al.,[19], Zandalinas et al.,[18], point out that the size of the fruits is smaller than normal; instead, the vegetative development of the plant is not affected by high temperatures. These researchers conclude that citrus fruits show various acclimatization responses to high temperatures. On the other hand, when episodes of extreme cold or frost are observed, they generate production losses, especially when they occur in the flowering period.

In the Cusco region, citrus crops are found in the regional Amazon, especially in the province of La Convención, however, due to changes in temperature and low rainfall, yields have decreased, affecting the economy of producers; therefore, the manifestations of climate change lead to climatic difficulties in the citrus sector and the main negative effect is the low productivity of the cultivars and the little dedication on the part of the producers. This phenomenon of changes in the magnitudes and meteorological distributions of the classic climatic variables that include temperature, precipitation, humidity, wind speed and evaporation, cause changes in the physiological behavior of plants and in turn impact agricultural productivity at scale. global.[20–22]

As mentioned above and according to Romero et al.,[23] a phenomenon associated with climate change, is the episode of severe drought, since the lack of available water for citrus negatively affects development, as well as production processes, which leads to lower production and lower quality; since, the water deficit during the period of formation and growth of the fruit causes a decrease in the size and quality of the fruit and increases the losses by abscission.

According to information from the General Directorate of Agricultural Development and Agro ecology of the Ministry of Agriculture and Irrigation,[24] Peru produced a total of 553 000 tons of orange in 2020. Among the prominent departments in the cultivation of Valencia oranges are Junín, which ranks first with the production of 54% of the national total, followed by San Martín (14%), Lima (7%), Puno (5%) and Cusco (4%).

Lines above it was argued that climate variability has direct incidences on agricultural productivity, in this regard, the Report of the Intergovernmental Group of Experts on Climate Change,[25] defines it as the variations of the average state and other statistical data of the weather on broader spatial and temporal scales than point weather events. Variability can be due to natural internal processes in the climate system, known as internal variability, or to processes influenced by natural or anthropogenic external forces, known as external variability. Therefore, climate variability is interpreted as intrinsic to climate and includes variations in the mean state of climate at all temporal and spatial scales, including extreme weather events that occur with a certain periodicity such as prolonged droughts, devastating rain events, extraordinarily hot years, floods and conditions resulting from periodic El Niño and La Niña events, among others.[26,27]

Montealegre[28] argues that climate variations occur at all spatial and temporal scales, and have important impacts on human activities. Similarly, Silva,[29] indicates that, on the time scale, the most significant fluctuations are daily, intra-seasonal, seasonal or annual, inter-annual and inter-decadal, each presenting various associated phenomena.

From what has been analyzed so far, it can be inferred that environmental conditions, mainly related to climate, are in continuous change and plant species, in some cases, adapt, evidencing resilience and, in other cases, modify their phenology and production. Nevertheless, the resilience shown, today humanity faces a change in the climate model in which the crops of a given region, as is the case of Cusco, are affected by changing the optimal conditions in a given scenario. This is the case of citrus cultivation, which suffers from physiological problems that lead to reduced production and quality of crops due to climate change and the concurrence of environmental stress factors such as high temperatures, drought, floods or the salinization and impoverishment of soils.

Scientific researches such as Balfagón et al.[30], Sengupta,[31], Pandey et al.,[32] point out that, despite advances in the knowledge of citrus tolerance mechanisms to stress conditions, there is still a need to evaluate other abiotic and biotic factors that constitute threats to citrus cultivation and, they conclude that stress situations have been evaluated in other crops of agronomic interest, still being a gap regarding citrus production. These authors state that agriculture has a particularity with respect to other human activities that are responsible for the generation of high CO_2 emissions and other greenhouse gases, due to the capacity of citrus fruits to capture these gases from the atmosphere as a biomass and specify that citrus crops are effective in this process, since they have carbon fixation rates that oscillate between five and 10 tons of carbon per hectare and year. Likewise, studies carried out by Iglesias and Tejedo (The role of citriculture in a context of climate change, 2017, p. 50) obtain this same net fixation rate.[33]

On the other hand, Martínez et al.,[34] specify that citrus production comes to govern the community dynamics of peasants, whose performance has been affected by climate change. Added to these socio-economic scenarios is the constant increase in greenhouse gas emissions generated by human activities, which are responsible for the increase in atmospheric temperatures recorded in recent decades.[35]

According to MINAG,[36] adaptation to climate change in tropical Andean mountain ecosystems is, mainly, an issue of adaptation of appropriate technologies coming largely from local cultures, that is, it is more a sociocultural issue than a scientific one. MINAG maintains that the changes observed by the effects of climate change in Peruvian agriculture are: Impact on the quality and yield of crops, plantations and livestock, loss of biodiversity and increase in pests, physiological effects on crops (pastures, forests and livestock in quantity and quality), changes in soil and water resources (quantity and quality), increase in pests and diseases, decrease in flowering and fruiting of crops due to thermal anomalies, recurring climatic events (frost, excessive or untimely rain, drought, wind, hail or snow, due to their frequency, magnitude, intensity or simply because they are untimely, cause damage to crops and economic losses to farmers), impacts on the availability of water for crop irrigation due to droughts, impact of change climate in livestock in high Andean areas.

Considering the focus of the effects of climate change on crops grown in the Cusco region that have effects on low production and productivity; it is proposed that the orange (*Citrus sinensis* L. Osbeck) can be successfully cultivated in Cusco as a proposal for adaptation to climate change, particularly to the increase in temperature in habitually cultivated areas.

Objectives

General objective. Develop an experiment to propose an adaptation mechanism to climate change of the orange (*Citrus sinensis* L. Osbeck) in Cusco.

Specific objectives:

a. Evaluate the phenology of the orange in conditions of Cusco at 3 302 m.a.s.l.

b. Evaluate the characteristics of the fruit and the production of the orange tree.

Field of study

The city of Cusco is located in the western part of the valley of the same name and in the central part with respect to the department and towards the south east of the national territory, the city is the capital of the department that is at an altitude of 3 399 m.a.s.l. and is located between 13º30’45’’ south latitude and 71º58’33’’ west longitude.

In Cusco, there are two climatic seasons: the rainy season, from December to March with an average temperature of 12°C, and the dry season, from April to October with an average temperature of 9°C. The average minimum temperature is -2,6°C and the maximum recorded is 22,8°C. The adaptation test was carried out in the COVIDUC urbanization, located at 3 302 m.a.s.l. in the district of San Sebastián, during the last 12 years, since 2011; the basic climatic characteristics are indicated in the following Figures 1–4 and Table 1.

The driest month is July, with 15 mm of precipitation; instead, January is the month with the highest precipitation, with an average of 241 mm (Figure 5).

According to SENAMHI, the lowest temperatures in Cusco are recorded between the months of May and August (Table 2).[37,38]

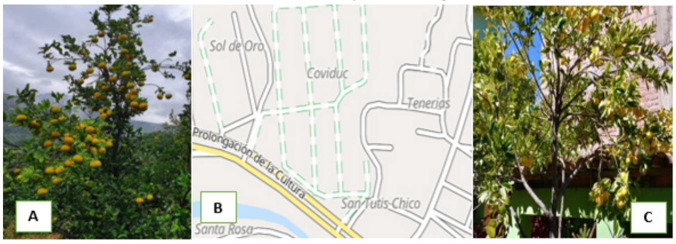

Figure 1 Location of the study plot and two specimens of the orange tree.

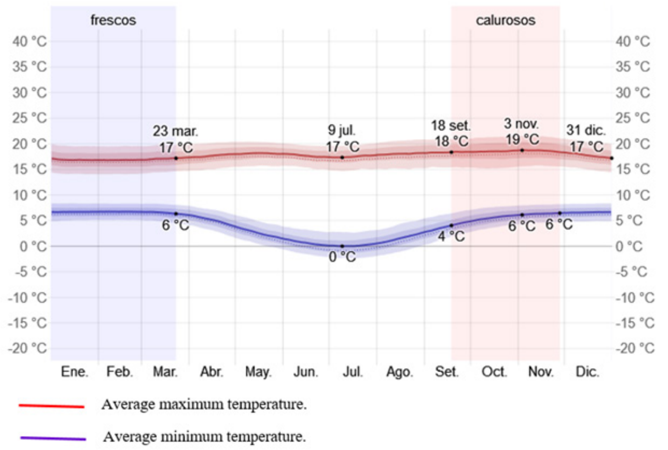

Figure 2 Average maximum and minimum temperature in Cusco.

Source: Weather Spark, 2023.

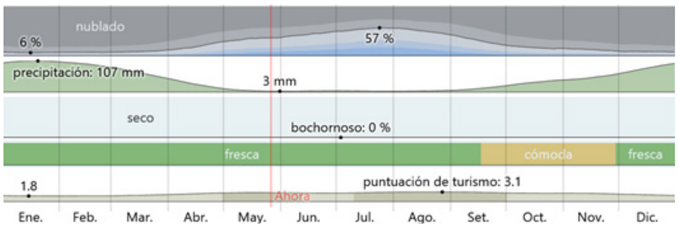

Figure 3 Precipitation and relative humidity in Cusco.

Source: Weather Spark, 2023.

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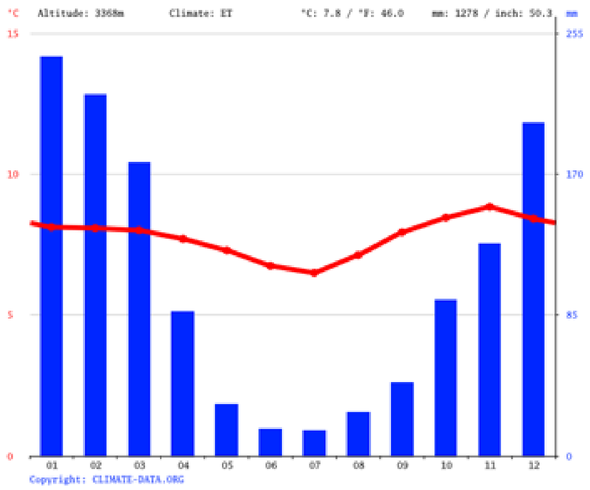

Figure 4 Climogram Cusco.

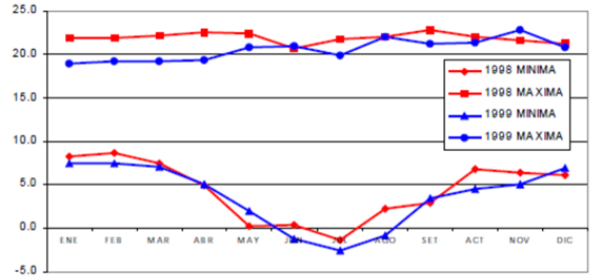

Figure 5 Average temperatures recorded for Cusco.

Source: SENAMHI, K'ayra Weather Station, Cusco. 2012.

The measurement of the climatic data presented by SENAMHI in an important period of 23 years, indicates that the lowest temperatures are registered from April to September and the maximum temperatures between August and December; the driest months show a period from May to August, there are intermediate months such as April, September, October and November, the rest of the year is rainy.

Table 1 Historical weather data Cusco

	January	February	March	April	May	Jun	July	August	September	October	November	December
Medium temperature (°C)	8.1	8.1	8	7.7	7.3	6.7	6.5	7.1	7.9	8.5	8.8	8.4
Minimum temperature (°C)	5.1	5.1	4.9	4.2	3.3	2.3	1.8	2.3	3.6	4.6	5.2	5.3
Maximum temperature (°C)	12.4	12.3	12.3	12.3	12.2	12.1	12.1	13	13.5	13.7	13.7	12.9
Precipitation (mm)	241	218	177	87	31	16	15	26	44	94	128	201
Humidity (%)	80%	81%	80%	77%	69%	62%	59%	58%	62%	69%	71%	78%
Rainy days (days)	21	19	20	15	7	3	3	6	11	16	17	20
Hours of sun (hours)	5.1	4.7	5.2	5.7	6.6	7.4	7.6	7.9	7.5	6.7	6.7	5.7

Data: 1991-2021: Mim. temperature. (°C), max. temperature. (°C), Precipitation (mm), Humidity, rainy days. Data: 1999 - 2019: Hours of sun.

Source: Climate-data.org. 2022.

Table 2 Average monthly maximum, minimum and mean temperatures (23-year averages: 1993-2018)

MES	T (C)	Tonin (2C)	Tined (2C)	Precipitacion (mm)
Enero	19,1	7,0	13,0	138,8
Febrero	19,1	6,9	13,1	116,1
Marto	19,4	6,5	12,9	99,6
Abril	19,9	3,9	11,4	47,3
Mayo	20,2	0,8	10,1	7,0
Junio	19,1	-1,7	9,1	2,7
Julio	19 ,7	-2,0	85	4,4
Agosto	20,2	0,1	10,1	7,2
Setiembre	20,1	3,0	11,8	21,7
Octubre	21,0	5,0	12,9	50,4
Noviembre	21,2	6,0	12,1	70,3
Diciembre	20,0	6,5	12,0	105,7
Promedio anual	19,9	3,5	11,4	671.2 Total Anual

Source: SENAMHI, K'ayra Weather Station, Cusco. 2020.

Material and methods

Due to the nature of the problem under study, as well as the proposed objectives and, considering the proposal of Hernández-Sampieri et al.,[39] the research developed corresponds to a quantitative investigation, because measurements of the fruits (size, circumference, diameter, weight) and production were carried out; therefore, the present work is of a quantitative approach, of a descriptive and correlational type. Likewise, non-probabilistic sampling called consecutive sampling was used. In this type of sampling, an initial sample was first chosen, investigated, and after obtaining the results of the initial sample, another sample was studied. In other words, this type of sampling does not focus on a single sample, but studies different samples from the same statistical population and, in the end, draws conclusions with the information obtained from all the groups.[40] In addition, cultural management was used before the effect of climate change, substantially referred to pruning.

Results

Management of the orange tree: The management of the orange tree is substantially referred to pruning. In the experiment carried out in Cusco, pruning began when the trees were four years old and before they began the flowering process. The first pruning had the purpose of removing excess branches and allowing sunlight to enter evenly throughout the crown; in such a way that the photosynthesis process is adequately developed by the plant; on the other hand, another reason for pruning allows adequate aeration of the tree.

Subsequently, after the first production, this occurred in the fifth year, pruning was carried out annually, after the harvest, using tools such as pruning shears and a manual saw for the thickest branches that exceed five centimeters in thickness; in this pruning it was possible to extract approximately 10% of the branches. Pruning guarantees that the nutrients are distributed evenly throughout all the branches, making it possible for the fruits to be of good quality and good size. Pruning ensures greater vigor of the branches, greater aeration, better flowering, faster access to pollinators and good size and quality fruits.

The management of the orange tree also includes removing the thorns on the main trunk and on the thicker branches, using manual pruning shears, in such a way that it facilitates access to the tree for harvesting without damaging the collector. Finally, the management also included the application of a soil conditioner that allows to improve the existing nutrients; in the case of the test in Cusco, the dung of cattle from the municipal slaughterhouse located in K'ayra mixed with compost was used, and the concentration used was two parts of guano and two parts of compost, for each tree an amount was applied of 2 kg/plant/year (Figure 6).

Figure 6 Pruning that allows more entry of sunlight for photosynthesis, greater aeration; the removal of thorns allows an easy harvest.

Phenology of the orange tree: From the evaluations carried out, the orange tree shows growth flows or rhythms, which are presented in variable number and intensity, with interspersed periods of relative rest; this implies that the occurrence of phenological phases in the orange tree is influenced by climatic variables. For the evaluation of the phenology regarding the phases of sprouting, flowering, relative rest, fruiting and harvest period, weekly observations were made, considering the following variables: flowering intensity and sprouting intensity. The beginning of sprouting and flowering was considered in all cases from the presence of the corresponding structures in 5 % of the tree surface. The duration of the flowering and sprouting flow (total days) was determined by the difference between the final date where the emission of flowers or buds ceases and the initial date where their presence is detected.

Sprouting: During the evaluated period, two sprouting flows occurred with variable duration and intensity. The first occurred between January and May, with a duration of more than 150 days, after a rest period of approximately three months between October and December; the second period occurred from August to September, with less intensity and shorter duration (61 days), after a two-month rest (June-July).

In the first sprouting, the reproductive shoots predominated, that is to say, that, in the axils of the leaves, the flowers are formed and later develop the fruits. The second sprouting, like the first one, was also characterized by the fact that the buds come into activity in several waves, but in this period the waves appear more spaced from each other and often between two waves the vegetative activity, due to its massiveness, drops to a weak level; this was observed between 2016 and 2022. In the seven years examined, the end of the second sprouting generally takes place at the end of September.

Bloom: Flowering occurred in two flows, the first from April to June and the second from September to November with differences in duration and intensity and correspond to dry periods in Cusco. As previously stated, the reproductive shoots are observed during the first sprouting; therefore, flowering coincides in time with this sprouting (Table 3) (Table 4) (Figure 7).

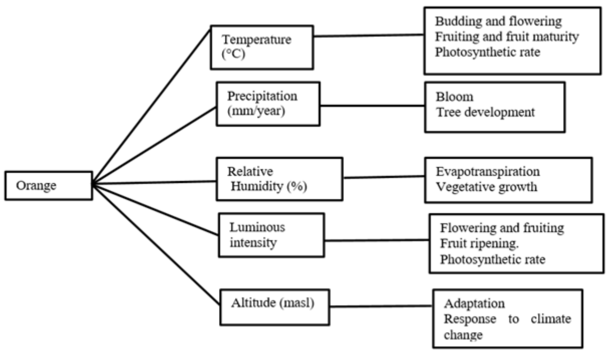

Figure 7 Eco physiological factors of orange cultivation.

Source: Own elaboration based on field observations.

Production: From the first harvest (2016) and during the time of the adaptation experiment to conditions in Cusco, an average of 225 oranges per tree was obtained; which implies approximately an average of 27 kg/tree (Table 5).

Table 3 Flowering start date of *Citrus sinensis* in Cusco

Year	Start (weak level)	Start (high level)	Flowering duration (days)
2016	18-Apr	25-May	63
2017	21-Mar	2-May	51
2018	28-Mar	22-May	54
2019	2-Apr	3-Jun	58
2020	17-Mar	15-May	55
2021	26-Mar	28-Apr	63
2022	5-Apr	27-May	58
2023	3-Mar	24-Apr	56

Table 4 phenology of *Citrus sinensis*

Flower bud swelling	Flower bud opening	Bloom	Fructification	Maturation
The buds begin to swell. The opening of the buds begins.	Due to the swelling and increase in size, the leaflets that cover the buttons separate.	The buds swell and the scales become visible.	The fruits reach a size of approximately two centimeters.	The fruits reach the characteristic size and color.
Leaf primordia are visible.		The buds burst, the scales separate and the floral primordia become visible.		The fruit turns from green to yellow-orange.
		Flower buds fully open.		
		The petals grow, the sepals envelop half of the corolla; the sepals open, the ends of the petals become visible.		

Table 5 Production of oranges in Cusco

Year	Average number of fruits/tree	Average diameter of the fruits (cm)	Average weight (Kg/tree)
2016	65	3.2	5.2
2017	128	4.3	12.16
2018	185	6.1	20.35
2019	253	6.8	28.34
2020	266	7.3	31.92
2021	294	7.8	36.75
2022	315	7.6	37.8
2023	325	8.4	39
Average	229	6.44	26.44

From the preceding table it can be inferred that orange production increases year by year to the extent that management is adequate and that the plant and physiological processes adapt to the local climate (Figure 8).

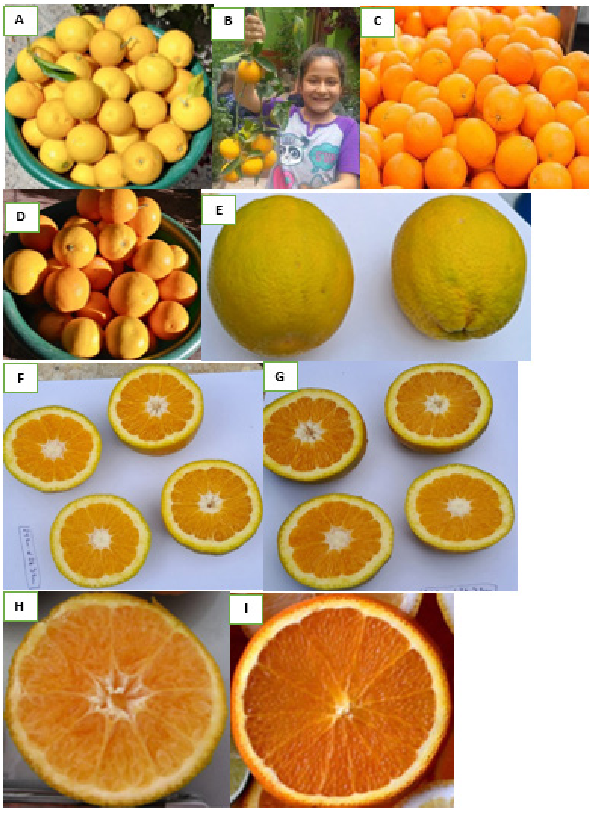

Figure 8 Characteristics of the orange fruit in the experiment.

Discussion

The observations in the cultivation of the orange tree at the conditions of Cusco, evidenced flows or growth rhythms, which are presented in variable number and intensity, with interspersed periods of relative rest; this shows that it is influenced by climatic variables; aspects that coincide with the studies by Pérez et al.[41] and the conclusions of Fournier.[42]

The orange is a plant capable of saving water and overcoming periods of drought, this characteristic is related to physiological and anatomical factors such as the depth of the root system.[43,44] From the studies at high altitude conditions in Cusco, it can be inferred that water stress is the most relevant environmental factor for the induction of flowering, an aspect that has also been analyzed by Aubert and Lossois[45], Chaikiattiyos et al.[46]; Soulez and Fouque.[47] Under water deficit conditions, the vegetative buds are encouraged to flower, a fact that was also studied by Davies and Albrigo.[43]

Albrigo,[48] points out that both cold and drought can induce flowering. In Cusco, the greatest flowering observed begins in the low temperature season (June and July); this observation coincides with that of Orduz[49] who points out that low temperatures and drought induce the flowering of citrus fruits. Also coinciding with Mendel's[50] studies, which indicate that they seem to be regulated by physiological and climatic factors, especially temperature and water regime.

Regarding sprouting flows, which, in the case of Cusco, occurs between January and May, before the cold season, a result that coincides with the phenological observations made by Pérez et al.[41] and Sosa,[51] who showed that the most active sprouting flows occur in the first half of the year.

It should be noted that the sprouting period during 2016 (first flowering and first harvest) was longer, coinciding with the lowest rainfall records, an observation that differs from the findings of

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Aular,[52] who in his studies concludes that the sprouting flows occurred in the period of highest temperature and greatest thermal amplitude; on the other hand, in Cusco, the greatest sprouting flow occurs after the rainy season.

According to Mendel,[50] the rest periods between growth flows seem to be regulated by physiological and climatic factors, especially temperature and water regime. In the research carried out in Cusco, the duration of the first rest period was 90 days, from which sprouting begins followed by flowering.

The production of oranges under Cusco conditions was 39 kg/tree/year, this productivity being quite acceptable for an altitude higher than 3,300 m.a.s.l. instead, Vincent et al.,[53] points out that under adequate conditions production can reach more than 45 kg/tree/year; likewise, authors such as Orduz[54], Mendel[50], Sosa[51] and Aular,[52] maintain that the production of citrus fruits such as oranges can reach crops in the equatorial tropics, which exceed 58 kg/tree/year, after the eighth year.

Conclusion

For the study area in Cusco, located at 3,302 meters above sea level. The phenological parameters studied presented two flows, that of sprouting, the first between January to May and the second, between August and September; on the other hand, the flowering one, the first between April and June and the second between September and November.

The research corroborates the effect of water stress on the floral induction of orange, highlighting that, to the extent that the duration of the dry period was greater, the expression of the phase was brought forward and the duration and intensity of the floral flow increased.

Orange production at altitude conditions shows an adaptation to climate change and may constitute an action of economic interest, since production in Cusco has been increasing from 5kg/tree/year in the first year of harvest to 39 kg/tree/year, in the eighth harvest, contributing to the Peru proposal, since the country is committed to the global response to climate change and considers it a priority that updating its national contributions incorporate, through actions, both the objectives adaptation to climate change as well as with regard to the mitigation of greenhouse gases.

Suggestions

The authorities of the Ministry of Agriculture and Irrigation, must consider in the planning of actions, the increase in maximum temperatures, the substantial decrease in minimum temperatures and the decrease in precipitation in the south of the country, generating agronomic and meteorological drought for taking actions to mitigate its effects on agriculture.

The Ministry of the Environment (MINAM) and especially the National Meteorology and Hydrology Service of Peru (SENAMHI), implement a greater number of meteorological stations in the Cusco region, which allow determining the variability of climatic factors and intensify the dissemination of reports in relation to climate variability with scope to producers in the rural sector. These two institutions play a vital role in the risk management system and national development planning.

The Cusco Regional Government and local governments must promote and implement in the rural sector, particularly in agricultural areas, adequate adaptation measures; in this context, communities must know the vulnerability factors to which they are exposed; that is, to identify their weaknesses before the occurrence of different events of climatic origin that could occur in their territories; the training granted by these levels of government should be promoted so that farmers are able to know how to administer and manage the risks of climatic origin that exist in their environment. That is, the communities must know the relationship between the occurrence of the different climatic phenomena and the main hydro meteorological parameters, which allow them to identify possible scenario models, which allow decisions to be made leading to the implementation of measures to mitigate said effects.

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Conflicts of interest

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