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Technological Challenge of Agriculture in Climate Change and the Advancement of Desertification in Developing Countries

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Abstract

Climate change has a strong impact on agricultural production, which accentuates in developing countries, due to the lack of technology. From the perspective of food production, we must answer how to maintain agriculture in developing countries strongly affected by climate change, population growth, poverty and lack of technological capacity. The present mini review aims to explore the options that these communities have, which are fundamentally based on the development of technologies accessible to their reality, as the use of tolerant species such as quinoa and aloe or irrigation systems that improve water use efficiency. This article analyzes mechanisms and strategies of the plants to improve the efficiency in the use of water and the necessary requirements to establish a controlled deficit irrigation system.

Keywords: Food; Climate change; Water use efficiency; Deficit drip irrigation; Developing countries

Introduction

Traditional agriculture faces the uncertain conditions of climate change (CC) such as the increase in temperature by at least 1.7 °C, the increase of the wind force, rainfall regimes changes and natural production factors decay as soils, water and diversity [1-6]. This condition imposes a major challenge on agriculture: Producing food for more than 9000 million inhabitants by 2050 [7], this greater demand for food must be produced with less water and deteriorated soils. One scenario is that, the deterioration of resources leads to the abandonment of certain items and to the urgent search for alternative crops adapted to the new climatic reality, otherwise there is a risk of the definitive abandonment of agriculture in various areas affected by the irreversible damage in edaphoclimatic conditions [8]. There is uncertainty about the ability of improved traditional crops to adapt to this climate change especially because of their high homogeneity and dependence on agronomic factors, for instance availability and soil fertility. Several models indicate that developing countries will be the most affected, for example, the decrease in wheat yields is estimated between 20% and 34% [9]. Therefore, a reasonable doubt is: How can developing countries overcome this situation? The objective of this article is to explore the technological alternatives available to developing countries to maintain their agricultural production and thus the food security of their population.

Discussion

Numerous strategies are possible to apply in this scenario, from a biotechnological management, through the selection or modification of genes to create new varieties tolerant of drought or temperature increase, by means of Precision Farming. Perez et al. [7] propose an eco-intensive agriculture based on sustainable management of high technology (computers, remote sensors, drones and precision agriculture). However, developing countries do not possess sufficient resources for science and technology development. Therefore, the alternatives should focus on tools that they may be able to develop and apply. For instance, cultivating species tolerant to water deficit, the use of marginal waters or irrigation management with the implementation of technologies that allow a greater efficiency or through water restriction methods, known as deficit drip irrigation.

Use of tolerant species

The greatest tolerance to water deficit is observable in local species and cultivars, in selections that have been made by farmers for centuries. Quinoa is one of them, it presents various strategies to overcome stress conditions caused by a decrease in soil water potential, which can be morpho-physiological [10,11] and biochemical [12]. Quinoa possesses mechanisms for the management of plant transpiration throughout modifying stomatal density and / or stomatal opening [11,13,14]. A decrease in stomatal conductance not only reduces water loss but also affects CO_2 assimilation. This situation contributes to a decrease in the efficiency of water use, since less biomass will be produced per unit of water. When comparing two contrasting Chilean varieties for the decrease of water potentials, one tolerant obtained from the altiplano (Amarilla) and another sensitive from the southern zone (Hueque) [15]. Both selections presented a decrease in stomatal conductance. This was significantly greater in the Hueque selection (sensitive variety), in which the stomatal conductance (gs) fell from 471 to 201 mmol H_2O $m^{-2}s^{-1}$, that is, a contraction equivalent to 57.3% of the value. Whereas in Amarilla (tolerant variety) there was only a decrease of 17.4%. This phenomenon was proportional to the loss of the assimilation rate, with 37.7% for Amarilla and 65.1% for Hueque [16]. The previously mentioned experience demonstrates that there are varieties which maintain productivity despite the water deficit, turning them into applicable alternatives for the production of food or other raw materials under these conditions. In CAM plants, such as Aloe, it is possible to observe other strategies for instance succulence and slowdown in the delivery of water stored in their leaves, which is achieved by the synthesis of sugars, especially neofructans and insulins, which generate an intricate network of fibers [17,18]. These morphological modifications in the plant reduce water loss by improving the water use efficiency WUE) under conditions of water stress [16,19] and maintain their photosynthetic rates despite being more than 220 days in water deficit [20].

Controlled drip irrigation

The deficit drip irrigation (DDI) has been defined as a strategy of optimization of irrigation during the most sensitive states of a crop to the requirements of irrigation, mainly the periods of establishment, flowering and filling of fruits. Outside these periods, irrigation may be restricted. Doorenbos and Kassam [21], introduce an empirical performance response factor (Ky) to integrate the complex relationships between water production and consumption for crop production, which limits its applicability to make accurate estimations of the responses of the crop water performance due to other factors such as nutrients, different cultivated varieties, stress tolerance, among others, also impact on the performance response, it means that adjustments must be made for the specific conditions of each site. There are several studies that demonstrate the benefits of this method. In paprika [22], in quinoa [23-26], in aloe [27,17] among other crops. For the application of this method, models such as: Aqua Pro have been used to simulate the behavior of crops subjected to various environmental conditions [28] or the ORDI (Optimized Regulated Deficit Irrigation) [29] model, based on non-linear optimization, which aims to determine the mentioned combination of stress levels for arable crops.

In the case of quinoa, an application scheme for DDI is proposed, which allows starting from 13 pairs of leaves to subject the plants to a water deficit for 50 days until the emission of the flora button [30]. Subsequently, it must be maintained with supplementary irrigation until milky grain for 65 days. Irrigation is suspended from pasty grains. This proposed model should be validated for other varieties of quinoa and regions at the same time, it should be improved considering post-antecedent drought [31]. The reported values of seed yield per unit of water consumed (USA) ranged from 0.3 to 0.6kg/m3, in which the low fertility of the soil [32] and the stress tolerance of the species can have a lot of influence. In the case of Aloe, the deficit risks can be more extreme, due to their great capacity to tolerate the water deficit, in this regard Delatorre-Castillo [20] determined that aloe plants subjected to 222 days water deficit lose only 15% of the foliar volume. On the other hand, Oyarce, [19], finds similar results, evidencing a decrease in water content in Aloe vera leaves as the restriction period progresses, but an increase in the US with values 14.7kg of dry matter per m3 of water in plants with 25% irrigation and 12kg of dry matter per m3 of water in treatments with 100% irrigation, which allows a 75% saving of irrigation water.

Conclusion

Developing countries can improve existing research on the efficient use of water through the use of water-tolerant species, using existing information. The use of local tolerant species or cultivars represent an important alternative, on which scientists should work, since the improved varieties have high yields, but also high-water requirements and agronomic factors such as soil and fertility. It is relevant to return to the traditional varieties selected for centuries by farmers adapted to their own local realities. The greater food security of developed countries is achieved based on the use of technology that often exceeds CO_2 emissions and the water footprint, with developing countries being the most affected.

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Conflict of Interest

The Author has not declared any conflict of interest.

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