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Bibliographic review

Chickpea cultivation, a possible solution to climate change

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ABSTRACT

The cultivation of the chickpea has its origin in the Southwest of Turkey; from there it spread very soon to the rest of the continents. More than 90 % of world production is concentrated in Asia as an excellent food option for growing rural populations. In Cuba, the chickpea production until the 90's were not many and as such, there are no records in the national statistics of their production. This species tolerates very well the hydric stress and besides for being leguminous, it is able to live in a symbiotic relation with bacteria of the genus *Rhizobium* sp, and atmospheric nitrogen fixing microorganisms that incorporate it to the plant and soil, allowing culture it with low inputs. Due to this, the chickpea, like the rest of the legumes, contribute to reduce the greenhouse effect and combat climate change, since they improve the absorption of carbon from the atmosphere through photosynthesis, fix nitrogen in the soil. The chickpea seed grows with the moisture accumulated in the soil from previously fallen rain and does not need much work. There are three chickpea types according to consumer preferences; in addition, the management of varietal diversity within this crop is important to achieve a wide extension and adaptation. In Cuba a form of introduction and chickpea dissemination is through the diversity fairs, which has increased access and availability of the same to small farmers, in addition to training and marketing spaces in the new drought weather conditions that we are living. This paper presents a review of the main chickpea cultivation tasks to be as a solution to the climate change effects on agriculture used.

Key words: climate, climate change, legumes

INTRODUCTION

Origin, economic importance and geographical distribution

Chickpea is a crop of which around 10 million hectares are grown in the world approximately 7 million are cultivated in India, followed by Pakistan and Turkey. In Europe, the main producers are Spain, Italy and Portugal. In Latin America most of the crop is produced in Mexico and Argentina [(1)].

Chickpea is on the list of the most cultivated legumes worldwide, after soybeans (*Glycine max*), broad beans (*Vicia faba*), beans (*Phaseolus vulgaris*) and peas (*Pisum sativum*). More than 90 % of world production is concentrated in Asia. FAO statistics report 45 countries that produce chickpea on all continents, thus having great economic importance to guarantee the nutritional requirements of the populations in these countries [(2)].

The origin of chickpea cultivation is located in the Southwest of Turkey. From there it soon spread to Europe (especially the Mediterranean region), later to Africa (mainly Ethiopia), America (especially Mexico, Argentina and Chile) and Australia. Currently, the existence of 40 chickpea producing species has been verified that respond to the different edaphoclimatic conditions of these countries, as well as the nutritional and organoleptic properties of their consumers [(1)]. Chickpea has gone from being a marginal crop to an export business for countries such as Argentina, due to the wide acceptance it has in the population for its flavor, texture and its health properties [(3)].

The chickpea crop productions in Cuba until the 90s had not been important and consequently there are no records in the national or world statistics of its production. Due to this, to satisfy internal consumption it has been necessary to carry out imports, which were increasing between 1992 and 2001, with an annual average level of imports of 807.7 tons at an average cost of 1000 USD per ton, according to the harmonized code for dried chickpea, according to Cuba, National Statistics Office 2002. Imports come mostly from Mexico, Canada and Spain [(4)].

The increase in the chickpea cultivation in the country has been influenced by several factors, among others: the presence of varieties that respond to the country conditions, the crop growing knowledge and the farmer confidence in the possibility of its production. In addition, the climatic conditions have influenced, mainly, in the eastern provinces, which has motivated the search for new crops that respond to the stress conditions of drought and low inputs [(4)]. On the other hand, the price that the grain reaches in the national market due to its preference, its high cost in the foreign exchange market and its low production costs, in relation to other species of grains, makes it an attractive crop for its production as has been in Villa Clara province reported [(5)].

Crop description

The chickpea (*Cicer arietinum*) is a species of legume that belongs to the Fabaceae family, being a diploid annual plant, with a chromosome number of 2n=16. The reproductive system is fundamentally autogamy, the level of allogamy being around 1 %. The plant is herbaceous and can reach a height of 60 cm. It is by having deep roots with branched and hairy stems, and with numerous excretory glands characterized. The main stem is rounded and the branches are quadrangular and ribbed. The leaves can be paripinnate or odd-pinnate. The leaflets have a serrated edge. The flowers are axillary and solitary, usually white or purple in color and the fruits are bivalve pods with one or two seeds inside that are wrinkled. The plant has two large cotyledons. On a morphological level, the most important characters of chickpeas are presence of pseudo-imparipinnate leaves, serrated and glandular leaflets, inflated and hairy legumes and spherical or rounded seeds with a characteristic mucro (1).

This species, being legume, is capable of living in a symbiotic relationship with bacteria of the *Rhizobium* sp genus, atmospheric nitrogen-fixing microorganisms that incorporate it into the plant and the soil. However, of all the cultivated legume species, the chickpea is the one that contributes the least nitrogen to the soil. The fact that this species has the lowest nitrogen-fixing efficiency adds one more phenomenon: chickpea is very susceptible to a disease that occurs in winter called Rabies (*Dyvdimella rabiei*) (6).

However, chickpea cultivation has a property that makes it more interesting in production schemes and it is resistance to water stress and the low inputs it requires, making it an excellent option for grain production in drought conditions, one of the effects more frequent caused by climate change in rural areas (7).

Climate change and chickpea cultivation

Climate change is a phenomenon that is currently affecting the production of crops that support food security, including legumes. Chickpea is one of the crops that most resists drought or water stress, in addition to being obtained with low external inputs, because it is a nitrogen-fixing legume in the plant and soil. This quality is a practical and economical solution to include in the protocols of local rural development of local and national agro-productive systems (7).

Legumes, and within these the chickpea, produce benefits in agroecosystems in a global context of climate change, since: i) they improve soil conditions due to the nitrogen biological fixation (up to 300 kg per hectare cultivated as green manure) and; consequently its fertility; ii) improves the nutrition of the crops that are sown next to them; iii) optimizes performance in subsequent rotations; iv) it enhances the release of hydrogen gas in the soil (up to 5,000 liters ha day), which is positive for its enrichment (8); v) it contributes to maintaining and increasing the soil microbial biomass, in charge of improving its structure and making nutrients more accessible, and vi) it enhances the crop health by increasing resistance to diseases [(9)].

Legumes have natural symbiosis with bacteria, such as *Rhizobium* and *Bradyrhizobium*, which are capable of trapping nitrogen in the nitrous oxide form (N_2O) from the atmosphere and fixing them in legume roots as ammonia, a substance that can be used by the plant metabolism during the growth and development stages of the grain [(9)]. This property allows them to grow with lower requirements for nitrogen fertilizers, a source of greenhouse gas emissions in agriculture. It also improves the absorption of carbon from the atmosphere through photosynthesis, in which the plant and the productive land itself capture part of the carbon dioxide (CO_2) naturally. Both aspects contribute to reducing the greenhouse effect and combating climate change and greenhouse gas emissions from Agriculture [(10)].

This crop is inexpensive for farmers and has a long conservation time and that allows them to be used in intense drought times. On the other hand, it produces zero waste, since the grains are consumed by humans, the pods are used as animal feed and plant remains contribute to soil fertilization once composted, allowing its full use during the cycling of nutrients [(10)].

In general, when legumes are in rotation with other crops, they improve the soils since these have a greater potential for absorbing carbon than monocultures, and farmers have an increase in productivity, which is carried over to the following harvests. In addition, its presence increases the organic and microbial activity that enriches soil agricultural biodiversity, which allows the land to have a healthier life, that can be more fertile and better resist depletion [(11)].

Edaphoclimatic requirements and sowing

The chickpea seed grows with the humidity accumulated in the soil by the rain previously fallen, the grain responds positively to a supplementary moderate irrigation. From 10 ºC, the chickpea is able to germinate, although the optimum germination temperature ranges between 25-35 ºC. Lower temperatures increase germination time [(7)].

With regard to soils, it prefers siliceous-clay or silty-clay soils that do not contain gypsum. When there is an excess of clay it usually produces changes in the skin of the seed. When the soil has plaster, the chickpea obtained is of poor quality in general and very bad for cooking. If the soil has organic matter without decomposing it will also harm it. The good years for chickpea tend to coincide when it has been a little rainy year, especially in spring. The crop prefers deep-tilled soils, as its root system is well developed and drought tolerant [(12)].

It is advisable not to repeat its cultivation in the field for at least four years to avoid the development of diseases. Soils where moisture does not accumulate and airy soils are preferable. The ideal pH is between 6 and 9, apparently the more acidic the soil is, the greater *Fusarium* problems could arise, for this reason it is important to manage all these variables to achieve acceptable yields in the face of new edaphoclimatic conditions [1].

Among the rotation alternatives as a soil improver plant, the combination is used: Cereal-chickpea-cereal-fallow and Cereal-chickpea-cereal-sunflower. Sowing is in spring normally done. A delay in the sowing time can lead to a reduction in the growth and development of the plant, affecting flowering and as a consequence a reduction in the harvest. The sowing density depends on the environmental conditions and the plant type, normally 33 plants m^2 is used. In irrigated systems, the planting density can reach up to 50 plants m^2 [4].

Regarding irrigation, chickpea has good resistance to drought and it is sensitive to salinity and root suffocation, so it is advisable to avoid possible puddles due to excess water. Well-programmed irrigation improves nodulation and increases yield and the number of pods per plant [7].

Fertilization

The nutrients extracted by a harvest of 1T of grain and 1.5T of straw per hectare are approximately: 48kg of N and 10kg of P_2O_5. Chickpea is one of the crops that exports the least nutrients from the soil to achieve average productions and therefore would cause less chemical degradation of the same [4,10].

An adequate organic matter supply is recommended to improve the soil structure. Symbiotic fixation must be sufficient to satisfy the nitrogen requirements of the crop. Chickpea is a plant species with high sulfur requirements. In general, it has low iron, zinc and molybdenum deficiencies, easily correctable with foliar sprays [9]. The organic fertilizer use is of great importance to reduce greenhouse gas emissions from agrochemicals [13].

The weed controls in this crop are focused on pre-emergence, since the herbicides for broadleaf control in post-emergence, tested so far, generate phytotoxicity problems in the crop and deficient controls in the weeds present [12,13].

Collection and Handling

The time to harvest is when the leaves turn yellow and the pods appear dry. In some countries, harvesting is by hand, cutting the plants above ground or root level, stacking them in heaps and allowing them to dry for a week before being threshed. In other countries, harvesters mechanize harvesting; these are adapted in such a way as to cause the least possible grain match. Before storage, chickpeas should have a humidity of 8-15 % and should be kept in dry and ventilated places [1,4].

Varieties

There are three types of chickpeas, which mainly correspond to differences in the size, shape and color of the seeds:

- "KABULI" type: chickpea size medium to large, rounded and wrinkled, light color and un-pigmented flowers. Its cultivation is located in the Mediterranean region, Central America and South America.
- “DESI” type: small grain size, angular shapes and yellow or black color. The flowers and stems are generally pigmented, and sometimes the leaves. They are grown mainly in India.
- “GULABI” type: medium to small grain size, smooth, rounded and light in color [(1)].

The management of varietal diversity within this crop is important to achieve its wide extension and adaptation to different environments, maximizing the genotype-environment interaction. This allows to boost yields with the minimum use of agrochemicals, which are anthropogenic sources of emissions of nitrous oxide (N_2O), a greenhouse gas that is produced from agriculture with radioactive forcing with respect to CO_2 of 294 times. Another important indicator that influences the improvement of varieties and that affects the adoption of chickpeas, is that it meets the nutritional and organoleptic needs of consumers according to their cultural traditions [(2)].

In the genetic improvement of chickpea, hybridization is used, which provides a genetic diversity between the forms of chickpeas, in addition to deepening the study of the genetic structure of the species. Studies have been carried out on interspecific hybridization, on the relationships of crossbreeding. The genetic study determined a large number of qualitative characters in chickpeas such as the shape and leaf size, plant growth habit, flower, leaves and stem color, surface and coloration of the cotyledons [(1)].

Nutritional value

Chickpea is rich in protein, starch and lipids (more than other legumes), especially oleic and linoleic acid, which are unsaturated fats and lacking in cholesterol. In the same way, chickpea provides a good fiber and calorie contribution of to the daily diet. Chickpea beta-glucans make it difficult to absorb cholesterol, help diabetics regulate glucose levels; prevent the formation of colon diverticula, which is related to a diet low in plant fiber in Western populations. The high nutritional power of the plant is supported by its excellent caloric, protein and calcium intake, as well as containing fat, iron and B-complex vitamins [(14)].

The following table illustrates the main nutrients in chickpea. (Table 1).

Table 1. Average nutritional composition of chickpea per 100 grams

Proteins (g)	Lipids (g)	kcal	Carbohydrates (g)	Fiber (g)	Phosphorus (mg)	Magnesium (mg)	Potassium (mg)	Sodium (mg)
20.4	5.0	335.0	55.0	15.0	375.0	160.0	800	30.0

However, it must be taking into that if the chickpea is rich in proteins (between 20 and 25 % of its weight) these do not include all the essential amino acids necessary for human nutrition. To remedy this deficiency, it is advisable to complete the chickpea recipes by adding other foods to the dishes [(1)].

The nutritional properties of chickpea are determined by the growing conditions and the variety. From this, one can also obtain flours whose functional properties, the isolate and the protein concentrate, are affected by the treatments to which they are subjected to obtain them. The benefits provided by this legume and its components allow us concluding that it has great potential to be used for the formulation and development of functional foods [(15)].

Plagues and diseases

Chickpeas, like other legumes, are susceptible to attack by pests and diseases, knowing them is essential to guarantee their ecological control and avoid crop losses, as well as the abuse of chemical substances for their control. Currently an important factor is the presence of the effects of climate change that affect meteorological conditions favorable to the emergence of pests and diseases in chickpea plots [(16)].

Among the main pests and diseases are:

Chickpea fly (*Liriomyza cicerina*): the adult is 1.5-2 mm, whose 3 mm yellow larvae excavates galleries between the leaf epidermises, feeding on the parenchyma. This pest is exclusive to chickpeas, so if there are no chickpeas nearby, the harvest alternative will be a good remedy against the pest [(16)].

Weevil (*Bruchus* sp.): the damage caused by the weevil in chickpeas is important due to the seed depreciation. The weevil must be fought in the field when the flowers fall. If the chickpeas are to be preserved, it is convenient to treat them since the weevil greatly depreciates the product.

Heliothis (*Heliothis armigera*): it is the most important and widespread pest in the field, although its damage varies from year to year and from season to season.

Red chickpea moth (*Exelastis atomosa*): it is a widespread pest in various regions of India.

***Plusia orichalcea*:** its caterpillar can completely defoliate plants; it is a very widespread pest in Turkey, whose biological control is being developed.

Mining flies *(gen. Liriomyza)*: causes significant damage in Spain and Israel, being the *L. cicerini* species an important pest in Russia, whose losses are estimated between 10-40 %. As a method of biological control, the parasite *Opius cicerini* is used.

Chickpea rabies (*Ascochyta rabiei*): it is a very widespread disease. A fungus that produces round spots with dark edges on leaves and pods causes it. Stains on the stems are the most serious, they impede the circulation of the sap and the plant dries out. The disease is dispersed with the seed, being favored by increases in humidity and cool temperatures (below 25 ºC). Infection does not occur with low relative humidity.

***Fusarium* sp.;** this fungus causes a disease called fusariosis. The attacked plants have altered roots and brown spots appear on the neck. The fungus ends up obstructing the ascent of the sage through the vessels and destroys the roots. The optimal temperatures for the development of the fungus range between 25 and 35 ºC. This disease is accentuated by the lack of adequate depth in the soil, as well as the time and method of sowing and the time of irrigation. Today it is considered the most important disease in chickpea cultivation, although rabies was until recently (17).

Chickpea introduction in Cuba

In Cuba, chickpea sowing has gained importance in the last 10 years (4), due to its ability to grow under conditions of water stress and with low inputs. Another important element is that it contributes to import substitution, allowing for food sovereignty and security to be achieved with local own resources. Although in Cuba more than 80 varieties from other producing countries of this legume have been evaluated, there are only nine varieties registered in the official list of commercial varieties in the country. So the genetic base of the crop is limited, which undermines the availability of cultivars that respond to various edaphoclimatic requirements of the localities of the country that are dedicated to their planting and consumption (18).

In the last 10 years, various chickpea cultivars adapted to the soil and climate conditions of the country have been introduced in Cuban settings. However, the current genetic base that is available is scarce and it is necessary to continue evaluating new varieties to respond to the biotic and crop abiotic limitations in Cuba. Preliminary studies of new chickpea cultivars have been carried out under Cuban conditions to expand the existing genetic base and thus be able to increase the variety range that are offered to grain-producing farmers (19).

INCA, in its work with grain varieties, has introduced several promising chickpea lines from the germplasm bank of the Institute for Arid Zones Research (ICARDA) in Syria, and from them a group of promising cultivars has been selected to be evaluated in scenarios of Mayabeque and Artemisa together with the farmers. This practice has subsequently made it possible to disseminate them through the network of farms in the 12 provinces where the Local Agricultural Innovation Project (PIAL according its acronyms in English) affects as an option for the production and this grain consumption (20).

On the other hand, the chickpea crop has been evaluated regionally in Cuba provinces, using the FitoMas-E to study the chickpea yield, under conditions of drought stress, seeking greater adaptability of crop production in the country. The agronomic response of the Chickpea crop to the diverse treatments applied was favorable when the plants were subjected to hydric stress conditions and received FitoMas-E application. The yield per area and the yield components being number of grains per legume, number of legumes per plant and mass of 100 seeds, the ones that showed the best results before these conditions [9].

Participatory selection of chickpea cultivars in Cuba

Based on the Local Agricultural Innovation Project (PIAL), several crop fairs have been held to evaluate the grain diversity present in the localities where the PIAL project takes place, and within these crops, chickpea is [19]. Chickpea has been evaluated in San Antonio municipality, Artemisa province, during 2009 where 21 foreign cultivars were planted, from the Institute for Research in Arid Zones (ICARDA) in the Syrian Arab Republic and five national cultivars, from the Institute of Fundamental Research in Tropical Agriculture (INIFAT). In the participatory selection of varieties, 31 people participated who were grouped into professionals, administrators and beneficiaries for the field selection of the best varieties according to their selection criteria [20].

The 50 % of the selected cultivars turned out to be chosen for developing large grains (mass greater than 40 g 100 grains). This is a quality of the “Kabuli” type of chickpea, which is related to its quality for commercialization, being an important link in the agro-chains that are favored with the productive alliances between the actors [21].

Likewise, the cultivation of chickpea has been evaluated in the municipality of Los Palacios and in Villa Clara, obtaining satisfactory results of adaptation and acceptance by farmers. This type of participatory selection has been a quick and efficient tool for introducing varieties into Cuban agroecosystems in the face of new climatic conditions [22].

Another way of introducing chickpea cultivation in Cuban rural settings is through exchange workshops and farmers' schools nationwide, where farmers are with the cultural work of chickpea cultivation familiarized through theoretical and practical sessions. These actions seek to disseminate the plantations of this legume and, after an experimentation phase, take them to large scales in order to achieve their commercialization in the network of state markets in Cuba [23].

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