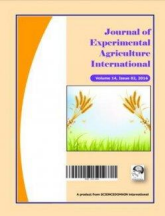

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Breeding Methods to Obtain Superior Genotypes of Okra

Kleyton Danilo da Silva Costa[1], Jackson da Silva[2*], Ana Maria Maciel dos Santos[3], José Luiz Sandes de Carvalho Filho[3], Paulo Ricardo dos Santos[4] and Maxwel Rodrigues Nascimento[5]

[1]Federal Institute of Alagoas (IFAL), Piranhas, AL, Brazil.
[2]São Paulo State University (UNESP), Botucatu, SP, Brazil.
[3]Rural Federal University of Pernambuco (UFRPE), Recife, PE, Brazil.
[4]State University of Northern Fluminense Darcy Ribeiro (UENF), Campos dos Goytacazes, RJ, Brazil.
[5]Capixaba Institute for Research, Technical Assistance and Rural Extension (INCAPER), Vitória, ES, Brazil.

Authors' contributions

This work was carried out in collaboration between all authors. Authors KDSC and JS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AMMS, JLSCF and PRS managed the analyses of the study. Author MRN managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The culture of okra, although little known, exhibits an interesting trade in relation to other vegetable crops. This is mainly due to its sensorial and nutritional qualities. However, despite their importance, there are still almost no breeding programs aimed at obtaining superior genotypes. Much of this is due to complications in the use of breeding methods for this culture. The objective of this work was to prepare a literature review for improved accuracy improvement of methods for obtaining superior genotypes of okra. Based on the present literature, the choice of the most appropriate method for each characteristic can result in superior lineages.

**Corresponding author: E-mail: jackson.silva.batalha@gmail.com;*

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1. INTRODUCTION

Okra (*Abelmoschus esculentus* L. Moench.) is a vegetable of great social and economic importance for several regions of the world, being mainly cultivated in the tropics, subtropics and hot regions of temperate zones [1,2]. In Brazil, okra finds ideal conditions for its cultivation in the Northeast and Southeast regions of the country [3].

The productivity of cultivated okra crop varies between 15 and 22 Mg ha^{-1}, under Brazilian conditions. It can be cultivated for good yield throughout the year. Such culture presents attractive characteristics in cultivation and consumption, such as ease of handling, relatively fast vegetative cycle, high food value, great utility and high profitability. Despite the importance of this culture, research is still incipient, both overall and in the plant breeding area [4].

Thus, it becomes necessary to develop early, productive and fruit quality varieties for farmers, as an alternative to that hybrid, mainly due to the low level of technology that the producers have. According to [5], besides good production, plants with greater maturity or those more precocious are desirable in okra cultivars, since they exceed the vegetative phase in a shorter time, reducing the exposure period of the plant to the attack of diseases and pests. This advantage is reflected in the possibility of commercialization of the product before cultivars of normal cycle, with the ability to obtain better prices. In this context, researchers [6] report that the development of new varieties is one of the technologies that increase productivity and stabilizes production, without additional costs to the farmer.

For the development of a well-structured breeding program, it is essential to know how to choose the best parents in relation to the characteristics of interest for breeding [7]. The use of methodologies for this purpose represents an excellent tool to aid the breeder in the attainment of promising segregating populations for obtaining good lines. According to [8] several methodologies, the genitors used for selection can also be used to cross each other in the case of diallel crosses, allowing the attainment of basic information regarding the genitors to initiate a program of genetic improvement for okra culture for both the production of self-pollinating varieties and the production of hybrid varieties. In possession of the best combination of parents, an appropriate improvement method should be used to drive the segregating population, for obtaining good progenies, which can be evaluated in preliminary tests, before reaching at a new variety [9].

The objective of this work was to review the literature to support the establishment of a future breeding program for the production of early, productive and quality varieties through consultation of scientific articles that deal with the subject in question.

2. GENERAL ASPECTS OF OKRA CULTURE

Okra belongs to the family Malvaceae, being the only relevant oleraceous culture within this family, presenting great importance for regions with semi-arid conditions because it is a vegetable adapted to this condition. It is a crop exploited mainly in Asia, Africa, America and in the Mediterranean regions [10].

The origin of okra is still unclear, with most authors citing Africa, possibly in Ethiopia [11]. In every way, this culture presents important centers of genetic diversity, which include West Africa, India, and Southeast Asia [12,13].

The cultivated species of okra is considered polyphyletic since it is believed that its origin came from more than one species. The main hypothesis regarding this information is the variation of the number of chromosomes in the genus that presents about 10 known species [14,15].

In relation to cytogenetics, as previously reported, there is considerable variation in the number of chromosomes, and also in levels of ploidy, both among the species of the genus *Abelmoschus* and within the cultivated species. It has been observed more frequently in *Abelmoschus esculentus* (L.) Moench 2n = 130. However, some authors such as [14], reported the existence of 2n = 72, 108, 120, 130 and 144 chromosomes.

Depending on the location, this culture is known by different denominations: gumbo, gombô, okra, lady´s finger (English), bhindi or bhendi (Indian), bamyah or bamiat (Arabic), quimbombo (Spanish) [16].

Okra is considered an annual plant, which is characterized by being a shrub of erect postage and semi-woody stem that can reach three meters in height. This plant shows a greenish coloration or greenish with reddish areas. Despite this size, in this plant, lateral branches can still occur, which are stimulated by handling practices in the cultivation, such as the use of larger spacings [17]. The leaves are large, with deeply cut limbus, lobed and with long petioles [17].

Okra is a culture that has its propagation via seeds, with planting in direct sowing being more usual, where it is considered an intermediate species with 4-19% cross-pollination. In addition, their flowers facilitate the crossing process by the fact that they are yellow and large (4 to 8 cm in diameter). Anthesis occurs most often between 06:00 h and 10:00 h.

Okra fruits measure about 25 cm, with five pilose locules, which are capsule type, plump, and present a circular or pentagonal cross-sections, Its production occurs even when the plant is small, both on the main stem and on the sides, and depending on the cultivar, there is the production of medium and short fruits with protruding angles or with almost circular sections. In general, they have a pyramidal shape, with an average yield of 60 seeds [18].

The development of okra culture is quite variable in relation to the duration of the vegetative and reproductive periods, being very influenced by the cultivar used. However, in general, the vegetative stage lasts from the emergence for about 60 days after sowing, then begins the reproductive stage that goes up to 120 days after sowing. It is worth emphasizing that the planting season influences the cycle of this culture intensely, for there are reports that the fruiting period exceeded 200 days [3].

The harvest of the fruits is performed several times. The aspect observed should be of soft or tender fruit with bright green coloration. In hot times, harvest begins from five to six days after the opening of the flower, and in the winter from six to seven days after the opening of the flower. Harvesting is usually manual, at least twice a week, being ideal for alternate days [16].

Despite the importance of okra, there are few institutions that work with this culture, and this gets worse when breeding programs are taken into account.

3. IMPROVEMENT FOR PRECOCITY, PRODUCTION AND QUALITY

For the improvement of any crop, it is necessary to add to the varieties, a series of not only productive characters, but also the quality, to meet the demands of producers and consumers. For okra, characters such as precocity, production, and quality are indispensable.

The selection of early materials of okra facilitates the cultivation of this vegetable in regions scarce of financial and natural resources. Early cultivars may be part of the variety handling strategy, for these, if compared with cultivars of normal cycle, influence product trading. This is because its attainment is faster, reflecting the possibility of trading strategies, and in the field, it allows the attainment of a better quality product, reducing the exposure of okra to the biotic and abiotic intemperateness [5].

Researchers [19] report that the importance of the precocity variable of harvest is evidenced besides the agronomic advantages because early harvest facilitates labor hiring at the beginning of harvest which is a critical period. This becomes a great economic advantage, because it allows economic return at the beginning of the activity.

The use of early cultivars allows the concomitant increase of fruit production [5]. Besides this increase in planting, early cultivars allow a greater amount of cultivation of this vegetable, allowing greater return over time. It is worth noting that, despite this interesting relationship to arrive at a productive and precocious variety, these characters are strongly influenced by the environmental component [20], thus requiring, according to [5], improvement methods that use greater control of the environment, such as those presenting progeny testing. Selection, according to [21], should be performed using populations with large numbers of individuals, so that the maximum number of recombinations occur due to the large number of chromosomes of this species. Besides the possibility of okra improvement by means of the attainment of segregating populations, there is also the possibility of exploitation of hybrid vigor in F_1.

In plant breeding, in addition to meeting productive needs by means of the attributes of precocity and productivity in okra, it is necessary to develop quality products, which are well accepted, being the fiber content and the

coloring of okra fruit, two important parameters in this segment.

Okra fruits should be marketed fresh and tender, because of its complete vegetative development begins the increase of the fiber content. The ideal okra harvest point is when the fiber content is less than 6.5%, it is tender and has the size from 10 to 14 cm. After these values, the *in natura* consumption of this vegetable becomes inadequate [16]. Fiber content and coloration varies greatly between different okra cultivars, which is interesting, for breeding programs. In general, cultivars of North America have a higher fiber content than indigenous cultivars [2].

4. DIALLELIC ANALYSIS IN THE CHOICE OF PARENTS

The choice of parents, not always the most productive agronomically, are those that have the best combination capacity to be used in breeding programs. In this way, the genetic analysis of parents is used to identify the best combinations for the precocity, production and quality [22,23].

In the genetic analysis for the choice of parents, [8] cites several methodologies. Among them, diallel crosses are the most widely used in almost all cultivated species in the attainment of promising segregating populations, and this stage is fundamental to succeed in subsequent stages of the breeding program [24].

Depending on the complexity, there are several types of dialleles which have been used: 1. Complete or balanced dialleles - are those that include the hybrids in generation F_1 or F_2 or any generation among all pairs of combinations of the parents; 2. Circulating dialleles – are those in which parents are represented in the hybrid combinations in a smaller number of crosses than in the other types; 3. Unbalanced dialleles - are those from which some programmed hybrid combinations are not obtained; 4. Incomplete dialleles - are those by which the progenitors are represented by a variable number of crossings; 5. Partial dialleles – are those involving two groups of parents [8-25].

According to [25], there are some more used methodologies of analysis of a diallel. Among them are: [26] that evaluates the effects and sums of squares of effects of the general and specific capacity of combination; [27] evaluating the effects of varieties and varietal heterosis; and the proposal by [28] who informs the inheritance of the character, genetic values of parents and the selection limit.

Partial diallel analysis has the objective of studying the attainment of favorable phenotypes that are found in distinctive groups of parents. Moreover, combinations within each group are not of interest, which is similar to the factorial model proposed by [29,30].

According to [8], the use of the methodology of diallel crosses, allows the selection of parents from the estimates of General combining ability and specific combining (GCA and SCA), seeking to identify those with high estimates of these parameters, thus, segregating populations of these parents are expected to have a high average and expressive genetic variability, these parameters are fundamental for the extraction of lineages in segregating populations. In general, the general combining ability (GCA) is very useful for directing future hybridization works, because it is expected that individuals with a high value of this parameter will allow good hybrid combinations with the other parents [31].

Okra is considered an autogamous plant, in the improvement thereof, self-pollinated methods can be used or can exploit the heterosis. For both situations, it is necessary to know how to select the best parents that allow the best combinations [32]. According to [9], heterosis or hybrid vigor is the increase of progeny performance in relation to the parents, due to the crossing between contrasting individuals. This phenomenon in the culture of the okra was studied by some authors [33,34,35], who observed a productive increase in several characters of the culture.

5. METHODS OF SEGREGATING POPULATION DRIVING AND PRE-LIMINARY PROGENY EVALUATION

With the variability generated from the best combination of parents, one of the appropriate methods of conducting segregant populations should be used for autogamous plants for the extraction of advanced lines. According to [9], the methods are classified in two ways: 1. Those that do not separate the phase of endogamy and selection, which mainly include the mass method and the genealogical method, in which selection starts from F_2 generation, where variability already exists; and 2. Other methods, which separate these two phases.

Particularly the genealogical method, known as the pedigree method, was proposed by Hjalman Nilsson, being very popular for the development of lines of autogamous species. But over the years, it has been replaced by other methods such as the single seed descent method [9]. Even so, it is of great importance and is used until the present day. In this method, the whole genealogy of the plants is annotated to support selection, providing accurate kinship among progenies [36].

According to [37], the method involves the following phases: 1. Crossing between two or more varieties; 2. Selection of a large number of individual plants in generation F_2; 3. Planting of the progenies of the individual plants by selecting between and within them until generations F_4 and F_5 in which selection can be initiated only among progenies, by the attainment of the accentuated homozygosity; 4. Carrying out the production and quality tests for two or three years to choose the progenies that will constitute the new varieties.

6. CONCLUSION

Based on the literature, several important elements were identified in relation to okra breeding and culture, taking into account the aspects from the correct selection of the parents to the early evaluation of the lineages.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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