Review Article

Genetic improvement methods with anagroecological approach

.

ABSTRACT

Conventional genetic improvement programs play a fundamental role in Brazilian agriculture, transforming this activity into an important contributor to the national economy. However, most of the time it does not serve family farmers, as this cultivation system has different characteristics from conventional agriculture, where it is often composed of agroecological and diversified crops, in a smaller territorial extension, without conditions for carrying out controls using technologies and inputs acquired externally. Thus, participatory breeding aims to align the improvement of cultivar productivity with the provision of biodiversity for family farming. This technique consists of the farmer's ability to select the cultivars best adapted to their environment based on the selection of their seeds, adopting agroecological principles and agrobiodiversity management.

Keywords: Sustainable; environmental quality; socioeconomic.

1. INTRODUCTION

Conventional genetic improvement programs play a fundamental role in Brazilian agriculture, transforming this activity into an important contributor to the national economy. In this type of agricultural system, the focus is on large areas dominated by monoculture of species with an economic impact. In conventional breeding, the environment is controlled in order to obtain gains in the characteristics that are desired to be selected [1]. However, in these improvement programs, the conduct of genetic diversity has the consequence of dilapidation, or promotion of the genetic homogeneity of species, transforming crops increasingly dependent on external inputs, while for the correct management of this diversity it is fundamental the relationship between man and the environment,so that there is a direct influence on agroecosystems [2].

Still on conventional breeding, this does not serve family farmers, as this cultivation system has different characteristics from conventional agriculture, where it is often composed of agroecological and diversified crops, in a smaller territorial extension, without conditions for carrying out controls with the use of technologies and inputs acquired externally, in this way, this notable difference in the production system reflects in lower yields of materials developed in conventional breeding, where the ecological adaptation of the cultivated species is the characteristic that most contributes to the success of farming, different from agriculture conventional that has as its main bias the productive potential of the cultivar [1].

By using external inputs such as inorganic fertilizers and agrochemicals to protect plants, the conventional production system sometimes provides homogeneity in the diversity of the agroecosystem, in systems where the use of external inputs is low, such as in organic agriculture, for example, the environment is more diverse, characterized by a greater number of weeds, pressure from pests and diseases, use of rotation techniques, succession, intercropping and plant protection. This fact often means that competitive trials of cultivars in the organic system do not perform similarly to the conventional system [3].

As an alternative to conventional plant breeding methods, participatory breeding emerges, which aims to align the improvement of cultivar productivity with the provision of biodiversity for family farming. This technique consists of the farmer's ability to select the cultivars best adapted to their environment based on the selection of their seeds [4].

Thus, participatory improvement and the adoption of agroecological principles are directly related to the management of agrobiodiversity. These actions contribute significantly to the adaptability and productivity of varieties, in addition to being fundamental to avoiding the process of loss of existing genes and recomposition of lost diversity [2].

2. HISTORY AND CRITICAL ANALYSIS OF PLANT BREEDING

From the first agricultural revolution established around ten thousand years ago, the process of domestication of cultivars began. With the advent of agriculture, it was possible to reduce risks in relation to the extinction of the human species, without the need to be nomadic, thus enabling population growth. It is well known that the domestication of plants has contributed to the survival of the human species, however, the transition from wild species to domestic plants had a major impact on the loss of the ability to survive independently, becoming dependent on human interference. In addition, characteristics of wild plants were lost during their domestication, such as: ability to disseminate and loss of seed dormancy, reduction of protection mechanisms with thorns,changes in reproduction habits, alteration of the life cycle and increase in fruit size [5].

The theory of plant breeding originated based on work carried out by Charles Darwin (1809 – 1882) and Gregor Mendel (1822 – 1884), whose studies of natural selection, transfer of genetic characteristics from parents to their descendants and plant phenology were very relevant in relation to the topic until the beginning of the 20th century [6]. Based on these theories, contemporary plant breeding was created. In the beginning, plant breeding activities were linked to diverse environments, with a great wealth of genetic diversity in cultivation in different regions of the world, which were based on the ecological management of biodiversity.However, with the bias towards more productive agriculture, a contemporary crisis began to arise in the most diversified improvement processes [2].

Within this vision of agricultural production, plant breeding aimed to select varieties that minimized environmental effects so that these cultivars responded to the desired purpose, such as uniformity of production and response to the application of fertilizers and agrochemicals. This uniformity in cultivation and exploitation of monocultures has led to the loss of biodiversity and a serious problem of genetic erosion. The loss of species diversity is closely related to the increase in hunger, poverty and food security. As a measure to mitigate biodiversity loss, research focusing on agrobiodiversity,agroecology and sustainability through participatory actions and the appreciation of local customs and the recognition of the role of family farmers in conserving diversity must be effective [2].

This fact happens because conventional breeding does not take into account factors typical of family farming, such as the stability of production in the face of environmental variations that can induce biotic and abiotic stress on cultivars, in addition to the preference of certain cultivars based on each community. Therefore, the cultivar selection criteria in the conventional breeding model may not have relevant characteristics for these farmers [1]. Furthermore, the development of conventional cultivation techniques aimed solely at economic gains has led to terrible and increasingly evident consequences in recent years, such as the contamination of natural resources with water and soil, deforestation, fires and the exodus of the rural population.Another negative fact linked to conventional farming models is food insecurity due to the exaggerated use of agrochemicals [2].

Currently, plant breeding has been adding new techniques and concepts to the traditional selection methods adopted over the last 100 years. New genetic improvement techniques are linked to biotechnology, such as the use of molecular markers, DNA sequencing, genetic engineering, gene flow and biosafety. Plant breeding must also be aware of sustainable cultivation techniques, based on economic, social and agroecological concepts, prioritizing plant selection methods associated with the preservation of environmental resources, genetic variability and interaction between social, cultural and economic conditions, to increase knowledge and wealth in an ecologically responsible way [7].

3. SUSTAINABLE PLANT BREEDING

3.1. MASS SELECTION

Mass selection is a breeding method that consists of choosing the best plants in your harvest, so that their seeds will be used in subsequent planting [5]. In this type of method, parental control is carried out only through the female parent since the male gamete originates from all populations that have open pollination. To ensure better selection efficiency, plants with unwanted characteristics can be eliminated before flowering. In mass selection there is no control over the environment, which can favor plants that are in a more fertile area. However, despite this limitation, this method has been practiced for thousands of years by indigenous populations and has contributed significantly to creating varieties of many cultivars. The advantage of mass selection is the possibility of evaluating a large number of plants, as well as being quick and cost-effective [8].

3.2. USE OF VARIETY AND CREOL SEEDS

Creole varieties constitute the basis of the ancestral and daily diet of many rural communities worldwide. These varieties foster relationships between rural farmers and urban consumers, in addition to having the function of contributing considerably to the conservation of species biodiversity. Because they have great variability and are democratic and widely distributed, landraces go against the grain in the process of economic control and concentration of power exercised by large industries in the agricultural sector [9].
Through the continuous process of selection and development carried out by many traditional communities, landraces have been cultivated throughout different cultivation systems and are associated with human and animal nutrition. Due to these characteristics, they are part of the concept of agrobiodiversity, as they are related to environmental issues, agroecosystems and traditional communities, characteristics similar to the concept of agroecology [2]. Agrobiodiversity management is related to the cultivation of different species within multiple agroecosystems, in addition to maintaining the cultural and traditional values of each region and the use of local and/or traditional varieties. Thus, it is possible to relate these varieties as being the basis of family and indigenous agriculture, being a fundamental constituent of the genetic basis for tolerance and resistance to stress and

adaptabilities to different environments, therefore, they have invaluable value for humanity and can guarantee food sovereignty [10].

The use of landraces is scientifically proven to be a viable measure for agricultural production, as demonstrated by Oliveira et al. [11], who studied the use of corn varieties, including 3 creoles (Aliança, Perin and ES 001) for the production of silage aimed at family farming in the municipality of Colatina, State of Espírito Santo, found that all genotypes studied produce a productive capacity higher than the average productivity of the State of Espírito Santo (2,830 kg/ha) (Table 1), with emphasis on the landrace variety Aliança, being the most productive with 6,550 kg/ha.

Table 1.Average productivity values (kg/ha) of nine corn varieties cultivated in the municipality of Colatina, State of Espírito Santo in 2016

Variety	Productivity (kg/ha)
Encapa	4,750
Perin	5,630
Cymmyt 11	4,470
Aliança	6,550
Fortaleza	3,180
ES 001	3,270
Piranão 14	5,740
Piranão 11	3,210
Cymmyt 14	5,220

Source: adapted from Oliveira et al. [11].

However, we can say that the conservation and development of creole and traditional varieties belonging to different locations are of fundamental importance. These varieties have an unspeakable value in terms of genetic diversity, as they contain genes for different types of biotic and abiotic stress, adaptability to different cultivation systems and agroecosystems, and can avoid events such as genetic erosion. Furthermore, these varieties represent cultural richness and enable greater autonomy for the peasant, becoming a key point for food security and sovereignty. In this way, encouraging public policies aimed at the conservation and rational and sustainable use of landraces within the concept of agrobiodiversity is of fundamental importance [2].

3.3. PARTICIPATORY IMPROVEMENT

Participatory improvement began in the 1980s and seeks to include the skills, experience, practices and preferences of rural people [12]. This technique appears as an alternative to conventional breeding methods, and aims to select cultivars belonging to the location and/or introduced to be used in the crop or as parents to follow the breeding program. In this type of technique, the selection of cultivars is made on the rural property, maintaining or, if necessary, incorporating genetic diversity, generating greater capacity for family farming to produce, select and exchange seeds [1].

The emergence of new techniques in genetic improvement became necessary due to the problems of conventional methods that focus on preparing crops for the excessive use of agrochemicals. The use of improvement techniques that are linked to the reality of small farmers and that use the genetic diversity of local species and that provide a substantial increase in productivity is beneficial for socio-environmental aspects. In this sense, the conception of participatory breeding aims not only to achieve productive gains commonly sought in conventional breeding, but also to increase and conserve biodiversity [2].

According to Machado [2], the use of participatory breeding depends on specific strategies to obtain good results, such as the rescue of different species and different varieties belonging to each species, recognition of the importance of local varieties, construction of new varieties, appreciation of cultural references and nutritional, agroecosystem management, sustainable cultivation system with an agroecological bias, adaptation to the local environment with increased productivity generated by participatory improvement.

Based on the mass selection technique and participatory breeding for zucchini cultivation, Jovchelevich[8] in the municipality of Botucatu, State of São Paulo, obtained an increase in the frequency of plants with commercial fruits, disregarding characteristics such as fruit color in his breeding program. (Figure 1), in addition to branch size, as these characteristics are not limiting in the commercialization of this product locally. Thus, this author considers joint work between the farmer and the researcher to be fundamental, making it possible to obtain cultivars adapted to each production reality and the market in which these products are sold.

Figure 1. Immature zucchini fruits, considered non-commercial (the three on the left) and classified as commercial (the five on the right).
Source: Jovchelevich[8].

In Table 2, it is possible to observe that the results obtained by Machado [13], in a trial conducted in the municipality of Catalão, in the State of Goiás, in corn cultivation, where varieties from participatory breeding (Sol da Manhã and Eldorado) and conventional breeding varieties (BR 106, BRS Caimbé, São Francisco, BR 473 e BRS 4103) varieties generated participatively through the crossing of landraces (MC 20, MC 50, MC 60, MC 6028) and landraces that had high productivity, showing the potential of participatory improved varieties, with special emphasis on the variety MC20, which stood out both in the production of dry matter, that is, for the production of silage, and in the average weight of ears.

Table 2. Average values of ear weight (kg/ha) and dry matter (kg/ha) of 25 varieties of corn grown in the municipality of Catalão, in the State of Goiás

Varieties	Ear weight (kg/ha)	Dry matter (kg/ha)
Sol da Manhã	8,435	7,415
El Dorado	10,935	10,250
MC 20	11,750	8,365
MC50	10,310	9,685
MC 60	10,060	9,710
São Francisco	7,685	6,750
BR 106	9,745	10,035
BR 473	8,025	7,750
BRS Caimbé	9,120	9,260
BRS 4103	9,245	9,650
São José	10,060	11,250
Fortaleza	10,185	12,180
Aliança 01	10,060	10,800
MPA 01	8,560	9,605
MCP Ribeirão	9,000	14,000
Caiano de Goiás	8125	14,420
MCP Taquaral	10,310	11,810
Caxambu	11,245	10,060
BR da Várzea	9,060	8,610
Coruja	9,810	16,250
Amarelão	8,495	15,135
Três Meses	8,870	10,285
MC 6028	10,120	7,750
El dorado Genético	10,745	9,350
MC Roxo de Tocantins	7,120	11,560

Source: adapted from Machado [13]

It is clear that the use of participatory improvement appears to be an aggregating measure for the agricultural system. Machado and Machado [14], evaluating the performance of 8 corn varieties obtained through participatory breeding and two commercial varieties (BR 473 and BR 106) in agroecological systems in the cities Oeste (Cunha settlement), Pirenópolis and Rio Quente in the State of Goiás, identified varieties from participatory breeding adapted to this cultivation system, with significantly higher production potential than commercial varieties (Table 3), proving the efficiency of these varieties.

Table 3.Average productivity values (kg/ha) of 10 varieties of corn grown in an agroecological system in the cities Oeste (Cunha settlement), Pirenópolis and Rio Quente in the State of Goiás

Varieties	Cunha	Pirenópolis	Rio Quente	Average
	Productivity (kg/ha)			
Sol da Manhã	5,733	5,167	6,067	5,655
El Dorado	6,567	4,667	8,567	6,600
MC 20	7,033	5,433	8,733	7,066
MC 50	5,500	5,667	7,133	6,100
MC 60	6,500	6,267	8,600	7,122
El dorado Muqui	7,067	6,067	7,267	6,800
Fortaleza	7,567	5,100	7,933	6,866
Sol da ManhãCatalão	3,900	4,333	5,767	4,666
BR 473	4,200	4,633	6,167	5,000

BR 106	3,100	5,533	6,633	5,088

Source: adapted from Machado and Machado [14].

Another success story that we can mention, still in relation to corn cultivation, Machado et al. [15], studying the management of genetic diversity and participatory improvement in agroecological systems in 3 different locations (Settlements Colônia e Cunha and EmbrapaCerrados) found that varieties improved in a participatory way (Sol da Manhã, Eldorado, Fortaleza, MC 20, MC 50 and MC 60) has high tolerance to abiotic stress due to lack of nitrogen and phosphorus in the soil (Table 4), and its cultivation can be established in places undergoing agroecological transition or in places with an already established system.

Table 4. Estimates of efficiency in the use of Nitrogen (Pg/Ng) and the use of phosphorus (Pg/Phg) in tests carried out in the Colônia and Cunha Settlements and in EmbrapaCerrados in the 2006/2007 agricultural years

Varieties	Colônia	Cunha	Embrapa	Colônia	Cunha	Embrapa
	Pg/Ng			Pg/Phg		
Sol da Manhã	49.68	64.41	50.90	19.36	28.05	24.85
El Dorado	52.16	74.28	60.28	20.78	34.49	30.91
MC 20	52.12	73.09	54.59	20.60	34.49	27.38
BR 106	51.02	77.15	56.33	20.27	34.29	29.13
BR 473	49.68	71.82	55.35	20.78	34.71	26.51
MC 60	52.73	71.90	61.78	23.42	33.53	29.20
Branco Morgado	46.58	58.38	59.23	17.98	30.75	31.15
Caiana ES	48.58	64.34	57.37	20.97	26.09	25.66
Fortaleza	49.14	69.55	61.77	20.27	29.08	30.36
Grão de Ouro	49.76	71.81	58.20	20.84	33.29	31.36
Palha Roxa ES	50.86	70.59	54.75	22.08	33.02	28.82
Aliança	47.47	66.52	59.30	22.68	32.73	30.05
Pedra Dourada	52.21	67.48	58.48	19.64	28.00	24.45
MC 50	54.09	73.26	63.54	22.97	32.14	30.20

Source: adapted from Machado et al. [15].

In the Brazilian Northeast, a region characterized by adverse soil and climate conditions such as prolonged periods of drought and where there is a predominance of small producers, the use of participatory breeding was a fundamental milestone for research into cassava cultivation, increasing the level of adoption and dissemination of results obtained, promoting the incorporation of cultivars into the region's production system more quickly. The process that was previously carried out exclusively by breeders, who defined everything from the problems to be corrected to the recommendation of new cultivars, now includes the participation of farmers, a characteristic that was previously not taken into account, such as the high rate of germination and establishment. even in periods of drought, high quality seed production,good flour production and high leaf yield for animal feed gained focus in breeding programs, thus, the adoption of these cultivars occurred within a short period of time [16].

However, the examples cited above demonstrate the potential and importance of participatory improvement for family farming, as in its essence socio-economic, cultural and ecological issues are considered, based on the selection of the farmer himself associated with the management of biotic and abiotic, a reality that is commonly observed in family farming [17] [8].

One of the advantages associated with the participatory breeding method over conventional breeding techniques is the relationship that rural producers have with all stages of the process, allowing the adoption of important parameters for family farming, thus, it is possible to combine productive capacity of crops with fundamental biodiversity for this type of agriculture. Therefore, participatory breeding plays an important role in adding value to local and traditional cultivars, making family farmers more empowered through the generation of employment and income, in addition to transforming cultivation habits into more sustainable ones [1].

It should also be noted that for the success of participatory improvement, a broad dialogue with rural producers is initially essential so that the genetic diversity belonging to the location can be characterized. Further, it should be known that there is a time between the characterization of local genetic variability and the definitive increase in new, participatory improved varieties and that this entire process, despite being decentralized, lacks great scientific input. In this way, through tests and evaluations, the farmer gradually acquires knowledge in the field of improvement within the agroecological context, coming to dominate the entire process [2].

4. CONCLUSION

Conventional plant genetic improvement techniques are linked solely to economic gains and uniformity of cultivation through monocultures, which can lead to loss of biodiversity, resulting in problems such as genetic erosion, increased hunger, poverty and food insecurity.

Participatory breeding methods are scientifically proven to be a viable way for the agricultural system, and the varieties obtained through this method have high productive potential and adaptation to stressful environmental conditions. Furthermore, by presenting the conservative character of biodiversity, participatory breeding prevents the loss of resistance genes to biotic and abiotic factors through genetic erosion and allows the farmer greater dustiness and autonomy in choosing the characteristics to be exploited in the crops in his properties.

REFERENCES

1. Fonseca MAJ. Genetic resources and vegetable improvement for and with family farming. Hortic. Brazil. 2014; 32.

2. Machado AT. The conservation and development of native seeds in an interdisciplinary perspective of agrobiodiversity. In: Boef WS, Thijssen MH, Ogliari JB, Sthapit BR (Orgs). Biodiversity and farmers: strengthening community management. Porto Alegre:LPM, 2007a.

3. Lammerts V, Bueren ET, Jones SS, Tamm L, Murphy KM, Myers JR, Leifert C, Messmer MM. The need to breed crop varieties suitable for organic farming, using wheat, tomato and broccoli as examples: A review. Wageningen Journal of Life Sciences. 2011; 58: 193-205.

4. Fonseca MAJ. Tools for participatory crop improvement. Agroecology Notebooks – ISSN 2236-7934 – Annals of VI CLAA, X CBA and V SEMDF. 2018; 13.

5. Paterniani E. Corn breeding and production in Brazil. Piracicaba: ESALQ, 1978. 650 p.

6. Betrán J, Moreno-González J, Romagosa I. Theory and application of plant breeding for quantitative traits. In: Cecarelli S, Guimarães EP, Weltzien E. (Ed.). Plant breeding and farmer participation. Rome: FAO, 2009; 27-62.

7. Borém A, Miranda GV. Plant breeding. 6th ed. Viçosa – MG: Ed. UFV, 2013.

8. Jovchelevich P. Participatory breeding of pumpkin (Cucurbita moschata Dusch), under biodynamic management. Thesis (Doctorate) - Universidade Estadual Paulista, Faculty of Agricultural Sciences, Botucatu, 2011, 44 f.

9. Pereira VC, Soglio FKD. The Conservation of Creole seeds: an interdisciplinary vision of agrobiodiversity. Porto Alegre: Editora da UFRGS, 2020. 558 p.

10. Machado AT. Biodiversity and agroecology. In: Boef WS, Thijssen MH, Ogliari JB, Sthapit BR. Biodiversity and farmers: strengthening community management. Porto Alegre: L&PM, 2007b.

11. Oliveira VS, Bitencourt LL, Berilli APCG, Cazaroti EPF, Varnier E, Spalenza DM, Couto DP, Souza SH, Felberg NP, Gomes JJO. Silage production with different corn populations for family farming in the municipality of Colatina, Espírito Santo. Ifes Science Magazine. 2018; 4.

12 Machado AT, Machado CTT, Coelho CHM, Arcanjo JN. Management of corn genetic diversity and participatory improvement in agricultural communities in the State of Rio de Janeiro and Espírito Santo. Research and development bulletin, Embrapa Cerrados, 2002.

13. Machado AT. The conservation and development of native seeds in an interdisciplinary perspective of agrobiodiversity. In: Pereira VC, Soglio, FKD. (Org.). The conservation of landraces an interdisciplinary vision of agrobiodiversity. 1st edition.Porto Alegre: Editora da UFRGS, 2020.

14. Machado AT, Machado CTT. Strategies for Participatory Corn Improvement in Agroecological Systems. Rev. Bras. of Agroecology. 2009; 4:4345-4348.

15. Machado AT, Machado CTT, Nass LL. Management of genetic diversity and participatory improvement of corn in agroecological systems Rev. Bras. of Agroecology. 2011; 6: 127-136.

16. Fukuda WMG, Fukuda C, Cardoso CEL, Vasconcelos OL, Nunes LC. Implementation and evolution of participatory research work on cassava breeding in the Brazilian Northeast. Cruz das Almas, BA: Embrapa Cassava and Fruticulture. 2000.

17. Boef WS, Thijssen MH, Ogliari JB, Sthapit BR (Eds). Biodiversity and farmers: strengthening community management. Porto Alegre: LPM, 2007.