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Participatory Plant Breeding in Relation to Genetic Diversity, Food Security, Plant Development and the Need to Pay Attention to Oilseed Crops

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ABSTRACT

Since the beginning of life on earth, mankind has always used animals and plants for its nutrition and has continuously trained and developed them for their benefits and social, cultural, and economic needs. In the past, livestock and crop breeding were done by traditional farmers and ranchers. It improves the performance of livestock and crops, they performed the selection, which is one of the principles of plant breeding and livestock breeding. They made this choice with the help of information that was passed down to them from successive generations. It is a participatory plant breeding and production of crops with the help of researchers alongside farmers. Farmers work with researchers, scientists, and other stakeholders -even consumers- to improve crops and develop resilient plant varieties. Farmers are aware of their needs and have a conscious understanding of their agricultural land in terms of soil type, seed type, weather conditions, surface water, underground water conditions, etc. Therefore, they can play an important role in making decisions about the implementation of plant breeding and the type of planting pattern in the cultivated microclimates. In other words, farmers determine their cultivation goals based on their environments, conditions, tastes, and local cultures. The seed that is obtained in this way by the breed researchers with the help of the leading farmers, actually contributes significantly to the food governance of the people of that region and that country.

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1. Introduction

Participatory Plant Breeding (PPB) complements conventional remedial approaches. PPB is seen as a way to overcome the limitations of conventional breeding. Farmers have the option to decide which species best suits their needs and conditions without putting their households at risk (Bhargava *et al*., 2019). In the following, the concept of Participatory plant breeding is derived from the two words "Plant Breeding" and "Participation". Participation means the act of cooperating in an event or activity or a multidimensional and dynamic process of participation, influence, resources, benefits, knowledge, and skills through the participation of researchers and farmers in decision-making achieved, while plant breeding is the science of improving the genetic structure of crops using various tools and techniques (Bhargava and Srivastava, 2019). In other words, PPB is the production and breeding of crops with the cooperation of farmers along with plant breeding researchers. Farmers work with researchers, scientists, and other stakeholders -even consumers- to improve crops and develop resilient plant varieties. Local farmers know their needs better. They set their production goals based on their local environments, conditions, tastes, and cultures (https://weseedchange.org). Farmer participation in plant breeding includes a wide variety of activities ranging from farmers' cooperation in helping plant production to develop plant ideotypes to deciding on the distribution of varieties and seed production. For this purpose, help can be sought from farmers to introduce well-known local cultivars and types of desirable traits desired by farmers. The first step in

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participatory plant breeding includes getting the opinions of farmers to design plant breeding programs. Active participation of farmers in the evaluation of segregating populations is still uncommon, but the involvement of farmers in the evaluation of improved lines, for example in field multi-locus analysis trials, is increasingly being used as a useful way of early identification of favorable varieties in Remedial programs are known (Campanelli *et al*., 2019).

Nowadays, many social science methods and techniques that can be used to implement farmer participation in variety evaluation and selection are well known (Ceccarelli and Grando, 2020). One of the approaches to decentralization of participatory plant breeding varieties can be the creation of organizations based on a community of experimenting farmers (that is, farmers who conduct variety testing on their initiative). Also, this approach increases the participation of farmers in seed research and production so that technology testing can be done in multiple and diverse micro-environments without incurring excessive costs and compromising quality, participation can be done properly (Joshi *et al*., 2023; Colley *et al*., 2022).

2. The importance of ecological conditions of farmers in the production of plants

A plant breeding program becomes participatory when farmers (although not limited to other stakeholders), participate or, as many prefer, collaborate with scientists at all key stages of the breeding program. Key steps include setting program goals, selecting parents and germplasm types, and developing product specifications, as well as methodological aspects such as plot sizes, agronomic management of trials, and organization of the farmer selection process (Ceccarelli and Grando, 2019 and 2022). In countries where the same crop is grown under both favorable and unfavorable conditions, plant breeding has traditionally given priority to more favorable areas. At the national level, a further increase in national production can be achieved by increasing production in good environments through the joint effect of improved cultivars and improved agricultural practices. However, such a strategy ignores many small and smallholder farmers who could represent the majority of farmers in the country. It is believed that agricultural production can be increased at the national level while serving small and smallholder farmers (Jowett, 2023). In general, for the successful implementation of breeding programs, one should have a detailed knowledge of the existing conditions and the favorable conditions of farmers. Therefore, this problem has been common in classical breeds and developing countries, and breeders think that by increasing the yield of crops (production of high-yielding varieties of plants), they will be able to impose these varieties for cultivation on farmers. But in the end, these varieties are not very well received by farmers due to the lack of performance stability in the real conditions of the farmer (Ceccarelli and Grando, 2022).

3. Participatory plant breeding and service to poor and dry farms

The new breed has a very important role in increasing agricultural production and the potential of this increase is increasing despite the progress in various fields of plant breeding techniques. However, high-yield cultivars improved in research stations are not always preferable to local cultivars, and also many cultivars grown in research farms or in the farms of rich farmers who can afford agricultural inputs (chemical fertilizers, chemical pesticides, etc.) have high-performance potential. Meanwhile, the small farms of farmers and weaker in terms of finances are not able to provide the above agricultural inputs. Therefore, it cannot have high-performance potential. Of course, the number of these small farmers is significant (Allahgholipour and Hossieni Chleshtori, 2020). Therefore, the use of participatory plant breeding techniques to support small-scale farmers can also be considered. In other words, poorer farmers who do not have the power to use additional inputs (which are required for seeds produced by conventional or concentrated plant breeding methods) therefore do not benefit from the cultivars modified by concentrated methods and become poorer over time (Bhargava *et al*., 2019).

4. Participatory plant breeding relationship with the theory of plant breeding and the advantage of maintaining genetic diversity

Plant breeding for specific adaptation to adverse environments requires a re-evaluation of the role of genetic resources such as native populations, which can

play an important role because they have traits adapted to these environments. This is the first consequence of plant breeding on biodiversity for specific adaptations. When local varieties are used in cultivation these cultivars have been able to maintain their stability against the attack of pests and diseases for many years, so the risk of epidemics of pests and diseases is very low. However, the distribution and availability of suitable varieties to small holder farmers do not need to follow the conventional methods of propagation, seed production, and seed certification used in developed countries. Indeed, there are examples of successful distribution and adoption of varieties through non-market methods (Begna, 2022). Due to the existence of pests and diseases, the variety of environmental conditions, and the diverse tastes of consumers and other factors, protecting the genetic diversity of plant gene stocks seems very necessary. Therefore, according to the theory of population genetics, the reduction of genetic diversity limits the maneuverability of a species against changing selection pressure, so knowing the genetic structure of species populations is necessary for their protection, with proper planning and management (van Frank *et al*., 2020). Of course, classical breeding usually leads to a decrease in genetic diversity (Vincourt and Carolo, 2018). In cooperative multi-breeding programs, modified cultivars that have favorable conditions in terms of performance and resistance to pests and diseases are crossed with local varieties, and therefore farmers show more luck in using these hybrid genotypes. In other words, biodiversity in general and agricultural biodiversity, in particular, are very important for adaptation to climate change, resilience, and human health in relation to food diversity. Plant breeding is a process of creating diversity with the help of crossbreeding, with the help of selection, within the range of the created diversity and by examining it during different years (depending on the type of plant), finally, a new variety is obtained, which in several years and several locations must be stable in order for the seed to be legally commercialized. Participatory plant breeding has been promoted because of its advantages of increasing selection efficiency, embracing diversity, and empowering farmers, and because it is more socially just than conventional plant breeding (Renard and Tilman, 2019; Ceccarelli and Grando, 2022).

In Fig. 1, for example, 4 farms can be considered and genotypes studied, and from the first farm to evaluate the selection of genotypes tolerant to drought stress, the second farm to check the selection of genotypes tolerant to cold, the third farm to evaluate, the selection of disease-tolerant genotypes and the fourth farm were used to evaluate the selection of pest-tolerant genotypes. In fact, with the help of the farmer and under the conditions of the farmer, the seeds of the related plant are checked. Both time and costs are saved, and the selection process is carried out according to the seasonal changes under the supervision of the researcher. Of course, such a review has also been reviewed by Ceccarelli and Grando (2020).

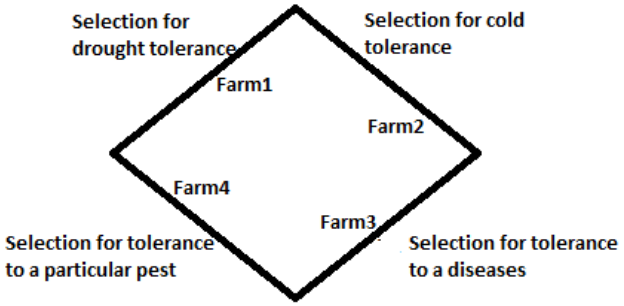

Figure 1. One genotype (genotypes) is distributed among different farmers (4 farms), Representing different target environments

5. Participatory plant breeding and plant development

Plant breeding by developing cultivation with the help of participatory plant breeding can help farmers' ability, which increases national production and also reduces poverty. Of course, active farmers can expand livestock activities in addition to developing this very important technique, which will increase genetic diversity and can improve the continuity of agricultural production with the created climate conditions. In Iran, the development of camelina oilseed plant cultivation is a valuable example of plant development with the help of participatory plant breeding technique, which was carried out by Bistun Shefa Medicinal Plant Cultivation and Development Company (Kermanshah-Iran) and developed strongly. Of course, participatory plant breeding can be followed in trans-territorial cultivations in different regions of the world, for example, it may not be possible to produce a specific product in a certain region, in which case we can test and develop it in other regions. Also, in trans-territorial

cultivation, there is an opportunity to exchange information and learn about plants that can grow and develop in the conditions of the farmer. Therefore, it is very necessary to develop plants as one side of the three sides of participatory plant breeding in participatory plant breeding technique (farmer, researcher and plant development can be considered complementary three sides in participatory plant breeding technique).

In general, plant breeding alone cannot lead to the creation and acceptance of multi-crop systems. Along with changes in reform approaches, changes in broader, private-sector research are needed. These changes include policies and investments that support the transition to multi-crop systems, increased interdisciplinary collaboration to support cropping system development, and public and private sector leadership to develop and promote the adoption of new cultivars. In order to support the transition to multi-crop systems, breeders should change their breeding programs and objectives to create more diverse systems, including diverse rotations, alternating seasonal crops, ecosystem service crops, and intercropping systems (Moore *et al*., 2022).

6. Participatory plant breeding and food security

Food security is improved through the rational use of resources and better adaptation of varieties and seeds to environmental conditions, and new options are offered to farmers, as well as traditional environmentally friendly practices are strengthened and maintained (Albahri *et al*., 2023). According to the UN definition, food security is the access of all people to enough food at all times to have a healthy body, and its three important elements; Availability of food, access to food, and sustainability in receiving food. The availability of food includes the amount of food within national borders through domestic production and food imports. Access to food, physical and economic access to resources, in order to provide the food items needed by society and sustainability in receiving food, is the stability and sustainability of receiving the nutritional values needed by the society (Tanumihardjo *et al*., 2020). The Global Food Security Assessment and Nutrition Report found that 9.2 percent of the world's population (about 700 million people) were likely to experience hunger and severe levels of food insecurity. Adding to the average level of food insecurity is a projected total of 26.4 percent of the world's population (2 billion people) who were food insecure (FAO, 2020). To deal with food insecurity, participatory programs, highlighting community-based food security improvement strategies and a wide list of safe food production techniques and methods are essential to creating this security for local projects and small holder farmers. Ownership and training of these farmers were used for food production (Doustmohammadian *et al*., 2022). Therefore, it is useful for participatory plant breeding to produce food in geographical microclimates using indigenous and local knowledge in this field, and this can be useful for everyone. Use available resources to support local agricultural knowledge for food production. Pesticides are a threat to human health and a sustainable threat to the environment. Governments must work with agriculture, health and environment sectors, private sectors, as well as food industries to tackle complex issues sustainably and reduce pesticide use and sustainable risks (Sapbamrer *et al*., 2023). The use of chemical pesticides contaminates the diet and water (Teysseire *et al*., 2021). In relation to participatory plant breeding and healthy food production, it should be noted that local farmers, due to their awareness and knowledge of arable land and seeds at their discretion, are able to reduce the use of chemical pesticides by planting local cultivars that are resistant to pests. As a result, these pesticides do not enter the remaining agricultural products, and food hygiene and health are respected, which is also one of the advantages of using cooperative breeding techniques. It is in the production of healthy food.

7. Successful examples of participatory plant breeding in Iran

Planning to carry out plant breeding activities using agricultural sector operators can be a new and common method in interbreeding and change the future of plant breeding (Allahgholipour and Hossieni Chleshtori, 2020). The samples produced by participatory plant breeding techniques regarding agricultural plants such as rice, wheat, and barley (with rainfed and irrigated cultivation), alfalfa plant, etc., are successful and effective examples in the form of production by this technique. Naeimi et al. (2017), in the study of the participatory plant breeding technique, stated that the farmers stated the problem of lack of communication and coordination between the various departments

influencing this technique as the problem and challenge ahead to achieving success in this method. They also stated that the ability to use seeds in fields, to investigate the ability of new varieties in different microclimates, as well as the ability to exchange knowledge and experiences of other farmers are among the relative advantages of this plant breeding method.

8. Alfalfa plant and the importance of participatory plant breeding and breeding in Iran

One of the successful examples of participatory plant breeding can be called the treasury of 150 alfalfa populations collected with domestic and foreign origins (in the Faculty of Agriculture of Bu Ali Sina University in Hamedan-Iran). Susceptible to alfalfa leaf weevil pest and studied its molecular aspects in some of these populations and varieties tolerant to weevil were identified. Such populations and valuable treasury can be visited by farmers and can be produced under the conditions of the farmer and different aspects of the environment and nutrition can be tested in the microclimates available to the farmer (Kakaei and Mazahery-Laghab, 2015). Because the different environmental conditions of agricultural microclimates may cause different environmental conditions for pest growth and subsequent damage percentage (Skendžić *et al*., 2021).

9. The need to focus and research on oilseed plants via participatory plant breeding

After cereals, oilseeds form the second-largest food reserve in the world. These plants are known as the most important sources of oil by supplying unsaturated fatty acids. The position and importance of oilseeds in terms of food security and comprehensive economic development are one of the indicators of development, therefore the cultivation of oilseed plants compatible with climatic conditions and the development of research programs such as participatory plant breeding should be considered.

Oilseeds as industrial plants have many applications in human nutrition and their meal in livestock, poultry and many industrial uses. This wide scope of consumption in various fields confirms the depth of necessity and importance of this special product. Due to the diversity of vegetable oils, oilseeds are considered one of the most strategic agricultural products (Tavassoli *et al*., 2022). Perhaps, in addition to the many relative advantages that oilseed plants have over other crops, the following can be mentioned, including high seed loss, lack of sufficient experience of all farmers, lack of nutritional knowledge of farmers, and low yield. Due to these weaknesses that have been mentioned, it seems that the participatory plant breeding technique can find a way out of these cases in reducing the mentioned weaknesses with the help of the farmers themselves.

One of the most important challenges of rural development from the perspective of sustainable development in Iran is the migration of manpower from rural areas. This challenge weakens the rural economy and culture and causes the aging of the workers in the agricultural sector. Considering the strong role of economic factors in the migration of rural people to the city, any factor that can lead to the creation of employment with adequate income in the villages will help the sustainable development of the village (Abdollahzadeh *et al*., 2019; Tavassoli *et al*., 2022). By the way, the participatory plant breeding technique is considered a suitable version to solve this problem.

Currently, according to the conditions of more or less reduction of rainfall and the need to produce healthy oil crops (El Sabagh *et al*., 2019), the need to plant oilseeds for dry and low-water climatic conditions with low fertilizer requirements is felt. Also, due to the high consumption of water in oil plants such as rapeseed and soybean, it seems necessary to introduce and produce a camelina oil plant, which is a low-expectation plant. There is a strong possibility that the development of camelina in Iran's semi-arid fields is the result of this cooperative breeding technique. The potential of developing and multiplying such plants with the help of cooperative breeding is felt in all regions.

10. Cereals and the need to develop and conduct research on them in Iran

Increasing genetic diversity in rainfed wheat (and barley) fields and paying extra attention to special adaptation to increase the productivity of microclimates in Iran's rainfed areas are effective methods to deal with environmental and biological stresses and are among the solutions. The most effective way to achieve these things is the implementation of a part of the breeding program of research stations in farmers' fields (target areas) and the

use of local knowledge and many years of experience of dry farmers in the form of a participatory plant breeding program (Elahi *et al*., 2011). Elahi et al. (2011) in the study of 21 bread wheat genotypes in terms of grain yield and physio-morphological characteristics related to drought tolerance in cooperative multi-breeding programs in farmer conditions, generally stated that the average score of farmers has a positive relationship with grain yield. And it was significant at the probability level of 5%, and they also stated that the choice of farmers based on the appearance of the product is reliable to identify high-yielding cultivars. In rice, Allahgholipour and Hossieni Chleshtori (2020) introduced successful examples of rice cultivars with the help of participatory plant breeding techniques and the cooperation of farmers.

11. Conclusion

Considering that according to the mentioned contents, the participatory plant breeding technique has many relative advantages. Among its advantages are the rapid promotion and promotion of high-yield cultivars with sufficient evidence, reducing the cost of promoting the characteristics of high-yield cultivars, more local farmers being more likely to accept high-yield production seeds, increasing yield, and finally increasing farmers' profits. Reducing research costs in research stations (Allahgholipour and Hossieni Chleshtori, 2020) and more importantly, increasing the food security factor. In the classical plant breeding method, to create a variety, it is necessary to investigate and study different lines for many years in different places, which requires a lot of money and time, and of course, this high-yielding variety may become a pest after several generations or a certain disease becomes sensitive and is released from the production cycle. Also, in classic and usual breeding, the choice of the farmer to select varieties is very limited, while in the participatory plant breeding technique and method, different genotypes are provided to agriculture and it can have wider choices. This respect is for the taste and preferences of the farmer according to his conditions. Even in a small microclimate, soil conditions, and other conditions may be different for two farmers. When the farmer participates in the participatory plant breeding technique in the production of a new variety, the farmer's motivation and attention to this variety is increased for cultivation, and therefore he considers himself the owner of the production variety (along with the researcher, of course). Therefore, the farmer, because he was in the process of all the stages of creating the variety, will have the role of a researcher, promoter, and transmitter of the research findings at the same time, and in public circles in the village (especially during the days of low agricultural work), he will tell the characteristics of the product variety and how to produce it. That this work manages many costs and these costs can be used to advance other requirements. Climate change requires a dynamic response with rapid impact at the farm level and in farmer conditions. Changes in the spectrum of pests, associated with changes in temperature and rainfall, pose a challenge to focused breeding programs (classical plant breeding). A breeding program based on decentralized selection is dynamic, so it is able to expose breeding materials to a wide range of target environments, including locations, years, crop management, and social contexts (Ceccarelli and Grando, 2022). Most likely, the main obstacle to the streamlining of PPB is that agricultural biodiversity, which is created in space and time, requires a dispersed seed system created by small enterprises, possibly organized with the participation of farmers themselves. Such a system does not lend itself to centralized control. (Ceccarelli and Grando, 2022).

Conflict of Interests

Both authors have stated that there is no conflict of interest.

Ethics approval and consent to participate

No human or animals were used in the present research.

Consent for publications

The final article has been approved by both authors of the study and its content.

Availability of data and material

All the data are embedded in the manuscript.

Authors' contributions

The original draft of this version was written by the first researcher and revised and revised by the second researcher.

Informed Consent

The authors declare not to use any patients in this research.

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