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AGROFORESTRY - ORGANIC - PARTICIPATORY
HOW TO CLUSTER THESE TERMS IN A PLANT BREEDING PROGRAM?

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Abstract: "Agroforestry", "Organic" and "Participatory" are 3 keywords not enough affixed and thought together. The challenge is to link them into breeding programs to release AgrOrgForestry-adapted varieties. To be adapted both to Agroforestry and to Organic conditions, a crop variety must present environmental responses traits but also effects traits. Participatory Ecobreeding is the most useful way to breed such variety. The involvement of a great diversity of actors (farmers, processors, consumers, researchers, etc) renew the way to envision agroforestry and organic breeding and to target no more GMO but SMO and even SEMO (Socially and Environmentally Modified Organisms).

Introduction: Agroforestry and Organic: a bond that is tightening?

Agroforestry (AF) is often defined as "an ecologically-based land management system that maintains ecosystem diversity and processes contributing to long-term sustainability and environmental quality". But surprisingly in Europe and mainly in France, AF -notably alley cropping- was mainly implemented by conventional farmers, using chemical herbicides, pesticides and mineral fertilizers. On one hand, AF was sold as enhancing biodiversity of plants and insects and on the other hand, it was managed by intensive methods known to kill biodiversity.

This paradox interrogates the capacity of organic farming to well address stakes of agroforestry.

In France, organic AF knows, currently, a shy development and is mainly oriented towards systems mixing fruit trees and vegetables or crops.

Concerning the understorey crops, two needs have to be clustered: adaptation to organic conditions and adaptation to fruit trees association.

But these needs are not yet fulfilled. For instance, in France, the first variety selected for- and -into organic conditions was LA1823 (durum wheat), that had not being registered because of a lack of official organic evaluation network at that time (2005). Since, only 5 soft wheat varieties, especially breed for organic farming, have been registered in France. No one for AF conditions.

The demand for varieties presenting traits well adapted both to organic and to agroforestry is increasing. The question is: Is-it the same ideotype required for both?

Material and methods:

Organic-adapted varieties: what are the required crop traits?

Because herbicides and fungicides are prohibited and organic fertilizers are expensive, Organic agriculture requires varieties that are competitive with weeds, resistant to disease and efficient in the use of resources (water, N, P, K).

For instance, the useful traits for cereals to compete with weed are: early sowing to tolerate mechanical weed control, emergence seedling vigor, rapid biomass accumulation and ground cover, tillering capacity, high plant height, relevant leaf characteristics and canopy structure able to intercept light (leaf area index, flag leaf length and open angle), competitive roots, etc.

Concerning disease resistance, the diverse strategies used by varieties to fight infectious microorganisms (fungi, bacteria, viral and nematodes) off, should be considered in a breeding program. Among them, the ability to keep a barrier at stem and leaf level, to use of inducible defenses (toxins, enzymes, antimicrobial proteins), to close stomata rapidly, to show hypersensitive response (rapid cell death), to use endophyte assistance (the roots release chemicals that attract beneficial bacteria)[1] helps reducing infection.
The traits to improve resources use efficiency are numerous. For instance, improving N use efficiency encompasses increasing N uptake, N utilization efficiency, and N harvest index, each involving many crop physiological mechanisms and agronomic traits. Headforming crops (lettuce, cabbage) depend on the prolonged photosynthesis of outer leaves to provide N supply to the photosynthetically less active, younger inner leaves. Grain crops largely depend on prolonged N availability for uptake and for remobilization to the grains. Improving root performance is relevant for all crop types, but especially short cycle vegetable crops benefit from early below-ground vigor[2].

Agroforestry-adapted varieties: what are the required crop traits? Are they compatible with organic traits?
In AF systems, the presence of trees imposes to consider others important traits for the associated crop related to the easiness of management and to the above and belowground interactions.
Concerning the first point, duration of crop cycle must be compatible with the fruit tree phenology. For instance to facilitate the harvest of fruits (e.g olives), the associated crop (e.g. cereals) should be sown after fruit harvesting. Therefore late sowing is often targeted and farmers are looking for crop varieties able to support consequently high temperature during grain development.
Aerial interactions such as changes in light, temperature, and humidity are frequently cited in terms of possible effects on understory crops. Tolerance to shade (horizontal leaf orientation, low leaf area index[3]) or ability to bear some adverse conditions (e.g. excess of humidity) are useful to consider as breeding traits. The "aggressiveness" of the crop for capturing moisture and nutrients is subject to discussion. Because, rather than competition is the facilitation between crop and tree that must be sought.
Bird and insects damage may be important in AF, as trees are hosts of them or create favorable conditions. Biochemical or morphological genetic traits in some crop varieties protect ripening seeds or grain from these damages. For instance, “bird-resistance” in some varieties may come from open-head or lax-panicle known to limit perchfeeding for birds (sorghum), from large glumes (cereals), from long awns (wheat, millet), from longer, heavier husks (corn) that were difficult for birds to penetrate, or from concave heads facing the ground, long bracts and seed held tightly (sunflower) [4] .
Concerning belowground interaction, the ability of an associated plant to explore the soil and capture its resources is largely determined by the architecture of the root system and its altering in response to environmental cues, the biogeochemical interactions occurring in the root-soil interface and root resource uptake efficiency resulting from efficient intrinsic transport and signaling. To avoid underground competition with deeper tree roots, superficial crop roots are sometimes considered as a breeding trait to target.

Results: towards an Organic AgroForestry-oriented breeding
Some of the breeding traits are common between organic and agroforestry adaptation but some others like phenology, roots architecture, plant morphology may differ. These differences must be seen as highly challenging for plant breeding.
Moreover, one of the great specificities of organic agriculture and agroforestry is to require the consideration of two main types of variety traits: responses traits and effect traits[5].
Response traits are those outlined above and concerning the response of plants to the environment (weeds, pathogens, nutrients and water limitations): notion of resistant, tolerant, competitive varieties are usually called up. Among effects traits, we may include not only service traits such as attractiveness of auxiliaries, soil aeration, stimulation of natural defences, storage of carbon by increased biomass, stimulation of the soil microbiome, allelopathy,[…], but also traits that allow the variety to contribute positively to the biophysical, economic, and social environment.
At the farming level, the challenge is to achieve a complex balance between competition vs facilitation, adaptation vs contribution.
But the challenge is also to take into account process, market and consumers levels.
In organic and AF system, clustered into OrgAgroForestry[6] or AgrOrgForestry, the great diversity of processing methods (slow and soft process, e.g. stone mill, drying in open air and not at UHT, etc.), and of distribution channels (short chain, on farm sales, etc.) of the products, oblige to integrate new processing, organoleptic and nutritional traits into a plant breeding program.

This major diversity cannot be managed by one person alone but it is a collective that must be involved in Ecobreeding[6] approaches that then become participatory.
The critical participation of everyone, in the service of the collective, allows taking into account the diversity of each individual's demands in terms of varieties adapted to the AgrOrgForestry.

Discussion: Perspectives
Ecobreeding for OrgAgroForestry emphasizes the need to strengthen the sustainability of AF. It implies to implement ecological plant breeding through participatory approaches.

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