Which Wheat for Smallholder Ethiopian Farmers? Joining Traditional Knowledge with Metric Phenotypes

C. Mancini[1], Y.G. Kidane[1,3,4], D. K. Mengistu[2], M.E. Pe`[1], C. Fadda[4], M. Dell'Acqua[1]

[1] Scuola Superiore Sant'Anna di Pisa, Italy; [2] Mekelle University, Ethiopia; [3] Sirinka Agricultural Research Center (ARARI), Ethiopia;
[4] Bioversity International, Ethiopia; [5] University of Bologna, Italy

Abstract

Smallholder farms account for most part of the African farming system. In Ethiopia, smallholder farming employs more than 75 million people, whose subsistence depends on low yielding agriculture exposed to increasingly erratic precipitations. Modern varieties developed for high-input agriculture might not be suitable for the marginal areas of Ethiopia, as they fail to address the enormous diversity of environments and end-user needs. The unique diversity of Ethiopian durum wheat (*Triticum turgidum* L. subsp. durum) is the result of thousands of years of selection operated by smallholder farmers. A better understanding of this traditional knowledge may help in identifying and disseminating material aimed at addressing local needs. We involved 60 smallholder farmers in two locations in Ethiopia to evaluate traits of their interest in 400 wheat accessions, producing 192,000 data points. We couple this information with metric measurements of 10 agronomic traits, breaking down farmers' preferences on quantitative phenotypes. We found that the relative importance of wheat traits is gender- and locality- dependent, and produced a ranking of the 400 varieties identifying the combination of traits most desired by farmers.

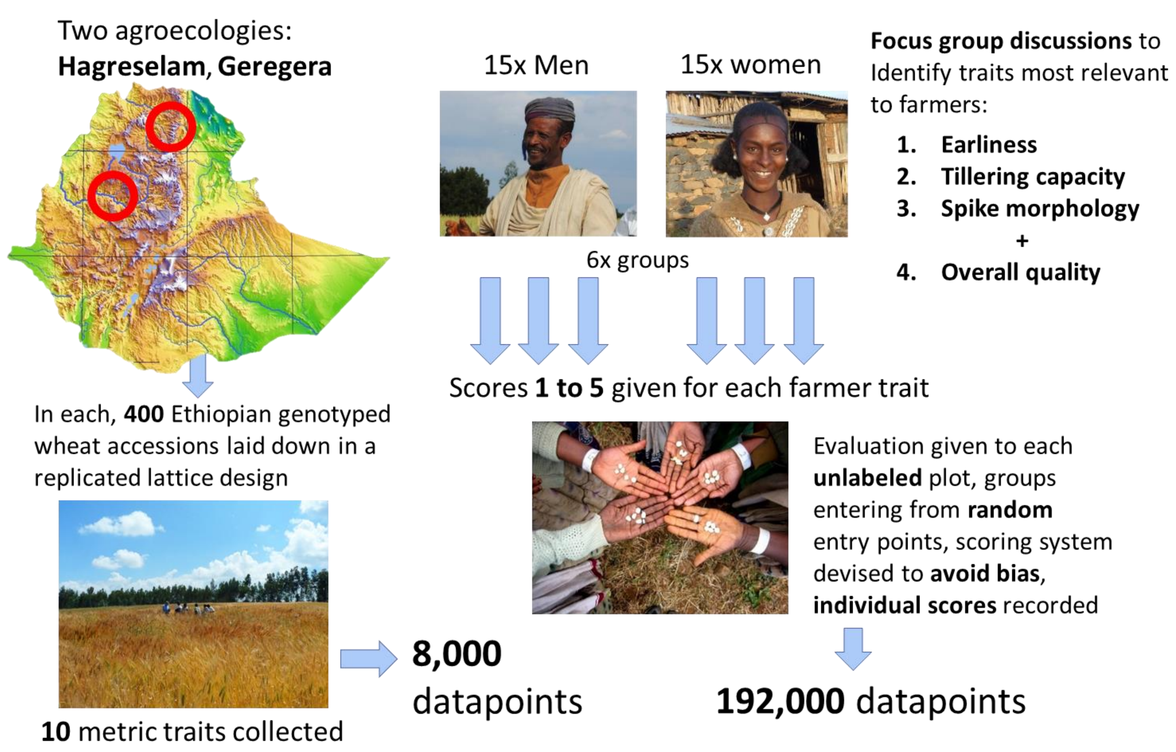

Figure 1 – Diagram showing our approach. In the 2 locations we concurrently characterized 400 accessions using agronomic traits and farmers' evaluation.

The Role of Smallholder Farmers in Food security

Addressing the need of smallholder farmers and provide them with superior varieties well adapted to local conditions is an essential strategy to address food security in 21st century. The breeding of few varieties with good average yields over a number of agro-ecologies is not sufficient anymore, particularly when there is a need to produce more food with less inputs under changing climatic conditions. A better strategy is to maximize yields at any given location by identifying and selecting the most productive varieties for that site. This is particularly important if we consider that, according to FAO, smallholders produce around of 70% of the bulk of food in developing countries and they represent the majority of the population (98% of the world's farms are small farms).

Involving those farmers in the identification of those superior varieties was a winning strategy for durum wheat in Ethiopia, as they are very knowledgeable about the crop, their soils, prevalent environmental conditions, pests and diseases.

The Approach

The study was conducted in two very different agro-ecologies of Northern Ethiopia in 2012 (Figure 1). Thirty farmers per site (15 males and 15 females) participated to a Focus Group Discussion (FGD) to share main climate related changes and most important traits related to durum wheat production. At the same time we grew 400 accessions, including 27 improved varieties and 273 farmers' varieties obtained from the Ethiopian National Gene Bank and we measured 10 agronomic traits in 2 consecutive seasons. Eventually, we ended up with 3 traits evaluated by farmers during participatory evaluation (tillering capacity, spike, earliness) and a fourth overall score. For each accession and for each trait farmers had to provide a score from 1 (poor) to 5 (excellent). We then merged the 2 databases to link traditional knowledge with scientific characterization.

Results

Correlation between farmers' score and the metric measures of phenotypes is essential to understand how the perception of farmers of different genotypes correlate with agronomic evaluation of the accessions. Table 1 shows the correlation between the farmers' scores and analogous agronomic data. Overall would give a clear understanding of which traits are considered more important by the farmers in the 2 locations. It is clear that overall is largely affected by grain and biomass yield, the number of seeds/spike and plant height in both locations. Biomass is important as straws are used as construction material or animal fodder while yield and yield components are important for food security and livelihood.

A canonical correspondence analysis (Fig.2) confirm that spike associated traits and biomass and grain yield are the most important selection traits in both sites.

Based on farmers' preferences, we were able to rank the varieties in both sites in order to be able to distribute them for further testing. Interestingly, while the top 50 varieties are selected from the same combination of traits, only 38% of the genotypes were co-identified. This is shown in figure 3, a principle component analysis of the phenotypic values for both sites representing 75% of the total variance.

	Hagreselam				Gere Gera			
	Earliness	Tiller capacity	Spike morphology	Overall	Earliness	Tiller capacity	Spike morphology	Overall
Days to maturity	-0.734**			0.176**	-0.771**			-0.247**
Number of fertile tillers		0.268**		-0.054		0.261**		-0.03
Spike length			0.029	-0.112*			-0.05	-0.047
Number of seeds per spike			0.314**	0.331**			0.482**	0.442**
Grain yield				0.417**				0.485**
Plant height				0.359**				0.374**
Biomass yield				0.362**				0.031

This result is very useful as it provides clear indications to breeders on farmers' varieties. It is also very useful top note farmers' perception of climate change as it emerged from the FGD: farmers mentioned an increase in temperature, which reflects the average annual minimum temperature increase by about 0.37°C every ten years in Ethiopia. However, the shorter duration of the rainy season was most important climate related threats identified by farmers. Rainfall trends are difficult to analyze at a local level, as the available historical series are riddled with gaps and span intervals covering different years. The Ethiopian wheat farming system is rain-fed for the most part, thus justifying farmers' focus on rainfall. In this situation, early wheat varieties are advantageous.

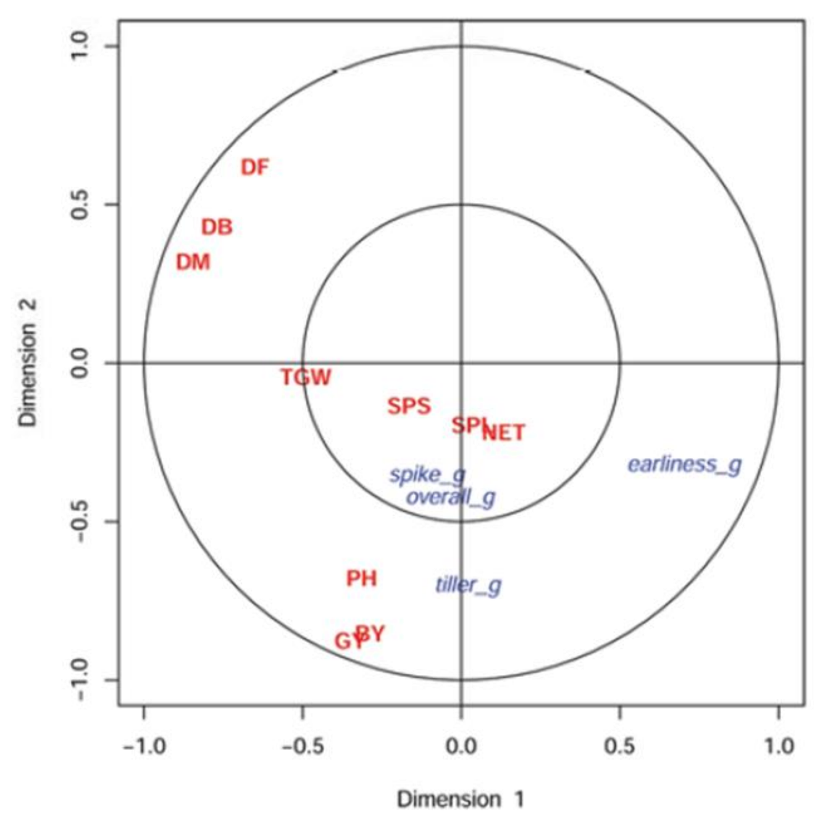

Figure 2 – CCA biplot of the original variables in the first two dimensions of the CCA space. The agronomic measures are shown in red. The PE scores are shown in blue.

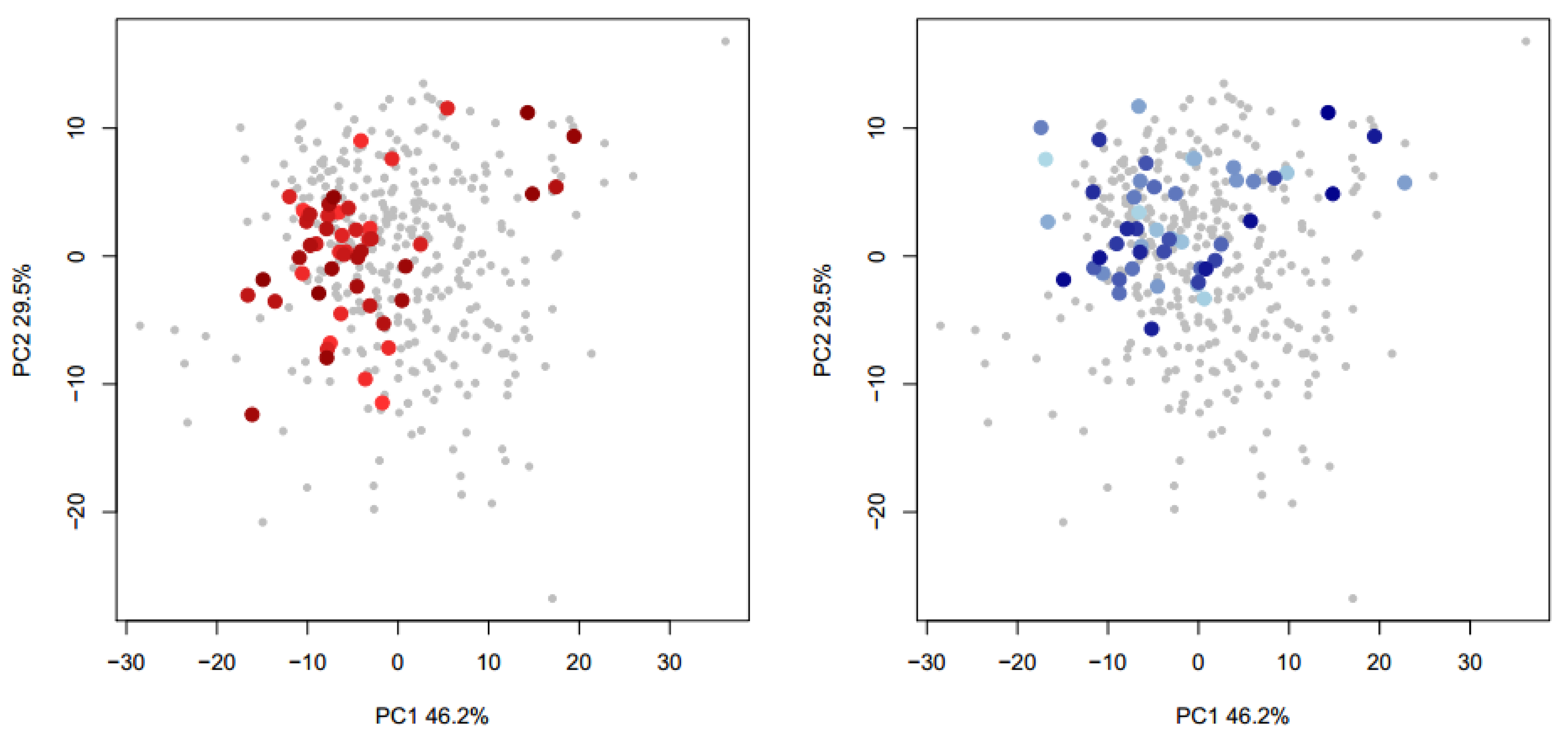

Figure 3 – top 50 varieties in increasing shades of color. On the left, Hagreselam; Geregera on the right. PC 1-2 explain most of the phenotypic REML variance, although with little structure.

Way ahead

Smallholder traditional knowledge can be gathered and related to quantitative traits, a necessary step towards the design of locally adapted ideotypes. Here we broke smallholder farmers' perceptions onto metric phenotypes, linking traditional knowledge with scientific knowledge. The evaluation of an untapped collection of wheat diversity allowed us to survey their preference towards specific trait combinations and to inject novel genetic diversity into the local farming system. Farmers from the two agro-ecologies selected similar trait combinations, but found them in different varieties. This reflects differences in genotype performances in the two agro-ecologies, supporting the notion that local adaptation may maximize yield at any given location and favor farmers uptake of genotypes. In this study, several famer varieties ranked above modern varieties in the tested agro-ecologies. Based on PE ranking outcomes in each location, 20 farmer varieties were distributed to 200 farmers in each location following a crowd-sourcing approach that in 2014 involved a total of 924 individual households in 24 villages. Focusing on a narrower set of wheat genotypes on a broader collection of environments will advance our understanding of farmers' perception of a wheat genotype value, helping to address the local needs of smallholder agriculture.

Poster presented at Tropentag 2016, Wien, Austria,18th-21st September 2016