Comparison Between the Prognostic and the Traditional Methodology of Crop Genetic Improvement

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Introduction

Traditional breeding adopted the densely-grown field plot as its unit of evaluation and selection. **Prognostic breeding** is an integrated crop improvement methodology founded on the principle that the unit of evaluation and selection is the individual plant grown in the absence of competition. Individual plants are evaluated for two parameters that constitute the components of the crop yield potential (Fasoula and Fasoula 2000; Fasoula 2013). The first parameter is the plant yield potential and the second is the plant yield stability and heritability. The product of the two parameters is the crop yield prognostic equation (Fasoula 2006, 2013), the elaboration of which is closely linked with the development of the honeycomb selection designs (Fasoulas and Fasoula 1995). Details on the principles and research of this methodology are analyzed in the review papers (Fasoulas and Fasoula 1995; Fasoula and Fasoula 1997, 2000, 2002, Fasoula 2013)

PROGNOSTIC BREEDING

CROP YIELD COMPONENTS →	Plant yield potential	Plant yield stability and heritability
	↓	↓
MEASURING PARAMETERS →	$(x/\bar{x}_r)^2$ Yield index	$(\bar{x}_g/s)^2$ Stability index
FIELD DESIGNS →	Honeycomb selection designs	

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$$pPE = (x/\bar{x}_r)^2 \cdot (\bar{x}_g/s)^2$$

Prognostic Equation measures the crop yield potential of single plants

Fig. 1. An example of a honeycomb field design evaluating switchgrass plants in the absence of competition

Principles upon which prognostic breeding is founded

1 - Crop yield is maximized when all plants in the field share equally the growth resources and produce the same yield. Equal sharing of growth resources is achieved through the use of monogenotypic cultivars

2 - Competition, i.e, the unequal sharing of growth resources among plants, being either genetic or acquired, affects negatively both crop yield and selection efficiency

3 - Crop yield is affected negatively by competition because plants' competitive advantages fail to compensate for their competitive disadvantages

4 - The negative effects of competition on crop yield are reduced by the use of monogenotypic cultivars and by a number of other agronomic measures (i.e., even distribution of seeds across fields, synchronous germination and growth of plants, etc)

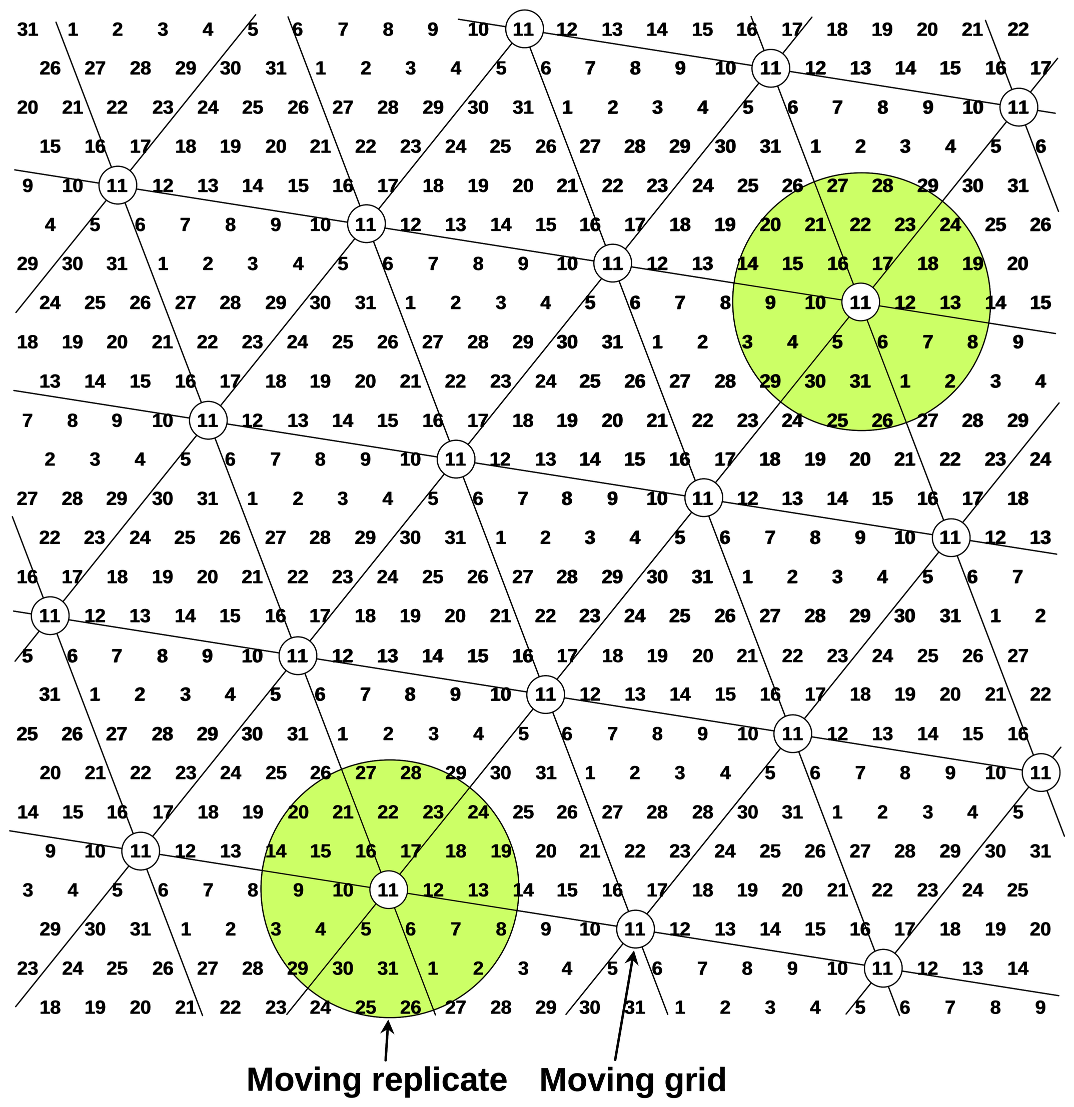
5 - Selection efficiency is reduced drastically by competition because of the negative relationship between yielding and competitive ability which, under dense stands, favors selection of low yielders/strong competitors plants at the expense of high yielders/weak competitors plants

6 - The negative effects of competition on selection efficiency and the need to maximize the phenotypic expression and genetic potential of plants necessitate the adoption of the **individual plant grown in the absence of competition** as the unit of evaluation and selection

7 - Evaluation of single plants for crop yield potential necessitates the partition of the crop yield potential into genetic components

8 - Crop yield potential is partitioned into two components measured in the same generation (concurrently) by utilizing sibling lines instead of progeny lines. The first component is the plant yield potential and the second is the plant yield stability and heritability

9 - Accurate measurement of the crop yield components is accomplished by innovative field designs known as honeycomb selection designs or moving complete block honeycomb designs. The designs form moving replicates and moving grids to effectively control soil heterogeneity



Honeycomb designs allow selection for

$$pPE = PYI \cdot SI = (x/\bar{x}_r)^2 \cdot (\bar{x}_g/s)^2$$

x	yield of each plant
$\bar{x}_r$	mean yield of the plants within the moving replicate
$\bar{x}_g, s$	mean yield and standard deviation of the moving-grid plants
pPE	plant prognostic equation

Fig. 2. An example of a replicated-31 honeycomb design that evaluates plants of 31 sibling lines. Each plant is placed in the center of a moving complete replicate (green circles). The plant yield index (PYI) measures plant yield devoid of the confounding effect of soil heterogeneity. Plants of each line are placed in the corners of triangular moving grids (shown for line no. 11) which ensure effective sampling for soil heterogeneity. The moving grid allows measurement of the stability and heritability of each line by using the stability index (SI)

10 - Prognostic breeding studies revealed that epistatic interactions among nonallelic loci belong to three categories, i.e., interactions among hemizygous loci, heterozygous loci, and homozygous loci. Results obtained by the application of the prognostic equation in different crops (Fasoula 2006, 2012, 2013; Greveniotis and Fasoula 2016) elucidated the role of the three types of epistasis in the control of important genetic phenomena

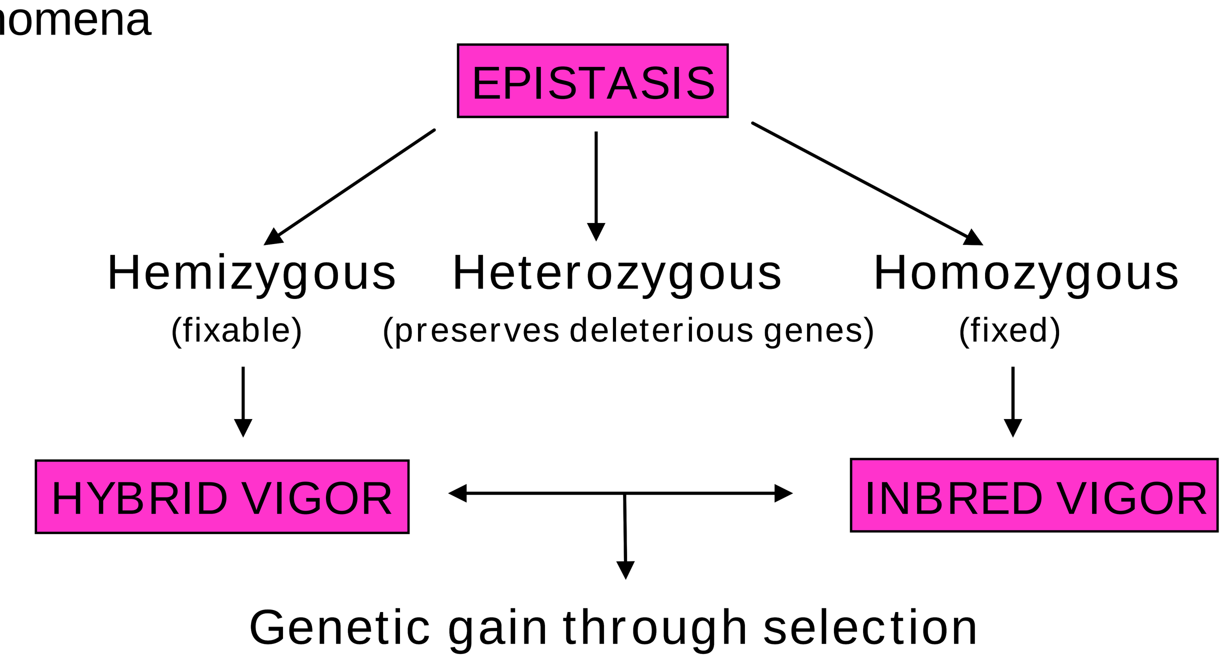


Fig. 3. Hybrid vigor is controlled by hemizygous and heterozygous epistatic interactions, whereas inbred vigor and advance through selection are controlled by homozygous epistatic interactions. Hybrid vigor controlled by hemizygous loci is amenable to immediate fixation, while hybrid vigor controlled by heterozygous loci masks deleterious genes. The three types of epistasis are interconnected and explain the genetic basis of crop improvement through selection

Conclusions

- **The principal differences between prognostic and traditional breeding are: 1) the replacement of the field plot with the individual plant grown in the absence of competition and 2) the replacement of progeny lines with sibling lines**
- **Prognostic breeding, by using the innovative prognostic equation, has paved the way to increasing the annual genetic gain and to the direct selection for crop yield potential and its prospective automation**

References

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