New field pea selections for Central and Southern Italy

CONTEXT

Conservation Agriculture in particular, and sustainable agriculture in general, are not compatible with the extensive monoculture and the repeated cropping of wheat that are widespread in rainfed areas of the Mediterranean region. **Including legumes in crop rotations** would be particularly valuable, because greater cultivation and utilization of these crops can contribute to climate change mitigation, lower energy consumption, increased soil fertility, more resilient cropping systems, greater feed and food security, and healthier food and living environments (Figure 1). **These crops, however, are little cultivated in Europe and North Africa** because of their wide profitability gap relative to wheat and other major cereals, which profited of much greater crop improvement research and usually greater supporting measures than legumes. This is why **legume yield improvement was one of the objectives of the project CAMA.**

CAMA identified field pea as a major target of its plant breeding effort, because this crop is:

(1) widely adapted to soil, climate and management conditions of the Mediterranean region, and fairly drought tolerant (because of its winter-spring cycle and early maturity);

(2) well-known by farmers of the Mediterranean region;

(3) flexible and diversified for crop use (feed or food grain; fodder; protein concentrates and isolates);

(4) more competitive against weeds than other grain legumes;

(5) not targeted by the international research centre ICARDA with a Mediterranean mandate, and promising on the basis of prior knowledge and available germplasm and genomic resources (also thanks to earlier projects such as LEGATO, REFORMA and GENLEG).

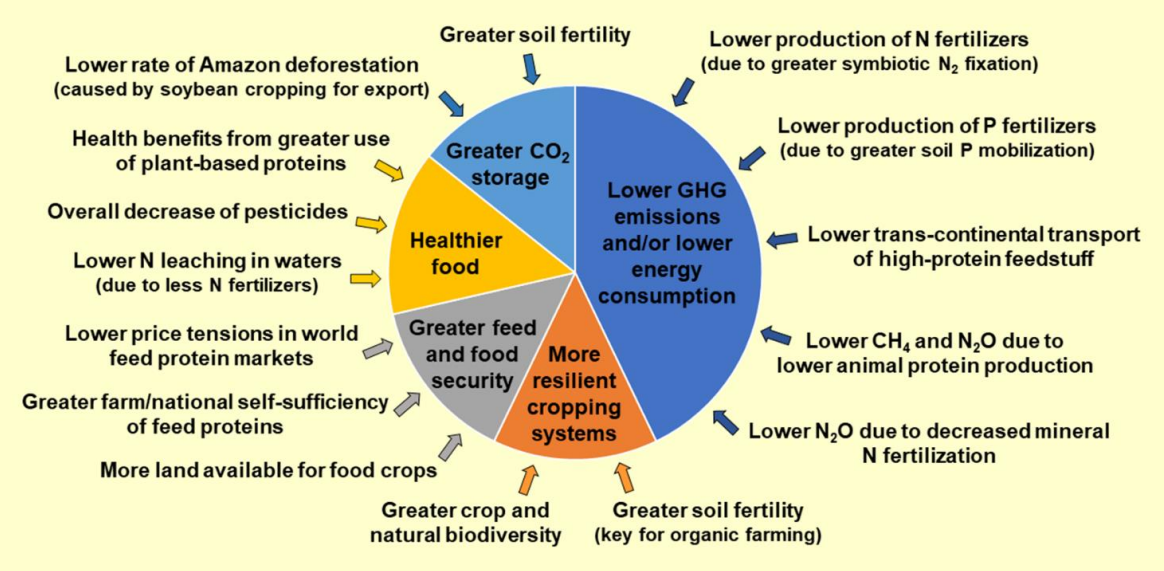

Fig. 1. Advantages associated with greater cultivation and utilization of legume crops

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WORK DONE IN CAMA

CAMA devised pea improvement research for different climatically-contrasting Mediterranean regions, namely, Central and Southern Italy, coastal Algeria, and inland Morocco. One aim was producing new cultivars with higher grain yield for each of these regions. A second aim was comparing the ordinary phenotypic selection of inbred lines with two innovative selection methods: a biotechnology-based one, i.e., the genomic selection of inbred lines (which could reduce the cost and the time needed for variety selection), and an agroecology-based one, i.e., the selection of evolutionary populations (which are genetically heterogeneous, unlike the inbred lines, and are characterized by very low selection cost).

All the selections originated from connected crosses between three international semi-dwarf, semi-leafless cultivars that displayed high and stable grain yield across climatically-contrasting Italian environments in earlier work. In Italy, the genomic selection targeted Central Italy (based on the model by Annicchiarico et al., 2019a) as well as a more stressful region roughly corresponding to Southern Italy (by combining the mentioned model and a second one based on plant responses in managed severe drought and in Morocco, reported by Annicchiarico et al., 2020), using genotyping-by-sequencing marker data. The evolutionary population evolved mostly under natural selection, initially for four years in Northern Italy (as described in Annicchiarico et al., 2023) and then for three years in Central Italy.

The selections were evaluated in field experiments under autumn sowing in Central Italy (Perugia) for two cropping years (2021-22; 2022-23) and under managed moderate drought in a large phenotyping platform in Lodi (Figure 2). The material in Perugia underwent a participatory evaluation by farmers of AIAB (Associazione Italiana per l'Agricoltura Biologica) according to a visual assessment (Figure 2) whose value has been highlighted by a specific study (Annicchiarico et al., 2019b).

Fig. 2. Left: farmers' participatory evaluation performed in Perugia in 2022-23.
Right: overview of the evaluation under managed moderate drought stress in Lodi

RESULTS

Results for **grain yield and other traits** of a subset of well-performing inbred lines and the evolutionary population bred for Italy and the three elite parent cultivars (which acted as reference commercial material) are reported in Table 1. The table reports the LSD value for each trait, which indicates the threshold of difference beyond which the values of two materials are statistically different with a probability of error ≤ 5%.

In Central Italy, the **lines AI_L23 and KI_L166 (selected phenotypically and genomically**, respectively, for this region) displayed a clear grain yield advantage over any other material (Table 1). They out-yielded also the top-yielding **cultivar Attika**, relative to which they showed a yield advantage of at least 43%. The line AI_L23 performed well also under managed drought, representing a mild-winter condition more similar to that of coastal areas of Southern Italy, in which Attika and a few early-flowering lines selected genomically for stressful Italian environments (AI_S144, KI_S92, AI_L231) were top-performing (Table 1).

Table 1. Grain yield and other traits assessed in a two-year field evaluation in Central Italy, and grain yield under managed moderate drought, for a subset of well-performing inbred lines issued by phenotypic selection (PS) or genomic selection (GS), one evolutionary population and three elite parent cultivars of the selected material

MATERIAL	Central Italy (Perugia)				Managed drought
	Grain yield (t/ha)	Farmers' acceptability (score 1-9)	Plant height (cm)	Onset of flowering (dd from Jan. 1)	Grain yield (t/ha)
New selections[a]					
AI_L23 (PS line)	4.48	7.0	52	50	4.16
KI_L166 (GS line)	4.40	6.4	49	48	3.20
AI_L155 (GS line)	3.96	6.2	46	43	3.96
KI_L16 (PS line)	3.78	7.6	57	54	2.31
KI_S184 (GS stress line)	3.74	4.7	45	39	4.08
AI_S144 (GS stress line)	3.54	5.2	44	40	4.89
KI_S92 (GS stress line)	3.53	4.8	44	38	4.42
AI_L231 (GS stress line)	3.41	5.6	47	45	4.36
Evolutionary population	3.50	6.3	57	50	3.50
Parent cultivars					
Attika	3.07	5.3	49	42	4.90
Isard	2.93	5.4	37	41	3.18
Kaspa	2.88	5.9	45	46	3.45
LSD (P < 0.05)	0.53	1.1	5	2	0.66

[a] *GS line: selected for Central Italy; GS stress line: selected for drought-prone environments of Southern Italy*

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The line **AI_L23 also displayed high farmers' acceptability** according to values of the score in Table 1 (ranging from 1 = very poor material to 9 = exceptional), whereas the line KI_L16 was top-ranking for this characteristic. Both of these lines had a relatively high plant stature (Table 1) along with good standing ability. This feature was appreciated by organic farmers because of its association with high competitive ability against weeds, and can be very important also for Conservation Agriculture.

The **evolutionary population displayed moderately high grain yield** in Central Italy and under managed drought, along with good farmers' appreciation and relatively high plant stature. Beside, this population exhibited **higher yield stability** than most inbred lines in the sample of drought-prone evaluation sites of the project Cama (which included also environments of Algeria and Morocco; data not reported).

Most best-performing inbred lines, such as the lines AI_L23, AI_S144 and KI_L16, possess a yellow cotyledon (which, for KI_L16, is accompanied by a reddish-coloured tegument) and are, therefore, potentially suitable also for the production of protein concentrates and protein isolates. Information will also be generated on the grain protein content of the new selections.

CAMA PROJECT FACTSHEET

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CONCLUSIONS AND RECOMMENDATIONS

The project CAMA succeeded in **generating a few potential varieties** which, for the main Italian target region (Central Italy), represent a clear **improvement in terms of grain yield and/or farmers' acceptability**.

The **line KI_L16**, which was top-ranking for farmers' acceptability, is undergoing the third year of evaluation in national trials **aimed to registration in the Italian Register of Varieties** (with the proposed name of 'Pimed'). The **lines AI_L23 and AI_S144** are under multiplication for further testing, before proposing at least one of them for registration in the Italian Register of Varieties.

The evolutionary population could be suitable for cultivation in **low-input or drought-prone environments**, particularly those featuring highly variable climatic conditions across years (as increasingly occurring due to the climate change). Because of its genetic heterogeneity, this material cannot be registered as a commercial variety. However, the EU allows the registration of populations of inbred species for organic farming as **Organic Heterogeneous Material (OHM)** since 2022, and this population will be proposed for registration within this framework.

CAMA produced also **important scientific information for crop improvement** of pea and other inbred grain legumes. It demonstrated the **value of genomic selection**, which generated inbred lines with agronomic value similar to that of phenotypic selection in a shorter period of time, and highlighted the adaptability and high yield stability of an **innovative and low-cost variety type such as the evolutionary population**.

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