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ABSTRACT: The research aims at selecting the most suitable high oleic sunflower varieties in different environments in order to produce pure vegetable oil as bio-fuel. This work is a technical activity within the LIFE EU project *Vegetable Oil Initiative for a Cleaner Environment (VOICE)*, which objectives are oriented to a significant reduction of GHG and other gaseous emissions by the development of short bio-fuel chain for decentralised energy generation and transports. The variety trial allowed obtaining data about the main productive parameters of 16 commercial high oleic sunflower varieties, according to a specific environment. For a right variety choice, the following parameters were taken into account: adaptability to the environments (cropping cycle length and plant height), productivity (seed and oil yield); qualitative character (oil content and composition), resistance/tolerance to the pests and diseases. According to the objectives above mentioned, two experimental trials were carried out in two representative localities, Cesa in Arezzo Province and Coltano in Pisa Province, both located in Tuscany. The 16 varieties were assessed in a balanced lattice experimental design with four incomplete blocks and five replications.

Keywords: Sunflower, liquid bio-fuel, agro-energy farm.

1 INTRODUCTION

1.1 The LIFE-VOICE project

The research is a support for the farmers in seed variety choice within the LIFE EU project *Vegetable Oil Initiative for a Cleaner Environment (VOICE)*. The project aims to generate a significant reduction of GHG and other gaseous emissions [1] [2] [3] in decentralized energy generation and transports by: stimulating EU, National and Regional/Provincial authorities towards the use of pure Vegetable Oil (VO, also called Pure Plant Oil, PPO) for clean transports and energy generation; raising the awareness of these competent bodies in order to create favorable conditions for the establishment of incentive measures in Italy; showing the technical and economical feasibility of extracting and using vegetable oils in converted/adapted technologies by adopting innovative system chains and technologies under Southern EU conditions; disseminating the results towards farmers, directly involved in the present action, and creating new source of income in rural areas. The project intends to face all technological, agronomical, practical and administrative issue of the chain. In a broader sense, the VOICE objective is the development of technologically, environmentally, and economically feasible models for EU farmers in the "agro-energy" sector. In order to optimize the oil yield and quality, it is necessary to give support to the farmers involved in the short chain of the Pure Vegetable Oil, indicating the best sunflower seed variety suitable for their area.

1.2 The short chain layout

The production and the use of PVO are proper to the farmers. The production can be get in the farm or in a farmers' consortium, allowing the farmers to increase the economical income, especially if the oil is used directly in the farm, generating electricity, heat or used as fuel in the tractor engine.

The core of the chain is the small-scale decentralized extraction plant. The conceptual scheme of a decentralized oil extraction plant is illustrated in the figure 1. Seeds arrive from the fields by truck and are stored into silos. By a screw they pass through a seed cleaner, that removes dirty and eventually metal fragments. Than, they are pressed and from this operation the raw oil is produced (about a 30% of the inlet mass flow). The solid part from the screw press (approximately 2/3 of the total seed input flow), called seed cake, is sent to a buffer storage, prior to its final use (usually animal feeding). The raw oil is first decanted and then filtered. A small fraction of solids is also coming from the filter, which is added to the cake from the press. The filtered oil can so be stored and then sent to the end-users (Fig. 1).

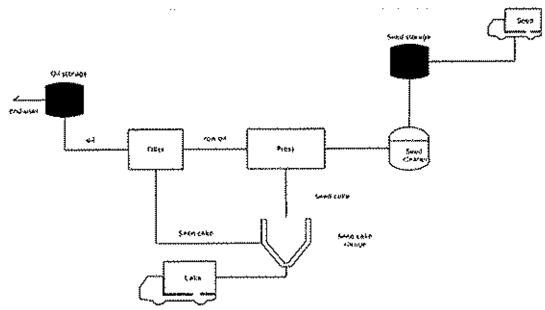

Figure 1: The short chain layout

1.3 The oil quality standard

The technical innovation of the various implementations relies in the compatibility with the physical and chemical characteristics of the pure vegetable oils under consideration. In fact, pure oils differ from diesel oil (and bio-diesel) mainly in terms of viscosity (one order of magnitude above diesel at ambient temperature), density, acid value, iodine number, solid residue, etc. For these reasons, a standard (named RK) has been developed for the Rape Seed Oil as transport fuel [4] [5]. At the present, the RK standard is considered as reference scheme also for sunflower oil. The technological quality of sunflower oil is linked to the quantity of oleic acid (C18:1) and linoleic acid (C18:2), both representing the 85-90% of the lipidic fraction. The high oleic varieties contain a rate of oleic acid ranging from 70-90%. The low rate of unsaturation makes the oil of high oleic sunflower a very suitable fuel if used in converted diesel engine.

2 MATERIALS AND METHODS

In order to evaluate the performances of 16 commercial high oleic sunflower varieties in seed yield, oil content and oil composition, two experimental fields were carried out in Coltano (Pisa Province) and Cesa (Arezzo Province) both in Tuscany Region.

The 16 varieties were assessed in an incomplete balanced lattice experimental design with four incomplete blocks and five replications, totally 80 parcels each of 84 m^2. A plot size of 12 rows, 10 m long and 8.4 wide was used.

In balanced square lattices, the number of treatments is equal to the square of the number of units per block. Incomplete blocks are grouped to form mutually orthogonal replications. The number of replicates in the basic plan is equal to block number plus one. The varieties used are the main commercial in the Italian seed market: Pioneer_H41, Olsavil, Proleic 204, Logisol, Heliabest, Paco, Latino, Trisun 860, Orasole, Nutasol, Heroic, Lg5450, Viviana, Mas 97Ol, Mas 92Ol, Carla.

Conventional tillage practices were used in all trials. All trials were not irrigated and nutrient deficiencies were integrated by fertilization. The trials received both in pre-sowing a fertilization supply of 2 q of a ternary mineral fertilization 8:24:24. Weeds were controlled mechanically, but not pest and disease control was applied. For the sowing a mechanical plot seeder was used. Yields were determined from plants hand harvested in the three central rows of each plot. Threshing was done with an experimental machine.

The oil content of sunflower seed sample of each plot was determined using the Soxhlet extractor. The extraction was executed from a milled sunflower seed sample. The oil composition was obtained by a gaschromatography, from oil chemically extracted from sample of each plot.

Statistical analysis was performed according to the experimental design. Bonferroni test was applied to compare mean values from each source of variation.

3 RESULTS AND DISCUSSION

3.1 Seed yield

The environment had a direct influence on seed yield. The average yield in Cesa (1.6 ton/ha) is significantly higher than in Pisa (1.1 ton/ha), with a difference of more than 50% (Fig.2).

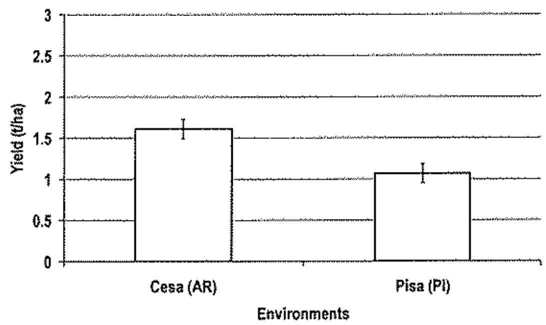

Figure 2: Effect of the environment on the seed yield (ton/ha)

The effect of the variety on yields is also highly meaningful, highlighting a notable difference between varieties. The average value of the most productive variety (Carla, 1.8 ton/ha) is higher of 64% than the less productive variety (Table I).

Table I: Effect of varieties on the seed yield (ton/ha)

Variety	Cesa (AR)	Pisa (PI)	Average
Carla	2.54	1.05	1.80
Heliabest	1.46	0.79	1.12
Heroic	1.50	0.89	1.19
KWS_logisol	1.34	0.84	1.09
Latino	1.56	1.40	1.45
Lg5450	1.68	0.98	1.33
Mas 92Ol	2.33	0.91	1.62
Mas 97Ol	1.36	1.38	1.37
Nutrasol	1.45	0.92	1.12
OLSAVIL	1.77	1.17	1.47
Orasole	1.56	1.02	1.29
Paco	1.60	1.10	1.35
PIONEER_H41	1.39	0.87	1.13
PROLEIC_204	1.16	1.04	1.10
Trisun 860	1.39	1.42	1.41
Viviana	1.71	1.35	1.53

Variety effect is clearly affected by the environment (Fig. 3), as demonstrated by good performances in Cesa, not confirmed in Pisa. This is evident in Carla and Mas92Ol, that in Cesa achieved yields respectively of 140% and 154% higher than in Pisa. Notable is the yield stability recorded in Mas 97Ol and Trisun860, raising almost the same yields in both sites.

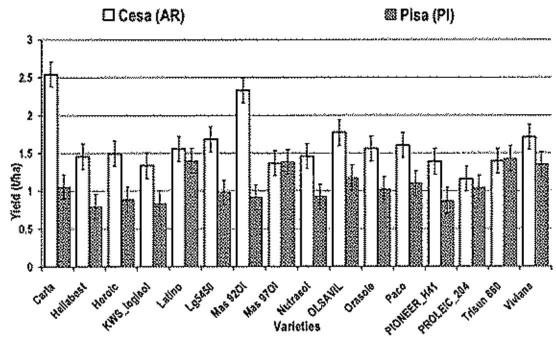

Figure 3: Effect of varieties and environments on the seed yield (ton/ha)

3.2 Oil content

As for seed yield, the environment effect on seed oil content is highly meaningful, with a difference of 20% between Pisa and Cesa (Fig. 4), in part compensating the Pisa low seed productivity.

The variety with the highest oil content resulted Olsavil, with a value of 48.7% on seed dry weight. Olsavil oil content resulted upper of the 20% than oil content of Trisun860, the variety with the lowest value (41.0%), showing a clear variety effect on oil content (Table II).

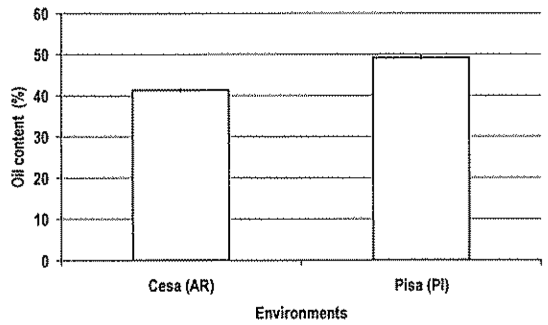

Figure 4: Effect of environment on seed oil content

Table II Effect of varieties on seed oil content %

Variety	Cesa (AR)	Pisa (PI)	Average
Carla	44.53	50.68	47.61
Heliabest	42.42	47.64	45.03
Heroic	43.34	46.19	44.77
KWS_logisol	42.02	50.79	46.40
Latino	40.41	53.52	46.97
Lg5450	41.24	46.08	43.66
Mas 92OI	46.60	48.50	47.55
Mas 97OI	43.37	47.08	45.23
Nutrasol	38.81	47.07	42.94
OLSAVIL	44.70	52.76	48.73
Orasole	40.54	43.48	42.01
Paco	43.23	51.99	47.61
PIONEER_H41	41.73	50.09	45.91
PROLEIC_204	34.61	52.86	43.74
Trisun 860	36.09	45.72	40.91
Viviana	37.36	51.90	44.68

The effect of variety and environment interaction on seed oil content was also interesting (Fig. 5). In fact, all the results were higher in Pisa than in Cesa, even if there was not observed a correspondence between the most oil productive varieties in Pisa and in Cesa (respectively Latino and Mas92OI). The same difference was also detected between the lowest oil productive varieties (Orasole in Pisa and Proleic in Cesa).

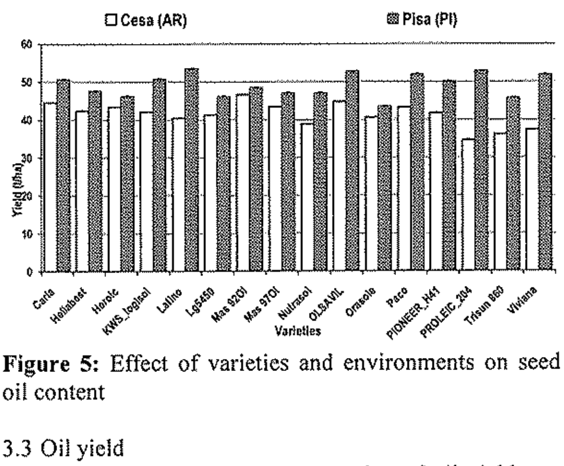

Figure 5: Effect of varieties and environments on seed oil content

3.3 Oil yield

In Pisa and Cesa the average value of oil yield was respectively 6.7 q/ha and 5.3 q/ha. (Fig. 6).

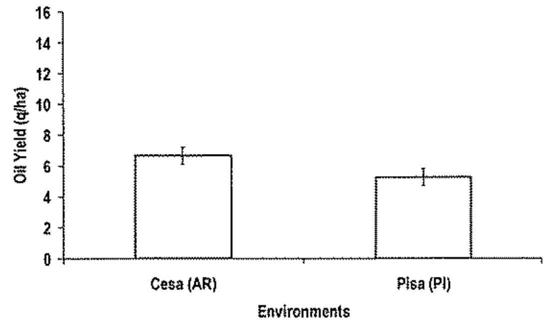

Figure 6: Effect of environment on the oil yield q/Ha

Variety effect highlighted significative differences. At this regard the difference between the most and the lowest oil productive varieties (respectively Carla with 8.6 q/ha and Nutrasol with 4.8 q/ha) arose the value of 78%.

Table III Effect of varieties on the oil yield (q/ha)

Variety	Cesa (AR)	Pisa (PI)	Average
Carla	11.32	5.34	8.56
Heliabest	6.18	3.76	5.05
Heroic	6.48	4.10	5.33
KWS_logisol	5.62	4.24	5.04
Latino	6.28	7.49	6.80
Lg5450	6.94	4.52	5.81
Mas 92OI	10.84	4.42	7.69
Mas 97OI	5.91	6.50	6.20
Nutrasol	5.64	4.34	4.80
OLSAVIL	7.91	6.18	7.17
Orasole	6.30	4.43	5.41
Paco	6.92	5.71	6.42
PIONEER_H41	5.78	4.34	5.17
PROLEIC_204	4.01	5.49	4.80
Trisun 860	5.03	6.51	5.76
Viviana	6.39	7.02	6.84

Variety x environment interaction demonstrates that such varieties are not suitable for any environment. Carla and Mas92OI are for example suitable for the Cesa area, while not indicated for Pisa area.

The varieties arising the highest oil content in Pisa and not in Cesa were Latino, Mas97OI, Proleic, Trisun860 and Viviana. These varieties also showed the highest seed yield stability in both environments. Nevertheless varieties grown in Pisa reached the highest oil content (Fig. 7).

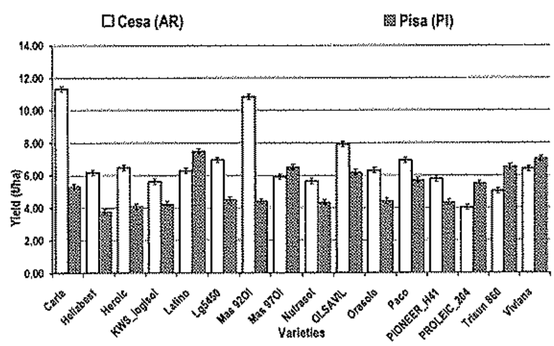

Figure 7: Variety and environment effect on oil yield

3.4 Oil Composition

All the varieties showed an acid oleic content higher than 80%, confirming that the commercial varieties are really High Oleic.

Table IV Variety effect on oleic acid content

Variety	Cesa (AR)	Pisa (PI)	Average
Carla	86.55	88.56	87.55
Heliabest	86.95	87.21	87.08
Heroic	87.13	88.74	87.94
KWS_logisol	83.86	84.63	84.24
Latino	85.18	83.06	84.12
Lg5450	87.27	87.02	87.14
Mas 92Ol	87.61	88.44	88.02
Mas 97Ol	89.08	89.90	89.49
Nutrasol	83.03	81.88	82.46
OLSAVIL	87.64	90.10	88.87
Orasole	86.48	88.92	87.70
Paco	86.75	86.55	86.65
PIONEER_H41	88.54	89.02	88.78
PROLEIC_204	86.76	87.16	86.96
Trisun 860	87.65	88.28	87.96
Viviana	79.32	83.73	81.52

The similar temperature ranges registered during the crop cycle in both environments, confirmed the positive correlation for linoleic acid content between the great part of varieties grown in Pisa and Cesa (Fig. 7) and the effect of the temperature on the activity of enzyme Δ12-desaturase[6].

4 CONCLUSION

The screening of the commercial sunflower varieties is an important activity to starting the short chain of Pure Vegetable Oil [7] [8] [9] [10]. At the moment this kind of chain has a positive energetic balance, so the choice of the variety, since the high susceptibility of sunflower to the environment in oil yield, became an fundamental step for the maintenance of the positive energetic balance.

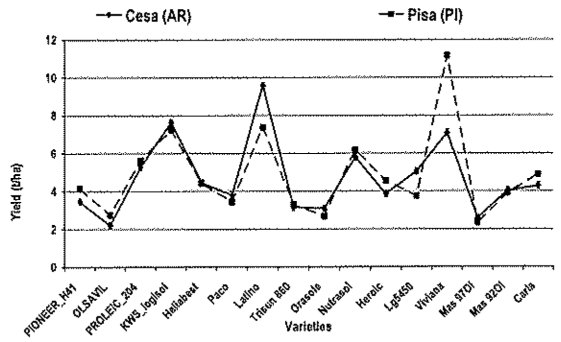

Figure 7: Variety and environment effect on linoleic acid content

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