

Winter cover crops in processing tomato: an aid-independent test of an eco-scheme practice delivered through a multidisciplinary EIP Operational Group (GOS ACCESO, Spain)

Type of contribution	Synthesis of achievements on specific topics
Topics addressed	Recent achievements in designing new crop rotations · Interactions with farmers' groups and EIP operational groups (multidisciplinary delivery model)
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Project	ACCESO is a supra-regional Operational Group co-financed by FEADER at 80% and by the Ministry of Agriculture, Fisheries and Food at 20%. Total investment: €599,779.31. https://grupoooperativoaccessoeu/
Case study	Cover cropping in industrial tomato, Badajoz (Extremadura, Spain) — 2024/25 seasons, conventional fertigated management. ACOPAEX as a farming cooperative member.
Reporting date	02/09/2026

1. Rationale: assessing an eco-scheme practice

Eco-schemes under the CAP Strategic Plan 2023–2027 have made cover cropping, crop diversification, and reduced tillage economically attractive to many European farmers. They have also created a risk that is rarely stated openly: practices adopted because a payment is attached to them tend to be abandoned when the payment changes. GOS ACCESO, a Spanish supra-regional EIP Operational Group, was built on the opposite premise — that eco-scheme practices should be demonstrable as agronomically and economically worthwhile in their own right, and that the green payment should be a reason to start rather than the only reason to continue.

This report synthesises one closed field case from the group's 2025 industrial tomato trials with the cooperative ACOPAEX in Badajoz (Extremadura), in which a winter cover crop was inserted into a fertigated processing-tomato rotation and evaluated against an uncovered control on six independent dimensions — input use and cost, soil water, soil microbiome, arthropod communities, industrial fruit quality and plant health. It is presented here as a worked example of two TOP Agri-Network topics at once: the design of a new crop rotation, and the capacity of an Operational Group to deliver a genuinely multidisciplinary assessment of that rotation on a single shared dataset.

2. Trial design and implementation

2.1 Site, treatments, and crop sequence

The trial was established on commercial processing-tomato ground managed by ACOPAEX in the Guadiana irrigation district (Badajoz, Extremadura), under conventional management and drip fertigation. The rotation assessed inserts a rainfed autumn–winter cover crop into the fallow window that normally separates two irrigated summer crops, with the cover terminated and incorporated ahead of spring transplanting. Three treatments were compared:

Treatment	Description	Winter cover mixture (sown 12/11/2024)
T0	Control — bare winter fallow, no cover crop, no flower strip	—
T1	Winter cover crop, terminated and incorporated 07/04/2025	<i>Raphanus sativus</i> 50% · <i>Trifolium alexandrinum</i> 30% · <i>Phacelia tanacetifolia</i> 20%
T1+	Winter cover crop as T1, plus microbial soil inoculation and a perennial/aromatic flower strip on one field margin	Cover as T1 · Strip: <i>Ocimum basilicum</i> , <i>Santolina chamaecyparissus</i> , <i>Lavandula angustifolia</i> , <i>Salvia rosmarinus</i> , <i>Thymus vulgaris</i> , <i>Tagetes erecta</i>

Table 1. Treatment structure. The brassica–legume–forb mixture combines a deep-rooting biofumigant brassica, a nitrogen-fixing legume, and a fast-covering, insect-attractive forb. T1+ is the full package assessed by the group: cover crop, flower strip, and microbial inoculation.

2.2 Implementation record

Cover establishment was homogeneous and reached full vegetative growth about 45 days after sowing. A flood event on 19 March 2025 affected the plot only marginally. The cover was terminated and incorporated to the soil as organic fertilizer on 7 April 2025, roughly five months after sowing. The tomato crop followed under an irrigation schedule that was identical in all three treatments.

The flower strip in T1+ failed and is reported here as a negative result. It could be planted on only one of the two intended margins, and 20–25 days after planting it was overrun by *Datura stramonium*. Mowing and hand-pulling did not achieve effective control. The strip survived but produced scarce vegetative growth and almost no flowering, so T1+ must be read as "cover crop plus microbial inoculation plus a failed strip", not as a treatment with a functioning strip. Under Spanish conditions, spring-planted aromatic strips established from plugs immediately before the summer crop are highly exposed to this competition; autumn establishment, or a nurse-crop approach, is the obvious design correction.

2.3 Measurements

Soil moisture was logged at 15-minute intervals by capacitance probes at eight depths (10–80 cm) in T0 and T1+, aggregated to hourly means; the analysis below uses the full July 2025 window (n = 740 hourly records per depth and treatment), corresponding to the peak-demand phase of the crop. Arthropods were sampled in February (cover established) and August (cover incorporated, tomato in place), with three samples per treatment, identified to family and assigned to functional guilds. At harvest, 10–15 fruits per lot and three lots per treatment were analysed for calibre, firmness, soluble solids, pH, acidity, and colour (D65, 2°, three readings per fruit). Soil microbiome and biological activity were characterised on one composite soil sample per treatment, formed by ten sub-samples taken from the top 20 cm of the root-influence zone of ten plants: bacterial (16S rRNA, V3–V4) and fungal (ITS2) communities by Illumina MiSeq metabarcoding, and dehydrogenase, BAA-protease, urease, alkaline phosphatase and β-glucosidase activities, microbial biomass carbon and basal respiration. Fertiliser and plant protection use were taken from the cooperative's farm books. Treatment effects were assessed by one-way ANOVA with Tukey HSD post-hoc comparisons; soil-moisture differences were assessed by Welch t-test at each depth; microbiome results, with a single composite sample per treatment, are reported descriptively.

3. Results

3.1 Fertiliser use and cost — the aid-independent argument.

Fertigated NPK volumes were reduced in both covered treatments while the crop was managed to the same commercial target. This is the single result that advocates to the group's premise, because it is a saving realised at the farm gate irrespective of any eco-scheme payment.

Treatment	Liquid NPK (L/ha)	Fertiliser cost (€/ha)	N units (kg/ha)	P ₂ O ₅ (kg/ha)	K ₂ O (kg/ha)	Δ cost
T0	1.905	1.410,00	200,9	12,8	86,8	—
T1	1.675 (–12,1%)	1.262,94	181,3 (–9,8%)	12	72,5 (–16,5%)	–147,06 €
T1+	1.875 (–1,6%)	1.367,72	187,3 (–6,8%)	12	72,5 (–16,5%)	–42,28 €

Table 2. Fertiliser use & cost by treatment. Formulations used: 17-0-0, 12-2-2, 10-0-7, 3-0-10, all by fertigation. T1+ received additional 200 L/ha of a 3-0-0 solution; on the NPK products common to all treatments, T1 and T1+ are identical. Nutrient units calculated from formulation percentages assuming a solution density of ~1 kg/L & are therefore indicative.

The mechanism behind this reduction is not fully resolved by the present dataset, but the composition of the mixture makes two contributions plausible and separable in future seasons. The legume component (*Trifolium alexandrinum*, 30% of the mixture) fixes atmospheric nitrogen that becomes available on mineralisation of the incorporated residue, which is consistent with the nitrogen units applied falling by ~10%. The potassium reduction is larger in relative terms (–16.5%) and cannot be attributed to fixation; it more likely reflects the deep-rooting *Raphanus sativus* component recycling potassium from below the normal rooting depth of the tomato crop back into the surface horizon as residue. The soil-biology data for T1 (Section 3.4) are compatible with faster nutrient turnover — microbial biomass carbon was 28% and urease activity 38% above the control — but potential enzyme activities measured on a single composite sample are not a measure of nutrient supply, and protease activity was in fact slightly lower (–18%). Distinguishing the two contributions would require mineral nitrogen and exchangeable potassium measurements.

3.2 Plant protection programme.

The plant protection programme was identical in the three treatments: twelve applications totalling 835 €/ha. No pesticide saving can therefore be claimed from this trial, and the field record books showed no treatment-specific pest or disease episode either — a first, weak indication of phytosanitary parity rather than of any resilience gain. Because this is the dimension of most direct interest to the network, the structure of the programme matters since it defines where a future saving could and could not come from.

Target	Active substance (dose)	Applications	€/ha	% of cost
Nematodes (pre-plant)	Fluopyram (0.625 L/ha)	1	250,00	29.9%
Spider mite	Hexythiazox 10% (1 kg/ha); milbemectin 0.93% (1 L/ha, ×2)	3	269,50	32.3%
Downy mildew	Mandipropamid + difenoconazole (60 cc/hL); boscalid + pyraclostrobin (1.5 kg/ha)	2	161,00	19.3%
Weeds	Rimsulfuron 25% (30 g/ha, ×2); clethodim 12% (1 L/ha)	3	72,50	8.7%
Heliothis	Chlorantraniliprole 20% (0.2 L/ha, ×2)	2	54,00	6.5%
Phytophthora	Metalaxyl 25% (0.8 kg/ha)	1	28,00	3.4%
Total	Identical in T0, T1 and T1+	12	835,00	100%

Table 3. Plant protection programme applied to all three treatments, 2025 season. Two lines — the pre-plant nematicide and the acaricide sequence — account for 62% of the programme cost

3.3 Soil and water

Across July 2025 the covered plot held substantially more water at every depth under an unchanged irrigation schedule. Averaged over the 10–80 cm profile, volumetric moisture was 42.1% in T0 and 54.8% in T1+ (+12.7 percentage points, +30% relative). The difference was concentrated in the 40–80 cm horizon (43.1% vs 60.4%) rather than in the surface layers (0–30 cm: 40.5% vs 45.5%) and was statistically significant at every depth except 30 cm ($p < 0.001$; 30 cm $p = 0.19$).

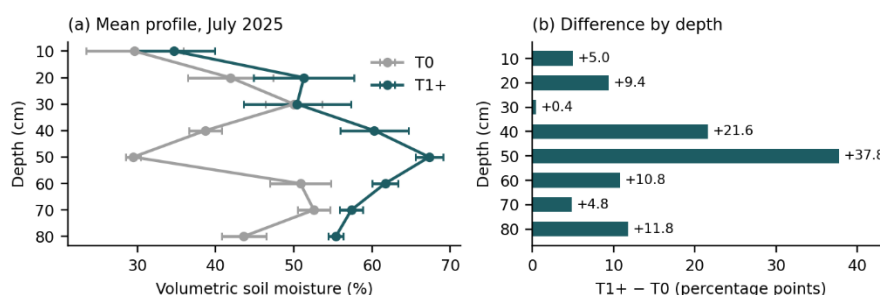


Figure 1. Mean July 2025 soil moisture profile (a) and absolute treatment difference by depth (b). Hourly means, $n = 740$ per depth and treatment.

Depth (cm)	10	20	30	40	50	60	70	80
T0 (%)	29,7 ± 6,3	41,9 ± 5,5	50,0 ± 3,7	38,7 ± 2,2	29,5 ± 1,0	50,8 ± 4,2	52,6 ± 2,3	43,6 ± 3,2
T1+ (%)	34,7 ± 5,2	51,3 ± 6,5	50,4 ± 6,9	60,3 ± 4,4	67,3 ± 1,8	61,7 ± 1,6	57,4 ± 1,5	55,4 ± 1,0
Δ (p.p.)	+5,0	+9,4	+0,4	+21,6	+37,8	+10,8	+4,8	+11,8

Table 4. Mean volumetric soil moisture by depth, July 2025. All differences significant at $p < 0.001$ except 30 cm ($p = 0.19$). The 30 cm probe is the only depth showing no separation, which is consistent with a local drip-wetting-front effect at that position rather than with a profile-scale exception.

The difference was also stable over time rather than event driven. Both treatments responded in parallel to the mid-month wetting event around July 12, and the gap between them stayed within a narrow band of 10.5 to 14.2 percentage points across the whole month (mean 12.7). Interpreted relevance: a cover-crop effect that appeared only after irrigation events point to differences in infiltration, whereas a constant offset that survives both wetting and drying phases points to a genuine difference in stored water and the soil's retention capacity.

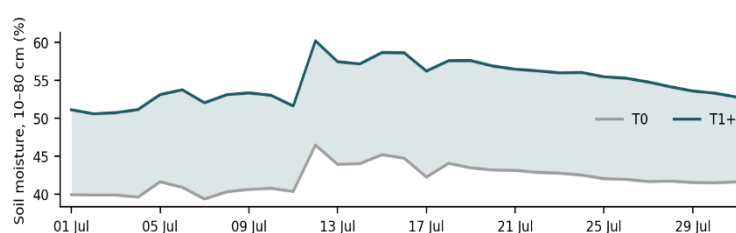


Figure 2. Daily profile-mean soil moisture (10–80 cm) through July 2025. The shaded band is the difference between treatments.

3.4 Soil microbiome and biological activity

The first-year (2025) results from CEBAS-CSIC show a clear response of soil biology to the cover crop. Microbial biomass carbon was 28% higher in T1 and 26% higher in T1+ than in the bare-fallow control, and basal respiration roughly doubled (+96% and +133%). The enzyme profile, however, separated the two covered treatments (Table 5). T1 showed the largest increases in dehydrogenase, an intracellular enzyme used as an integrated index of viable microbial activity (+134%), and in urease (+38%), closely related to the nitrogen cycle. Nevertheless, protease was slightly below the control (−18%). T1+, which also received the microbial inoculant, showed the largest increases in β -glucosidase (+215%), alkaline phosphatase (+69%) and protease (+36%) — enzymes of the carbon, phosphorus, and nitrogen cycles respectively — whereas its dehydrogenase activity remained at control level.

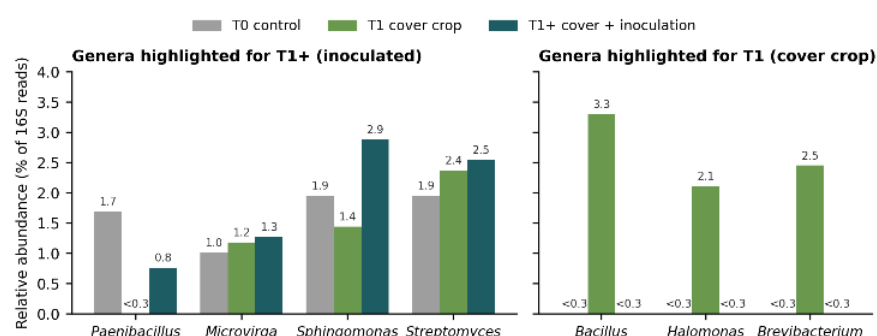
Indicator	Unit	T0	T1	T1+
Dehydrogenase	$\mu\text{g INTF g}^{-1} 20 \text{ h}^{-1}$	50,7	118,8 (+134%)	53,1 (+5%)
BAA-protease	$\mu\text{mol N-NH}_4^+ \text{ g}^{-1} \text{ h}^{-1}$	0,88	0,72 (−18%)	1,20 (+36%)
Urease	$\mu\text{mol N-NH}_4^+ \text{ g}^{-1} \text{ h}^{-1}$	0,89	1,23 (+38%)	1,13 (+27%)
Alkaline phosphatase	$\mu\text{mol PNP g}^{-1} \text{ h}^{-1}$	1,29	1,37 (+6%)	2,18 (+69%)
β -glucosidase	$\mu\text{mol PNP g}^{-1} \text{ h}^{-1}$	0,52	0,85 (+63%)	1,64 (+215%)
Microbial biomass carbon	$\text{mg C kg}^{-1} \text{ soil}$	1,628	2,082 (+28%)	2,055 (+26%)
Basal respiration	$\text{mg C-CO}_2 \text{ kg}^{-1} \text{ h}^{-1}$	4,74	9,29 (+96%)	11,04 (+133%)
Bray–Curtis vs T0, bacteria (16S)	dissimilarity (0–1)	—	0.518	0.451
Bray–Curtis vs T0, fungi (ITS2)	dissimilarity (0–1)	—	0.716	0.719

Table 5. Soil biological indicators and community dissimilarity by treatment, 2025 season (CEBAS-CSIC).

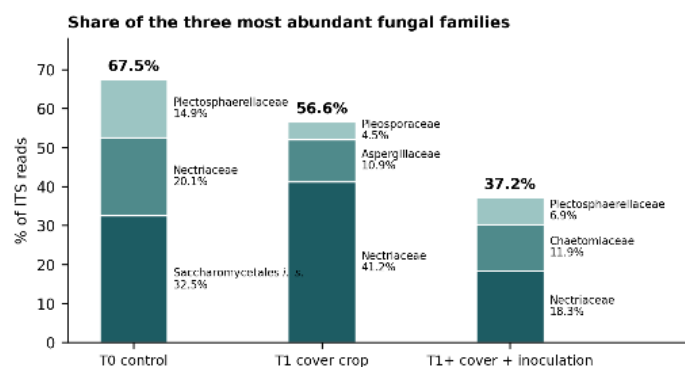
Community composition shifted in both groups, and more strongly in fungi (Bray–Curtis dissimilarity from the control 0.72 in both covered treatments, against 0.45–0.52 for bacteria). Regarding bacterial communities, microbial inoculation (T1+) particularly favoured the development of genera such as *Paenibacillus*, *Microvirga*, *Sphingomonas* and *Streptomyces*, all of which are commonly associated with beneficial processes for soil and plants, such as the promotion of plant growth, biological nitrogen fixation, nutrient solubilization, degradation of organic matter and suppression of pathogens. On the other hand, the T1 treatment was characterized by a higher relative abundance of the genera *Bacillus*, *Halomonas* and *Brevibacterium*, which indicated that the implantation of plant covers and floral bands was sufficient to significantly modify the bacterial composition of the soil, even in the absence of microbial inoculation.

Regarding the fungal communities, the implantation of vegetation covers produced a marked reorganization of the community, characterized by a strong increase in Nectriaceae, Aspergillaceae, and Pleosporaceae, together with the increase of less abundant families such as Bionectriaceae and Podosporaceae. In contrast, Saccharomycetales fam. Incertae sedis and Plectosphaerellaceae decreased drastically. These changes suggested a favourable response of filamentous fungi associated with the decomposition of plant residues and the recycling of organic matter.

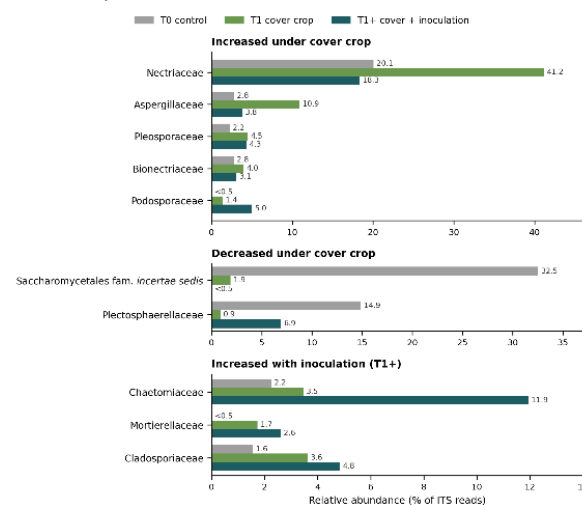
Microbial inoculation (T1+) favoured a more diverse and balanced community. With this treatment, the relative abundances of Chaetomiaceae, Mortierellaceae and Cladosporiaceae increased. At the same time, the levels of Saccharomycetales fam. Incertae sedis and Plectosphaerellaceae, while Nectriaceae decreased with respect to T1. Overall, T1+ decreased the dominance of the most abundant taxa and promoted a more heterogeneous and balanced community structure.



Values digitised from CEBAS-CSIC (2026), intermediate report, Fig. 3. One composite soil sample per treatment (Badajoz processing tomato, 2025); approximate (± 1 p.p.), no statistical test.



Values digitised from CEBAS-CSIC (2026), intermediate report, Fig. 5. One composite soil sample per treatment (Badajoz processing tomato, 2025); approximate (± 1 p.p.), no statistical test. Unassigned reads and "others" excluded from the ranking.



Values digitised from CEBAS-CSIC (2026), intermediate report, Fig. 3. One composite soil sample per treatment (Badajoz processing tomato, 2025); approximate (± 1 p.p.), no statistical test.

3.5 Arthropod communities

In February, with the cover in place, total arthropod abundance was three times higher in the covered plots (T0 319 individuals; T1 957; T1+ 1,013) and family richness rose from 27 to 44 and 43, respectively. A composite index combining abundance, richness and a conservation-interest weighting gave gains of +40% (T1) and +29% (T1+) over the bare control.

Indicator	Feb T0	Feb T1	Feb T1+	Aug T0	Aug T1	Aug T1+
Total individuals	319	957	1,013	171	244	42
Families recorded	27	44	43	27	29	16
Detritivores	133	217	406	62	28	7
Predators / parasitoids	55	60	47	27	31	5
Non-pollinating phytophagous	122	635	517	73	165	24
Composite gain vs T0	—	+40%	+29%	—	+26%	−21%

Table 6. Arthropod indicators by treatment and sampling date (three samples per treatment). The composite gain combines abundance, family richness and a conservation-interest weighting, and averages +33% (T1) and +4% (T1+) across the two dates.

Guild disaggregation changes the reading considerably. The February increase was driven by detritivores and non-pollinating phytophagous Diptera — *Chironomidae* rose from 119 to 152 (T1) and 346 (T1+) individuals, and *Drosophilidae* from 8 to 242 and 324 — whereas predators and parasitoids were essentially flat (55, 60 and 44 individuals in T0, T1 and T1+). Pollinators were negligible in all treatments at that date. In other words, the headline biomass gain reflects a decomposer and moisture-associated fauna responding to a green, humid winter surface, not a build-up of natural enemies.

By August, after incorporation, the signal had largely dissipated: the composite index gave +26% for T1 but −21% for T1+, with only 42 individuals and 16 families recovered from T1+ against 171 (27 families) in the control. Since the T1+ flower strip had failed, an outcome close to T1 would have been expected; the August T1+ figure is more plausibly a sampling artefact or a stochastic local effect than a treatment response, or even a phenomenon of repellence of the weeds (*Datura stramonium*) that colonized the surface, and we report it as such rather than smoothing it.

3.6 Industrial fruit quality

Fruit from covered plots was significantly larger and significantly lower in soluble solids. Significant differences among treatments (T0, T1, and T1+) were observed across most parameters evaluated. Fruit calibre showed a steady, highly significant increase following the order T1+ > T1 > T0 (62,1 mm, 57,4 mm, and 53,6 mm, respectively, with $p < 0,001$), and fruit firmness was also significantly greatest under treatment T1+. In contrast, soluble solids peaked in the control group T0 (4.48 °Brix) compared to T1 and T1+ ($p < 0,001$), while juice pH showed no statistically significant variations ($p = 0,45$, remaining around 4.43–4.48). Titratable acidity and maturity index remained relatively stable. Finally, colour was slightly but consistently different in T1+: lighter (higher L^*) and with a lower a^*/b^* ratio, which in processing tomato indicates marginally less advanced red development.

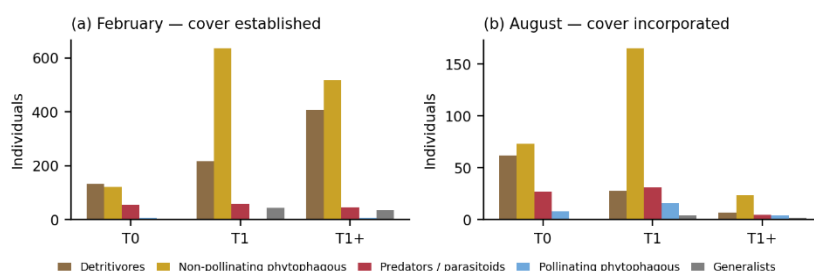


Figure 3. Arthropod abundance by functional guild in February (cover established) and August (cover incorporated, tomato crop present).

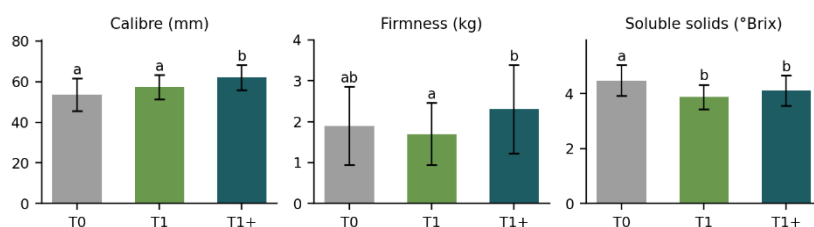


Figure 4. Fruit calibre, firmness, and soluble solids by treatment (mean $\pm$ SD, $n = 30$ fruits from 3 lots). Different letters indicate significant differences (Tukey HSD, $p < 0,05$).

Parameter	T0	T1	T1+	ANOVA p	Effect
Calibre (mm)	53,6 $\pm$ 8,0	57,4 $\pm$ 6,0	62,1 $\pm$ 6,2	< 0,001	T1+ > T1 > T0
Firmness (kg)	1,90 $\pm$ 0,96	1,70 $\pm$ 0,76	2,31 $\pm$ 1,08	0,045	T1+ > T1
Soluble solids (°Brix)	4,48 $\pm$ 0,57	3,89 $\pm$ 0,45	4,12 $\pm$ 0,55	< 0,001	T0 > T1, T1+
pH	4,48 $\pm$ 0,17	4,43 $\pm$ 0,15	4,43 $\pm$ 0,23	0,45	n.s.
Acidity (g citric acid/L)	2,60	2,71	2,60	—	lot-level, $n = 3$
Maturity index (°Brix / acidity)	1,72	1,43	1,58	—	derived
L^*	42,6 $\pm$ 1,7	41,8 $\pm$ 1,5	43,6 $\pm$ 1,5	< 0,001	T1+ > T0, T1
a^*/b^* ratio	1,18 $\pm$ 0,13	1,15 $\pm$ 0,11	1,09 $\pm$ 0,10	0,012	T1+ < T0

Table 7. Harvest quality parameters by treatment. Colour data from ninety fruits (3 readings each) under D65/2°. Lots are sampling units within the same commercial plot, so ANOVA on fruit-level data is best read as descriptive of this site-season rather than as inference across independent field replicates.

4. Discussion

4.1 Moisture retention as the trial's objective, and irrigation as the pending savings lever

The objective of the cover crop in this trial was to improve the soil's moisture-retention capacity to, ultimately, reduce the irrigation requirements of processing tomato. On this point, the main result confirms the starting hypothesis: the covered plots (T1+) entered the summer with a wetter soil profile and, under an irrigation programme deliberately kept identical across treatments to isolate the effect of the cover crop, retained that moisture advantage throughout July (by more than 17 percentage points at 50 cm depth). The cover crop

therefore fulfilled its intended function: under identical water input, the soil retained significantly more water. This is consistent with the recognised mechanism by which cover crops improve the field water balance — by protecting the surface and generating root channels they raise infiltration and rainfall capture and thereby increase in-season soil moisture. In a recent field study, cover crops and conservation tillage improved in-season soil moisture and infiltration, cover crops increased rainfall capture by 13% relative to bare soil, and conservation tillage combined with cover crops reduced or even eliminated the need for supplemental irrigation (Roberts et al., 2026). Our summer result is the same phenomenon expressed in a Mediterranean processing-tomato system: a cover-mediated gain in retained water carried into the cash-crop cycle.

By holding irrigation constant, the greater water availability could translate into an irrigation saving. Larger fruit, with lower soluble solids ($^{\circ}\text{Brix}$) and a lower maturity index, is the classic signature of a dilution effect driven by greater water availability, and it is well documented in processing tomato: in one of the main Spanish production areas, raising the irrigation dose above the recommended 100% ETc produced no agronomic benefit and instead caused a dilution effect that lowered total soluble solids and lycopene, whereas deficit irrigation at 75% ETc cut water use by 28.2% and raised soluble solids by 8.4%, at the cost of a 16.4% reduction in marketable yield (Lahoz et al., 2016). We therefore interpret the reduction in $^{\circ}\text{Brix}$ not as an intrinsic quality penalty of the cover crop, but as the direct and expected consequence of not having yet adjusted irrigation to the greater moisture available.

4.2 Soil Microbiome Analysis

Compared with conventional management (T0), the cover crop treatment (T1) was associated with a bacterial community of greater functional potential, indicating an improvement in soil biological quality. A plausible driver is the larger and more diverse supply of root exudates and organic matter from the cover crop, which widens the range of substrates available to soil microorganisms. Under controlled conditions, plant-driven increases in root biomass and exudation raised both bacterial and fungal biomass, with the strongest response in fungi (Eisenhauer et al., 2017). The size of the biological response is consistent with the published evidence on cover cropping. Across sixty field studies, cover crops increased soil microbial abundance by 27% and microbial activity by 22% relative to bare fallow (Kim et al., 2020). A meta-analysis of eighty-one studies found increases of 24–51% in microbial biomass C, microbial biomass N, and PLFA, with fungi favoured more than bacteria (Muhammad et al., 2021). Effects on diversity are considerably smaller, averaging 2.5% (Kim et al., 2020), which makes the more complex community observed in T1 a noteworthy result. Its relevance lies in function: in experimental grassland systems, richer microbiomes with more complex co-occurrence networks supported higher multifunctionality in nutrient cycling (Wagg et al., 2019).

In T1+, microbial inoculation appeared to strengthen this effect, favouring a higher relative abundance of genera potentially beneficial for soil biological functioning. This is plausible: in 86% of 108 studies reviewed by Mawarda et al. (2020), inoculants modified resident soil microbial communities, and 80% of longer-term studies observed no return to the initial community. Because T1+ also differed from T1 in other management components, however, the contribution of the inoculum cannot be isolated. Whether these shifts benefit the tomato rotation over the medium to long term will require multi-season monitoring.

Both covered treatments also supported more balanced fungal communities, potentially more resilient to environmental disturbance. The fungal groups that increased (Nectriaceae, Aspergillaceae, and Pleosporaceae in T1; Chaetomiaceae, Mortierellaceae and Cladosporiaceae in T1+) are filamentous taxa that CEBAS-CSIC associate with plant-residue decomposition. This outcome is not guaranteed with brassica covers. In a Canadian horticultural rotation that included tomato, radish-based cover crops reduced fungal evenness (Tosi et al., 2022), which gives the result added weight, since the cover crop in this trial included *Raphanus sativus*. Resilience was not measured directly. It is supported indirectly by evidence from grassland mesocosms, where drought destabilised bacterial but not fungal co-occurrence networks (de Vries et al., 2018), a relevant property under Mediterranean summer conditions. Finally, the February arthropod gain was carried by detritivores. Soil microarthropods regulate decomposition at local scale and contribute to nutrient cycling through their interactions with the microbial community (Neher & Barbercheck, 2019). The parallel increase in detritivores and decomposer fungi is therefore consistent with a detrital food web stimulated by cover-crop residues, in which the two groups are likely to have reinforced each other.

4.3 Biodiversity gains are real and guild specific.

Reporting only the composite index (+33% annual average for T1) would have overstated what this rotation delivers for crop protection. Two disaggregation are essential. Functionally, the February gain sits mostly in detritivores and phytophagous *Diptera*; predator and parasitoid abundance did not increase. Temporally, the effect only survived incorporation of the cover in T1. At this point it is important to note the absence of floral bands in T1+ due to colonization by the weed *Datura stramonium*, which is detrimental to populations in T1+. Both observations are consistent with the termination literature: first, the repellent effect of *Datura stramonium* has been widely documented in plots where a reduction in the biodiversity of phytophagous arthropods has been observed. It drastically modifies the physicochemical characteristics of the soil, generating a highly toxic or unfavourable microenvironment for multiple species of arthropods and plants, and also produces extracts and metabolites with insecticidal and deterrent activity (Villegas et al., 2019; Lv, J. et al., 2023).

On the other hand, the detritivore community that the winter cover supported is functionally important in its own right, independently of any natural-enemy role: two desirable functions of healthy soil are nutrient cycling and pest suppression, and soil microarthropods contribute to both through their intersecting roles in decomposition and nutrient cycling and in the direct and indirect suppression of plant pests (Neher & Barbercheck, 2019). Detritivorous microarthropods fragment detritus into smaller particles that increase the surface area available for microbial colonisation and raise substrate moisture, thereby stimulating microbial activity and regulating decomposition in a way that reduces the risk of nutrient loss from the agroecosystem (Neher & Barbercheck, 2019).

4.4 Where a pesticide saving could come from, and why none appeared in 2025.

For a network working towards reduced pesticide dependence, the null result in Section 3.2 is worth dissecting rather than reporting once. Three mechanisms could in principle link this rotation to a lighter programme, and they behaved very differently. The first is soil-borne suppression: *Raphanus sativus*, half the mixture, releases glucosinolate breakdown products on incorporation, and the target it would act on — the pre-plant fluopyram application — is the single most expensive line in the programme at 250 €/ha, almost 30% of the total. The first-year microbiome data point in both directions for this pathway: genera commonly associated with antagonism towards soil-borne pathogens (*Streptomyces*, *Sphingomonas*) gained representation mainly in T1+, the inoculated treatment, while the share of *Fusarium* doubled in T1 and returned to control level in T1+ (Section 3.4); neither signal is a measured suppression effect, and neither changes that advice. The second is weed suppression. A dense winter cover can reduce early weed pressure, but the herbicide programme was unchanged and the *Datura stramonium* invasion of the flower strip shows that seedbank pressure at this site is high and expresses itself after cover termination, not during it — a winter cover that is incorporated in April simply does not cover the window in which the tomato herbicides are applied. The third is conservation biological control against *Heliothis* and spider mite, which together carry 39% of the

programme cost. The guild data give no support for this pathway here: predator and parasitoid abundance was flat under the cover and the whole community effect disappeared after incorporation. Acaricide-heavy programmes in processing tomato are in any case associated with hot, dusty mid-season conditions that a terminated winter cover cannot influence.

To all this, we must add the savings from implementing these voluntary eco-schemes for the farmer consisting of practices in favour of the environment, which go beyond the baseline (reinforced cross-compliance). In Spain, for the implementation of vegetation cover and rotation with improving species, current aid can range from €141.98/ha to €166.98/ha.

4.5 What the rotation design should change.

Three concrete design corrections follow from this season: (i) adjust irrigation to measured soil moisture rather than to calendar, so the water benefit becomes an input saving; (ii) change the way the flower strip is established. Two corrections follow directly from the *Datura stramonium* episode. First, the strip should be established from transplants (plugs) rather than from direct sowing, as they have been reported to reach twice the size of seed-sown plants, and transplanting confers quicker establishment. Second, the strip footprint should be occupied by a deliberately established ground cover before the flowering species go in, so the space is not left open to colonisation by the weed seedbank (Bretzel et al., 2024); and (iii) extend arthropod sampling to at least three dates spanning termination, so that the decay of the winter effect is quantified rather than inferred from two snapshots. The fertiliser reduction, by contrast, requires no correction: a 12% cut in fertiligated volume and 147 €/ha at the same commercial outcome is a result the cooperative can act on immediately.

4.6 Limitations and what this case cannot show.

Four limitations should travel with these results wherever they are cited. First, the treatments are lots within a single commercial plot in a single season, not independent field replicates across sites or years; the statistical tests describe the variability of this site-season and are not a basis for generalising effect sizes. Second, soil moisture was instrumented in T0 and T1+ only, so the moisture profile of T1 — the treatment carrying the cleanest fertiliser result — is inferred rather than measured, and the water and input results therefore rest on partially different treatment pairs; moreover, because T1+ also received the microbial inoculant, the moisture gain belongs to the full T1+ package rather than to the cover crop alone. Third, the biodiversity read-out comes from two sampling dates, which fixes the direction of the effect but not its decay: we can say the winter gain did not survive to August, but not when between April and August it was lost. Fourth, the soil microbiome and biological-activity results come from one composite sample per treatment on a single occasion, so they indicate the direction and relative size of the soil-biology response but cannot separate treatment effects from within-plot spatial variation, and genus-level taxonomy does not resolve pathogenic from non-pathogenic taxa. None of these limitations affects the input-use conclusion, which comes from complete per-treatment application records rather than from sampling.

5. Delivery through an EIP Operational Group: the multidisciplinary model

The second topic this contribution addresses is organisational. A single field case of this kind normally requires either a large research consortium or a series of disconnected studies. Within GOS ACCESO, six specialised partners worked in parallel on the same plots and the same season: ACOPAEX and CTAEX contributed the commercial field, the agronomic management and the record books; ZERYA coordinated the protocol and the integration of results; CEBAS-CSIC has delivered the first-year soil microbiome and biological-activity characterisation, with nematode quantification to follow; Fundación Global Nature designed and executed the biodiversity sampling and the functional-guild indexing; University of Zaragoza carried out post-harvest physicochemical and colorimetric analysis; and the University of Zaragoza contributed to soil-quality assessment. The Operational Group instrument is what made a five-dimension read-out on one commercial plot affordable and coherent.

Two features of this model are worth transferring. First, the farmer organisation is the host of the trial, not a recipient of its conclusions: results return to ACOPAEX's growers through the cooperative's own technical channels, in the units they use — litres of fertiliser, euros per hectare, calibre and °Brix — rather than as indices. Second, the group's aid-independent framing changes which results are considered publishable. In a subsidy-justification logic, the failed flower strip, the absence of pesticide savings and the transient biodiversity effect would all be omitted. Here they are the load-bearing findings because a practice recommended on agronomic grounds must be described with its limits intact or the recommendation will not survive contact with the field.

5.1 Regulatory context and why aid-independence is a crop-protection question.

Cover cropping is supported in the Spanish CAP Strategic Plan as an eco-scheme practice, and uptake has grown quickly. From a crop-protection perspective this creates two regulatory risks. The first is discontinuity: benefits that depend on soil biological processes — organic matter turnover, decomposer activity, moisture buffering — accumulate over several seasons, whereas payment eligibility is decided annually, so practices can be switched on and off before the biological effect establishes. The second is displacement of evidence: when a practice is justified administratively, the incentive to measure what it does to pests, diseases and inputs weakens. This trial resists both: a bankable fertiliser saving was demonstrated, while the more attractive claim — natural-enemy enhancement — was not supported by the guild-level evidence and is therefore not made.

5.2 Transfer pathway to growers.

Results reach ACOPAEX's member growers through the cooperative's own technical advisory channels and field meetings, with a deliberately narrow message: a winter cover crop in the tomato rotation cut fertigation inputs by 12% and 147 €/ha without any yield or handling penalty, and irrigation should be reduced in the following season to convert the retained soil water into a second saving. The biodiversity and colour results are left out of the grower-facing message because they are either transient or not actionable at farm level.

6. Proposed collaboration and dissemination

The virtual mobility phase of this grant was used to discuss this case with TOP Agri-Network participants from other countries through video meetings, with three specific questions on the table: how the use of cover crops increases soil moisture retention; whether guild-level rather than aggregate biodiversity reporting is becoming standard practice in cover-crop trials; and how soil microbiome results are being linked, if at all, to observable phytosanitary outcomes at field scale.

Date	Participants (country / institution)	Question addressed	Outcome
10/set/2026	Turkey – Ege University	Microbiota-based Approaches for Sustainable Crop Protection	Online - Listening
15/set/2026	Portugal – IPV	Participatory approaches in crop protection	Online - Participation

Table 7. Record of the video meetings held during the virtual mobility phase, as required by the grant conditions.

7. Conclusions

- A winter brassica–legume–forb cover crop in a fertigated processing-tomato rotation cut NPK volume by 12% and fertiliser cost by 147 €/ha at equal commercial outcome, independently of any eco-scheme payment.
- No plant protection saving was demonstrated: the programme was identical across treatments (835 €/ha, twelve applications). Field records showed no treatment-specific health episode.
- The covered profile held 12,7 percentage points more soil moisture in July under an unchanged irrigation schedule, concentrated below 40 cm.
- Cover crops promoted the development of more diverse and functional bacterial and fungal communities than conventional management, improving the biological quality of the soil. In addition, microbial inoculation in T1+ seemed to enhance this effect, favouring a greater relative abundance of genera potentially beneficial for the biological functioning of the soil and the sustainability of tomato cultivation in the medium and long term.
- Fruit from covered plots was larger with lower °Brix and a lower maturity index; this is interpreted as a dilution artefact of unadjusted irrigation, and it defines the priority protocol change for 2026.
- Winter arthropod abundance tripled under the cover, but the gain was carried by detritivores and phytophagous Diptera rather than natural enemies and did not persist after incorporation.
- The flower strip in T1+ failed through *Datura stramonium* competition and is reported as a negative result. Measures will be conducted next season.
- The Operational Group structure allowed five specialised partners to characterise one commercial plot across agronomy, soil water, biodiversity, industrial quality, and soil biology within a single season.

Annex. Dataset inventory and division of work

Dataset	Partner	Method and resolution	Status
Field record books (fertiliser, PPP, operations)	ACOPAEX	Per-application records by treatment: volumes, active substances, doses, costs/ha	Closed
Soil moisture	ACOPAEX / CTAEX	Capacitance probes, 8 depths (10–80 cm), 15-min logging, T0 and T1+	Closed
Arthropod communities	Fundación Global Nature	Two dates (Feb, Aug), three samples/treatment, identification to family, guild assignment, composite indexing	Closed
Harvest quality	ACOPAEX / Univ. Zaragoza	3 lots × 10–15 fruits per treatment: calibre, firmness, °Brix, pH, titratable acidity, 3 readings per fruit	Closed
Soil microbiome and soil biological activity	CEBAS-CSIC	One composite sample per treatment (10 sub-samples, 0–20 cm); 16S (V3–V4) and ITS2 metabarcoding, Illumina MiSeq; five enzyme activities, microbial biomass C, basal respiration	2025: intermediate report delivered (09/09/2026). 2026 sampling <i>in progress</i>
Nematodes and soil quality	CEBAS-CSIC	Archaeal profiling; PCR quantification of <i>Meloidogyne</i> and <i>Pratylenchus</i> ; physical and chemical soil-quality indicators	Closed
Synthesis and reporting	ZERYA	Integration of all datasets, transfer to growers	This report

Table 8. Division of analytical work within the Operational Group for the Badajoz processing-tomato case, 2024/25 season.

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