DRIVE
Drought Resilience Improvement in Vineyard Ecosystems

LIFE19 ENV/IT/000035

Report on the implementation of resilience plans in the DEMO farms

Sub-Action B2.2 Implementation of the water resilience solutions

31.10.2022

Abstract

Techniques of soil and canopy management for improved vineyard water resilience were implemented during the first project year and assessed vs traditional management over the second project year. New protocols for canopy and soil management have been applied in the 6 demo farms, under the aim to treasure available rainfall and limit water competition of cover crops toward the consociated vines. Final goal to preserve remunerative yield at the desired quality and at the minimum cost. Description of the activities performed in the different demo vineyards Drive Life project follows.
Table 1 shows a brief description of the resilience techniques selected and applied in each DEMO farms.
For each DEMO farms features of the selected demonstrative vineyards are presented and preliminary results of the last season (2022) are reported.

Table 1: selected resilience techniques for each DEMO farms. N = legume prevalent; C = grass prevalent; B = balanced.

DEMO FARM CODE*[1]	Project area[2]	Adopted techniques
VCB	CP	Green manure applied using three different winter cover-crop (N, C, B)
GNP	CP	Green manure applied using balanced and grass-prevalent winter cover crop (C)
VCB_2	CP	Foliar application of kaolin and anti-transpirants.
CRT	CP	Rolling and the “mow and blow” termination of C cover crop
BRP	OP	Green manure applied to B and C winter cover crops.
SMV	OP	-Application of all termination techniques to C and N cover crops -Under row sowing and transplanting of ground cover species
CNV	OP	Between-row rolling of C cover crops.

[1] DEMO farms codes are refereed to Deliverable B2.1 “Report on chemical-physical features and hydraulic properties of selected vineyard soils”
[2] CP = Colli Piacentini; OP = Oltrepò Pavese

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Water resilience techniques applied in the demonstrative vineyards

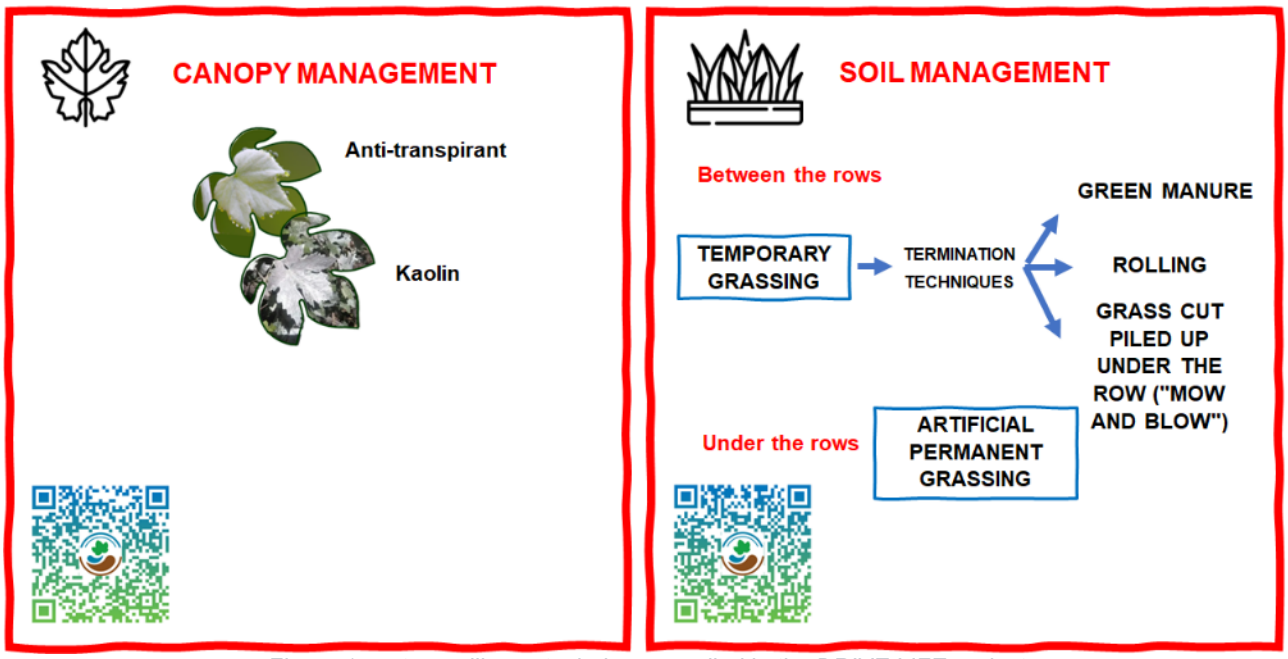


Figure 1: water resilience techniques applied in the DRIVE LIFE project

Soil management techniques

Between row temporary grassing

The soil management techniques implemented in vineyards involved the use of autumn-spring grassing to increase vineyard water resilience (Fig.1). Winter cover crops, an alternative to permanent grassing and total tillage, is then terminated in spring according to the following modalities:

- green manure (GM),
- inter-row mulching obtained by rolling (R)
- piling of grass under the row (“mow and blow”) (MB)

Seed mixture for grassing

The composition of the sown seed-mixtures may involve the use of different proportions of cereals, legumes, brassica and other botanical families according to the specific needs of the vineyard. The field trials selected a seed-mixture with predominance of grasses (C), one with mostly leguminous (N) and a third one (B) with a more balanced legume-to-grass ratio and the presence of small fractions of brassica and other species. (Fig. 2)

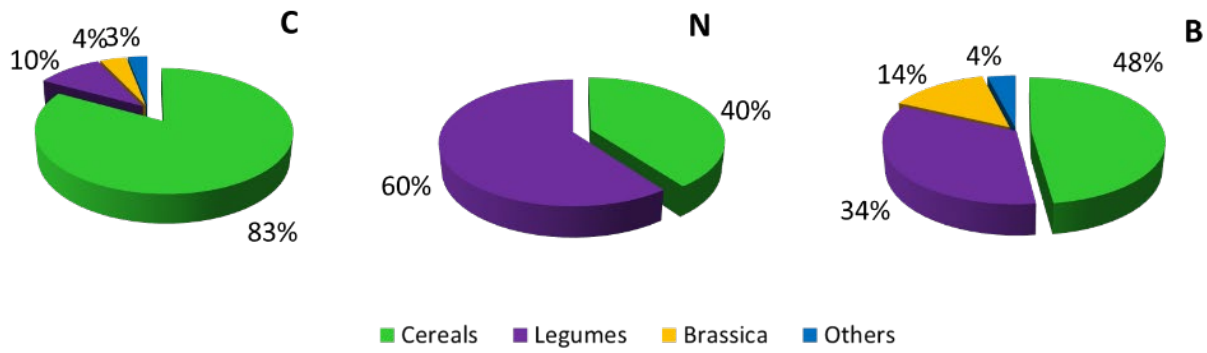


Figure 2: cover crops seed mixtures composition used in DRIVE LIFE project

Sowing

Sowing operations were carried out using a tractor and seed drill combined with a power harrow (Fig. 3). The sowing rate for all three mixtures was 100 kg/ha and the sowing width was 160 cm.

Figure 3: sowing operation in October 2022

Techniques applied for the termination of biomass

The grown biomass is terminated in spring according to the three techniques mentioned above (Fig.4):

Green manuring (GM): it implies mowing and subsequent burying in the soil of the biomass grown during the winter; the aim is promoting the release of nutrients and enhancing its water holding capacity. According to agronomical needs, a mixture with a different ratio of cereals, legumes and brassicas is used.

Between-row mulching (R): it requires a crimper roller to press biomass produced between the rows, creating a permanent mulching layer. This technique is considered beneficial for saving soil

water content due to the formation of a 'coating' that reduces direct evaporation and transpiration of the plot, as well as the growth of potential weeds in proportion to the amount of biomass produced.

Piling of grass under the row ("mow and blow") (MB): it is achieved with a special mulcher that conveys the residues under the vines, forming a localised mulch. In addition to maintaining moisture in the soil, weed growth is naturally controlled with minimal recourse to tillage over the remainder of the season.

Figure 4: different termination operations: a) and b) between rows mulching; c and d) piling the grass sward under the row

Sowing and transplanting of ground cover species under the rows

In addition to the specific trials concerning temporary grassing management, a trial of planting/sowing ground cover species under the row began (Fig.5). Herbaceous species from different botanical families all having attitude to suffocating growth patterns were established with primary aims of limiting the growth of native weeds while preserving soil structure and alleviating erosion issues.
Several pre-tests were made by UCSC to identify species with lower water consumption and best suffocating properties. The selected ones were: *Dichondra repens, Trifolium subterraneum, Glechoma hederacea, Pilosella officinalis, Festuca ovina, Festuca rubra* rubra.

Figure 5. "Living Mulch" under the row. Left: Pilosella officinarium at the moment of transplanting. Right: Glecoma hederacea during establishment.

Canopy management techniques

Resilient canopy management strategies implemented during the project to preserve plant water status and limit overheating damage involve the foliar applications of kaolin and anti-transpirants. Kaolin rock powder is able to reflect solar radiation resulting in a cooling effect of canopies and clusters. The anti-transpirant used in experimental vineyards reduce transpiration through the formation of a film that occludes the stomata and, in turn, slows down the leaf gas exchanges (Fig. 6).

Figure 6: Kaolin and anti-transpirants sprayed on canopy.

Demo farms action plans

In Table 2 techniques chosen for each demo farm are summarized.
Demonstrative vineyards were selected according to the following considerations:
- uniformity of vineyard and soil management;
- uniformity of vine variety to enable the analysis of vine behavior through the data collected during harvest and pruning time.

Table 2: selected resilience techniques for each DEMO farms with indication of the cover crop seeds mixture choose

TECHNIQUE	SOIL MANAGEMENT										CANOPY MANAGEMENT
SEED MIXTURE	N			B			C			SUB-ROW GRASSING	
TERMINATION T.	GM	R	MB	GM	R	MB	GM	R	MB		
VCB	X			X			X				
GNP	X			X							
CRT								X	X		
BRP	X			X							
SMV	X	X	X				X	X	X	X	
CNV								X			
VCB_2											X

Demonstrative activities in vineyards and collected data

For each DEMO vineyard an experimental plan and a survey scheme have been developed. Data assessment is performed by UCSC researchers.

Survey scheme

UCSC developed and executed a sampling plan to collect parameters on vine behavior.
For each DEMO vineyard the following parameters were assessed/recorded:

- **Fresh and dry weight of biomass** (g/m^2) produced by winter cover crops in both the inter-row and under-row areas before terminations.
- **Plant growth, productivity and fruit composition measurements**: pruning weight, yield components and main must parameters at harvest.
- **Physiological measurements:** Leaf assimilation (A), transpiration (E), stomatal conductance (g_s), pre-dawn and midday water potential (Ψ) under pre-stress and ongoing water stress conditions.
- **Visual surveys** of the degree of native weeds colonization in the sub-row.

Outline of activities

Figure 7: scheme of activities and surveys in DEMO vineyards

During the preliminary 2021 season, techniques were fine-tuned in all demo vineyards. The activities were useful for the calibration of seeding and termination operations; several critical points were detected, which led to some adjustments for the following year: the seeding rate was increased and the sowing width was reduced in order to optimise the terminations of the mixtures. Some changes were also made on the roller and the mulcher to improve the mulching effect.

The 2022 season was characterised by high average temperatures and reduced level of rainfall compared to the historical average. A particularly mild autumn-winter period with no rainfall (Tab.3) led to an early water shortage in the wine-growing areas involved in the project. This influenced the growth of the grapevines and the general development of the sown species of cover crops. In addition to the abnormal thermal trend and rainfall, hailstorms hit some of the project's vineyards, making it impossible collecting data related to yield and grape composition. The VCB, VCB_2 and SMV farms were particularly affected by hail.

Table 3: main meteorological data acquired during the season

DEMO FARM	RAINFALL (mm)				ETp (mm)			GDD (∑Tmed-10)
	Sowing – Termination (Oct-May)	Jan - Termination	Apr– Sept	Jun – Aug	Sowing - Termination	Apr – Sept	Jun – Aug	Apr – Sept
VCB	**325**	139	326.1	187	**287**	599.3	368.6	2077
GNP	**285**	127	310	160	**227**	642.8	391.6	1904
CRT	**275**	104	252.1	150.3	**270.3**	645.6	395.3	2109
BRP	**234.6**	76.5	124.8	66.2	**291.9**	667.6	407.9	2049
SMV	**303.1**	106.3	344.5	204	**219.8**	595	378.3	1914
CNV	**286.6**	117.4	190	78	**327**	628.9	369.4	2008

For each demonstrative vineyard an **Action Plan** is in place composed by:

- **General features of the vineyard**
- **Experimental plan**: which techniques are applied and the layout of treatments
- **Description of performed activities**
- **Data collected**: presentation of preliminary data of 2022 season. Complete data assessment and discussion will be presented at the end of the project in the deliverable *"Report on effectiveness of resilience strategies in DEMO farms".* For each farm only the most relevant data are presented,
  Meteorological data were recorded from the weather station installed at the beginning of the project in each DEMO farms.

A complete analysis of data collected during the project in DEMO vineyards will be reported in Deliverable B2.2 "*Report on effectiveness of resilience strategies in DEMO farms"* (M35)

DEMO FARM	VCB
Farm name	***Ampeli Antonio***
Project area	Colli Piacentini
Demonstrative vineyard	
Variety	Croatina
Rootstock	K5BB
Training system	Guyot
Vine spacing	2.5 x 1.00 m
Row orientation	E-W
Altitude	250 m a.s.l.
Geographical localization	44°59'29.56"N - 9°21'25.17"E

Figure 8: VCB Demo vineyard.

Action plan description

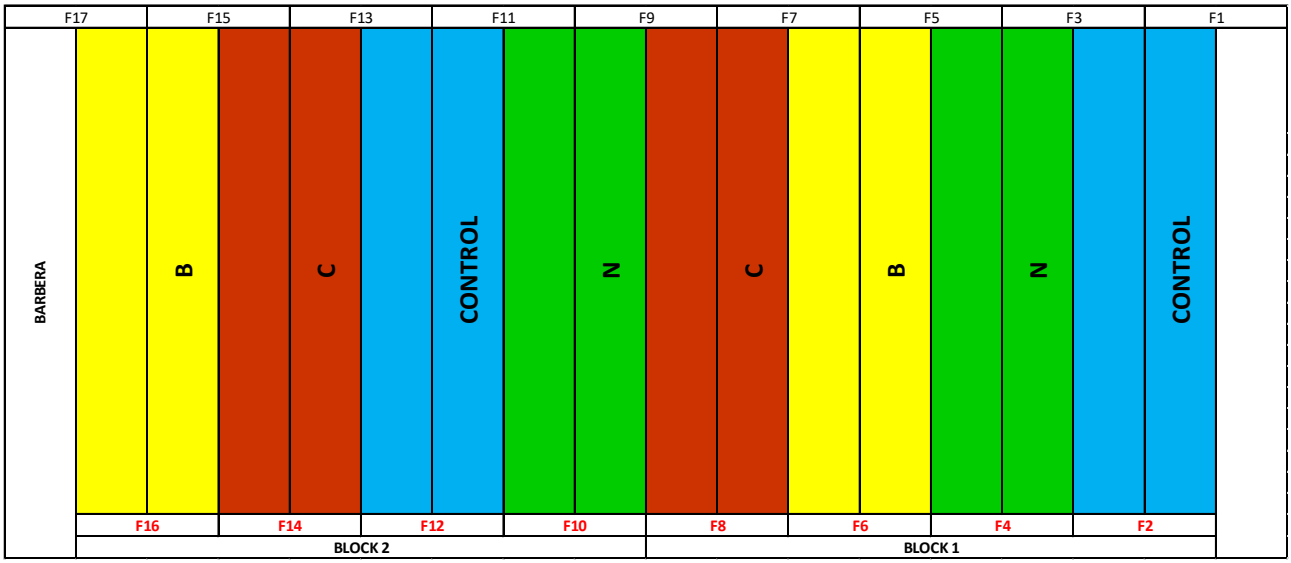


Figure 5: experimental map VCB. For each treatment 2 blocks were defined and, in each block, 5 plants were tagged for vine behavior assessment.

Resilience techniques applied

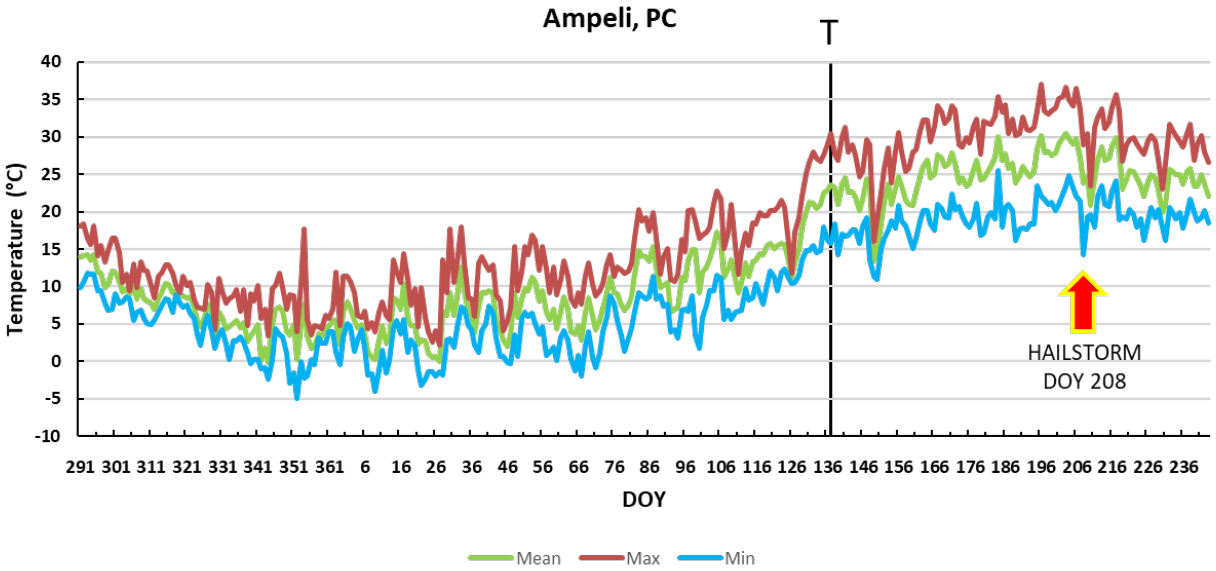
Techniques	Description
N	Between rows space grassed with the **N seeds mixture** and then finished with green manure technique (GM).
B	Between rows space grassed with the **B seeds mixture** and then finished with green manure technique (GM).
C	Between rows space grassed with the **C seeds mixture** and then finished with green manure technique (GM).
Control	Standard farm management with tilled inter-row and under-row

What we do

Activities	Date	Notes
	2021	
Sowing	Late spring	
Termination	10-15 of May 2021	
Harvest	21 of September 2021	
Pruning	12 of January 2022	
Activities	**Date**	**Notes**
	2022	
Sowing	15 October 2021	mixtures: N, B and C
Termination	12-16 of May 2022	green manure
Harvest		not harvested due to hail
Pruning		Not yet performed

Data collected

Meteorological data (season 2022)



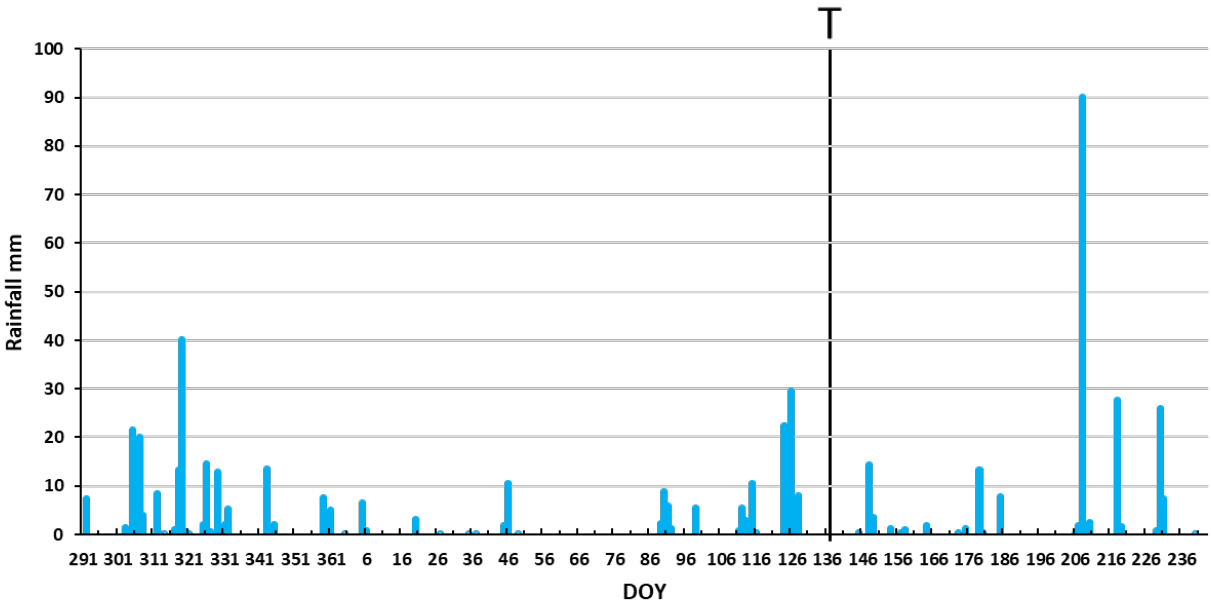


Figure 6: Temperature and Rainfall from sowing 15/10/21 to 31/08/22.

Activities

Figure 7: biomass assessment (12.05.2022)

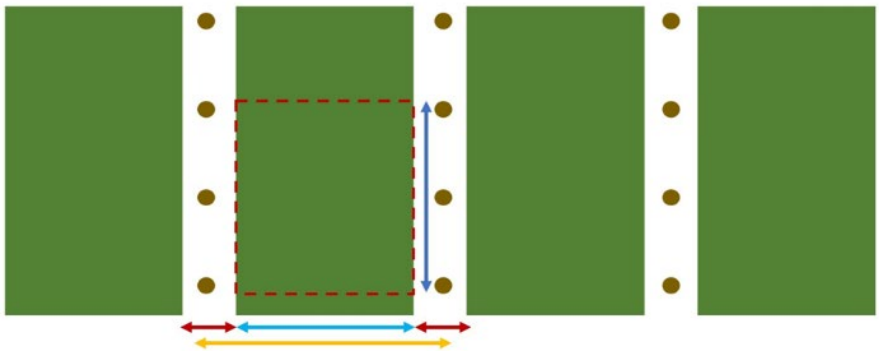


Figure 82: biomass assessment scheme.

The evaluation of the growth of the mixtures is usually carried out just before terminations and consists of biomass sampling of areas between the rows (Fig.12). The samples are then weighed directly in the field while the dry matter assessment is conducted later in the laboratory. The biomass formed during the winter and spring was good enough for the green manure technique. Unfortunately, a hailstorm that occurred at the end of July (photos below) completely compromised the harvest and the analyses to be carried out on the grapes. Further evaluation will be carried out on the pruning wood.

Figure 13: the vineyard after the hailstorm (29.07.2022)

DEMO FARM	GNP
Farm name	***Az. Magistrali Anna***
Project area	Colli Piacentini
Demonstrative vineyard	
Variety	Ortrugo
Rootstock	SO4
Training system	Guyot
Vine spacing	2.00 x 1.00 m
Row orientation	NW-SE
Altitude	275 m a.s.l.
Geographical localization	44°55'51.12"N - 9°22'7.00"E

Action plan description

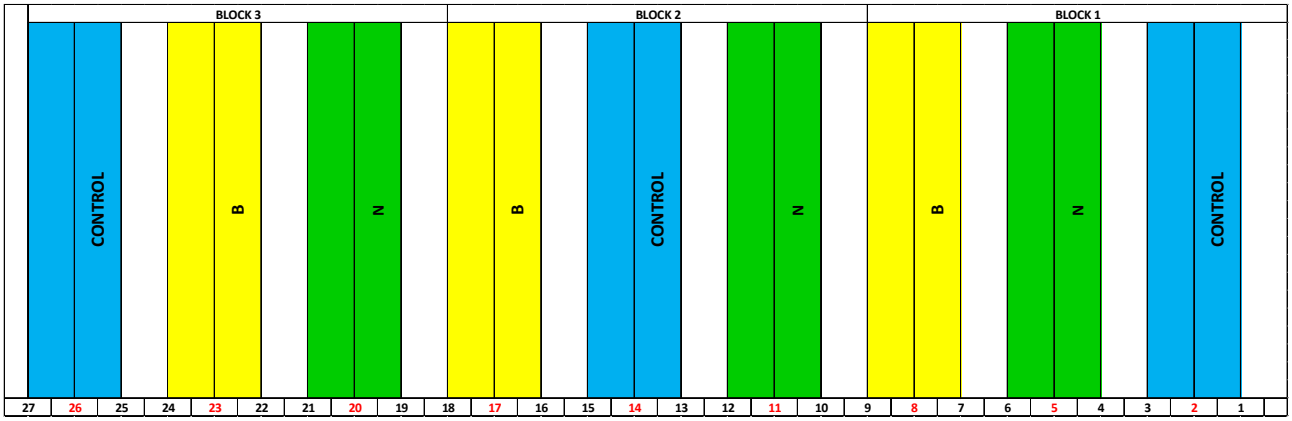


Figure 14. Experimental map of GNP demo vineyard. For each treatment 3 blocks were defined and, in each block, 3 plants were tagged for vine behavior assessment.

Resilience techniques applied

Techniques	Description
N	Between rows space grassed with the **N seeds mixture** and then finished with green manure technique (GM).
B	Between rows space grassed with the **B seeds mixture** and then finished with green manure technique (GM).
Control	Standard farm management with tilled inter-row and under-row

What we do

Activities	Date	Notes
	Season 2021	
Sowing	Late spring	
Termination	12-18th May	

Harvest	7th September	
Pruning	25th January (2022)	
	Season 2022	
Sowing	19th October (2021)	mixtures: N, B
Termination	21-25th May	green manure
Harvest	31th August	
Pruning		Not yet performed

Data collected

Meteorological data (season 2022)

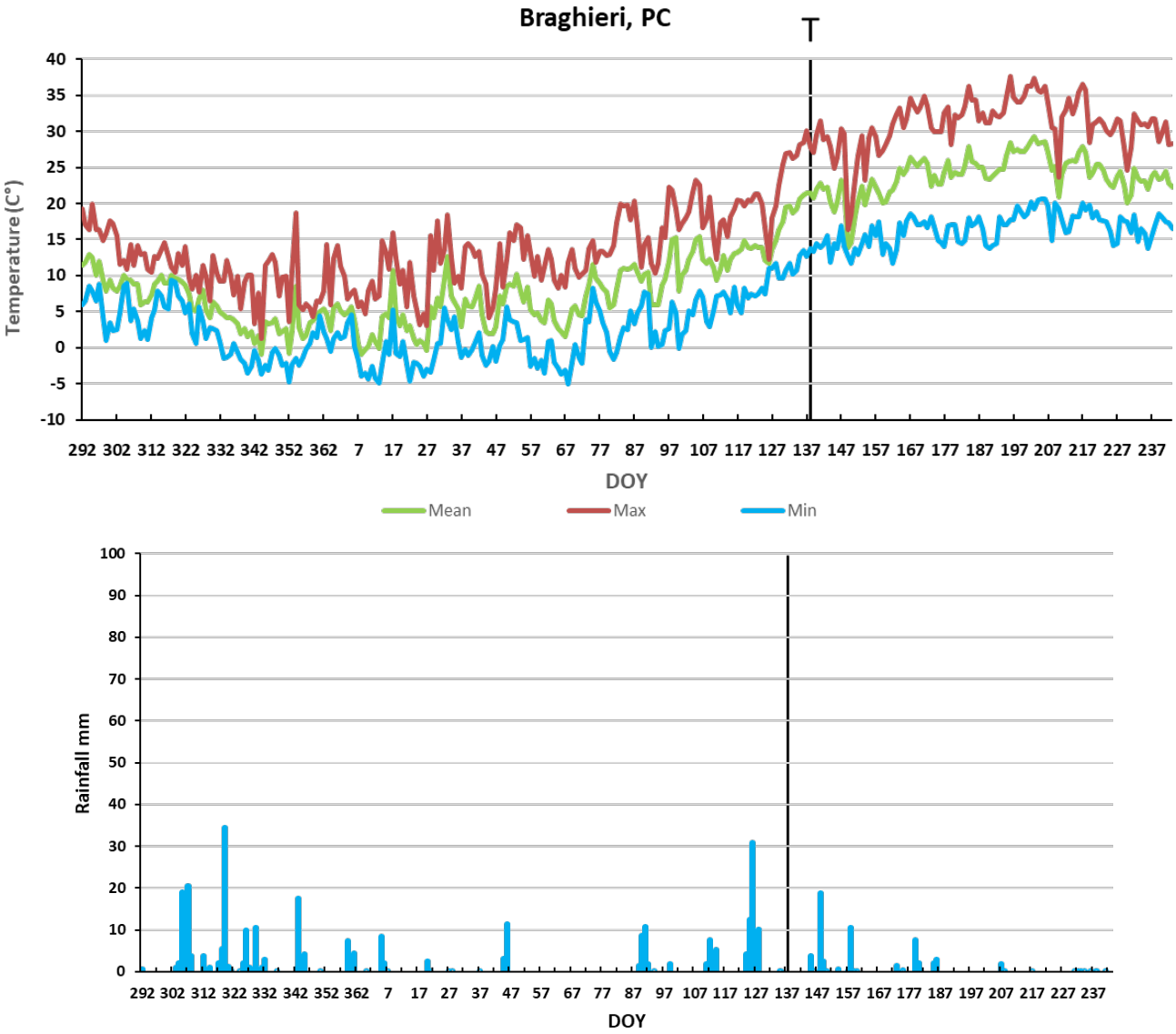


Figure 15: Temperature and Rainfall from sowing 15/10/21 to 31/08/22.

Activities

Some critical aspects emerged during the tillage and sowing phases: the vineyard has a narrow row spacing, which allowed sowing operations to be carried out only manually. The low rainfall in the autumn and winter period allowed for a moderate development of the sown mixtures.

Figure16: Biomass evaluation 20/05/2022 and harvesting 31/08/2022.

DEMO FARM	VCB_2
Farm name	***Az. Malvicini Paolo***
Project area	Colli Piacentini
Demonstrative vineyard	
Variety	Ortrugo
Rootstock	SO4
Training system	Guyot
Vine spacing	2.30 x 1.00
Row orientation	E-W
Altitude	272 m a.s.l.
Geographical localization	44°59'27.06"N - 9°21'59.87"E

Action plan description

Figure 17. Experimental map VCB_2 DEMO vineyard. For each treatment 4 blocks were defined and, in each block, 3 plants were tagged for vine behavior assessment.

Resilience techniques applied

Techniques	Description
K	Canopy treated on both sides with a 6% kaolin solution
A	Canopy completely treated on both sides with a 1% anti-transpirant (Pinolene) solution
Control	Standard canopy management

What we do

Activities	Date	Notes
	2022	
Installation of thermal sensors	30th June	
Physiological measurements	13th July	
Spraying Kaolin + Antitranspirant	13th July	
Physiological measurements	25th July	
Harvest	31th August	Slightly damaged by hail

Activities

The spraying of kaolin and antitranspirant was carried out manually on both sides of the canopy. A rather severe hailstorm at the end of July partially damaged the grapes. Measurements of the main physiological parameters were performed before and after treatments.

Figure 18. Treatment day 13/07/22.

DEMO FARM	CRT
Farm name	***Az. Sartori Federico***
Project area	Colli Piacentini
Demonstrative vineyard	
Variety	Malvasia di Candia Aromatica
Rootstock	SO4
Training system	Double Guyot
Vine spacing	2.30 x 1.00
Row orientation	NE-SO
Altitude	150 m a.s.l.
Geographical localization	45° 1'41.95"N - 9°23'11.60"E

Figure 19: CRT DEMO vineyard

Action plan description

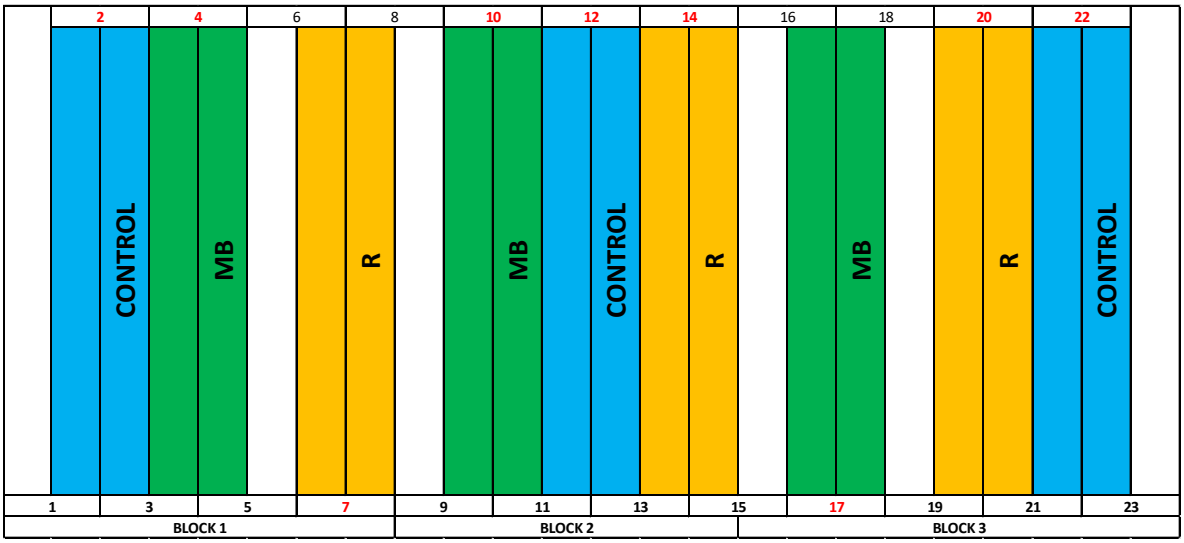


Figure 20. Experimental map of CRT DEMO vineyard. For each treatment 3 blocks were defined and, in each row, 5 plants were tagged for vine behavior assessment.

Resilience techniques applied

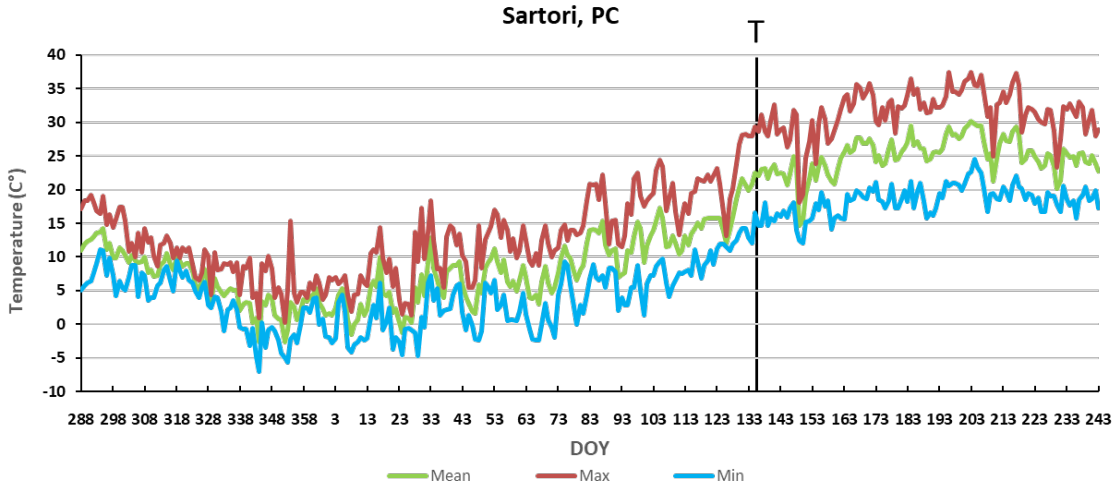
Techniques	Description
MB	Between rows space grassed with the **C seeds mixture** and then finished using the "mow and blow" technique.
R	Between rows space grassed with the **C seeds mixture** and then finished using the rolling technique.
Control	Standard farm management with alternating tilled inter-row.

What we do

Activities	Date	Notes
	Season 2021	
Sowing	Late spring	Cover crop: C
Termination	20th May	R and MB techniques
Harvest	26th August	
Pruning	3rd February (2022)	
Activities	**Date**	**Notes**
	Season 2022	
Sowing	19th October (2021)	Cover crop: C
Termination	18th May	R and MB techniques
Physiological measurements	14th June	
Physiological measurements	14th July	
Physiological measurements	3rd August	
Harvest	25th August	
Pruning		Not yet performed

Data collected

Meteorological data (season 2022)



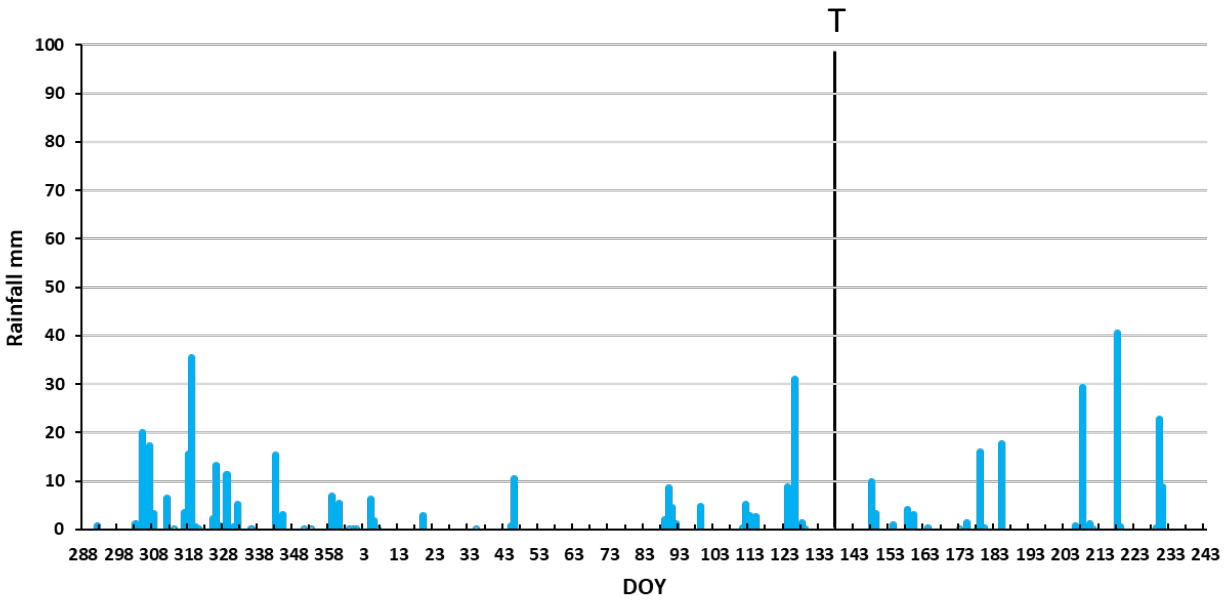


Figure 21. Temperature and Rainfall from sowing 15/10/21 to harvest 25/08/22.

Activities

The mixtures grew optimally during the autumn-winter period and resulted in a good biomass for the implementation of the techniques. Some problems emerged in the management of the under-row. Indeed, effectiveness of the “mow and blow” technique is maximised when, just prior to piling, the under the row soil strip is free of weeds. This was not exactly the case and, besides not getting the most uniform mulching effect under the row, probabilities that pre-existing weeds can actually “escape” or “perforate” the dead mulch are quite high.

Termination activities ran smoothly; however, the special mulcher for piling residues under the row needed further fine-tuning and adjustment to improve effectiveness of the mulching layer.

During the summer, activities took place regularly with as a total of three physiological data acquisition points during the season.

Harvest was about 10-day earlier than the previous year.

Figure 22. Biomass evaluation 12/05/2022 and termination day 18/05/2022.

DEMO FARM	BRP
Farm denomination	***Az. Agr. Dacarro Bernardo di Dacarro Claudio***
Project area	Oltrepò Pavese
Demonstrative vineyard	
Variety	Pinot Noir
Rootstock	SO4
Training system	Spur pruned cordon
Vine spacing	2.60 x 1.50
Row orientation	E-W
Altitude	330 m a.s.l.
Geographical localization	44°58'2.43"N - 9° 7'22.12"E

Figure 23: BRP DEMO vineyard.

Action plan description

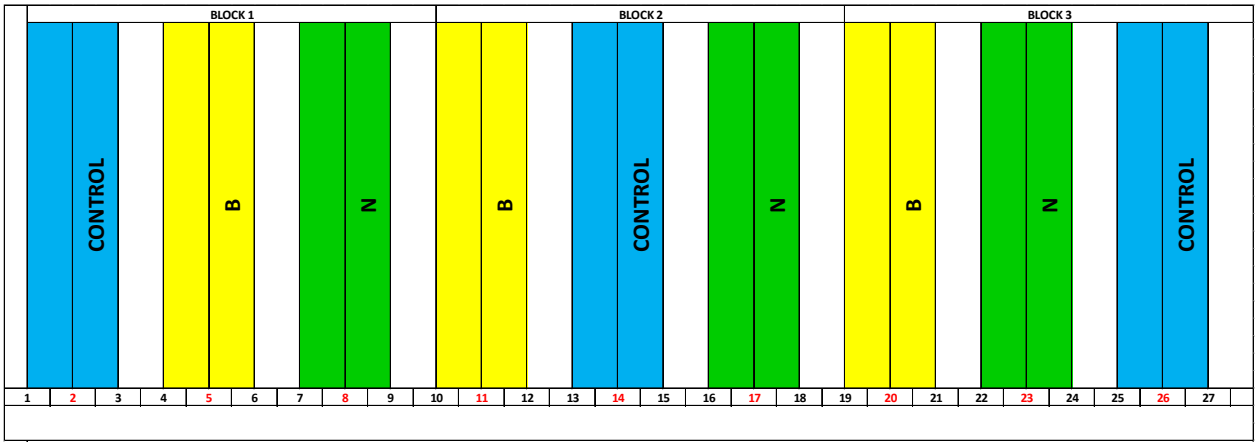


Figure 24. Experimental map BRP DEMO vineyard. For each treatment 3 blocks were defined and, in each block, 3 plants were tagged for vine behavior assessment.

Resilience techniques applied

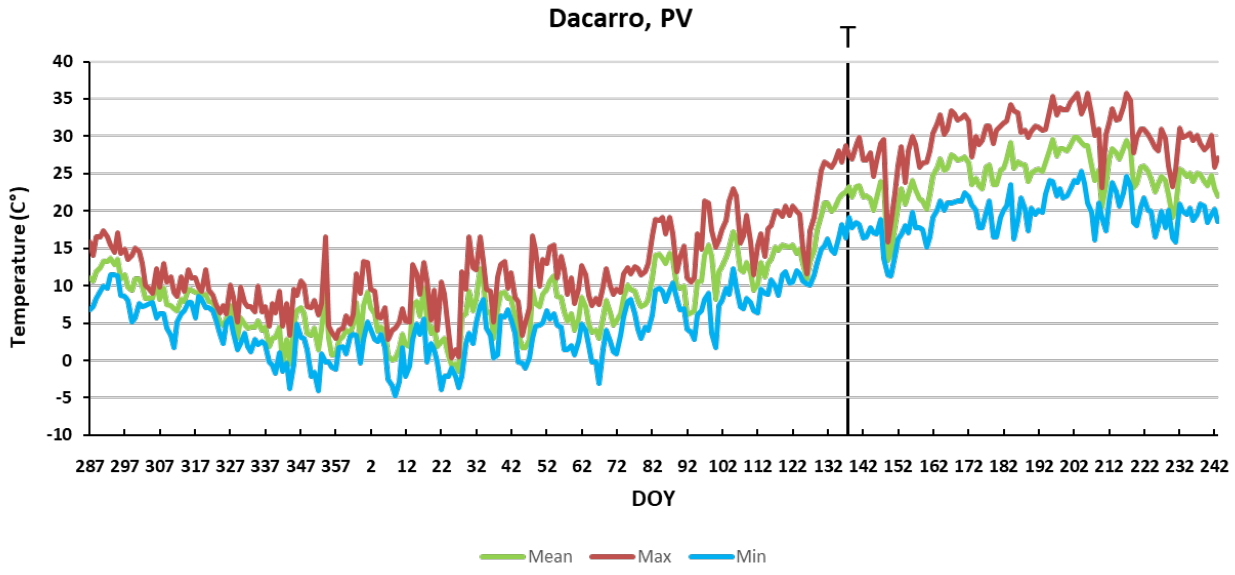
Techniques	Description
N	Between rows space grassed with the **N seeds mixture** and then finished with green manure technique (GM).
B	Between rows space grassed with the **B seeds mixture** and then finished with green manure technique (GM).
Control	Standard farm management with tilled inter-row and under-row

What we do

Activities	Date	Notes
	Season 2021	
Sowing	Late spring	
Termination	15-20 of May	
Harvest	1 of September	
Pruning	4 of February (2022)	
Activities	**Date**	**Notes**
	Season 2022	
Sowing	14 October (2021)	Cover crop: N, B
Termination	21-25 of May	green manure
Harvest	22 August	
Pruning		Not yet performed

Data collected

Meteorological data (season 2022)



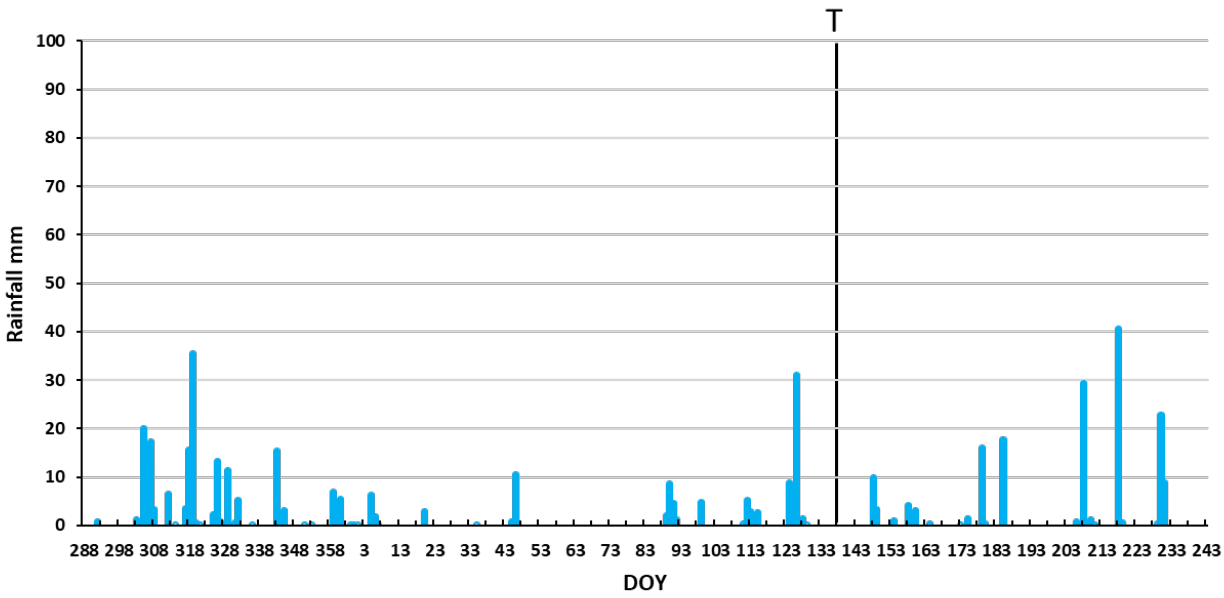


Figure 25. Temperature and Rainfall from sowing 14/10/21 to harvest 22/08/22.

Activities

In this specific vineyard, it was decided to adopt the green manure technique due to the scarcity of nutrients available. Once buried, the mixtures should improve structure, increase water holding capacity and release nutrients to the vine.

The very dry season led to insufficient development of the two sown mixtures. In addition, due to a high active lime content in the soil, the development of the legumes was negligible. In particular, soil composition has an important effect on the development of cover crops, in fact, water availability,

texture and the presence of limestone can inhibit the growth of legumes, whereas cereals are less affected. BRP has 40% total limestone and 27% active lime. This can affect the growth of all cover crops and the growth of the different botanical species within the seed mix. It will be crucial to check which species are better suited to the quite peculiar features of the vineyard.

Figure 26. Photos from biomass assessment of N and B cover crops 17/05/2022 and harvesting at the end of August 2022.

DEMO FARM	SMV 1
Farm name	***Az. Ottina Enrico Gustavo Aldo***
Project area	Oltrepò Pavese
Demonstrative vineyard	
Variety	Pinot Noir
Rootstock	SO4
Training system	Guyot
Vine spacing	2.20 x 0.90
Row orientation	NW-SE
Altitude	290 m a.s.l.
Geographical localization	45° 0'6.01"N - 9°16'36.69"E

Figure 27: SMV_1 DEMO vineyard

Action plan description

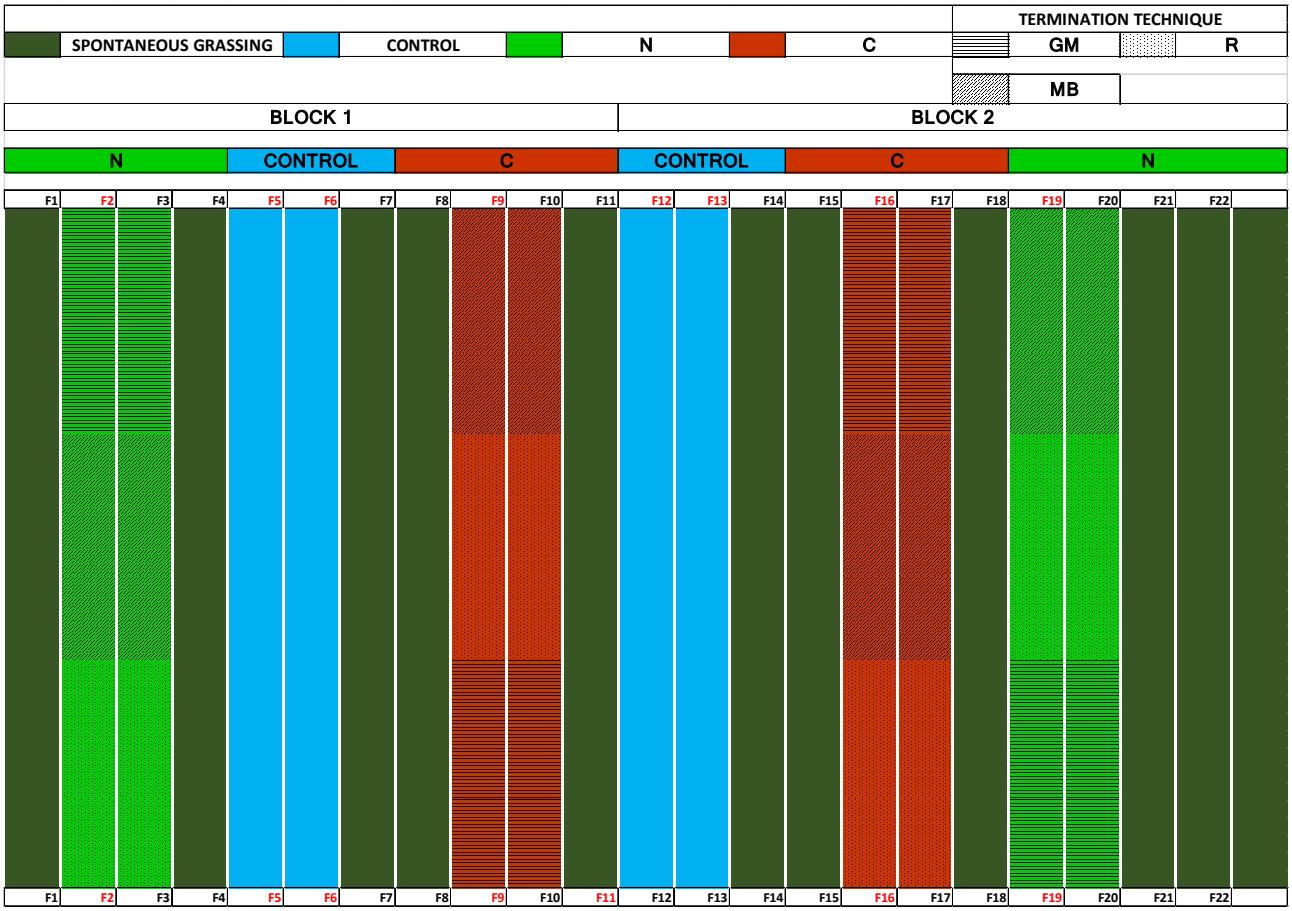


Figure 28. Experimental map SMV_1 DEMO vineyard. For each treatment 2 blocks were defined and, in each row, 5 plants were tagged for vine behavior assessment.

Resilience techniques applied

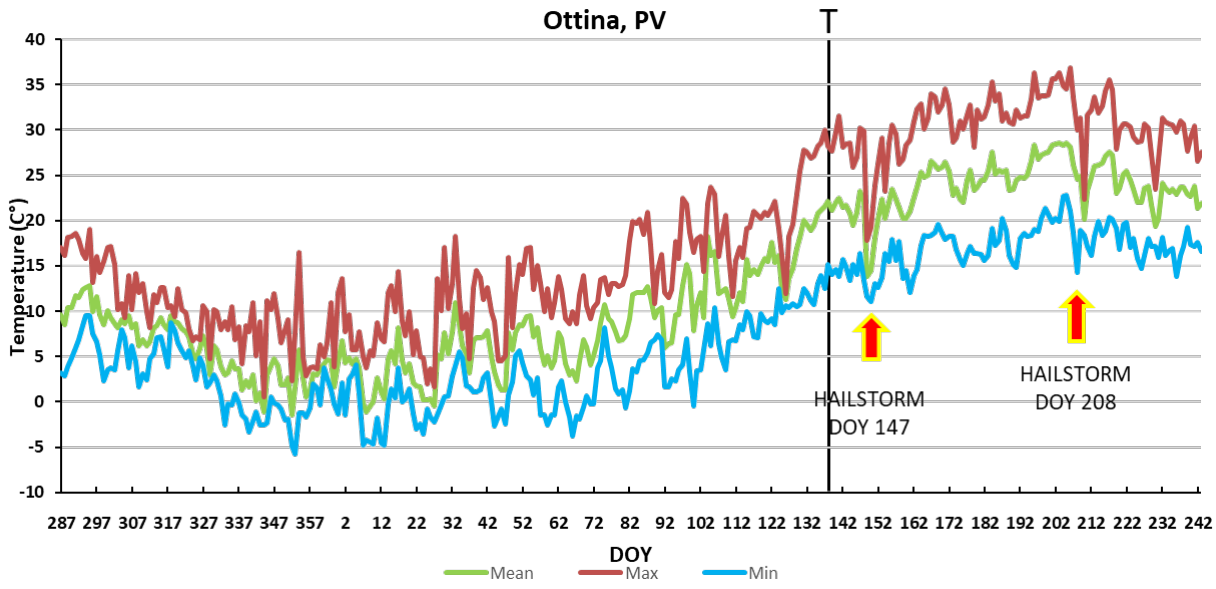
Techniques	Description
GM	Between rows space grassed with the **N (green rows on the map) or C (red rows on the map) seeds mixtures** and then finished with green manure technique (GM).
MB	Between rows space grassed with the **N or C seeds mixture** and then finished using the “mow and blow” technique (MB).
R	Between rows space grassed with the **N or C seeds mixture** and then finished using the rolling technique (R).
CONTROL	Standard farm management with permanent spontaneous grassing.

What we do

Activities	Date	Notes
Season 2021		
Sowing	Late spring	Cover crop: C and N
Termination	20th May	GM, MB and R techniques
Harvest	31th August	
Pruning	21th December	
Season 2022		
Sowing	14th October (2021)	Cover crop: C and N
Termination	19th May	GM, MB and R techniques
Physiological measurements	5th July	
Physiological measurements	19th July	Stress
Harvest		Not harvested due to hail
Pruning		Not yet performed

Data collected

Meteorological data (season 2022)



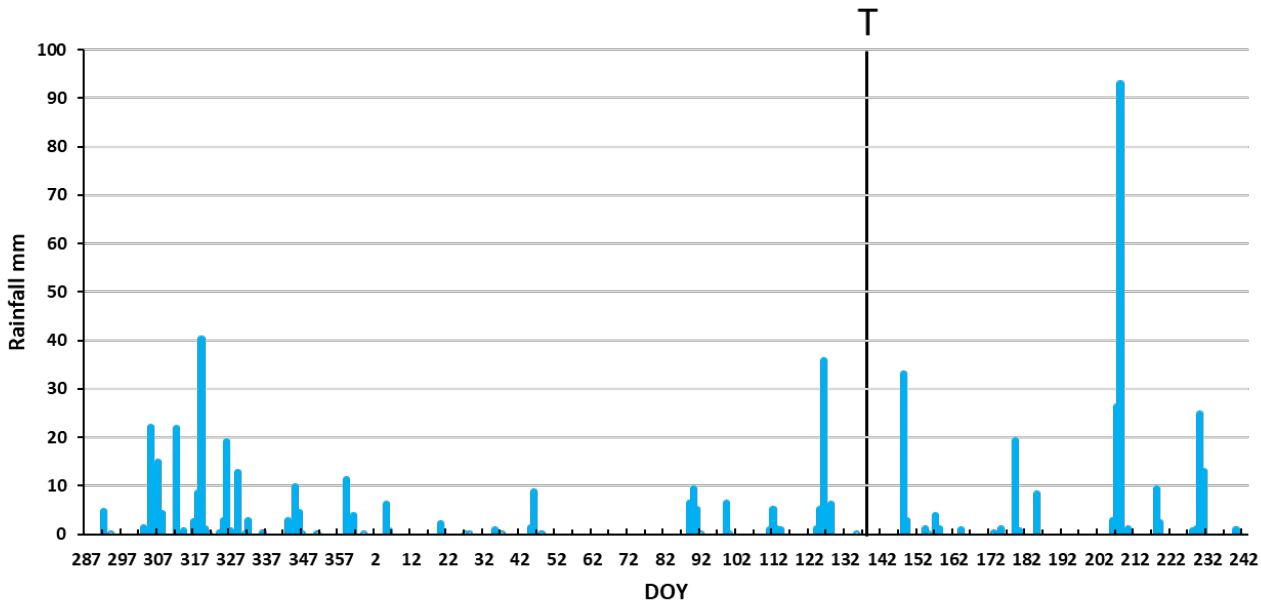


Figure 29. Temperature and Rainfall from sowing 14/10/21 to 31/08/22.

Activities

Activities at the SMV_1 vineyard were considerably compromised by two hailstorms: the first at the end of May damaged vines canopy; subsequently, the vines recovered, but at the end of July, a second severe hailstorm almost destroyed the vegetation and production.

Figure 30. Biomass evaluation 12/05/2022 and termination day 18/05/2022

DEMO FARM	SMV 2
Farm name	***Az. Ottina Enrico Gustavo Aldo***
Project area	Oltrepò Pavese
Demonstrative vineyard	
Variety	Riesling italico
Rootstock	SO4
Training system	Guyot
Vine spacing	2.20 x 0.90
Row orientation	NW-SE
Altitude	200 m a.s.l.
Geographical localization	44°59'51.02"N - 9°17'2.57"E

Figure 31: SMV_2 DEMO vineyard

Action plan description

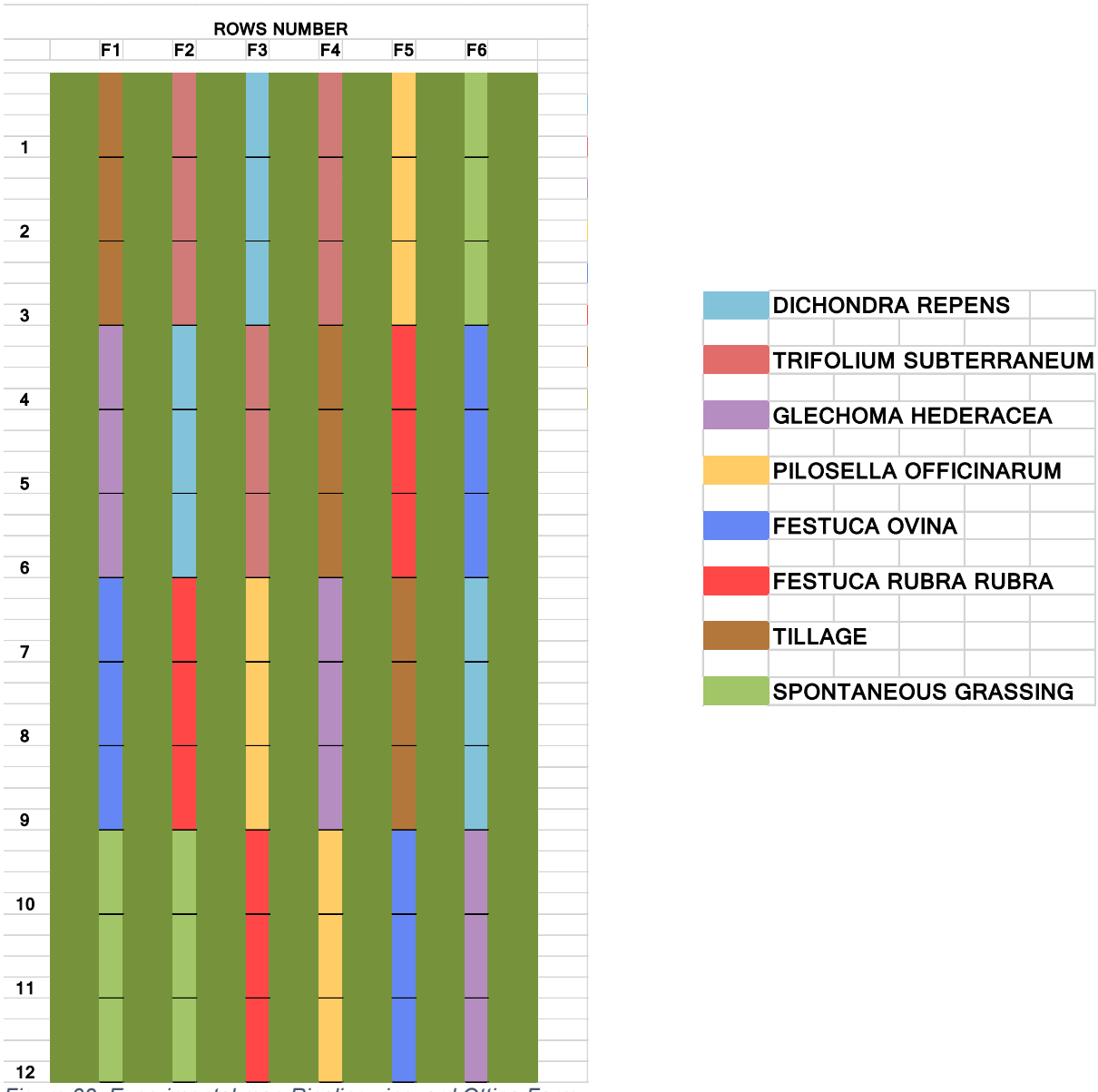


Figure 32. Experimental map Riesling vineyard Ottina Farm.

Resilience techniques applied

Techniques	Description
Sub row Grassing	Six different herbaceous ground cover species were sown (*Dichondra repens, Trifolium subterraneum, Festuca ovina* and *Festuca rubra rubra*) or transplanted (*Glechoma hederacea* and *Pilosella officinarum*) in the sub-row.
Tillage	Sub-row tilled with rotary harrow
Spontaneous Grassing	Herbaceous species growing wild in the area

What we do

Activities	Date	Notes
	2022	
Under the row tillage	4th February	First cleaning
Under the row tillage	6th April	Power harrow
Sowing and transplant	28th April	
Harvest		Not harvested due to hail
Pruning		Not yet performed

Activities

This vineyard was also heavily damaged by two hailstorms at the end of May and in July.
The aim of this trial is to establish the covering species in the sub-row. Unfortunately, since sowing and transplanting, total rainfall throughout the season was very low and we had to intervene with numerous emergency irrigations. *Glechoma hederacea* and *Pilosella officinarum* overall established well, whereas for the other species we had to intervene with additional sowing.

Figure 33. Tillage machinery, sowing and transplanting operations.

DEMO FARM	CNV
Farm name	***Az. Fontana di Piaggi Maurizio***
Project area	Oltrepò Pavese
Demonstrative vineyard	
Variety	Pinot Noir
Rootstock	SO4
Training system	Guyot
Vine spacing	2.50 x 0.90 m
Row orientation	E-W
Altitude	400 m a.s.l.
Geographical localization	44°56'14.78"N - 9°16'18.65"E

Figure 34: CNV DEMO vineyard with Cereals based cover crop (C).

Action plan description

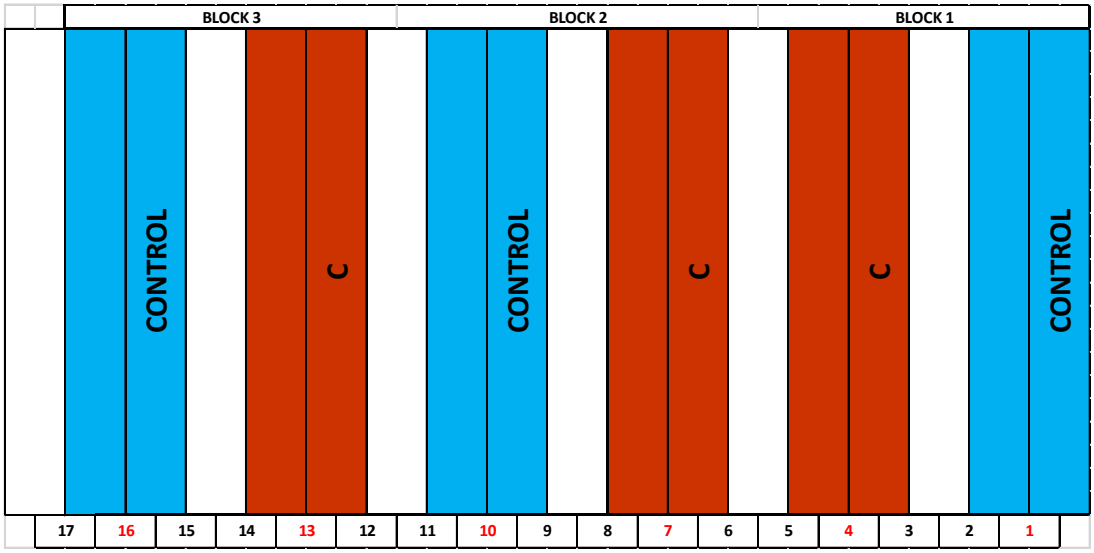


Figure 35. Experimental map of CNV DEMO vineyard. For each treatment 3 blocks were defined and, in each row, 3 plants were tagged for vine production assessment.

Resilience techniques applied

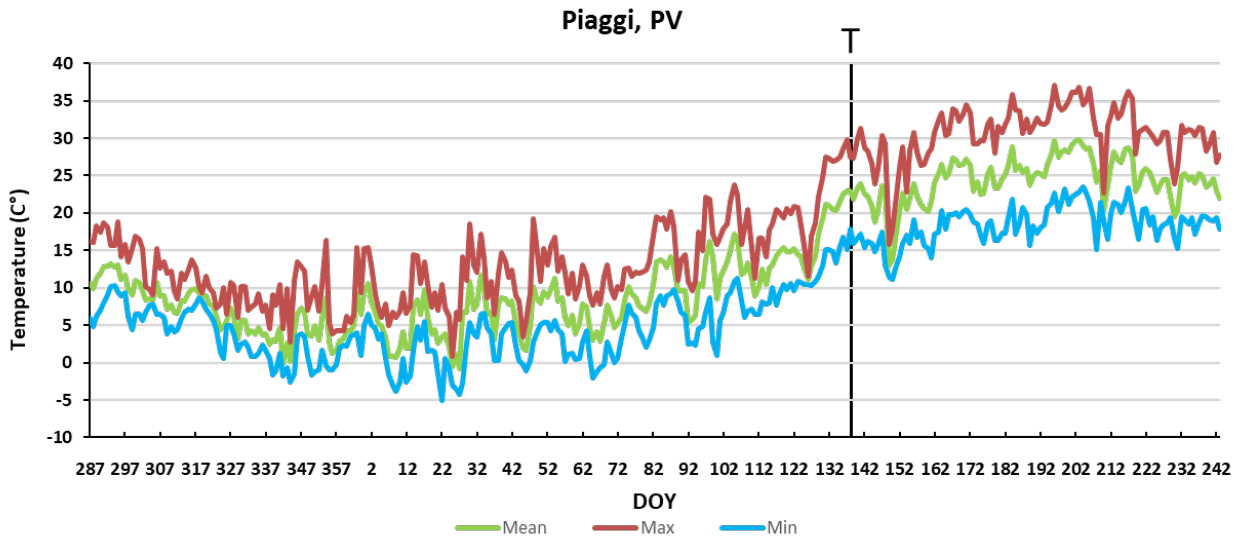
Techniques	Description
R	Between rows space grassed with the **C seeds mixture** and then finished using the rolling technique for a mulching effect.
Control	Ordinary farm management with grassed inter-row, mowed sub-row.

What we do

Activities	Date	Notes
	Season 2021	
Sowing	Late spring	Cover crop: C
Termination	20th May	Rolled
Harvest	1st September	
Pruning	27th January (2022)	
Activities	**Date**	**Notes**
	Season 2022	
Sowing	14th October (2021)	Cover crop: C
Termination	19th May	Rolled
Harvest	23rd August	
Pruning		Not yet performed

Data collected

Meteorological data (season 2022)



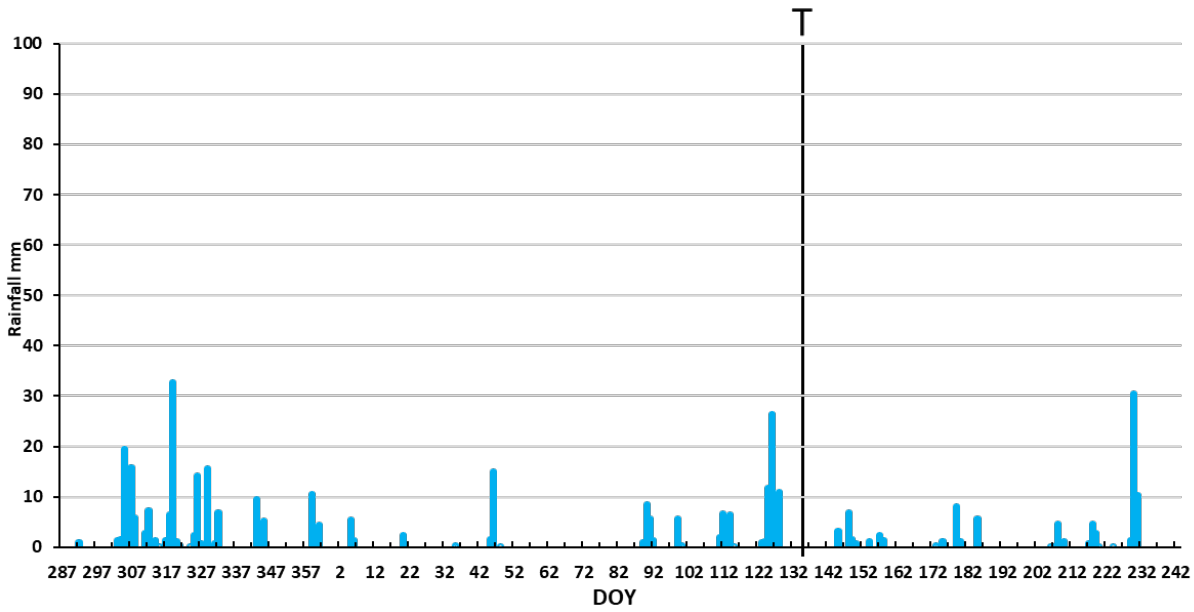


Figure 36. Temperature and Rainfall from sowing 14/10/21 to harvest 23/08/22.

Activities

The CNV vineyard is where the most severe drought occurred, affecting both cover crop growth and the resulting rolling technique. The production we harvested for analysis was scarce due to extreme water and temperature stress.

Figure 37. Photos from Biomass evaluation 17/05/2022 and harvesting 23/08/2022.