

23 Aug 2024 13:06

SATI	CFPA	HORTGRO	RAISINS SA	WINETECH
tarryn@satgi.co.za Tel: 021 863-0366	inmaak@mweb.co.za Tel: 021 872-1501	anita@hortgro.co.za Tel: 021 870 2958	ferdieb@raisinsa.co.za Tel: 054 495 0283	andraga@sawine.co.za Tel: 021 276 0499
				X

FINAL REPORT 2024

SA WINE number: US SS EL 1

1. PROGRAMME & PROJECT LEADER INFORMATION

	Research Organisation leader	Project leader
Title, initials, surname	Prof C.E. Clarke	Dr E.L. Lategan
Present position	Departmental Chair	Researcher
Address	Stellenbosch University Department of Soil Science Lombardi Building Victoria Street	Stellenbosch University Department of Soil Science Lombardi Building Victoria Street
Tel. / Cell no.	021 808 3659	083 321 6750
E-mail	cdowding@sun.ac.za	vink@sun.ac.za

2. PROJECT INFORMATION

Project title	The effect of different scion/rootstock combinations on grapevine water status (Establishment of WATER FLAGSHIP 4)
Short title	Grapevine water status of scion/rootstock combinations

Fruit kind(s)	Wine grapes		
Start date (mm/yyyy)	2017-09	End date (mm/yyyy)	2021-08

Key words	Water potential, Shiraz, Petit Verdot, Cabernet Sauvignon, Pinotage, Merlot, rootstocks, pot-planted grapevines
------------------	---

	CFPA	RAISIN SA	HORTGRO	SATI	SA WINE	ARC	OTHER
TOTALS	R 0	R 0	R 0	R 0	R 0	R 0	R 0
All years							

Total cost of entire project	R 0
-------------------------------------	-----

3. EXECUTIVE SUMMARY

Objectives and Rationale

Knowledge of how different scion cultivars are affected by similar water constraints and atmospheric conditions, and how different rootstocks contribute to the water potential of grapevines, is lacking. By understanding how different cultivars are affected by the aforementioned conditions, the water constraint thresholds for cultivars without known thresholds can be determined using previous research.

Methods

Establish five red cultivar scions, grafted onto four different rootstocks and own-rooted, in 105 L pots with a good water holding capacity, soil to investigate the effect of water availability and different genetic combinations under the same climatic conditions on the leaf water status response of the different combinations near Stellenbosch.

Key Results

Unfortunately, the project was marred with misfortunes and problems that resulted in the prolongation of the establishment of experimental grapevines and ultimately did not allow the primary objective of exposing well-developed grapevines to an array of similar soil water availabilities under the same climatic conditions and investigating these effects on the plant water status of different genetic combinations.

Key Conclusion of Discussion

The developed Arduino Logging system will contribute to making irrigation research affordable in the near future. The soil water retention model developed during the project still needs to be validated and further developed to add value to producers by determining soil water holding capacities by conducting soil texture analysis in commercial laboratories.

Take Home Message for Industry

Since the application of concurrent water constraints was not possible during the establishment phase of the project, how different scion/rootstock combinations would respond under the same climatic and soil water availabilities has not been answered yet. It is highly recommended that, at the conclusion of the Water Flagship 4 project, the initial proposed water constraint treatments need to be applied and the plant water potential responses quantified.

4. PROBLEM IDENTIFICATION AND MOTIVATION

Problem Identification

Plant water potentials, i.e., leaf water potential (Ψ_L), have been well documented as a way to determine water constraints in plants affected by external climatic and soil water availability factors (soil-plant-atmosphere continuum). Plant water thresholds for grapevines have been published over the last 15 years. However, these thresholds differ substantially as different cultivars were reported on, and research was done under vastly different conditions (rootstocks, atmospheric conditions, soil types, etc.). The effect of different scion/rootstock combinations and each component's effect on plant water status under the same climatic and soil water availability conditions is unknown.

Motivation

The main aim of the proposed trial is to investigate the effect of cultivar different scions, rootstocks and/or their combinations on grapevine Ψ_L , under similar climatic conditions, soil type and water status. This information would help to adapt published plant water potential thresholds for more accurate irrigation scheduling and accumulated water constraints in grapevines to produce wines of good quality, and the effect on fruit and wine quality.

5. ACCUMULATED PROGRESS TABLE

Objectives	Milestones (Significant event or stage in a project)	Date Achieved
O1. Establishment of a pot experiment.	M1.1 Order plant material combinations;	All objective dates will be
	M1.2 Procure pots (ca. 100 L);	discussed in
	M1.3 Lay out pot trial and install trellis system;	Sections 6
	M1.4 Identify and order soil, as well as pack soil into pots;	and 7.
	M1.5 Plant grapevines in pots;	
	M1.6 Install irrigation system;	
	M1.7 Determine soil physical and chemical properties;	
	M1.8 Determine soil water holding capacity;	
	M1.9 Install and calibrate soil water monitoring system;	
	M1.10 Irrigate grapevines at low PAW depletion level for establishment and development of grapevines; and	
	M1.11 Procure and install a weather station to measure atmospheric conditions.	
O2. Compare the water status of different scion/rootstock combinations at similar soil water availability and atmospheric conditions	M2.1 Apply irrigations at predetermined soil water depletion levels per phenological stages of the plant seasonal cycle;	
	M2.2 Monitor soil water content and irrigation volumes applied per scion cultivar;	
	M2.3 Monitor atmospheric conditions; and	
	M2.4 Measure plant water potentials for three window periods within the season.	
O3. Compare the plant vegetative and reproductive responses of different	M3.1 Measure grapevine cane mass to quantify vegetative responses;	

scion/rootstock combinations at similar soil water availability and atmospheric conditions.		
	M3.2 Measure berry mass, bunch numbers and mass, as well as yield per grapevine when sugar contents are ca. 24°B; and	
	M3.3 Compare juice pH, sugar and TTA.	
O4. Compare the water usage of different scion/rootstock combinations at similar soil water availability and atmospheric conditions.	M4.1 Calculate water usage per grapevine by means of a soil water balance.	
O5. Process data and write progress reports	M5.1 Give feedback on progress annually	
O6. Write the final report		

6. WORKPLAN (MATERIALS AND METHODS)

In mid-July 2016, the project leader met with Mr Nico Spreeth (Vititec). During this meeting, Mr Spreeth suggested the most popular clones per predetermined scion cultivar should be used to ensure that the industry gains the most out of the project and that the same clone should be grafted on the four predetermined rootstocks (Table 1). Some of the proposed scion clone numbers and rootstock combinations were not in stock and had to be made up over the next year. Fourteen (14) grapevines of each treatment combination were ordered from Vititec. This number included the 9 trial grapevines on which the destructive measurements would be done, but also five grapevines of each combination to make up the buffer rows on the sides of the trial rows and act as backup plants.

Due to the fact that the specific clone scion and rootstock combinations were ordered from Vititec and had to be made up especially (cartonage) for this project to enable all plants to be planted on the same date, plant material would only have been available for planting in November 2017.

Table 1. Proposed grapevine scion and rootstock combinations and scion clone numbers that will be planted in a pot trial at Welgevallen experiment farm near Stellenbosch.

Treatment No.	Scion	Rootstock	Combination code	Clone number (as suggested by N. Spreeth)
1	Own rooted Shiraz	---	Sh	22
2	Own rooted Petit Verdot	---	PV	400
3	Own rooted Cabernet Sauvignon	---	CS	46
4	Own rooted Pinotage	---	Pi	45
5	Own rooted Merlot	---	Me	348
6	---	Trained 110Richter	Ri	
7	---	Trained Ramsey	Ra	
8	---	Trained 101-14 Mgt	Mg	
9	---	Trained USVIT 8-7	US	
10	Shiraz	110Richter	Sh/Ri	22
11	Shiraz	Ramsey	Sh/Ra	22
12	Shiraz	101-14 Mgt	Sh/Mg	22
13	Shiraz	USVIT 8-7	Sh/US	22
14	Petit Verdot	110Richter	PV/Ri	400
15	Petit Verdot	Ramsey	PV/Ra	400
16	Petit Verdot	101-14 Mgt	PV/Mg	400
17	Petit Verdot	USVIT 8-7	PV/US	400
18	Cabernet Sauvignon	110Richter	CS/Ri	46
19	Cabernet Sauvignon	Ramsey	CS/Ra	46
20	Cabernet Sauvignon	101-14 Mgt	CS/Mg	46
21	Cabernet Sauvignon	USVIT 8-7	CS/US	46
22	Pinotage	110Richter	Pi/Ri	45
23	Pinotage	Ramsey	Pi/Ra	45
24	Pinotage	101-14 Mgt	Pi/Mg	45
25	Pinotage	USVIT 8-7	Pi/US	45
26	Merlot	110Richter	Me/Ri	348
27	Merlot	Ramsey	Me/Ra	348
28	Merlot	101-14 Mgt	Me/Mg	348
29	Merlot	USVIT 8-7	Me/US	348

For cost efficiency, it was decided to procure 210 L PVC barrels and cut them in half to create 105 L pots, with four 10 mm drainage holes drilled in the bottom of each pot. One hundred and sixty 210 L PVC barrels were ordered from KaapAgri Stellenbosch in August 2017 and set to be delivered by October 2017.

The locality of the planting site has been done inside an established vineyard so that the buffer rows/grapevines can be made up out of the Shiraz/101-14 Mgt grapevines (planted 2001). The locality is in a Shiraz vineyard (-33.940521°, 18.865628°), that is fenced in, on the Stellenbosch University's Welgevallen Experimental Farm (Fig. 1). The based on the long term mean (LTM) climate data of an Agricultural Research Council's Institute for Soil, Climate and Water weather station, ca. 2.5 km from the locality (Fleurbaix) the Köppen Geiger climate classification is a Temperate climate with dry hot summers (Csa). The LTM climate data from the Fleurbaix weather station is indicated in Table 2.



Figure 1. Aerial view of the Shiraz vineyard in which the pot experiment will be established (indicated with the white rectangle) and on Welgevallen Experimental Farm, Stellenbosch. A circle with WS indicate the locality where the automatic weather station was installed.

Table 2. The long term mean (LTM) values of mean daily maximum (T_x) and minimum temperature (T_n) and the monthly mean daily maximum (RH_x) and minimum (RH_n) relative humidity, mean daily incoming solar radiation (R_s), wind (u_2), mean monthly rain and mean reference evapotranspiration (ET_o) for Fleurbaix (-33.955538°, 18.844636°).

Month	T_x (°C)	T_n (°C)	RH_x (%)	RH_n (%)	R_s (MJ.m ⁻² .d ⁻¹)	u_2 (m/s)	Rain (mm)	$ET_o^{(1)}$ (mm/d)
April	26.1	12.0	90.8	40.4	15.0	1.11	55.6	2.5
May	22.7	10.6	91.3	47.2	10.0	1.03	91.7	1.5
June	20.1	8.8	91.3	49.6	8.4	1.04	120.9	1.2
July	20.0	7.9	90.3	48.5	9.9	1.04	109.3	1.2
August	19.9	8.3	92.2	48.5	11.6	1.06	98.6	2.0
September	21.8	9.3	92.3	45.9	15.4	1.06	67.2	2.8
October	24.5	11.6	90.1	40.2	20.9	1.21	41.1	4.0
November	25.9	12.8	90.6	39.8	25.1	1.22	34.1	4.8
December	28.3	14.9	90.2	38.5	26.7	1.34	16.3	5.5
January	30.1	15.9	89.8	37.8	27.4	1.32	15.7	5.8
February	30.1	15.7	90.0	37.5	24.0	1.27	13.8	5.4
March	28.9	14.3	90.5	36.9	20.6	1.22	18.7	4.5

¹: Reference evapotranspiration (ET_o) was determined using the modified daily Penman-Monteith equation (Allen *et al.*, 1998).

Grapevines within the area of the vineyard that was to be replaced by pots had leaves sprayed with a 5% Glyphosate herbicide, and three weeks later, had three holes drilled in their trunks and the same dosage of herbicide injected during March 2017, to kill the grapevines. Once the dieback of these grapevines was confirmed, their trunks were sawed off, and the stem chopped

back 10 cm below the soil surface. It was planned to use the established trellis system (6-strand Double Perold system) to train potted grapevines during establishment (Fig. 3).



Figure 3. Photo of existing Shiraz/101-14 Mgt grapevines removed to make way for pot experiment near Stellenbosch.

Scion/Rootstock combinations were laid out in a randomised block design with nine replications each and an extra row of spare vines on the other side of the experimental vines, making up eight rows in total (Fig. 4). Of the original grapevines in the vineyard, two grapevines at the start of the row (closest to the anchor pole), as well as all grapevines that did not need to be replaced by pots, in adjacent rows and northern side of the experimental layout, were left to grow and mimic a natural vineyard microclimate.

An alluvial soil was identified ca. 800 m away from the selected experimental site in the Welgevallen Experimental Farm (-33.943108° , 18.862876°). A digger loader was used to excavate ca. 38 m^3 (ca. 64 tons due to 20% alluvial rock present) soil and transported via a tractor and wagon to the experimental site, after which all stones were removed (Fig. 5).

Soil physical and chemical properties, as well as soil water holding capacity was determined at the Department of Soil Science, Stellenbosch University. Design of the irrigation system was with the help of Messrs Willem Smit and Willem Botha of Netafim SA™. Netafim SA™ also sponsored blind pipe, 2 L/h PCJ Netafim pressure compensated button drippers, barb tubing, barb tubing T-joints and two arrow drippers for each pot. In 2017, Mr Smit had his doubts whether two arrow drippers per pot would be sufficient to wet the soil surface evenly enough and said that should this become an issue, Netafim SA™ would sponsor additional components.

The installation of the irrigation system could only be done just before the pots were received, soil chemical amendments and rectifications were done, and grapevines were planted in the allocated pots. Due to the fact that grapevines were going to be irrigated at a low soil water depletion rate during development and during the canopy development stages of experimental seasons, it was decided to monitor the soil water status by means of six sets of tensiometers, i.e., at 150 mm and 350 mm depths. Due to a lack of funding and the high cost of continuous soil water monitoring equipment, the project leader later developed an Arduino® based continuous monitoring system between 2018 and 2020, which was installed at the same six pots that contained tensiometers at 100 mm and 300 mm, respectively, under arrow drippers. A WH2303 Automatic Weather station was procured and installed behind an extra fence ca. 30 m east-southeast from the pot experiment (Fig. 1). Plant water status was to be quantified by determining leaf water potentials in mature leaves full sun lit leaves on primary shoots by means of the pressure chamber technique (Scholander *et al.*, 1965), according to the protocol described by Myburgh (2010).



Figure 5. Alluvial soil excavated (left) and transported to experimental vineyard (right) for pot trial.

7. RESULTS AND DISCUSSIONS

7.1 July 2016 to April 2017

A suitable site for the experimental site was identified on the Welgevallen Experimental Farm (Stellenbosch) as described earlier. Since specific clone scion and rootstock combinations were ordered from Vititec and had to be made up especially for this project to enable all plants to be planted on the same date, plant material would only be available for planting in November 2017.

Trial layout and other planning were done, and grapevines in the established vineyard where the pot experiment was to be established were killed and removed as previously explained.

7.2 May 2017 to April 2018

Prof Melané Viviers (Department of Viticulture and Oenology) was approached to collaborate in the pot experiment and the experimental layout, and planned irrigation applications were discussed. She requested that three grapevines per treatment/combination be made available for an MSc student to work on in the glasshouse of the J.H Neethling building once plant material was received, and the Project leader agreed with the request.

The alluvial soil transported to the experimental site was analysed during the winter of 2017 to determine the chemical status and ameliorant requirements. Random soil samples were taken to determine lime, P and K requirements that had to be rectified during the soil mixing process, prior to planting of grapevines. The lime requirement was determined by mixing 0, 0.1%, 0.2%, 0.5%, 0.75%, 1%, 2.5%, 3.0%, 3.5%, 4%, 5% and 6% dolomitic lime to know the mass of soil (m/m) and the $\text{pH}_{(\text{H}_2\text{O})}$ of saturated paste extracts was measured. The relationship between the percentage dolomitic lime added and $\text{pH}_{(\text{H}_2\text{O})}$ revealed that 4% lime to mass of soil was necessary to increase the $\text{pH}_{(\text{H}_2\text{O})}$ from the existing 4.09 to ca. 6.50 (Fig. 6). The soil P was determined by means of the Bray II method. For each 100 L of soil respective ca. 4.5 kg dolomitic lime, ca. 6.8 g Triple Super Phosphate and ca. 9.3 g Potassium Chloride to adjust the soil's P and K contents to be within the grapevine requirement norms published by Conradie (1994).

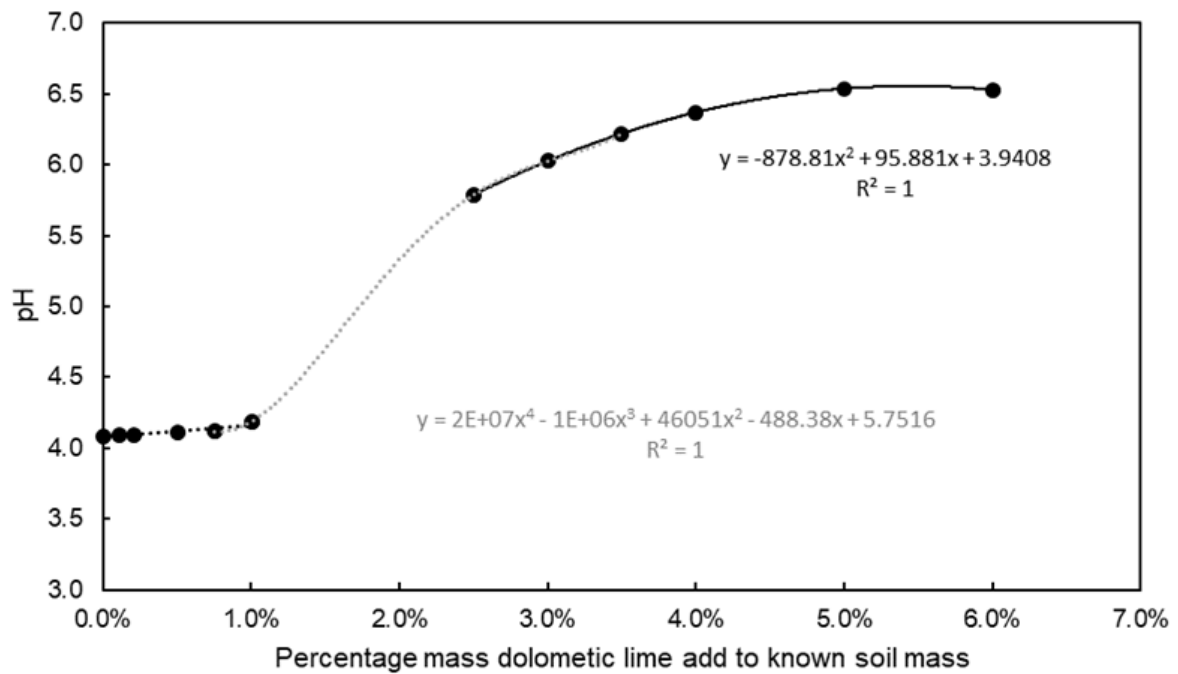


Figure 6. The relationship between the percentage mass of dolomitic lime added to a known mass of soil and the soil pH(H₂O).

During the sampling for chemical analysis, clods were collected to determine the soil's natural bulk density. It was determined that the bulk density was ca. 1 517 kg/m³. Soil was deemed to have a Medium sandy loam texture after soil organic matter content and particle size distribution (eight fractions) were determined (pipette method)(Table 3).

Table 3. The particle size distribution of a medium sandy loam soil that will be used to investigate the response of five different scion cultivars and four different rootstock combinations on water constraint situations in a pot experiment near Stellenbosch.

Organic matter	Clay	Fine Silt	Coarse Silt	Very fine sand	Fine sand	Medium sand	Coarse sand	Very coarse sand	Rock
2.1%	12.9%	9.3%	17.1%	10.4%	20.5%	24.6%	4.3%	0.9%	2.0%

Soil water retention curves were determined with the help of the pressure membrane method as described by Klute (1986). From retention curves it could be estimated that Field capacity (FC) would be at ca. -12.48 kPa matric potential (0.215 mm.mm⁻¹) as a change in the slope of the water characteristic curve was observed between water contents at -10 kPa and -15 kPa matric potential, compared to that between -2 kPa, -5 kPa, -8 kPa and -10 kPa, respectively (Fig. 7A). Permanent wilting point (PWP) was accepted to be -1 500 kPa (0.114 mm.mm⁻¹)(Fig. 7B). The total plant available water was calculated as the deficit between FC and PWP, calculated to be ca. 0.101 mm.mm⁻¹, and a total plant available water at a depth of 400 mm (the depth of soil in pots) as 40.4 mm.

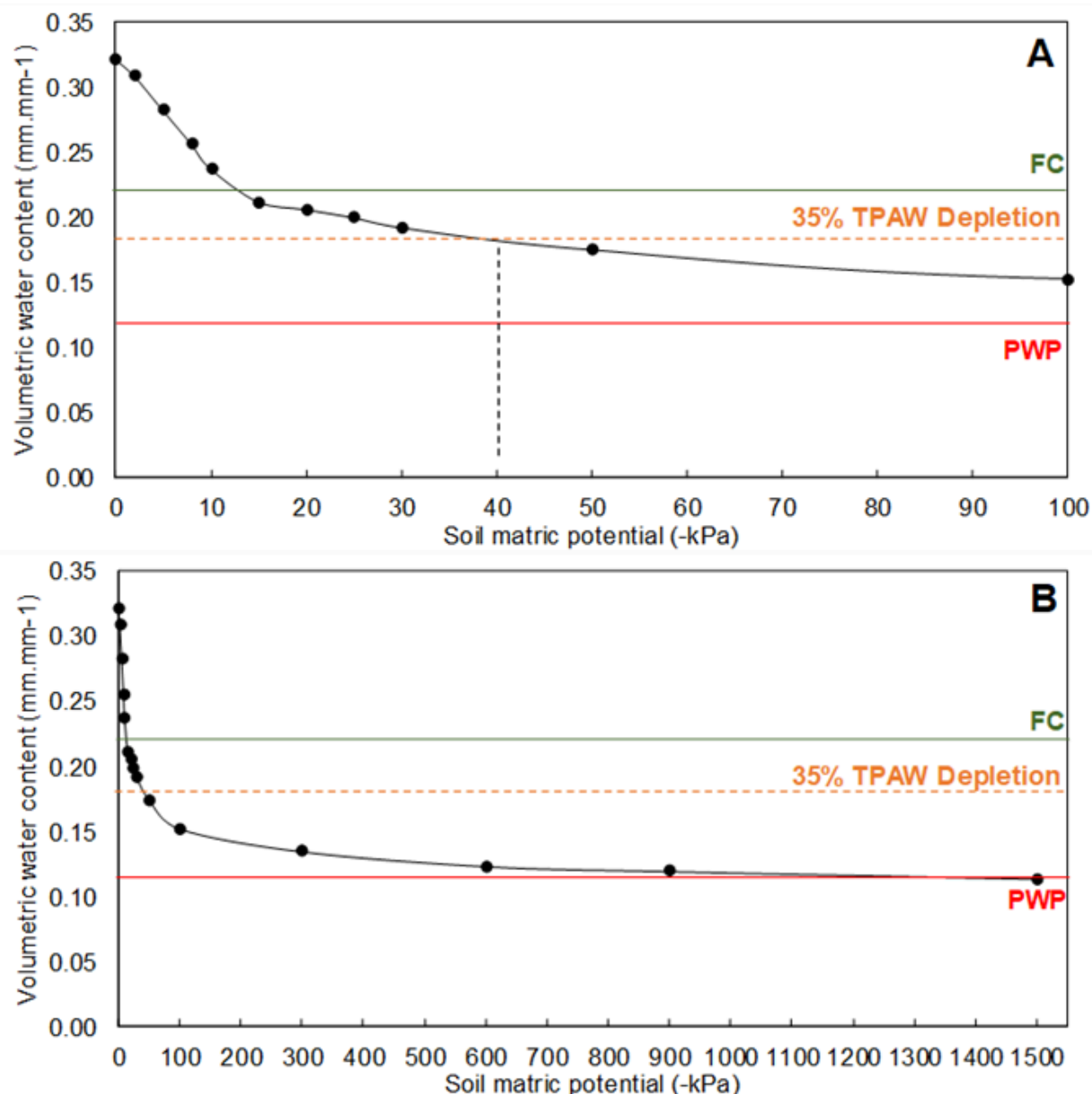


Figure 7. Soil water retention curves of a medium sandy loam soil near Stellenbosch.

Even though KaapAgri was supposed to deliver ordered barrels in October, they could only deliver barrels in small quantities due to the drought in the Cape Town Metropole, resulting in a high demand for water storage containers. By Mid-February 2018, only 80 barrels were delivered, whereafter 10 barrels were delivered on 16 February, 40 by 16 March, and the final 30 on 28 March 2018. This caused a delay in the achievement of milestones such as planting of grapevines that was planned for November. Although plant material was ready for collection from Vititec by early December 2018, due to the fact that barrels weren't available yet, Mr Dirk Visser was asked to keep grapevines in greenhouses until pots were ready to replant young vines. In mid-February 2018, Mr Visser, however, needed space in his greenhouses and grapevines had to be transported to Stellenbosch. Grapevines (in their cartilage containers) were stored in crates under shady conditions and watered by hand every second day until they could be planted in pots in mid-April (Fig. 8). In March 2018 Prof Viviers was supplied with three healthy grapevines of each plant material combination for their glasshouse study.



Figure 8. Experimental grapevines growing in crates placed in a partially shaded area.

During April 2018, once all barrels were received, the barrels were cut in half with an angle grinder (Fig. 9) to make two pots of 105 L and four 10 mm $\varnothing$ holes drilled in the bottom of the makeshift pots and covered with gravel to allow drainage of excessive water once soil was added. A shallow trench was left in each plant row, which was covered with two 300 mm wide 300 micron thick dpc plastic. This was done to suppress weed growth in the grapevine row and for blind 20 mm polyethylene irrigation pipes to be placed on (Fig. 10). Pots were placed over irrigation pipes, ca. 1.2 m between the centres of two pots, and gravel was placed over the drainage holes in the bottom of each pot before pots were filled with soil (Fig. 11). To stabilise the grapevines growing in crates, 29 pots were hastily prepared to plant vines in while the rest of the pots were prepared during the winter of 2018. Soil was mixed with required ameliorants in 25 L buckets, and 29 pots were filled halfway before all grapevines of the same scion/rootstock combinations were planted in the same pot (Fig. 12) to see through the 2018 winter and were to be planted out in their allocated pots (Fig. 4) during September 2018.



Figure 9. Polvinylchloride barrels (210 L) cut in half to create ca. 105 L pots for pot trial.



Figure 10. A 105 L PVC pot is placed on top of dpc and irrigation pipes.



Figure 11. Gravel was placed in the bottom of pots to cover drainage holes (left) before soil was placed into pots (right).



Figure 12. Experimental grapevines were planted in May 2017 into pots before they were transplanted into allocated pots during September 2018.

7.3 May 2018 to April 2019

After the healthiest plants were provided to Prof Melané Vivier for her glasshouse experiment, extra plants were ordered from Mr Dirk Visser (Vititec) in April 2018 as a backup for plants that might have incurred too much damage and wouldn't survive. When Mr Visser was contacted in September 2018, he said he would see what they have in stock and notify me. Subsequently, Mr Visser retired, and on visiting Vititec, Mr Johan Louw, who replaced Mr Visser after his retirement as nursery manager, informed me that no order for the requested grafted material was made. He took it upon himself to find more of the same clones requested and try to do some green grafting, but was unsuccessful. In February 2019, Mr Louw informed me that the requested material had been confirmed to be grafted during June 2019 and will be ready for collection in early October 2019. This order was also confirmed by Mr Renier Louw in June 2019 when following up on the order.

During May and June, the irrigation system was installed, and all pots filled to the brim with amended soil as previously described to allow winter rain to consolidate soil in pots. During early September 2018, all grapevines were planted in their allocated pot within the pot experiment. Soil from 10 random pots was sampled during planting and mixed before three sub-samples were drawn for a chemical analysis (Table 3). The pH, P-content, as well as exchangeable Na, K and Mg were well within norms prescribed by Conradie (1994). The exchangeable Ca was high, and the ratio to Mg exceeded the norm of 6 (Oberholzer et al., 2016).

Table 3. Mean chemical composition of the soil of the pot experiment as sampled and analysed in September 2018.

pH _(H2O)	pH _(KCl)	P Bray II mg/kg	Exchangeable cations (cmol _c /kg)				EC _e ⁽¹⁾ (dS/m)
			Na	K	Ca	Mg	
7.0	5.9	16.0	0.596	0.939	4.636	0.568	0.241
±0.1	±0.1	±1.5	±0.055	±0.068	±0.788	±0.039	±0.042

¹ Electrical Conductivity of Saturated Paste Extract.

A manifold was assembled in such a way to enable water supply for the pot experiment from a reservoir via the pump and sand filter that supplies irrigation to the rest of the vineyard. The manifold consisted of six solenoid valves, each with a water meter, to irrigate each of the five individual cultivars (grafted and own-rooted), as well as an extra ball valve with a water meter to irrigate the spare grapevines separately (Fig. 13). Valve 1 will control the irrigation to all Shiraz vines, Valve 2 all Petit Verdot, Valve 3 all Cabernet Sauvignon vines, Valve 4 to all Pinotage and Valve 5 the irrigation to all Merlot grapevines. Valve 6 will control the irrigation to all the trained Rootstocks. Six 20 mm polyurethane irrigation pipes are each connected to a solenoid valve and are situated below the pots (Fig. 14). A 2 L/h Netafim pressure compensated dripper was installed in the relevant 20 mm pipe and extended with barb tubing into the pot, split with a T-fitting and two arrow drippers at the ends two 10 cm long barb tubes were inserted into the soil on either side of the grapevine to ensure even water delivery on either side (Fig. 15). Tensiometers were monitored between two and three times a week (peak season) and irrigation was applied once the mean soil water matrix of the 350 mm deep tensiometers reached -40 kPa to ensure water is readily available for grapevine growth and development.

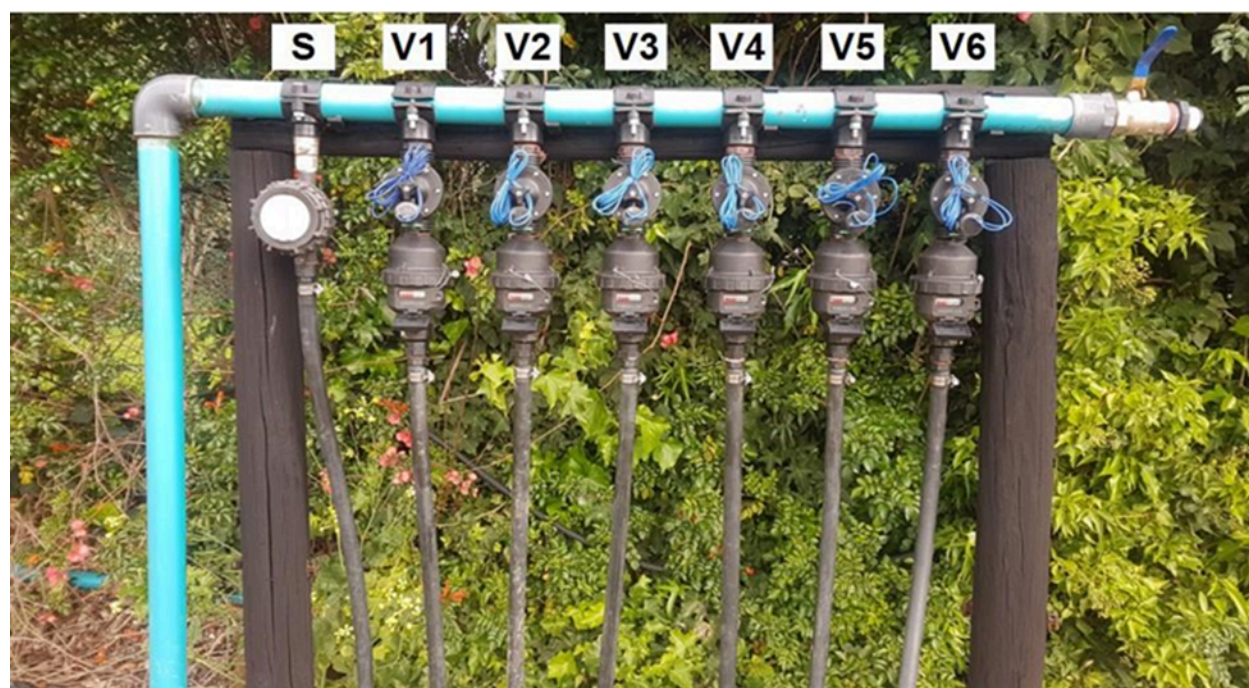


Figure 13. An image of the installed manifold. Solenoid valves V1 to V5 controlled irrigation to grapevines containing Shiraz, Petit Verdot, Cabernet Sauvignon, Pinotage and Merlot, respectively, while V6 controls irrigation to all Rootstocks. Valve S supplied irrigation to all spare grapevines.

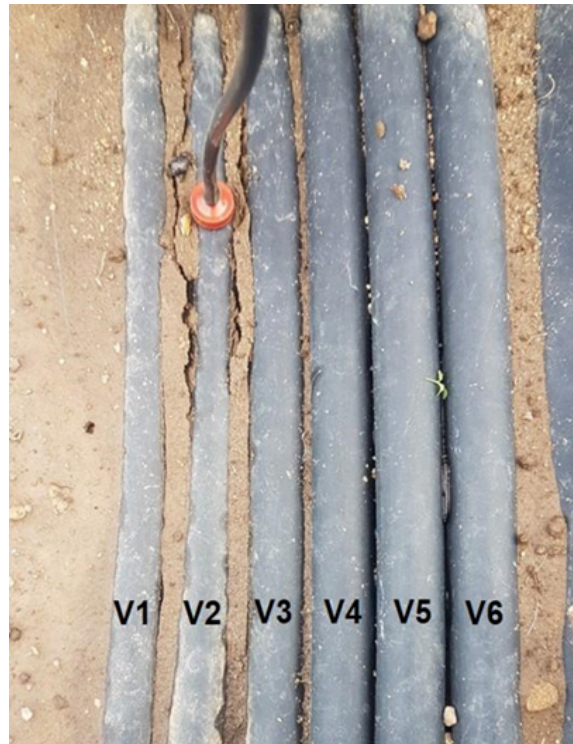


Figure 14. An image of the six 20 mm polyurethane irrigation pipes located between and underneath the experimental grapevine pots. The insertion of the orange 2 L/h Netafim dripper in Line 2 is visible, meaning this is the line that supplied water to the Petit Verdot grapevines.



Figure 15. An image of the barbed tubing connecting the pressure-compensated dripper and the arrow dripper, as well as their placement. Note the grapevine being pruned to one cane and secured to the cordon wire.

During September 2018, Mr Alan Lindeque (Spilhaus Irrigation) was consulted regarding the installation of a flow switch to automate the current pump. He advised that not only would a flow switch be necessary on the current 5.5 HP DAB pump, but also a variable speed drive (VSD), as the irrigation system was designed to irrigate a whole hectare, and irrigation of a smaller area could cause damage to the pump and/or pressure build-up in the PVC pipe, resulting in ruptured pipes. Mr Vaatjie Jacobs (former vineyard manager of the Welgevallen Experimental Farm), however insured me that the current pump system will be adequate for the pot experiment's needs. During an investigation of the pressure on the main line in October 2018, it was noted that the pressure only reached 0.7 Bar, and the sand in the sand filters was replaced. This, however, did not increase the pressure, and due to the fact that the sand filter bank was after the spin clean filter bank (ring filters) and the unbudgeted amount for a VSD, Mr Lindeque suggested installing a separate 0.37 kW pump with an automatic flow controller to accommodate the lower irrigation volumes required for the pot experiment. The pump could readily be connected to the extraction pipe out of the irrigation reservoir, which leads to the main pump, and connected to the experiment manifold to the new pump by means of a 50 mm class 6 PVC pipe. Mr Willem Smit (Netafim SA) agreed with Mr Lindeque's suggestion.

The use of the current vineyard's irrigation infrastructure was not viable, and the project budget did not make provision for an upgrade of the system. During October and November 2018 irrigation two irrigation designers were consulted on a cost-efficient alternative that would meet the pot experiments' irrigation requirements. In December 2018, a 0.37 kW DAB K20/41M pump was installed (Fig. 16) and connected to the extraction pipe between the reservoir and the 5.5 HP DAB pump that supply two vineyards with irrigation water (Fig. 17). A flow switch was fitted onto the installed pump to enable the automatic start of the pump once a solenoid valve was opened. Two 120 Micron Arkal® disc filters were installed in parallel to prevent dripper clogging (Fig. 18). These filters will be cleaned manually on a regular basis. A ca. 117 m long 50 mm class 6 pipe chain was installed ca. 0.3 m below the surface and connected to the manifold at the experimental site.



Figure 16. An image of the installed 0.37 kW DAB pump with fitted flow switch fixed onto concrete on Welgevallen Experimental farm.



Figure 17. An image of the connection in the extraction pipe between the reservoir and the existing pump used to irrigate vineyards on the Welgevallen Experimental farm.



Figure 18. An image of the two-ring filters installed in parallel after the new pump.

In February 2019, a meeting was held between the project leader, Prof Melané Viviers, Dr Carlos Poblete-Echeverria and Mr Stenford Matsikatze (registered PhD student who was working on the project). It was decided that, due to unforeseen delays that occurred, for the 2019/20 season, no water constraints will be applied to grapevines. This will allow rapid growth and grapevine structure development, and Mr Matsikatze will start comparing physiological

measurements of the different plant material under no water constraint conditions. Irrigation scheduling will be done by means of tensiometers installed at two depths until the continuous soil water content logging system is installed. Irrigation will be applied once the soil water matric potential of the deeper layer reaches -40 kPa. It was also suggested in the meeting that once water constraints start being applied, soil will be allowed to dry progressively during the season, i.e. irrigation at ca. 35% Plant Available Water (PAW) Depletion during the first part of the season and at ca. 90% PAW Depletion during ripening. The DVO also requested that once water constraints start being applied, two rows, i.e., three replications, be irrigated continuously at ca. 30% PAW to compare molecular adaptations or variations between “stressed” and none “stressed” grapevine material.

7.4 May 2019 to April 2020

7.4.1 Cultivation actions

New plant material ordered in March 2019 was received in November 2019 and planted soon thereafter. Plant material was also provided for Prof Melané Vivier (DVO, SU) for their part of the glasshouse experiment.

On 17 September 2019, a team of contract workers started loosening the cordon wires of the block, in which the pot experiment was established, to start with the removal of the commercial block, without notifying the project leader. The project leader happened to arrive at the pot experiment while this action was done, but half of the cordon wires were already loosened. During the pruning back to one cane in August 2019 and the cane being tied to the cordon wires, numerous grapevines were damaged, either being partially pulled out of the soil or having their grafting unions damaged. The damage was assessed, and loose cordon wires were tightened again on the next day. After receiving new ordered plant material at the beginning of November, the grapevines that were damaged and did not recover were replaced.

During the 2019/20 season, all weeds in pots were removed by hand on a regular basis. Snail repellent was applied in October 2019 in all pots, and a young grapevine pesticide (fungicide and insecticide) spray program was drawn up with the help of Wenkem and Mr Johan Louw (Vititec) and applied throughout the season. A prescribed dosage of KOINOR 350 SC (a variant of Confidor®), also containing the active ingredient *Imidacloprid (chloronicotiny)*, was applied as a blanket treatment to all pots (grapevines) to protect particularly ungrafted scion vines against the possibility of Phylloxera (*Daktulosphaira vitifoliae*) infestation, possible fatality of grapevines and/or an extra abiotic stress variant. Weeds in the work row area of the pot experiment were controlled before bud break by a broadband herbicide application with a covered spray nozzle, but after active growth commenced, had to be managed by means of manual labour to remove and kill weed growth. Potassium and nitrogen fertilizer was applied in the form of KCl and limestone ammoniumnitrate (LAN) according to prescribed norms (Conradie, 1994). The KCl was applied once off at the beginning of September 2019, while the LAN was applied in monthly increments until March 2020.

During the 2019 Project Progress feedback meeting, the committee suggested that the project team should abstain from applying high water constraint soil water conditions for the 2019/20 season to allow young grapevines to develop optimally. It was decided apply irrigation only once the mean matric potential of the soil at 350 mm reaches -40 kPa matric potential. Thus, all pots were irrigated the same, and the newly upgraded irrigation system installed during the previous year delivered a constant delivery rate of ca. 2 L/h.

Grapevines were suckered in November 2019. Initially, only three shoots were left per grapevine until the two strongest shoots were between 30 and 40 cm and could be tied to the cordon wire. The third shoot was removed, and all other water shoots were removed continuously throughout the season, except if one of the two main shoots incurred any damage. Once a shoot reached a length of 80 cm or more, it was topped to a length of 65 cm on the cordon wire to stimulate lateral shoot growth. The two shoots together thus made up a total grapevine cordon length of 1.3 m. Any flowers formed during the season were removed to inhibit reproductive competition with the vegetative growth.

From the end of February, it was judged that the majority of grapevines had adequately formed good cordons and numerous secondary shoots and mid-day leaf water potentials (Ψ_L) were measured in two of the most homogeneous replications (Replications 3 and 4). Seven measurement days (2, 3, 4, 10, 11, 17 and 18 March 2020) were set out to determine the effect of soil conditions before and after irrigation applications once the 350 mm soil depth reached ca. -40 kPa matric potential. During this period, Dr Philip Young (DVO, SU) collected plant samples from the same grapevines on which the Ψ_L was determined, for biomarker determination in Prof Melané Viviers' project.

7.4.2 Seasonal climatic data

In mid-January 2020, the Cape Winelands were hit by a big storm with very high winds. Between 13:00 on 17 January and 07:00 on 20 January 2020, a mean hourly wind speed of 8.7 m/s (31.2 km/h) raged over the 67 hours of the storm. The maximum hourly wind speed recorded during this period was 13.9 m/s (50.0 km/h) with wind gusts up to 25.5 m/s (88.1 km/h). Within this 67 hours, 38 hours had a mean wind speed in excess of 8.3 m/s (30 km/h) with gusts of at least 14.7 m/s (52.8 km/h), 9 hours had a mean speed of more than 11.1 m/s (40 km/h) with gusts of 19.6 m/s (70.9 km/h) or more and 3 hours had mean wind speeds of more than 12.5 m/s (45.0 km/h) with wind gusts exceeding 22.0 m/s (79.2 km/h). Numerous vineyards in the Stellenbosch area had a lot of damage done to it, with even whole grapevine rows being blown over, breaking trellis poles and grapevines off just above the soil surface. It was assessed that even though newly formed cordon arms were tied to the cordon wires, 12% the grapevines had at least one of their cordon arms twisted or broken off, with about 5 grapevines having had both arms damaged. Damaged arms were pruned back to allow new shoots to grow out of dormant buds, and new arms were formed.

Comparing the temperatures of the 2019/20 season with the long-term mean (LTM) data of a weather station at Fleurbaix (ca. 2.4 km away), the season can be viewed as a relatively cool summer (Table 4). September 2019 and February 2020 were warmer and drier than the LTM data, with the rest of the growing season generally having drier atmospheric conditions than the LTM, with lower relative humidities recorded (Table 4). The exception, however, was October 2019, due to high rainfall during this month. Except for September 2019 and February 2020, the seasonal mean monthly incoming solar irradiance was lower than that of the LTM, given an indication that much more cloud was present than usual (Table 3). The average amount of wind can also be seen to have been much less than in a normal season, with the exception of the storm between 17 and 20 January 2020. October 2019 was a particularly wet month with 2.5 times the amount of the LTM rain recorded, and December 2019 was on par with the LTM, while the rest of the months received considerably less rain than the LTM values. The reference evapotranspiration (ET_o) per month, calculated from the aforementioned elements, was comparable with those of the LTM values, with September having marginally higher and January 2020 having lower ET_o values calculated.

Table 4. The mean daily maximum (T_x) and minimum (T_n) temperatures, maximum (RH_x) and minimum (RH_n) relative humidity, solar irradiance (R_s), wind speed (u_2), rain and reference evapotranspiration (ET_o) at the pot experiment (Stellenbosch) for the 2019/20 growing season.

Element	T_x (°C)		T_n (°C)		RH_x (%)		RH_n (%)	
Month	<u>LTM</u> ⁽¹⁾	2019/20	<u>LTM</u>	2019/20	<u>LTM</u>	2019/20	<u>LTM</u>	2019/20
Sep	<u>21.8</u>	23.6	<u>9.3</u>	11.4	<u>92.3</u>	87.4	<u>45.9</u>	42.1
Oct	<u>24.5</u>	20.1	<u>11.6</u>	11.4	<u>90.1</u>	87.1	<u>40.2</u>	49.7
Nov	<u>25.9</u>	24.5	<u>12.8</u>	13.0	<u>90.6</u>	83.8	<u>39.8</u>	41.7
Dec	<u>28.3</u>	27.1	<u>14.9</u>	13.4	<u>90.2</u>	85.4	<u>38.5</u>	34.6
Jan	<u>30.1</u>	28.9	<u>15.9</u>	16.3	<u>89.8</u>	85.6	<u>37.8</u>	38.9
Feb	<u>30.1</u>	31.0	<u>15.7</u>	15.9	<u>90.0</u>	85.4	<u>37.5</u>	33.3
Mar	<u>28.9</u>	28.4	<u>14.3</u>	14.5	<u>90.5</u>	86.9	<u>36.9</u>	36.9

Element	R_s (MJ.m ⁻² .d ⁻¹)		u_2 (m.s ⁻¹)		Rain (mm.month ⁻¹)		ET_o ⁽²⁾ (mm.d ⁻¹)	
Month	<u>LTM</u>	2019/20	<u>LTM</u>	2019/20	<u>LTM</u>	2019/20	<u>LTM</u>	2019/20
Sep	<u>15.4</u>	15.6	<u>1.1</u>	0.8	<u>67.2</u>	27.7	<u>2.6</u>	3.1
Oct	<u>20.9</u>	19.0	<u>1.2</u>	1.4	<u>41.1</u>	104.4	<u>3.8</u>	3.5
Nov	<u>25.1</u>	24.3	<u>1.2</u>	0.9	<u>34.1</u>	5.6	<u>4.7</u>	4.7
Dec	<u>26.7</u>	25.7	<u>1.3</u>	0.9	<u>16.3</u>	17.0	<u>5.3</u>	5.2
Jan	<u>27.4</u>	25.2	<u>1.3</u>	0.9	<u>15.7</u>	5.6	<u>5.6</u>	5.1
Feb	<u>24.0</u>	24.0	<u>1.3</u>	0.7	<u>13.8</u>	2.5	<u>5.0</u>	4.7
Mar	<u>20.6</u>	18.7	<u>1.2</u>	0.6	<u>18.7</u>	4.8	<u>4.2</u>	4.4

¹ Long-term mean (LTM) values used are those of the Agricultural Research Council's Institute for Soil, Climate and Water's Fleurbaix weather station, ca. 2.4 km away from the pot experiment.

² Reference evapotranspiration was calculated using the adapted Penman-Monteith equation (Allen *et al.*, 1998).

7.4.3 Irrigation volumes applied and soil water content variation

As mentioned, irrigation was only applied once the deeper soil reached -40 kPa matric potential to encourage roots to develop throughout the soil volume in the pots. Tensiometer reading was recorded at least every second day from 26 September 2019 until 31 March 2020 (Fig. 19). A total of 28 irrigation applications were applied, with only six incidences of the soil matric potential going below -50 kPa. Irrigation volumes applied and displayed in Figure 19 are the amount of water in litres applied per the mean pot surface area of 0.229 m².

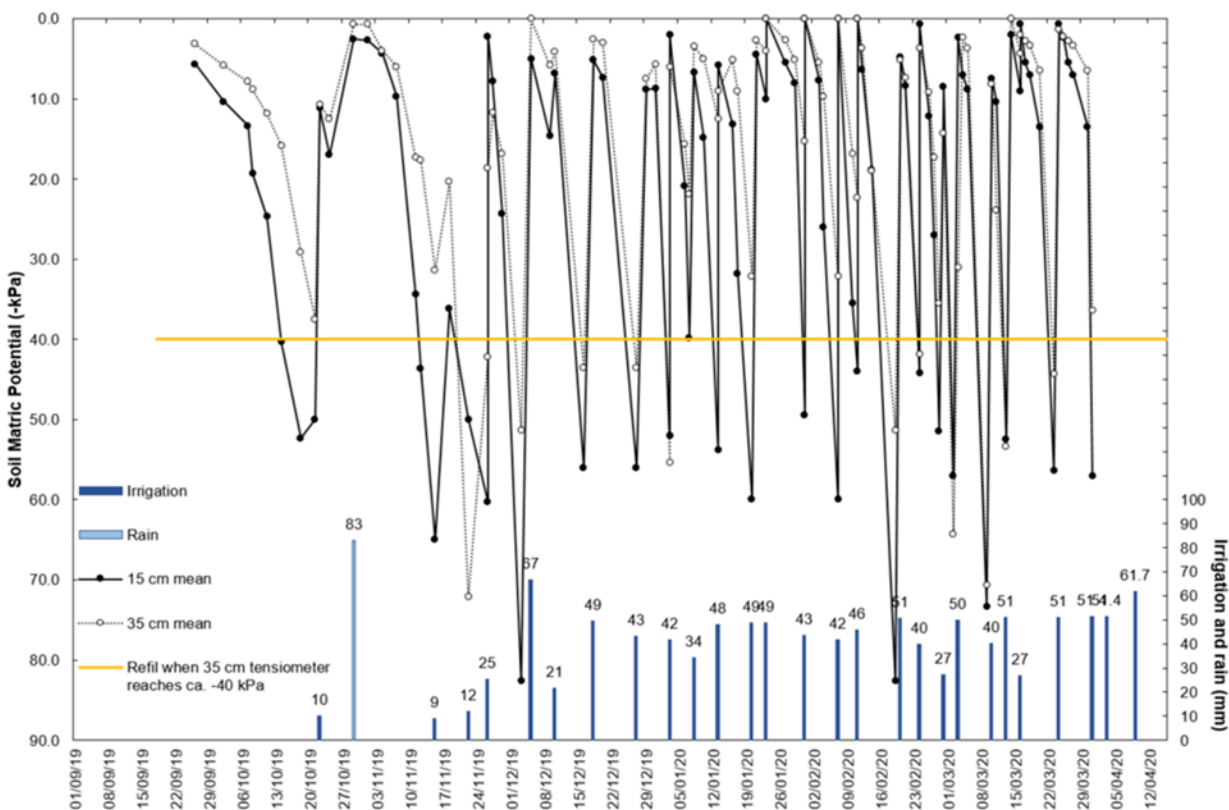


Figure 19. The mean soil matric potential variation of a pot experiment with different scion/rootstock combinations near Stellenbosch during the 2019/20 season.

Except for the 167.6 mm of rain that the pots received between September 2019 and March 2020, 925.7 mm was irrigated per pot (surface area of 0.229 m²). This equates to grapevines receiving a total of 1 093.3 mm during this period, and the total ET_o for the same period being 934.5 mm. With the presumption that no to little water was drained out of the pots during this period, the mean crop coefficient for the pots between September 2019 and March 2020 could be estimated as being 1.2. This entailed that the water application was just more than the evaporation demand. This, with the fact that grapevines still had very small leaf areas, and therefore low transpiration abilities, and that tensiometer readings were kept in the relatively wet soil matric potential range, confirms that grapevines did receive adequate water not to experience water constraints.

7.4.4 Plant water potentials

Leaf water potential measurements taken during March 2020 were very variable, but compared to results from previous studies reporting Ψ_L data and out of experience, it can be said that no water constraints were experienced by the young grapevines (Table 5). The variation may be attributed to the variations, however small, in the leaf area of the different grapevines. What was notable was that after an irrigation application, e.g. the irrigation applied after readings were taken on 2 March 2020, the response to the added water was delayed by some combinations and only reflected 42 hours later. Unfortunately, it was not possible to repeat measurements before irrigation applications were applied, as overcast conditions prevailed on the two other occasions and the deeper tensiometers' readings had already exceeded 40 kPa. The same trend was not present in all the same combinations during the second and third rounds of measurements, as it was during the first round, but some combinations did show a decrease in plant water constraints on the second day.

Table 5. Variation in mid-day leaf water potential (Ψ_L) of different scion/rootstock combinations measured under similar soil water availability and climatic conditions during March 2020 in Stellenbosch. Solid line before a specific date indicates that an irrigation application was applied on the preceding day.

Scion	Rootstock	2 March	3 March	4 March	10 March	11 March	17 March	18 March
Ψ_L (-kPa)								
Shiraz	None	860	1 310	680	810	1 000	900	1 100
Petit Verdot	None	1 320	900	650	850	1 100	890	1 000
Cabernet	None	1 410	1 040	770	610	1 180	990	890
Sauvignon								
Pinotage	None	640	1 090	510	720	1 090	750	650
Merlot	None	770	1 040	820	710	940	950	690
None	Richter 110	910	780	640	770	1 130	1 010	890
None	Ramsey	1 360	820	750	850	1 140	1 110	980
None	101-14 Mgt	1 420	600	670	560	1 140	900	680
None	USVIT 8/7	990	1 240	660	1 000	970	950	700
Shiraz	Richter 110	1 200	670	650	1 070	1 080	810	770
Shiraz	Ramsey	1 140	910	780	770	840	750	770
Shiraz	101-14 Mgt	1 260	1 220	650	890	940	1 020	790
Shiraz	USVIT 8/7	1 440	870	660	750	1 130	900	790
Petit Verdot	Richter 110	1 210	1 250	780	1 210	970	1 150	790
Petit Verdot	Ramsey	1 090	1 230	700	1 110	1 250	920	770
Petit Verdot	101-14 Mgt	910	1 190	600	920	960	790	880
Petit Verdot	USVIT 8/7	1 110	1 150	650	1 140	1 060	770	740
Cabernet	Richter 110	1 450	620	640	640	1 090	890	1 050
Sauvignon								
Cabernet	Ramsey	1 280	640	640	780	840	870	740
Sauvignon								
Cabernet	101-14 Mgt	1 140	1 000	760	1 250	960	950	750
Sauvignon								
Cabernet	USVIT 8/7	1 460	600	650	910	1 270	940	800
Sauvignon								
Pinotage	Richter 110	1 010	920	570	710	940	950	720
Pinotage	Ramsey	1 080	970	790	880	710	990	580
Pinotage	101-14 Mgt	1 010	970	640	1 020	940	990	680
Pinotage	USVIT 8/7	1 000	1 120	630	800	770	850	840
Merlot	Richter 110	1 040	1 050	700	800	930	970	1 020
Merlot	Ramsey	1 310	960	760	920	900	910	730
Merlot	101-14 Mgt	960	1 080	660	700	1 070	940	770
Merlot	USVIT 8/7	1 240	1 130	820	910	1 090	990	660

Although there was an indication that the Ψ_L recovery response of some plant material and/or combinations may vary, this effect may be found to be much more pronounced when the water constraints in grapevines are increased through irrigation at higher soil water depletion levels and larger leaf areas per grapevine.

7.5 May 2020 to August 2021

7.5.1 Cultivation actions

Pruning was only done in mid-August 2020. Grapevines were pruned to single bud spurs, and 12 evenly spaced spurs were allocated per grapevine. Due to the fact that a high variation in pruning mass was expected, and no grapes were produced during the 2019/20 season, this data was not processed.

Due to late and uneven budbreak, snail repellent was applied in two increments (mid-October and early-November 2020). A prescribed dosage of KOINOR 350 SC (a variant of Confidor®) also containing the active ingredient *Imidacloprid* (*chloronicotinyI*), was applied as a blanket treatment to all pots (grapevines) to protect particularly own-rooted scion vines against the

possibility of Phylloxera (*Daktulosphaira vitifoliae*) infestation, during November 2020. Weeds in the work row area of the pot experiment were controlled before bud break by a broadband herbicide application with a covered spray nozzle, but after active growth commenced, had to be managed by means of manual labour to remove and kill weed growth. Weeds growing in pots were removed four times during the growing season by hand.

Potassium and nitrogen fertilizer was applied in the form of KCl and limestone ammoniumnitrate (LAN) according to prescribed norms (Conradie, 1994). The KCl was applied once off at the end of September 2020, while the LAN was applied in monthly increments until March 2021.

During a meeting with Prof Melané Viviers and her co-workers (end of September 2020), it was decided that until véraison, all grapevines should be irrigated at a low depletion level, i.e. ca. 30% plant available water (PAW) (or once deeper tensiometers are installed during 2019, reaching a matrix potential of ca. -40 kPa), which would be followed by a high soil water depletion level, ca. 90% soil water depletion. This would allow efficient shoot growth and canopy establishment. Three of the nine replications would, however, receive irrigation at a low PAW depletion level and be irrigated separately from the other six replicates. This would enable the IWBT team to assess whether any molecular adaptations would occur within grapevines after a switch in water availability is experienced. Prof Viviers also suggested that waterproof covers be made to cover the soil surfaces of grapevines irrigated at a high PAW depletion level, should any untimely rainfall be predicted during a soil drying out stage. This task was performed by Dr Philip Young early in January 2021. It was also decided to fix the lowest movable trellis wire on either side of the poles 10 cm above the cordon wires to protect young shoots against wind damage.

Suckering of grapevines was done in November 2020, and any unwanted shoots growing out of the stems were removed continuously. Grapevines that did not have adequate shoot growth during the 2019/20 season had new shoots laid onto cordon wires and were topped as soon as the cordon wires were filled. At the end of October, it was assessed that six of the experimental grapevines did not survive. A own-rooted Cabernet Sauvignon, Pinotage/110Richter, Petit Verdot/Ramsey and Petit Verdot/110Richter was each replaced with two-year-old spare vines. Unfortunately, due to no spare two-year-old Cabernet Sauvignon/Ramsey and own-rooted Pinotage, these two plants had to be replaced with one-year-old grapevines. Cabernet Sauvignon/101-14 Mgt and Petit Verdot/110Richter each had a grapevine where the cordon-arms had died back and were retrained onto the cordon wire

Mid-day leaf water potentials (Ψ_L) were measured in two replications to acquire enough degrees of freedom in data to perform statistical analyses (analysis of variance - ANOVA). Due to the Project leader contracting Covid-19 early in February 2021, two sets of Ψ_L measurements were done mid-December 2020, while ten sets were done between 5 March and 3 May 2021.

Pruning of grapevines was done on 6 and 7 August 2021. During August 2020, grapevines were pruned to 10 evenly spaced single bud spurs.

High rainfall during and after budbreak made fungicide application difficult to apply and ineffective. Powdery mildew infected some grapevines' flowers quite severely (Fig. 20A), an incidence that was widely experienced in the Stellenbosch area during the spring of 2020. Bunch phenology was recorded by Mr Stenford Matsikidze (Student in the IWBT), and all bunches were removed in early January 2021. Some vines were also infected with Grapevine bud mites (*Colomerus vitis*) (Fig. 20B), but after the application of KOINOR 350 SC in November, it seemed to have been contained in only older leaves.

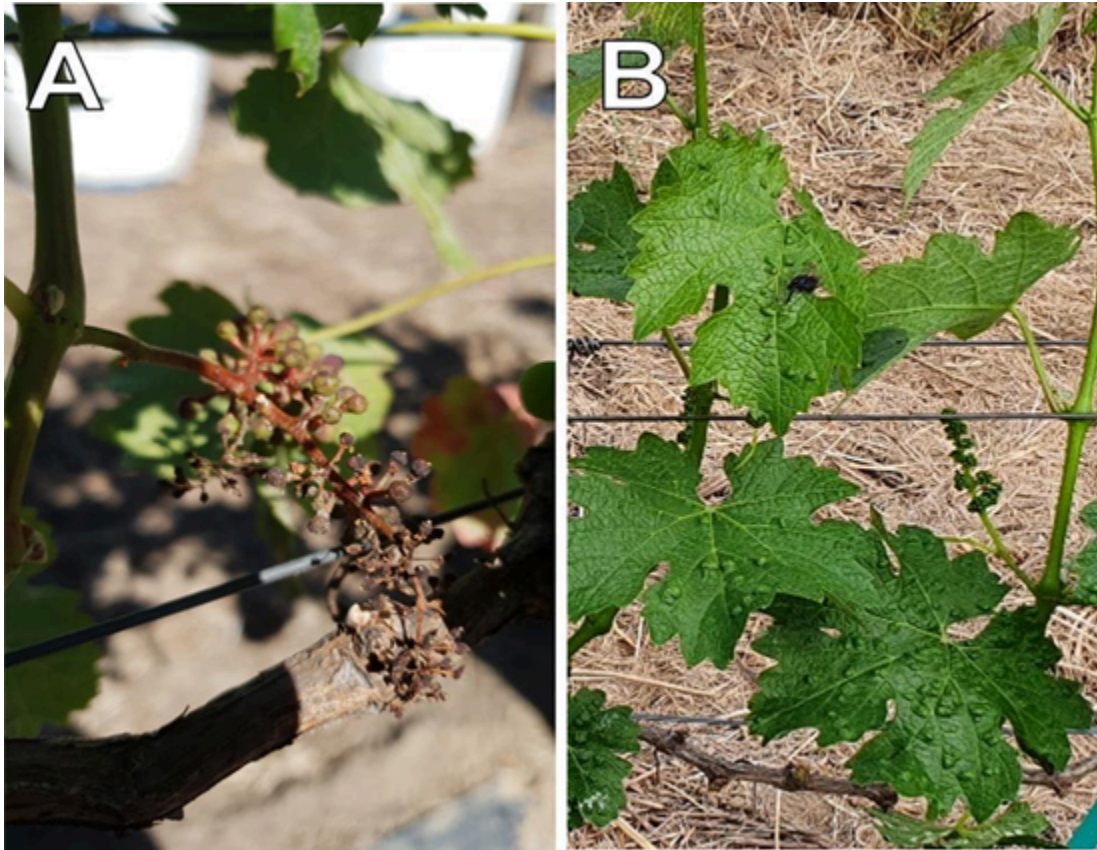


Figure 20. Illustration of (A) powdery mildew-infected bunch and (B) Grapevine bud mite symptoms during the early phase of the 2020/21 season.

Moveable trellis wires were tightened during November 2020. Growing shoots were continuously tucked into the trellis system. A plaque with the plant material combination and replication of each experimental grapevine pot was installed during November 2020 (Fig. 21). The rest of the cultivation practices occurred without any unmanageable incidents.



Figure 21. Grapevines with their shoots tucked into the trellis system during the early phase of the 2020/21 season, and plaques with treatment information visible on the side of each pot.

7.5.2 Seasonal climatic data

The 2020/21 season started off with much lower temperatures during September 2020, as well as February and March 2021, when compared to the long-term mean (LTM) data of a weather station at Fleurbaix (ca. 2.4 km away) and the 2019/20 season (Table 6). Only October 2020 and January 2021 were warmer than the same month during the preceding season (Table 4), while the other months were relatively comparable to the LTM temperature. Throughout the 2020/21 season, relative humidity (RH) was higher than that of the comparable months during the 2019/20 season (Table 4) and long-term data (Table 6). This would have contributed to the increased potential of fungal infections.

Similarly to that of the RH, the mean daily solar irradiance throughout the season was much lower than that of the LTM and the 2019/20 season (Table 6). This indicate much more days with cloud cover and could have also contributed to the higher mean RH during the 2020/21 season. Higher wind speeds were observed during October 2019 than during October 2021, with the rest of the months having similar mean wind speeds to the preceding season. October 2020 had much less rain than the same month during 2019 and the LTM, while November 2020 and March 2021 received much more rain than the previous season (Table 6). The calculated mean daily reference evapotranspiration (ET_o) for September and October was similar to that for the same months during the 2019/20 season and LTM data. The rest of the months, however, had lower calculated ET_o values due to the higher atmospheric RH and lower total daily solar irradiance measured. The 2020/21 season thus had a lower atmospheric water demand than the 2019/20 season (Table 4).

Table 6. The mean daily maximum (T_x) and minimum (T_n) temperatures, maximum (RH_x) and minimum (RH_n) relative humidity, solar irradiance (R_s), wind speed (u_2), rain and reference evapotranspiration (ET_o) at the pot experiment (Stellenbosch) for the 2020/21 growing season.

Element	T_x (°C)		T_n (°C)		RH_x (%)		RH_n (%)	
Month	<u>LTM</u> ⁽¹⁾	2020/21	<u>LTM</u>	2020/21	<u>LTM</u>	2020/21	<u>LTM</u>	2020/21
Sep	<u>21.8</u>	19.6	<u>9.3</u>	8.8	<u>92.3</u>	97.7	<u>45.9</u>	58.5
Oct	<u>24.5</u>	23.3	<u>11.6</u>	11.0	<u>90.1</u>	94.6	<u>40.2</u>	50.2
Nov	<u>25.9</u>	25.0	<u>12.8</u>	12.4	<u>90.6</u>	93.1	<u>39.8</u>	48.6
Dec	<u>28.3</u>	27.1	<u>14.9</u>	14.2	<u>90.2</u>	93.9	<u>38.5</u>	47.2
Jan	<u>30.1</u>	29.9	<u>15.9</u>	15.5	<u>89.8</u>	92.1	<u>37.8</u>	44.3
Feb	<u>30.1</u>	28.7	<u>15.7</u>	15.0	<u>90.0</u>	91.5	<u>37.5</u>	44.1
Mar	<u>28.9</u>	26.6	<u>14.3</u>	14.6	<u>90.5</u>	95.5	<u>36.9</u>	50.8

Element	R_s (MJ.m ⁻² .d ⁻¹)		u_2 (m.s ⁻¹)		Rain (mm.month ⁻¹)		ET_o ⁽²⁾ (mm.d ⁻¹)	
Month	<u>LTM</u>	2020/21	<u>LTM</u>	2020/21	<u>LTM</u>	2020/21	<u>LTM</u>	2020/21
Sep	<u>15.4</u>	13.0	<u>1.1</u>	0.8	<u>67.2</u>	102.3	<u>2.6</u>	2.5
Oct	<u>20.9</u>	17.4	<u>1.2</u>	0.7	<u>41.1</u>	13.4	<u>3.8</u>	3.6
Nov	<u>25.1</u>	18.8	<u>1.2</u>	0.8	<u>34.1</u>	36.1	<u>4.7</u>	4.0
Dec	<u>26.7</u>	20.5	<u>1.3</u>	0.6	<u>16.3</u>	14.5	<u>5.3</u>	4.5
Jan	<u>27.4</u>	21.2	<u>1.3</u>	0.6	<u>15.7</u>	6.6	<u>5.6</u>	4.8
Feb	<u>24.0</u>	19.3	<u>1.3</u>	0.6	<u>13.8</u>	1.0	<u>5.0</u>	4.4
Mar	<u>20.6</u>	14.6	<u>1.2</u>	0.7	<u>18.7</u>	51.0	<u>4.2</u>	3.2

¹ Long-term mean (LTM) values used are those of the Agricultural Research Council's Institute for Soil, Climate and Water's Fleurbaix weather station, ca. 2.4 km away from the pot experiment.

² Reference evapotranspiration was calculated using the adapted Penman-Monteith equation (Allen *et al.*, 1998).

7.5.3 Irrigation volumes applied and soil water content variation

Tensiometers installed in 2019 were used to monitor soil water status. Irrigation was only applied once the deeper soil layer reached -40 kPa matric potential to encourage roots to develop throughout the soil volume in the pots. Tensiometer reading was recorded as often as possible from 23 September 2020 until 14 May 2021 (Fig. 22). After 5 January 2021, the soil dried out to the extent that the vacuum inside the tensiometers was broken, i.e. soil matrix potentials were less than -80 kPa. No tensiometer measurements could be done during this period until 12 January, as the student in charge of the measurements was unfamiliar with the servicing of tensiometers (Fig. 22a). Between 4 and 18 February 2021, the project leader had Covid-19, and his research assistant and student helping in the pot trial was exposed and had to self-isolate (Fig. 22b). A total amount of 30 irrigation applications were applied and irrigation volumes recorded by means of water meters on the manifold. During the 2020/21 season, irrigation applications were also frequently interrupted by load shedding.

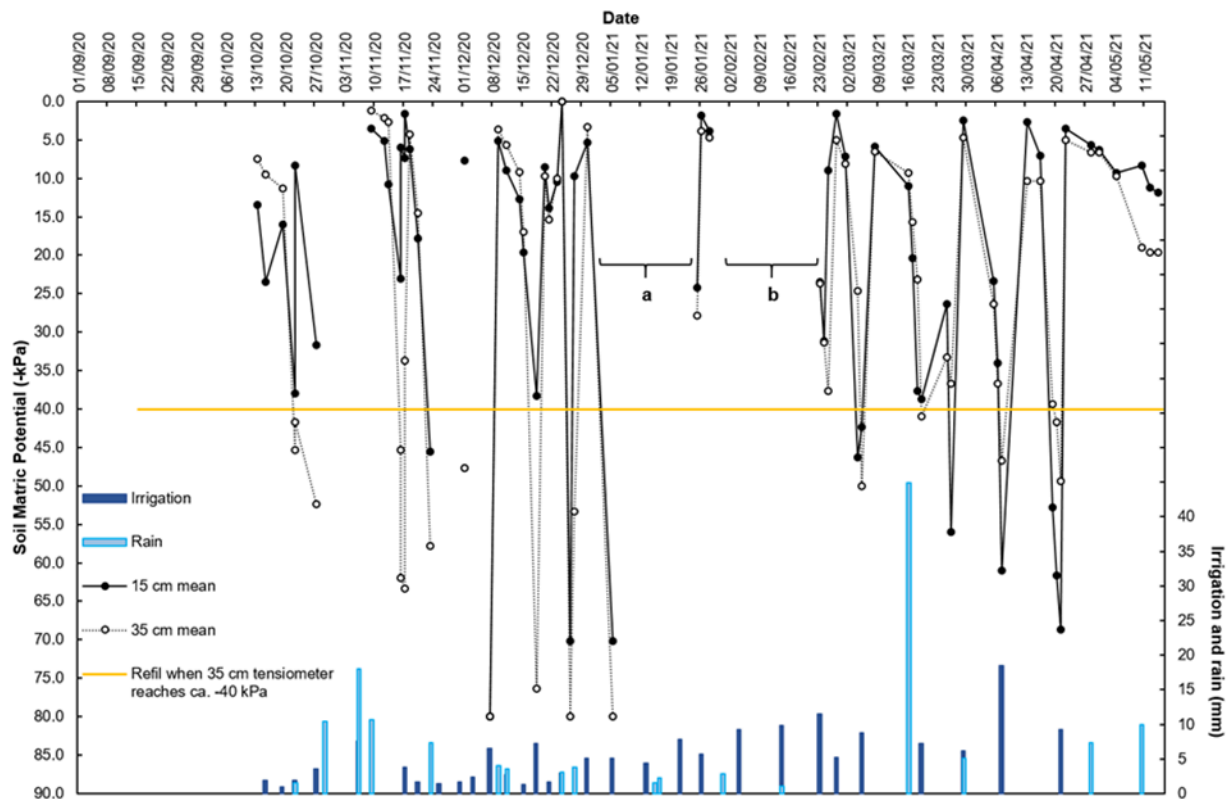


Figure 22. The mean soil matric potential variation of a pot experiment with different scion/rootstock combinations near Stellenbosch during the 2020/21 season.

During November and December 2020, it was noted that the volumes applied per hour were constantly decreasing (Fig. 23). During the 2019/20 season, the mean delivery rate per dripper was ca. 2.4 L/h. During mid-December 2020, ring filters at the pump were packed with silt and organic matter and cleaned. It was also noted that the soil surface within the pots wetted by the two arrow drippers (maximum delivery rate of 1.6 L/h each) delivering water supplied by the 2 L/h button dripper per pot, were declining and wetting less than ca. 33% of the soil surface during irrigation applications (Fig. 24). An extra set of 2 L/h Netafim button drippers connected to two arrow drippers was sponsored by NetafimSA, but could only supply stock at the end of February 2021. In late November 2020, it was noticed that some arrow drippers were blocked and not delivering water (Fig. 25A). All blocked or low-flowing arrow drippers were removed from the connecting barb tubing and cleaned using lukewarm water and a toothbrush before reconnecting the arrow drippers. This action improved the dripper delivery rates. However, during the latter part of December 2020, the delivery rates decreased again. Cleaning of arrows only resulted in a temporary improvement in dripper delivery. During December, delivery rates plummeted again and on 21 January, all arrow drippers and button drippers were removed and cleaned of organic and silt blockages. After discussing the problem with the Welgevallen Farm Manager, Mr Willem van Kerwel, he explained that water from the reservoir from which water for the pot trial is refilled is out of the Eerste River. We took a water sample at the reservoir outlet to the pump and found a lot of silt and organic matter that had gradually pumped into the reservoir over time and had flocculated down to the bottom, where the outlet was situated. This meant that once irrigation is stopped, high organic content and silt accumulate inside the arrow- and button drippers and dried, causing blockage (Fig. 25B). It was decided to and an in-line membrane Filter (10 micron) as the parallel two Arkal ring filters (130 micron) could not filter out organic matter (Fig. 25C). Figure 26 illustrates the amount of silt and organic matter trapped by the in-line membrane filter, that had to be cleaned every two weeks.

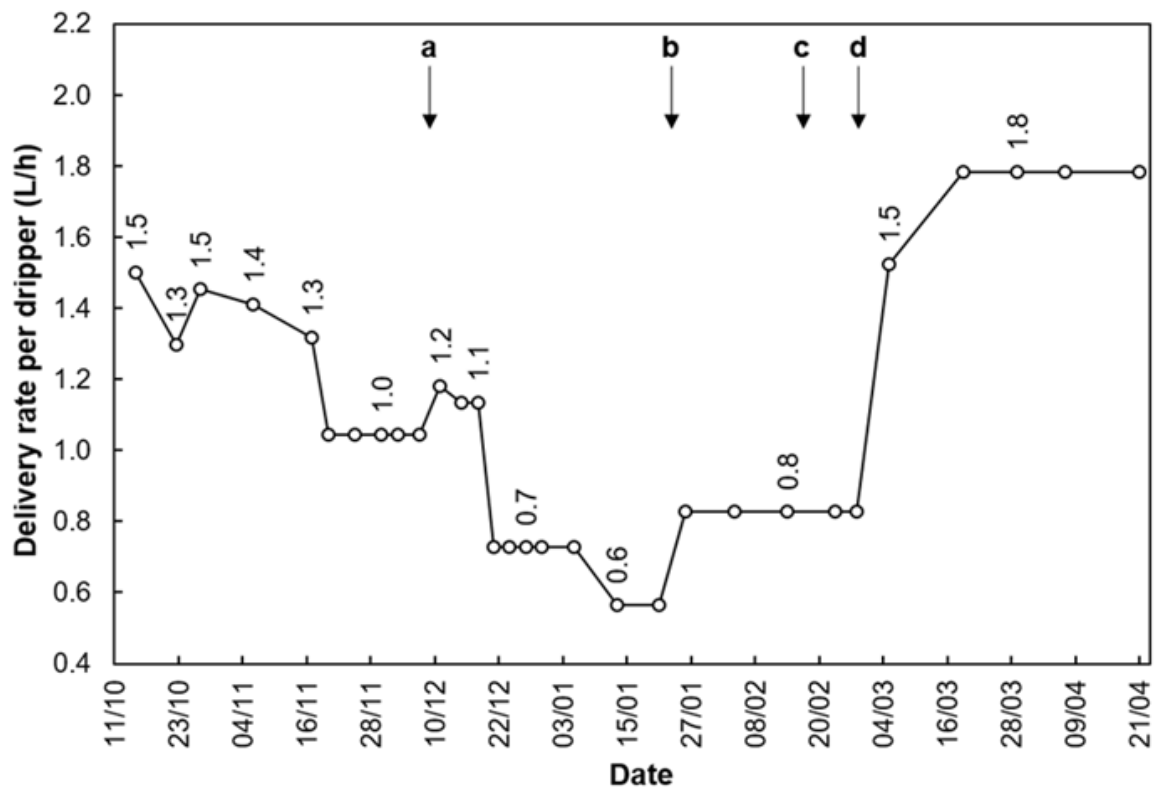


Figure 23. The mean dripper delivery rate during the 2020/21 season. Downward arrows indicate the following actions: (a) cleaning of arrow drippers, (b) cleaning of all button and arrow drippers, (c) cleaning of all button and arrow drippers, as well as install membrane filter and pressure gauge, and (d) install new pump and an extra 2 L/h button dripper with two arrow drippers.



Figure 24. The volume of soil wetted by drippers declined continuously from the beginning of the 2020/21 season.

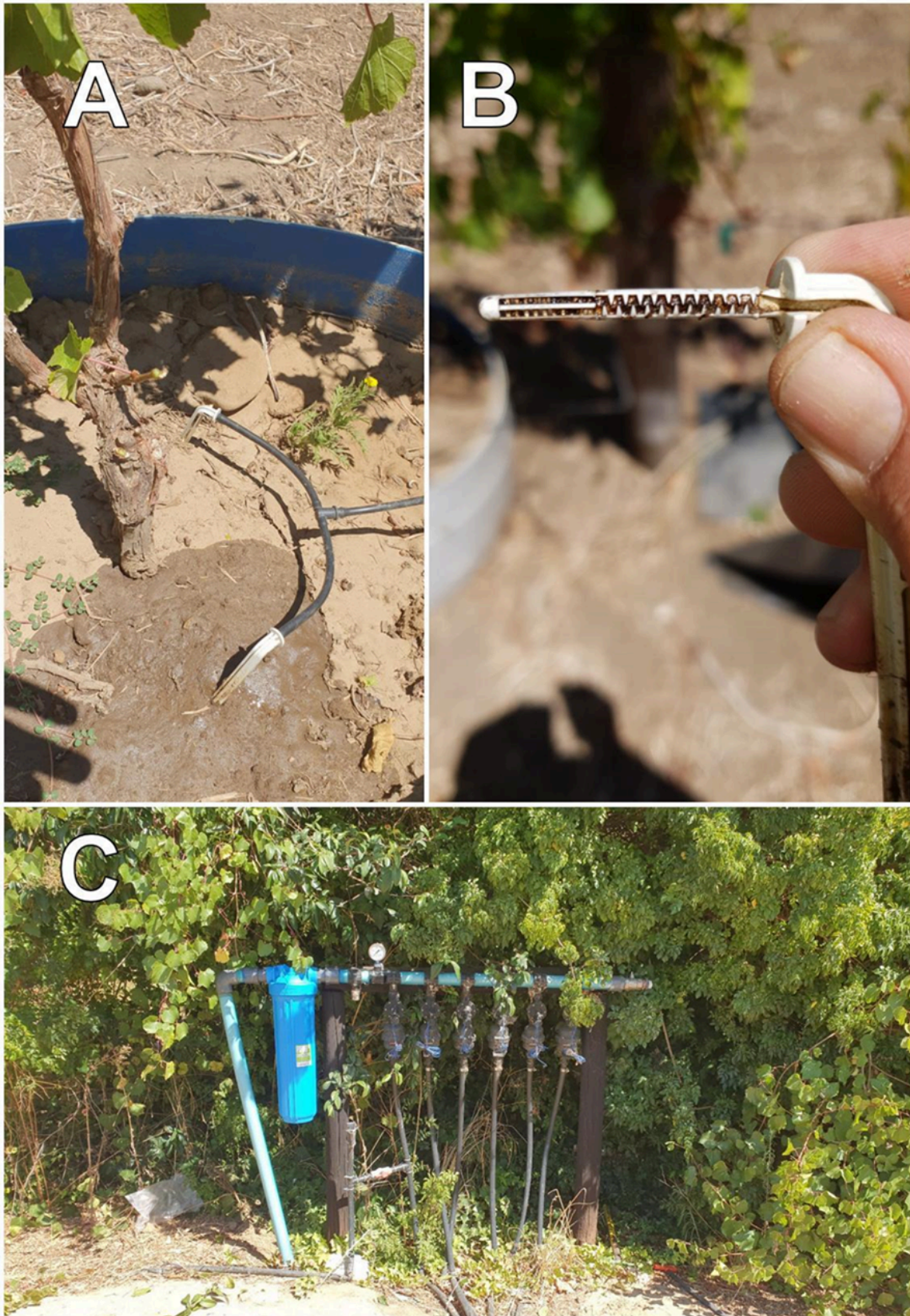


Figure 25. Illustration of (A) blockage of arrow drippers, (B) silt and organic matter build up inside the arrow dripper's sieve and labyrinth flow path causing blockage and (C) membrane filter installed at the experiment's manifold with a pressure gauge between the filter and drippers.

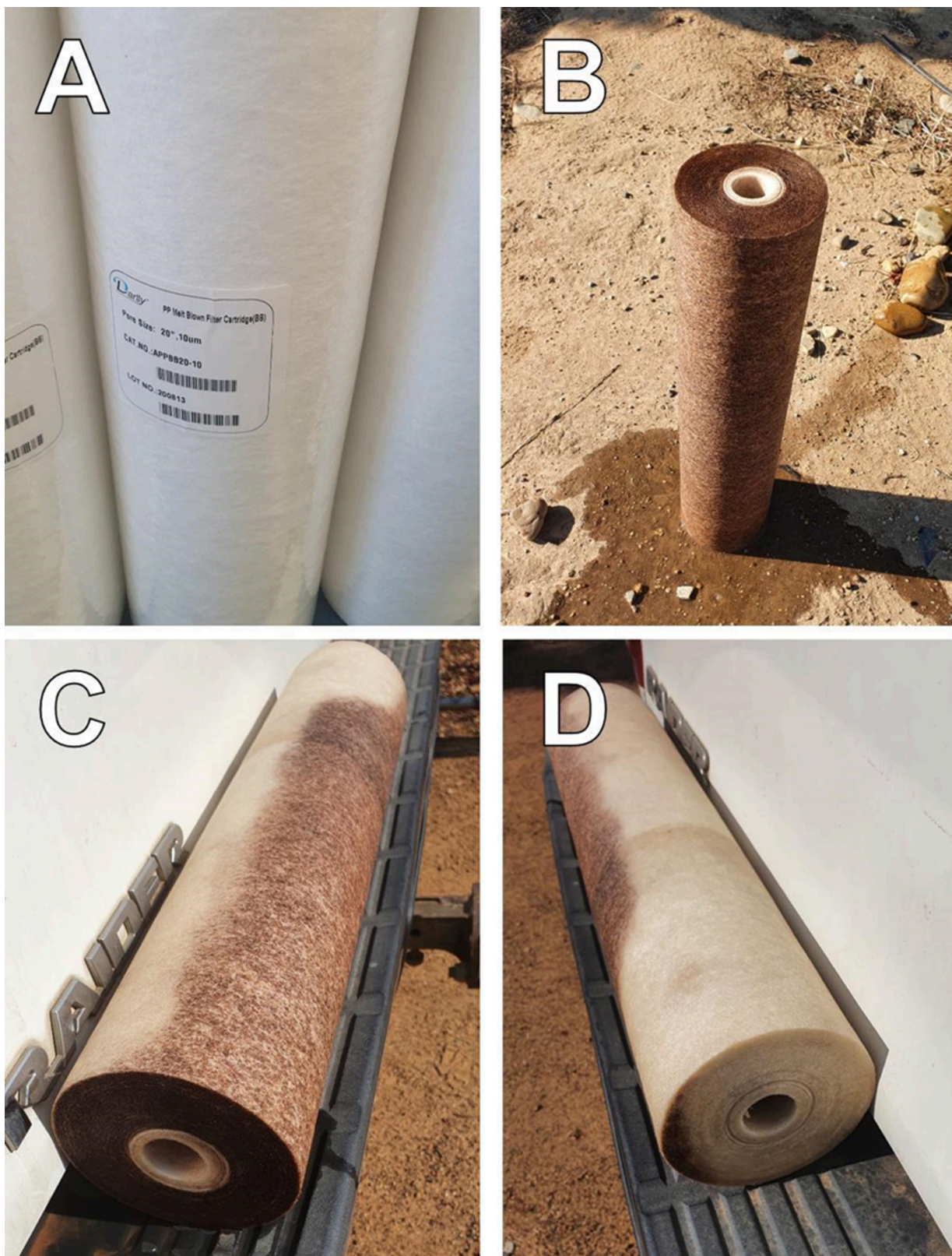


Figure 26. Illustration of (A) the new 10 micron filter membrane before installation, (B) the amount of organic matter intercepted by the filter after two irrigation applications and (C and D) the membrane after being rinsed under a tap, membrane filter installed at the experiment's manifold with a pressure gauge after the filter.

After the installation of the membrane filter, pressure on the dripper side still varied between 0.4 and 0.6 Bar or 40 and 60 kPa (Fig. 27A). This was still well below the pressure requirements for optimum delivery rates of Netafim PCJ 2 L/h pressure compensated button drippers (installed in the pot trial), which should be between 0.8 and 4.0 Bar, with optimum delivery rates being achieved between 1.5 and 2.5 Bar. It was decided, after discussing the issue with Mr Willem Smit (NetafimSA), who stated that the pump we had (DAB-K20-41M; 0.37 kW) should be sufficient to provide the necessary flow and pressure required for the drippers, to procure and replace the old pump at the reservoir. A new DAB-K30-70M (0.75 kW) was procured, and during the replacement of the pumps, it was noticed that the capacitor of the old pump had exploded, thus not being able to run on full capacity (Fig. 27B). This could very well have been during the period that the country experienced electricity load shedding during late-December 2020 and early January 2021. The electricity went off on two occasions while the pump was running, and a high voltage surge during the re-instatement of electricity is most probably to blame for the explosion of the capacitor. The pump replacement, as well as the addition of an extra Netafim PCJ 2 L/h pressure compensated button dripper with barb tubing and two 1.6 L/h arrow drippers per pot, was done on 26 February 2021.

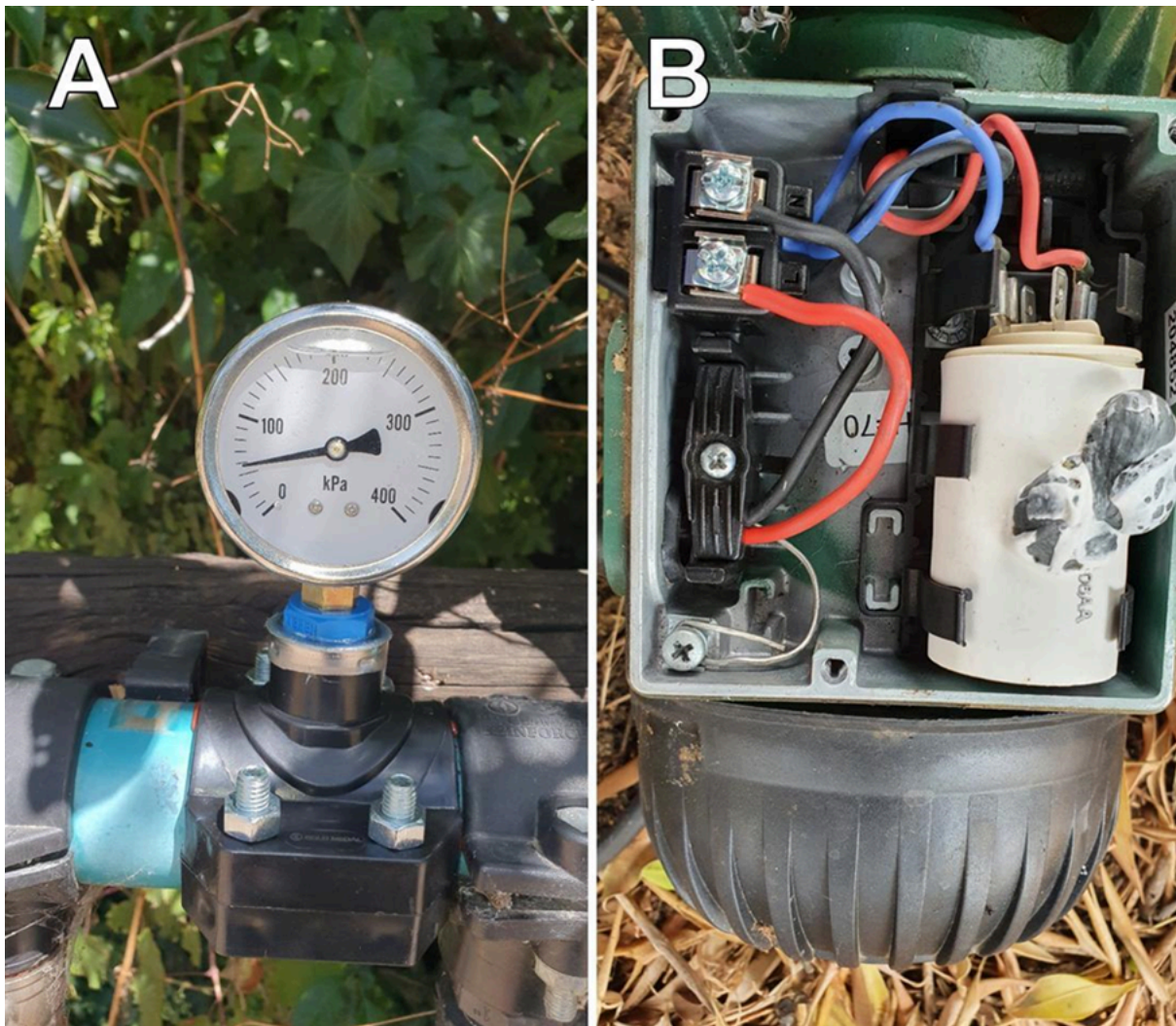


Figure 27. The (A) measured pressure at the manifold between the drippers and membrane filter before replacement of the irrigation pump, and (B) the exploded pump capacitor noticed while installing the new procured pump.

An Arduino, an open-source hardware and software company, logging system was assembled, and the programming code was written for the use of capacitance sensors to remotely monitor

soil water variations. This process has been ongoing for the past 3 years. The system comprised of an Arduino microcontroller (Model: UNO R3), a GSM Modem, 12 voltage battery, solar charge controller and 12 V 6 W solar photovoltaic panel (Fig. 28A). Two capacitance soil moisture sensors were installed in two pots and 10 cm and 30 cm depths, respectively (Fig. 28B). These sensors were pre-installation calibrated against variations of gravimetric water contents of the same soil in the pot experiment pots, as well as in dry air and water, and the calibration entered into the coding that was used to program the Arduino microcontroller before installation. The sensors and system were installed on 20 December 2020 and the logging system was enclosed in a lockable weatherproof PVC box and locked to a trellis system pole (Fig 28C). Due to suppliers not having stock and being placed on a waiting list for more sensors to arrive (58 required in total just to measure each pot within one replication), this period was used to monitor the system's performance. The program pre-installation upload to the Arduino microcontroller contained coding to send the four sensors' data to a cloud-based server website called Thingspeak (<https://thingspeak.com>), and data could be accessed and downloaded remotely.

After the soil dried out to the point where the vacuum inside the tensiometers broke during the first week of January 2021, and no tensiometer readings could be taken before the project leader's return to the Western Cape on 12 January 2021, after irrigation applications were applied, the tensiometers could be serviced. The Arduino data collected between the installation date and when the solar panel could not load the battery sufficiently on 11 January 2021. The continues logging data collected during this period showed, that even though irrigations were applied frequently, the deeper soil layer was not replenished with water (Fig. 29). This, with the fact that from 2 to 5 January 2021, the grapevines were also exposed to temperatures between 33.5 and 36.5°C, resulted in grapevines experiencing sunburn and heat stress (Fig. 30). After this period the many of grapevines shed their leaves on shoot nodes 2 to 5 and active shoot growth seized. With leaf fall occurring and Ψ_L measurements still needing to be conducted, it was decided to continue irrigation at a low to moderate depletion level for the rest of the season to encourage regrowth of secondary shoots and leaves (Fig. 31).

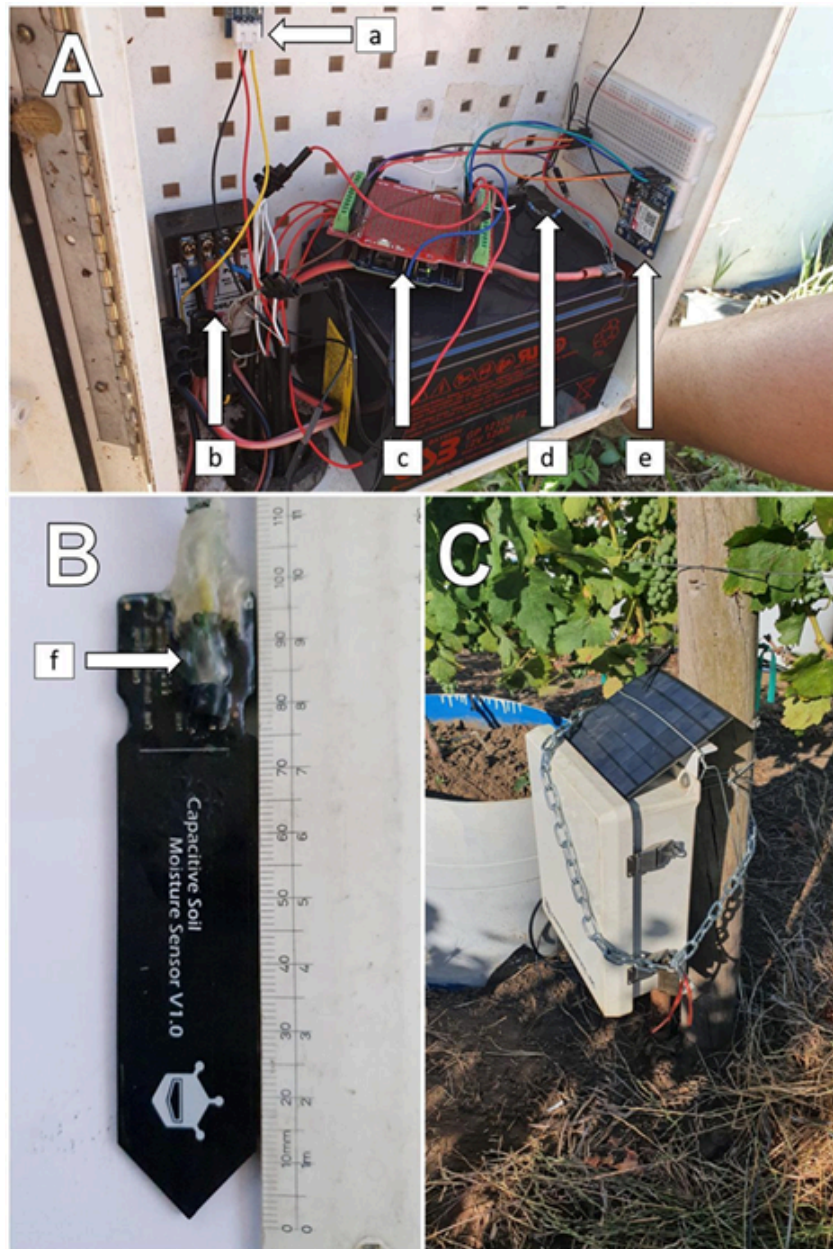


FIGURE 28. Illustration of (A) the Arduino logging system with a (a) digital temperature and relative humidity sensor (Model: DHT22), (b) 12 V solar charge controller, (c) a preprogrammed Arduino UNO R3 microcontroller, (d) a set of split-resistors calibrated to monitor battery voltage and (e) a GSM modem. The capacitance sensor (B) measures ca. 10 cm, with capacitance probes encased of ca. 6.5 cm length and can be fitted with a digital temperature sensor to measure soil temperature variations (f). The system was installed in a lockable enclosure (C), locked and fitted to a trellis pole with the solar photovoltaic panel fixed on top of the enclosure and facing North.

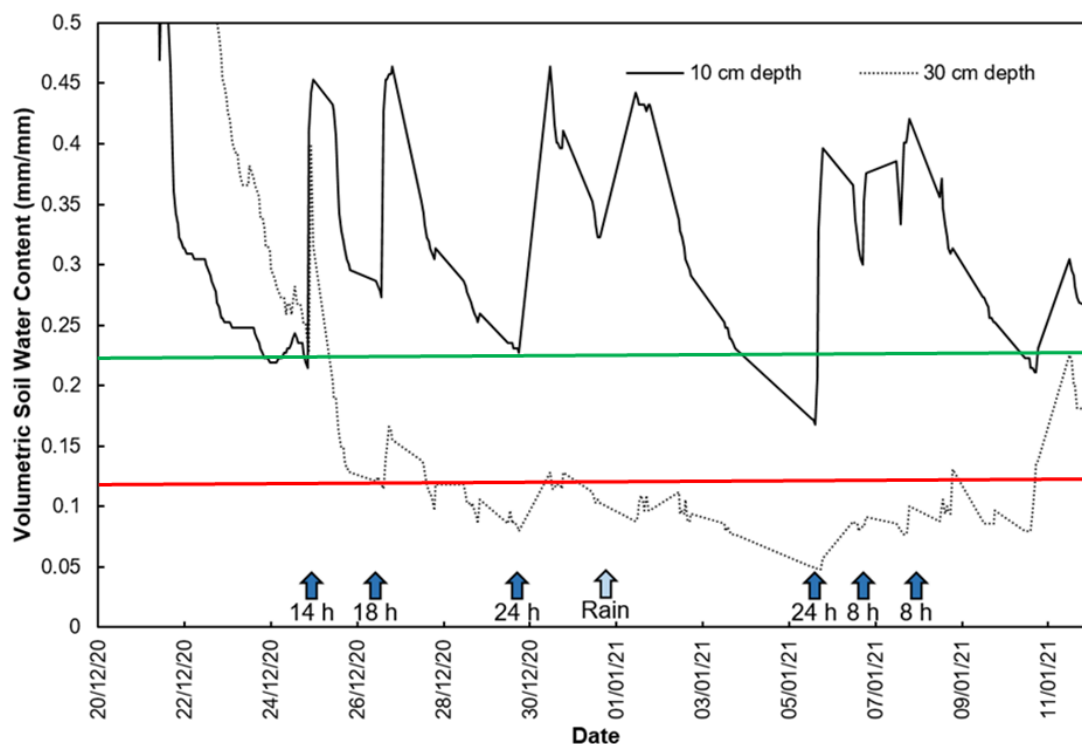


Figure 29. The soil water content variation at -10 cm and -30 cm depths was monitored by using the continuous logging Arduino system between 20 December 2020 and 11 January 2021. The green line represents soil field capacity, and the red line represents the permanent wilting point (-1 500 kPa soil matric potential).

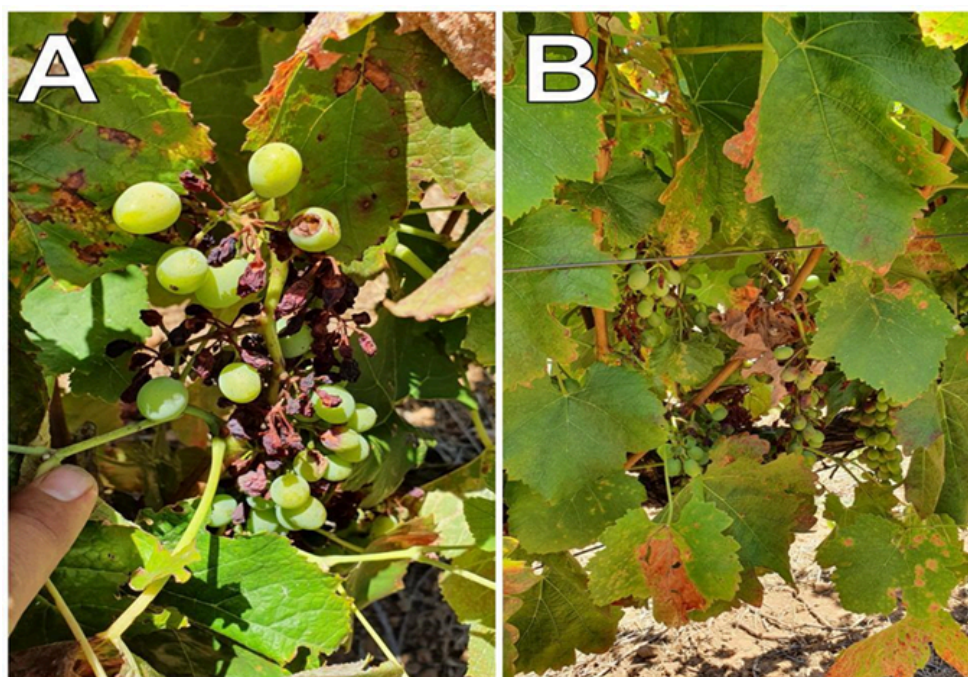


Figure 30. Sunburn damage (A) and heat stress symptoms on leaves (B) after high atmospheric temperatures and low soil water availability between 2 and 5 January 2021.

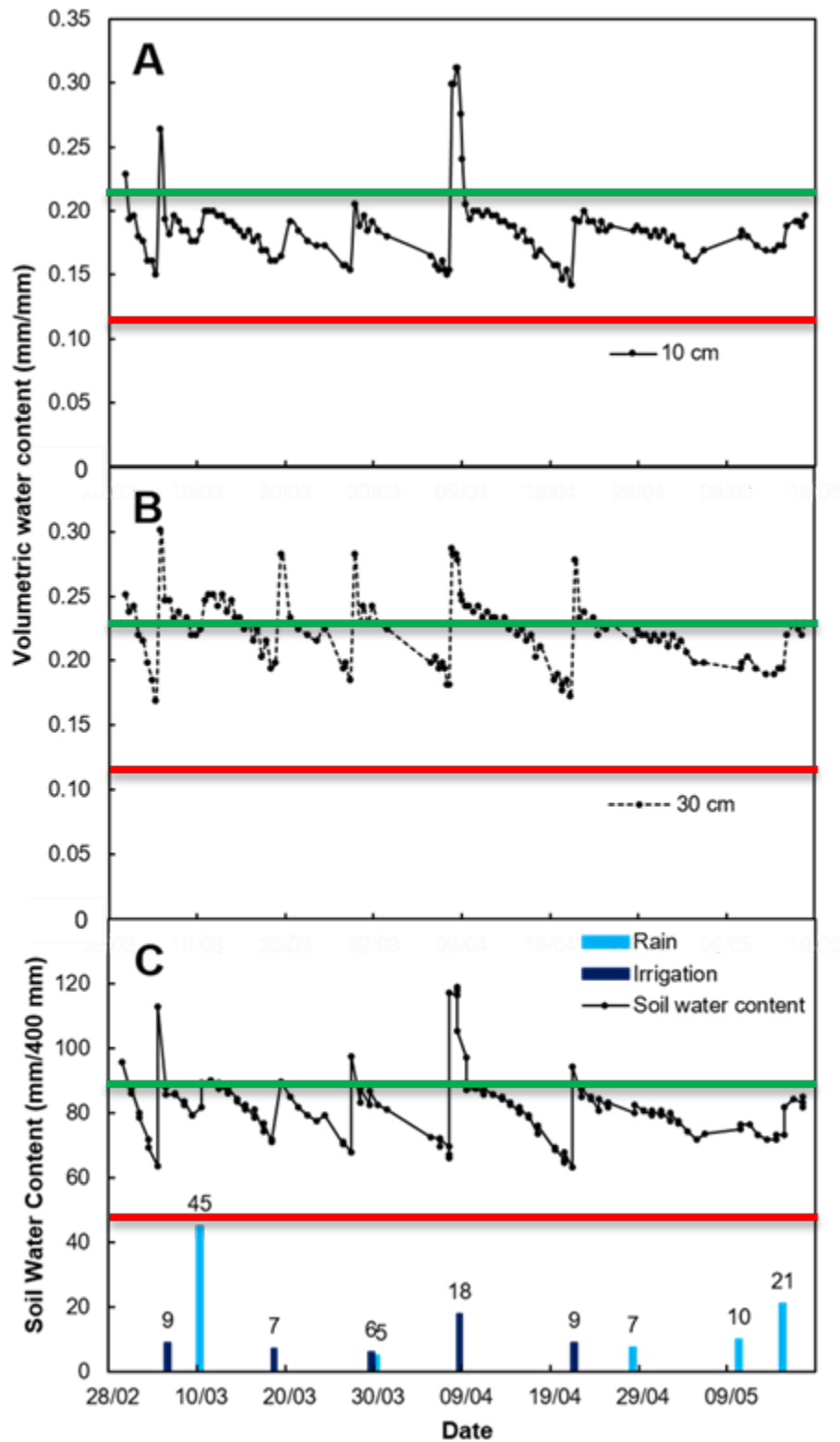


Figure 31. Soil water content variation at (A) -10 cm depths, (B) -30 cm depths and (C) total soil water content monitored by the continuous logging Arduino system, as well as rain and irrigation volumes applied, between 1 March and 17 May 2021. The green lines represent soil field capacity, and the red lines represent the permanent wilting point (-1 500 kPa matric potential).

7.5.4 Vegetative responses

Stronger vegetative growth was visually observed at some grapevines, particularly in some of the trained Ramsey and Cabernet Sauvignon/Ramsey grapevines, with only some genetic combinations having one grapevine with stronger vegetative growth. All grapevines were pruned to have ten two-bud spurs as evenly spaced out as possible (Fig. 32). Shoot mass determined during pruning, the aforementioned two treatments tended to have produced the highest cane mass during the 2020/21 season, while Trained USVIT 8-7 produced the lowest cane mass (Table 7). Similarly, Scions grafted onto Ramsey tended to produce higher cane mass, while those grafted onto USVIT 8-7 produced the lowest. Taking into account that the soil water contents during the middle part of the season may have varied a lot due to block drippers and the subsequent potential differences in soil water availability, it cannot be said whether or not these cane mass values are a true reflection of the genetic combinations. Changes made to the irrigation system were expected to level out potential water application differences.



Figure 32. Illustration of grapevine development during early August 2021, with downward arrows indicating ten two-bud spurs. The four arrow drippers per pot, being supplied by two 2 L/h Netafim button drippers is clearly visible.

Table 7. The effect of the vegetative responses of different scion/rootstock combinations measured under similar soil water availability and climatic conditions during the 2020/21 season in Stellenbosch.

Scion	Rootstock	Pruning mass per vine (g)		Fraction of maximum mean pruning mass	
		All vines	Grafted vines	All	Grafted
Shiraz	Own Rooted	277 defg ⁽¹⁾		0.42 defg	
Petit Verdot	Own Rooted	229 fg		0.35 fg	
Cabernet Sauvignon	Own Rooted	267 efg		0.41 efg	
Pinotage	Own Rooted	231 fg		0.35 fg	
Merlot	Own Rooted	174 fg		0.27 fg	
Trained	Richter 110	449 bcde		0.69 bcd	
Trained	Ramsey	613 ab		0.94 ab	
Trained	101-14 Mgt	474 abc		0.72 abc	
Trained	USVIT 8/7	146 g		0.22 g	
Shiraz	Richter 110	313 cdefg	313 defg	0.48 cdefg	0.48 defg
Shiraz	Ramsey	450 bcd	450 bc	0.69 bcd	0.69 bc
Shiraz	101-14 Mgt	270 defg	270 defgh	0.41 defg	0.41 defg
Shiraz	USVIT 8/7	328 cdefg	328 cdef	0.5 cdefg	0.5 cdef
Petit Verdot	Richter 110	346 cdef	346 bcde	0.53 cdef	0.53 bcde
Petit Verdot	Ramsey	353 cdef	353 bcd	0.54 cdef	0.54 bcd
Petit Verdot	101-14 Mgt	188 fg	188 gh	0.29 fg	0.29 fg
Petit Verdot	USVIT 8/7	177 fg	177 gh	0.27 fg	0.27 fg
Cabernet Sauvignon	Richter 110	470 bc	470 b	0.72 bc	0.72 b
Cabernet Sauvignon	Ramsey	655 a	655 a	1.00 a	1.00 a
Cabernet Sauvignon	101-14 Mgt	334 cdef	334 cdef	0.51 cdef	0.51 cdef
Cabernet Sauvignon	USVIT 8/7	335 cdef	335 bcde	0.51 cdef	0.51 bcde
Pinotage	Richter 110	260 fg	260 defgh	0.4 fg	0.4 defg
Pinotage	Ramsey	265 fg	265 defgh	0.41 fg	0.41 defg
Pinotage	101-14 Mgt	276 defg	276 defgh	0.42 defg	0.42 defg
Pinotage	USVIT 8/7	212 fg	212 efgh	0.32 fg	0.32 efg
Merlot	Richter 110	175 fg	175 h	0.27 fg	0.27 g
Merlot	Ramsey	198 fg	198 fgh	0.3 fg	0.3 efg
Merlot	101-14 Mgt	231 fg	231 defgh	0.35 fg	0.35 defg
Merlot	USVIT 8/7	191 fg	191 gh	0.29 fg	0.29 fg

¹ Values designated by the same letter within each column do not differ significantly ($p \leq 0.05$).

7.5.5 *Plant water potentials*

Leaf water potential measurements were taken on two occasions during December 2020 and ten times between the beginning of March and the beginning of May 2021 (Tables 8A, 8B and 8C). With the exception of measurements done in December 2020, other measurements were conducted before and shortly after irrigation applications. Measurements were very variable, as could be expected due to the large variation in vegetative responses of grapevines.

Compared to results from previous studies reporting Ψ_L data, Ψ_L measurements taken after irrigation applications had recovered sufficiently and could be classified as not having any water constraints. The large variation in Ψ_L measurements within the same treatments may be attributed to the variations, however small, in leaf area of the different grapevines, caused by either weaker plants or experiencing different severity of soil water constraints when the irrigation system was not functioning properly.

Table 8A. Variation in midday leaf water potential (Ψ_L) of different scion/rootstock combinations measured under similar soil water availability and climatic conditions during the 2020/21 season in Stellenbosch. A dashed line before a specific date indicates that an irrigation application was applied on the preceding day.

Scion	Rootstock	15/12/20	18/12/20	05/03/21	08/03/21
Ψ_L (-kPa)					
Shiraz	Own Rooted	695 a ⁽¹⁾	1010 abc	925 abcdef	680 ab
Petit Verdot	Own Rooted	725 a	1020 abc	975 abcdef	510 ef
Cabernet Sauvignon	Own Rooted	720 a	1040 abc	830 cdef	600 abcdef
Pinotage	Own Rooted	675 a	1050 abc	1080 abcdef	545 def
Merlot	Own Rooted	655 a	1055 abc	1075 abcdef	645 abcd
Trained	Richter 110	705 a	1070 abc	860 bcdef	655 abcd
Trained	Ramsey	720 a	1095 abc	995 abcdef	555 cdef
Trained	101-14 Mgt	685 a	1110 abc	1265 ab	575 abcdef
Trained	USVIT 8/7	670 a	1115 abc	970 abcdef	690 a
Shiraz	Richter 110	660 a	1165 abc	1015 abcdef	585 abcdef
Shiraz	Ramsey	705 a	1175 abc	815 cdef	625 abcde
Shiraz	101-14 Mgt	700 a	1205 abc	1200 abcd	540 def
Shiraz	USVIT 8/7	680 a	1220 abc	735 ef	585 abcdef
Petit Verdot	Richter 110	755 a	1245 abc	690 f	510 ef
Petit Verdot	Ramsey	715 a	1260 abc	1320 a	510 ef
Petit Verdot	101-14 Mgt	695 a	1275 abc	785 def	600 abcdef
Petit Verdot	USVIT 8/7	685 a	1380 abc	1230 abc	645 abcd
Cabernet Sauvignon	Richter 110	750 a	1450 abc	1065 abcdef	640 abcd
Cabernet Sauvignon	Ramsey	750 a	735 c	1295 a	650 abcd
Cabernet Sauvignon	101-14 Mgt	720 a	740 c	935 abcdef	590 abcdef
Cabernet Sauvignon	USVIT 8/7	665 a	745 c	910 abcdef	565 bcdef
Pinotage	Richter 110	770 a	825 bc	1080 abcdef	540 def
Pinotage	Ramsey	765 a	830 bc	1035 abcdef	665 abc
Pinotage	101-14 Mgt	720 a	845 bc	1125 abcde	490 f
Pinotage	USVIT 8/7	705 a	880 bc	1230 abc	595 abcdef
Merlot	Richter 110	680 a	905 abc	1035 abcdef	665 abc
Merlot	Ramsey	775 a	925 abc	895 abcdef	565 bcdef
Merlot	101-14 Mgt	660 a	940 abc	1020 abcdef	625 abcde
Merlot	USVIT 8/7	665 a	995 abc	865 bcdef	635 abcd

¹. Values designated by the same letter within each column do not differ significantly ($p \leq 0.05$).

Table 8B. Variation in midday leaf water potential (Ψ_L) of different scion/rootstock combinations measured under similar soil water availability and climatic conditions during the 2020/21 season in Stellenbosch. Dashed lines before a specific date indicate that an irrigation application was applied on the preceding day.

Scion	Rootstock	18/03/21	20/03/21	07/04/21	10/04/21
Ψ_L (-kPa)					
Shiraz	Own Rooted	1160 abcde ⁽¹⁾	635 ab	1375 a	500 de
Petit Verdot	Own Rooted	1150 abcde	600 ab	1380 a	490 e
Cabernet Sauvignon	Own Rooted	1420 a	695 ab	1390 a	600 ab
Pinotage	Own Rooted	1145 abcde	695 ab	1280 ab	495 de
Merlot	Own Rooted	1025 de	600 ab	1285 ab	530 abcde
Trained	Richter 110	1290 abcde	690 ab	1340 ab	610 a
Trained	Ramsey	1205 abcde	685 ab	1035 abc	550 abcde
Trained	101-14 Mgt	1180 abcde	595 ab	1055 abc	555 abcde
Trained	USVIT 8/7	990 e	780 ab	1070 abc	510 cde
Shiraz	Richter 110	1060 bcde	570 b	1070 abc	560 abcde
Shiraz	Ramsey	1210 abcde	705 ab	1070 abc	525 bcde
Shiraz	101-14 Mgt	1355 abcd	560 b	1080 abc	605 ab
Shiraz	USVIT 8/7	1265 abcde	590 ab	1120 abc	525 bcde
Petit Verdot	Richter 110	1085 abcde	730 ab	1120 abc	510 cde
Petit Verdot	Ramsey	1135 abcde	755 ab	1125 abc	535 abcde
Petit Verdot	101-14 Mgt	1050 cde	585 ab	1140 abc	565 abcde
Petit Verdot	USVIT 8/7	1255 abcde	705 ab	1145 abc	575 abcd
Cabernet Sauvignon	Richter 110	1280 abcde	645 ab	1165 abc	505 de
Cabernet Sauvignon	Ramsey	1245 abcde	770 ab	1165 abc	590 abc
Cabernet Sauvignon	101-14 Mgt	1360 abcd	635 ab	1165 abc	560 abcde
Cabernet Sauvignon	USVIT 8/7	1325 abcde	605 ab	1180 abc	525 bcde
Pinotage	Richter 110	1365 abc	705 ab	1185 abc	560 abcde
Pinotage	Ramsey	1235 abcde	655 ab	1190 abc	540 abcde
Pinotage	101-14 Mgt	1155 abcde	665 ab	1195 abc	600 ab
Pinotage	USVIT 8/7	1270 abcde	695 ab	1245 abc	575 abcd
Merlot	Richter 110	1045 cde	740 ab	1265 abc	495 de
Merlot	Ramsey	1390 ab	675 ab	1010 bc	545 abcde
Merlot	101-14 Mgt	1330 abcd	700 ab	910 c	535 abcde
Merlot	USVIT 8/7	1310 abcde	680 ab	910 c	545 abcde

¹. Values designated by the same letter within each column do not differ significantly ($p \leq 0.05$).

Table 8C. Variation in midday leaf water potential (Ψ_L) of different scion/rootstock combinations measured under similar soil water availability and climatic conditions during the 2020/21 season in Stellenbosch. Dashed lines before a specific date indicate that an irrigation application was applied on the preceding day.

Scion	Rootstock	21/04/21	22/04/21	30/04/21	03/05/21
Ψ_L (-kPa)					
Shiraz	Own Rooted	1215 abcde ⁽¹⁾	415 bcd	805 abc	840 abc
Petit Verdot	Own Rooted	1245 abcde	560 a	630 abcdef	980 abc
Cabernet Sauvignon	Own Rooted	1300 abcd	465 abcd	860 a	630 bc
Pinotage	Own Rooted	1135 abcde	425 bcd	500 bcdef	750 abc
Merlot	Own Rooted	1050 cde	525 ab	815 ab	1090 ab
Trained	Richter 110	1160 abcde	510 ab	690 abcdef	1215 a
Trained	Ramsey	1125 abcde	445 abcd	725 abcdef	1180 a
Trained	101-14 Mgt	1265 abcd	560 a	740 abcdef	765 abc
Trained	USVIT 8/7	1190 abcde	530 ab	425 f	835 abc
Shiraz	Richter 110	1105 abcde	450 abcd	485 bcdef	790 abc
Shiraz	Ramsey	1215 abcde	510 ab	730 abcdef	1175 a
Shiraz	101-14 Mgt	1405 ab	515 ab	790 abcd	765 abc
Shiraz	USVIT 8/7	1120 abcde	385 cd	600 abcdef	1090 ab
Petit Verdot	Richter 110	1315 abc	460 abcd	595 abcdef	1095 ab
Petit Verdot	Ramsey	1355 abc	505 abc	505 bcdef	595 c
Petit Verdot	101-14 Mgt	1365 abc	430 bcd	460 cdef	1125 ab
Petit Verdot	USVIT 8/7	905 e	375 d	430 ef	1000 abc
Cabernet Sauvignon	Richter 110	1070 bcde	505 abc	655 abcdef	1055 ab
Cabernet Sauvignon	Ramsey	1175 abcde	510 ab	640 abcdef	995 abc
Cabernet Sauvignon	101-14 Mgt	1100 abcde	435 bcd	575 abcdef	815 abc
Cabernet Sauvignon	USVIT 8/7	960 de	425 bcd	780 abcde	805 abc
Pinotage	Richter 110	1195 abcde	485 abcd	450 def	715 abc
Pinotage	Ramsey	1420 a	455 abcd	490 bcdef	905 abc
Pinotage	101-14 Mgt	1335 abc	480 abcd	620 abcdef	760 abc
Pinotage	USVIT 8/7	1100 abcde	530 ab	575 abcdef	950 abc
Merlot	Richter 110	970 de	450 abcd	695 abcdef	670 abc
Merlot	Ramsey	1230 abcde	450 abcd	480 bcdef	755 abc
Merlot	101-14 Mgt	1230 abcde	500 abc	700 abcdef	1010 abc
Merlot	USVIT 8/7	1160 abcde	485 abcd	495 bcdef	820 abc

¹. Values designated by the same letter within each column do not differ significantly ($p \leq 0.05$).

7.6 Extra outputs

At the beginning of 2017, a student who studied BSc Agric (Viticulture and Oenology), Mr J.N. Opperman, applied to do his MSc Agric on the pot experiment. With subsequent obstacles and problems that occurred in the establishment of the pot trial, it was decided to let him collect a wide range of different textured soils, determine their physical properties and draft the soil water retention curves by means of the pressure membrane method as described by Klute (1986).

Due to the time involved in determining soil water holding capacities using the pressure membrane technique, most laboratories either estimate it using generic values or models, or it could result in a very high cost. Fifty soil samples over a wide range of texture classes were collected, and their particle size distribution (eight fractions), organic matter and bulk densities were determined (Fig. 33). Soils were exposed to 2 kPa, 5 kPa, 8 kPa, 10 kPa, 15 kPa, 20 kPa, 25 kPa, 30 kPa, 60 kPa, 100 kPa, 300 kPa, 600 kPa, 900 kPa and 1 500 kPa pressures in triplicate within pressure pots and their volumetric water contents at each pressure calculated. Some of the more sandy-textured soils were also packed at 1.4, 1.5 and 1.6 g.cm⁻³ bulk densities to create more variation. The idea was to create a model, using multiple regression at different pressures, to determine what physical properties could be used to predict the volumetric water content at that specific soil water matric potential. Some soils, mostly those containing high clay contents, tended to crack and ceased to lose water at higher pressures, i.e., 30 kPa and higher, due to preferential flow of pressurised air through the cracks, instead of through the soil volume (Fig. 34). These soils were deemed as outliers and were not used. Eventually, 92 samples were deemed usable. Only physical properties with a p-value < 0.05 were accepted to make a statistical difference (Table 9).

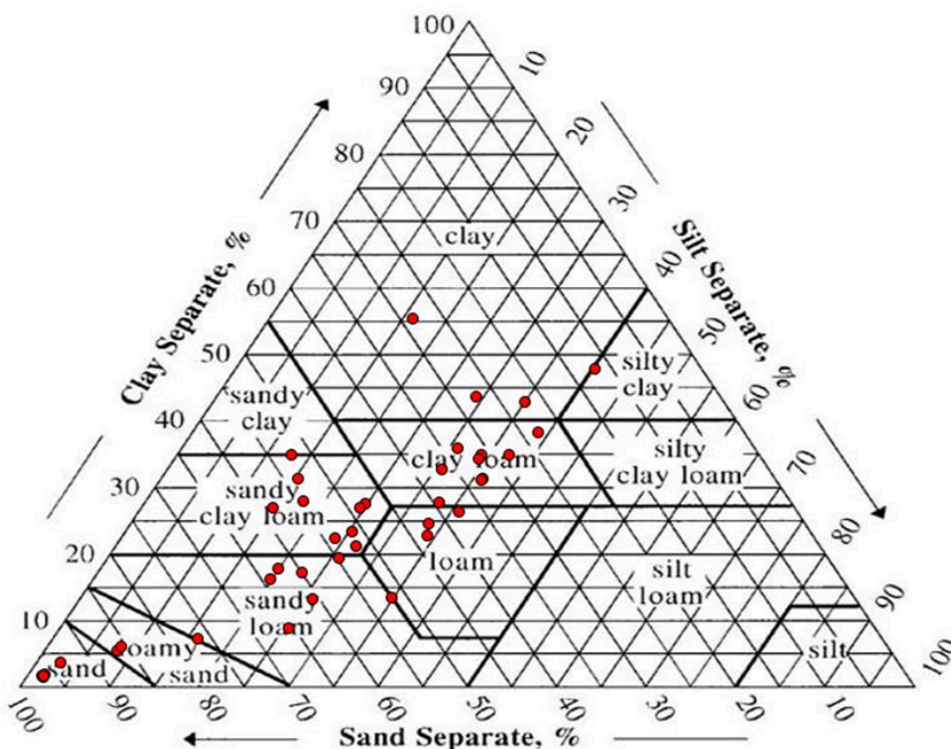


Figure 33. Variation of soil texture classes sampled for the use of pedotransfer function determinations of soils in the wine growing regions of the Western Cape.



Figure 34. Examples of (A) soils with high clay contents on the pressure plate exhibiting cracks near the edges of sample rings and (B) a close-up view of a crack resulting in a preferential air flow path along the sides of the sample ring, and not through the soil sample.

Table 9. The initial multiple regressions per pressure value and model found the slopes of contributing factors of different soil physical properties.

	Pressure Constant	Bulk density	Organic matter	Clay	Fine silt	Coarse silt	Very fine sand	Fine sand	Medium sand	Coarse sand	R ²	Standard error
	kPa	g/cm ³					%					
2	-0.150	0.130	1.290	0.295	0.509	0.259	0.302	0.227	0.207	0.083	0.944	0.022
5	-0.191	0.148	1.745	0.217	0.585	0.230	0.308	0.241	0.095	0.035	0.962	0.022
8	-0.166	0.131	1.507	0.196	0.678	0.198	0.283	0.192	0.069	-	0.958	0.020
10	-0.164	0.127	1.533	0.196	0.665	0.198	0.235	0.159	0.069	-	0.941	0.016
15	-0.150	0.113	1.222	0.178	0.688	0.181	0.214	0.135	0.062	-	0.924	0.023
20	-0.144	0.105	1.065	0.156	0.730	0.139	0.192	0.112	0.055	-	0.876	0.027
25	-0.200	0.140	1.290	0.138	0.733	0.141	0.175	0.069	0.039	-	0.870	0.026
30	-0.240	0.173	1.476	0.141	0.712	0.163	0.147	-	-	-	0.853	0.027
60	-0.196	0.139	1.369	0.137	0.714	0.146	0.104				0.850	0.025
100	-0.190	0.132	1.431	0.135	0.694	0.123	0.080	-	-	-	0.855	0.024
300	-0.163	0.111	1.123	0.155	0.687	0.104	0.058	-	-	-	0.891	0.019
600	-0.140	0.096	0.778	0.174	0.642	0.090	0.044	-	-	-	0.906	0.016
900	-0.137	0.093	0.748	0.175	0.609	0.079	0.028	-	-	-	0.909	0.015
1 500	-0.101	0.070	-	0.214	0.594	0.068	0.027	-	-	-	0.894	0.015

This model, however, needs to be further developed and refined. A more conclusive model would be useful for the use of irrigation scheduling for producers and in the use of the VinET® model.

8. CONCLUSIONS AND RECOMMENDATIONS

The project had more than its share of misfortune since the start of the experiment. Originally, the project would have been set up and conducted at the ARC Nietvoorbij experimental farm. When the experiment had to move from Nietvoorbij, because of the inadequate number of pots available, Welgevallen and pots (210 L PVC drums) had been ordered in the middle of the drought. No supplier could provide drums on time, resulting in a delay in the start of the experiment, and plants were alive by daily watering while in their cartilage holders in semi-shade until pots were delivered and the irrigation system could be installed. A lot of effort from the project leader and funding from Winetech have gone into the establishment of this project. The pot experiment was specifically selected to be in the Shiraz vineyard for weed, pest, and fungal management to be done with the rest of the vineyard. The removal of the Shiraz grapevines from the vineyard had put extra responsibilities on the project leader. The project leader continuously implemented mitigation responses immediately to minimise the risk of problems recurring. Unfortunately, with all the challenges experienced, the effort that went into planning, mitigating risks as well as possible, and establishing the pot experiment, by accommodating collaborating colleagues from a different department, the project leader was still blamed by said colleagues for failures due to actions by this department's student and his supervisors and problems beyond his control. This forced the project leader to hand over the experimental site to the said department as the collaborative relationship became distrustful. Once the Water Flagship 4 project is concluded, the project leader would like to reapply to finish and investigate the objectives he has set out since the start of this project.

The developed Arduino Logging system will contribute to making irrigation research more affordable in the near future. The soil water retention model developed during the project still needs to be validated and developed further to add value to producers by being able to determine soil water holding capacities by doing soil texture analysis at commercial laboratories.

9. PLANNED OUTPUTS

a) TECHNOLOGY DEVELOPMENT, PRODUCTS AND PATENTS

Even though Arduino microcontrollers are open hard- and software and no intellectual property rights can be obtained from the development of a remote logging system, the implementation of it into the industry and research community may have large benefits. This is due to the low cost involved in setting up a continuous logging soil water content system, compared to that of commercially available systems. Thus, it will be possible to monitor more measuring points in future projects and cut soil water monitoring equipment costs considerably.

b) SUGGESTIONS FOR TECHNOLOGY TRANSFER

c) HUMAN RESOURCES DEVELOPMENT / TRAINING (STUDENTS)

{Honours}{Masters}{PhD}{Postdocs}

Student Name and Surname	Student Nationality	Degree (e.g., Hons, MSc)	Level of studies in the final year of the project	Total Bursary Cost for Industry for the entire project
Honours				

Masters				
K.J. Hoogendijk	South African	MSc Agric	Finished	R 156 902
J.N. Opperman	South African	MSc Agric	Did not finish	R 165 000
PhD				
Postdocs				

d) LIKELY PUBLICATIONS (POPULAR, PRESS RELEASES, SCIENTIFIC)

Publications will most probably be written after the completion of the Water Flagship 4 project, of which this project turned out to be the establishment and testing phase.

e) PRESENTATIONS/PAPERS THAT COULD BE DELIVERED

None

10. PROJECT OUTCOME AND IMPACT

New Knowledge	Benefits Chain	Supply	Direct Application	Grower	Direct Packhouse/Winery/Cellar Application	Other
X						

Other is:

The Value of the project to the industry

11. PERSONS PARTICIPATING IN THE PROJECT:

INITIALS AND SURNAME	HIGHEST QUALIFICATION	RACE (B, C, I, W)	GENDER (M, F, X)	INSTITUTE DEPARTMENT	POSITION	TOTAL COST TO PROJECT
RESEARCH PERSONNEL						R 0
SUPPORT PERSONNEL						R 0

POSITION: Co = Co-worker (other researcher at your institution)

Coll = Collaborator (participating researcher that does not receive funding for this project from industry)
 PF = Post-doctoral fellow
 PL = Project leader
 RA = Research assistant
 TA = Technical assistant/ technician

12. TOTAL COST OF PROJECT

TOTAL ANNUAL COSTS (ALL YEARS)	CFPA	RAISIN S SA	HORTGRO	SATI	SA WINE	ARC	OTHER	TOTAL
2019 before and	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0
2020	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0
2021	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0
2022	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0
2023	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0
2024	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0
TOTAL	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0