SATI	CFPA	SAAPPA/SASPA	DFTS	Winetech
tarryn@satgi.co.za Tel: 021 863-0366	inmaak@mweb.co.za Tel: 021 872-1501	theresa@hortgro.co.za Tel: 021 882-8470	dappies@dtd.co.za Tel: 021 870 2900	andraga@winetech.co.za Tel: 021 276 0499
				x

FINAL REPORT
(2018)

1. PROGRAMME AND PROJECT LEADER INFORMATION

	Research Organisation Programme leader	ARC Research Team Manager	Project leader
Title, initials, surname			Albert Strever
Present position			Lecturer
Organisation, department			Stellenbosch University Private Bag X1 7602 MATIELAND
Tel. / Cell no.			072 6014925
E-mail			aestr@sun.ac.za

2. PROJECT INFORMATION

1 *Research Organisation Project number*	AS DVO5
2 *Project title*	Optimising productivity in vineyards and potential effects on grape and wine composition for a specific production goal
3 *Short title*	Optimising productivity in vineyards

Fruit kind(s)	Grapes		
Start date (mm/yyyy)	01/01/2012	**End date** (mm/yyyy)	31/12/2016

Key words	Training systems, optimising productivity

Approved by Research Organisation Programme leader (tick box) ☐

3. EXECUTIVE SUMMARY

Objectives & Rationale

The main objective of this project is to study optimisation of vineyard yield and product quality through modified grapevine balance and microclimate by studying some underlying factors that need to be taken into account when adapting training/trellising and/or pruning systems under different vigour conditions.

In the current economic context, wine grape producers are under great pressure to maximise yield while maintaining a certain quality aimed at a specific production goal and price point. There may be many causes for vineyards that function sub-optimally; one of the aspects that add to this problem is the perception that only low yielding vineyards are able to produce high quality grapes, which in many cases also lead to excessive crop control practices. It is not often debated how larger or more vigorous grapevines that are in physiological balance can be managed to produce higher yields of high quality suitable for ultra-premium/icon wines.

In this study four different trellis/training systems (double split-cordon gable, vertical shoot positioning, sprawling and a ballerina or double Smart-Dyson system) were established in a trial layout. The trial was located in a *Vitis vinifera* cv. Shiraz vineyard in Stellenbosch, and some trellis/training modifications were also additionally studied in an industry case study. Basically productivity and grape- and wine composition were altered as a result of differing canopy microclimate, grapevine balance regimes and yield component compensation reactions. There were two different sprawling training systems (double and standard bud load) which were combined in the second season and subjected to a lighter pruning – namely “simulated mechanical pruning” (box pruning by hand). Pruning and harvest data were collected over two growth seasons from each grapevine in the plot. The large number of single-vine replicates made it possible to determine main yield components in a large part of the study. Shoot growth, shoot characteristics (leaf area, lateral number, internode length), canopy microclimate, physiological measurements, water status and ripening evolution were recorded for some of the treatments to establish trends between grapevine balance and associated compensation reactions. Qualitative descriptive analysis was performed on the wines produced from treatments for selected seasons.

Key Results

In general, the industry case studies highlighted the difficulties related to training system conversion in a practical setting, as well as observed mismatching between the applied system and the existing vigour and yield in the converted vineyards. Generally (as in the field trial) the converted vineyards were not irrigated or fertilised differently – and our results showed how this negatively impacted over seasons.

Results from canopy microclimate as well as soil and plant water status measurements accentuated external effects on the grapevine’s adaptation to microclimate. Bud load increase led to the obvious differences in shoot and cane numbers, as well as differential effects on yield components (bunch numbers, fertility, budburst percentages) which also impacted on grapevine water status as well as fruit development and ripening. It also seemed that seasonal climate, soil and plant water status effects and microclimate can interact to either accentuate or diminish effects of trellis/training system adaptation.

The treatments (considering that all were performed in an existing vineyard) needed time for adaptation in order to find a “new balance”, which was evident in especially the first season of both trials. Increased bud load led to increased shoot numbers and yield, but with decreased bunch mass and grapevine vigour, in terms of total cane- and mean mass per cane and shoot length. The gable trellis system produced the highest yield between treatments in both seasons, but due to trellis conversion completion in the 2012/13 season, low vigour was present. For this reason, imbalanced grapevine conditions occurred in terms of high yield to cane mass ratios (Y/CM) and low leaf area to yield ratios (LA/Y) and consequently delayed ripening. Nevertheless, the gable trellis system seemed to reach maximum productivity, as the yield between seasons remained relatively similar. The main yield component responsible for yield difference in the 2012/13 season was the number of bunches produced per shoot (fertility), while increased budburst percentage and bunch mass in the 2013/14 season affected yield most. More shoots led to decreased fertility and increased bunch mass in this treatment, and improved growth and high yields during the 2013/14 season resulted in more desirable grapevine balance, thereby not affecting ripening negatively.

The two sprawling systems only differed according to shoot number, with the double sprawling system (double the amount of buds) producing twice as many shoots and consequently higher yields. Simulated mechanical pruning, in the 2013/14 season decreased grapevine vigour as expected but increased yield considerably as a result of increased fertility. However, imbalanced Y/CM ratios occurred, delayed ripening, and a highly exposed canopy bunch zone which increased the process of leaf degradation and the occurrence of water deficits. The VSP treatment produced highly vigorous grapevines together with low yields in both seasons and as a result increased canopy density and decreased Y/CM ratios.

The SD treatments had higher yield:pruning mass ratios, but not initially due to higher yields, but more due to reduced vigour. This reduced vigour did not seem to favour ripening, as it seemed to coincide to high water demands from the more exposed canopy. The SD and sprawl treatments showed large increase in yield, mostly due to bud load and bunch number increase, but from the 2013/14 season's results this does not seem to be sustainable. Despite higher vigour of other treatments in this season, the vigour of the SD and especially the sprawling treatments did not increase – suggesting issues with reserve status early season.

Grapevine balance, bud load and canopy density were most associated with sensory wine attributes. The intensity of fruity wine attributes increased and vegetative wine attributes decreased as bud load and Y/CM ratios increased and canopy density decreased. The sprawling treatment displayed the highest Y/CM ratio and bud load as well as the least dense canopy. Therefore the sprawling training system produced wines containing the highest fruity attributes which is generally desirable in new world Shiraz. The dense canopy as a result of vigorous growth, low Y/CM and bud load of the VSP treatment produced wines dominated by vegetal attributes. The gable treatment, which displayed Y/CM ratios, bud load and canopy densities with general values between the VSP and sprawling treatments, produced wines with vegetal and fruity attributes, with the latter probably being more dominant.
Wine sensory results did not show large differences for the SD treatments, and it was not evident that the higher yield caused any negative effects.

Conclusion/Discussion

Changing trellising-, training- and pruning systems clearly led to the production of different wine styles. Grapevine balance, canopy density and pruning severity should be taken into consideration when attempting to produce wines intended for specific production goals. Therefore, increased yield as a result of alternative pruning-, training- and trellising systems does not necessarily affect wine composition negatively, if not more beneficially, and should be considered as a solution regarding production profitability.
It is clear that trellis/training system conversion has to be done in conjunction with careful planning and execution of short term practices such as irrigation and fertiliser application. In these trials, we did not adapt these two aspects separately in the modified systems, with the goal to show its impact on the grapevine's long-term sustainability. We showed so far that bud load can be significantly increased, even in lower vigour grapevines, without clear negative effects on grape composition or wine attributes, but rather changes in wine style for Shiraz.

Main summarised conclusions:

- Changing trellising-, training- and pruning systems clearly led to the production of different wine styles.

- Grapevine balance, canopy density and pruning severity should be taken into consideration when attempting to produce wines intended for specific production goals

- Increased yield as a result of alternative pruning-, training- and trellising systems does not necessarily affect wine composition negatively, if not more beneficially, and should be considered as a solution regarding production profitability.

- Trellis/training system conversion has to be done in conjunction with careful planning and execution of short term practices such as irrigation and fertiliser application

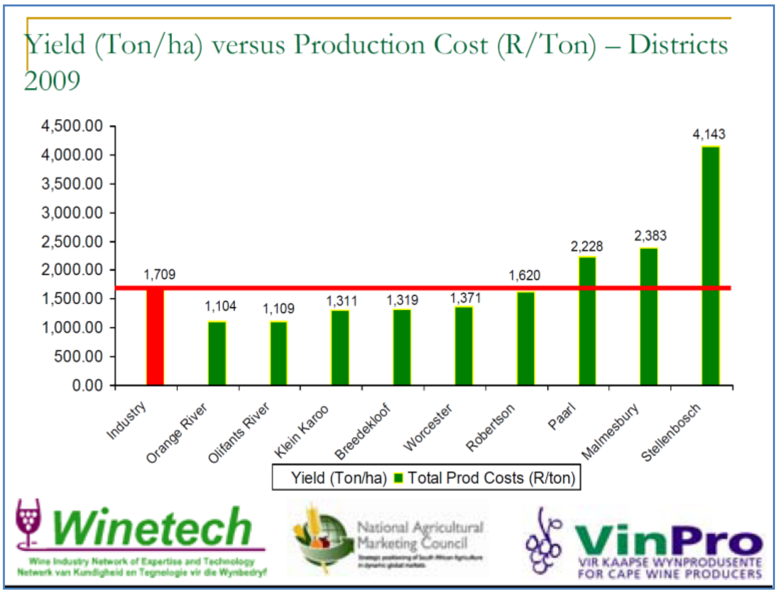
- Bud load can be significantly increased, even in lower vigour grapevines, without clear negative effects on grape composition or wine attributes, but rather changes in wine style for Shiraz.

4. PROBLEM IDENTIFICATION AND OBJECTIVES

After many years of research results suggesting the contrary, there is still a perception that “quality” grapes and wine can only be produced from low-yielding vineyards. However, many viticulturists and researchers alike today believe that balanced grapevines will produce fruit of high quality. With that in mind, balance may surely also exist on larger grapevines, with similar outcomes in terms of grape composition? Furthermore it is widely recognised that wine quality is a subjective term, and that it has more to do with the product’s success than its price on the market. Provided that basic viticultural principles are respected, it is believed that local producers should in many ways venture out of their “comfort zone” to evaluate viticultural practices that could lower input costs, improve product marketability or maximise productivity.

The current economic climate and rising production costs are putting renewed pressure on grape producers. As shown in

Figure 1, this is especially a problem in Stellenbosch, since the majority of vineyards do not function optimally when viewed from an economic sustainability viewpoint, also considering an average grape price per tonne of less than R 4,500 in 2010.



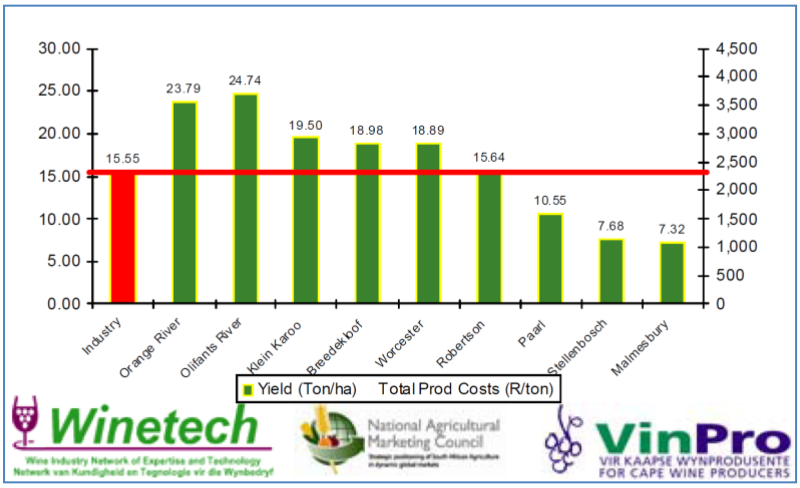


Figure 1 Yield versus production costs for different grape production areas (2009) (courtesy G van Wyk, Vinpro as presented by Bosman (2010).

Sub-optimal grapevine productivity can have many causes, which is to be expected with several long- and short term viticultural practices interacting with environmental factors to realise or suppress the genetic potential of the rootstock-scion combination. One reality could also be a perception created, possibly largely in wine marketing language, that lower yield is the reason for exceptional wine quality/properties. In many cases fruit removal is performed to achieve a “desired” yield without any scientific justification of the perceived imbalance of the grapevine.

Considering the relatively limited lifespan of our vineyards and high capital inputs for establishment, it is proposed that today there are many reasons for realising a maximum production per unit soil without jeopardising grape composition.

Rising production costs and the current economic climate places extreme pressure on grape producers to increase grape yields without compromising product quality. Current production systems (training or pruning systems) are not always dynamically adapted towards this goal, and although these systems are already in wide spread use in industry, some scientific principles underlying their execution are not yet well understood.

The purpose of the study was to determine the effect of trellis conversion in a Shiraz vineyard on vegetative and reproductive growth parameters, grapevine microclimate, grape composition and sensory wine attributes.

The significance of this study for the South African wine industry in particular, is to introduce various growing conditions for grapes and to show how the grapevine can be manipulated to obtain balance and optimal productivity by fully ripened grapes thus ensuring optimal vineyard performance and sustainability. This will help producers to choose the best suited trellis system for optimum sunlight utilisation to produce quality and quantity grapes by improving grapevine capacity through enlarged effective leaf surface.

Ultimate aim:

Optimising vineyard yield and product quality through modified grapevine balance and microclimate and studying some underlying factors that need to be taken into account when adapting training/trellising and/or pruning systems under differing vigour conditions.

Taking these aspects into account, this project’s objectives can be summarised as:

1. Performing a case study in industry to evaluate the effects of trellis conversion on the sustainability of a vineyard.
2. Assessing variability in grapevine growth and yield components as a tool to study grapevine balance.
3. Modifying grapevine balance in a field trial and study the effects of the modification.
4. Analysing grape and wine composition from the trial.

5. DETAILED REPORT

a. PERFORMANCE CHART

Milestone	Target Date	Extension Date	Date completed
1. Industry case study - modified training/trellis systems	2012		2014
2. Assessing within-vineyard differences in grapevine balance 2.1 Vigour classification and pruning mass determination of trial sites 2.2 Determining key yield components' differences between grapevines	 2012 2014		 2012 2014
3. Field trial (Shiraz, Stellenbosch) 3.1 Gable and sprawling trellis conversion in high vigour area, control is unmodified vines in same region 3.2 Imposing treatments for balance modification, Ballerina (Double Smart-Dyson) on low and high vigour classes as well as reduced canopy 3.3 Evaluation of "guyot SD" (only in high Ravaz index – control is normal SD on these vines) 3.4 Growth, microclimate and yield component monitoring for treatments 3.5 Ripening monitoring in treatments 3.6 Root studies for selected grapevines	 2014 2014 2012 2014 2014 2015/16		 2014 2014 2012 2014 2014 Not achieved
4. Analysis of grapes and wines from field trial and selected industry sites 4.1 Microvinification for field and industry sites 4.2 Wine chemical and sensory analysis	2012-2014		2014
5. Economic impact study	End of study		Partly achieved

b) WORKPLAN (MATERIALS AND METHODS)

Please note: Due to the extensive nature of the materials and methods and results in the three trials (Table 1), only the core elements will be presented in the main body of the report with reference to Addendum A for the details.

Table 1 Trial description for the study

Trial	Description
1	Industry case studies
2	Shiraz training systems (Gable, Sprawl, VSP, Indicator)
3	Shiraz training systems (Ballerina, VSP, Indicator)

Plot layouts of the different field studies are presented in Addendum C.

1 Materials and methods - Industry case studies

Yield and pruning data were collected from selected industry sites where training systems were modified and where modified systems were available within the same block. There were other options where different vineyards on farming units were modified with other blocks being a "control", but due to differing soils and irrigation or other practices this was rather avoided. Table 2 shows the case study vineyards, cultivars and nature of the modifications.

Table 2 Description of codes and details of industry case study sites (all controls are within the same block)

Code	**Control**	**Description**
Spr	SprC	Sprawling canopy, Cabernet Sauvignon
LY	LYC	Adapted Lyre system, Chardonnay
SblSDA (upper shoots)	SblC	Smart-Dyson, Sauvignon blanc
SblSDB (lower shoots)	SblC	

2 Assessing within-vineyard differences in grapevine balance (for trial 2 setup)

The advantage of the weak relation between measured pruning mass per vine (kg) and yield in tonnes per hectare (projected from the per-vine yield in kg) (Figure 2), is that it is possible to find a wide range of potential yields for grapevines with different pruning mass.

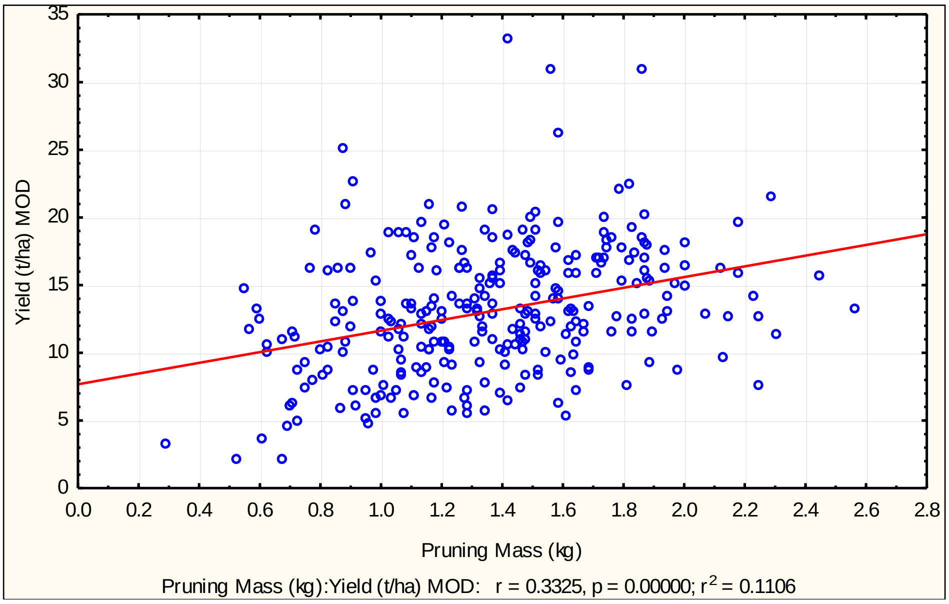


Figure 2 Crop load in single grapevines from a Shiraz vineyard where further work is proposed (2009/10 data).

Refer to Addendum A for the method of vigour segmentation in order to split the SD trial (trial 3) into lower and higher vigour grapevines.

3 Field trials, Shiraz, Stellenbosch

The trials were carried out in a Shiraz/101-14 *Mgt* vineyard situated at the Welgevallen Experiment farm Stellenbosch University, South Africa (33 56'S, 18 52'E, 157 m mean height above sea level) during the 2011/12, 2012/13 and 2013/14 growing seasons. More details on the vineyard are supplied in Table 3.

Table 3 Characteristics of the experiment vineyard located on the Welgevallen Experiment Farm in Stellenbosch.

Descriptor	**Stellenbosch**
Cultivar	Shiraz
Clone	SH9C
Rootstock	101-14 *Mgt* (*Vitis riparia x Vitis rupestris*)
Year established	2000
Row orientation	North-South
Terrain	Flat
Grapevine spacing	2.7 x 1.5 m
Trellis/training system	7-wire hedge VSP trellis system with three sets of moveable canopy wires Double split cordon gable trellis system Sprawling training system
Irrigation system	Pressure compensated drip system

Layouts of the two trials are in detail discussed in Addendum A. Please note that whenever reference is made to the SD system, what is actually meant in the field trial is a "ballerina-type" training system or Double Smart Dyson, as shoots were bent down to both sides and not only to one side as in the conventional Smart Dyson system.

A few vines were also converted to a "Guyot SD system" during pruning in 2012 to test its viability. The intent was not to design a full experiment around this, but to assess how Shiraz will react to a long bearer pruning system and under high vigour if the upward and downward shoot positioning can still be attained with success. The concept is that with these cordons it will be relatively easy to convert to the SD system, as every naturally up- or downward pointing shoot can be positioned into the respective canopies. The Guyot system development was been challenging with Shiraz, and due to high vigour, the ideal Guyot configuration could not be achieved - it will therefore not be included in the final report, as it was not possible to get a stable Guyot SD system by the 2013/14 season.

Growth, microclimate and yield component monitoring for treatments - Modified grapevines were monitored to assess compensation effects by monitoring shoot growth, leaf area development, grapevine water status, bunch and canopy microclimate as well as most of the yield components on selected grapevines. Details of this is presented in Addendum A.

Ripening monitoring in treatments - Berry ripening was monitored for the treatments. Analyses included berry mass and volume, pH, titratable acidity, total soluble solids and soluble solid content ("sugar loading"). The reader is referred to the final report of prof WJ du Toit (WW WdT 12/02) for details on phenolic development of the grapes, as this study was conducted on the same trial vineyard. It was not viable to harvest grapes at three ripeness levels in this trial due to the amount of winemaking required that did not fit into budgetary and logistical constraints.

Root studies for selected grapevines - Due to the allocated student and MSc study not finishing in 2015/15, unfortunately the root studies for the respective training systems could not be performed.

Analysis of grapes and wines from field trial and selected industry sites - Details of these measurements are provided in Addendum A.

Microvinification for field and industry sites - Experimental wines were made from the two main trials, as well as in prof du Toit's part of the study (see project WW WdT 12/02 – "Investigating the leaf to fruit ratio (source-sink) and bunch microclimate (training system x canopy manipulation") for more details. It was unfortunately not possible to make wines from the industry trial sites.

Wine chemical and sensory analysis - Wine chemical (phenolics) and sensory analysis were done for the two trials respectively, but please also refer to the final report of prof du Toit for additional results. His study utilised all the grapes from the high vigour SD treatments, as well as the control VSP and "reduced canopy" VSP treatments.

c) RESULTS AND DISCUSSION

Please note: Due to the extensive nature of the results and discussions in the three trials (Table 1), only some core elements will be presented in the main body of the report with reference to Addendum B for the details.

General notes on seasonal climate/rainfall and plant reaction - Growing degree day accumulation was similar between the 2012/13 and 2013/14 seasons which indicated that temperature differences between the two seasons were not substantial. However, the 2011/12 season was much drier in-season, initially warmer, but then much cooler than the other two seasons. Grapevine growth, in terms of both vigour and bunch mass, improved during the 2013/14 season probably mainly due to high November rainfall and high temperatures, with the exception of the S grapevines where it was also due to the implementation of a different pruning system.

1 Results and discussion - Industry case studies (Trial 1)

Please refer to Figure 3 to Figure 5 for the pruning and yield results for 2012 and 2013 in the respective industry trials.

Sprawling canopy, Cabernet Sauvignon
Probably as a result of intra-block variability, the sprawling control had more bunches per vine than the treatment, with little yield difference in 2012. Bunches were smaller in the control than in the treatment, and apparent fertility slightly higher. Cane mass and Ravaz index was also quite similar. Total pruning mass was lighter in 2013, especially for the sprawling treatment, which also showed lower yields mostly due to very small bunches, despite having similar or slightly more bunches than the control. One comment about the possible small differences in the measured values is that the sprawling system also grew very upright, and were not drastically topped (i.e. at 50 cm) as done in many other sprawling systems. The example of the sprawling Shiraz in the field trial is therefore much more of a drastic treatment than in this case study.

Adapted Lyre system, Chardonnay
The Lyre adaptation showed lower yields compared to the control in both years, mostly caused by much smaller bunches. The lyre treatment also had heavier pruning in 2013, which caused heavier mass per cane, but lower cane mass per vine. This was associated with lower yields in this system.

Smart-Dyson, Sauvignon blanc

The control grapevines in this system was the only ones of the case studies with a significantly higher yield per vine in 2012 (more than 6 kg/vine) due to a very high (over 5:1) Y/PM ratio also brought about by very large bunch masses (over 180g). This was however not sustained in 2013, as bunches were smaller and yield less, even with similar cane mass per vine. The Smart Dyson treatment here did not go hand in hand with much higher cane numbers (only about 7 more in 2012 and the same in 2013. Despite this the yield was even lower on the SD vines in 2012 and similar in 2013 compared to the control, which meant very little advantage with regards to yield. In both years the SD treatments showed much smaller bunches which meant that the additional canes with their extra bunches did not really increase yields. Visibly the SD treatments were also much more stressed than the control vines, probably due to the higher total leaf areas and more exposed canopies and bunches, in combination with similar yields.

The producers really struggled to get downward pointing spurs/canes, considering that the system was not established originally as a SD system. It would in our opinion have been better to perhaps saw off and seal the cordons and re-establish with the purpose of creating this system. This may also have worked better in the Shiraz trial retrospectively, although it would have led to one year of harvest loss, which may be economically less viable.

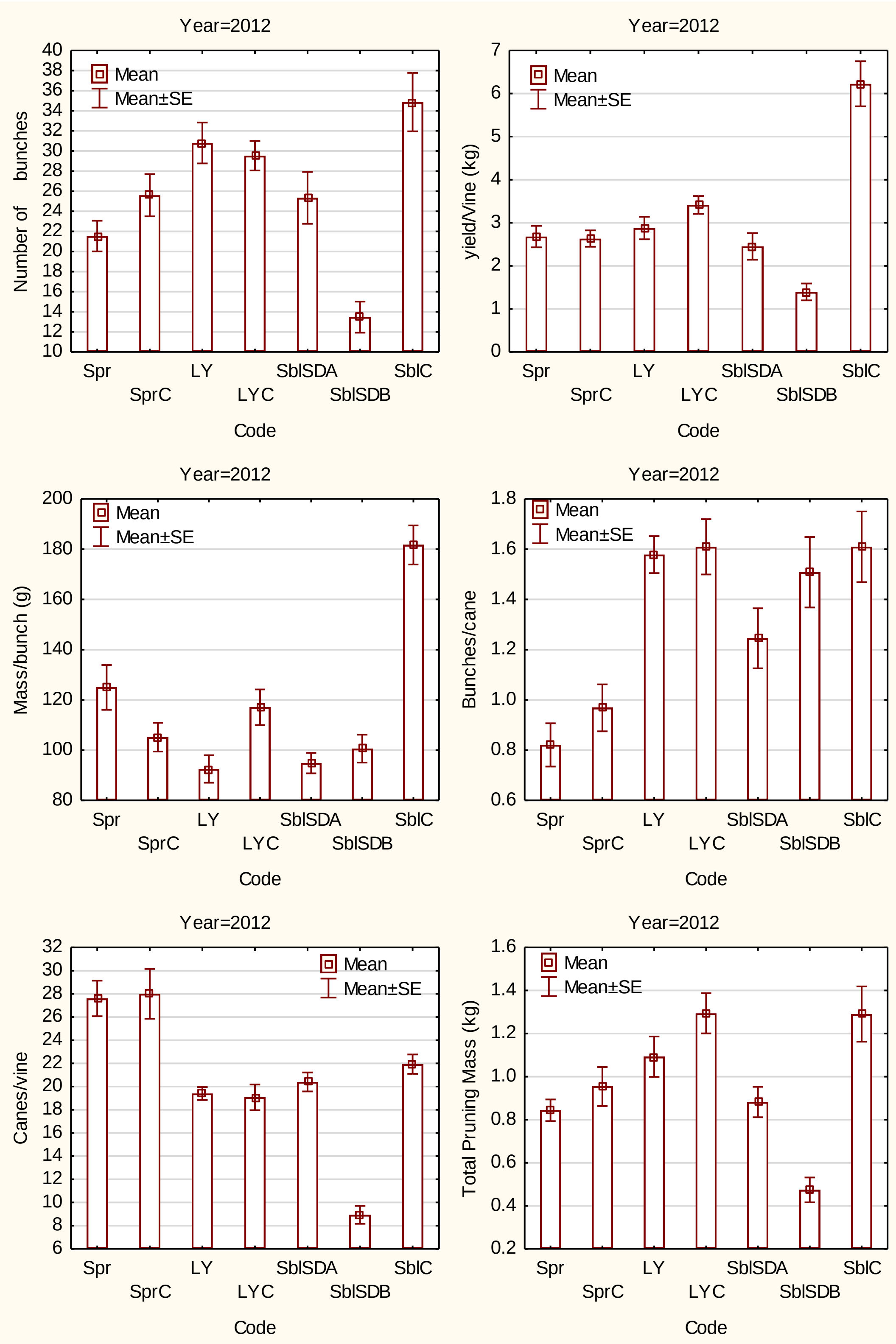


Figure 3 Pruning and yield results for the different industry trials in 2012 and 2013.

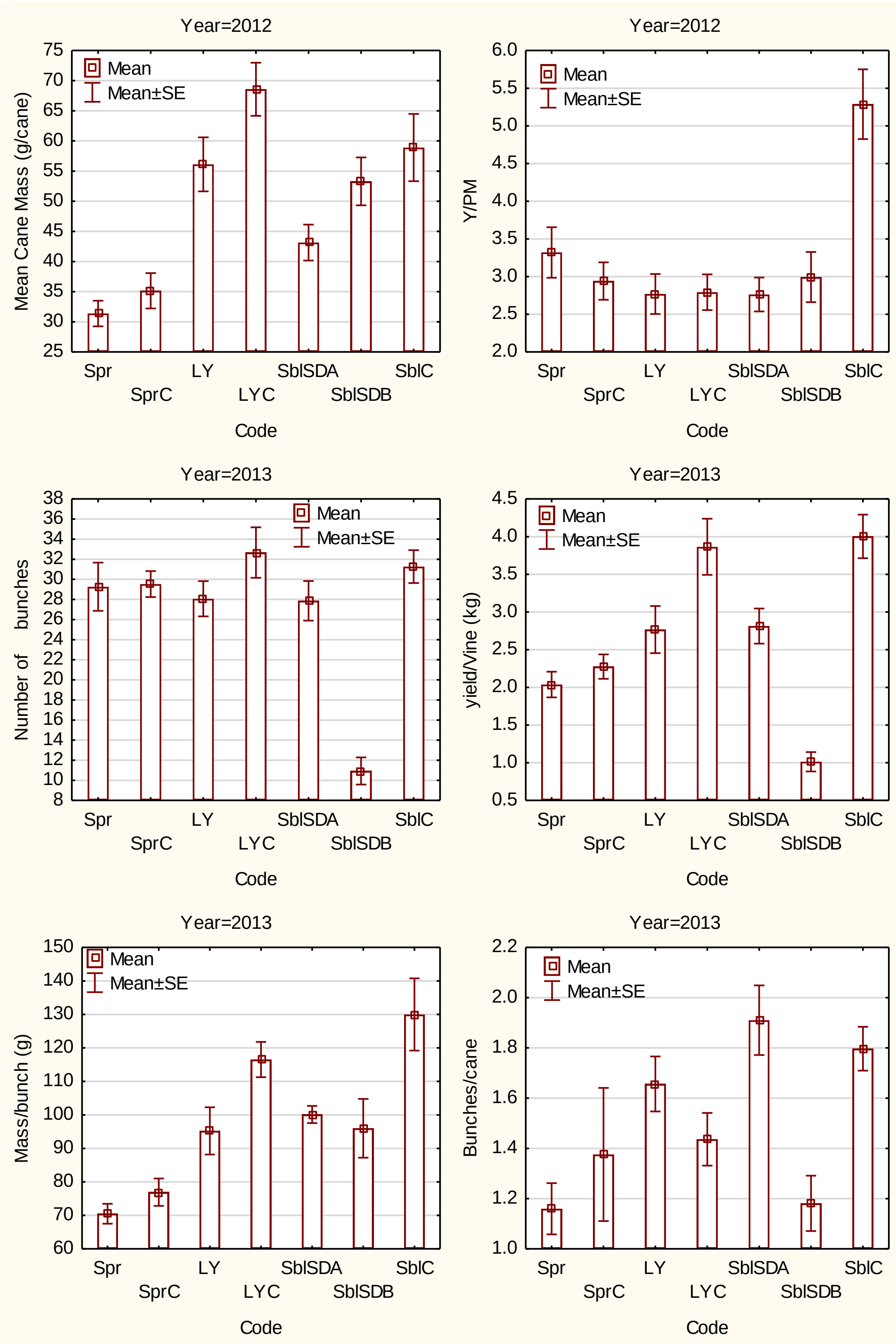


Figure 4 Pruning and yield results for the different industry trials in 2012 and 2013.

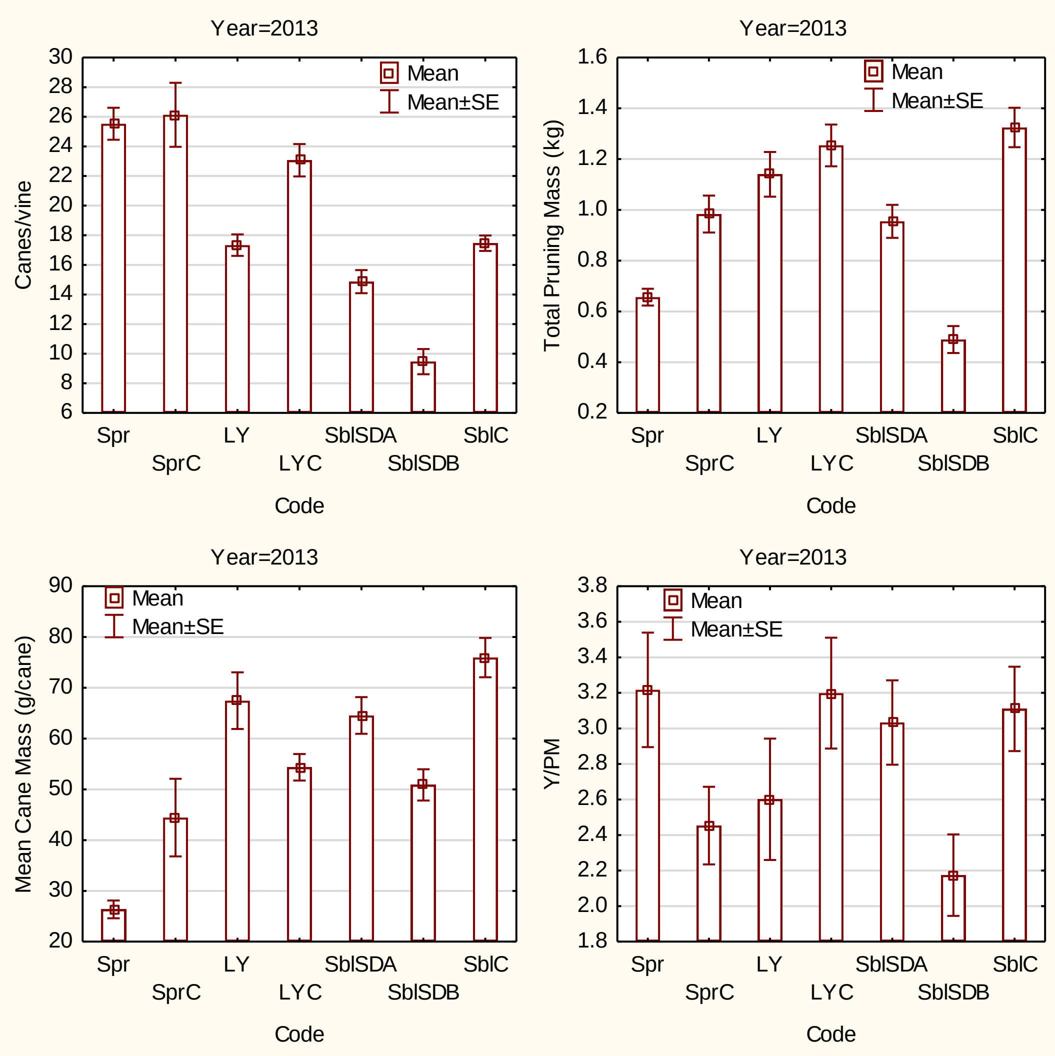


Figure 5 Pruning and yield results for the different industry trials in 2012 and 2013.

2 Shiraz training systems - Gable, Sprawl and indicator vines (Trial 2).

2.1 Bunch temperature and canopy microclimate

Bunch temperatures in the GA and S treatments displayed the greatest differences relative to ambient temperatures during season 2013/14. The GA treatment had the highest mean bunch temperatures throughout the season as well as increased degree days (DD) accumulation which was a function of higher maximum and higher minimum bunch temperatures. Large variability was present with regards to the canopy light microclimate during season 2012/13 for all treatments. Although we do not show the details of the canopy light measurements for brevity, it is summarised here. The highest variability was evident for the SS, DS and GA treatments, which was expected due to higher canopy gap fraction. The highest canopy density and lowest quality and quantity light were present within the bunch zone of the VSP treatment during season 2013/14. The S treatment had the most exposed bunch zone throughout the day. The GA treatment's canopy bunch zone was not as exposed as expected being slightly higher than the VSP treatment. The presence of more bunches may have contributed to this, as well as the horizontal canopy configuration, which may have restricted air flow more than in the canopies from the VSP treatment. This may have caused higher minimum and maximum bunch temperatures, especially in the afternoon in Stellenbosch where the effect of the cooling breeze would not have been so effective (Moffat, 2013). The minimum and maximum bunch temperatures of the S treatment varied the most with very high maximum temperatures and low minimum temperatures. The more exposed bunch zone together with high canopy gaps could have been responsible for this, where the grapes would also have been more exposed to the inversion effect of temperature during early mornings (Moffat, 2013). The GA treatment also had higher vigour in the second season, which could have led to a more dense canopy.

2.2 Soil and plant water status

It appeared that crop load did not affect water status as much as canopy exposure. The canopy of the S treatment was the most exposed between treatments and experienced severe water deficits after véraison. Disequilibrium between soil and plant water was present with reference to the GA treatment in both seasons and grapevines from the S treatment in the 2013/14 season. Nocturnal transpiration may have influenced predawn leaf water potential values and it can be recommended as to measure night-time transpiration in the future. Nevertheless, the larger trellis system of the GA treatment experienced the least stressed conditions.

With regards to grapevine water status, it was speculated that the conversion of the GA system led to compensatory root growth in terms of increased root density and thus improved utilisation of the soil volume (Richards, 1983). With this, the roots possibly acted as stronger sinks for carbohydrates than the growing shoots (Hunter & le Roux, 1992), which was evident with regards to generally higher PAR (lower canopy density), lower budburst percentage and decreased shoot growth. It is possible that the compensatory root growth may also have played a role in the GA treatment's water status. The driest soils accompanied by the least negative predawn leaf water potentials were present here. It may be that root density or root soil colonisation increased, increasing water absorption, but the decreased shoot growth (and lowest leaf area) led to decreased transpiration. It may also be that the stomatal recovery during the night was better due to an improved root system, contributing to the least negative predawn values. It was first thought that vines from the GA treatment displayed isohydric-like behaviour by conserving water in the presence of possible deficits, but the stomatal conductance of the GA treatment was not different than the rest of the treatments and regulated when water was abundant (rain and irrigation) - which signifies possible anisohydric like behaviour. The S treatment's grapevines experienced water deficits to great extents after véraison, possibly due to the highly exposed bunch zone and canopies, to a point where recovery was impaired resulting in early leaf senescence, possibly also contributing to the low pruning- and cane mass and sunburned bunches. The S treatment also displayed disequilibrium between soil and plant water, but in this case consisted of the wettest soils and most negative predawn leaf water potentials. This may be due to increased night-time transpiration; however the S treatment definitely displayed signs of severe stress conditions after véraison.

It will therefore be beneficial for future studies to measure night-time transpiration as some evidence suggests that stomata are not completely closed during the night, allowing nocturnal transpiration and leading to night-time soil-plant water disequilibrium which can influence plant water relations in the day (Kathleen, 2007; Rogiers, 2009). With this information, it could be established whether the grapevines of the GA treatment decrease nocturnal transpiration to greater extents than the grapevines of the S treatment. When high nocturnal transpiration does occur, it will be better to measure stem water potential as an indicator of plant water deficits (Choné *et al*., 2001). Stem water potential measurements indicating whole-plant transpiration and soil/root hydraulic conductivity, together with stomatal conductance measurements should therefore be performed on the same day.

2.3 Shoot growth/leaf area

The most vigorous treatment, in terms of shoot growth; shoot- and lateral length; total leaf area/vine and total cane- and mean cane mass were displayed by the VSP. The vigorous grapevines from the VSP treatment resulted in increased canopy density. Shoot growth of VSP grapevines did not seem to cease.

Interesting results were obtained for the shoot growth of shoots where grapes were removed at flowering (“indicator shoots). It was previously reported that the presence of fruit even seemed to increase shoot growth tempos, which was not expected. The GA trellis had early limited shoot growth, which is already interesting, considering it probably had less soil profile moisture, but not more plant water deficits than the VSP. It would seem however that the presence of fruit could have stimulated growth for the GA vines, while it seems to have inhibited the growth in the VSP treatments (Figure 6).

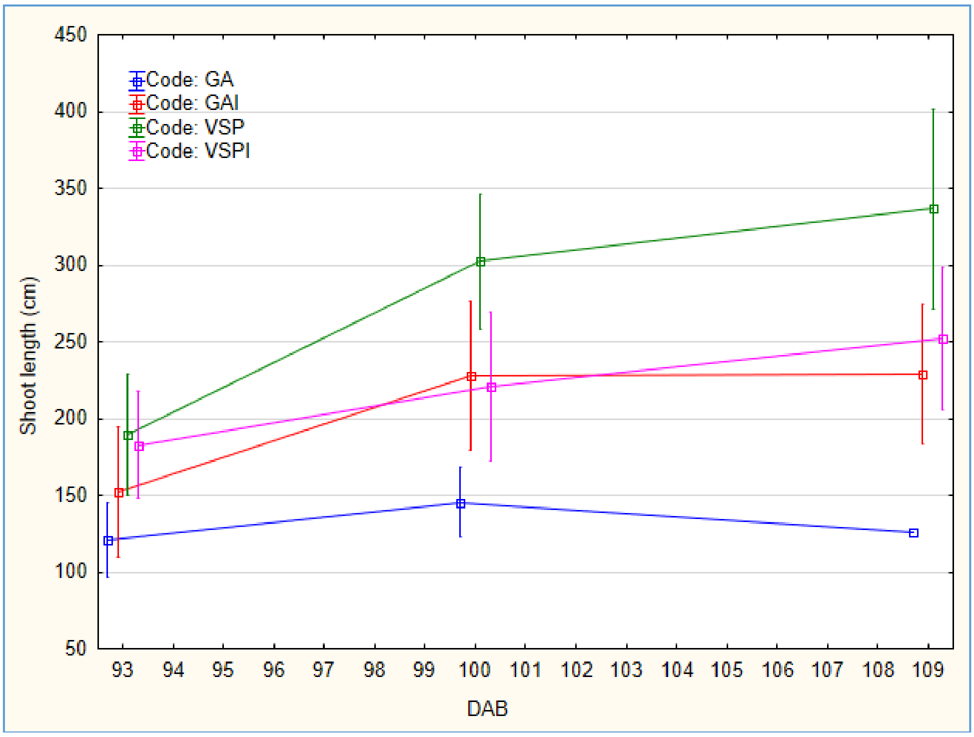


Figure 6 Shoot growth on GA and VSP and their associated “indicator” vines during the 2013/2014 growing season.

2.4 Pruning data

Increased bud load resulted in decreased budburst percentages which were also accompanied by decreased total cane mass as well as mass per cane. However, the amount of shoots was still higher than the systems containing standard bud loads. Grapevine vigour, in terms of cane mass and canopy leaf area, of GA grapevines increased considerably from season 2012/13 to 2013/14. Trellis conversion of the GA treatment may have led to the presence of increased root compensatory growth and improved soil colonisation in season 2012/13. Decreased budburst percentage resulted in decreased shoot numbers and ultimately decreased canopy leaf area and pruning mass. The main difference between the DS and SS treatments was decreased grapevine vigour in terms of shoot length, total cane mass and mean mass per cane. Yet, the number of shoots produced by the DS treatment produced a larger canopy in terms of total leaf area per vine.

2.5 Yield data

Increased bud load resulted in increased yield and bunches per vine. Bunch mass decreased in the treatments pruned to higher bud numbers but the increased number of shoots and number of bunches per shoot (fertility) was responsible for the eventual increased yields. In the case of the GA treatment in the 2012/13 season, the main yield component responsible for the expression of yields 2.5 times greater than the VSP treatment (or equivalent to 22.5 tonnes/hectare), was fertility with the GA treatment producing almost three bunches per shoot resulting in three times more bunches per grapevine than the VSP treatment. The GA treatment seemed to reach maximum productivity where yield stayed relatively constant in the 2013/14 season (up to 24 tonnes per hectare). In the 2013/14 season, increased budding percentage of grapevines from the GA treatment was mainly responsible for in the expression of yield. This was accompanied by the compensation of yield components such as decreased fertility and increased bunch mass. In the case of the VSP treatment, bunch mass was responsible for the expression of yield in both seasons. The DS and SS treatments produced clusters with similar bunch mass; number of berries per bunch and berry size, but the higher yield of the DS treatment was an expression of higher fertility and number of shoots per grapevine (more shoots due to increased bud load).

The lightly pruned S treatment, with the aim to simulate mechanical pruning, reacted according to expectations. A bud load of 2.5 and 5.5 times greater than the GA and VSP treatments, respectively, resulted in the treatment producing the lowest budburst percentage, total cane- and mean cane mass and the smallest bunches (in terms of bunch mass and number of berries per bunch). However, the decreased budding percentage still resulted in the production of high number of shoots per grapevine and this together with the highest fertility among treatments led to increased yield. Yet, yield did not increase to the same extent as displayed by the grapevines from the GA treatment due to the occurrence of smaller bunches.

In 2014 the simulated mechanical pruning caused an extremely high bunch number (about 85 mean) in the S treatment, which also led to the lowest bunch mass for this treatment. It is also suggested that the VSP had higher yields in this year, due to large bunches (210 g mean for Shiraz is very high), probably due to favourable set conditions in this season.
The 2014/15 season results for the GA, sprawl and VSP systems (**Error! Reference source not found.**) showed that the Gable system was able to sustain the productivity from previous years, but not the sprawling system, possibly for the same reasons as stated in the SD case.
Yield benefits of the different systems are summarised in Table 4. This can be translated to potential economic benefits depending on what the grape goals are (grape sales, winemaking).

Table 4 Yield gain/loss of different systems in the field trials.

Season	Treatment vs control	Yield advantage
2011/12	HSD	28%
2012/13		41%
2013/14		42%
2012/13	Gable	58%
2013/14		26%
2012/13	Single sprawl	-20%
2012/13	Double sprawl	34%
2013/14	Sprawl (mech)	22%

2.6 Balance ratios

The treatments producing higher yields in the first year of conversion (the GA and S treatments) increased the Y/CM ratio due to decreased vegetative growth. However, the GA treatment improved vegetative growth in the second season which led to decreased Y/CM ratios. Y/CM values higher than 10, resulted in delayed ripening (in terms of sugar accumulation, TA, berry volume), but did not seem to affect wine composition negatively. The vigorous growth and lower yields of the VSP treatment resulted in very low Y/CM ratios.

The higher fertility however fully compensated for the loss of shoots. Despite high canopy light variability that occurred during the first season, the GA treatment displayed the highest PAR values, which could have resulted in the high fertility in the next season, indicating a favourable light environment in the canopies from the GA treatment. Fertility alone in season 2013/14 was however not the main yield component responsible for high yields, but also an increase in budburst percentage and bunch mass, consequently increasing shoot numbers as well as bunches per vine. The GA treatment seemed to reach optimal productivity with the yield remaining constant throughout seasons, but it compensated through alterations in budburst percentage and fertility. Slightly decreased fertility in season 2013/14 resulted in the production of larger bunches. The number berries remained similar, but larger berries were produced in

season 2013/14. In general the second season brought more favourable conditions for the VSP and GA treatments, with an increase in budburst percentage, shoot growth and berry- and bunch mass. This was most probably due to favourable early-season conditions (high rainfall during November), stimulating early shoot growth as well as berry and bunch development.
The lightly pruned S treatment in season 2013/14 showed decreased budburst percentage as expected, but the number of shoots was still equal to those of the GA treatment. These high shoot numbers together with the highest fertility between treatments resulted in the presence of a large number of bunches. The number of bunches per vine was the main yield component responsible for the retention of relatively high yields, as bunch sizes were reduced.

The theory of increased root compensation of vines from the GA treatment can be supported by grapevine balance ratios. The GA treatment had a very high Y/CM ratio and very low LA/Y ratio during season 2012/13. This indicated that the yield exceeded vegetative growth. Yet, during the following season the Y/CM ratio decreased and LA/Y ratio increased considerably which led to the conclusion that the subterranean growth had enough reserves to support growth in the next season, to increase vegetative growth and sustain ripening. Increased biomass in season 2013/14 was the response of increased shoot numbers due to increased budburst percentage. However, increased shoot lengths were also evident, therefore the presence of sufficient reserves is assumed. The VSP treatment displayed the lowest Y/CM ratio during both seasons and although yield was increased during the second season, vegetative growth also increased which led to constant Y/CM ratios between seasons. The low Y/CM ratios of VSP were due to low yields (half of the yield produced by GA grapevines) and very vigorous growth (high leaf area/vine, pruning- and cane mass and shoot lengths). The vigorous growth of vines from the VSP treatment was evident as shoot growth cessation did not seem to occur, while growth ceased for the GA treatment at 71 DAB. Very dense canopies of the VSP treatment were the result of vigorous growth and this greatly affected the resulting wine quality.

Shorter and thinner shoots produced by the S treatment suggests a clear vigour decrease effect, but it also led to less vegetative growth in relation to the high yield. As a result a very high Y/CM ratio occurred, delaying ripening and possibly affecting future grapevine longevity. Nevertheless, the canopy compensated and produced larger leaves resulting in an improved and seemingly sufficient LA/Y ratio. Decreased shoot growth may also be the result of severe topping during anthesis, which eliminated high amounts of vegetative growth which was not replaced by compensatory lateral growth. As a result, shoot growth cessation could not reliably be determined.

A favourable relationship between reproductive and vegetative growth should show a linear correlation between yield and pruning mass, meaning that as yield increases, pruning mass increases correspondingly (and vice versa). This desirable relationship will therefore ensure that sufficient vegetative growth occur to sustain the increased amounts of fruit and as a result improve grapevine sustainability. A steeper slope (between yield and total cane mass mass) indicates grapevines more in favour of reproductive growth, while a flattened slope favours vegetative growth, with both extremes probably not being in favour of either sustainable yields or sustained growth and reserve allocation. It appeared that the DS and SS treatments in season 2012/13 and the GA treatment in season 2013/14 contained a favourable relationship (Figure 7). The VSP treatment showed the most constant relationship, but with increased vegetative growth in season 2013/14. The GA treatment indicated a more favourable relationship in season 2013/14 due to increased vegetative growth improving grapevine balance. The lightly pruned S treatment clearly displayed an enormous shift between seasons with yield exceeding vegetative growth. Even though this seemed to be unfavourable grapevine balance, the S treatment produced the most desirable wine (more detail later). The question is: will this be sustainable in terms of reserve status, especially if subsequent seasons present more difficult conditions?

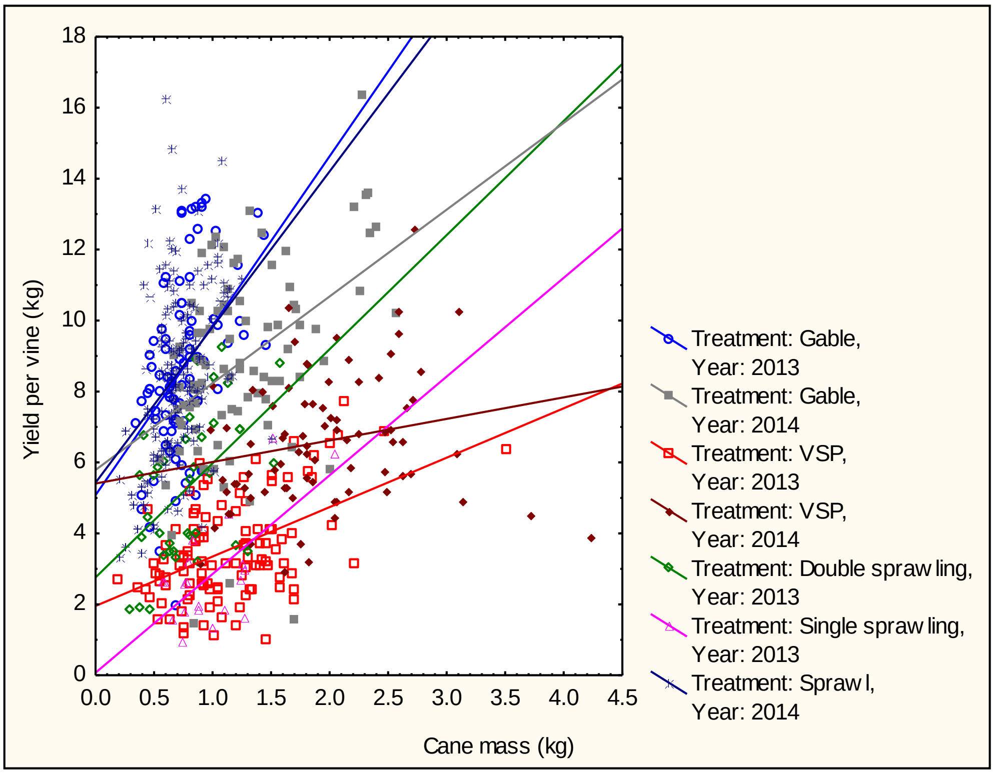


Figure 7 Relationship between yield (kg) and total cane mass (kg) for the treatments during both seasons.

2.7 Ripening

Berry mass evolution showed smaller berries from the start in the GA treatment for 2012/13, but it was similar to the VSP in 2013/14. In 2013/14 the S treatment was extremely stressed, probably explaining the much smaller berry sizes. This can also be a result of the high bunch numbers previously discussed for this treatment. Ripening (in terms of total soluble solids) seemed the fastest in the sprawling treatments and the slowest in the GA treatment for 2012/13, but in 2013/14 both the GA and S treatments showed delayed ripening, especially in the S treatment as confirmed by the berry sugar content evolution. The delayed ripening could maybe be deemed negative if certain sugar levels are desired, but it has to be confirmed from phenolic and colour measurements if these grapes are really unripe, as well as through sensory analysis of the resulting wines. The positive aspect of the grapes from the GA and S with its delayed ripening, may be that the pH was lower in both years.

Ripening (in terms of sugar accumulation, TA, berry volume) was delayed when very high Y/CM ratios occurred with reference to the GA treatment in season 2012/13 and the S treatment in season 2013/14. This suggested that a more balanced grapevine can impact ripening favourably (Miller & Howell, 1998). The GA treatment also had the lowest pH of treatments in season 2012/13, which can support the occurrence of a more exposed canopy environment.

2.8 Phenolic measurements

Apart from the accompanying work in the MSc of De Beer (W du Toit Winetech project), more results are presented in Addendum B.

2.9 Sensory

The difference in canopy microclimate, bud load and Y/CM ratios correlated strongly with wine sensory attributes. Canopy density, bud load and Y/CM were proportional to fruity attributes and inversely proportional to vegetal attributes. As a result, the VSP treatment produced the most vegetal wines and the S treatment the fruitiest in terms of berry taste and aromas. The GA treatment, occurring in between the above mentioned measurements, displayed both

vegetal and berry characteristics but shifted more to fruity attributes possibly due to the higher bud load, more beneficial Y/CM ratio and better microclimate than VSP grapevines.
New world Shiraz wines are generally characterised as fruity and peppery rather than smoky (Clarke & Rand, 2007). Fruity characters, mainly presented by the S treatment, could arguably therefore be the most desired wine of the treatments, which had more vegetal/smoky and neutral wine characteristics. Questions can however be raised with regards to the desirability of the sprawling system, especially in the Stellenbosch context. Labour intensity was increased during harvest due to high bunch numbers and small bunches. Pruning was however the easiest comfortable between treatments with no canes strangled and tendrils gripping between foliage wires. As a result, pruning could be executed in one action, without first brush cutting the grapevines (pre-pruning). Stressed conditions however also increased when berry colouring initiated and the grapevines struggled to recover thereafter. This led to possibly smaller bunches, early leaf senescence and thinner shoots. Some literature suggest that a sprawling system may be a viable alternative for grapevine training, but they emphasised that this system may only be sustainable on soils where the grapevine water deficit and nutrient levels can be maintained (Stolk, 2014), and where mechanical harvesting would be feasible. In addition to this, judicial water and nutrient management in the soils would need to be applied.
The combined vegetal and fruity effect of the GA treatment on wine attributes concludes that increased yield did not affect grape and wine quality negatively or positively. If not, the GA treatment might be more complex containing both sides of the comparable wine attributes but more fruity, which is desired in a Shiraz wine.
Excessive vigour did produce wines high in vegetal attributes and correlated to bitterness as well as horsey, smoky and tarry attributes, which is certainly not desirable. A denser canopy of the VSP treatment did not seem to be the primary cause for these aromas, due to higher grape phenolics, wine- hue and total red pigment produced by the VSP treatment. It appears that the Y/CM and bud load rather played a significant role. Furthermore, the presence of *Brettanomyces* in the experimental wines can also be ascribed to the tarry, horsey and smoky characters and should be considered as a research topic in the future.

3 Shiraz training systems - Ballerina, VSP, Indicator vines (Trial 3)

3.1 Soil and plant water status

Please refer to the Addendum (B) for the plant water status results of this trial.

3.2 Shoot growth/leaf area

It was clear that downward positioned shoots not only showed less growth than the upward positioned shoots, but also ceased growth earlier in the season. The mechanical damage to the downwards positioned shoots may also play a role. As a compensatory effect, it was clear from preliminary analysis of the data that the reduced canopies stimulated shoot growth as well as thickening, which is evident from the mass per cane data, but also from shoot growth measurements.
An interesting result was shoot growth on grapevines selected within the block, of which all fruit were removed (so-called “indicator vines”). It seemed here that vigour affected shoot growth more than the presence of fruit on the vine, and it even seemed as if the presence of fruit increased shoot growth tempos (Figure 8).

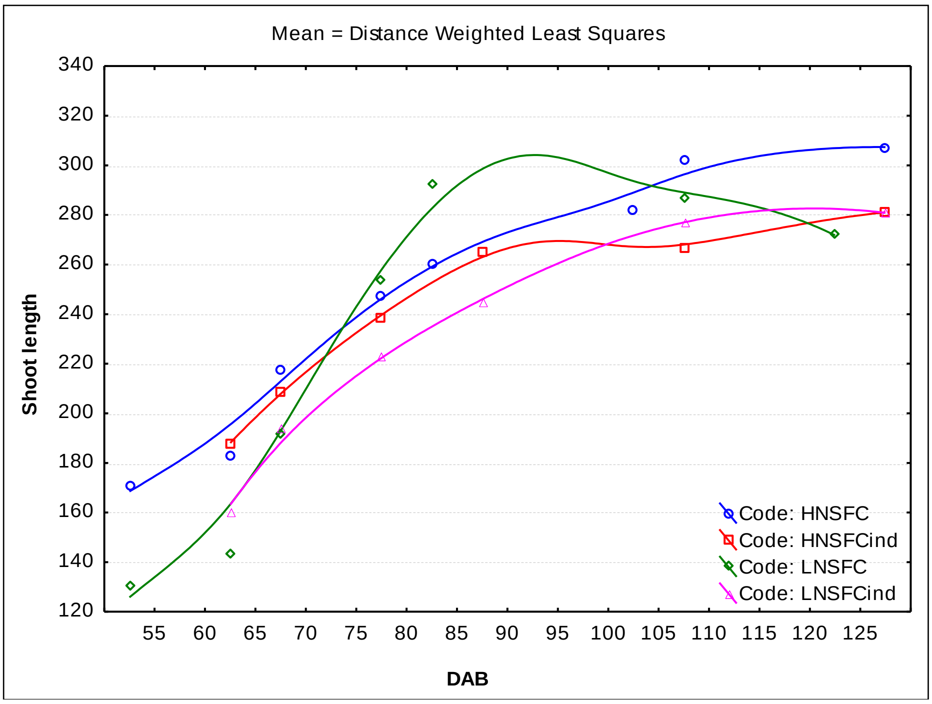


Figure 8 Shoot growth on “control” and “indicator” vines for both vigour levels during the 2012/2013 growing season.

3.3 Pruning and yield data

Please refer to Addendum B for the pruning and yield results for this trial.

3.4 Balance ratios/yield components

When the yield component effects in the SD/Control/Reduced canopy parts of the trial are considered for the past years, as well as the yield parameters for the 2014/15 recent season (**Error! Reference source not found.** in Addendum C), the SD conversion did give significant benefit in terms of productivity, especially in the 2012/13 and 2013/14 season, where the combined yield for the HSDA and HSDB (above and below) parts were about 40% higher than the control. This was however not so significant in the 2014/15 season, which may point to these grapevines struggling in terms of reserve capacity.

3.5 Ripening

Berry mass for the 2011/2012 season and the 2012/2013 season highlighted the variability between treatments, and showed consistent berry size limitations in the lower shoots of the low vigour Smart-Dyson treatment (LSDB). This highlights two possible effects, namely the possible over-bearing on these shoots (**Error! Reference source not found.**) as well as the physiological limitation (photosynthetic activity up to 30% lower) on downward positioned shoots. Especially in the 2013 season, all SD treatments showed reduced berry sizes, probably strongly linked to elevated water deficit stress levels, confirmed by pre-dawn leaf water potential results Total soluble solid accumulation in both seasons showed the fastest ripening in the reduced canopy and control treatments, and points to possible ripening limitation in the SD treatments due to elevated stress levels, which were also confirmed in the per-berry sugar accumulation (“sugar loading”) results.

3.6 Phenolic measurements

Phenolic and colour development were determined by Mr P de Beer as part of Dr WJ du Toit’s collaborating study.

3.7 Sensory

Even though the sensory results suggested strong seasonal effects, even over-powering the treatment effects with regards to wine sensory characteristics, it could again be concluded from the detailed sensory results that wine style was more impacted than necessarily quality. For instance, especially in the 2011/12 season, wines from the SD and reduced canopy treatments seemed to be more astringent, but less floral than the control wines. There were however no clear across-season negative parameters really associated with the SD and reduced canopy wines. For the SD treatments it therefore makes sense even if significant yield increases could not always be attained, to perform the treatments more for the wine colour advantage (only really seen in the warmer 2012/13 season) than for the sensory advantage alone.

3.8 Economic impact study

The MSc study of Mr PA Rabie (Rabie, 2015) included a simulation model “VITISIM101” as well as scenarios for gauging the impact of training system choice within a farming cost model. Parts of his thesis were based on costing from this study, and it would be possible to apply his model to the real yields attained in order to see the full impact of training/trellis modification. For this to be done however, further work is needed to determine more accurately the minimum required inputs (and cost of those inputs) of irrigation and fertiliser required to sustain the higher yields in these systems without negative consequences. A follow-up study is needed where these inputs are made on the longer term – preferably in a working farming environment where costing can be modelled of these adapted systems over the long term. This can therefore be a case study for instance in the VINPRO study groups where production costs/productivity is determined, but then also between altered and current training systems where available.

d) CONCLUSIONS

The study aimed to provide insights into popular belief that high yielding grapevines generally tend to produce lower quality grapes and wine. The results may help to determine what is required for high yielding Shiraz grapevines to produce a desirable new-world cultivar wine getting closer to the elusive concept of high yield combined with superior wine attributes. In this study different trellis/training systems were investigated to determine how grapevine productivity and grape- and wine composition can be altered as a result of differing canopy microclimate, grapevine balance regimes and yield component compensation reactions.

The results displayed evidence that different trellis- and training systems can produce different styles Shiraz wines. Implementing various training/trellising systems in order to produce different wine styles may be a viable marketing strategy as well as provide interesting blending options. This together with increased yield produced by alternative trellising may improve economical sustainability, if not increase production income/profitability. The construction of a larger trellis system does increase establishment costs, but the increased yields will ensure positive cumulative cash flow in five to seven years (Landbouweekblad, 2010). Thereafter, income profitability will increase if the trellis system is sustainable and therefore it is important to ensure adequate grapevine balance.

In conclusion, results suggest that alternative training-, trellising- and pruning methods can lead to the production of different wine styles. Increased yield did not necessarily decrease grape and wine quality. This could be important for the financial survival of the wine grape growing community.

General recommendations/shortcomings of the studies

It will be very interesting and helpful to note the sustainability for each grapevine in the years to come by repeating the measurements as displayed in the spatial plots (see Chapter three) as well as performing reserve status measurements/carbohydrate analysis to determine the carbohydrate content of certain demarcated grapevines (according to different vigour classes) within each treatment. Non-structural carbohydrates located in vegetative parts of the grapevine (wood and roots) provides important contributions in grapevine sustainability and grape quality potential (Zufferey *et al*., 2012) Studies on the seasonal carbohydrate variation in canes, trunks and roots can provide information regarding non-structural carbohydrate dynamics and allocation of carbohydrates between the various source and sink organs of the grapevine (Williams, 1996).

Furthermore, root studies for each treatment would have been beneficial and recommended in the future, to establish if the assumptions made with regards to the root compensation of the GA treatment were accurate. Root studies will also provide information regarding root distribution within the soil environment of each treatment. The effect of trellis conversion on root distribution and the allocation of carbon between above-ground and subterranean growth (Hunter & Volschenk, 2001) can therefore be established.

As mentioned under the economic impact study, further work is needed to determine more accurately the minimum required inputs (and cost of those inputs) of irrigation and fertiliser required to sustain the higher yields in these systems without negative consequences.

Nevertheless, the implementation of alternative trellis- and/or training systems should be considered according to wine production goals. Not only can vigorous growth be maintained and consequently improve the canopy microclimate, but also increased yield is attained which may improve economic sustainability.

6. ACCUMULATED OUTPUTS

a) TECHNOLOGY DEVELOPED, PRODUCTS AND PATENTS

None

b) SUGGESTIONS FOR TECHNOLOGY TRANSFER

c) HUMAN RESOURCES DEVELOPMENT/TRAINING

Student Name and Surname	Student Nationality	Degree (e.g. MSc Agric, MComm)	Level of studies in final year of project	Graduation date	Total cost to industry throughout the project
Honours students					
Masters Students					
Ms A Bosman	SA	MScAgric	Year 4	-	Study fees (part)
Mr P de Beer	SA	MScAgric	Year 3	2015	None
Ms A Davel	SA	MScAgric	Year 2	2015	126 000
Mr PA Rabie	SA	MScAgric	Year 2	2015	None
Mnr J Els	SA	MScAgric	Year 2	-	63000
PhD students					

Postdocs					
Support Personnel (not a requirement for HORTGRO Science)					
Mr L Adams					
Ms T Venter					
Ms E Moffat					

PERSONS PARTICIPATING IN THE PROJECT (Excluding students)

Initials & Surname	Highest Qualification	Degree/ Diploma registered for	Race (1)	Gender (2)	Institution & Department	Position (3)	Cost to Project R
Me A Bosman	BSc(Agric)	MSc(Agric)	W	F	Viticulture and Oenology	Co	Study fees (partial)
Me A Davel	BSc(Agric)	MSc(Agric)	W	F	Viticulture and Oenology		63000x2
Prof A Deloire	DSc(Oenology)		W	M	"	Co	
Dr WJ du Toit	PhD		W	M	"	Co	
Mr D Bosman	MSc		W	M	Distell	Coll	
Prof E Archer	PhD		W	M	Private	Coll	
Mr L Adams	Matric		B	M	Viticulture and Oenology	TA	-
Mr JF Els							63000
Mr PA Rabie	BScAgric	MScAgric	W	M	Agricultural Economy	Co	-
Ms T Venter	BScAgric	MScAgric	W	F	Viticulture and Oenology	TA	Part of salary

(1)Race	B	=	African, Coloured or Indian
	W	=	White
(2)Gender	F	=	Female
	M	=	Male
(3)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

d) PUBLICATIONS (POPULAR, PRESS RELEASES, SEMI-SCIENTIFIC, SCIENTIFIC)

Davel, A., 2015. Optimising productivity in vineyards and potential effects on grape and wine composition for a specific production goal. MScAgric thesis, Stellenbosch University.
Rabie, PA. 2015. A simulation model for evaluating the long-term financial impact of different wine grape production systems. MScAgric thesis, Stellenbosch University.
Du Toit, WJ 2016. WW WdT 12/02 – "Investigating the leaf to fruit ratio (source-sink) and bunch microclimate (training system x canopy manipulation"). Winetech Final report.

e) PRESENTATIONS/PAPERS DELIVERED

Please list using the format illustrated in the example below.

Bosman, A. & Strever, A.E., 2012. The impact of modifying grapevine balance by trellis system conversion on yield components of a grapevine. In: Proc. 34th SASEV Conference, 14-16 November, Allee Bleue, Groot Drakenstein.

Bosman, A, Strever, AE. 2012. Modification of vine balance and the influence thereof on various yield components. Western Cape Viticulture discussion group meeting, 17 May 2013.

Strever, AE, 2012. Training systems, plant spacing and plant water use. SASEV winter forum 20 July 2012.

Strever, AE, 2012. Water use of training systems – underlying principles. Distell technical meeting, 17 August 2012.

Strever, AE, 2014. Training system conversion, some preliminary thoughts. SASEV forum day, April 2014.

Strever, AE, 2014. Training system conversion, some preliminary thoughts. VINPRO information day, Rawsonville 21 May 2014.

Bosman, A, 2014. The impact of modifying grapevine balance by trellis system conversion on yield components of a grapevine. SASEV forum day, April 2014.

7. BUDGET

TOTAL COST SUMMARY OF THE PROJECT

YEAR	CFPA	DFTS	Deciduous	SATI	Winetech	THRIP	OTHER	TOTAL
2013					R 283 000			R 283 000
2014					R 300 000			R 300 000
2015					R 300 000			R 300 000
2016					R 105 000			R 105 000

EVALUATION BY INDUSTRY

This section is for office use only

Project number	

Project name	

Name of Sub-Committee*	

Comments on project

Committee's recommendation (Review panel in the case of PHI)

- Accepted. ☐
- Accepted provisionally if the sub-committee's comments are also addressed. Resubmit this final report by____________________________________ ☐
- Unacceptable. Must resubmit final report. ☐

Chairperson____ Date____________________

*SUB-COMMITTEES

Winetech
Viticulture: Cultivation; Soil Science; Plant Biotechnology; Plant Protection; Plant Improvement;
Oenology: Vinification Technology; Bottling, Packaging and Distribution; Environmental Impact; Brandy and Distilling; Microbiology

Deciduous Fruit
Technical Advisory Committees: Post-Harvest; Crop Production; Crop Protection; Technology Transfer
Peer Work Groups: Post-Harvest; Horticulture; Soil Science; Breeding and Evaluation; Pathology; Entomology

Version 2015