Australian Government

Australian Grape and Wine Authority

SARDI

SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Managing vineyard rootzone salinity and maximising water saving by subsurface irrigation techniques





FINAL REPORT to

AUSTRALIAN GRAPE & WINE AUTHORITY

Project Number: **SAR 0902**

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Date: **October 2016**

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Cover photographs: Gypsum block logger and SoluSamplers and trench with drip line in place prior to backfilling in a subsurface irrigated plot.

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Abstract

The results of a five-year field experiment in the South Australian Riverland indicated that under non-restricted irrigation allocations there were no water use savings or improvements in rootzone salinity with the use of subsurface irrigation; either using conventional subsurface drip line or when the subsurface drip line was enclosed in a porous fabric strip designed to improve the lateral movement of water. Only under severely reduced irrigation volume was there some yield advantage with the two types of subsurface irrigation. There was deposition of fine colloidal clay within the fabric covering which may have influenced the long-term performance of this irrigation system with the water source used in this experiment and this warrants further investigation.

Executive Summary

During winter 2009 a large field experiment was established by Treasury Wine Estates at the Markaranka vineyard in the South Australian Riverland to determine whether subsurface irrigation resulted in any water use savings and improved rootzone salinity. Support from Wine Australia enabled the installation of monitoring equipment in 2010 and collection of soil water and salinity data over ensuing seasons.

Three types of irrigation were installed: standard drip irrigation, subsurface drip and subsurface drip within a porous fabric cover designed to increase the lateral movement of water away from the emitter. Four irrigation treatments were established, resulting in applications of about 50, 67, and 84% of the standard irrigation (100%) used in the remainder to the block of Chardonnay grapevines, which were planted on to Ramsey rootstock in 2004. The soil type varied from sandy to loamy sand across the trial site.

A split-plot design was used with irrigation volume as main plot along a single row of vines, and irrigation type the sub-plot within the row. Each subplot consisted of nine vines irrigated using the same lateral, and treatments were replicated five times across the width of the block. In-line water meters were installed strategically to enable the calculation of water volume applied to each treatment. Irrigation treatments were applied during five consecutive seasons with conclusion of field work at pruning in winter 2015.

Aggregated data for season and irrigation volume indicated that the yield of subsurface irrigated vines was significantly lower than standard drip or fabric covered subsurface, which were similar. However, there was a significant interaction between irrigation type and volume. For 100% irrigation volume, subsurface drip yielded significantly less fruit than the other two irrigation types. Under severely restricted irrigation (50%) vines irrigated with the standard drip were significantly lower in yield than the other irrigation types, which were similar. The yield of 50% subsurface irrigated vines was less than all irrigation types at 67%, with vines indicating that a change to subsurface irrigation does not maintain yield with less water. This is a significant outcome that is somewhat contrary to previous findings.

The lower yield of subsurface irrigated vines may have been in part due to higher rootzone salinity. The four-season mean of water samples collected from SoluSamplers indicated the three irrigation types were significantly different to each other with subsurface drip being about 50% higher in overall rootzone salinity than standard irrigation and fabric covered subsurface drip being intermediate and significantly different to the other two irrigation types. Within each season, subsurface drip recorded the highest overall rootzone salinity and standard irrigation the lowest. The location of the drip line determined soil water content with the upper layers of the profile being wetter with standard irrigation compared with subsurface drip, while at depth the pattern of ‘wet’ or ‘dry’ soil was similar. In years one and two the profile under fabric covered subsurface drip was more often dry than wet however, at the time, it was hypothesised that this may have been the result of soil water sensor location alongside the fabric cover. However in the third season the pattern reversed to more closely resemble subsurface drip. This unexpected change in water distribution may indicate a change in properties of the fabric cover and hence may highlight potential longevity issues of this system, depending on the physical properties of the irrigation water at the site.

In conclusion, this long term field experiment demonstrated that under non-restricted irrigation allocations there were no water use savings or improved root zone salinity with the use of subsurface irrigation, or when the subsurface drip line was enclosed in a porous fabric strip designed to improve the lateral movement of water compared with standard drip irrigation. Subsurface irrigation resulted in the highest overall rootzone salinity for the four years of data. There was a yield penalty using subsurface irrigation under non-restricted or reduced irrigation volume. Only under severely reduced irrigation volume there was some yield advantage with the two types of subsurface irrigation.

Acknowledgments

Dr. Paul Petrie, formerly National Viticulturist, Treasury Wine Estates, established the trial site and over the duration of the project Jack Caulfield and Brenton Turner at the Markaranka vineyard liaised closely with SARDI staff to ensure vineyard operations did not compromise data collection and this is assistance gratefully acknowledged. A number of SARDI staff assisted in data collection and laboratory analysis and are acknowledged later.

Background

In 2008, the Winemakers' Federation of Australia (WFA) reported that more than 60% of Australia's grape growers utilised standard above-ground drip irrigation systems. Other survey data indicated that vineyards using record low water volumes imposed by reduction in irrigation allocation and/or those adopting precision irrigation technologies were at greater risk of rising rootzone salinity and finished wines exceeding Food Standard Limits. Economic analysis of the threat posed by rootzone salinity in the Lower Murray suggested losses up to an estimated $120 million per year in yield loss.

The Millennium drought was also Australia's first 'irrigation drought' (Hayman and McCarthy 2013) and highlighted the need to further improve irrigation efficiency. It had been demonstrated that Partial Rootzone Drying (PRD) was one successful management practice however industry uptake of PRD was slow due to the need for extra management skills and monitoring to successfully implement it. Some sites were unresponsive due to lateral spread of water at soil textural changes through the profile.

Subsurface drip irrigation was perceived to offer benefits in salinity management and water savings through claimed benefits of:

(i) Significantly lower crop water requirements due to reduced evaporation from the soil surface,
(ii) Lower root zone salinity, and
(iii) Lower requirements for other inputs such as herbicides due to reduced weed growth from off-target water application.

Subsurface irrigation in annual cropping systems had demonstrated benefits and some perennial tree crops were using subsurface, however, this was more to facilitate mechanical harvesting operations than for water use savings. For a number of reasons, some real, others perceived, the uptake of subsurface irrigation in irrigated viticulture has been slow.

Biswas (2008) reported that soil salinity under standard drip was up to double that under subsurface drip irrigation when irrigated with reclaimed water in McLaren Vale (Table 1).

Depth of SoluSampler	Standard Drip EC_{SW} (dSm^{-1})	Subsurface Drip EC_{SW} (dSm^{-1})
30cm	6.0^{97} *	2.9^{74}
60cm	9.4^{43}	5.2^{56}
90cm	9.3^{24}	8.2^{34}

* Superscript represents population size.

Table 1. Influence of Standard Drip and Subsurface Drip Irrigation on EC_{SW} in a McLaren Vale Shiraz vineyard. 1.8 $MLha^{-1}$ reclaimed water at 1.2 dSm^{-1}. Jan 2006 – Jul 2008

Salinity values recorded at these two sites reflected the inadequate winter leaching of salts applied in the irrigation water during several years of below average rainfall. Hanson and Bendixen (1995) reported high salinity close to the soil surface using subsurface drip, with lower values closer to the drip emitter indicating the continuous three dimensional leaching of salt away from a buried emitter compared with only lateral downward leaching of salt with standard drip. However, highly salinised soil above the rootzone of subsurface irrigated crops potentially exposes the root system to osmotic shock if rainfall leaches this zone of accumulated salt into the rootzone from upper layers.

Australia's water resources are limited and in the future, the availability of good quality irrigation water resources will be exposed to further risk from reduced rainfall and increased evaporative demand as a result of climate change. To ensure the sustainability of the grape and wine industry, it is imperative that more efficient methods of irrigation are identified and their impact on water use, root zone salinity and nutrient loss thoroughly evaluated. This project was developed to explore whether subsurface irrigation offered any improvement in water use and salinity management.

Project Aims and Performance Targets

The initial primary objectives of the project were:

1. Review international Subsurface Drip Irrigation work in vineyards as there is limited/no published Australian research.
2. Calibrate and validate water savings and soil salinity models for subsurface irrigation techniques through strategic field experimentations.
3. Quantification of potential water and nutrients savings with subsurface irrigation compared with standard drip irrigation.
4. Improve our understanding by quantifying the dynamics of rootzone salinity, deep drainage and vineyard water movement under standard drip irrigation and subsurface drip irrigation.
5. Development of sustainable management systems to maximise salt leaching and minimise nutrient loss from irrigated vineyards.
6. Generate underpinning knowledge to enable vineyards managers/growers to better manage periods of low supply and elevated irrigation water salinity.
7. Transfer new knowledge to grape and wine industries.

Materials and Methods

The field experiment was conducted in the Markaranka vineyard (34.08ºS and 139.87ºE), located near Waikerie in South Australia. The Chardonnay wine grapes (clone Bernard 95) on Ramsey rootstock were planted in November 2004 at a vine spacing of 2.5 m and row spacing of 3.35 m, and prior to the establishment of the experiment were irrigated using a standard drip system.

The soils at the site are predominately light textured, ranging from sand to loamy sand, with the sand content in the range of 84 to 91%, the clay content from 9 to 13%, and the silt content from 0 to 3%. The climate is characterised as dry, with warm to hot summers and mild winters. Weather data were collected from an automated weather station located approximately 4 km from the trial site.

Irrigation treatments and measurements

Installation of the new irrigation system commenced in winter 2009 and additional monitoring equipment was installed during 2010.

The new irrigation system was retrofitted using emitters (Toro Drip-In® Rootguard®), with a discharge rate of 1.6 L hr^{-1} and a spacing of 40 cm. Along each converted row a single length of drip line was used; for the standard drip, the line was laid on the surface, for the subsurface treatment the drip tubing was installed in a narrow (10 cm) trench approximately 25 cm deep and 25 cm away from the vine line on the eastern side of the vine row. For the fabric covered drip treatment, the drip line was pre-installed inside the woven fabric covering and laid in the trench in the same configuration as the subsurface treatment.

Four irrigation treatments were established, resulting in applications of about 50, 67, and 84% of the standard irrigation (100%) applied in the remainder of the block of Chardonnay vines which was irrigated based on biweekly soil moisture monitoring using a portable capacitance sensor (Diviner, 2000, Sentek, Stepney, South Australia). Irrigation was applied when the soil water content reached the refill point i.e. the soil water content where experience showed the rate of water extraction would start to diminish.

A split-plot design was used with irrigation volume as main plot along a single row of vines, and irrigation type the sub-plot within the row. Each subplot consisted of nine vines irrigated using the same lateral, and treatments were replicated five times across the width of the block

Soil water at the experimental site was monitored at 15, 30, 60, and 90 cm depth using gypsum blocks (Watermark®) connected to GBug® data loggers. The logger was calibrated to measure a range of 0 to 200 kPa. The sensors were separately installed at 10 cm intervals along the drip line and soil matric potential was recorded every two hours over each growing season with data downloaded from the loggers weekly.

Growth and Yield

The trial site was harvested in 2010 but data are not presented as it was considered that vines in the subsurface irrigated treatments required a season to recover from any root pruning that occurred during installation. At harvest 2011 a single vine in each sub-plot was hand harvested with the total number of bunches per vine and the total weight of fruit removed recorded. The same vine in each sub-plot was harvested in the four subsequent years. After the final harvest the total cordon length of each hand-harvested vine was recorded to normalise data.

The same vines were hand-pruned each winter in a manner designed to simulate the machine prune/hand-cleanup used across the remainder of the vineyard block. The weight of all one-year old growth removed was recorded. Pruning weight was not collected in one season as the vines were machine-trimmed post veraison for improved penetration of applied fungicides.

Results & Discussion

Climate

Rainfall

Monthly rainfall data are presented in Table 2. With harvest in the last week of January in each season the period from post-harvest in the previous year to the end of January was used to quantify seasonal rainfall with 2010/11 being the wettest season and 2012/13 the driest,

Month	2010/11	2011/12	2012/13	2013/14	2014/15
February	6.8	66.4	43.0	11.6	52.0
March	18.8	62.6	8.4	1.6	4.6
April	18.2	0.0	8.4	22.0	77.2
May	42.0	6.8	18.6	34.6	41.8
June	6.8	1.4	12.4	28.2	13.0
July	19.4	16.2	27.6	28.0	16.6
August	37.0	29.2	7.4	12.8	18.0
September	64.0	10.0	6.0	22.6	22.2
October	43.6	26.4	4.0	2.6	0.6
November	18.4	44.6	9.6	0.6	22.6
December	123.0	67.2	19.8	19.8	11.2
January	8.6	13.6	1.4	14.6	27.2
Total	**406.6**	**344.4**	**166.6**	**199.0**	**307.0**

Table 2 Monthly rainfall (mm) from post-harvest to harvest (last week of January in each season) for each of the five years. Data from the SAMDBNRM AWS (Qualco) located approximately five km South-east from the experiment site.

Temperature

Growing Degree Days (base 10^0C) was used to describe temperature with the period 1 September to 31 January representing the annual growing season from budburst to harvest. The first season was the coolest (Figure 1) with the final two seasons being the warmest. 2011/12 and 2012/13 were similar in GDD being about 100 GDD warmer than 2010/11 and cooler than the last two seasons. The highest growing season maximum temperature recorded was 47.2^{0}C on 30 November 2014

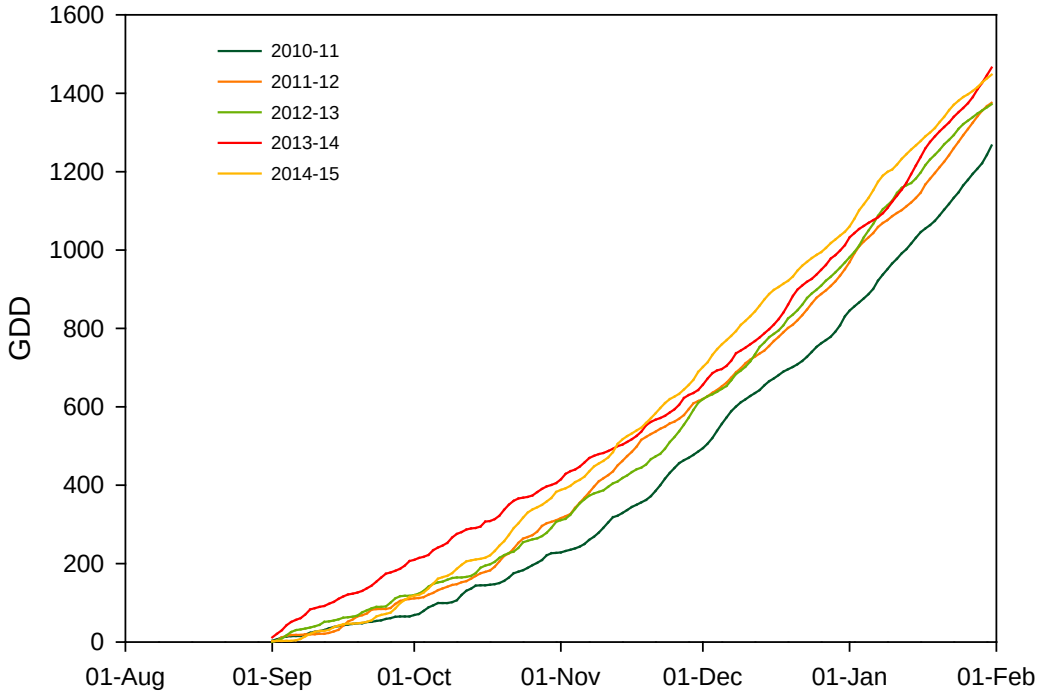


Figure 1 Cumulative Growing Degree Days (base 10^0C) calculated from daily maximum and minimum temperature recorded at the SAMDBNRM AWS (Qualco).

Yield and components

Season

There were significant differences in yield.m cordon^{-1} when data were aggregated for each harvest year (Figure 2). The significantly higher yield in 2011 was the result of higher than average growing season rainfall (Table 2) which may have also resulted in the 2012 yields being significantly higher than 2013. Yield differences were driven by a combination of significant differences in the number of bunches and bunch weight. The higher yield in 2011 was the result of both high bunch number and weight and in contrast lower yield in 2014 was due to fewer and lighter bunches.

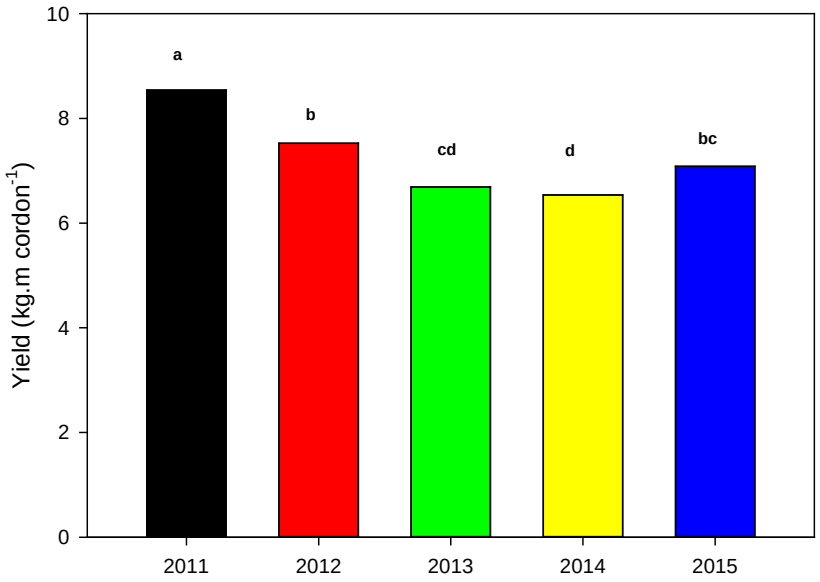


Figure 2 Aggregated yield.m cordon^{-1} for irrigation type and volume for the five harvests. Years with the same letter are not significantly different.

Harvest year	Bunches.m cordon^{-1}	Bunch wt. (g)
2011	83.6 ab	102.3 a
2012	74.4 b	102.3 a
2013	73.0 b	92.2 b
2014	73.2 b	80.9 c
2015	90.9 a	81.9 c

Table 3 Aggregated bunches.m cordon^{-1} and bunch weight for irrigation type and volume for the five harvests. Years with the same letter are not significantly different

Irrigation volume

There was a significant effect of irrigation volume on yield (Figure 3) when year and irrigation type were aggregated. Reducing the irrigation volume to 50% of the control resulted in a significant reduction in yield and the 67% and 84% treatments were statistically similar. There was no effect of irrigation volume on the number of bunches per vine and reducing the irrigation volume resulted in a significant step-wise reduction in bunch weight. (data not presented).

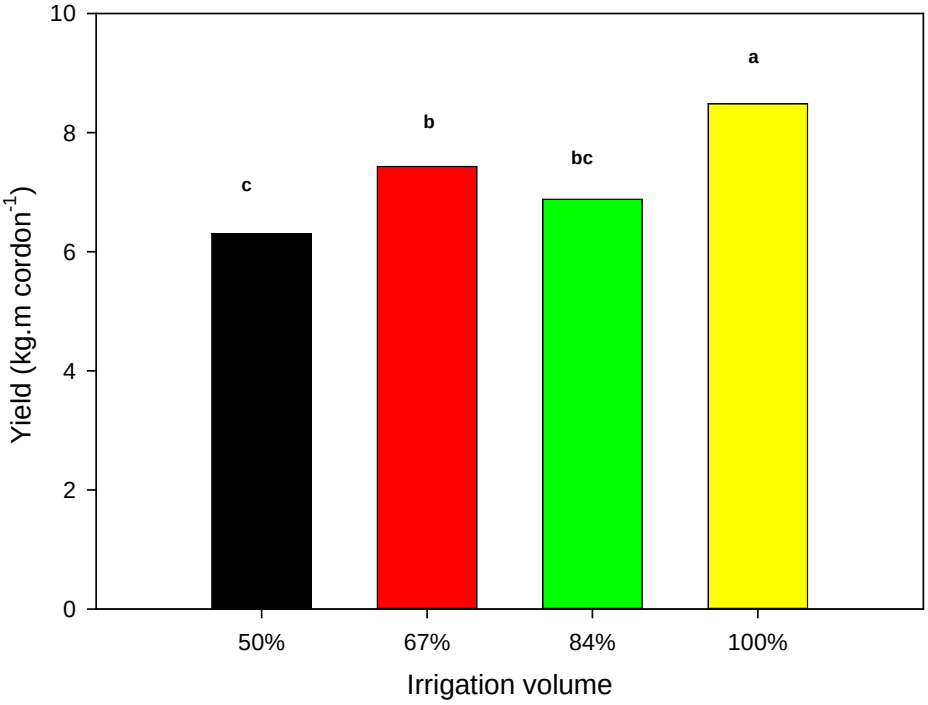


Figure 3 Aggregated yield.m cordon^{-1} for harvest years and irrigation type for the four irrigation volumes. Irrigation volumes with different letters are significantly different.

Irrigation type

Mean yield for subsurface irrigation (Figure 4) for all seasons and irrigation volumes was significantly lower than standard drip irrigation and the fabric covered subsurface irrigation, which were similar, as a result of lighter bunches (Table 4). The fabric covered subsurface treatment resulted in significantly more bunches per metre of cordon however there was no difference in the bunch weight compared with standard drip irrigation (Table 4).

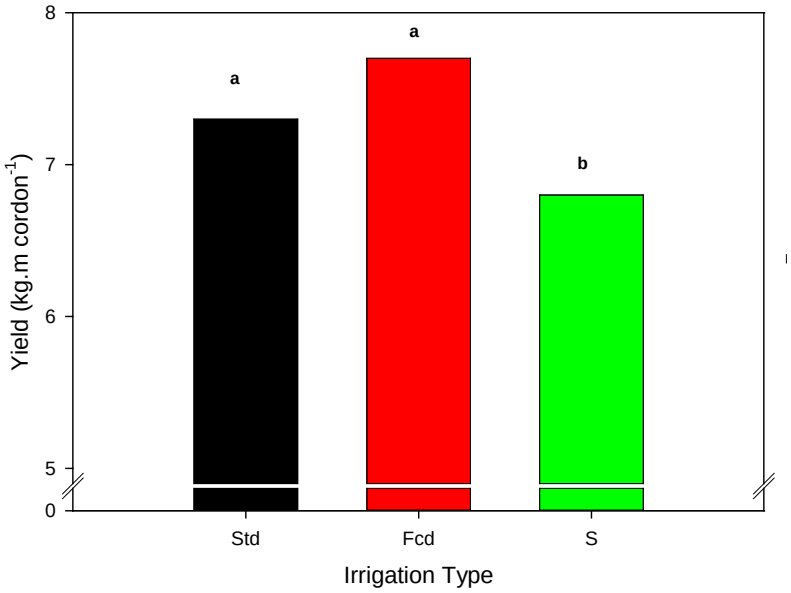


Figure 4 Yield.m cordon^{-1} for irrigation type for all harvest years and irrigation volume. Irrigation type with similar letters are not significantly different.

Irrigation type	Bunches.m cordon^{-1}	Bunch wt. (g)
Standard drip	76.9 b	94.6 a
Fabric covered subsurface	82.7 a	94.0 a
Subsurface	76.4 b	87.3 b

Table 4 Mean yield for irrigation type for all seasons and irrigation volumes. Irrigation type with similar letters are not significantly different

Irrigation volume x irrigation type

The significantly aggregated lower yield of subsurface irrigated vines was a result of a smaller change in yield as the irrigation volume varied (Figure 5). There was a significant interaction between irrigation type and volume. For 100% irrigation volume, subsurface yielded significantly less fruit than the other two irrigation types, however at 50%, vines irrigated with the standard drip irrigation were significantly lower in yield than the other irrigation types, which were similar.

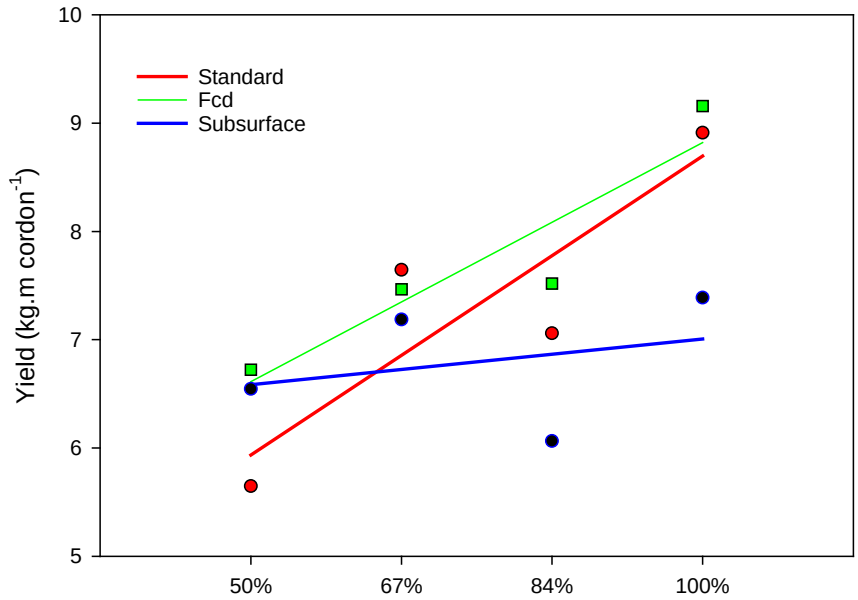


Figure 5 Regression of yield (kg.m cordon^{-1}) for the three irrigation types against irrigation volume for the five harvest seasons.

The responses in yield reported in Figure 5 were primarily due to bunch weight rather than the number of bunches per vine based on normalised data. Increasing the volume of irrigation resulted in heavier bunches (as expected), higher bunch weights were recorded in 2012, being significantly heavier than in 2013, 2014 and 2015. The lightest bunches were recorded in 2014 although not significantly lower than 2015 (data not reported). Subsurface irrigation yielded the lightest bunches while Standard and fabric covered subsurface were similar (Table 5).

Irrigation type	Bunch wt. (g)
Standard drip	94.6 a
Fabric covered subsurface	94.0 a
Subsurface	87.3 b

Table 5 Mean bunch weight (g) for harvest years 2011 to 2015 for three irrigation types. Numbers with different letters are significantly different (5%)

Vegetative Growth

The weight of prunings removed from the vines that were hand-harvested was used to quantify annual vegetative growth. Prior to the establishment of the experiment vines had been machine pruned with some minor hand clean-up and this was simulated by hand pruning all viable shoots to 2-3 retained buds. Any dead spur positions were removed however this material was not weighed. Where the cordons from adjacent buffer vines overlapped these were shortened to aid hand harvest of the target vines. Pruning weight was not recorded in 2012 as the vineyard was moderately trimmed prior to harvest to assist in fungicide spray penetration into the canopy. After pruning in 2015 the cordon length of all target vines was recorded to normalise yield and pruning weight data.

There were significant year, irrigation type and volume effects on weight of prunings per metre of cordon and reflected the reported yield responses above. The heaviest prunings were recorded in 2011 and the lightest in 2013 (Table 6), subsurface irrigated vines had the lightest pruning weights but only significantly less than the standard drip while 100% irrigation vines recorded the heaviest weight of prunings and 50% the lightest.

Year	Pruning weight (kg)	Irrigation type	Pruning weight (kg)	Irrigation volume	Pruning weight (kg)
2011	0.72 a	Standard drip	0.49 a	100%	0.60 a
2013	0.21 c	Fabric covered subsurface	0.48 ab	84%	0.40 c
2014	0.33 b	Subsurface	0.44 b	67%	0.47 b
2015	0.62 a			50%	0.39 c

Table 6 Effect of year, irrigation type and volume on weight of prunings (kg) .m cordon^{-1}. Numbers with different letters are significantly different (5%)

These data suggest that under non-restricted conditions there is no yield advantage in subsurface irrigation compared with the standard drip irrigation. However, as the volume of irrigation water is reduced, such as happened across the Murray Darling Basin during the Millennium drought, and when this trial was initiated, there was less of a yield penalty with subsurface irrigation compared with standard drip. This response is further examined later in this report in the section on soil water responses.

Soil water content

For the duration of the experiment approximately 250,000 gypsum block readings were recorded. The logger default range of 0 to 200 kPa soil water tension and initial analysis and interpretation of data using individual readings was problematic due to the large data set. An example of a data set from one irrigation volume for standard drip irrigation from a single season is presented in Figure 6. (See Appendix 5 for additional figures)

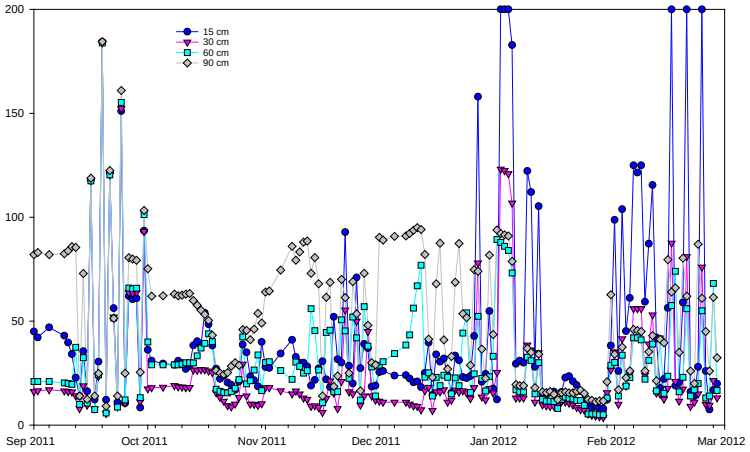


Figure 6 Gypsum block readings at 15, 30, 60and 90 cm depth for standard drip at 67% of the control volume between September 2011 and March 2012.

An alternative approach dividing the data at each depth into two groups in the ranges of 0-50 and >50 kPa was utilised. For the soil type at the site the 0-50 kPa range represents approximately Readily Available Water (RAW - wet) and readings more negative than 50 kPa are indicative of deficit available water (dry). It was considered this approach would reveal some information on soil wetting zones with the three irrigation types and assist in the interpretation of soil salinity data from the SoluSamplers. Data presented here is the comparison of the three irrigation types at 62% Irrigation between 1 September and 31 January in each season, representing the period between budburst and harvest. There were differences in the counts for wet and dry between irrigation treatments and season as a result of intermittent errors or missing values in the data.

2010-11 season

There were marked differences in the distribution of soil matric potential readings for the three irrigation types and soil depth (Figure 7). For standard drip irrigation the majority of the readings at 15, 30, and 60 cm were in the RAW range indicating the frequency of irrigation designed to maintain adequate plant available water. At 90 cm there were more readings >50 kPa compared with shallower depths indicating that the irrigation wetting front did not always reach that depth. With subsurface irrigation the gypsum block at 15 cm depth is above the emitters and the approximate even spread of wet and dry at 15 cm reflects only occasional upward movement of water and also sporadic effective rainfall events. At 30 cm, closer to the emitters, and 60 cm depth (below the emitters) there were more readings in the wet range while at 90 cm, similar to standard drip the wetting front was not always detected. For the fabric covered subsurface drip the opposite occurred with the majority of readings at the four depths being in the dry range (Figure 7) being most evident at 90 cm depth.

Some of these differences may be due to the positioning of the gypsum blocks relative to the drip line. For standard drip the blocks were approximately beneath the drip lateral lying on the ground while for the two buried systems the blocks were horizontally displaced about 25 cm to one side as a result of method used to install the buried systems (see cover photo) and the need to locate the gypsum blocks in the vine row to prevent mechanical damage.

2011-12 season

A similar trend in soil water distribution was observed for the standard drip treatment in 2011-12 (Figure 8), however, there were more dry readings at 90 cm depth compared with the previous season. The soil above the subsurface drip was again about equally wet and dry with the majority of the gypsum block readings at 30 cm and 60 cm depth being wet more often than dry while the opposite occurred at 90 cm depth. At each depth in the fabric covered subsurface drip the soil was more often dry than wet and most apparent at 90 cm.

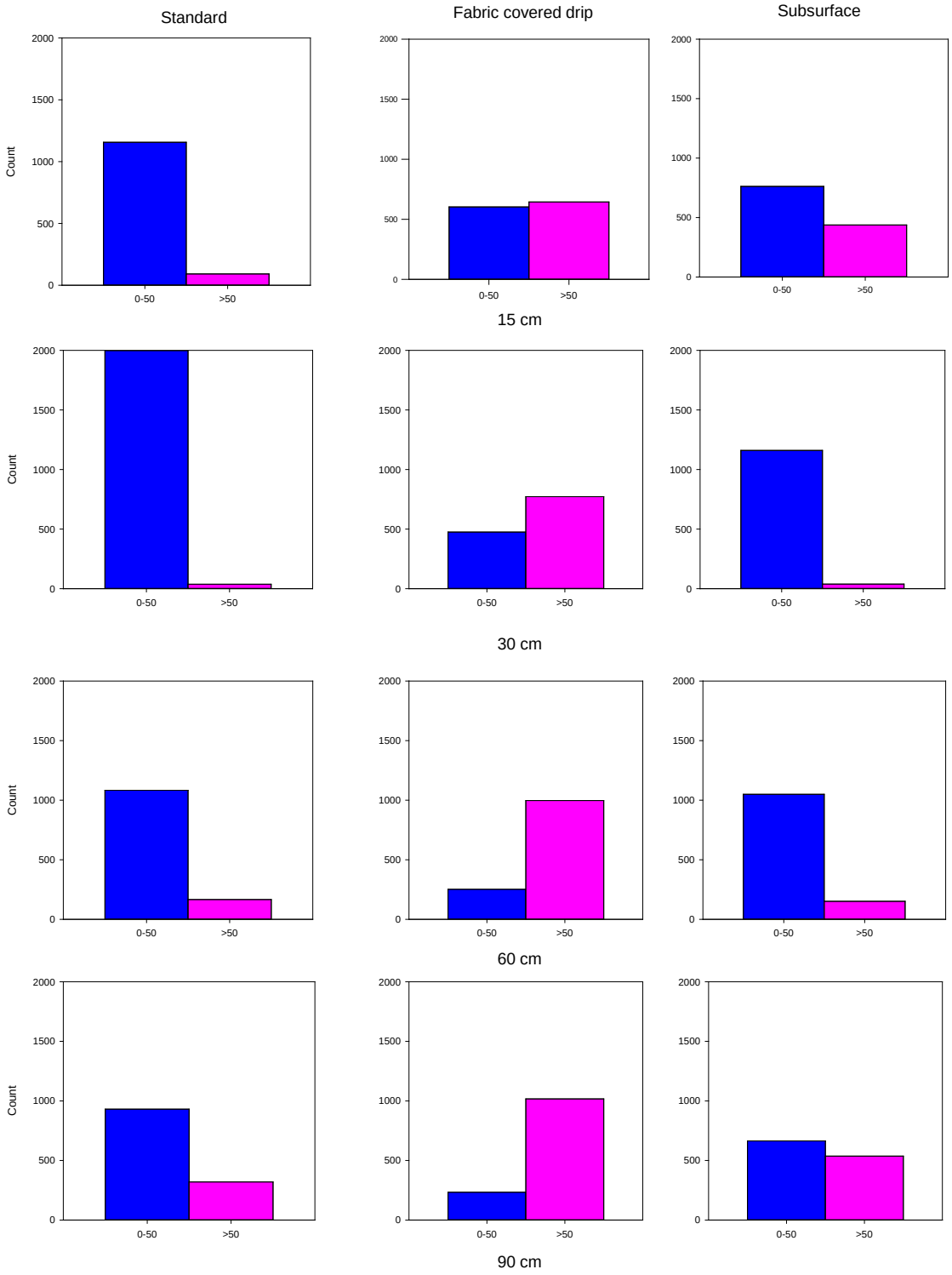


Figure 7 Soil matric potential for the 0-50 and >50 kPa ranges for standard, fabric covered subsurface drip and subsurface drip irrigation at 15, 30, 60 and 90 cm depth at 67% Irrigation between 1 Sept 2010 and 31 January 2011

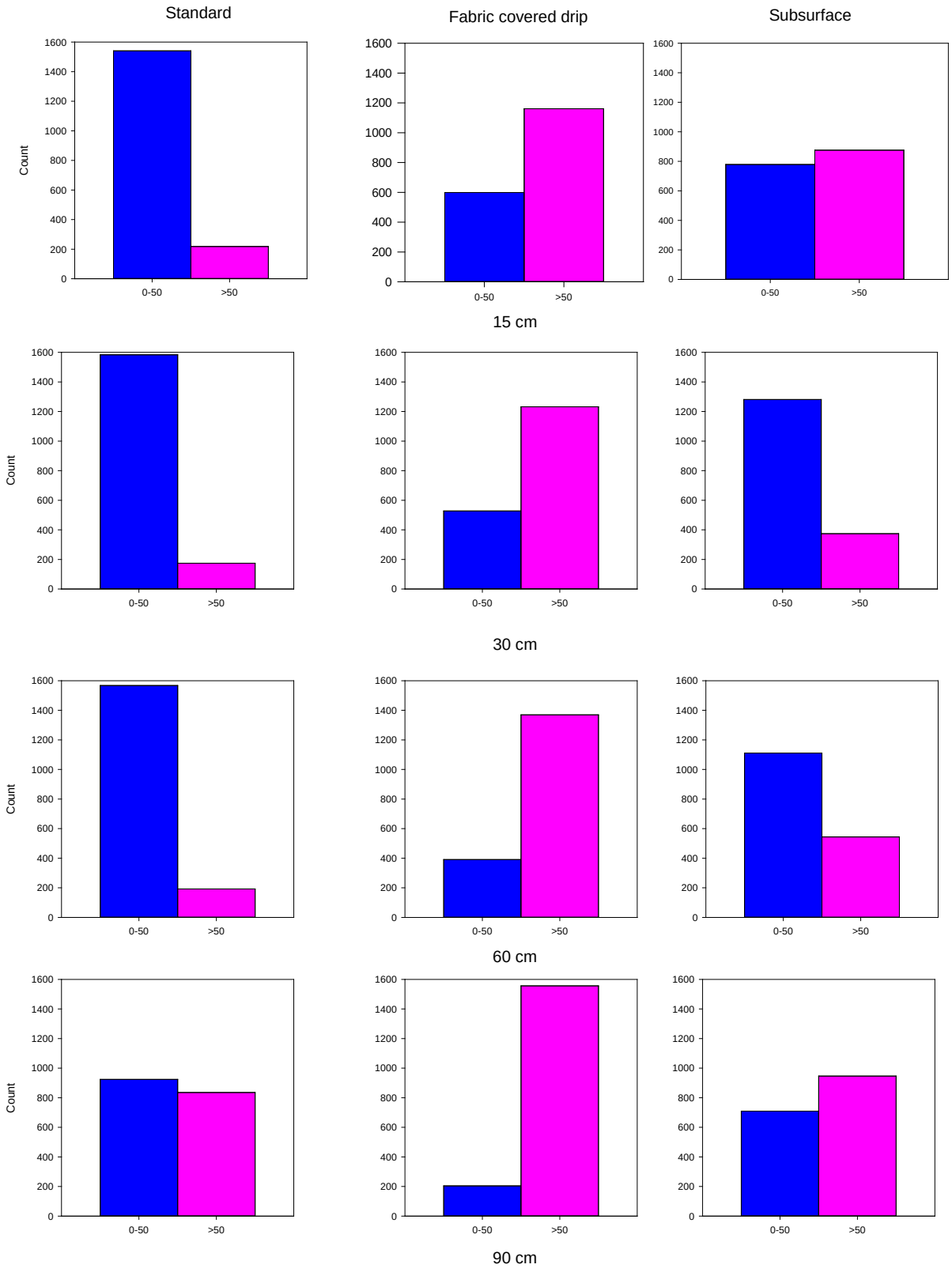


Figure 8 Soil matric potential for the 0-50 and >50 kPa ranges for standard, fabric covered subsurface drip and subsurface drip irrigation at 15, 30, 60 and 90 cm depth at 67% Irrigation between 1 Sept 2011 and 31 January 2012

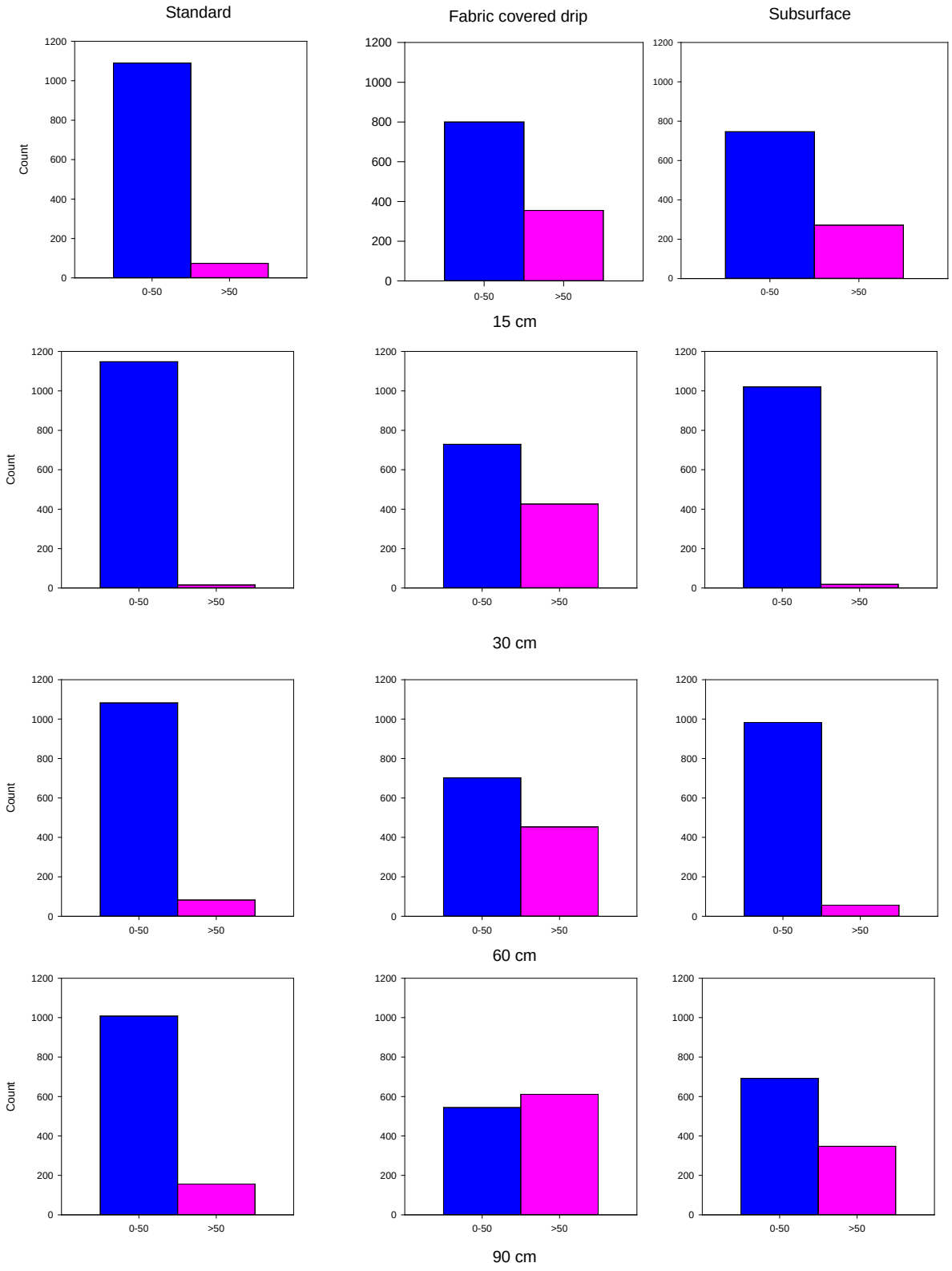


Figure 9. Soil matric potential for the 0-50 and >50 kPa ranges for standard, fabric covered subsurface drip and subsurface drip irrigation at 15, 30, 60 and 90 cm depth at 67% Irrigation between 1 Sept 2012 and 31 January 2013

2012-13 season

During the 2012-13 season the pattern of soil water distribution with standard and subsurface irrigation was similar to the two previous seasons (Figure 9). However, the pattern for fabric covered subsurface drip was the opposite of the previous seasons. In 2012-13 the soil was more often wet than dry at 15, 30 and 60 cm and about equally distributed at 90 cm. There is no apparent reason for this change in soil water distribution. At the conclusion of the experiment a section of the subsurface and fabric covered drip line was excavated for examination. Within the fabric cover there was a significant deposit of colloidal clay distributed along the drip line which may have affected the ability of the fabric to 'wick' water movement laterally, and perhaps resulted in the development of preferential pathways for water movement from the fabric to the soil medium. If such a pathway developed in proximity to the gypsum blocks the blocks would have registered the increase in soil water content.



Figure 10 Excised section of fabric covered subsurface drip line at conclusion of experiment exhibiting deposition of colloidal material within the fabric cover.

In summary, there were quantifiable differences in the pattern of wet and dry zones between the three irrigation types with, as expected, the upper layers of the profile being wetter for the standard drip compared with the two buried irrigation systems. The reversal of the pattern of soil water distribution with the fabric coated subsurface to be somewhat similar to subsurface drip irrigation by year three indicates a change in performance of this irrigation type which warrants further investigation, as this may impact on the effective longevity of the fabric covered subsurface drip system.

SoluSampler soil water salinity

Approximately 2000 samples were collected over seasons one to four. The number and volume of samples collected decreased during each season as the soil profile dried and successful sample collection was only possible immediately after irrigation or any significant rainfall events as occurred in the first season.

Across the four seasons of data collection rootzone salinity was within acceptable limits for irrigated viticulture in the region and reflects the acceptable salinity of the irrigation water used at the experimental site.

Season

Using aggregated results for the three depths, irrigation volumes and types for the four-year data set (Figure 13) there were only minor, however significant changes in soil salinity between seasons with

the final year recording the lowest salinity compared with seasons one and three, but similar to season 2.

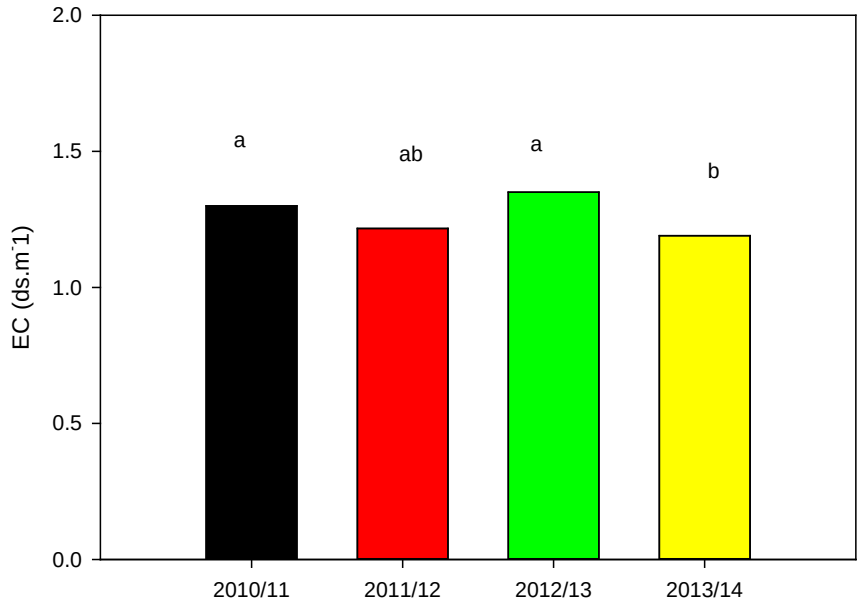


Figure 11 Salinity of water (EC dS.m^{-1}) recovered from SoluSamplers for four seasons for all irrigation types, volumes and depths

The four-season mean indicated that the three irrigation types were significantly different to each other with subsurface drip being about 50% higher in overall rootzone salinity than standard irrigation (Table 7). Within each season, standard irrigation recorded the lowest overall rootzone salinity (Figure 12) and subsurface drip the highest.

Irrigation Types	EC (dSm^{-}1)
Standard	1.05 a
Fabric covered subsurface	1.35 b
Subsurface	1.55 c

Table 7 Mean rootzone salinity for all seasons, irrigation volume and sampling depth for three irrigation types. Numbers followed by different letters are significantly different

There was a similar pattern in mean rootzone salinity in each of the four years (Figure 12) with the ranking being the same in each year as for the four-year mean.

Depth

The SoluSamplers at 30 cm depth in standard irrigation recorded the lowest salinity with an increase in salinity at depth (Figure 13). There was a similar pattern for the fabric covered subsurface irrigation type however for subsurface irrigation the overall rootzone salinity at 60 cm and 90 cm was similar. The highest rootzone salinity was reported in the 50% irrigation volume treatment suggesting inadequate leaching under this reduced volume regime.

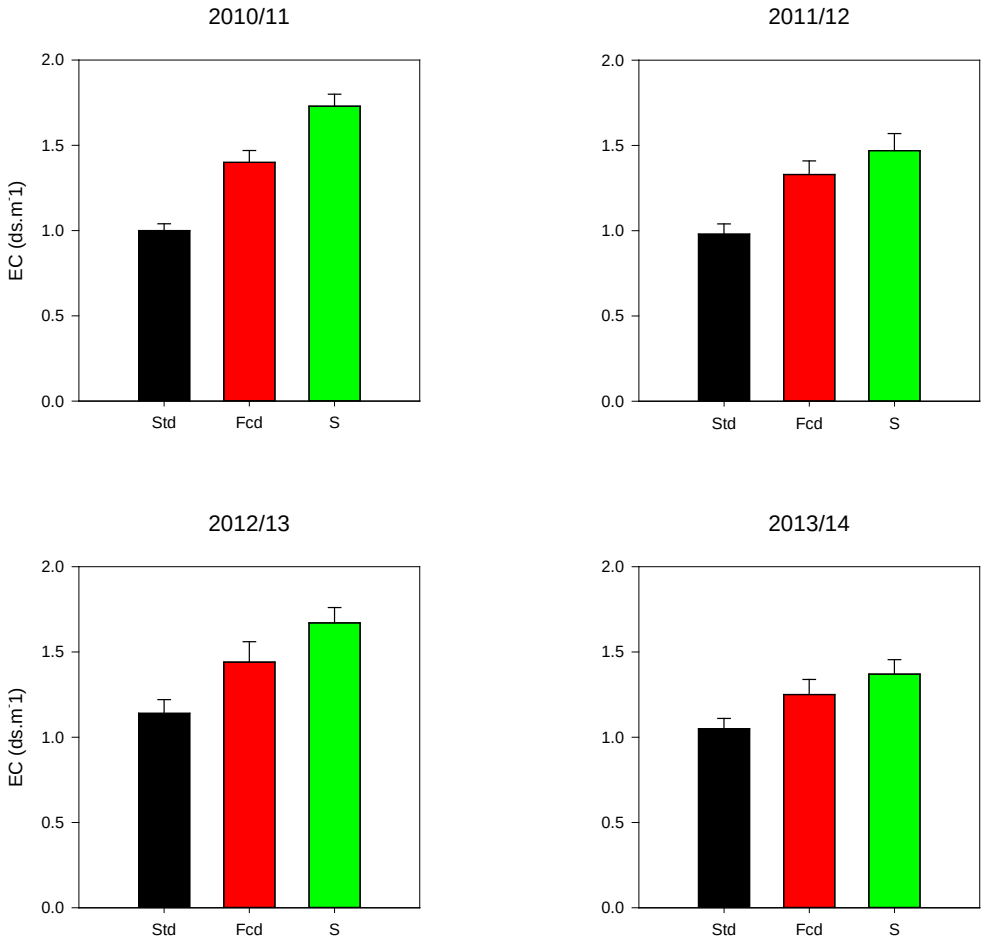


Figure 12 Mean rootzone salinity for each season for all irrigation volumes and sampling depth for three irrigation types. Vertical bars represent standard error for each irrigation type.

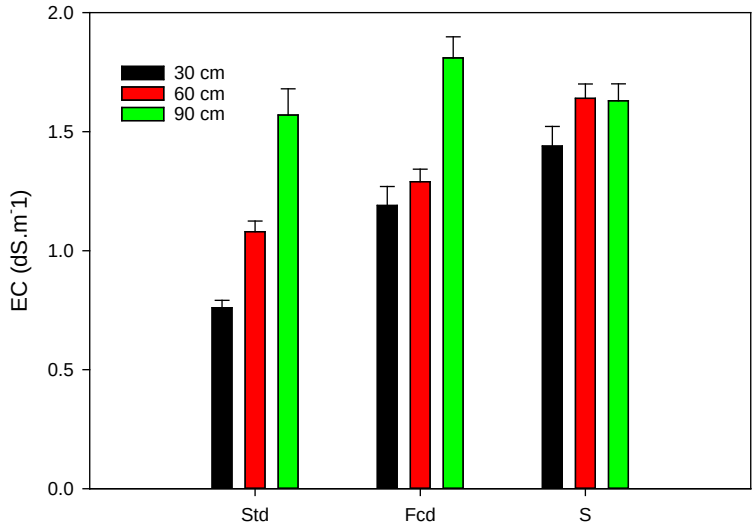


Figure 13 Salinity of water (EC dS.m^{-1}) for the mean of all seasons and irrigation volumes for three irrigation types for 30, 60 and 90 m depth. Vertical bars represent standard error for each soil depth.

The four-season data presented in Figure 13 were the result of a similar pattern in each season with standard irrigation recording the lowest rootzone salinity in each year (Figure 14) and rootzone salinity at 30 cm for all irrigation type being lowest for eight of the 12 grouped bars. The highest

recorded rootzone salinity was at depth for subsurface irrigation in the first season and by season four was similar to standard irrigation at 90 cm.

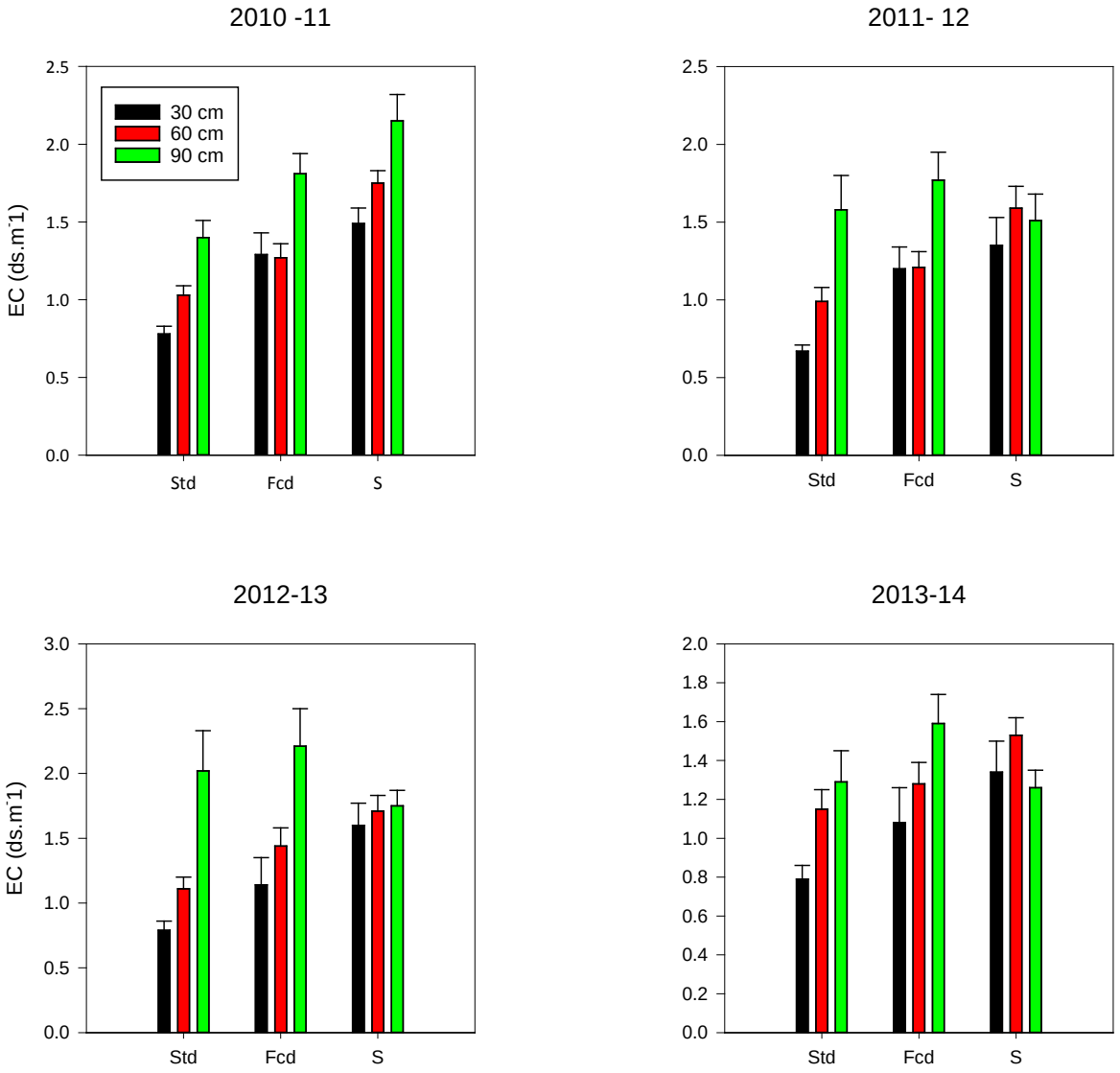


Figure 14 Salinity of water (EC dS.m^{-1}) for the mean of all irrigation volumes recovered from SoluSamplers at 30 60 and 90 cm depth for the three irrigation types in each of the four seasons. Vertical bars represent standard error for each soil depth.

Irrigation Volume

Increasing the volume of irrigation water applied normally results in potentially increased leaching of applied salt below the rootzone and is demonstrated in Figure 15. At 50% irrigation there was higher rootzone salinity at 90 cm for the three irrigation types indicating insufficient leaching of applied salt in the irrigation water. As the volume of irrigation increased, salinity at 90 cm declined with all readings being < 2 ds.m^{-1} and at 100% irrigation standard drip irrigation recorded the lowest salinity at each depth. Standard drip irrigation also recorded the lowest salinity at 30 cm depth for the 67% and 84% irrigation volumes, indicative of water being applied at the surface and percolating downwards while fabric covered subsurface drip recorded the lowest 30 cm salinity at 50% irrigation.

In summary these data indicate that there is no improvement in mean rootzone salinity through the use of subsurface irrigation with or without fabric covering when normal irrigation volumes are applied,

while there may be some minor improvement in overall rootzone salinity under restricted irrigation volumes.

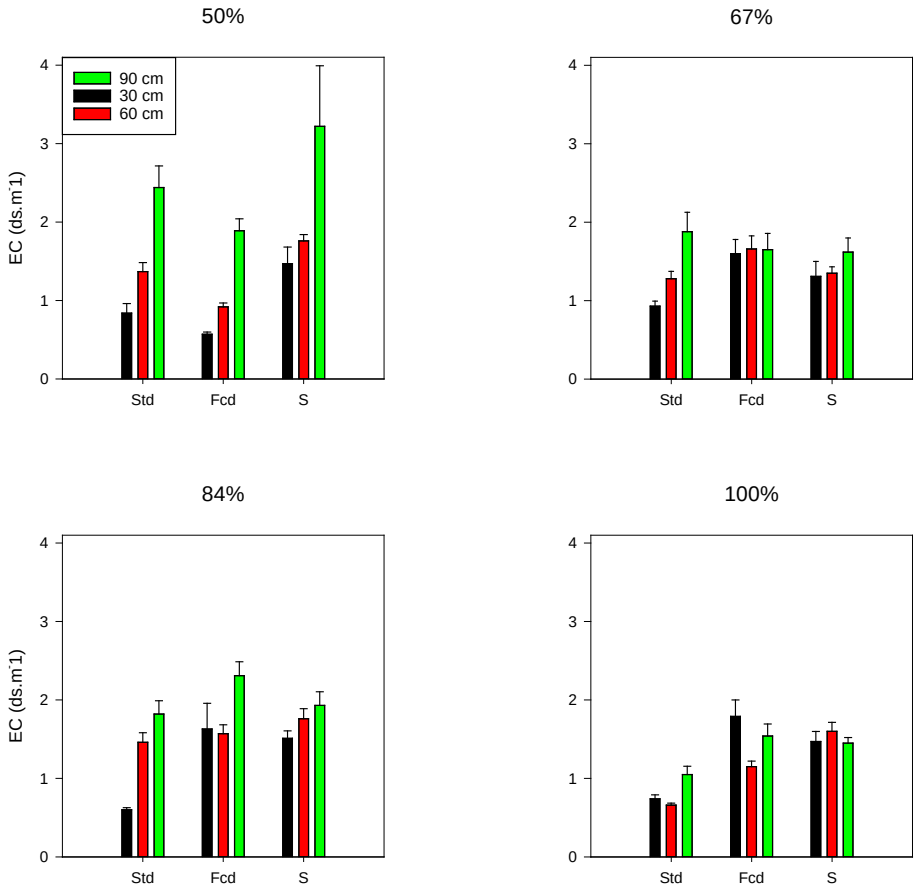


Figure 15 Salinity of water (EC dS.m^{-1}) for the mean of all years recovered at 30 60 and 90 cm depth for the four irrigation volumes and three irrigation types. Vertical bars represent standard error for each soil depth.

Outcome/Conclusion

The five-year field experiment reported here demonstrated that there was no yield or soil salinity improvement using subsurface drip irrigation, or the use of fabric covered subsurface drip for vineyard irrigation. This is contrary to a number of previously published reports. Only at the most severely restricted irrigation volume was there any benefit in yield with subsurface irrigation or the fabric covered subsurface drip designed to increase the lateral distribution of water in the profile.

Examination of the subsurface drip line at the conclusion of the experiment revealed a build-up of colloidal clay within the fabric envelope which may have affected its properties. Previous investigations have reported colloidal deposits around subsurface drippers when using irrigation water sourced from the Murray/Darling System. The Darling River is characterised by its high colloidal clay content under certain flow conditions and this may negate its use for subsurface irrigation both along the Darling and downstream of its confluence with the River Murray.

Recommendations

The data presented here indicate that subsurface irrigation may offer some advantages in sites where irrigation water is always severely restricted to quantities much lower than accepted crop water requirements, however, if moderate or high salinity irrigation water was the only water source, salt accumulation within the rootzone would need to be carefully monitored and remediated once thresholds were exceeded.

In situations where irrigation is not restricted the data presented here indicate that there are no water use savings from switching to either form of subsurface irrigation investigated in this five-year study.

Appendix 1: Communication

Phogat, V., McCarthy, M.G., Skewes, M., and Cox, J.W. (2014). Assessment of subsurface drip irrigation system for water balance, irrigation efficiency and water productivity of Chardonnay grapevine. Presented at Irrigation Australia 2014 Conference. Gold Coast Queensland, June 2014.

Phogat, V., Skewes, M., McCarthy, M.G., Cox, J.W., Šimůnek J., Petrie, P.R., (2017). Evaluation of crop coefficients, water productivity, and water balance components for wine grapes irrigated at different deficit levels by a sub-surface drip. Agricultural Water Management. 180, 22-34.

Phogat, V, Šimůnek, J., Skewes M.A., Cox J, W., McCarthy, M.G. (2016). Improving the estimation of evaporation by the FAO-56 dual crop coefficient approach under subsurface drip irrigation. Agricultural Water Management. 178, 189-200.

Appendix 2: Intellectual Property

None identified

Appendix 3: References

Biswas, T. (2008). A short notice on subsurface drip irrigation (SDI) in wine grapes for managing water, salt and nutrients. Internal draft SARDI March 2008.

Hayman, P.T. and M^{c}Carthy, M. (2013). Chapter 5 *in:* Schwabe, K**.** (Ed) Drought in arid and semi-arid regions. A multidisciplinary and cross-country perspective.. Springer.

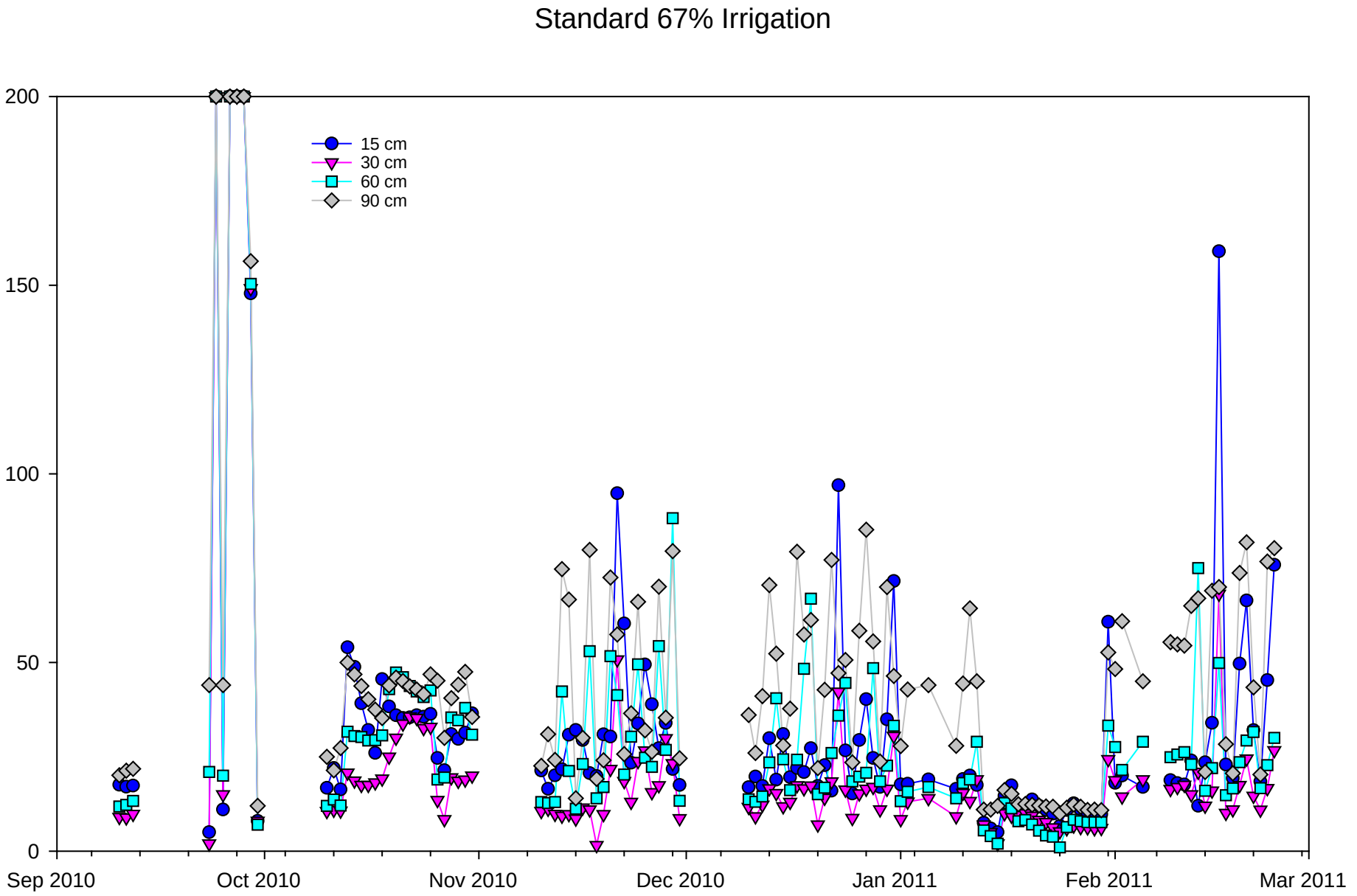
Hanson, B.R. and Bendixen, W.E. (1995). Drip irrigation controls soil salinity under row crops. California Agriculture July-August 1995,

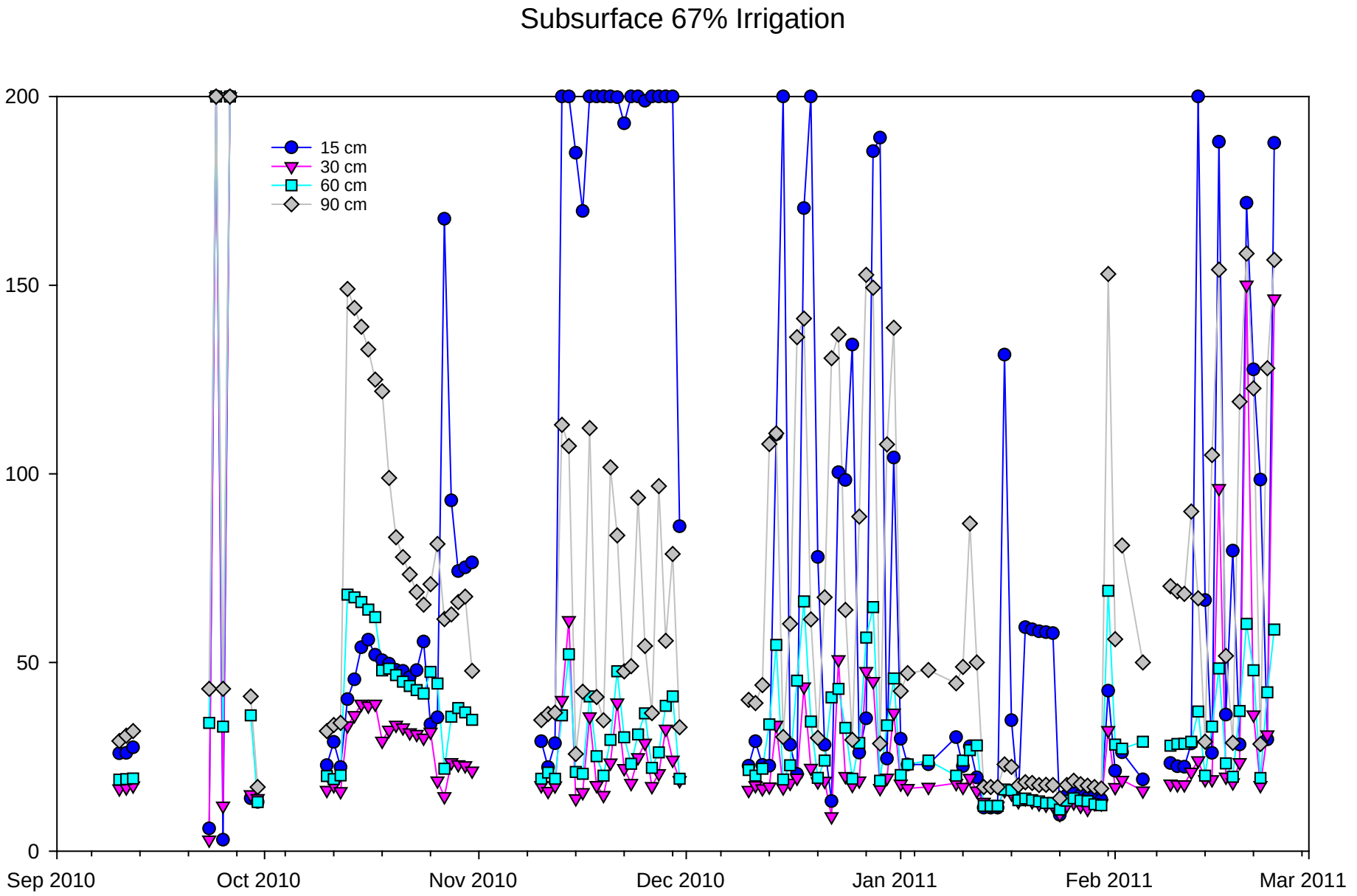
Appendix 4: Staff

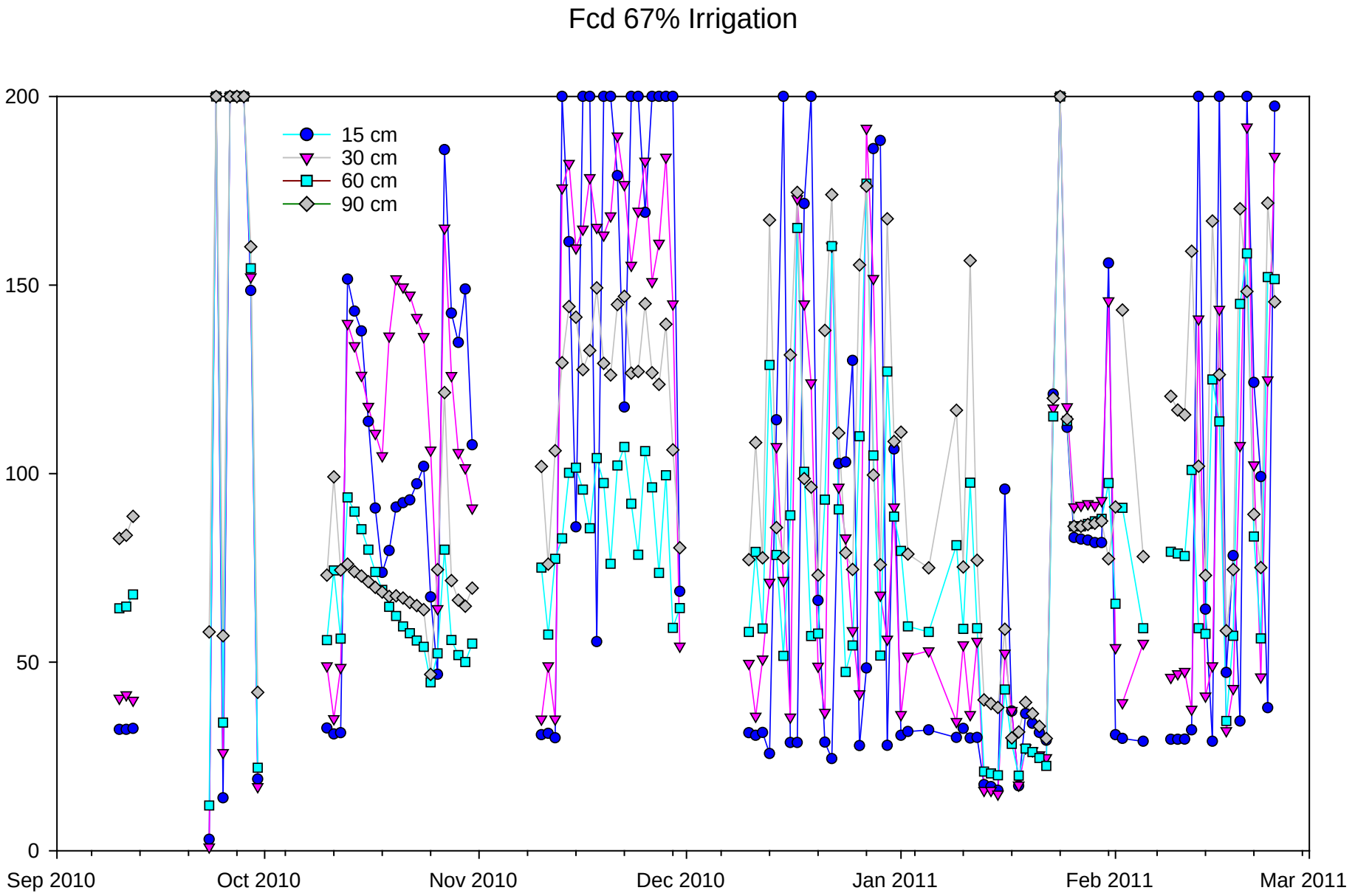
Ms. Emily Taylor, Dr. Mahalakshmi Mahadevan and Mr. Mark Skewes, SARDI Sustainable Systems ably assisted with the weekly SoluSampler and other data collection over the five years of the experiment. Staff from the SARDI Nuriootpa Research Centre and Dr. Paul Petrie and his staff from Treasury Wine Estates assisted in harvest which was always in temperatures approaching 40^{o}C.

Appendix 5: Additional Material

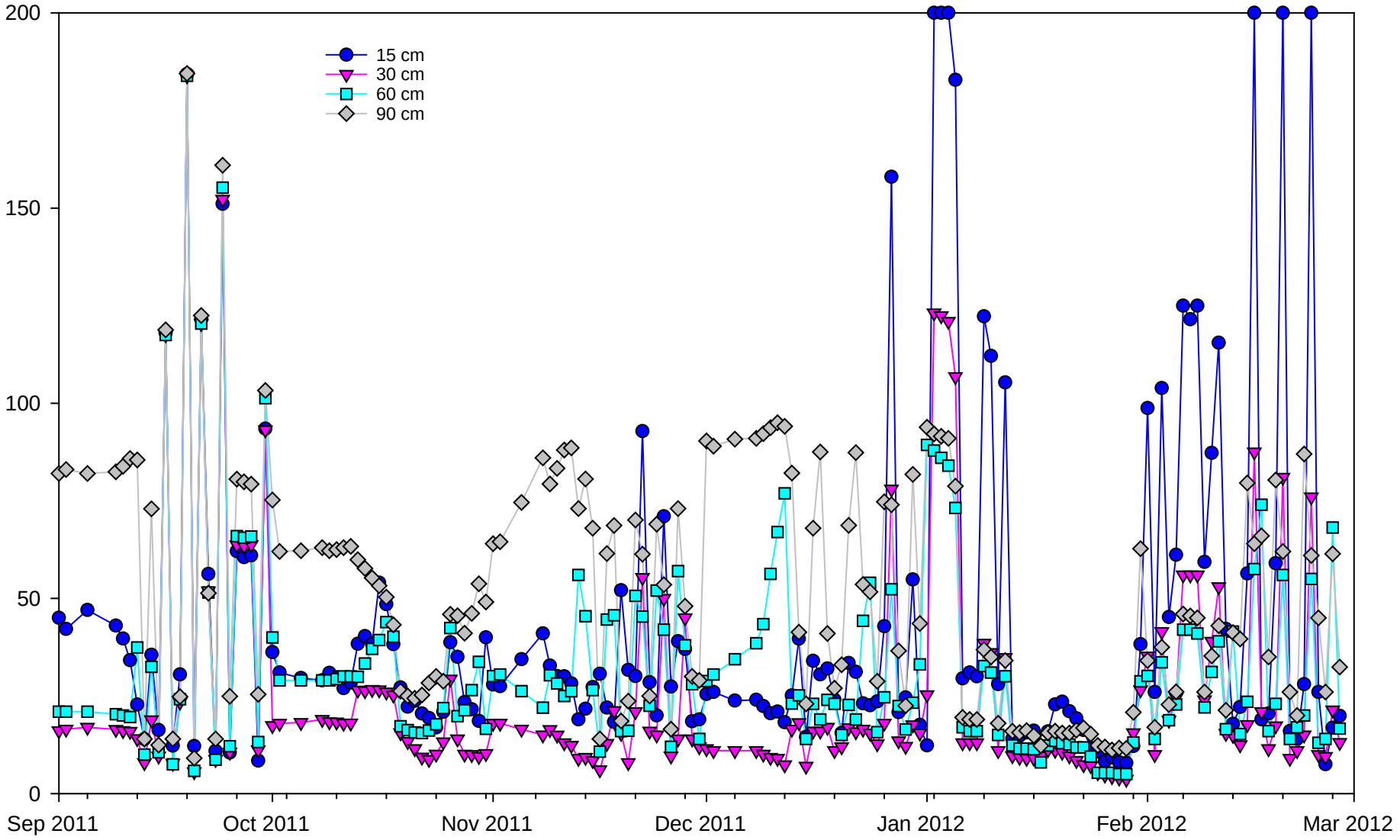
Two-hourly Gypsum Block readings at 15, 30, 60 and 90 cm depth from Standard, Subsurface and Fabric covered drip treatments irrigated at 67% of Control for seasons 2010-11, 2011-12 and 2012-13

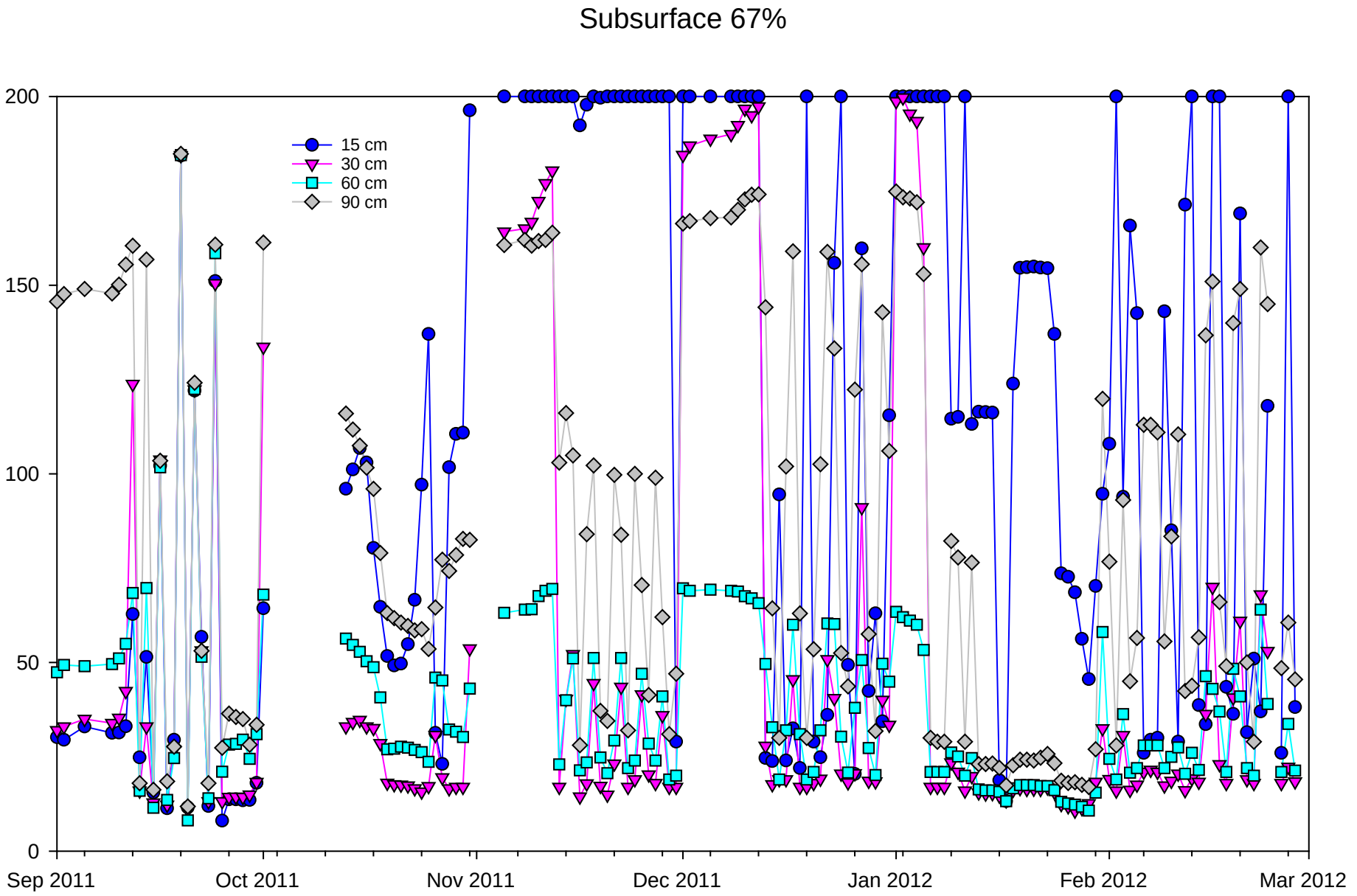

Standard 67% Irrigation
15 cm
30 cm
60 cm
90 cm
200
150
100
50
0
Sep 2010
Oct 2010
Nov 2010
Dec 2010
Jan 2011
Feb 2011
Mar 2011

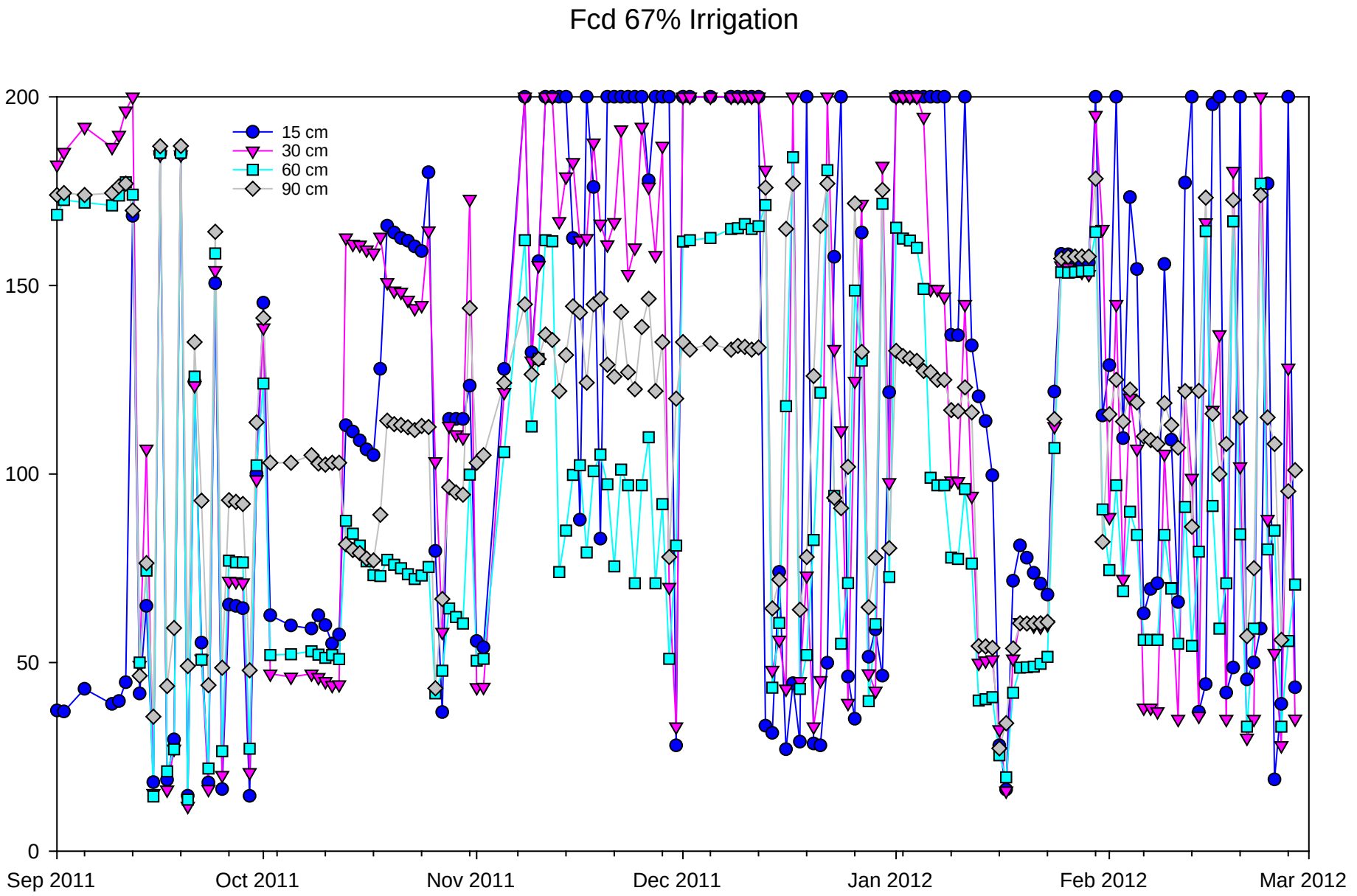

Subsurface 67% Irrigation
200
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0
15 cm
30 cm
60 cm
90 cm
Sep 2010
Oct 2010
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Jan 2011
Feb 2011
Mar 2011

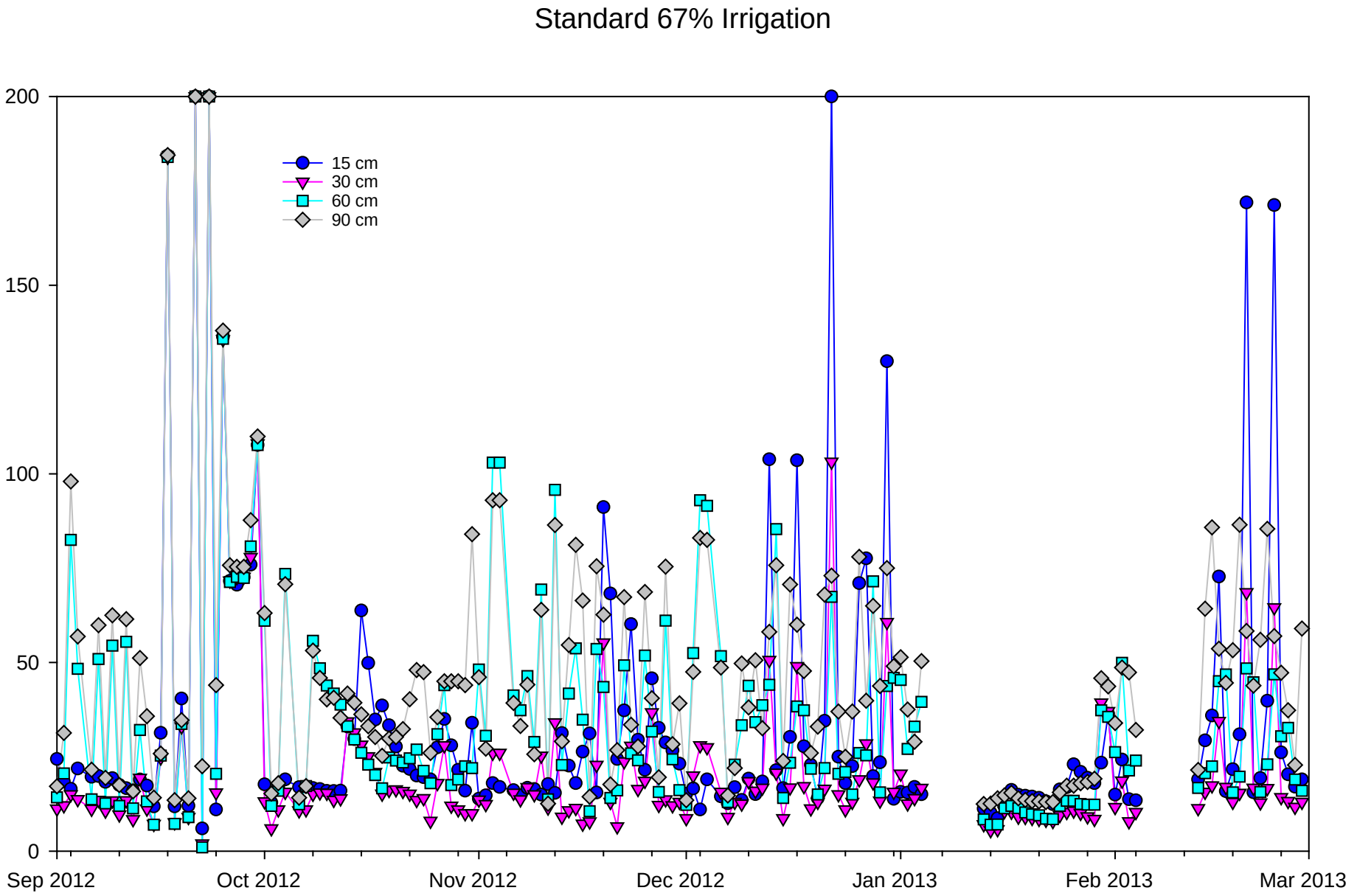

Fcd 67% Irrigation
15 cm
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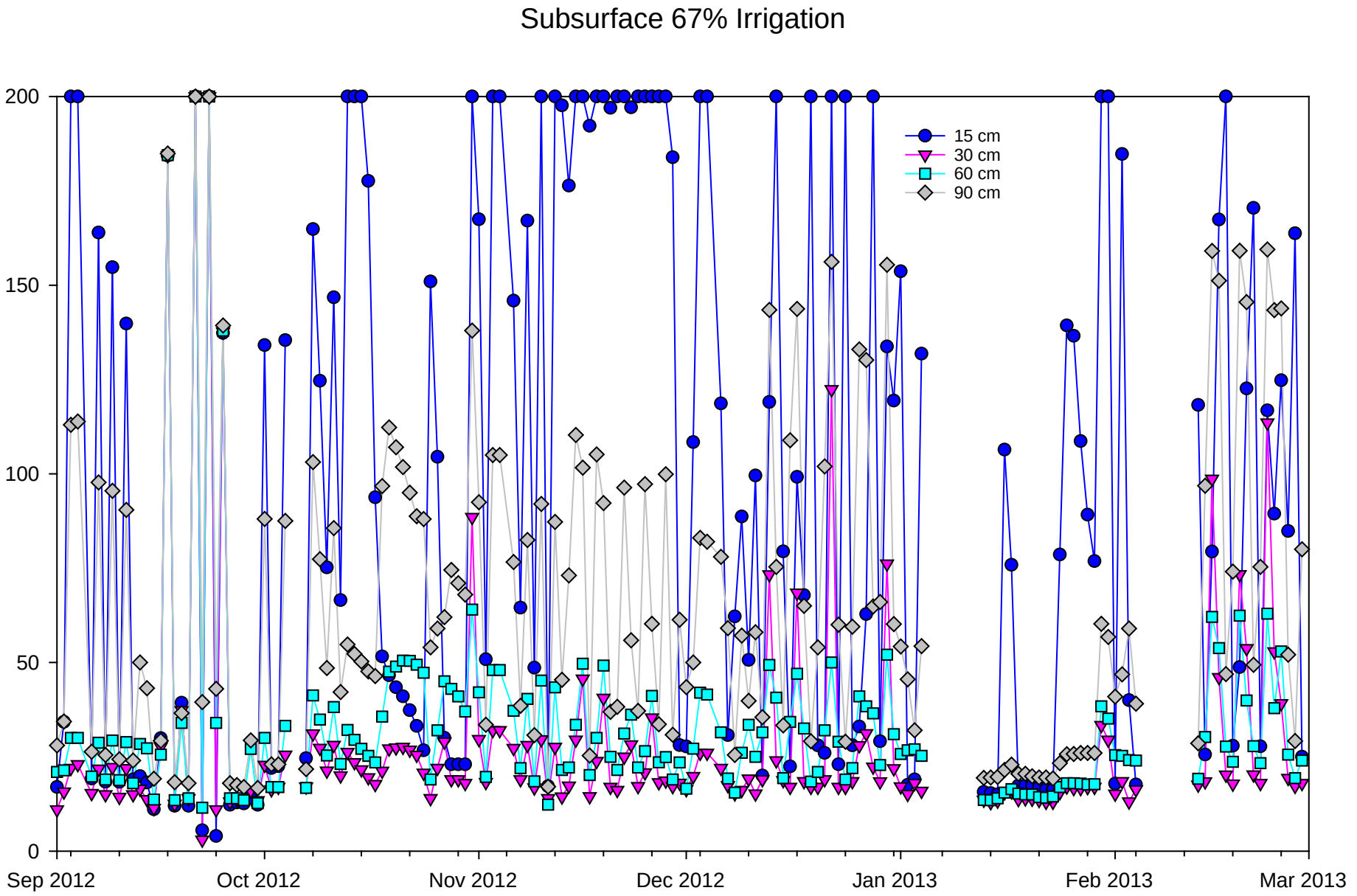
Standard 67% Irrigation




Subsurface 67%
15 cm
30 cm
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Sep 2011
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Feb 2012
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Fcd 67% Irrigation
15 cm
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Standard 67% Irrigation
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Subsurface 67% Irrigation
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Sep 2012
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Nov 2012
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Feb 2013
Mar 2013
15 cm
30 cm
60 cm
90 cm

Fcd 67% Irrigation

