



Effect of deficit irrigation and *in situ* moisture conservation on soil moisture content and frequency of irrigation in kiwifruit cultivar Allison

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Abstract: The effect of deficit irrigation and *in situ* moisture conservation in kiwifruit cv. Allison vines was studied during the years 2011 and 2012 in the Department of Fruit Science, Dr. Y. S. Parmar University of Horticulture and Forestry, Solan, HP, India. Soil moisture content and frequency of irrigation were investigated in kiwifruit in response to deficit irrigation and *in situ* moisture conservation techniques. Seven treatments viz., irrigation at 80 per cent Field Capacity (T₁), 60 per cent Field Capacity (T₂) and 40 per cent Field Capacity (T₃), 60 per cent Field Capacity (FC) plus grass mulch (T₄) or black polythene (T₅) and 40 per cent FC plus grass mulch (T₆) or black polythene (T₇) were applied from March to October with three replications in Randomized Block Design (RBD). During the year 2011, the soil moisture content under kiwifruit vines was highest under the treatment T₁ (15.3, 16.9), followed by T₅ (15.2, 16.8) and T₄ (14.9, 16.6) at 30 cm and at 60 cm soil depth, respectively. Whereas, during the year 2012, the soil moisture content under kiwifruit vines was highest under the treatment T₁ (14.9, 16.4), followed by T₅ (15.0, 16.3) and T₄ (14.6, 16.1) at 30 cm and at 60 cm soil depth, respectively. However, the least soil moisture content was, however, observed under T₃ (11.0, 12.8) at 30 cm and 60 cm soil depth, respectively, during the year 2011, similarly, during the year 2012, the least soil moisture content was also observed under T₃ (10.6, 12.7) at 30 cm and 60 cm soil depth, respectively. The frequency of irrigation was highest under T₁ (16 irrigations) followed T₂ (10 irrigations) while the least was recorded under T₆ and T₇ (7 irrigations). Total numbers of irrigations applied were reduced from 16 (under T₁) to 8 (under T₅). The use of black plastic mulch may be beneficial as it helped to conserve moisture under DI regime which is comparable to those in well irrigated vines. It may also reduce the high irrigation requirement of kiwifruit in areas where sufficient water is not available.

Keywords: Black plastic mulch, Deficit irrigation, Irrigation frequency, Kiwifruit, Soil moisture content

INTRODUCTION

The kiwifruit or Chinese gooseberry (*Actinidia deliciosa* Chev.) is a deciduous fruit vine, native to Yangtze valley of south and central China (Ferguson, 1984). The kiwifruit is a dioecious vine, bearing pistillate and staminate flowers separately. Kiwifruit requires 700-800 chilling hours below 7°C and the summer temperature should not go beyond 35°C (Lal *et al.*, 2010). The Kiwi fruit is unique in many ways. While most other fruits are attractive in appearance, it is dull brown in colour similar to Sapota. The flesh in cross section is however very beautiful and attractive. It is light green in colour and the seeds are soft and small. Interestingly some seeds of Chinese gooseberry i.e. Kiwi fruit were introduced in New Zealand in the beginning of 20th Century from China. New Zealand nurserymen realizing its potential as a new crop, developed cultivars and standardized its cultural practices.

In India, therefore it can be grown successfully in areas

situated at elevation of 900- 1800 m above mean sea level where, the winters are cold and summers are warm and humid, and receive well distributed annual rainfall of about 150 cm. It can be successfully grown in Jammu and Kashmir, Himachal Pradesh, Assam, Meghalaya, Nagaland, Mizoram and hills of Tripura. A deep friable sandy loam soil, well drained and supplied with irrigation is the best for growing kiwifruit vines. In Himachal Pradesh, the area under its cultivation is 121 ha with annual production of 625 metric tons (Anonymous, 2015).

In Himachal Pradesh, however, kiwifruit cultivation has extended to those areas where, demand for water exceeds that of local resources. The problem of water limitation may prove to be a more critical constraint to temperate fruit productivity in future due to global environmental change. Secondly, the kiwifruit vines are prone to water stress mainly because of their very large leaves and very high rate of water conductivity and transpiration rate. According to Goodwin (2009)

the water stress can be controlled under Regulated Deficit Irrigation by the application of short irrigations at specific soil moisture levels. The use of different mulching materials is known to be beneficial for *in situ* moisture conservation during the drought period (Guleria, 1986). Mulches also regulate soil temperature, prevent soil erosion, surface run-off of water and control the weeds. The aim of *in situ* moisture conservation and deficit irrigation is to maintain water stress within a desirable range so that the physiological reactions of the vine can be harnessed to the benefit of the kiwifruit grower. This type of work is of great importance in water scarce areas where the kiwifruit plants cannot fulfill their water requirement which resulted in reduction in fruit set, fruit growth and fruit size which ultimately leads to reduction in the overall production of kiwifruit.

MATERIALS AND METHODS

The present investigation was done during the years 2011 and 2012 in the Department of Fruit Science, Dr. Y. S. Parmar University of Horticulture and Forestry, Solan, HP, India. For this investigation, the uniform twenty five-year-old vines of kiwifruit cv. Allison, planted at 6x4 m spacing on T-bar training system were selected. The seven irrigation treatments viz., irrigation at 80 per cent (T₁), 60 per cent (T₂) and 40 per cent Field Capacity (T₃), 60 per cent Field Capacity (FC) plus grass mulch (T₄) or black polythene (T₅) and 40 per cent FC plus grass mulch (T₆) or black polythene (T₇) were applied from March to October and the mulching was applied in mid- March. These treatments were arranged in Randomized Block Design (RBD) with three replicates each of one kiwifruit vine. The statistical analysis of the data was carried out as per method described by Gomez and Gomez (1984). The significance of different treatment's effect was tested at 5 per cent level of significance as suggested by Cochran and Cox (1963).

Scheduling of irrigation: Basins (measuring 3x2 m size) of experimental vine were prepared and properly leveled at the start of the experiment in March. The first irrigation to the vines under each treatment was applied to bring the soil to field capacity level by flooding method. The soil moisture was allowed to deplete to 80, 60 and 40 per cent of field capacity in the respective treatments and then, it was again brought to field capacity by applying a measured quantity of water. The quantity of water applied to bring the soil moisture to field capacity in the vine basins during each irrigation in different treatments was determined with the aid of soil moisture characteristic curve.

Soil moisture characteristic curve: The composite soil samples from vine basins (0-60 cm) were taken. These samples were saturated with water for 24 hours and then subjected to -0.3, -0.5, -1.0, -5.0, -10.0 and -15.0 atmospheric pressure using Pressure Plate apparatus (Richard, 1949). The moisture contents of the

soil retained at different atmospheric pressure were determined by gravimetric method and expressed in per cent on dry weight basis (Table 1). On the basis of these observations, soil moisture characteristics curve was prepared to determine the amount of water retained by soil at different soil moisture levels, which served as a guideline to calculate the quantity of water to be applied to bring the moisture in soil at field capacity.

Calculation of quantity of water: The quantity of water applied to each experimental vine to bring the soil moisture to field capacity from 20, 40 and 60% depletion level was calculated as under:

Total quantity of water applied per vine = Ax d

Where, A= Basin area to be irrigated

d= Depth of irrigation water (cm)

The depth of irrigation water for each application was calculated by the following formula:

$$\text{Depth of irrigation water (d)} = \frac{\text{Pw} \times \text{Bd} \times \text{D}}{100}$$

Where,

Pw = Moisture percentage to be raised

Bd = Bulk density of the soil (1.31 gm/ cm³)

D = Depth of root- zone to be moistened (60 cm)

The quantity of water applied under each treatment on the basis of the above calculation was 198.1, 396.1 and 594.2 litres at 80, 60 and 40 per cent of field capacity levels, respectively.

Soil moisture: Soil moisture data were recorded using soil moisture profiler (AquaPro sensors) with soil moisture probe Model - AquaPro-PocketPro Logger by lowering the probe at 30 and 60 cm depth down the access tubes installed in the basins of each experimental vine. The readings were taken at fortnightly intervals during the growing season and average values were expressed in percentage.

Frequency and number of irrigation: Frequency of the irrigation applied under different treatments was calculated by counting the number of days between two consecutive irrigations. The number of irrigations applied under these treatments over the growing period was calculated during both the year of study.

RESULTS AND DISCUSSION

Soil moisture: The soil moisture content fluctuated greatly during the growing season of kiwifruit from March to October in both the years (Figures 1 & 2), however it also varied with different irrigation treat-

Table 1. Soil moisture level at different atmospheric tensions in kiwifruit vineyard.

Tension (bars)	Moisture (%)
-0.3	21.03
-0.5	17.80
-1.0	13.57
-5.0	7.87
-10.0	6.07
-15.0	4.82

Table 2. Effect of irrigation and mulching treatments on periodic soil moisture contents at 30 cm and 60 cm depth under the vines of kiwifruit cv. Allison during the year 2011.

Date of observation	Soil moisture content (%) during the year 2011													
	At 30 cm soil depth							At 60 cm soil depth						
	T1	T2	T3	T4	T5	T6	T7	T1	T2	T3	T4	T5	T6	T7
15-Mar	17.7	17.2	14.5	17.4	17.6	14.6	14.8	18.9	18.4	15.5	18.6	18.8	15.6	15.8
30-Mar	17.3	16.8	12.5	17	17.2	12.5	12.8	18	17.5	13.2	17.7	17.9	13.4	13.6
15-Apr	12.2	11.7	11.5	11.8	12.1	11.6	11.8	14.3	13.8	14	14	14.2	14.1	14.3
30-Apr	17.5	17	13.5	17.2	17.4	13.7	13.9	19.4	18.9	15.3	19.1	19.3	15.4	15.6
15-May	15.3	14.8	10.5	14.9	15.4	10.7	10.9	15.5	15	11.3	15.1	15.2	11.4	11.7
30-May	19.5	19	11.7	19.2	19.4	11.8	12	20.5	20	16.5	20.3	20.4	16.6	16.8
15-Jun	17.3	16.8	10.4	17.9	17.2	10.5	10.7	17.7	17.2	8	17.4	17.6	8.5	9
30-Jun	17.5	17	9.6	17.3	17.4	9.7	9.9	18.9	18.4	9.5	18.5	18.8	9.6	9.8
15-Jul	17.5	17	9.8	17.2	17.4	9.9	10.1	19.3	18.8	15	18.9	19.2	15.2	15.4
30-Jul	15.5	15	12.5	15.3	15.4	12.7	12.9	19.5	19	14.9	19.2	19.4	15.2	15.5
15-Aug	13.8	13.3	10.5	13.4	13.7	10.6	10.8	17	16.5	15	16.8	16.9	15.2	15.6
30-Aug	11.5	11	9.8	11.2	11.4	9.9	10.2	14.9	14.4	13	14.6	14.8	13.1	13.4
15-Sep	14.8	14.3	11.5	14.4	14.7	11.7	11.8	15.3	14.8	11.2	14.9	15.2	11.3	11.5
30-Sep	14.2	13.7	10	13.8	14.1	10.2	10.4	17.3	16.8	12.2	16.9	17.2	12.5	12.7
15-Oct	11.3	10.8	9	10.9	11.2	9.2	9.4	12.6	12.1	10.7	12.3	12.5	10.8	11.1
30-Oct	11.2	10.7	8.5	10.8	11.1	8.6	8.8	11.8	11.3	9.8	11.5	11.7	10	10.3

Table 3. Effect of irrigation and mulching treatments on periodic soil moisture contents at 30 cm and 60 cm depth under the vines of kiwifruit cv. Allison during the year 2012.

Date of observation	Soil moisture content (%) during the year 2012													
	At 30 cm soil depth							At 60 cm soil depth						
	T1	T2	T3	T4	T5	T6	T7	T1	T2	T3	T4	T5	T6	T7
15-Mar	17.5	17	14	17.1	17.4	14.4	14.6	19	18.5	15.7	18.6	18.9	15.9	16.1
30-Mar	17.4	16.9	12	17.2	17.3	12.3	12.5	18	17.5	13.3	17.7	17.9	13.6	13.8
15-Apr	14.3	13.8	11	14	17.2	11.2	11.5	17.4	16.9	14.1	17.1	17.3	14.2	15.5
30-Apr	18.1	17.6	13	17.8	18	13.3	13.6	18.8	18.3	15.5	18.4	18.7	15.7	15.9
15-May	14.7	14.2	10	14.4	14.6	10.2	10.5	16.1	15.6	11.4	15.8	16	11.6	11.8
30-May	20	19.5	11	19.7	19.9	11.1	11.3	20.9	20.4	16.6	20.6	20.8	16.7	16.9
15-Jun	12.7	12.2	10	12.3	12.6	10.2	10.5	11.3	10.8	8.1	10.9	11.2	8.4	8.7
30-Jun	11.4	10.9	9.1	11	11.3	9.3	9.7	11.9	11.4	9.5	11.5	11.8	9.7	9.9
15-Jul	14.5	14	9.8	14.2	14.4	10.1	10.4	18.7	18.2	15.1	18.4	18.6	15.3	15.5
30-Jul	18.1	17.6	12	17.8	18	12.2	12.6	18.9	18.4	15.2	18.6	18.8	15.5	15.8
15-Aug	14	13.5	10	13.7	13.9	10.3	10.5	17.5	17	13.1	17.2	17.4	13.3	13.7
30-Aug	11.7	11.2	9.5	11.4	11.6	9.8	10.1	15	14.5	11.5	14.7	14.9	11.7	11.9
15-Sep	15.3	14.8	11	15	15.2	11.2	11.5	15.6	15.1	10.3	15.2	15.5	10.8	10.8
30-Sep	14.3	13.8	9.8	14	14.2	10.2	10.5	17.5	17	13.3	17.2	17.4	13.5	13.9
15-Oct	12.4	11.9	8.8	12.1	12.3	9.3	9.6	13.1	12.6	10.5	12.8	13	10.8	11
30-Oct	12	11.5	8.2	11.7	11.9	8.4	8.6	12.7	12.2	9.7	12.4	12.6	9.9	11.3

Note: * the values of soil moisture content in tables 2 & 3 are average of 3 replicates in each treatment.

Table 4. Dates of irrigation given to kiwifruit vines under different treatments (2011).

Irrigation at 80 % of FC		Irrigation at 60 % FC		Irrigation at 40 % FC		Irrigation at 60% FC+ GM		Irrigation at 40% FC+ BM		Irrigation at 40% FC+ GM		Irrigation at 40% FC+ BM	
Date of irrigation	Interval (days)	Date of irrigation	Interval (days)	Date of irrigation	Interval (days)	Date of irrigation	Interval (days)	Date of irrigation	Interval (days)	Date of irrigation	Interval (days)	Date of irrigation	Interval (days)
15.03.2011	-	15.03.2011	-	15.03.2011	-	15.03.2011	-	15.03.2011	-	15.03.2011	-	15.03.2011	-
22.03.2011	7	25.03.2011	10	27.03.2011	12	29.03.2011	14	31.03.2011	16	02.04.2011	18	05.4.2011	21
29.03.2011	7	12.04.2011	18	19.04.2011	23	16.04.2011	18	19.04.2011	19	03.05.2011	31	10.05.2011	35
5.04.2011	7	10.05.2011	28	12.05.2011	23	12.05.2011	26	17.05.2011	28	15.06.2011	43	23.06.2011	44
19.04.2011	14	24.05.2011	14	14.06.2011	33	17.06.2011	36	28.06.2011	42	06.08.2011	52	20.08.2011	58
3.05.2011	14	21.06.2011	28	01.08.2011	48	6.08.2011	50	26.08.2011	59	24.09.2011	39	30.09.2011	41
17.05.2011	14	30.07.2011	39	08.09.2011	38	9.09.2011	34	30.09.2011	35	25.10.2011	21	29.10.2011	29
31.05.2011	14	12.08.2011	13	01.10.2011	27	8.10.2011	29	30.10.2011	30				
14.06.2011	14	14.09.2011	33										
28.06.2011	14	11.10.2011	27	8	8	8	8	8	8	7	7	7	7
26.07.2011	28												
16.08.2011	21												
06.09.2011	21	10											
27.09.2011	21												
11.10.2011	14												
18.10.2011	7												

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Table 5. Dates of irrigation given to kiwifruit vines under different treatments (2012).

Irrigation at 80 % of FC		Irrigation at 60 % FC		Irrigation at 40 % FC		Irrigation at 60% FC+ GM		Irrigation at 40% FC+ BM		Irrigation at 40% FC+ GM		Irrigation at 40% FC+ BM	
Date of irrigation	Interval (days)	Date of irrigation	Interval (days)	Date of irrigation	Interval (days)	Date of irrigation	Interval (days)	Date of irrigation	Interval (days)	Date of irrigation	Interval (days)	Date of irrigation	Interval (days)
14.03.2012	-	14.03.2012	-	14.03.2012	-	14.03.2012	-	14.03.2012	-	14.03.2012	-	14.03.2012	-
20.03.2012	6	23.03.2012	9	25.03.2012	11	27.03.2012	13	30.03.2012	16	04.04.2012	21	06.04.2012	23
27.03.2012	7	11.04.2012	19	18.04.2012	24	16.04.2012	20	22.04.2012	23	02.05.2012	28	09.05.2012	33
04.04.2012	8	07.05.2012	26	11.05.2012	23	11.05.2012	25	20.05.2012	28	2.06.2012	31	15.06.2012	37
18.04.2012	14	23.05.2012	16	12.06.2012	32	15.06.2012	35	25.06.2012	36	5.08.2012	66	22.08.2012	68
02.05.2012	14	21.06.2012	29	03.08.2012	52	5.08.2012	51	17.08.2012	53	11.09.2012	37	29.09.2012	40
16.05.2012	14	1.08.2012	41	08.09.2012	36	9.09.2012	35	23.09.2012	37	10.10.2012	29	29.10.2012	30
12.06.2012	27	11.08.2012	10	05.10.2012	27	8.10.2012	29	26.10.2012	33				
25.06.2012	13	14.09.2012	34										
13.07.2012	18	10.10.2012	26										
28.07.2012	15			8	8	8	8	8	8	7	7	7	7
14.08.2012	17												
14.09.2012	31	10											
25.09.2012	11												
08.10.2012	13												
19.10.2012	11												

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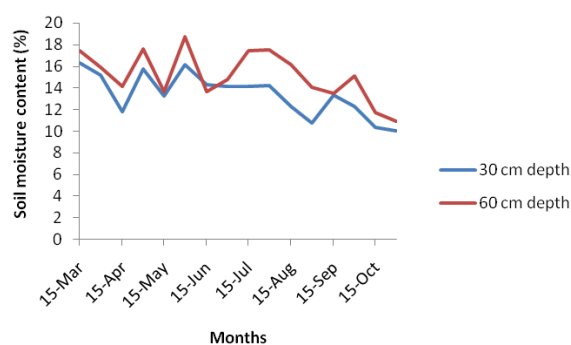


Fig. 1. Periodic variation in average soil moisture content (%) of kiwifruit cv. Allison under different irrigation levels and in situ moisture conservation treatments at 30 cm and 60 cm soil depths during the year 2011.

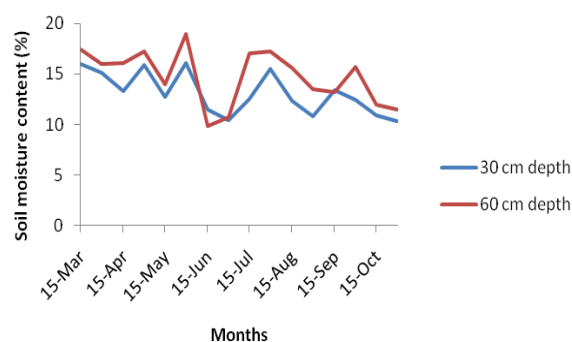


Fig. 2. Periodic variation in average soil moisture content (%) of kiwifruit cv. Allison under different irrigation levels and in situ moisture conservation treatments at 30 cm and 60 cm soil depths during the year 2012.

ments, *in situ* moisture conservation techniques and with both the soil depths at 30 and 60 cm. In the year 2011, at 30 cm of soil depth greatly higher soil moisture content was recorded in the month of May under T₁, T₄ & T₅ and the least soil moisture contents were observed in T₃ in the month of October. However, at 60 cm depth the soil moisture content was highest in the month of May under T₁ followed by T₅ and T₄ during the same period (May month) and the least was observed under T₃ in June (Table 2). During the year 2012, the highest soil moisture content at 30 cm soil depth (20 %) was recorded in the month of May under T₁, followed by T₅ and T₄ in the decreasing order and the least moisture level was observed in October under the vines subjected to T₃. Whereas, at 60 cm depth, the highest soil moisture content (20.9%) was recorded in the month of May under T₁, followed by T₅ and T₄ and the least was observed under vines subjected to T₃, in the month of June (Table 3).

During the year 2011 at 30 cm soil depth the soil moisture content of kiwifruit cv. Allison was highest under the treatment T₁ (15.08), followed by T₅ (15.07) and T₄ (14.78) and at 60 cm soil depth the soil moisture content in kiwifruit vines was also recorded to be highest under T₁ (16.66), followed by T₅ (16.56) and T₄ (16.33) (Table 2)*. During the year 2012, at 30 cm soil depth, the increase in soil moisture content was more under black plastic mulch (0.49%, 0.44) than under grass mulching (0.20, 0.20) over the respective Deficit Irrigation (DI) treatments given without mulching i.e. irrigation at 60 per cent FC and 40 per cent FC, respectively. Whereas, at 60 cm soil depth, the increase in soil moisture content was however, more under black plastic mulch (0.39%, 0.52) than under grass mulching (0.17, 0.19) over the respective DI treatments without mulching. The least soil moisture content was, however, observed under T₃ (10.78 at 30 cm and 12.75 at 60 cm soil depth) (Table 3)*.

Frequency and number of irrigations: The data pertaining to the frequency and number of irrigations under various levels of irrigation treatments revealed that the

irrigation interval fluctuated not only among the treatments but also during different periods of growing season (Table 4 & 5). The maximum frequency of irrigation was recorded under irrigation applied at 80% of Field Capacity followed by irrigation at 60% of Field Capacity plus black polythene mulch treatment. The lowest frequency of irrigation was found under the irrigation treatment applied at 40% of Field Capacity. Total numbers of irrigations applied were reduced from 16 under T₁ to 8 under T₅. It is clear from present findings that under moderate water stress condition, the use of black plastic mulch may be beneficial as it helped to conserve moisture under DI regime which is comparable to those in well irrigated vines. It may also reduce the high irrigation requirement of kiwifruit in areas where sufficient water is not available. Earlier, it has been reported that the soil moisture decreased with Deficit Irrigation in young kiwifruit (Gucci *et al.*, 1996); in Grape cv. Cabernet Sauvignon (Boselli *et al.*, 1998); in Wine Grapes (Centeno *et al.*, 2010) and increased with straw and plastic mulching in grape cv. Perlette (Phadung *et al.*, 2005); with organic mulches plus pan evaporation replenishment (PER) treatment in Mango var. Lal Sundari (Kumar *et al.*, 2008). Total numbers of irrigations applied were reduced from 16 under standard irrigation to 8 under the treatment of Deficit Irrigation (DI) at 60 % Field Capacity plus black polythene mulching, during both the years. Thus, the present findings clearly demonstrated that under moderate water stress condition, the use of black plastic mulch may be beneficial as it helped to conserve moisture under DI regime and resulted in fruit quality and production attributes comparable to those in well irrigated vines. It may also reduce the high irrigation requirement of kiwifruit in areas where sufficient water is not available.

Conclusion

In conclusion, the present study suggests that the soil moisture content decreased linearly with the water deficit condition. However, the mulch application to

moderately water stressed kiwifruit vines markedly increase the soil moisture content. The increase in soil moisture content was however, more under black plastic mulch than under grass mulching over the respective DI treatments given without mulching. The least soil moisture content was, however, observed under irrigation treatment at 40% FC. The soil moisture content at 30 cm and 60 cm depths is also affected by various treatments and type of mulch material. The frequency and total number of irrigation under deficit irrigation condition alone is more, compared to those which are applied along with mulching. The total number of irrigations were reduced from 16 under standard irrigation (T₁) to 8 under deficit irrigation at 60 per cent Field Capacity along with black plastic mulch (T₅). It is clear from present findings that under moderate water stress condition, the use of black plastic mulch may be beneficial as it helped to conserve moisture under DI regime which is comparable to those in well irrigated vines. It may also reduce the high irrigation requirement of kiwifruit in areas where sufficient water is not available.

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