Chapter 3

Microcatchment water harvesting systems for fruit trees and shrubs

Chapter 3: Microcatchment water harvesting systems for different fruit trees and shrubs

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3.1 Introduction

Jordan depends on annual rainfall, estimated at 8500 million m^3, for water for its domestic and irrigation needs since there are no rivers or lakes in Jordan, and the River Jordan is almost dry. Therefore, the utilization of surface water has been the focus of the Jordanian government for decades. Many dams have been built in the Jordan Valley and other places in Jordan to secure water for irrigation; however, a large percentage of this water has been shifted from irrigation to domestic use.

The water reserved behind dams (i.e. macrocatchment water harvesting) is used to irrigate land downstream through complicated and expensive irrigation systems, and so there was an urgent need to find a way to supplement the rainfed irrigated area located in the highlands, particularly those in the eastern desert of Jordan (called the Badia) by using microcatchment water harvesting (WH) systems.

Microcatchment WH is recognized as useful technique in improving vegetation and reducing land degradation. In the last ten years, increasing attention has been given by the Jordanian Government and farmers to microcatchment WH systems in the low rainfall zones (< 250 mm) to enable production of crops which require 300–400 mm of rainfall.

Experiments were conducted for four years (2002/03–2005/06) using the following microcatchment WH systems:

- Small runoff basins and semicircular bunds for fruit trees
- Ridges for shrubs
- Runoff strips for field crops (only 2002/03 and 2003/04 seasons)

The results obtained from the 2002/03 and 2003/04 seasons were encouraging for the small runoff basins, semicircular bunds, and ridges. However, the use of runoff strips to produce field crops did not significantly increase yields compared to not using the WH system. Thus the runoff strips were not used in the experiments of 2004/05 and 2005/06.

Since manually constructing the ridges is costly and time consuming, the Vallerani implement (Photo 3.1) was used to construct the ridges, up to 5 m long, 0.5 m wide, and up to 0.5 m deep, at an average rate of 400 bits/h at estimated cost

Photo 3.1. (a) The Vallerani implement, (b) the field after implementing the microcatchments, (c) target basins full of runoff water after a rainstorm and (d) small ruminants grazing shrubs after two seasons

of US$0.15/bit; compared to US$1.50/bit at a rate of 8 bits/d if done manually. The Vallerani implement can also make continuous contour ridges at a rate of 1 ha/h with 5-m spacing between ridges.

The Vallerani implement is a mounted reversible single-furrow plow, fitted with a subsoiler with a mechanism for gathering the surface fertile layer of soil and depositing it at regular and selected pre-set programmable intervals in the furrow in order to create ridges.

This report will focus on results of 2004/05 and 2005/06 seasons in which the conventional handmade microcatchment was compared to the mechanized one through research done at the Jordan University of Science and Technology site.

3.2 Materials and methods

3.2.1 Site specification

The experiment site, on the Jordan University of Science and Technology (JUST) campus at Ramtha City, is located at 32° 33' N, 35° 51' E and 520 m altitude. It is located in the semiarid zone in which the average annual rainfall is < 250 mm with an erratic distribution over the rainy season, which starts in October and ends in May (Tables 3.1a and 3.1b, and Figure 3.1).

An area of 12 ha of land located on the north east of JUST campus was selected (Figure 3.2). This piece of land was surveyed and the topographical map drawn. Soil profile description and analysis of the study area is shown in (Table 3.2).

3.2.2 Methodology

Four microcatchment WH systems were tested:

- Runoff basins
- Semicircular bunds
- Conventional ridges
- Mechanized ridges using Vallerani implement (Photo 3.1).

Runoff basins and semicircular bunds

The experiment was conducted on a 4-ha area. The experiment was a Completely

Table 3.1a. Monthly and seasonal rainfall distribution (mm) at Ramtha station for 1994/95–2005/06 seasons.

Season/ Month	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
1994/95	0.0	4.0	146.2	73.5	3.4	27.2	18.5	6.3	6.8	285.9
1995/96	0.0	0.0	0.0	31.1	52.6	7.0	58.2	3.9	0.0	152.8
1996/97	0.0	15.4	27.3	20.3	54.8	69.1	48.8	11.5	0.8	248.0
1997/98	2.9	26.7	27.5	60.3	64.9	31.9	76.5	4.4	5.6	300.7
1998/99	0.0	0.0	0.5	13.8	30.7	29.2	15.7	10.8	0.0	100.7
1999/00	0.0	0.0	0.0	7.6	94.1	20.2	19.0	0.0	0.0	140.9
2000/01	0.0	37.0	0.0	23.4	15.4	41.8	18.3	3.6	6.6	146.1
2001/02	0.0	3.7	23.2	55.0	73.8	19.1	66.0	32.0	0.6	273.4
2002/03	0.0	0.0	17.2	111.1	31.5	141.0	71.4	10.1	0.6	382.9
2003/04	0.0	14.8	5.3	65.0	58.1	44.4	17.7	2.8	3.1	211.2
2004/05	0.0	22.8	48.8	19.6	32.2	86.9	20.0	7.1	3.0	240.4
2005/06	0.0	5.3	14.6	30.0	50.8	49.5	8.8	29.7	0.0	188.7
Average	0.2	10.8	25.9	42.6	46.9	47.3	36.6	10.2	2.3	222.6

Table 3.1b. Monthly and seasonal rainfall distribution (mm) at the newly established weather station on JUST campus close to the experimental site for 2002/03–2005/06 seasons.

Season/ Month	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
2002/03	0.0	0.0	5.0	113.8	26.4	162.3	77.6	9.5	0.0	394.6
2003/04	0.0	6.2	15.2	63.5	47.4	63.5	18.0	3.5	7.8	225.1
2004/05	0.0	16.0	52.5	19.5	30.7	91.0	8.0	2.4	3.5	223.6
2005/06	0.0	0.0	18.3	24.3	46.6	76.1	9.2	33.0	0.0	207.5
Average	0.0	5.6	22.8	55.3	37.8	98.2	28.2	12.1	2.8	281.1

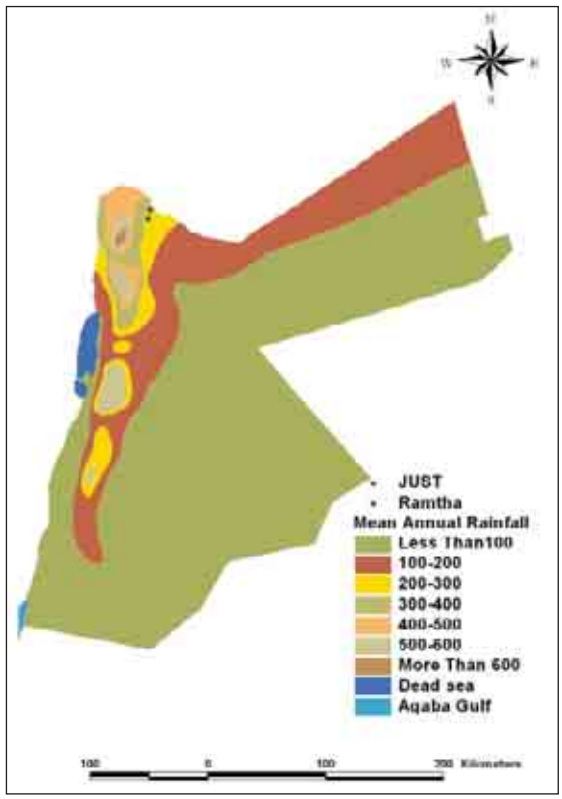

Figure 3.1. Mean annual rainfall in Jordan and location of the experimental site.

Randomized Design (CRD) in a split-plot arrangement, microcatchment types in the main plots, and microcatchment size in the subplots (Figures 3.3 and 3.4, and Photos 3.2 and 3.3). Fruit trees species selected for the experiment were pistachio (*Pistachio vera*), wild almond (*Prunus dulcis*), and olive (*Oleas europea*). Weeds grown on the plots were removed manually.

Table 3.2. Soil analyses of the experimental site.

Soil depth (cm)	0–20	20–40
pH	8.08	8.18
EC (ds/m)	1.006	0.445
Nitrogen (%)	0.083	0.107
Phosphorus (µg P/g soil)	58.3	41.1
Soil particle size distribution		
Clay (%)	59.25	48.40
Silt (%)	23.75	26.40
Sand (%)	16.95	25.20
Texture	Clay silty loam	Clay silty loam
Infiltration rate planted area	8.4 cm/h	
Infiltration rate Catchment area (compacted)	6.0 cm/h	
Infiltration rate Catchment area (control)	7.2 cm/h	

The applied treatments differed according to species:
Pistachio trees received two microcatchment type treatments: runoff basins and semicircular bunds with three catchment area treatments: 36, 64, and 100 m^2 with 12 replicates.

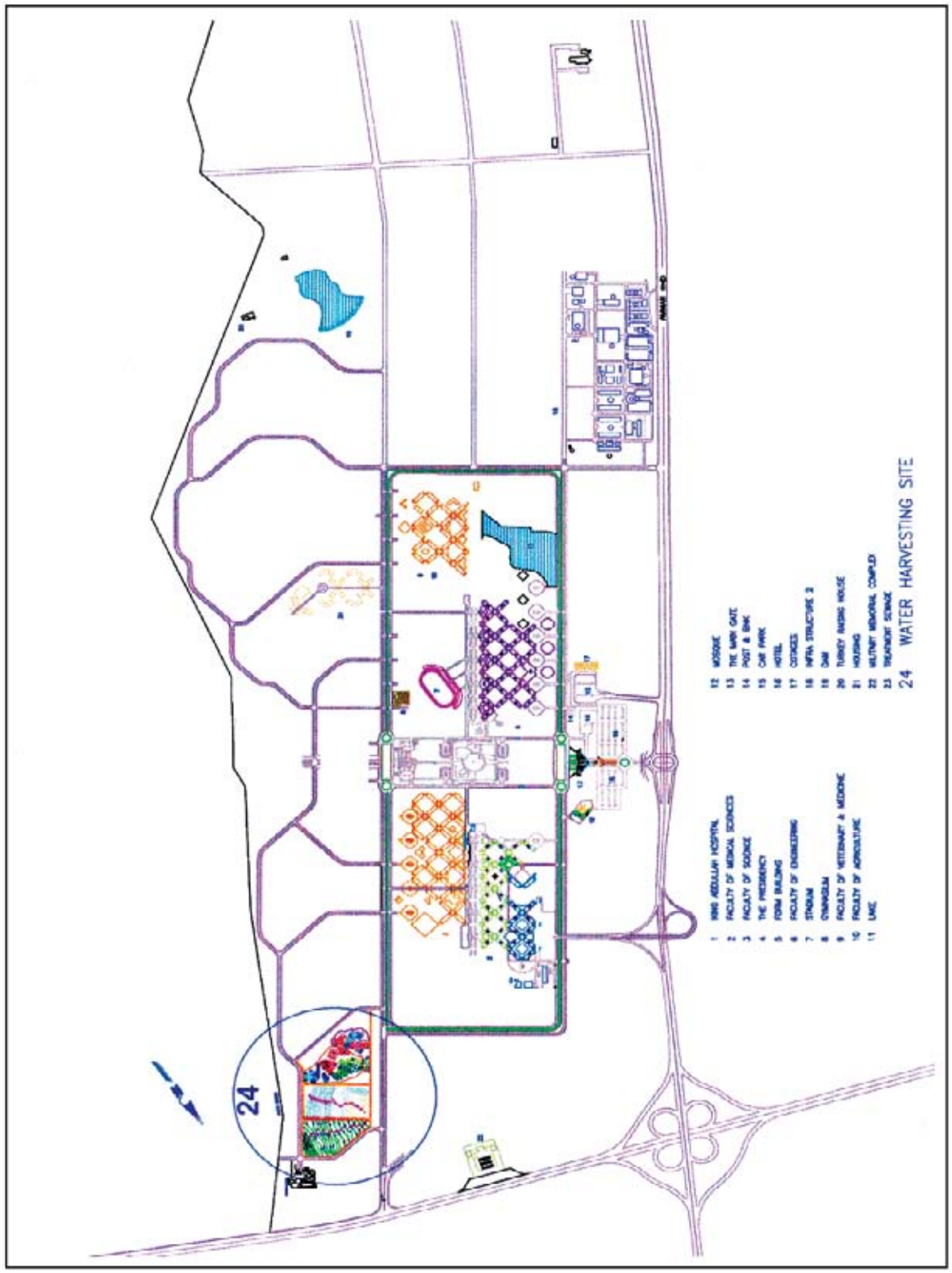

Figure 3.2. Location and layout of the water harvesting experimental site on the JUST campus.

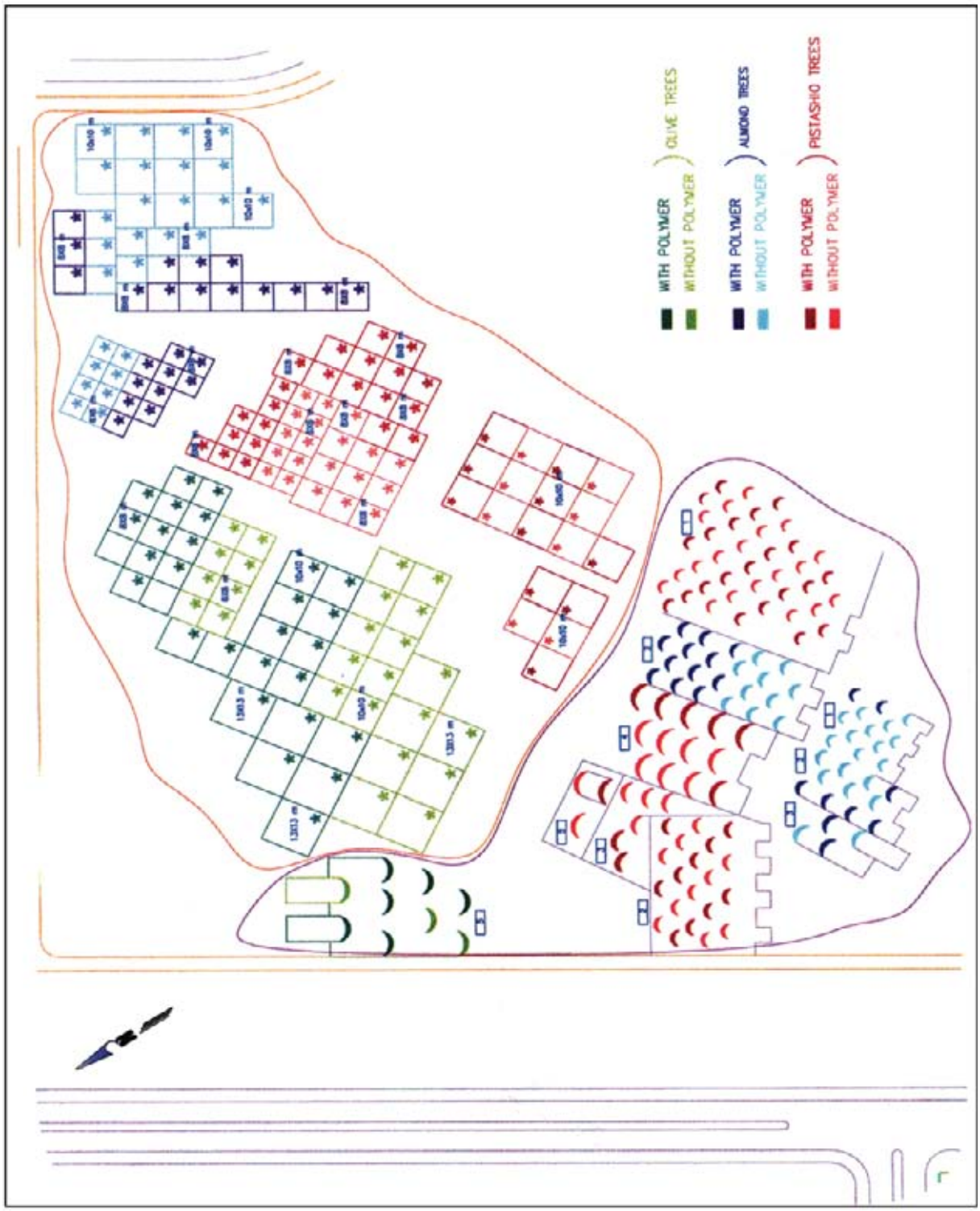

Figure 3.3. Layout of the runoff basin and semicircular bund experiment.

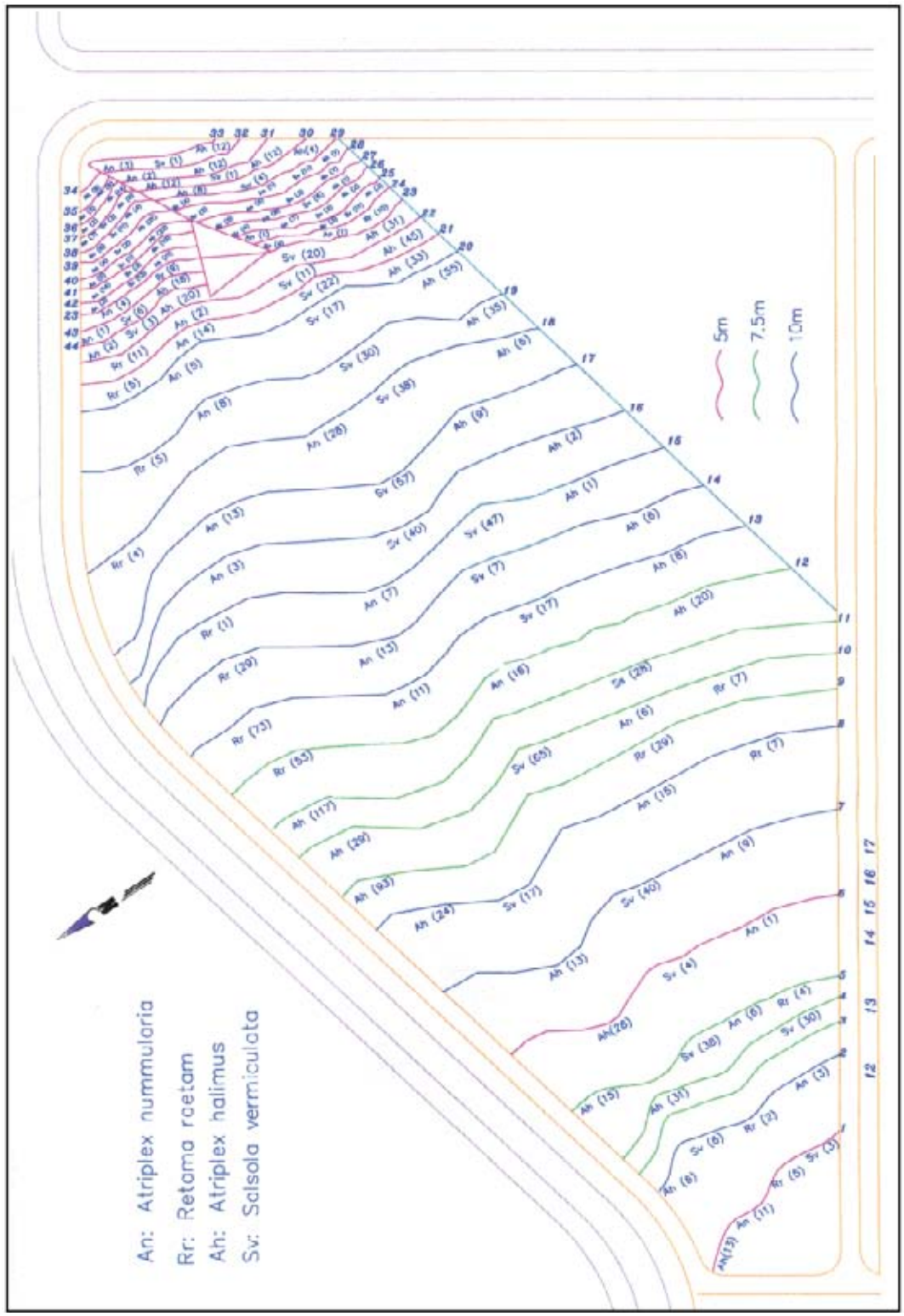

Figure 3.4. The dimensions and sizes of catchment areas of the semicircular bunds (1–5) in the Vallerani ImplementVallerani implement experiment (6 and 7).

Photo 3.2. The runoff basins for fruit trees after the 2nd seasons.

Photo 3.3. The semi-circular bunds for fruit trees.

Almond trees received three catchment area treatments: 36, 64, and 100 m^2. Each of the 36-m^2 and 64-m^2 treatments was assigned to four semicircular plots and six runoff basins; the 100-m^2 was applied to two semicircular plots and three runoff basins.

Olive trees received three catchment area treatments: 64, 100, and 169 m^2. The 64-m^2 treatment was applied to 12 runoff basins, the 100-m^2 to 6 runoff basins, and the 169-m^2 to six semicircular bunds and 12 runoff basins.

A control treatment was included in which no catchments were prepared.

Trees were planted on 15 and 16 March 2003 and some were replanted on 1 January 2004. Parameters measured included:

- Amount of water harvested
- Survival rate
- Vegetation cover

Conventional ridges

The experiment was conducted on 6 ha of land using conventional methods – a combination of using a disc plow and manual labor. Ridges were planted with shrub species at 2 m apart during January 2004 and some shrubs were replanted during December 2004. The planted shrubs were two Atriplex spp. (*A. halimus and A. nummularia*), retem (*Retama raetam*), and Mediterranean saltwort (*Salsola vermiculata*). A control treatment was included in which no catchments were prepared.

The experiment was a CRD with treatments of three spacings between ridges with unequal numbers of replicates. Treatments were 5, 7.5, and 10-m spacing between ridges forming 10, 15, and 20 m^2 catchment areas, respectively. The 7.5-m spacing treatment was replicated seven times, the 10-m spacing was replicated 11 times, and the 5-m treatment was replicated 26 times (Photo 3.4 and Figure 3.5). Parameters measured were amount of harvested water, survival rate, vegetation cover, and plant height.

Mechanized ridges

The experiment was conducted on 2 ha of land. The Vallerani implement was used to form the ridges, which were approximately 2.8 m long, 0.5 m wide, 0.4 m deep, and 1.2 m apart (Figure 3.6 and Photo 5). Treatments of two microcatchment spacings

Photo 3.4. The conventional ridges site for shrubs.

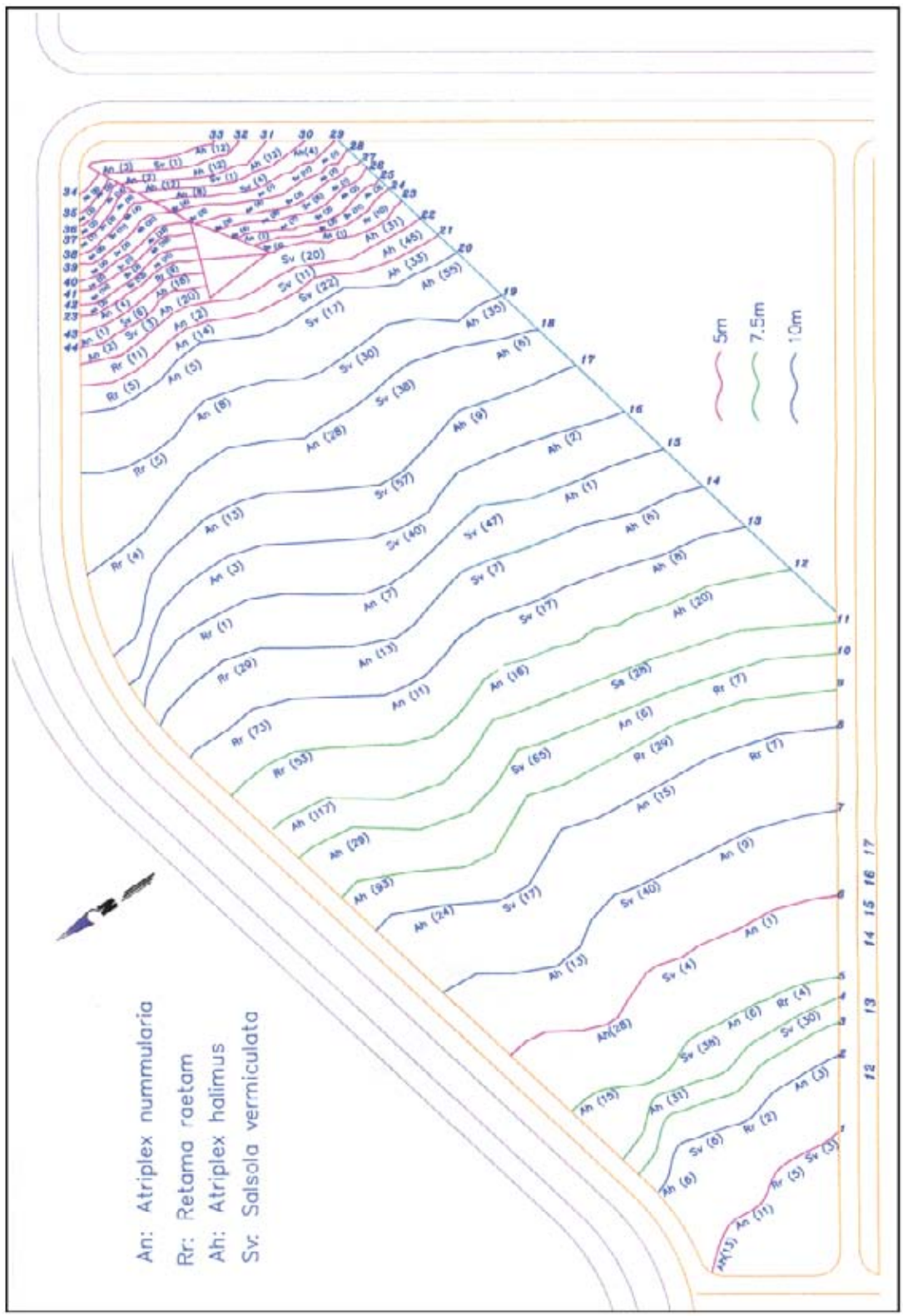

Figure 3.5. Layout of contour ridge experiment.

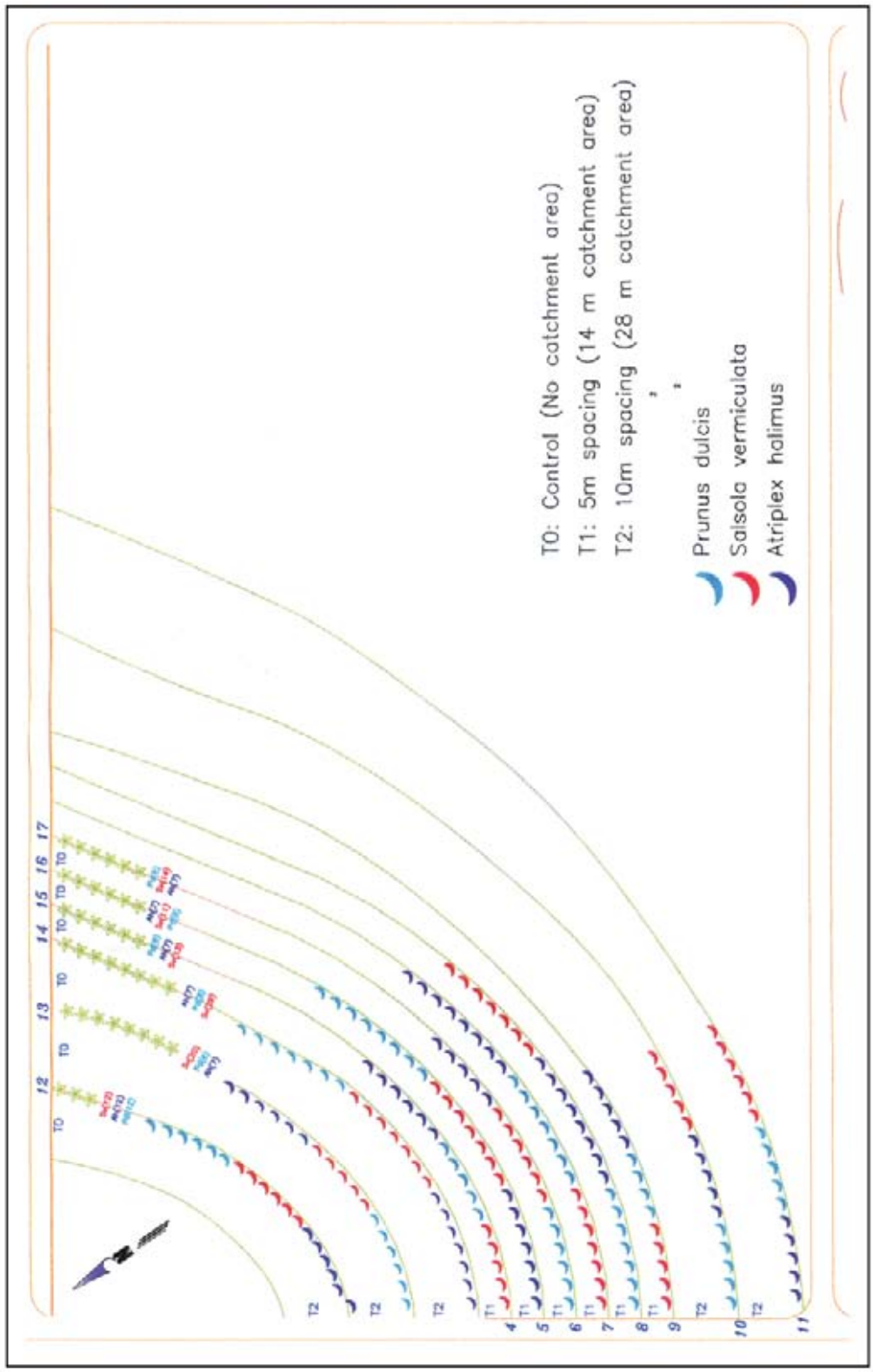

Figure 3.6. Layout of the Vallerani implement experiment.

Photo 3.5. The (Vallerani) ridges for forage shrubs after 3 seasons.

between ridges were used: one at 5 m, forming 14-m^2 catchments; and the other at 10-m spacing, forming 28-m^2 catchments. Wild almond, *A. halimus*, and *Mediterranean* saltwort were used in the experiment. A control treatment was included in which no catchments were prepared.

All selected species were planted on 9 January 2005. Two seedlings, 1 m apart per each species were planted in each ridge.

A CRD with unequal replicates was used. Control and 5-m spacing treatments had six replicates each, and the 10-m spacing treatments had five replicates.

Parameters measured were amount of harvested water, survival rate, vegetation cover, and plant height.

3.3 Results and discussion

In this report, the emphasis is on results for the ridges; however, for the sake of completing the picture on the microcatchment WH systems, the results of the runoff basins and semicircular bunds will also be discussed.

3.3.1 Runoff basins and semicircular bunds

Amount of water harvested: The amount of water harvested was higher in the runoff basins followed by semicircular bunds and least in controls for all fruit trees (Tables 3.3 and 3.4). The catchment size had no effect on the volume of water harvested. The percentage of evapotranspiration was highest in the runoff basins followed by semicircular bunds and lowest in controls (Tables 3.5 and 3.6).

Survival rate: The survival rate was 100% for all catchment sizes.

Vegetation cover: Vegetation cover was measured in terms of canopy diameter. The canopy diameter was not influenced by the type of catchment or by their size (Tables 3.7 and 3.8).

3.3.2 Conventional ridges

Amount of water harvested: The amount of water harvested and the percentage of evapotranspiration were highest for a catchment area of 20 m^2 (10-m spacing) and 15 m^2 (7.5-m spacing), and lowest for controls (Table 3.9).

Table 3.3. Amount of water harvested (cm) for fruit trees for two catchment types during the 2005/06 rainy season.

Catchment type	Pistachio	Almond	0–20
Control*	69 c**	69 c	69 c
Runoff basins	96 a	98 a	101 a
Semicircular bunds	86 b	87 b	95 b

Note: * Without catchment

** Means followed by the same letters are not significantly different ($P < 0.05$).

Table 3.4. Amount of water harvested (cm) for fruit trees for two catchment types during the 2005/06 rainy season.

Catchment area	Pistachio	Almond	Olive
36 m^2	90 a	90 a	– *
64 m^2	92 a	94 a	102 a
100 m^2	91 a	95 a	101 a
169 m^2	–	–	99 a

Note: * Not applicable catchment area.

Table 3.5. Evapotranspiration percentage for fruit trees for different catchment types during the 2005/06 growing season.

Catchment type	Pistachio	Almond	Olive
Control*	75 c	69 c	66 c
Runoff basins	104 a	324 a	97 a
Semicircular bunds	93 b	289 b	90 b

Note: * Without catchment.

Table 3.6. Evapotranspiration percentage for fruit trees for different catchment areas during the 2005/06 growing season.

Catchment area	Pistachio	Almond	Olive
36 m^2	98 a	297 a	–*
64 m^2	100 a	311 a	97 a
100 m^2	99 a	316 a	96 a
169 m^2	–*	–*	95 a

Note: * No applicable catchment area.

Table 3.7. Canopy diameter for fruit trees for different catchment types during the 2005/06 growing season.

Catchment type	Pistachio	Almond	Olive
Runoff basins	50 a	43 a	46 a
Semicircular bunds	52 a	37 b	35 a

Table 3.8. Canopy diameter for fruit trees for different catchment areas during the 2005/06 growing season.

Catchment area	Pistachio	Almond	Olive
36 m^2	53 a	35 a	–*
64 m^2	50 a	42 a	41 a
100 m^2	51 a	43 a	58 a
169 m^2	–*	–*	42 a

Note: * Not applicable catchment area.

Table 3.9. Amount of water harvested and evapotranspiration (ET) percentage for conventional ridges at different spacing treatments (catchment areas) during the 2005/06 rainy season.

Spacing (Catchment area)	Amount of water harvested (cm)	ET (%)
Control	66.5 c	120 c
5 m (10 m^2)	74.4 b	134 b
7.5 m (15 m^2)	77.5 ab	139 ab
10 m (20 m^2)	80.6 a	145 a

Survival rate: The survival rate was 100% for all species in all treatments.
Vegetation cover: The vegetation cover was greatest at 10-m spacing (20 m^2 area) and lowest in controls, i.e. no catchments (Table 3.10).

Plant height: The increase in plant height was not affected by catchment size for all shrub species (Table 3.11). However, the increase in plant height for controls (no catchments) was significantly lower than for catchment treatments.

3.3.3 Mechanized ridges

Amount of water harvested: The amount of harvested water was significantly higher for catchment areas of 14 and 28 m^2 than for the control (Table 3.12). However, the evapotranspiration percentage was significantly ($P < 0.05$) higher for 10-m spacing (28 m^2 catchment) than in 5-m spacing (14 m^2 catchment), and both were significantly higher than for controls (no catchment). When comparing conventional ridges with mechanized ridges at spacings of 5 and 10 m, although the catchment area was different, in the two systems for the same spacing, we find that amount of harvested water was not significantly different between them (Table 3.13).

Survival rate: The survival rate was 100% for *Atriplex* spp. and Mediterranean saltwort in all catchment treatments including controls; however, it was very low (16%) for controls and 40% for the 10-m spaced

Table 3.10. Vegetation cover for conventional ridges at different spacing treatments (catchment areas) during the 2005/06 growing season.

Spacing (Catchment area)	Vegetation cover (%)
Control	15 b
5 m (10 m^2)	59 a
7.5 m (15 m^2)	56 a
10 m (20 m^2)	64 a

Table 3.11. Plant height increase for conventional ridges at different spacing treatments (catchment areas) during the 2005/06 growing season.

	Plant height increase (cm)			
Spacing (Catchment area)	**Atriplex halimus**	**Atriplex nummularia**	**Salsola vermiculata**	**Retama raetam**
Control	5.25 b	1.25 b	1.25 b	– *
5 m (10 m^2)	38.25 a	19.5 a	5.75 a	1.25 b
7.5 m (15 m^2)	31.25 a	18.8 a	25.00 a	14.75 a
10 m (20 m^2)	10.75 a	17.25 a	16.25 a	11.25 a

Note: * No control treatment.

Table 3.12. Amount of water harvested (cm) and evapotranspiration (ET) percentage for Vallerani experiment for different spacing treatments (catchment areas) during the 2005/06 rainy season.

Spacing (Catchment area)	Water harvested (cm)	ET (%)
Control	60.7 b	109 c
5 m (14 m^2)	71.1 a	128 b
10 m (28 m^2)	75.8 a	136 a

Table 3.13. Amount of water harvested (cm) for Vallerani experiment with different spacing treatments (catchment areas) during the 2005/06 rainy season.

	Water harvested (cm)		
Catchment area	**5-m spacing**	**10-m spacing**	**Overall**
Conventional ridges	74.4a	80.6a	77.5a
Vallerani implement	71.1a	75.8a	73.4a

wild almonds. The only explanation for the low survival of 10-m spaced almond trees is that survival was low for reasons other than lack of water, e.g. shallow soil or disease (Table 3.14).

Vegetation cover: The vegetation cover was highest for 5-m and 10-m spaced *Atriplex* spp. and 5-m spaced Mediterranean Salsola(Table 3.15). The lowest vegetation cover was for controls.

Plant height: The plant height was highest for 10-m spacing and lowest in controls for *Atriplex* spp.; and was highest for 5-m and 10-m spacing and lowest for controls of Mediterranean saltwort (Table 3.15).

Table 3.14. Survival rate (%) for shrubs planted in ridges made using the Vallerani implement during 2005/06 growing season.

Spacing (Catchment area)	Atriplex halimus	Salsola vermiculata	Prunus dulcis
Control	100 a	100a	16 b
5 m (14 m^2)	100 a	100 a	100 a
10 m (28 m^2)	100 a	100 a	40 b

Table 3.15. Vegeation cover and plant height increase for *Atriplex* and *Salsola* species in the Vallerani experiment at different spacing treatments (catchment areas) during the 2005/06 growing season (until June).

Catchment area	*Atriplex* spp.		*Salsola* spp.	
	Cover (%)	Height (cm)	Cover (%)	Height (cm)
Control	17 b	13 b	17 c	7 b
5 m (14 m^2)	85 a	25 b	78 a	33 a
10 m (28 m^2)	82 a	42 a	62 b	35 a

3.4 Conclusions

The results of the experiments of 2004/05 and 2005/06 led to the following conclusions:

3.4.1 Runoff basins and semicircular bunds for fruit trees

The amount of water harvested in the runoff basin system was significantly higher than that harvested in the semicircular bund system.

The amount of water harvested was not influenced by catchment size, i.e. the amount of water harvested from a catchment of 36 m^2 was as much as that harvested from 64 or 100 m^2 for pistachio and almond. Similarly, the amount harvested from a catchment of 64 m^2 was the same as that harvested from a catchment of 100 m^2 for olive.

The canopy size of almond and olive trees was not influenced by the type of WH system. However, the canopy size of almond trees was significantly higher for the runoff basin system than the semicircular system.

The catchment size did not influence tree canopy size. A catchment 36 m^2 yielded the same canopy size as 64 or 100 m^2 for pistachio and almond; and a catchment of 64 m^2 yielded the same canopy size as a catchment of 100 or 169 m^2 for olive.

3.4.2 Conventional ridges for shrubs

Spacing of 10 m (20 m^2 area) gave a significantly higher amount of harvested water than the control and the 5-m (10 m^2 area) but not significantly higher than the 7.5-m spacing (15 m^2 area).

The vegetation cover was significantly higher in ridges of any catchment size than in controls (no ridges). However, catchment size did not influence the percentage of vegetation cover.

Plant height was significantly higher in ridges of any catchment size than in controls (no catchment). However, catchment size did not influence plant height.

3.4.3 Mechanized ridges for shrubs

The amount of water harvested was significantly higher in ridges constructed by the Vallerani implement than the control. However, there was no significant difference between spacings of 5 m (14 m^2 catchment) and 10 m (28 m^2 catchment).

Vegetation cover was significantly higher in ridges constructed by the Vallerani implement than the control. However, there was no significant difference in the percentage of vegetation cover between spacings of 5 m (14 m^2 catchment) and 10 m (28 m^2 catchment) for *Atriplex* spp. However, for Mediterranean Salsola, the

percentage of vegetation cover was significantly higher at spacing of 5 m (14 m^2 catchment) than at 10 m (28 m^2 catchment).

Plant height was significantly higher in ridges for spacing of 10 m (28 m^2 catchment) than for 5 m and controls for *Atriplex* spp. However, plant height was significantly higher in ridges of spacings of 5 and 10 m than for controls for Mediterranean saltwort.

3.4.4 Comparison between conventional ridges and mechanized ridges

Within any one overall spacing the amount of water harvested did not significantly differ between conventional and mechanized ridges. However, a slight difference was due to the catchment size.

3.5 Recommendations

The experiment results for the 2004/05 and 2005/06 seasons led to the following recommendations:

For fruit trees: use the runoff system with a catchment of 36 m^2 for growing pistachio and almond trees, and 64 m^2 for olives.

For shrubs: use ridges constructed by the Vallerani implement at a spacing of 5 m (14 m^2 catchment) as it is much cheaper and faster than for ridges constructed conventionally.