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Abstract

The aim of the study is to evaluate effectiveness of a rainwater harvesting technique with polyethylene film covered ridges (RHCR) on pumpkin seed production under rain-fed conditions in Kayseri/Turkey. For this purpose, a two-year experiment, of which were consisted three covered ridge widths (R_1= 0.5, R_2= 0.7, and R_3= 0.9 m) and a control treatment, was conducted. The experimental design was completely randomized plots in blocks with three replications. Significantly higher seed yields were obtained from R_2 and R_3 (202 and 208 kg ha^{-1}) in first year and from R_2 (660 kg ha^{-1}) in second year. Although excessive drought conditions were experienced during pumpkin growing period in those years, especially R_2 treatment resulted significantly higher yield. Higher plant density in R_1 and lower density in R_3 negatively affected seed yield especially in water scarce second year. In second year, leaf area, mean fruit weight, fruit yield, seed yield and 1000-seed weight were found higher than ones in first year because of application of nitrogen a whole at sowing. We concluded that RHCR with optimum plant density and proper covered ridge wide, and application whole nitrogen at sowing under rain-fed conditions are effective ways to obtain higher pumpkin production in semiarid regions.

Keywords: Water harvesting, micro catchment, rainfed agriculture

1. Introduction

Generally, pumpkin seed consumed as snack in Turkey but has been also used as medicinal purposes in other countries (Yavuz et al 2015; Babayee et al 2012). Pumpkin seed production is one of the important livelihood ways of semiarid Middle Anatolian Regions of Turkey. Turkey pumpkin seed production was 41,326 tons from 64,964 ha in 2014 and great amounts of that production (71.8%) were supplied in semiarid Middle Anatolian Region of Turkey, especially in Kayseri and Nevşehir provinces (TSI 2017). Since pumpkin seed can be stored for long durations such as 1 or 2 years, the farmers in the region can sell their production without experiencing considerable marketing problems (Yanmaz 2014).

Better rainwater management foresaw considerable scope for increased food production and poverty alleviation while minimizing additional water use and can help to upgrading rain fed agriculture (De Fraiture et al 2010). The net return for a unit water used was described briefly as water productivity. Producing more food, income, better livelihoods and ecosystem services by using less water could be succeeded by improvement of water productivity. Practices that contribute the improvement in water productivity include water harvesting, supplemental irrigation, deficit irrigation, precision irrigation techniques and soil-water conservation practices (Molden et al 2010).

Capturing precipitation from one part of the land and transfer it to another part is the basic principle of agricultural water harvesting that differs from traditional soil-water conservation practices, and water availability is increased, thereby (Oweis et al 2012). A lot of techniques were experienced to harvest rainwater (Boers & Ben-Asher 1982; Boers et al 1986; Abu-Awwad 1999). Rainwater harvesting can be classified as flood-water, macro-catchment, micro-catchment, rooftop and courtyard water harvesting (Studer & Liniger 2013). The main advantages of micro-catchment systems are simple, cheap, replicable, efficient and adaptable (Reij et al 1988). Polyethylene (PE) covered ridge and furrow rainwater harvesting (RHCR) systems that were called as “ridge-furrow rain water harvesting” were classified as micro-catchment water harvesting techniques and considered as one of the most efficient harvesting methods.

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Ridges and furrows are built parallelly to counters on field surface for this technique and harvested rain waters from the covered ridge were concentrated to the furrows on where plants were grown. Different ridge and furrow ratios were used according to rain amount, rain intensity, crops and soil characteristics (Li et al 2000; Tian et al 2003; Wang et al 2009).

The purpose of this study was to increase pumpkin seed yield and quality for rain-fed farming under semiarid conditions by harvesting rain water with polyethylene covered ridges and find out proper ridge width for Central Anatolian Region.

2. Materials and Methods

This research conducted two years by a collaboration of Erciyes University Agricultural Faculty and Ankara Soil, Fertilizer and Water Resources Central Research Institute to improve pumpkin seed yield and quality under semiarid rain-fed conditions in Develi/Kayseri/Turkey. Develi Research Station of the Agricultural Faculty was at 38°23′ N latitude and 35°27′ E longitude above 1190 m sea level. Long-term annual temperature of Kayseri province is 10.7 °C and monthly mean temperatures varied from -1.7°C for January and to 22.6°C for July. Total rainfall is 384.9 mm of which 28% fall in pumpkin growth period from 1 May until 31 August (TSMS 2017). Reference evapotranspiration values (ETo), that represent atmospheric evaporative demand and estimated according to Allen et al. (1998), and some meteorological parameters for trial years were shown in Table 1. Total atmospheric evaporative demands (ETo) were 587 and 557 mm in 2013 and 2015, respectively. Therefore, ETo in 2013 growing season was 30 mm higher then one in 2015.

Table 1

Soil samples from the soil surface to 0.9 m deep for each 0.3 m soil layer were taken and analyzed in the collaborated Institute laboratories according to Tüzüner (1990). Soil texture was loamy sand and sandy loam with 175 mm m^{-1} available water holding capacity. Soil salinity was low (ECe< 0.7 dS m^{-1}) and soil reaction was about 7.5 (Table 2).

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Table 2

There were three rainwater harvesting treatments consisted of three different PE film covered ridge widths and a control treatment. PE film covered ridge widths were 0.5 m, 0.7 m and 0.9 m for R_1, R_2 and R_3 treatments, respectively. Pumpkin plants were grown on 0.3 m-width furrow areas also used for infiltration of harvested rainwater. Therefore, plant row spaces were 0.8 m, 1.0 m and 1.2 m for R_1, R_2 and R_3 treatments, respectively (Figure 1). Rainwater harvesting with PE covered ridges (RHCR) treatments were compared to control treatment which represents conventional pumpkin cultivation in the region. Plant row space in control was 1.0 m and pumpkin plant spaces at rows for all treatments were 1.2 m in 2013 and 1.0 m in 2015. Narrower plant distance in the second year was used to increase plant density and to obtain higher seed yield. The experimental design was completely randomized plots in blocks installed parallelly to counters. Three times replicated each treatment' plot had three rows and each row had 15 pumpkin plants. To avoid the side effect, the middle row of each replications was considered at harvest. Widely used Develi pumpkin population (*Cucurbita pepo* L.) called "pumpkin seed with frame" was utilized in the experiment. Polyethylene cover (PE+UV) was 0.1 mm thickness and resistant to ultraviolet radiation of sun (Figure 1).

Figure 1

After soil tillage and preparation of ridge furrow system, 100 kg ha^{-1} phosphorus (P_2O_5), 100 kg ha^{-1} potassium (K_2O) and 50% of 100 kg ha^{-1} nitrogen (NH_3-NH_4) applied at sowing (Vural et al., 2000) according to soil analysis and mixed in to the soil by hoeing manually in 2013. The rest of 50 kg nitrogen was applied at 3-4 true leaf stage. Because of light rains or possible non-rainy periods during the vegetative growth stage of pumpkin, all of the fertilizers applied at sowing time below seed bed in 2015. Sowing and harvesting were performed on 26 April and 28 August in 2013 and on 1 May and 26 August in 2015, respectively. Pumpkin seeds were sowed about 3 cm below soil surface manually and 3 seeds were used for each point. After germination, one seedling at 1 true leaf stage was left by thinning.

Soil moisture of the treatments was monitored by 503 DR Hydroprobe neutron moisture meters. Soil moisture measurements were taken at 0.2, 0.4, 0.6, and 0.8 m soil deeps in a 50 mm-diameter aluminum access tubes by neutron probe. Soil moisture measurements were performed 4 times in 2013 and 9 times in

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2015 (Figure 2). Neutron meter calibration and measurements were carried out according to the method offered by Evett (2007). Rain amounts were measured by pluviometers next to the experimental area. Plant water consumptions were determined by following Equation 1 based on soil water budget (James 1988; Wang et al 2009):

$$ET = I + P \pm \Delta W - d_p \quad (1)$$

In where, ET pumpkin evapotranspiration (mm), I irrigation water amount (mm), P is rainfall amount (mm), ΔW is stored soil water difference between the sowing and the harvest (mm) and d_p is deep percolation below root zone (mm). Irrigation amount (I) was considered zero because of rain fed conditions. Deep percolation was neglected due to light rains.

Mid-season leaf area of pumpkin was determined as a plant growth parameter by non-destructive method (Cemek et al 2011). Relationships between leaf area and leaf dimensions (leaf width and length) were found out by regression and correlation analysis using 100 pumpkin leaves. Whole leaf dimensions (length and width) of five pumpkin plants for each treatment were measured at mid-season and then leaf areas were calculated based on these relationships.

Fruit numbers and fruit weight of the middle rows were recorded at harvest. Pumpkin seeds were extracted from fruits manually and dried under sun light in plastic pans. Empty or partly empty pumpkin seeds were removed and then seed weight was determined. 1000 seeds were weighted as a seed quality parameter.

All data was subjected to variance analysis and means were compared at 0.05 probability level by Duncan Multiple Separation Test by SPSS 11.5 statistical software. Microsoft Excel 2016 software was used for regression and correlation analysis.

3. Results

3.1. Rainfall and Plant Water Consumption

Precipitation date and rain amounts during pumpkin growth season were presented in Table 3. Although the average rainfall of 55 years was 117 mm for the growing period (between 5th and 8th months), the

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recorded rainfalls for the growing period were only 24.2 and 13.8 mm, in 2013 and 2015, respectively. Consequently, lower rainfall than regular precipitation during pumpkin growth season was occurred.

Water consumption of control, R_1, R_2 and R_3 RHCR treatments were determined as 152, 143, 148, and 132 mm in 2013 and 101, 110, 107, and 98 mm in 2015, respectively. Not significant differences in plant water consumption were occurred among the treatments in both years. Although lower rainfall amounts were recorded during pumpkin growth season, pumpkin consumed higher than 98 mm water because of storing pre-season precipitations in the soil profile of its rooting depth. Averaged initial soil moistures for 0.9 m soil depth were 216 mm in 2013 and 196 mm in 2015, and averaged soil moisture at the harvest were around 97 mm in 2013 and 95 mm in 2015 (Figure 2). Therefore, great amounts of water for plant consumption were supplied from stored soil water in the rooting depth of pumpkin in the both of years (Table 3). Soil moistures along growing season in control treatment were lower than ones in RHCR treatments in 2013 and also lower in 2015 until 190th day of that year (Figure 2).

3.2. Leaf Area

Leaf area, some yield components and 1000-seed weight presented in Table 4 and variance analyze results were shown in Table 5. Leaf area was considered as a growth parameter and determined at the full growth stage of pumpkin in a non-destructive manner. Stronger relationships (R^2= 0.97) between leaf width-leaf area (LA= 0.6397 W^2-1.6551 W+19.467) and leaf length-leaf area (LA= 0.3709 L^2+10.859 L-54.463) were determined. Leaf area changed significantly for both years (Table 4). Leaf area varied from 0.151 to 0.256 m^2 in 2013 and from 0.333 to 0.464 m^2 in 2015. Maximum leaf area (0.256 m^2) was observed for R_2 treatment and minimum leaf area (0.151 m^2) for the control in 2013. R_3 produced maximum leaf area (0.464 m^2) and other treatments produced minimum leaf area (0.333 to 0.355 m^2) in 2015.

3.3. Pumpkin Fruit Yield

Maximum fruit yield obtained from R_2 (9.85 t ha^{-1}) and R_3 (7.89 t ha^{-1}) while minimum ones from the control (3.85 t ha^{-1}) and R_1 (4.20 t ha^{-1}) in 2013 (Table 4). Minimum fruit yields in the second year were harvested again from the control as 20.5 t ha^{-1} and R_1 as 20.43 t ha^{-1}. R_2 and R_3 treatments produced maximum fruit yields as 29.28 and 28.73 t/ha, respectively (Table 4). Similar results were obtained for

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mean fruit weights (Table 4). Mean fruit weight was changed significantly. In the first year, the control and R_1 treatments produced the lower fruit weights as 0.67 and 0.73 kg fruit^{-1}, respectively while the heavier ones were produced by R_2 and R_3 as 1.31 and 1.14 kg fruit^{-1}, respectively. In second year, mean fruit weights were obtained as 2.34 kg fruit^{-1} and the heaviest fruits were harvested from R_3 (3.33 kg). R_1 and the control treatments produced the smallest fruits (Table 4).

3.4. Seed Yield

Significant differences in seed yield among treatments both in 2013 and 2015 were found. Maximum seed yields as 202 and 208 kg ha^{-1} were obtained from R_2 and R_3, respectively, while minimum seed yield was 55 kg ha^{-1} in the control treatment in 2013 (Table 4). In 2015, maximum seed yield as 660 kg ha^{-1} was harvested from R_2 and minimum seed yield as 397 kg ha^{-1} was harvested from R_1. Higher seed yields were obtained from R_2 treatment for both years.

3.5. 1000 Seed Weight

In both years, 1000-seed weight was affected significantly by the treatments. In 2013, the highest 1000-seed weights as 210 g was recorded in R_3 water harvesting treatment and the least one as 156 g was recorded in the control (Table 4). In 2015, the highest 1000-seed weight 264 g from R_3 and the least 1000-seed weight 190 g from R_1 were obtained4).

4. Discussion

Pumpkin water consumption in this region was estimated 430 mm under full irrigation conditions according to FAO-56 Penman-Monteith method (Ünlükara 2014). Pumpkin mean water consumption under full irrigation and rainfed conditions were determined as 474 and 293 mm in Kayseri (Kirnak et al 2019), as 645 and 201mm in Konya (Yavuz et al 2015) and as 539 and 336 mm for squash in Van (Ertek et al 2004). Water stress free squash (*C. pepo L.*) consumed 304 mm and 344 mm water under trickle and furrow irrigation for spring period in Egypt (Amer 2011). Pumpkin water consumptions in the current experiment were found less than the ones above mentioned because lower rainfalls were recorded in pumpkin growing season for both experimental years. However, Zotarelli et al (2008) reported 108 to 171 mm water

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consumption for zucchini cultivated with a plastic mulch bed system in Florida for two years under full irrigation. Plastic mulching considerably reduced water consumption of pumpkin in that experiment.

In 2013, leaf area, mean fruit weight, fruit yield, seed yield per fruit, seed yield and 1000-seed yield were higher in RHCR treatments than ones in the control treatment. In 2015, maximum leaf area, fruit weight and 1000-seed weight were found in R_3, maximum fruit yield in both R_2 and R_3, maximum seed yield per fruit and seed yield in R_2. The purpose of pumpkin farming in semiarid middle Anatolian region of Turkey is to produce pumpkin seed for confectionary consumption. Especially, RHCR treatment with 0.70 m covered ridge (R_2) improved pumpkin seed yield and nearly all growth and yield parameters for both experimental years. In severely drought 2015, higher plant density in R_1 reduced both seed yield and quality because of competition for water. R_3 treatment improved 1000-seed weight but reduced seed yield because of its lower plant density in unit area.

Fruit yields in R_1, R_2 and R_3 were found 9%, 156% and 105% higher than the control in 2013 and 0%, 43% and 40% higher in 2015. RHCR treatments improved fruit yield considerably. Mean fruit yields of RHCR treatment for two years were 6.45 and 29.28 t ha^{-1}. In researches in semiarid conditions in Turkey, 14.8 and 7.3 t ha^{-1} pumpkin fruit yields for two years were obtained (Yavuz et al 2015). Comparing to results reported by Yavuz et al (2015), we obtained higher fruit yields in second year. Tian et al (2003) also reported that larger potato tubers obtained from RHCR and smaller tubers from control treatment.

R_1, R_2 and R_3 treatments improved seed yield 104%, 267%, and 278% compared with the control in 2013. Mean seed yield increase for R_2 was 29% according the control in 2015. Similar to our findings, Tian et al (2003) found 219% yield increase in potato grown in RHCR system. Wang et al (2009) also determined sweet sorghum biomass yield increases from the RHCR technique with covered both ridge and furrow and the RHCR technique with covered ridge compared with conventional cultivation and non-covered ridge and furrow technique.

Kirnak et al (2019) obtained 470 and 427 kg ha^{-1} pumpkin seed yield against 256 mm and 227 mm water consumption and, Yavuz et al (2015) reported 545 and 247 kg ha^{-1} seed yield against 194.2 mm and 208.2 mm water consumption under rain fed conditions. We obtained 606 kg ha^{-1} seed yield against 110 mm

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water consumption for R_2 in 2015. Covered ridges concentrate harvested rain water to furrow areas and allow harvested water percolating and storing in deeper soil profile. Undesirable evaporation losses from relatively narrow furrow surface beneath crop canopy decreased greatly in RHCR. Furthermore, covered ridges keep soil moisture before and during the growing season and promote plant transpiration. The main reason for yield increase of RHCR system resulted from preventing evaporation and improving available water for plant transpiration.

All parameters considered in the current experiment were found higher in second year. The main reason was changing nitrogen application. In 2013, nitrogen divided into two parts and the first part was applied at sowing and the second part was applied at 3 or 4 leaf stage. But in 2015, whole fertilizers were applied during the sowing. We observed that nitrogen application by dividing several parts in rain-fed conditions was not efficient due to low rainfall characteristic of the region. Drier soil surface during the application of second nitrogen part resulted inefficient use of nitrogen. Similar result also reported by Dumanlar (2018) for pumpkin even in full irrigation. Maximum pumpkin growth and yield characteristics were obtained by application whole nitrogen need at sowing. Although plant densities for control, R_1, R_2 and R_3 treatments increased 20% in the second year, seed yield increased 831%, 254%, 227% and 130%, respectively. We concluded that great amount of seed yield increase resulted from application whole fertilizers at sowing.

5. Conclusions

Effects of rainwater harvesting technique with PE film covered ridges (RHCR) were investigated for pumpkin growth and yield under semiarid rain fed conditions of Develi/Kayseri in Turkey for two years. RHCR treatments had plastic covered ridges with 0.5, 0.7 and 0.9 m widths and all treatments had constant 0.3 m furrow width between these covered ridges. RHCR treatments and conventional pumpkin farming treatment (the control) in the region were compared. We concluded according to our findings that:

- RHCR technique improved pumpkin growth, fruit yield, seed yield and 1000-seed weight considerably by relatively preventing evaporation from soil surface and by increasing transpiration. Because of these

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positive effects of RHCR, we concluded that RHCR is one of ways to increase pumpkin production and quality in rain fed farming under semi-arid regions of Turkey.

- Considering seed yield of two trial years, polyethylene film covered ridges with 0.7 m width came in prominence with higher pumpkin yield and quality despite scarce rainfall in pumpkin growing season. It is suggested to use 0.7 m covered ridge and 0.3 m furrow widths to decrease plant competition for soil water and prevent plant failure and to obtain higher seed yield under RHCR technique.

- Fertilizer need of pumpkin should be applied at sowing stage as a whole to improve efficient utilization under semi-arid rain fed conditions. Under semi-arid rain fed conditions, applying nitrogen requirement of pumpkin by dividing in to several parts caused poor growth and yield because of possibly insufficient and lower rainfalls during growth stage of pumpkin.

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Table 1. Reference evapotranspiration and some meteorological parameters for the trial years.

	2013				2015			
	May	June	July	August	May	June	July	August
T_{min} (°C)	11.1	13.1	14.7	14.7	9.6	12.3	14.5	16.7
T_{max} (°C)	24.2	27.8	29.7	30	22.2	25.1	30.3	31.5
RH_{min} (%)	26.2	19.4	18.7	17	29.2	32.5	20.7	21.9
RH_{max} (%)	70.4	65.9	60.1	58.1	76.8	85.7	66.8	70.4
n (hour)	287.6	363.2	395.9	383.3	285.6	276.9	391.8	370.9
U_2 (m/s)	1.4	1.3	1.3	1.2	1.4	1.3	1.3	1.2
ETo (mm)	123	153	171	140	122	127	168	140

T_{min} and T_{max}: Monthly mean minimum and maximum temperature, RH_{min} and RH_{max}: Monthly mean minimum and maximum relative humidity, n: Monthly total sunshine duration, U_2: Monthly mean wind speed at 2 m height, ETo: Reference evapotranspiration or atmospheric evaporative demand.

Table 2. Some soil characteristics of Seyrani Agricultural Faculty Develi Research Station Area in Kayseri/Turkey

Soil Layers (cm)	Field capacity (%)	Wilting point (%)	Soil density (g cm^{-3})	pH	EC_e (dS m^{-1})	Sand (%)	Silt (%)	Clay (%)	Soil tex.
0-30	24.5	8.9	1.15	7.50	0.628	79.6	13.5	6.9	LS
30-60	24.1	8.4	1.13	7.45	0.453	72.0	18.5	9.5	SL
60-90	24.6	9.4	1.12	7.58	0.462	70.3	19.5	10.2	SL

ECe: Electrical conductivity of soil saturation paste extract, LS: Loamy sand, SL: Silt loam

Table 3 Pumpkin evapotranspiration, soil moisture differences at the sowing and the harvest dates, rainy days and rain amount during pumpkin growth season in 2013 and 2015.

2013	Rain dates	1 May	2 May	3 May	12 May	14 May	18 May	4 June	10 June	Total
	Rain amounts	0.1	3.3	7.7	6.8	1.6	1.0	2.7	1.0	24.2

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	Treatments	P (mm)		ΔW (mm)		ET (mm)		
	Control	24.2		127.7		151.9		
	R_1	24.2		119.1		143.3		
	R_2	24.2		123.7		147.8		
	R_3	24.2		108.3		132.4		
2015	Rain dates	24 May	31 May	1 June	3 June	12 June	16 June	Total
	Rain amounts	2.8	2.2	0.7	5.3	2.3	0.5	13.8
	Treatments	P (mm)		ΔW (mm)		ET (mm)		
	Control	13.8		87.2		101		
	R_1	13.8		96.2		110		
	R_2	13.8		93.8		107		
	R_3	13.8		84.2		98		

P: Rainfall (mm), ΔW: Soil water difference between the sowing and the harvest (mm), ET: Pumpkin evapotranspiration (mm), R_1, R_2 and R_3: Rainwater harvesting treatments with 0.5, 0.7 and 0.9 m polyethylene covered ridge widths, respectively.

Table 4. Some growth and yield parameters of pumpkin plants grown under rainwater harvesting with polyethylene film covered ridge treatment and conventional cultivation in 2013 and 2015

Year		Leaf area (m^2)	Mean fruit wgt. (kg)	Fruit yield (tha^{-1})	Fruit seed yield (g)	Seed yield ($kg\ ha^{-1}$)	1000-seed wgt. (g)
2013	Control	0.151 c	0.67 b	3.85 b	9.7 c	55 b	156 b
	R_1	0.189 bc	0.73 b	4.20 b	17.0 bc	112 ab	179 ab
	R_2	0.256 a	1.31 a	9.85 a	27.4 ab	202 a	199 ab
	R_3	0.235 ab	1.14 ab	7.89 ab	30.0 a	208 a	210 a
2015	Control	0.333 b	1.87 c	20.50 b	46.2 b	512 ab	204 bc
	R_1	0.355 b	1.57 c	20.43 b	30.3 c	397 b	190 c
	R_2	0.338 b	2.60 b	29.28 a	60.7 a	660 a	234 ab
	R_3	0.464 a	3.33 a	28.73 a	54.9 ab	478 b	264 a
2013		0.208 b	0.96 b	6.45 b	21.0 b	144 b	186 b
2015		0.372 a	2.34 a	24.48 a	48.0 a	512 a	223 a

Table 5. Variance analyze results

	2013			2015		
	Std. error	F	Sig.	Std. error	F	Sig.
Leaf area	0.0098	5.754	0.021	0.0148	4.306	0.044
Mean fruit wgt.	0.0726	4.567	0.038	0.108	13.403	0.002
Fruit yield	0.616	5.585	0.023	1.186	3.818	0.05
Fruit seed yield	1.894	6.184	0.018	1.978	11.232	0.003
Seed yield	21.284	3.038	0.05	20.869	6.924	0.013
1000-seed wgt.	5.205	5.302	0.026	5.297	9.601	0.005

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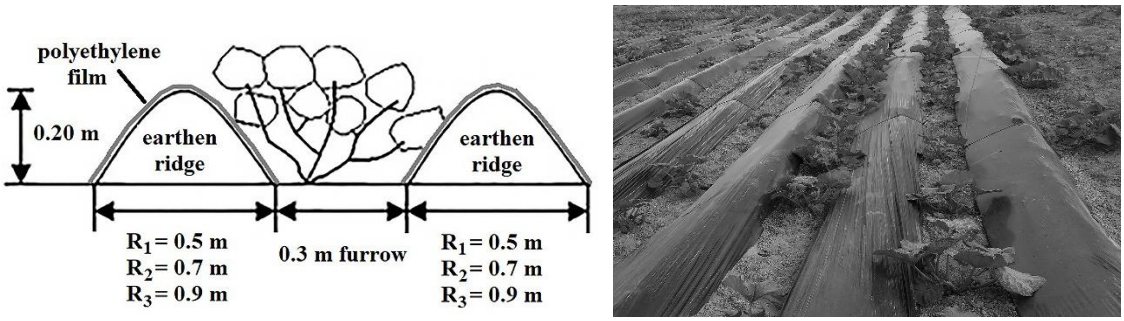


Figure 1 Rain water harvesting with polyethylene film covered ridge (RHCR) techniques and experimental treatments

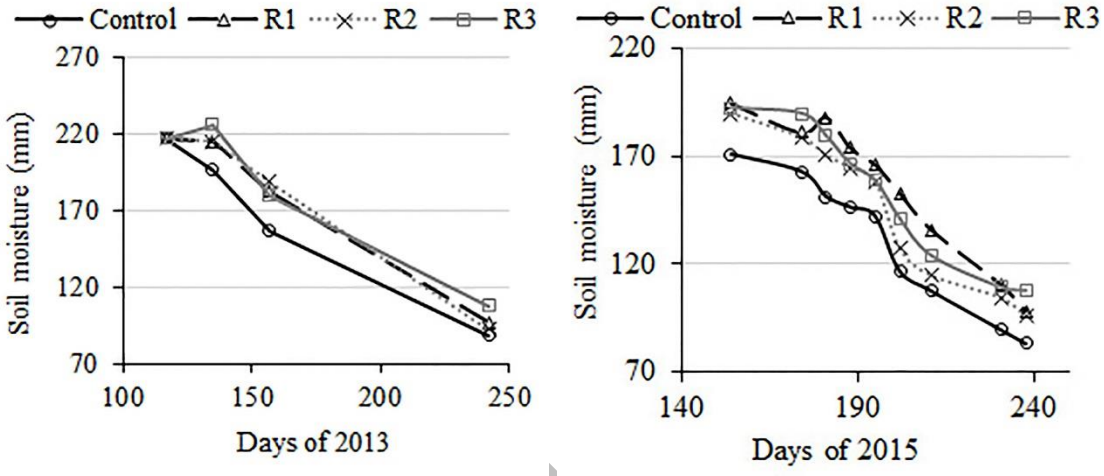


Figure 2 Soil moisture changes along growing season of pumpkin in 2013 and 2015

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