other apple cultivars in the same CA storage room at 1 °C.

Our results have shown that lowering the temperature from 3 to 1 °C during storage in air did not increase the number of apples that developed internal browning. Therefore, 'McIntosh' apples may be stored with other apple cultivars in air at 1 °C.

Apples grown in some region may be less tolerant to extreme storage condition (e.g., CA conditions at 1 °C) and therefore greater number of fruit will develop internal browning than apples from other regions. Storage operators for this region must follow the storage recommendation more closely or develop their own proper apple storage condition for their region.

Apples can show internal browning disorder after 6 months of storage even when there is no symptom after 4 months of storage. Therefore, apples showing no symptom during early sampling from storage does not mean apples will be free from this disorder when storage duration is extended.

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Incorporating Water Harvesting into Plasticulture Production of Muskmelon

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ADDITIONAL INDEX WORDS. water conservation, rainfall capture, trench planting, plastic mulch, water catchments, cucumis melo, cantaloupe, irrigation, seed bed configuration

SUMMARY. Competition for limited water supplies is increasing world wide. Especially hard hit are the irrigated crop production regions, such as the Lower Rio Grande Valley and the Winter Garden areas of south Texas. To develop production techniques for reducing supplemental water needs of vegetable crops, an ancient water harvesting technique called rainfall capture was adapted to contemporary, large scale irrigated muskmelon (*Cucumis melo* var. *reticulatus* L.) production systems. The rainfall capture system developed consisted of plastic mulched miniature water catchments located on raised seed beds. This system was compared with conventional dry land and irrigated melon production. Rainfall capture resulted in 108% average yield increase over the conventional dry land technique. When compared with conventional furrow irrigation, rainfall capture increased marketable muskmelon yield as much as 5355 lb/acre (6000 kg·ha⁻¹). As anticipated,

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the drip irrigation/plastic mulch system exceeded rainfall capture in total and marketable fruit yield. The results of this study suggest that rainfall capture can reduce total supplemental water use in muskmelon production. The major benefit of the rainfall capture system is believed to be in its ability to eliminate or decrease irrigation water needed to fill the soil profile before planting.

Water is an essential requirement for plant growth. Its deficiency in the soil during critical growth stages seriously affects the metabolic growth and yield in plants (Gupta, 1989). The lack of a good quality and adequate water supply is a major limiting factor worldwide to successful vegetable production. As populations continue to increase so do the demands placed on our limited water supply. Agriculture, which accounts for 70% of global water use, is in direct competition with municipalities and nonagricultural industries (Fisher, 1995). In the United States alone irrigated crop production is estimated to cause water table draw downs between 0.5 to 5 ft (0.15 to 1.5 m) per year.

Sustaining irrigated crop production requires a continual improvement in water use efficiency. In arid regions, water harvesting techniques have been used to reduce the effects of droughts and declining water supplies (Fink and Ehler, 1983; Sharma et al., 1986). Water harvesting is not a new concept. Evidence suggests that this concept was practiced in the Negev Desert during the Middle Bronze I age, 21 to 19th century B.C. (Evenari et al., 1961). The term water harvesting describes the process of collecting and storing water from an area that has been treated to increase precipitation runoff. The runoff is then held in a tank or catchment for future use (Fraiser and Meyers, 1983). Although there are many variations in water harvesting, they all can be divided into two major types. The first type utilizes in-field methods to transfer water over a short distance, 164 to 328 ft (50 to 100 m). This type includes contour ridges, furrow diking, furrow benches and strip planting. The second type is external catchments that collect runoff from an area a considerable distance from the receiving area which is trans-

ferred by channels to the utilization area. This type includes hillside conduit systems and dams for recession planting (Growing et al., 1994).

In early water harvesting systems, runoff was collected from cleared and smoothed hillside areas and rock surfaces. In the past 50 years, barrier type materials have been employed to increase runoff. Materials evaluated include concrete, cement, sheet metal, asphalt fabric membranes, and gravel covered sheeting. However, most of these materials were found to be cost prohibitive (Emmerich et al., 1987).

Surface runoff is a major source of water loss from crop production fields (Redinger et al., 1984). In some areas water loss through surface runoff can equal 33% of the received precipitation. Soil cultivation and other means of soil manipulation such as furrow diking and tied ridges, which reduce runoff from production fields, has had a greater impact on crop production than runoff farming. These techniques use a mechanical tillage process which mounds soil at intervals across the furrow between beds or at the end of the furrows to form mini-catchments for precipitation runoff collection (Colburn and Alexander., 1986; Piha, 1993).

Reducing runoff enables increased deep moisture percolation into the soil profile and reduces erosion and supplemental water needs. Attempts to alter infiltration properties probably date from the dawn of agriculture (Fink, 1984). Soil treatment with paraffin wax and antistripping agents have been reported to be of some value in this regard (Emmerich et al., 1987; Fink, 1984). Other plant bed manipulations have also been shown to be beneficial in collecting and holding moisture. Gonzalez and Heilman (1971) reported a 2% increase in soil moisture in trenched tomato beds than in standard tomato (*Lycopersicon esculentum* Mill.) beds. Dainello et al. (1982) also reported an increase in seed bed moisture using a midbed trench system for muskmelon production.

Historically most attempts at harvesting water have employed large structures and/or catchments located outside of the area of intended use. However, several investigators have attempted to devise in-field catchments for use within a cropping system. Oebker et al. (1971) experimented with perforated plastic aprons 6 mil

(0.152 mm) thick $\times$ 10.8 ft (1 m) square in which vegetables were sown into a 2-inch (5-cm) hole located in the center of the square. The aprons served as watersheds to collect rainfall. The author was able to produce vegetables with <5.1 inches (13 cm) of captured rainwater under arid conditions. Fisher (1995) used rounded, raised, plastic mulched beds as watersheds to concentrate rainfall in the furrow area between the mulched beds. Maize (*Zea mays* L.) was then planted in the nonmulched furrow area. Maize yields produced from these areas exceed those from conventionally planted plots. The major drawback reported with this technique was that heavy rains caused soil saturation in the crop zone. Using clear polyethylene mulch in combination with depressional planting, Dainello and Heineman (1987) found a significant increase in seed zone soil moisture as compared to standard flat-top beds. However, they also reported water ponding on the polyethylene mulch in the area over the depressions. Dainello (1993) modified the above system by perforating the plastic covering in the depression areas to take advantage of its ability to capture and concentrate rainfall into the seed bed. The purpose of the work reported in this paper was to adapt this rainfall capture system to commercial vegetable production.

Materials and methods

COMMON TO ALL STUDIES. Potential of rainfall capture (RFC) to reduce supplemental water needs was evaluated in three separate studies. A schematic depiction of the installation of the RFC system is presented in Fig. 1. Step one consisted of shaping a standard 78-inch (198-cm) wide $\times$ 6-inch (15-cm) high raised bed with a conventional sled type bed shaper (Fig. 1A). In step two, the conventional sled type bed shaper was modified by bolting two mini-boats to the underneath surface (Fig. 1B). The modified bed shaper was pulled over the previously shaped beds in step three to form two trenches, 22.8 inches (58 cm) apart, in the bed surface. Each trench was $\approx$ 10 inches (25 cm) wide across the top, 5 inches (12.5 cm) deep and 3 inches (7.5 cm) wide across the bottom (Fig. 1C). The trenches were located $\approx$ 11 inches (29 cm) on either side of bed center. Step four involved laying black plastic polyethylene mulch [1.5 mil

A. Step 1= Shaped standard raised bed

C. Step 3= Shaped bed with twin mini-catchment trenches

E. Step 5= Lined mini-catchments and emerging crop

(0.0381 mm) $\times$ 6 ft (1.8 m) wide] over the trenched beds in the usual manner with a standard mulch applicator (Fig. 1D). To facilitate water entrance into the soil profile, holes were manually punched into the plastic at 3 ft (0.9 m) increments in a straight line over each trench in step five. Soil was manually placed over each hole with a garden spade to cause the plastic mulch to conform to the trench shape (Fig. 1E). The crop was then established in the center of the bed between the mini-catchments trenches.

REPLICATED STUDY. A replicated study was conducted to develop a RFC technique that could be incorporated into conventional crop produc-

tion. The study was conducted at the Texas A&M University Agricultural Research and Extension Center at Uvalde on a Uvalde silty loam soil. Nonmulched smooth surface beds (the control) were compared to nonmulched and mulched trenched beds for influence on muskmelon fruit yield and quality. Treatment effectiveness was evaluated using a randomized complete block design with four replicates of three-bed plots per treatment. Each bed was $\approx$ 50 ft (15.2 m) long $\times$ 6.3 ft (1.9 m) wide. The center bed served as the data bed and the outer two beds as treatment buffers. Mulched and nonmulched trenched bed plots were established in late summer, just before the normal rainy period of the region, on 18 and 14 Aug. 1988 and 1989, respectively. Seeds of the hybrid muskmelon variety 'Explorer', were then sown the following spring on 13 and 14 Mar., respectively, in 1989 and 1990. Three to four seeds were hill

B. Step 2= Modified sled type bed shaper used to form mini-catchments on raised beds

D. Step 4= Mulched rainfall capture bed

Fig. 1. Cross-sections of the rainfall capture beds after each step in construction.

fall received in each treatment was determined by dividing the volume in inches of rainfall received by the fruit yield in pounds. No supplemental water was applied to the crop. All other cultural practices used were as recommended by the Texas Agricultural Extension Service for muskmelon (Stein et al., 1990).

COMMERCIAL PRODUCTION EVALUATION OF RFC. Based on the results of the replicated study, mulched trenched beds appeared to be a viable rainfall capture concept with potential adaptation to commercial production. To determine this, field studies were conducted in two commercial production fields in the Texas Winter Garden. The initial field study was established on a Knippa clay soil at the McFadin Farms located east of Uvalde, Texas. In this study the RFC treatment was compared with drip irrigation/plastic mulch and with conventional furrow irrigation (the control) under a commercial production environment for influence on muskmelon yield and quality and water use efficiency. The RFC system was established on 26 October 1993. The control and the drip irrigated/plastic mulched plots were established at planting 4 Apr.

planted in a single seed row down the center of the bed between the two trenches. Each hill was spaced 22 inches (55.0 cm) apart within the row. Plots were thinned to one plant per hill at the four-true-leaf stage.

The muskmelons were once-over harvested at the three-quarters-fruit-slip stage per treatment (13 to 29 June 1989 and 18 June to 2 July 1990), weighed and size graded based on fruit count (9s, 15s, 22s) per standard 42 to 45 lb (19.1 to 20.4 kg) half carton. Rainfall data were also recorded. Use efficiency of rain-

Fig. 2. Rainfall capture with double plant rows per bed and one mini-catchment trench.

1994. Bed size was 500 ft (152.4 m) long $\times$ 6.3 ft (1.9 m) wide. About 1 acre (0.4 ha) blocks were established for the RFC and the drip irrigation/plastic mulch treatments within a furrow irrigated field (the control). Drip tape used in the drip irrigated/plastic mulch treatment had emitters spaced 12 inches (30.5 cm) apart and was buried $\approx$ 3 inches (7.6 cm) deep and 3 inches (7.6 cm) to one side of the bed center. Black polyethylene, 1.5 mil (0.0381 mm) thick $\times$ 6 ft (1.8 m) wide was used as the mulch material for the trench lining. The RFC and the drip irrigated/plastic mulched blocks were direct seeded using a mulch transplanter to punch holes into the plastic and drop seeds. The hybrid muskmelon cultivar 'Caravelle' was used. Plant spacing was 12 inches (30.5 cm) apart within the row. Treatment blocks were thinned to stand at the four-true-leaf stage.

The scheduling and quantity of water applied via furrow irrigation was managed by McFadin Farms in the

normal manner. Both when and how much water applied was recorded. In the drip irrigated/plastic mulched block, $\approx$ 1 inch (2.5 cm) water was applied when soil moisture tension, as measured by Irrrometer Moisture Indicators (Irrrometer Company, Inc., Riverside, California.) reached 40 centibar at 12 inches (30.5 cm) deep. A self-contained portable drip irrigation trailer was used to deliver water to the treatment block from the underground delivery lines of the farm. No supplemental water was applied to the RFC.

Yield data was determined from a once over hand harvest. The RFC and the drip-irrigated/plastic-mulched blocks were harvested on 27 June, and the furrow control on 6 July 1994. Fruit from four subplot [133 ft² (12.4 m²)] per treatment were harvested, weighed and size graded. Rainfall and irrigation water applied were also recorded and the water use efficiency determined as described in the replicated study.

A second study was established in 1995 on another commercial muskmelon field in the Texas Winter Garden area. In this study, muskmelon yield, quality and water use efficiency was evaluated by comparing RFC with drip irrigation alone and with plastic mulched-furrow irrigated beds. To be consistent with the farm's production system, the RFC design was modified to accommodate two plant rows spaced 12 inches (30.5 cm) apart on the bed. As a result only one trench was placed in the center of each bed (Fig. 2). Except for this change similar conditions as described for the above com-

mercial field evaluation was employed in this study.

Results and discussion

REPLICATED STUDY. No significant treatment $\times$ season interaction was found in the replicated study, therefore data are presented as two year averages (Table 1). The mulched trenched beds (RFC) increased yield $\approx$ 11 lb (5 kg)/plot over the control (nonmulched smooth surface beds), and, 8.8 lb (4 kg)/plot over the nonmulched-trenched bed treatment. As a result RFC produced a yield increase that exceeded the control by 108% and the nonmulched twin trenched treatment by 70%. These results suggest that the increased yield was due to increased water use efficiency of the RFC treatment.

One measure of water use efficiency is the ratio of the volume of water applied and/or received required to produce a given unit of fruit. The greater the volume of water required, the lower is the water use efficiency. The average water use efficiency for treatments evaluated in the replicated study can be found in Table 1. Under the conditions of this study water use efficiency ratios ranged from 40.6:1 with the mulched twin trenched bed (RFC) to 88.1:1 for the control. Based on these ratios it was determined that the control required 881 gal (330 L) of water to produce 1 lb (0.45 kg) of fruit as compared to 698 gal (251 L) by the nonmulched twin trenched treatment and 406 gal (152 L) by the RFC treatment. These results suggest that of the two key components of the RFC treatment, the perforated plastic mulch provided the greatest influence on water harvesting. It is speculated that, unlike conventional beds mulched with plastic that tend to shed rain

Table 1. Influence of seed bed construction technique on muskmelon yield, grade and water use efficiency as a two season average (replicated study).

Treatment	Total yield (lb/plot) ^x	Water use efficiency ratio ^z (gal water : lb fruit)	Fruit harvested/ size grade ^y (%)			
			22s	15s	9s	Culls
Mulched twin trenched beds	22.5	40.6:1	23	52	6	19
Non mulched twin trenched beds	13.2	69.8:1	48	37	2	13
Control, nonmulched smooth surface raised beds	10.8	88.1:1	56	25	4	15
LSD _(0.05)	7.1	---	---	---	---	---

^zRatio of rainwater received in gallons (3.78 L) per pound (0.45 kg) fruit produced.

^ySize grade = fruit count per half carton, $\approx$ 42 lb (19 kg) per half carton.

^xAverage weight in pounds (0.45 kg) fruit harvested per treatment plot, 130.2 ft² (12.1 m²).

Table 2. Monthly distribution and total rainfall (in inches) received during the replicated study, 1988–90.

Month	Rainfall (inches) ²	
	1988–89	1989–90
August	0.04	0.55
September	2.91	0.43
October	2.44	4.09
November	0.16	1.18
December	0.9	0.39
January	3.78	0.87
February	0.9	3.43
March	0.59	1.57
April	1.65	3.19
May	1.14	2.68
June	0.28	0.12
July	0.0	0.0
Preplant total ³	11.7	11.5
Growing season ^x	3.07	6.97
Total	14.8	18.46

²1 inch = 2.54 cm.³Rainfall received mid-August to mid-March in inches.^xRainfall received mid-March to early July in inches, 1994.

water which often leaves the field as runoff, RFC enabled rainwater to be channeled into and concentrated within the plant bed. The plastic mulch of the RFC treatment also afforded the usual benefit of reducing moisture loss through surface evaporation. As a result more soil moisture was available to the muskmelon plants in the RFC treatment for a longer period of time than those grown with the other treatments.

Although bed treatment was not found to affect overall fruit set (data not presented), it did appear to affect fruit size. The fruit grade size distribution indicated that RFC produced more fruit in the larger, higher value grade sizes. Fifty eight percent of the fruit harvested from the RFC beds graded in the size 9s and 15s grades. Only 29% of the fruit harvested from the control and 39% from the nonmulched trenched beds met these grade sizes.

As suggested above the increase in reported fruit yield and size with the

mulched trenched beds over the control is believed to be due to increased in rainwater infiltration into the beds as a result of the mulched trenches capturing and concentrating water. The distribution and total rainfall received during the preliminary study is presented in Table 2. A total of 14.8 inches (37.5 cm) rain fell during the 1988–89 season. Of this, 11.7 inches (29.7 cm) occurred during the preplant water harvesting period, mid-August through mid-March. An additional 3 inches (7.8 cm) were received during the cropping season, mid-March through late June. Nearly the same quantity of rainfall [11.7 (29.2 cm)] was received during the 1989–90 preplant water harvesting season. However, nearly 10 cm (4 inches) more rain [7 inches (17.7 cm)] was received during the 1990 cropping season as compared to the 1989 season. As a result slightly higher yields were obtained in 1990 than in 1989 (data not presented). It is speculated that the RFC treatment enabled a large percentage of the rainfall received during the growing season to be channeled into and stored within the plant bed soil profile for future use by plants to size fruit. The quantity of rainfall is not the only consideration important to plant growth but rather its distribution which determines cropping success. Under the conditions of this study, the rainfall quantity and distribution (Table 2) enabled acceptable muskmelon yields to be produced with RFC. It was evident, however, that reduced size of the muskmelons produced with this treatment as compared to fruit normally produced in the area under irrigated conditions resulted from a depletion of stored soil moisture. It is believed that one timely irrigation may have been sufficient to properly size these fruit.

COMMERCIAL PRODUCTION EVALUATION OF RFC. As expected the highest yield was produced by the drip irriga-

tion/plastic mulch treatment (Table 3). Total fruit yields of 26,463, 20,990 and 20,010 lb/acre (29,649, 23,517 and 22,419 kg·ha⁻¹) were produced with drip irrigation/plastic mulch, RFC and furrow irrigation, respectively. This data indicates that RFC was equally as effective as furrow irrigation with regard to yield. No major detectable differences were found in fruit grade (Table 3).

More important than the effect on total yield was the treatment influence on marketable yield; 25,812, 19,172, and 13,367 lb/acre (28,920, 21,480 and 14,976 kg·ha⁻¹) were obtained with drip irrigation/plastic mulch, RFC and furrow irrigation, respectively. Furrow irrigation resulted in 33% culled fruit as compared to 2% with drip irrigation/plastic mulch and 9% with RFC (Table 3). The increased culled fruit with furrow irrigation was due to the large amount of fruit decay found in this block. One explanation for this occurrence is the fact that a total of 24.8 inches (63 cm) of supplemental water was applied in four furrow irrigations (Table 4). In addition 15.3 inches (39 cm) of rainfall was received during the growing season (Table 5). As a consequence, periods of water logging occurred. Such periods induced excessive fruit loss due to soil borne diseases. The absence of mulch in the furrow irrigated treatment caused fruit to come in direct contact with the soil. As a result soil borne pathogens were able to readily infect fruit in this treatment. Since plastic mulch is a major component of the RFC system only minor fruit loss occurred as a result of these soil borne diseases. In the two mulched treatments in this study, the plastic served as a barrier between the fruit and the soil thereby reducing the potential for soilborne disease infection of the fruit. The use of barriers has been shown to reduce the incidence of soil borne disease by others (Baxter et al., 1977). It

Table 3. Yield and grade response of 'Hy Caravelle' muskmelon to supplemental water application techniques during the commercial evaluation of rainfall capture at McFadin Farms.

Treatment	Yield (lb/acre)		Fruit harvested/size grade ² (%)						
	Total	Marketable	9s	12s	15s	18s	23s	30s	Culls
Drip irrigation + plastic mulch	26463	25812	6	27	33	8	5	8	2
Rainfall capture ³	20990	19172	8	32	19	21	2	8	9
Control (furrow irrigation nonmulch)	20010	13367	6	37	19	23	9	5	33

²Fruit count per 42-lb half carton (≈19 kg).³Rainfall capture treatment established 26 Oct. 1993; other treatments established just before planting 4 Apr.

Table 4. Influence of supplemental water application technique on water use efficiency of 'Hy Caravelle' muskmelon during the commercial evaluation of rainfall capture at McFadin Farms.

Treatment	Yield (lb/acre)	Moisture received (inches) growing season					Water use efficiency ratio ^z (gal/lb)		
		Preplant rain ^y (inches)	Irrigation ^x	Rain ^w	Irrigation + rain ^v	Total water ^u	Irrigation	Irrigation + rain	Total water
Drip irrigation + plastic mulch	26463	13.7	3.9	15.3	19.2	32.9	17:1	836:1	142:1
Rainfall capture	20990	13.7	0	15.3	15.3	29.0	---	83:1	158:1
Control (furrow irrigation)	20010	13.7	24.8	15.3	40.1	53.8	141:1	229:1	307:1

^zWater use efficiency ratio = gallons water required to produce 16 fruit (0.45 kg).

^yPreplant rainfall = that received at the study site during the period of time from 26 Oct. 1993 (RFC establishment) through crop planting date (4 Apr. 1994).

^xSupplemental water applied during the growing season in inches (1 inch = 2.54 cm).

^wRainfall received plus supplemental water applied during growing season.

^vRainfall plus irrigation water received during the growing season.

^uTotal rainfall received from 26 Oct. 1993 (rainfall capture establishment) through 6 July 1994 (end of harvest) plus irrigation water received during the growing season.

is also acknowledged that the influence of RFC on observed yield was a direct benefit normally attributed to the use of black plastic mulch such as soil warming, weed control and earliness (Bonanno and Lamont, 1987; Fipps and Perez, 1995; Gupta, 1989; Porter and Etzell, 1982; Van Derwerken and Wilcox-Lee, 1988).

Water use efficiency ratios were determined for each of the treatments (Table 4). Based on these ratios, drip irrigation/plastic mulch increased irrigation water use efficiency in muskmelon production nearly 10 times over furrow irrigation (17:1 to 141:1, respectively). RFC resulted in a 0:1 ratio because no supplemental water was used to produce fruit in this treatment. With regard to water available during the growing season (rainfall + irrigation water) drip irrigation/plastic mulch culture and RFC were nearly three times as efficient as furrow irrigation. Only slight differences were noted in total water (preharvest rainfall + growing season rainfall + irrigation) use ratios between RFC and drip irrigated/plastic mulch treatment. The RFC was also found to be nearly twice as efficient in producing fruit with available total water as furrow irrigation, 158:1 and 307:1 respectively. Even though the water use efficiency ratios for RFC were extremely favorable in this study, it should be pointed out, that these ratios do not necessarily reflect treatment total yield or fruit grade distribution. The fact that drip irrigation/plastic mulch resulted in nearly 4909 lb/acre (5000 kg·ha⁻¹) greater yield indicated that the RFC treatment could have benefited from

at least one properly time irrigation. A similar observation was evident in the replicated study.

The rainfall received and its distribution for the commercial field evaluation on the McFadin Farm is presented in Table 5. Nearly 13.8 inches (35 cm) of rain fell on the McFadin Farm during the preplant rain water harvesting period from late October to mid-April, and 15.3 inches (39 cm) during the cropping season. This quantity and distribution was sufficient to enable the RFC treatment to produce 875 lb/acre (980 kg·ha⁻¹) greater yield than furrow irrigation which received an additional 24.8 inches (63 cm)/acre of supplemental water (Table 4). This compares to only 4 inches (10 cm) of supplemental water applied in the drip-irrigated/plastic mulched treatment when a soil moisture tension was used to schedule irrigation. From this data, we concluded that the cooperators' scheduling techniques were not only ineffective but detrimental to successful muskmelon production. These results, however, are a good indication of the effectiveness of RFC to capture and store water for crop use.

A vine decline complex of soil-borne fungi including charcoal rot (*Macrophomina phaseolina* Tassi Goidanich) and monosporascus root rot (*Monosporascus cannonballus* Pollach and Uecker) swept through the Winter Garden region in the 1995 season and caused premature vine death (M.C. Black, personal communication). Although the muskmelon fruit were in the full net stage of maturity, fruit quality was such that marketable

quality could not be met. Consequently no yield data is presented for the second commercial field evaluation. However, similar treatment water usage

Table 5. Rainfall received during the commercial evaluation of rainfall capture at McFadin Farms, 1993-94.^z

Month	Rainfall received (inches)
Moisture harvest period (13.8 cm)	
October	0.04
November	0.70
December	5.4
January	2.96
February	0.28
March	4.37
Growing season (15.3 cm)	
April	6.54
May	5.12
June	1.77
July	1.89
Total	29

^zMoisture (1 in = 2.54 cm) harvesting period October through March (rainfall capture established 26 Oct. 1993), muskmelon planting date 4 Apr. 1994, final harvest 6 July 1994.

Table 6. Rainfall^z received during the commercial evaluation of rainfall capture at Cargil Produce 1995.

Month	Rainfall received (inches)
April	1.5
May	4.06
June	2.99
Total	8.54

^zRainfall capture establishment date = 14 Apr. 1995; planting date = 6 Apr. 1995; final harvest date = 22 June 1995; 1 inch = 2.54 cm.

Table 7. Supplemental water applied and rainfall received during commercial evaluation of rainfall capture at Cargil Produce, 1995.

Treatment	Water received (inches)		Total water ^x
	Irrigation ^z	Rain ^y	
Drip irrigation	8.27	8.54	16.81
Rainfall capture	0	8.54	8.54
Furrow irrigation plus plastic mulch	20.87	8.54	29.41

^zQuantity of irrigation water applied during growing season in inches (1 inch = 2.54 cm).

^yQuantity of rainfall received during the growing season.

^xQuantity of irrigation water applied plus rainfall received during growing season.

was observed in this evaluation (Tables 6 and 7) as reported for the previous on-farm test.

Conclusion

Under the conditions of this evaluation RFC was found to reduce total supplemental water needs of muskmelon production through capture and storage of preplant rainfall. We believe that the key components of the RFC system evaluated are the mini-catchments trenched in the bed surface and the perforated black plastic used to mulch the beds and line the trenches. Unlike traditional plastic mulch systems which hold plastic sheets tightly across the soil surface (Fisher, 1995), rain water is not shed from the bed surface and the field as run off with the RFC system. Instead, the mulched bed surface acts as a water shed region and the perforated plastic-lined trenches as a means to collect and store the bed surface runoff for future crop use. As a result, the use efficiency of the rain water received in a field is increased.

Often sufficient moisture is received in a region that would support economic yields if the precipitation was distributed uniformly over the growing season. Surface runoff is a major source of water loss from crop production fields (Redinger et al., 1984) equaling 30% of the received precipitation some instances. Field water may be lost through soil surface evaporation and deep percolation as well (Pruitt et al. 1984). Therefore, capturing and storing received moisture in the field for future use can result in less dependence on irrigation. The results from this study indicate RFC was successful in this regard.

RFC provides a means of replenishing the soil profile with water prior to crop establishment. Although RFC continues to harvest moisture during

the growing season, it is believed that its real value in a production system occurs prior to planting. As a result the need for preplant irrigation to fill the soil profile, as often practiced in irrigated production regions, is significantly reduced or eliminated. For example, under field conditions such as found in south Texas, 6 to 10 inches of water/acre (15 to 25 cm·ha⁻¹) are normally required to fill the soil profile using furrow irrigation before sufficient moisture is available for successful seed germination and stand establishment to occur (J. Mulkey, Jr., unpublished data.). Under laboratory conditions, sufficient seed to establish one acre of muskmelon can be germinated by with less than two quarts of water (F. J. Dainello unpublished data). Therefore, from a plant response prospective, the preplant irrigation is the least efficient use of water made during the cropping cycle. The volume of water required to fill the soil profile represents ≈50% of the total water needs [13 to 20 inches (35 to 50 cm)] reported for muskmelons grown in Texas (Dainello, 1996). In these studies, germination and stand establishment were achieved with RFC without supplemental water application. In addition sufficient rainfall occurred during the growing season that enabled the RFC to limit moisture stress in these plots.

Based on the results of this study, we conclude that the RFC system evaluated offers a commercially adaptable method of achieving water harvesting and storage for use in the production of high value crops such as muskmelon. Producers who are currently utilizing plasticulture can obtain the added benefits of water harvesting through the slight, inexpensive modification of their conventional bed shaping equipment. It is acknowledged that much of the observed influence

on yield were direct benefits normally experienced with the use of black plastic mulch such as soil warming, earliness, weed control and disease reduction. Although there continues to be water harvesting benefits during the growing season with RFC, its real value is in water harvesting during the pre-plant period. RFC provides a means to fill the soil profile with water prior to crop establishment, thus, eliminating or significantly reducing the need for a preplant irrigation as practiced in many irrigated crop production regions.

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Shiitake Mushroom Growth on the Formulated Culture Media, Production of Spawn, and Basidiocarps in the Laboratory

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ADDITIONAL INDEX WORDS. *Lentinula edodes*, hardwood sawdust, exotic mushroom

SUMMARY. Culture media YMMBSA (yeast extract, malt extract, multigrain oatmeal, brown sugar, agar), YVMBSA (yeast extract, V-8 vegetable juice, multigrain oatmeal, brown sugar, agar), and YVMSA (yeast extract, V-8 vegetable juice, multigrain oatmeal, sucrose, agar) and broths YVMBS (yeast extract, V-8 vegetable juice, multigrain oatmeal, brown sugar), YVMS (yeast extract, V-8 vegetable juice, sucrose), and MVBS (multigrain oatmeal V-8 vegetable juice brown sugar) were formulated and demonstrated to be excellent media and broths for growing shiitake mushrooms [*Lentinula edodes* (Berk.) Pegler] in the laboratory. When a portion of the unopened basidiocarp or mushroom fruit (cap or stipe) was isolated on PSA (potato sucrose agar) medium and transferred to the formulated culture media, the mycelia significantly ramified to flocculent

(wooly or fluffy) growth texture within 20 days. For the first time, shiitake mushroom basidiocarps have been induced on the formulated plated media within 20 to 35 days. In tissue culture vessels, mycelia grew well on substrates composed of maple, oak, maple + oak, maple + vermiculite, and oak + vermiculite which had been amended with the broths YVMBS, YVMS or MVBS, attaining spawn texture in 25 to 30 days. Shiitake basidiocarps appeared on the tissue vessels, Magenta GA-7, in 2.6 to 4.1 months. Shiitake mushroom strains, LE1, LE2, LE6, LE7, and LE8, attained flocculent mycelia on the formulated culture media YMMBSA, YVMBSA, and YVMSA in 20 days. Growing the same shiitake strains in the bigger tissue culture vessels, P4928, containing hardwood sawdust amended with broth YVMBS or YVMS or MVBS resulted in significantly larger volume of mycelia growth and spawn texture was attained in 35 to 45 days. Shiitake basidiocarp initials or pins were induced on the spawn blocks in 3 to 5 days after the blocks were squeezed off from the sides of the tissue culture vessels. These results are the first that the formulated culture media considerably enhanced the growing of shiitake mushroom mycelia, production of spawn, and basidiocarps in less time (2.6 to 4.1 months after inoculation) in the laboratory. Basidiocarp productions of shiitake mushroom on amended hardwood sawdust may have an excellent economic potential commercially. It takes 1 to 2 years for basidiocarps to appear in shiitake spawn inoculated logs.

The shiitake mushroom (*Lentinula edodes*) was indigenous to Asia and introduced into the United States in logs by Asian immigrants that settled in the Pacific States in the early 70's (Cook, 1989). It is a wood-rotting and beneficial fungus that belongs to the class basidiomycetes, produces edible basidiocarps or fruit (cap and stipe), and considered an exotic mushroom. Production of the fresh shiitake mushroom crop in the United States in 1995-96 was 6.2 million lbs (2.8 million kg) worth about \$19.8 million (USDA, 1996).

Shiitake mushroom are commonly produced in holed inoculated logs, which basidiocarps typically appeared in ~1 to 2 years later depending on the shiitake strain used (Donoghue, 1994; Sabota,

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