Subsurface Drip Irrigation and Plastic Mulch Effects on Yield and Brix Levels of Kabocha Squash,

Cucurbita moschata

Mahbub Alam[1] and Rick Zimmerman[2]

ABSTRACT:

Kabocha squash, *Cucurbita moschata,* is an important cash crop for western Colorado. A combination of different colored plastic mulches with subsurface drip irrigation (SDI) was compared to non-mulched furrow irrigated Kabocha squash. An average of 18 inches of water was applied through SDI, which was one-fourth the amount applied by furrow irrigation. Subsurface drip in combination with plastic mulch produced consistently higher total yield averaging 26,940 lbs. per acre compared to furrow irrigated squash without mulch, which produced 6,080 lbs. per acre. Transplanted squash produced higher yields compared to direct seeded plots, which produced average 21,127 lbs. per acre. Average marketable yield from two years of data was 19,761 lbs. per acre for SDI with mulch treatments for transplanted squash. Furrow irrigated transplanted squash with no mulch averaged at 5,018 lbs. per acre. Soluble solids (measured as Brix) ranged from 11.29 to 15.2 and were consistently higher for subsurface drip irrigated squash compared to furrow irrigated squash.

INTRODUCTION:

Virtually all of the Kabocha squash produced in Western Colorado is exported to Japan. Rich in beta-carotene, it is prized for its delicious smooth textured flesh. This winter squash has a beautiful jade green rind with celadon green streaks (Fig.2). Its pale orange flesh is tender smooth and sweet when cooked. Colorado Kabocha producers receive a premium price for squash due to its high quality. However, to remain competitive, growers need to utilize methods, which can increase production, while maintaining quality and economic viability.

The use of plastic mulch and subsurface drip irrigation has been recognized as two methods that might increase squash yields and maintain and/or increase quality. Feibert et al (1992) observed improvement in quality from use of plastic mulch in eastern Oregon. At the Rocky Ford Research Station in Southeastern Colorado, Bartolo (1996) found a significant increase in yield of cantaloupes when grown with plastic mulch and subsurface drip irrigation. There are several colored plastic mulches available for horticultural crop production. The effect of plastic mulch color on yield of squash has not been reported. A combination of subsurface drip irrigation and plastic mulch can lead to a significant water savings.

Fiebert et al (1992) reported a 50% water savings from use of drip irrigation when compared to furrow irrigation. Water conservation is an important issue in Western Colorado, which depends on limited water

[1] Associate Professor and Extension Specialist Irrigation, Department of Biological and Agricultural Engineering, Kansas State University, SWREC, Garden City, KS 67846, malam@oznet.ksu.edu
[2] Research Scientist, Agricultural Experiment Stations, Colorado State University, Rogers Mesa Research Center, Hotchkiss, CO 81419

supplies for use in both urban and agricultural areas. Subsurface drip irrigation also gives growers the flexibility to inject liquid fertilizer at the time when plants need it and according to the amount needed.

Applying fertilizer according to growth stage and plant needs will increase the efficiency in terms of uptake and reduction of losses. Growers could also decrease the amount of fertilizer by applying fertilizer directly to the root zone. Lamm et al (1997) reported saving nitrogen applications for corn (*Zea mays*) using subsurface drip system.

Objectives of the study were to see the effect of different colored plastic mulch in combination with subsurface drip irrigation on (1) Kabocha squash yield, (2) sugar content as Brix level, and (3) water saving compared to producers practice of surface irrigating without mulch. The study also included evaluating of planting method, transplanting versus direct seeding, on squash yield.

METHODS:

This study was conducted for three years, 1998-2000, at the Western Colorado Research Center at Rogers Mesa, located 20 miles east of Delta, Colorado (latitude:38^{o} $47^{'}$ and longitude:107^{o} $47^{'}$). The elevation is 5,640 feet above mean sea level. The growing season is approximately 150 days. Weather data were collected from the weather station at the research center. The field was prepared by disking followed by roto-tilling. Plastic mulch and drip tape was laid with a Buckeye combination mulch layer drip tape applicator and bed shaper.

The beds were 42 inches wide and 8 feet between centers. The drip tube used for irrigation was T-Tape™ TSX-51030-340 (T-Systems International, San Diego, California)[3]. The T-Tape was laid 2-3 inches below the surface of the soil in the center of the bed. The beds were prepared in mid-May in 1998, 1999 and 2000.

Planting methods used were direct seeding and transplanting. Three different colored plastic mulches were used: 1) clear, 2) black and 3) green. The treatments were (a) drip irrigation with clear, green, or black plastic mulch, (b) drip irrigation with no-mulch, and (c) furrow irrigation with no-mulch on both transplanted and direct seeded squash. Furrow irrigation for a mulched squash bed by furrow irrigation is slow, consequently inefficient, and was not included.

Irrigation water was delivered through a series of ditches. Irrigation water from the ditch was first filtered through 2 Spin-Klin™ 140-mesh filters followed by 4 Amiad™ 120-mesh filters to achieve adequate filtration.

The amount of water used was measured with inline flow meters for 1999. Flow meters were not available for 1998. Water usage for 1998 was estimated from emitter flow rate at operating pressure of 9 psi.

---

[3] Mention of a trademark, proprietary product, or a vendor does not constitute a guarantee or warranty of the product by authors or institutes they represent.

Water pressure for the drip system was maintained at 9 psi for 1998,1999, and 2000. Soil water status was monitored using tensiometers and soil water potential was maintained between 15 to 45 centibars, which was in agreement with recommendation made by Top and Ashcroft (2000).

Fertilizers were injected using a Chem Feed™ C600P pump. In 1998, 1999 and 2000 approximately 15 gallons of Uran (32% nitrogen) and 21 gallons of 5-5-5 (5% nitrogen, 5% phosphate and 5% potash) was applied during the growing season. Transplanted seedlings were 4-week-old. The second half of the plots was direct seeded. Seeds and transplants were planted on May 28 –29 in 1998, June 15-16 in 1999, and June 12-13 in 2000. Figure 1, gives a view of a young squash plant in mulch.

Figure 1: Kabocha squash plant in black plastic mulch 16 days after seed was planted.

Plots were 40 feet long with 2 feet in-row plant spacing with 4 replications in a randomized complete block design. Row orientation was north to south. Squash were harvested in the first week of September in 1998 and the second week of September for 1999. Harvest was not possible in 2000 due to the loss of irrigation water at the end of August.

Squash were individually weighed and evaluated as marketable or non-marketable. Squash were considered non-marketable, based on the following criteria: 1) sunburn, 2) excessive scarring (scarring would include raised warts and ridges on squash surface), 3) too small (<2lbs), and 3) immature (immaturity was based on the greenness of the stalk (Figure 2). The Brix level (percentage of soluble solids which consist mostly of sugars) was taken from three squash randomly selected from each plot. The Brix levels were taken with a hand held refractometer (Atago Co., LTD., Tokyo, Japan).

Figure 2: Kabocha squash on the left is mature (the stalk is shriveled and dry). The squash on the right is immature and would be considered non-marketable. The peduncle is still green.

The major weed pests in 1998 and 1999 were common mallow (*Malva neglecta* Wallr.), lambsquarter (*Chenopodium berlandieri* Moq.), red root pigweed (*Amaranthus palmeri* S. Wats.) and bindweed (*Convolvulus arvensis* L.). A combination of the herbicides, 2-4-D (Dow AgriSciences, Indianapolis, IN) and Roundup

(Monsanto Co., St. Louis, MO) were used on the furrow irrigated and non-mulched plots until the plants were too large to safely spray around. Henceforth all weeding for non-mulched plots were done by hand on a weekly basis. Herbicide 2-4-D and Roundup were used to control weeds in the open space between the mulched beds until the vines covered the ground. After the vines filled in between the mulched beds, weeds were pulled when they broached the leaf canopy of the squash plant. These weeds were not competing with the squash plants. Squash bug populations were treated with Diazinon AG (Novartis Crop Protection Inc., Greensboro, NC)) twice per season.

RESULTS:

In 1998 there was a significant difference in the amount of irrigation water applied between the furrow-irrigated plots and the subsurface drip irrigated plots. The water applied in subsurface drip irrigated plots was equivalent to average 19 inches per acre. An equivalent of 76 inches per acre on average were applied to furrow irrigated plots. Water application by subsurface drip irrigation 1999 slightly improved and an equivalent of 18 inches per acre was applied, whereas an equivalent of 82 inches per acre was applied by furrow irrigation. Water usage decreased for subsurface drip irrigated plots whereas furrow irrigation amount increased. This may be due to better control of subsurface drip irrigation compared to furrow flood irrigation where efficiency is dependent on available flow from the ditch system at the time of irrigation.

Irrigation interval for subsurface drip irrigated plots was three days and the furrow irrigated plots were watered weekly. Soil water level in subsurface drip irrigated plots reached to field capacity (10-30 centibar) level in a short time and the distribution was uniform. In furrow irrigation it took longer time since water running down the furrow took time to seep down the rows and across the bed to the squash plants. Also, while the upper part of the squash beds might be adequately wet, the lower parts of the furrow may not have reached the proper soil water levels. Thus in order to attain proper soil moisture levels at the bottom of the field; the upper parts of the field became over saturated.

Kabocha squash yield results of 1998 and 1999 were combined for statistical analysis and are presented in Table 1. The weather of 1999 was somewhat cooler in September, Table 2, but had no significant influence on yield. There was significant difference in squash production between subsurface drip irrigated plots with mulch compared to non-mulched furrow irrigated plots (Table 1). Overall yields were lower for furrow-irrigated plots. Transplanted squash tended to produce higher yields compared to direct seeded, except for furrow-irrigated plots with direct seeding. Soil water contact with seed and subsequent root development were probably favorable for direct seeded furrow irrigated treatment. Direct seeded non-mulched drip irrigated plots performed poorly.

Black plastic mulch performed better for direct seeded squash, probably by increasing the necessary heat units. However, the color of plastic mulch showed no significant influence on total yield of squash. Mulch in combination with drip irrigation showed significant yield improvement. There was no significant difference in average fruit size across all treatments (average fruit weight ranged from 2.88 to 3.54 lbs). Brix readings were significantly lower for furrow irrigated direct seeded non-mulched squash. Brix reading was 11.6 for furrow-irrigated plots as compared to 15.2 for subsurface drip irrigated plots.

Table 1: Results of Kabocha squash trial (1998 and 1999 combined) investigating the influence of subsurface drip irrigation and plastic mulches at Rogers Mesa Research Center, Hotchkiss, Colorado.

Planting Method	Mulch Type	Irrigation Treatment	Fruit size (lbs.)[a]	Brix[b]	Yield	
					Total lbs/acre[c]	Marketable lbs/acre[d]
Transplant	Clear	Drip[e]	2.96a	13.81a	27,796a	20,173a
	Green	Drip	3.16a	15.04a	29,695a	23,522a
	Black	Drip	3.04a	14.92a	23,331a	15,590a
	No Mulch	Drip	3.03a	13.66a	24,389a	21,603a
	No Mulch	Furrow	2.71a	11.6c	6,080b	5,018b
Direct Seeding	Clear	Drip	3.39a	14.58a	20,744a	15,679ab
	Green	Drip	3.27a	15.19a	18,188a	12,383bc
	Black	Drip	3.49a	14.92a	24,451a	19,972a
	No Mulch	Drip	2.73a	13.23b	7,721b	5,767d
	No Mulch	Furrow	3.24a	11.62c	12,285b	7,814cd

[a]$F=1.4$, $n=38$, $P<0.26$. [b]$F=2.31$, $n=118$, $P<0.06$. [c]$F=6.27$, $n=38$, $P<0.0008$. [d]$F=3.36$, $n=38$, $P<0.02$, [e]Subsurface drip irrigation.

Treatments within the same column followed by the same letter are not significantly different.

Table 2: Weekly average weather data of Rogers Mesa Research Center at Hotchkiss, Colorado for 1998 and 1999.

Month	Weekly Av.[1]	Max. T °F		Min. T °F		Lngly[2]		Rainfall[3] inches		GDU[4]		Ref ET[5] inches	
		98	99	98	99	98	99	98	99	98	99	98	99
June	1	77.1	76.7	44.4	41.7	637	595	0.2	0.2	108	107	2.58	2.39
	2	74.3	81.9	45.8	46.8	629	584	0.1	0.0	197	220	2.03	2.16
	3	78.8	83.7	48.0	51.2	588	468	0.2	0.5	301	343	2.08	1.83
	4	90.8	89.3	51.0	53.4	754	511	0.0	0.0	452	500	3.30	2.72
July	1	90.7	90.7	57.3	59.9	618	482	0.4	0.2	623	681	2.70	2.50
	2	92.4	86.2	57.5	55.8	626	512	0.0	0.6	795	841	2.72	2.12
	3	94.6	85.5	61.8	56.4	635	487	0.1	0.3	984	1,003	2.78	1.96
	4	84.6	84.9	60.2	58.6	551	534	1.4	0.4	1,139	1,153	1.77	1.72
Aug	1	88.3	83.0	54.3	56.9	621	512	0.0	0.1	1,297	1,310	2.43	1.84
	2	88.9	83.0	56.1	52.9	564	491	0.0	0.5	1,462	1,454	2.30	1.83
	3	88.9	84.2	57.6	56.6	514	516	0.1	0.5	1,634	1,614	2.07	1.80
	4	89.9	83.8	55.7	56.6	529	438	0.1	0.2	1,780	1,755	1.85	1.41
Sept	1	88.8	79.3	57.1	48.6	515	482	0.1	0.7	1,948	1,878	1.97	1.69
	2	80.0	78.8	54.3	47.8	431	468	0.9	0.1	2,072	1,982	1.35	1.47
	3	82.4	73.2	47.13	44.3	488	467	0.0	0.5	2,186	2,063	1.48	1.21
	4	80.0	72.5	47.0	39.9	449	482	0.1	0.0	2,306	2,154	1.44	1.50

[1] Weekly average (of either 7 or 8 days), [2] Average Solar radiation in Langleys, [3] Total weekly rainfall, [4] Cumulative growing degree units starting from June 1 and based on equation {(Max. Temperature in ° F + Min. Temp in °F)/2 – 50°F}, where 86° F is maximum threshold and 50° F is the minimum threshold, [5] Weekly total reference evapotranspiration estimates in inches calculated using modified Penman equation for alfalfa as a reference crop.

DISCUSSION:

There was a significant decrease in the amount of water used between the subsurface drip and furrow irrigated plots. Lamm et al (1995) comments that a 25 percent net water savings are possible by using SDI compared to sprinkler irrigated corn and a 50 percent saving compared to furrow-flood irrigation. Feibert et al (1992) reported a fifty percent of water savings from drip irrigation compared to surface irrigation. Excessive run-off contributed to the higher diversion of water to furrow irrigated plots in this study, hence a higher difference was observed between drip and furrow irrigation, compared to what has been reported in literature. Measuring run-off would have helped.

Transplanted squash produced higher total yields compared to direct seeded plants. This is in contrast to findings of Feibert et al (1992) who found no advantage over direct seeding. The increase in yield observed in this study may be in part due to lengthening of the growing season by starting seedlings at a nursery. Transplanted squash started flowering approximately 20 days before the direct seeded squash plants. However, there is a cost of seedling and transplanting that need to be considered for evaluating an economic benefit from transplanting compared to direct seeding for commercial production.

The skin of Kabocha squash is very sensitive to sunburn. A reason for culls was sunburn. A good canopy cover is necessary to protect the squash from sunburn. In this study, the rows were farther apart than would be found in a commercial setting and may have contributed to more culls.

The major pest problems were common mallow, lamb's-quarter, red root pigweed, and bindweed. Squash bug, *Anasa tristis,* was the only insect pest of any concern. Powdery mildew, *Erysiphe polygoni,* was spotty throughout the field but weather conditions never attained optimum conditions to create an outbreak serious enough to affect the squash plants. Weed competition may have depressed yields in the furrow-irrigated plots. Squash bug populations started building at the outside of the plots and moved in towards the middle of the squash plots. In 1998, squash bugs may have had an effect on the outermost row of drip irrigated and black-mulched plots. Scouting for early infestations is difficult because the squash bugs is secretive and tend to stay near the base of the squash plant. The plastic mulch may have exacerbated the problem by providing a hiding place for the squash bugs at the point where the plant is growing through the mulch.

LITERATURE CITED:

Bartolo, M. 1996. Early Cantaloupe Production in the Arkansas Valley, Arkansas Valley Research Center Annual Report, Rocky Ford, Colorado State University.

Feibert, E.,C. Shock, T. Stieber, and M. Saunders. 1992. Groundcover Options and Irrigation Methods for the Production of Kabocha Squash. Malheur County Alternative Crops and Marketing Research. Special Report 900. Oregon State University. pp. 26-32

Lamm, F. R., A. J. Schlegel, and G. A. Clark. 1997. Optimum Nitrogen Fertigation for Corn using SDI. In proceedings of the 1997 Irrigation Assn. International Technical Conference, Nashville, TN, Nov. 2-4, 1997. pp. 251-258.

Lamm, F. R., H. L. Manges, L. R. Stone, A. H. Khan, and D. H. Rogers. 1995. Water Requirement of Subsurface Drip Irrigated Corn in Northwest Kansas. Transactions of the ASAE. 38(2): 441-448. ASAE, St. Joseph, MI 49085.

Top, M., and B. Ashcroft. 2000. Japanese Pumpkin – Kabocha: A production Manual for Victoria. Department of Natural Resources and Environment, Government of Victoria, Australia.