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

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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 for yield, Brix level, and water use. SDI method produced higher squash yield compared to furrow irrigation for a less water use. 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 and transplanting method produced consistently higher total yield averaging 26,940 lbs. per acre compared to furrow irrigated squash without mulch, which produced 10,022 lbs. per acre. However, mulch was not critical for transplanted squash with SDI, which produced 24,389 lbs. per acre. In case of direct seeding with SDI, mulch was critical for direct seeded squash. Direct seeded squash in SDI produced only 7,721 lbs. per acre without mulch, whereas direct seeded squash under black mulch produced an average yield of 24,451 lbs. per acre, which was as good as transplanted. After grading of the fruits, the average marketable yield was 19,761 lbs. per acre for transplanted squash with SDI in mulch treatments. Furrow irrigated transplanted squash with no mulch averaged at 8,056 lbs. per acre of marketable squash. Soluble solids (measured as Brix level) ranged from 11.3 to 15.2 and were consistently higher for subsurface drip irrigated squash compared to furrow irrigated squash. Kabocha yield and the Brix level were significantly improved under a combination of SDI and mulch. Mulch color type showed no significant effect on yield except for planting method. Color of mulch had no effect on Brix level.

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

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(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 and Brix level 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 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 soil type is classified as Mesa Utahline Complex clay loam. The growing season is approximately 150 days. 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

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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. Plastic mulches used were all smooth and 4 ft. wide. Colors were alternated randomly and four drip tapelines were used for each color type. Two plots each were transplanted and direct seeded under each color type. Plots were 40 feet long with 2 feet in row plant spacing with four replications in a randomized complete block. Row orientation was north to south.

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

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 3). 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.

There was significant difference in squash production between subsurface drip irrigated plots compared to furrow irrigated plots (Table 1) except for direct seeded squash irrigated by subsurface drip that performed poorly. Delay in germination and poor contact of seedling roots to water in the beginning of the season may have contributed to poor performance. Transplanted squash tended to produce higher yields compared to direct seeding, except for drip-irrigated plots with direct seeded squash under black mulch. Soil water contact with seed and subsequent root development from heat entrapment due to black mulch color were probably favorable. In general drip with mulch performed better compared to drip without mulch except for transplanted squash. The results show that it may not be critical to have mulch when squash is transplanted on subsurface drip-irrigated plots. Highest marketable squash yield was obtained from transplanted Kabocha seedlings in subsurface drip irrigated plots with green mulch. However, statistically the color of plastic mulch showed no significant influence on yield components measured for Kabocha squash except for planting method. Direct seeded squash responded to black mulch color.

Soluble solids (measured as Brix level) were significantly lower for the furrow irrigated non-mulched direct seeded plots. The Brix level, a measure for sugar content was 11.31 for furrow-irrigated direct seeded plots with no mulch. The highest value of 15.19 was seen for direct seeded squash in subsurface drip irrigated plots with green mulch.

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.

Irrigation Treatment	Mulch Type	Planting Method	Fruit size (lbs.)	Brix	Yield	
					Total lbs/acre	Marketable lbs/acre
Subsurface Drip	Green	Transplant	3.16 abc	14.77 ab	29,695 a	23,522 a
	Green	Seeding	3.27 abc	15.19 a	18,188 b	12,383 cd
	Clear	Transplant	2.96 c	14.04 ab	27,796 a	20,173 ab
	Clear	Seeding	3.39 ab	14.58 ab	20,744 b	15,679 bc
	Black	Transplant	3.04 bc	14.79 ab	23,331 ab	15,590 bc
	Black	Seeding	3.49 a	14.49 ab	24,451 ab	19,972 ab
	No mulch	Transplant	3.03 bc	14.76 ab	24,389 ab	21,603 ab
	No mulch	Seeding	2.72 d	13.80 ab	7,721 c	5,764 e
Furrow	No Mulch	Transplant	3.33 abc	13.34 b	10,022 c	8,056 de
	No Mulch	Seeding	2.95 c	11.31 c	10,834 c	5,770 e

Significant at $P<0.05$

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

Table 2: Significance of Treatments on Kabocha squash Yield components.

Yield Components	Furrow vs. Drip irrigation	Mulch Vs. no-mulch	Furrow with no-mulch Vs. drip with no-mulch	Transplant Vs. Seeding	Mulch Color	Mulch color vs planting method
Fruit size	ns	*	ns	ns	ns	ns
Total yield	***	***	*	***	ns	*
Marketable yield	***	***	**	***	ns	**
Brix level	***	***	***	ns	ns	ns

* at P<0.05; ** at P<0.005; and *** at P<0.0001; ns = not significant

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 from transplanting 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.

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