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Interactive effect of FYM and mulching on productivity and water use efficiency of squash melon (*Citrullus vulgaris* var. *fistulosus*) grown with supplemental irrigation in hot arid region of Rajasthan

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ABSTRACT

Squash melon (*Citrullus vulgaris* var. *fistulosus* Steward) is a rainfed crop in arid region but in these areas, the rainy days are very less. Due to this reason, the farmers could not get desired yield. Hence supplemental irrigation with water conservation practices is required for getting the economic return from this crop. Hence an experiment was conducted at ICAR-Central Arid Zone Research Institute, Regional Research Station, Bikaner, Rajasthan to study the effect of three mulching treatments (No mulching, straw mulching (2.5 tonnes/ha) using local shrub *Leptadenia pyrotechnica* and black polyethylene plastic mulching of 25 micron thickness) and four FYM doses (0, 20, 30 and 40 tonnes/ha) on growth, yield, WUE and economics of Squash melon grown with supplemental irrigation during *kharif* seasons of 2012 and 2013. Vine length, numbers of fruits per plant and yield of squash melon were significantly influenced by FYM, mulching and their interaction during both the years of experiment. Application of FYM caused significant improvement in squash melon yield up to 30 tonnes/ha. Averaged across mulching treatments, application of FYM @ 20, 30 and 40 tonnes/ha resulted 47.8, 79.5 and 88.4% higher yields compared to control. Application of mulch brought significant improvement in yield and yield components and the response of mulch varied with the level of FYM application. Plastic and straw mulching resulted 26.6 and 48.6% higher yield over no-mulch treatment. Straw mulch recorded the longest vine length, the highest numbers of fruits per plant and yield. The highest yield was recorded with application of 30 tonnes FYM /ha combined with straw mulch.

Key words: Farm yard manure, Mulching, Supplemental irrigation, Squash melon, Yield

Squash melon (*Citrullus vulgaris* var. *fistulosus* Steward), which is also called Apple Gourd or Indian squash is one of the most widely grown vegetable in rainfed areas of western Rajasthan. It is a rich source of Vitamin A and also has great medicinal value. The crop is short duration, deep rooted and low water requirement. Dried fruits are consumed by the local inhabitants during scarcity period. However, the productivity of squash melon remains low under rainfed condition in arid region due to less rainfall, poor soil fertility and low water holding capacity of soils. Increasing the productivity of this important arid vegetable is important for sustaining livelihood of the farmers of this region. The productivity of crops can be improved with proper technological intervention and adoption of the technology (Kumar 2012, Kumar 2013 and Kumar 2014).

Conservation of rain water is the main issue for improving crop productivity of this region. One possible way of conserving water is the use of mulching. Mulching can be made via addition of inorganic synthetic materials, (e.g. polyethylene sheets, and gravels) or organic material (e.g. crop residues, straw, grasses, and farmyard manure) to the soil surface to provide one or several ecosystem services such as enriching or protecting the soil, preventing pest establishment or enhancing crop yield. In-situ water conservation through mulches has been found to preserve soil moisture, controlling weeds, moderating soil temperature, stimulating microbial activity, increasing nutrient availability; reducing evaporation, minimizing fertilizer losses through leaching, reducing soil compaction, controlling weeds, and increasing yield of different vegetable crops (Ramalan and Nwokeocha 2000, Incalcaterra *et al*. 2003, Araki and Ito 2004). Human, livestock and crops produce approximately 38 trillion metric tonnes of organic wastes worldwide, and around 600 to 700 million metric tonnes of agricultural wastes including 272 million metric tonnes of crop residues in India are available every year, but most remains unutilized (Suthar 2009), which can fruitfully be used for purposes such as mulching.

The use of organic materials such as farmyard manure (FYM) is an important component for maintaining soil

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fertility and yield stability. They affect crop growth and yield, either directly by supplying nutrients, or indirectly by modifying water retention capacity, soil physical and biological properties (Hati 2006). Mulching and supplemental irrigation is also expected to improve the water use efficiency of crops in arid region. In this regard, very few studies have assessed the effect of various types of mulches and manures on growth and yield of squash melon in hot arid region. The present experiment was undertaken to study the effect of different levels of FYM and types of mulches on growth, yield and water use efficiency (WUE) of squash melon grown with supplemental irrigation in arid area of Rajasthan.

MATERIALS AND METHODS

The experiment was conducted in the research farm at Central Arid Zone Research Institute, Regional Research Station, Bikaner, Rajasthan (28°4' N; 74°3' E and 238.3 m above mean sea level) during *kharif* seasons of 2012 and 2013 to examine the effect of farm yard manure and mulching on growth behaviour, productivity and profitability of squash melon. The soil of the field was loamy sand, low in organic carbon (0.09%), low in available nitrogen (88.2 kg/ha), low in available P (9.2 kg/ha) and medium in available K (224.6 kg/ha) with pH 8.1, electrical conductivity 0.21 dS/m, field capacity of 11.8% (v/v) and permanent wilting point was 3 %. The average annual rainfall of zone was 283 mm of which about 90% is received during later half of June to September with erratic distribution over time and space (Fig 1) The experiment was laid out in split plot design and consists of four different rates of farm yard manure (FYM), viz. F_1 (0 tonnes/ha), F_2 (20 tonnes/ha), F_3 (30 tonnes/ha) and F_4 (40 tonnes/ha) in main plots and three mulching treatments, viz. M_1 (No mulching), M_2 (straw mulching using local shrub *Leptadenia pyrotechnica* @ 10 tonnes/ha) and M_3 (plastic mulching through black polyethylene of 25 micron thickness) and replicated thrice. Field preparation included deep ploughing by mouldboard plough followed by cross harrowing and planking. The squash melon variety Selection-1 was sown during 2nd week of August (2012) and 3rd week of July (2013) at 0.6 m × 1.0 m spacing in 4.0 m × 4.2 m sized plots on the occurrence of rainfall. After receding of rains (one month after sowing the crop during both the cropping season) two supplemental irrigation (13 mm each) in 2012 and four supplemental irrigation (13 mm each) in 2013 was provided with harvested rain water through drip to prevent crop failure during fruit picking stage. All the other recommended agronomic practices were followed as and when required at regular intervals. Growth and yield attributes were measured from 10 randomly selected plants from each plot excluding border rows. The fruits of squash melon were harvested at marketable maturity at regular interval by hand picking and weighed and harvest plot yields were calculated. Depth wise soil temperature was measured with the help of infrared thermometer at 2.00 p.m. during crop growth period in both the years. Water use efficiency of irrigation water applied was calculated for each treatment after harvesting of crop according to following equation.

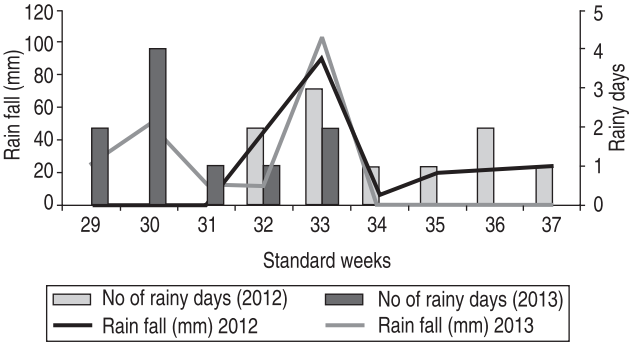

Fig 1 Rainfall pattern during cropping season

$$\text{Water use efficiency (kg/ha/mm)} = \frac{\text{Fruit yield (kg/ha)}}{\text{Rainfall} + \text{Irrigation water applied (mm)}}$$

The net returns of each treatment were calculated by deducting the total cost of cultivation from gross returns of respective treatments and the benefit: cost ratio was calculated by dividing the net returns with total cost of cultivation. All data recorded were analyzed with the help of analysis of variance (ANOVA) (Gomez and Gomez, 1984). The least significant differences test was used to separate main and interaction effects of treatments at 5% level of significance.

RESULTS AND DISCUSSION

Effect of FYM and mulching on growth attributes

The FYM levels and mulching treatments led to significant improvement in vine length. According to the result, the successive increase in FYM levels, vine length increased significantly up to 40 tonnes/ha. At same levels of FYM, straw mulch recorded the longest vine length (228.4 cm) followed by plastic mulch (195.4 cm) and control (146.4 cm). The combination of straw mulch and FYM @40 tonnes/ha gave the longest vine length (279.5 cm) which was at par with the combination of straw mulch and FYM @ 30 tonnes/ha (269.8 cm). The marked improvement in vine length could be attributed to improved soil moisture retention, favourable temperature in the crop root zone and adequate supply of essential nutrients resulting from the application of FYM and straw mulch (Singh, 2005).

Days taken to 1st flowering was found to be reduced significantly by 1-7 days with successive increase in FYM levels upto 40 tonnes/ha and; by 3 days with the application of straw and plastic mulch as compared to control. The combination of FYM @40 tonnes/ha with either type of mulching material reduced the days taken to 1st flowering by 12-13 days in comparison to the combination of no FYM and no mulch (F_1M_1). The enhanced vegetative growth completion as a result of optimum nutrient supply might have resulted in early floral initiation While in other treatments the nutrient supply was not optimum which delayed vegetative growth and also flowering. Normally, N supplied through FYM delay flowering due to increasing vegetative growth

Table 1 Effect of FYM and mulching on growth attributes of squash melon grown with supplemental irrigation

Treatment	Days to germination			Days to 1st flower			Vine length (cm)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
FYM									
F_1	6.9	7.1	7.0	30.7	29.8	30.2	119.6	142.2	130.9
F_2	6.8	6.7	6.7	29.3	28.7	29.0	165.6	191.6	178.6
F_3	6.7	6.6	6.6	26.1	25.3	25.7	200.9	235.3	218.1
F_4	5.3	5.6	5.4	23.9	23.1	23.5	215.1	250.3	232.7
CD (P=0.05)	NS	NS	NS	3.9	3.6	3.6	25.1	28.8	26.1
Mulching									
M_1	6.8	6.9	6.9	29.9	29.0	29.5	134.9	157.9	146.4
M_2	6.3	6.4	6.4	26.4	25.8	26.1	210.0	246.8	228.4
M_3	6.1	6.1	6.1	26.2	25.4	25.8	180.9	209.8	195.4
CD (*P*=0.05)	NS	NS	NS	3.00	2.10	2.5	9.9	11.7	10.3
FYM × Mulching									
F_1M_1	7.7	7.7	7.7	34.3	33.3	33.8	96.7	111.3	104.0
F_1M_2	6.7	7.0	6.8	29.3	28.7	29.0	136.7	168.3	152.5
F_1M_3	6.3	6.7	6.5	28.3	27.3	27.8	125.3	147.0	136.2
F_2M_1	6.7	6.7	6.7	30.3	29.3	29.8	124.7	142.7	133.7
F_2M_2	7.0	6.7	6.8	29.3	29.0	29.2	198.7	225.0	211.8
F_2M_3	6.7	6.7	6.7	28.3	27.7	28.0	173.3	207.0	190.2
F_3M_1	6.7	6.7	6.7	27.0	26.7	26.8	151.7	181.7	166.7
F_3M_2	6.7	7.0	6.8	25.7	24.7	25.2	248.3	291.3	269.8
F_3M_3	6.7	6.0	6.3	25.7	24.7	25.2	202.7	233.0	217.8
F_4M_1	6.3	6.7	6.5	28.0	26.7	27.3	166.7	196.0	181.3
F_4M_2	5.0	5.0	5.0	21.3	20.7	21.0	256.3	302.7	279.5
F_4M_3	4.7	5.0	4.8	22.3	22.0	22.2	222.3	252.3	237.3
CD (P=0.05)	NS	NS	NS	5.8	4.0	4.8	19.0	22.4	19.8

F_1 (0 tonnes/ha) , F_2 (20 tonnes/ha), F_3 (30 tonnes/ha) and F_4 (40 tonnes/ha). M_1 (No mulching), M_2 (straw mulching) and M_3 (plastic mulching)

in cereals and legume crops. But in cucurbits, the growth and flowering occurs simultaneously. So delay in flowering occurs with delay in vegetative growth. Such observations have also been recorded in flower crops (Ram *et al.* 1994) and Mishra 1998).

Effect of FYM and mulching on yield and yield attributes

FYM application did not lead to significant improvement in fruit weight (Table 2). However, mulching treatments, as well as the combination of FYM @ 30 tonnes/ha and straw mulch significantly improved the average fruit weight during both the years of study. The application of 30 tonnes FYM /ha significantly increased the number of fruits/plant (14.8 fruits per plant). Irrespective of material, mulching improved fruit number/plant. Straw mulch (14.8) proved to be superior in comparison to plastic mulch (12.7) in pooled analysis. Combination of 30 tonnes FYM/ha and straw mulch recorded significant improvement in number of fruits per plant during both the years and on pooled basis also, which was at par with the treatment 40 tonnes FYM/ ha and straw mulch.

Results of pooled analysis (Table 2) showed that application of FYM @ 30 tonnes/ha recorded significantly higher yield (18.2 tonnes/ha), and further increase in FYM level did not improve the yield significantly. Among the mulching material, straw mulch was found most effective in enhancing the yield of squash melon. Straw mulching had 18.6 tonnes/ha yield (pooled basis), representing 17.2 and 48.6% higher yield than plastic mulch and no mulching, respectively. The yield increase under organic mulches could be attributed to their ability to reduce soil temperature fluctuation, improve water holding capacity and smother

Table 2 Effect of FYM and mulching on yield and yield attributes of squash melon grown with supplemental irrigation

Treatment	Fruit weight (g)			Number of fruits/plant			Yield (tonnes/ha)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
FYM									
F_1	37.7	38.4	37.9	8.1	9.4	8.8	9.4	10.9	10.2
F_2	39.2	42.5	40.8	11.5	13.3	12.4	13.8	16.2	15.0
F_3	39.3	43.2	41.3	13.6	15.9	14.8	17.0	19.5	18.2
F_4	39.7	46.6	43.1	14.1	16.4	15.3	18.0	20.3	19.1
CD (P=0.05)	NS	NS	NS	1.8	1.7	1.8	1.6	2.5	2.1
Mulching									
M_1	37.3	38.7	38.0	10.3	11.4	10.8	11.8	13.2	12.5
M_2	40.1	46.7	43.3	13.4	16.2	14.8	17.1	20.1	18.6
M_3	39.2	42.8	41.0	11.8	13.6	12.7	14.7	17.0	15.8
CD (P=0.05)	1.1	5.8	3.1	0.8	0.8	0.8	0.6	0.7	0.5
FYM × Mulching									
F_1M_1	35.3	31.7	33.5	5.9	6.4	6.2	6.5	7.0	6.8
F_1M_2	38.9	42.4	40.6	9.1	11.1	10.1	11.2	13.4	12.3
F_1M_3	37.7	41.2	39.5	9.4	10.6	10.0	10.5	12.3	11.4
F_2M_1	38.1	43.1	40.6	9.7	10.7	10.2	11.4	13.3	12.3
F_2M_2	40.4	42.9	41.7	13.1	15.6	14.4	16.2	19.1	17.6
F_2M_3	38.9	41.4	40.2	11.8	13.5	12.6	13.8	16.3	15.1
F_3M_1	37.7	38.9	38.3	12.1	13.6	12.8	13.8	15.8	14.8
F_3M_2	40.2	45.4	42.8	15.9	18.9	17.4	20.3	23.3	21.8
F_3M_3	40.1	45.3	42.7	12.9	15.1	14.2	16.8	19.4	18.1
F_4M_1	38.2	41.0	39.6	13.3	15.0	14.2	15.6	16.5	16.1
F_4M_2	41.0	55.2	48.1	15.8	19.0	17.4	20.8	24.5	22.6
F_4M_3	39.9	43.4	41.7	13.1	15.3	14.2	17.6	19.8	18.7
CD (P=0.05)	4.0	11.2	6.0	1.5	1.5	1.5	1.1	1.3	1.1

F_1 (0 tonnes/ha) , F_2 (20 tonnes/ha), F_3 (30 tonnes/ha) and F_4 (40 tonnes/ha). M_1 (No mulching), M_2 (straw mulching) and M_3 (plastic mulching)

weed population, which led to favourable microclimate conditions for plant growth and development. The positive effect of organic mulch materials on yield was also reported by Bhatt *et al.* (2011) in summer squash, Uniyal and Mishra (2003), Singh and Ahmed (2008) in potato and Birbal *et al. (*2014) in squash melon under rainfed condition of arid region. Application of FYM with various mulching treatment was found complementary and the combination of FYM@40 tonnes/ha and straw mulch gave the highest yield (22.6 tonnes/ha) among all treatments, which however was at statistically at par with the combination of FYM@30 tonnes/ha and straw mulch (21.8 tonnes/ha).

Effect of supplemental irrigation on yield

Supplemental irrigation has been found very effective in increasing crop yields in areas prone to water scarcity and unbalanced precipitation. Supplemental irrigation increased the yield of squash melon by 22.6, 17.2 and 18.9% during 2012, 2013 and pooled basis, respectively as compared to rainfed crop (yield data of rainfed crop published by Birbal *et al.* 2014). Controlled supplemental irrigation has been reported to improve yields by several other researchers also (Erekul *et al.* 2012 Kahraman *et al.* 2016, Wang 2017). Erekul *et al.* (2012) reported significant increase in wheat grain yields up to 58% with supplemental irrigation. Raja *et al.* (2012) reported higher yields of maize, green gram, sesame, okra and chilli with supplemental irrigation. This increase in yield must be due to the maintenance of optimum moisture content in soil throughout the crop growing period coupled with the beneficial effects of manure and mulch, which reduced stress and led to better growth and yield.

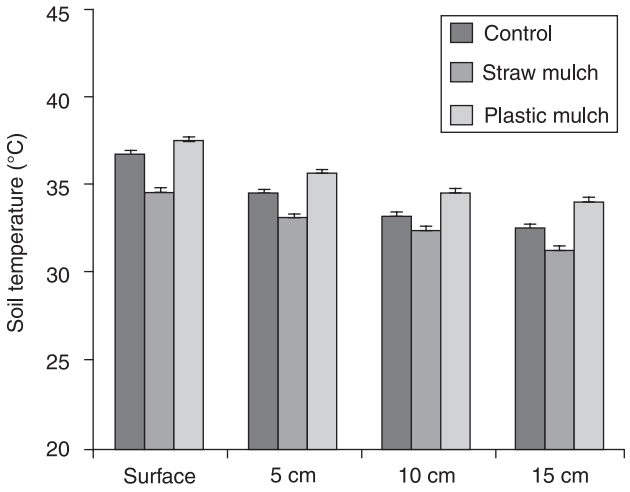

Fig 2 Effect of different mulches on soil temperature

Effect of mulch material on soil temperature

The soil temperatures in straw mulched treatments were lower than the unmulched soil during growth period, which might be because of the reduced interception of sun rays and hot dry air through mulches on the soil surface (Singh *et al.* 2013). He reported that mulching reduces the amount of radiant flux reaching the soil surface and minimizes evaporative heat loss during the day and inversion of soil temperature gradient at night, thus aiding in better crop stands in sandy soils of arid region. The highest soil temperature was observed under black plastic mulch (Fig 2). This might be due to greater net radiation and thus the higher heat flux under the black plastic mulch, as compared to bare soil; which agrees with the results observed by other researchers (Haynes 1987, Streak *et al.* 1994, Singh and Kamal 2012).

Effect of FYM and mulching on water use efficiency

Water use efficiency (WUE) of squash melon improved with the combined application of FYM and mulch (Table 3). Successive increase in application rate of FYM from 0 to 30 tonnes/ha significantly increased WUE, and with further increase in FYM up to 40 tonnes/ha, no improvement in WUE was observed. Among the mulching materials, significantly higher WUE (77 kg/ha/mm) was recorded with straw mulching, representing an increase of 18.5 and 48.1% compared to plastic mulch and no mulch, respectively. The combination of straw mulch with FYM@40 tonnes/ha recorded highest WUE (93.3 kg/ha/mm) amongst all treatment combinations, which was statistically at par with the combination of straw mulch with FYM@30 tonnes/ha. This might be due to the increase in yields obtained with the application of farmyard manure and mulch due to the shading effect and lowering the temperature of soil environment by mulch and FYM application in soil (Fig 2).

Effect of FYM and mulching on farm profitability

The maximum net return ₹ 363633 was obtained with the treatment combination of FYM (40 tonnes/ha) with straw mulch; followed by FYM (30 tonnes/ha) with straw mulch (i.e. ₹ 350142) as shown in Table 4. Highest benefit: cost ratio of 4.2 was found for FYM@40 tonnes/ha with straw mulch which was at par with the treatment combination of FYM@30 tonnes/ha with straw mulching (4.1). Net return and B:C ratios were better for straw mulch compared to plastic mulch at all the levels of FYM, which was due to lower cost of straw mulch.

Table 3 Effect of FYM and mulching on water use efficiency of squash melon under supplemental irrigation condition

Treatment	WUE (kg/ha/mm)		
	2012	2013	Pooled
FYM			
F_1	41.0	43.1	42.1
F_2	60.0	64.2	62.1
F_3	74.2	77.1	75.3
F_4	78.4	80.1	79.3
CD (P=0.05)	7.1	10.2	9.1
Mulching			
M_1	51.6	52.3	52.0
M_2	74.8	79.1	77.0
M_3	64.6	67.3	65.2
CD (P=0.05)	3.2	3.7	3.2
FYM × Mulching			
F_1M_1	28.1	28.2	28.1
F_1M_2	49.6	53.4	51.0
F_1M_3	46.5	49.5	47.0
F_2M_1	50.5	51.6	51.0
F_2M_2	70.2	74.6	73.3
F_2M_3	60.2	64.4	62.3
F_3M_1	60.4	62.4	61.4
F_3M_2	88.2	92.3	90.2
F_3M_3	74.1	75.9	75.0
F_4M_1	67.3	65.4	66.4
F_4M_2	90.4	96.2	93.3
F_4M_3	77.4	78.2	77.8
CD (P=0.05)	5.1	5.2	4.3

F_1 (0 tonnes/ha) , F_2 (20 tonnes/ha), F_3 (30 tonnes/ha) and F_4 (40 tonnes/ha). M_1 (No mulching), M_2 (straw mulching) and M_3 (plastic mulching)

Conclusion

The present study showed that the application of farmyard manure @ 30 tonnes/ ha along with straw

Table 4 Economic analysis of application of FYM and mulching in squash melon grown with supplemental irrigation

Treatment	Net return ₹./ha (in Lakhs)			B:C Ratio		
	2012	2013	Mean	2012	2013	Mean
F_1M_1	0.54	0.64	0.59	0.70	0.84	0.77
F_1M_2	1.43	1.87	1.65	1.79	2.34	2.07
F_1M_3	0.69	1.05	0.87	0.49	0.74	0.62
F_2M_1	1.43	1.90	1.66	1.68	2.49	2.09
F_2M_2	2.35	3.01	2.68	2.65	3.77	3.21
F_2M_3	1.26	1.85	1.56	0.84	1.31	1.08
F_3M_1	1.87	2.40	2.14	2.10	3.15	2.63
F_3M_2	3.14	3.87	3.50	3.37	4.83	4.10
F_3M_3	1.81	2.46	2.13	1.17	1.74	1.45
F_4M_1	2.18	2.54	2.36	2.33	3.34	2.83
F_4M_2	3.18	4.09	3.64	3.26	5.12	4.19
F_4M_3	1.94	2.55	2.24	1.22	1.80	1.51

F_1 (0 tonnes/ha) , F_2 (20 tonnes/ha), F_3 (30 tonnes/ha) and F_4 (40 tonnes/ha). M_1 (No mulching), M_2 (straw mulching) and M_3 (plastic mulching)

mulching and supplemental irrigation is the most suitable and sustainable strategy for improving growth, yield and water use efficiency of squash melon under arid conditions.

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