Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; SP1: 2556-2560

Mintu Job
Assistant Professor, Department of Agricultural Engineering, Birsa Agricultural University, Kanke, Ranchi, Jharkhand, India

DK Rusia
Senior Scientist, Department of Agricultural Engineering, Birsa Agricultural University, Kanke, Ranchi, Jharkhand, India

Dinmani
Research Associate, PFDC Project Department of Agricultural Engineering, Birsa Agricultural University, Kanke, Ranchi, Jharkhand, India

Vikas Kumar Singh
Senior Research Fellow, Department of Agricultural Engineering, Birsa Agricultural University, Kanke, Ranchi, Jharkhand, India

Correspondence
Mintu Job
Assistant Professor, Department of Agricultural Engineering, Birsa Agricultural University, Kanke, Ranchi, Jharkhand, India

Effect of drip irrigation and plastic mulch on yield, water use efficiency of cauliflower

Mintu Job, DK Rusia, Dinmani and Vikas Kumar Singh

Abstract
Cauliflower is one of the main vegetable crop grown in India. It is a rich source of vitamin B and protein. The area under cauliflower in Jharkhand is 18610 ha and average productivity is around 16 ton per ha. For higher yield and quality of produce genetic modification of seed in form of hybrid and partially modified microclimate through plastic mulching and drip irrigation is essential. A trail was conducted at PFDC farms, BAU to study the effect of drip Irrigation and plastic mulch on yield, water use efficiency of Cauliflower during November 2011 to February 2013. The treatment taken were T_1- Drip at 0.6 ET + Mulching, T_2- Drip at 0.6 ET +without Mulching, T_3- Drip at 0.8 ET + Mulching, T_4- Drip at 0.8 ET + without Mulching, T_5- Drip at 1.0 ET + Mulching, T_6- Drip at 1.0 ET + without Mulching, T_7- Conventional method of irrigation + without Mulching. The highest yield was observed in the treatment Drip at 1.0 ET with mulch (T_5) which was significantly superior to all other treatments. However water productivity was highest for 0.6 ET with mulch (T_1) followed by 0.8 ET with Mulch (T_3) at 0.37 and 0.35 Kg/litre of water. Mulches have effected moderation of soil temperature across all treatments. Soil temperature was increased by an average degree in month January and February while there was a reduction on around 2 degree in March. The cultivation of cauliflower through drip irrigation with black plastic mulch (25 micron) increases the productivity and quality of produce with added benefit of water saving.

Keywords: Drip Irrigation; Plastics Mulch; Water Use Efficiency; Uniformity

Introduction

Cauliflower is one of the vegetable crop in our country. Cauliflower (*Brassica oleracea* var. *botrytis L.)* is an important member of Cole crops and belongs to family Cruciferae. Cauliflower (*Brassica oleracea* var. *botrytis L.)* is the native of Cyprus. It was introduced in India in 1822 from England by the British. The nutritional value of 100 g of edible portion of cauliflower contains carbohydrate 3g, protein 1g, dietry fibre 2g, vitaminec 28 mg, vitamin B and little amount of minerals like sodium 9 mg, potassium 88 mg & folic acid 27 μmg are found and about 45% parts of its are used as edible. Cauliflower grows best in cool day time temperatures 21–29 °C with plentiful sun, and moist soil conditions high in organic matter and sandy soils. Ideal growing temperatures of cauliflower seedling are about 18 °C. In our country, India it grown on an area 369000 ha and its productivity is 18 t/ha (Jharkhand Ag 2012, NHB 2013) while in Jharkhand state it grown on an area 18610 ha and its productivity is 16 t/ha. The productivity of cauliflower in Jharkhand state is 11% less than that of country.

Drip irrigation is one of the efficient irrigation system under micro irrigation. drip irrigation differ from the other conventional methods of water application and suppling irrigation water directly into the root zone of crop. The drip irrigation method results in slightly higher marketable yield and irrigation production efficiency as compared to micro sprinkler methods, where as surface irrigation methods give considerably lower yield and irrigation production efficiency, (Kumar and Senseba, 2008). In general, traditional flood irrigation methods (basin, border and furrow) are being used, where the entire soil surface is almost flooded without considering the actual consumptive requirements of the crops. Frequent over or under irrigation create the problems of water stress or water logging leading to reduced irrigation efficiency (<30 %) (Ishfaq, 2002). This highlights the need to adopt modern efficient irrigation method of drip which offers several advantages over furrow irrigation including higher water and fertilizer use efficiency and high yield (Camp *et al*., 2001).

Drip irrigation method applies water and nutrient directly to the root zone of plants (Sharma, 2001). Its major advantages as compared to other methods include higher crop yields, saving in water, increased fertilizer use efficiency, reduced energy consumption, reduced labor cost, improved diseased and pest control and feasible for undulating sloppy lands (Michael, 2008). On the average, drip irrigation saves about 70 to 80% water as compared to conventional flood irrigation methods (Camp *et al*., 2001).

Mulching is the process or practice of covering the soil or ground to make more favorable conditions for plant growth, development and efficient crop production. Mulch technical term means "covering of soil", while natural mulches such as leaf, straw, dried leaves and compost have been used for centuries, during the last 60 years the advent of synthetic materials has altered the methods. When compared to other mulches with plastic mulches are completely impermeable to water; it therefore prevents direct evaporation of moisture from the soil and thus limits the water losses and soil erosion over the surface. In this manner, it plays a positive role in water conservation. It also reduces weed intensity. It maximizes water use efficiency. Mulch is defined as any material spread or laid on the soil surface or any protective covering of the soil surface (Masarirambi *et al.*, 2013). Hence it is evident that mulching is an important factor for the production of cauliflower.

Now a days plastic mulch is used more widely for conserving soil moisture and to decrease the cost of weeding in different countries, ultimately resulting in lower cost of cauliflower production and other. Therefore, the present study was undertaken to find out for following Objectives:

1. To determine the optimum crop water requirement and scheduling in cauliflower
2. To study the effect of mulch on crop growth and production
3. To assess the effect of drip mulch on crop yield and quality of cauliflower to work out the cost economics under drip and mulching.

Materials and Method

Study Area

The field experiment was undertaken on PFDC, farm of Department of Agricultural Engineering, BAU, Ranchi (Jharkhand) during November 2011 to February 2013 in winter season. The annual rainfall in the plateau and sub plateau region is 1400 mm, on an average of which 82.1% received during June to September. Only about 9 percent of the area in the state is irrigated. The physico-chemical properties of experimental plot was red loam in texture and had pH 5.5, EC 0.02 to 0.1 ds/m organic carbon(0.4%) and low in available NPK 200 to 250, 25,130 Kg/ha respectively. The field plots were prepared manually and its proper grade was formed to facilitate irrigations. The plot size was 15m x 1.0m.The plant to plant and row to row spacing were 40cm × 40 cm. The weeds were removed manually. Healthy, uniform sized 25 days old seedlings were used for transplantation.

The Recommended doses of fertilizers(RDF) were applied @ FYM 25000, N 200, P_20_5 150 and K_20 100 kg/ha to crop. The entire quantity of FYM was applied during land preparation, While half of N, full doses of P& K were applied as basal dose during transplanting. The remaining N was applied in five doses as fertigation. For comparison, there was control treatment of conventional method of fertilization as practiced by farmers of Jharkhand in Cauliflower cultivation were also considered in the design of treatments with three replications. The experimental design was Randomized Complete Block Design with 3 replications. Transplanting holes on the plastic mulch were made with a hole making tool at the transplanting spot for each seedling. Each plot had two rows of plants. Weeding was done properly when needed. Irrigation was done properly at its vegetative stages. Cauliflower were harvested at maturing stage. On an average 36 irrigation had applied during entire cropping season. Data of plant height (cm), plant spread area (cm x cm) at an 15 days interval after transplanting (DAT) were recorded. Soil temperature at 5 cm, 10 cm & 15 cm depths were recorded daily both mulched & non mulched crop.

The treatments details are as follows:

T_1 (I_1M_1) - Drip at 0.6 ET + Mulching,
T_2 (I_1M_2) - Drip at 0.6 ET +without Mulching,
T_3 (I_2M_1) - Drip at 0.8 ET + Mulching,
T_4 (I_2M_2) - Drip at 0.8 ET + without Mulching,
T_5 (I_3M_1) - Drip at 1.0 ET + Mulching,
T_6 (I_3M_2) - Drip at 1.0 ET + without Mulching,
T_7 (Control) - Conventional method of irrigation + without Mulching.

Crop water requirement for Cauliflower

The following formula was used to calculate crop water requirement: Gross volume of water (liter/day/dripper)
= (S_l x S_d x PE x P_c x K_c x wetted area)/E_u

Where:

S_l = lateral spacing along the submain, m
S_d =dripper spacing along the lateral, m
PE = Maximum pan evaporation, mm/day
P_c = Pan coefficient, taken as 0.8
K_c = Crop coefficient
Wetted area =it is the area which is shaded due to its canopy cover when sun is overhead.
E_u = Emission uniformity of drip system, decimal.

Methods of Water Application

The drip system consists of 75 mm PVC pipe mainline connected to 63 mm PVC pipe sub- main line, which was connected to 16 mm lateral line with 2.4 lph inline drippers spaced at 40 cm. The distance between row to row and plant to plant was kept 40 cm and 40 cm, respectively. The laterals were laid on the ground surface along the lines of plants. The top width of ridges was about 1 m. The row to row and plant to plant distance was same as in drip irrigation. In case of drip system the irrigations were scheduled on the basis of consumptive use of crop (ETc) as estimated using the average weekly pan evaporation data as suggested by Allen (1998). Irrigations were scheduled alternate day from drip system.

The irrigation schedule as per different irrigation levels was prepared based on daily climatic data. The climatic data included viz; maximum and minimum temperature, maximum and minimum relative humidity, wind speed, and sunshine hours were used to determine reference evapotranspiration (ETo) by using FAO 56 Penman Monteith Method. Using reference evapotranspiration (ETo) and crop coefficient (Kc), the crop evapotranspiration (ETc) was calculated. The following formula was used to calculate crop evapotranspiration:

$$ETc = ETo \ X \ Kc$$

Where:

ETc = Crop evapotranspiration, (mm day-1)
ETo = Reference evapotranspiration, (mm day-1)
Kc = Crop coefficient

The daily irrigation water requirement for Cauliflowe was estimated using the following relationship:

$$IR = ET_o \ X \ K_c - R_e$$

Where:

IR= Net deptjh of irrigation (mm/day)
ET_o= Reference evapotranspiration (mm/day)

K_c = Crop coefficient
R_e= Effective rainfall (mm/day)
The net volume of water required by the plant can be calculated by following relationship
V= IR X A

Where:
V= Net volume of water required by a plant (L/day/plant)
A= Area under each plant (m^2)
Select and tagging of selected three plants randomise were done in each treatment for observing various crop parameters like plant height (cm), plant spread area (cm x cm) at an 15 days interval after transplanting (DAT) were recorded.
In each treatment, harvested curd with leaf in each picking were noted down from three already selected plants. Counting of harvested curd from every experimental treatment was done till the final harvest. The average length and average spread area were noted in centimeters and square centimeter respectively. Total weight of harvested curd from each experimental treatment during each picking was noted till final harvest and total yield of cauliflower per hectare under different treatments were computed.

Measurement of Soil temperature
Soil temperature plays a vital role in the proper growth of cauliflower. To measure the soil temperature; insert thermometer at 5cm, 10 cm and 15 cm depths in mulched & non mulched crop and it recorded daily.

Results and Discussion
Effect of crop water requirement on cauliflower
Crop water requirement plays an important role for proper growth of cauliflower. As per calculated crop water and its irrigation schedule at different irrigation levels of cauliflower applied through drip irrigation system in cauliflower during entire crop season and irrigation scheduling at different growth stages is shown in the Table 1.Total number of irrigation provided during entire growing season of cauliflower is 36 and total amount of irrigation is 67.66 Liter/m^2.

Table 1: Average water applied in Cauliflower crop during entire cropping season

Month	No. of irrigations	Crop Stage	Frequency	Water/ irrigation (lt/sq.m)	Lt/ plant	Time/ irrigation (minutes)	Monthly water application (lt/sq.m)
November	8	Vegetative	Alternate Day	1.55	0.31	18.6	12.4
December	13	Vegetative	Alternate Day	1.60	0.32	19.2	20.8
January	8	Flowering	Alternate Day	2.38	0.59	28.5	19.04
	6	Harvest	Alternate Day	2.22	0.55	26.4	13.20
February	1	Harvest	Alternate Day	2.22	0.55	26.4	2.22
	36						67.66

Effect of mulch on crop growth, Soil temperature and production
This trial was conducted in winter season. During winter season temperature falls this zone far below than the germination temperature of cauliflower. To attain the optimum germination temperature for cauliflower to use black plastic mulch (25 µm).It can be clearly seen the effect of black mulch on biometric parameters such as Average plant height (cm), Average Spread area (cm^2) and total yield (q/ha) were analysed statistically and compared with furrow irrigation treatments (Control).The experimental results of plant height at an 15 days interval for three years are presented in Table 2. The experimental results of spread area at an 15 days interval for three years are presented in Table 3.The plant height was found to be highest in treatment combination $T_5(I_3M_1)$ [drip at 1.0 ET + Mulching] at 30 DAP,45 DAP,60DAP except treatment combination T_1 (I_1M_1) [drip at 0.6 ET + Mulching] at 15 DAP as compared to the rest of the treatment combination. There was a significant increase in black plastic mulch triggers plant growth and development (vegetative growth) while straw mulch encourages flower production both qualitatively and quantitatively in freesia plants (Adnan *et al*. (2012).
However, fruit size (spread area) response at 100 % irrigation supply treatment combination $T_5(I_3M_1)$ [drip at 1.0 ET + Mulching] at 30 DAP,45 DAP,60DAP except at 80 % of water requirement supply treatment combination T_3 (I_2M_1) [drip at 0.8 ET + Mulching] at 15 DAP as compared to the rest of the treatment combination. It can be seen that the 60% irrigation supply through drip treatment combination T_1 (I_1M_1) [drip at 0.6 ET + Mulching] has significant influnce on fruit size over two other irrigation levels under drip T_6 (I_3M_2) [drip at 1.0 ET + without Mulching] and $T_4(I_2M_2)$[drip at 0.8 ET + without Mulching].
The highest soil temperatures were obtained under transparent mulch. Maximum amplitude of soil temperature waves was smaller under opaque mulches. Further they stated that, Tomato yield was not significantly affected by mulch treatments, however, a tendency of greater yield was observed for opaque mulches as compared to transparent mulch Streck *et al*. (1995). It is seen that bed covered by mulch soil temperature increased by 1 to 3 deg than that of no mulched conditions. Table 4 at 15 days interval month wise (November, December & January) soil temperature was increased by 1 to 3 deg in mulched than that of no mulched conditions.
The study to investigate the effect of mulching and irrigation levels on soil temperature, soil moisture and yield of drip irrigated cauliflower. They concluded that, use of 80 per cent of crop water requirement through drip irrigation with silver mulch could be the best option under agroclimatic conditions (Sibale *et al*. (2015). It was found that the yield of Cauliflower, treatment combination T_5(I_3M_1) [drip at 1.0 ET + Mulching] were 178.00 & 217.1 q/ha in year 2011-12 & 2012-13 except T_3 (I_2M_1) **[**drip at 0.8 ET + Mulching] was 200.6 q/ha in year 2013-14 superior as compared to the rest of the treatment combinations shown in Table 5. The treatment combination T_5(I_3M_1) [drip at 1.0 ET + Mulching] created optimum soil conditions (appropriate moisture levels and soil temperature) for growth, development, flowering and maturity of Cauliflower which contributed to maximum yield. Plastic mulches were blue, black, clear, red and silver on black are best option to improve the yield as compared to without mulch. They concluded that, the highest early yield was obtained in clear plastic likely due to light entrance and raising soil temperature (Rajablariani *et al.* (2012).

Table 2: Average plant height at 15 days intervals of cauliflower var. Amazing

Sl. No.	Treatment	Plant Height (cm)			
		15 Dap	30 Dap	45 Dap	60 Dap
1	T_1 (I_1M_1)	16.60	23.60	30.13	38.83
2	T_2 (I_1M_2)	13.53	21.00	27.00	34.87
3	T_3 (I_2M_1)	14.67	25.27	31.07	37.07
4	T_4(I_2M_2)	14.13	20.49	26.16	36.07
5	T_5 (I_3M_1)	15.33	27.40	32.53	39.42
6	T_6 (I_3M_2)	14.33	21.20	27.15	34.33
7	T_7 (Control)	15.80	21.02	29.57	37.90

Table 3: Plant spread area at 15 days intervals of cauliflower var. Amazing

Sl. No.	Treatment	Plant spread Area (cm^2)			
		15 Dap	30 Dap	45 Dap	60 Dasp
1	T_1 (I_1M_1)	320.9	1074.80	1406.33	1912.28
2	T_2 (I_1M_2)	258.7	894.73	1315.87	1889.04
3	T_3 (I_2M_1)	354.4	1226.93	1281.93	1999.15
4	T_4(I_2M_2)	161.3	833.60	957.47	1387.15
5	T_5 (I_3M_1)	282.4	1289.87	1818.40	2503.28
6	T_6 (I_3M_2)	220.1	776.73	1146.00	1722.33
7	T_7 (Control)	289.7	774.60	1408.13	2140.10

Table 4: Average Soil Temperature at 15 days intervals of cauliflower var. Amazing

Sl. No.	Treatment	Soil Temperature (^0C)								
		November			December			January		
	Depth(cm)	5	10	15	5	10	15	5	10	15
1	Mulch	22.3	21.8	20.5	17	16	15	17	16	14
2	Non Mulch	20.6	18.6	17.3	15	14	13	16	15	13

Table 5: Treatment wise Year wise Cauliflower (q/ha)

Treatments	Yield (q/ha)		
	2011-12	2012-13	2013-14
T_1 (I_1M_1)	140.05	154.1	142.7
T_2 (I_1M_2)	109.71	120.1	113.7
T_3 (I_2M_1)	170.28	200.1	200.6
T_4(I_2M_2)	126.28	161.4	185.6
T_5 (I_3M_1)	178.00	217.1	193.4
T_6 (I_3M_2)	135.14	142.0	156.1
T_7 (Control)	106.25	116.1	145.7
CD 5%	8.02	11.43	17.9
S.Em (±)	4.52	3.67	5.75
CV %	9.35	13.35	6.13

Water productivity of Cauliflower

The economic water productivity (EWP) was positively related with WP. As observed in case of WP, the EWP of vegetables cultivated with drip irrigation was significantly higher over furrow method of irrigation. The efficient water can be used by drip irrigation technique and frequently water can be applied. Water loss through runoff and evapotranspiration was much lower from soil surface under drip irrigation. It increases the water use efficiency as compared to surface irrigation. Singh *et al*. (2009) also reported about the higher WP of vegetable crop under drip irrigation technique. Water productivity is defined as how much water is needed to produce on kg of cauliflower. Water productivity was highest for treatment combination T_1 (I_1M_1) [drip 0.6 ET with mulch] followed by T_3 (I_2M_1) **[**drip at 0.8 ET + Mulching] at 0.37and 0.35 Kg/litre of water shown in Table 6. There are some disadvantages inherent with drip irrigation technology such as high material and installation cost, emitter clogging, periodical maintenance and skilled operation. However, these can be easily tackled by providing training and hands-on-experience type of capacity building programs in participatory mode.

Table 6: Total water applied for different treatments

Treatments	Water Applied (lt/sq.m)	Yield (kg/sq.m)	Water productivity (kg/lt)
T_1 (I_1M_1)	40.58	1.43	0.035
T_2 (I_1M_2)	40.58	1.14	0.028
T_3 (I_2M_1)	54.11	2.01	0.037
T_4(I_2M_2)	54.11	1.86	0.034
T_5 (I_3M_1)	67.64	1.93	0.029
T_6 (I_3M_2)	67.64	1.56	0.023
T_7 (Control)	248.68	1.46	0.006

Cost- Economics

Table 7 presents the economic analysis of cultivation of cauliflower with drip irrigation and conventional method of cultivation for 0.0630 ha. The toatl variable cost for cauliflower cultivation with drip irrigation and conventional method were 6273 and 908 respectively. The fixed cost for cauliflower cultivation with drip irrigation was 945.the total cost of production for cauliflower cultivation with drip and conventional method were 7218 and 908 respectively. The gross income and BC ratio for drip was 18900 and 2.62 respectively, while for conventional method it was 2284 and 2.52 respectively.

Table 7: Cost- Economics of cauliflower cultivation with drip irrigation and conventional method.

Cost Economics format						
Particulars	Plasticulture Applications		Total amount (Rs)	Conventional method		Total amount (Rs)
	Quantity	Rate/ unit		Quantity	Rate/unit	
Crop Name- cauliflower						
Crop Variety- Amazing						
Area (ha)-0.0735						
Crop period/year-3 month						
Spacing (cm X cm)-40*40						
No. of Plants/sqm-6						
Yield per Plant /sqm-330gm				240gm		
Total Yield (Ton /ha)- t/ha	20			14.5		
Sale Price (Rs/Kg)-15						
Variable Costs (Rs / Sqm)						
Land Preparation	630	1/m^2	630	105	1/m^2	105
Fertilizer		1.73/m^2	1090		1.73/m^2	182
Irrigation Costs		.7/m^2	441		1.5/m^2	158
Seed Costs		.75/m^2	473		.75/m^2	79
Chemical Costs		1.45/m^2	914		1.45/m^2	152

Soil solarization		-	-		-	-
Nursery management		-	-		-	-
Low tunnel		-	-		-	-
Mulching	315	6.25/m^2	1969		-	-
Labour		.70/m^2	441		1.5/m^2	158
Interest @ 10%		-	-		-	-
System maintainance cost		.5/m^2	315		.7/m^2	74
Other Variable Costs		-	-		-	-
Total Variable Costs (Rs)			6273			908
Fixed Costs @ Sqm						
a. Shade net house					-	-
b. Greenhouse					-	-
c. Drip Irrigation System@ 10%	630	1.5/m^2	945		-	-
d. Sprinkler Irrigation System			-		-	-
Total Fixed Costs (a+b+c+d) Rs			945		-	-
Total Cost of Production (Variable + Fixed) Rs	630	9.8/m^2	7218	105	8.65/m^2	908
Gross Income(Rs)		30/m^2	18900		21.75/m^2	2284
BC Ratio			2.62			2.52

Conclusions

The drip irrigation is economical and cost effective as compared to conventional methods of irrigation and mulching. The use of drip either alone or in combination with mulching can increase the cauliflower yield significantly over furrow irrigation and basal method of fertiliser. To irrigate 1 ha of cauliflower crop with drip irrigation is 1590 m^3 (1590000 liter) of water will be needed for agro-climatic conditions of Ranchi, Jharkhand. The duration of operation of drip irrigation was 399 min, 228 min, 186 min respectively during vegetative, flowering and harvesting stages. The gross income could be increased by about by adopting drip with mulcjhing technology. The B:C ratio was found highest for drip irrigation as compared to conventional method on farming**.**

Acknowledgement

The authors are highly thankful to the National Committee on Plasticulture Applications in Horticulture (NCPAH), Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India for providing funds for this research. The authors are also thankful to Department of Agricultural Engineering, BAU, Ranchi, Jharkhand for making available necessary facilities to conduct this research studies.

References

1. Adnan Y, Zahid M, Atif R, Usman T, Arfan M, Muhammad A. Effect of different mulching materials such as transparent plastic sheet, rice straw and black plastic sheet was investigated on growth and flowering of Freesia. Aurora Journal of Agricultural Science. 2012; 49(4):429-433.
2. Camp CR, Sadler EJ, Busscher WJ, Sojlka RE, Karrlin DL. Experiencing with sprinkler irrigation for agronomic crops in the southeastern USA, 2001.
3. Ishfaq M. Water New Technology. Global Water Institute, Lahore, Pakistan, 2002.
4. Indian Horticulture Database, 2013.
5. Jharkhand Agriculture Database, 2012.
6. Kumar LG, Senseba T. Yield, irrigation production efficiency and economic return of broccoli *(brassica oleracea var. Italica)* under different xii irrigation methods and schedules. Journal of Environmental Research and Development. 2008; 2(4):145-158.
7. Michael AM. Irrigation Theory and Practice", Second edition (revised and enlarged) Vikas Publishing House PVT. Ltd, Delhi, India, 2008.
8. Masarirambi MT, Mndzebele ME, Wahome PK, Oseni TO. Effects of White Plastic and Sawdust Mulch on„ Savoy. Baby Cabbage (Brassica oleraceavar. bullata) Growth, Yield and Soil Moisture Conservation in summer in Swaziland. Department of Horticulture, Faculty of Agriculture, University of Swaziland, Swaziland, 2013.
9. Rajablariani H, Farzad H, Ramin R. Effect of Colored Plastic Mulches on Yield of Tomato and Weed Biomass. International Journal of Environmental Science and Development. 2012; 3(6):590-593.
10. Suwwan MA, Akkawi M, Al-Musa AM, mansour A. Tomato performance and incidence of tomato yellow leaf curl (TYLC) virus as affected by type of mulch. Scientia Horticulturae. 1988; 37(1-2: 39-45).
11. Sibale D, Mane MS, Patil ST, Ayare BL, Desai VS. Effect of mulching and irrigation levels on soil temperature, soil moisture and yield of drip irrigated cauliflower. Journal of Indian Society of Coastal Agricultural Research. 2015; 33(2):28-35.
12. Singh R, Kumar S, Nangare DD, Meena MS. Drip irrigation and black polyethylene mulch influence on growth, yield and water-use efficiency of tomato. African J of Agril. Res. 2009; 4(12):1427-1430.
13. Sharma BR. Availability, status and development and opportunities for augmentation of groundwater resources in India. Proceeding ICAR-IWMI Policy Dialogue on Ground Water Management, November 6-7, 2001 at CSSRI, Karnal, 2001, 1-18.
14. Streck N, Schneider F, Buriol G, Heldwein A. Effect of soil mulching with transparent, black, white, and co-extruded white-on-black polyethylene sheets on soil temperature and tomato yield was evaluated in the Subtropical Central Region of the Rio Grande do Sul State, Brazil. Sci. agric. 1995; 52(5):587-593.