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Effect of drip, fertigation and plastic mulching on growth and yield of cabbage

BIPUL DEKA[1]*, MANDAKINI BHAGAWATI[2] AND MARAMI DUTTA[3]

[1]AICRP on Irrigation Water Management, Assam Agricultural University, Jorhat-785 013, Assam, India

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ABSTRACT

A field study was carried out at Horticultural Research Station, Assam Agricultural University, Kahikuchi during 2013-2016 to standardize the drip and fertigation requirement in cabbage (var. Green Express) with or without mulch. The experiment was laid out in randomized block design which included three levels of drip irrigations through 100, 75, and 50 per cent reference crop evapotranspiration (ET_c) as well as three fertigation levels with 125, 100 and 75 per cent of recommended dose of fertilizers i.e. NPK @ 120:60:60 kg ha^{-1}. Black polyfilm mulch (30 micron) and no mulch were replicated thrice in all these nine treatment combinations. Various meteorological data viz. mean minimum temperature, maximum temperature, relative humidity, wind speed, sunshine hours and rainfall for a period of 30 years were collected and fitted to CROPWAT 8 software to find out the crop evapotranspiration (ET_c) as per FAO Penman-Monteith Approach. Based on the ET_c value the water requirement for the studied crop was estimated to be 13.96 cm for unmulched and 9.07 cm under mulched condition. Drip irrigation and fertigation was scheduled by the application of 8 minutes drip and 2 minutes fertigation through 2 LPH dripper at three days intervals. The study revealed that maximum fresh weight, head weight and number of wrapper leaves could be obtained in 100 % ET_c and 125 % of RD with polyfilm mulch (T_1). On the other hand, treatment combination of 100 % ET_c with 75% of RD with polyfilm mulch (T_3) recorded head diameter. Similarly, highest yield (53.80 t ha^{-1}) was recorded in T_1 treatment which was at par with treatment combination of 100 % ET_c and 75% of RD with polyfilm mulch (T_3). Highest benefit cost ratio (2.85: 1) and maximum water use efficiency (228.25 q ha^{-1} cm^{1}) was recorded in treatment T_3.

Keywords: Drip irrigation, fertigation, plastic mulching, irrigation water requirement

INTRODUCTION

Cabbage (*Brassica oleracea* var. capitata) requires a well-drained soil and regular watering to produce a good crop. It is a heavy feeder and as such requires regular applications of fertilizer. Irrigation is an important limiting factor of crop yield, because it is associated with many factors of plant environment, which influence growth and development (Yaghi *et al.* 2013). Under conventional surface irrigation method, major proportion of irrigation water is lost by surface evaporation and deep percolation resulting in lower irrigation efficiencies. Moreover, there is a tendency of farmers to apply excess water when it is available (Jain *et al.,* 2000). Drip irrigation, with its ability to provide small and frequent water applications directly in the vicinity of the plant root zone has attracted interest worldwide because of decreased water requirement and possible increase in production (Darwish *et al.,* 2003). Drip irrigation helps to increase water use efficiency by reducing soil evaporation and drainage losses, maintain soil moisture conditions that are favourable to crop growth and helps to sustain the productivity of the land. Fertigation offers the best solution for intensive and economical crop production where both water and fertilizers are delivered to crop through drip system. It provides essential elements directly to active root zone thus minimizing loss of expensive nutrients. Higher and quality yield is ensured along with saving water, labour and energy resulting in reduced cost of cultivation. This increase in yield is largely due to improvement in the nutrient use efficiency of crops through judicious and timely application of amounts of nutrients directly to the crop root zone with enhanced transport of dissolved nutrients by mass flow (Sathya *et al.,* 2018). The adoption of drip irrigation and fertigation system can efficiently reduce the water and fertilizer requirement with increased yields with better quality in vegetable crop (Kalita *et al.,* 2022). Mulch is a covering placed over the soil around the plants. Plastic mulch on the surface of the soil causes change in the microclimate on its vicinity. This results in moisture conservation, less soil compaction and

**Corresponding author: drbipuldeka@gmail.com* [2]*Krishi Vigyan Kendra, Chirang, Assam Agricultural University, Kajalgaon, 783385, Assam, India* [3]*Department of Soil Science, Assam Agricultural University, Jorhat-785 013, Assam, India*

higher CO_2 levels around plants (Mane and Umrani, 1981). Cabbage is widely grown throughout Assam and it has much commercial importance. However, scientific information with respect to drip irrigation on soil water dynamics, productivity and water use efficiency of cabbage under varying fertigation level is lacking in the Brahmaputra Valley Zone of Assam, India for making necessary recommendation to the farmers. By keeping these facts in mind an attempt was made to study the effect of plastic mulching under different irrigation and fertigation levels.

MATERIALS AND METHODS

Field experiments were conducted during 2013-14 to 2015-2016 at the PFDC research farm of Horticultural Research Station, Kahikuchi, Assam Agricultural University encompassing the Lower Brahmaputra valley zone of Assam, India. The place is situated at 26.11° N latitude and 91.61° E longitude with an elevation of 57 m above mean sea level. The soils of the experiment field were silt loam in texture and acidic in pH (5.4). The average values of physico-chemical properties of the surface soil (0-0.15 m) were: Organic carbon 1.50%, EC 0.12 dS m^{-1}, bulk density 1.38 (g cc^{-1}) and hydraulic conductivity 1.52 cm hr^{-1}. The soils were medium in available N (538.60 kg ha^{-1}), available P_2O_5 (31.80 kg ha^{-1}) and available K_2O (345.20 kg ha^{-1}). At 33 and 1500 kPa tensions, the soil retained around 27.40% and 9.86% moisture, respectively. The experimental plot was thoroughly ploughed with disc plough and tilled twice with cultivator to bring optimum soil tilth. The length and width of the field was 38 m and 29 m respectively. The total area is divided into various strips of 6 m x 3 m according to the treatments.

Design and Treatments

The experiment was laid out in randomized block design with three factors. These include: 1. Mulching levels *viz*., 30 micron black plastic mulch and no mulch. 2. Drip irrigation levels *viz*. D1, D2 and D3: 100 per cent, 75 per cent and 50 per cent of ET_c 3. Fertigation levels *viz*. F1, F2 and F3: 125 per cent, 100 per cent and 75 per cent RDF i.e. NPK @ 120:60:60 kg ha^{-1}. There were 19 treatments including control which were replicated thrice. The controlled plot was unmulched, conventionally irrigated and fertilized through soil application of NPK fertilizers (Urea, SSP and MOP) @ 100% RDF. Twenty five days old seedlings of cabbage (Variety: Green Express) were planted in the field at a spacing of 60 cm x 60 cm during the month of October. The plant parameters were recorded during the crop growing period and the yields as well as the yield attributes were recorded after the harvest. The data were analysed by one-way analysis of variance (ANOVA) using SPSS 16 software. Means were tested at a significance level of $p \leq 0.05$ through Duncan's Multiple Range Test (DMRT).

Irrigation Scheduling

Irrigations were scheduled for mulch and control plots on the basis of computed crop evapotranspiration (ET_c) data. Daily climatic data used for estimating ET_c was collected from weather station of Horticultural Research Station, Kahikuchi. The climatic data included: maximum and minimum temperature, maximum and minimum relative humidity, wind speed and sunshine hours. These parameters were used to determine reference evapotranspiration (ETo) with the help of FAO 56 Penman Monteith method. The following formula was used to calculate crop evapotranspiration for cabbage:

$ET_c = ET_0 \times Kc$

Where: ET_c = Crop evapotranspiration (mm day^1)

ET_0 = Reference evapotranspiration (mm day^1)

Kc = Crop coefficient

Kc values of cabbage were: 0.45 (initial), 0.75 (Development), 1.02 (Middle) and 0.95 (Maturity). The Kc value for cabbage under mulch condition was considered to be 35% less.

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

$IR = ET_0 \times Kc - Re$

Where: IR= Net depth of irrigation (mm/day)

Re = Effective rainfall (mm/day)

Life saving irrigation was given immediately after transplanting and the field was regularly irrigated continuously for ten days. After the tenth day, subsequent irrigations were scheduled once in three days based on the following formula and applied each time as per the treatment schedule. The discharge rate of single dripper was 2 lph at a nominal operating pressure of 50.66 kpa.

Installation of drip System and fertigation unit

Irrigation water was pumped through 5 hp bore well pump and conveyed through the main line of 75 mm diameter PVC pipes after filtering through screen filter. From the main pipe, sub main of 63 mm diameter PVC pipes were drawn. From the sub main, laterals of 16 mm diameter LLDPE pipes were installed at the surface. Each lateral was provided with individual tap control for imposing irrigation. Along the laterals, online drippers were fixed at a spacing of 60 cm. The number of laterals installed was based on the number of rows of crop grown. The discharge rate of single dripper was 2 lph. Sub mains and laterals were closed at the end with end caps. For fertigation the fertilizers were dissolved in water in the ratio of 1:5 and the solution was diluted in fertigation tank.

Fertigation scheduling

The recommended dose of NPK fertilizer (120:60:60 kg/ha) was supplied in the form of urea, SSP and MOP. Phosphororus in the form of SSP was applied manually as a basal dose. Water soluble N and K fertilizers were injected through ventury system. The high velocity water passing through the throat of the venturi created a vacuum or negative pressure, generating suction to draw chemicals into the injector from the chemical tank. After the tenth day, the daily irrigation and fertigation was scheduled by the application of 8 minutes drip and 2 minutes fertigation with 2 LPH dripper at 10-12 days interval. The varying percentage of recommended water soluble N and K fertilizers was regulated by operating the tap connected at the starting end of each lateral. The water use efficiency (WUE) was determined from the yield data and total depth of water applied. Water use efficiency was computed using following equation:

WUE = Yield of cabbage/depth of water applied ($q\ ha^{-1}\ cm^{-1}$)

RESULTS AND DISCUSSION

Rainfall and evapotranspiration

The mean rainfall, evapotranspiration and effective rainfall for the year 2013-14, 2014-15 and 2015-16 during growth period of cabbage are presented in Figure 1. The data indicated that total monthly evapotranspiration exceeded the total monthly rainfall during October. However, during the rest of the crop growth periods, monthly evapotranspiration was more than the total monthly rainfall.

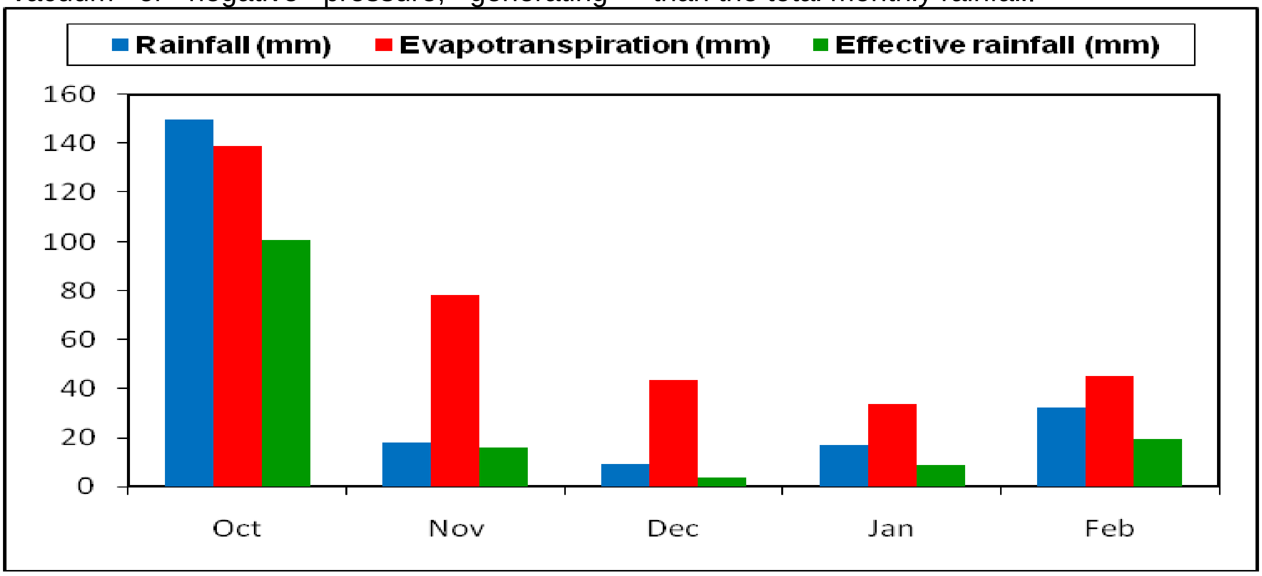

Fig. 1: Mean rainfall, evapotranspiration and effective rainfall for three years during crop growth period of cabbage

Yield and yield attributing parameters

The data pertaining to plant parameters like total fresh weight (shoot and root), individual head weight, head diameter, number of non wrapper leaves and number of wrapper leaves were recorded after the harvest and the mean values under various treatments are presented in Table 1.

Table 1: Yield and yield attributing parameters of cabbage as affected by different levels of drip, fertigation, mulch and without mulch

Treatment		Total fresh weight [shoot and root] (g)	Individual head weight (g)	Head diameter (cm)	No. of non wrapper leaves	No. of wrapper leaves	Yield (t/ha)
T_1	$(D_1F_1M_1)$	1568.89^{a}	1153.33^{a}	18.5^{a}	10.56^{fg}	21.22^{a}	53.8^{a}
T_2	$(D_1F_2M_1)$	1550.77^{a}	1149.11^{a}	18.4^{a}	10.67^{fg}	19.22^{bc}	52.5^{a}
T_3	$(D_1F_3M_1)$	1555.56^{a}	1152.78^{a}	18.73^{a}	10.44^{g}	20.44^{ab}	53.4^{a}
T_4	$(D_2F_1M_1)$	1469.44^{ab}	996.11^{b}	18.07^{ab}	10.67^{fg}	18.44^{cde}	47.13^{b}
T_5	$(D_2F_2M_1)$	1413.33^{bc}	841.11^{c}	17.69^{abc}	10.56^{fg}	18.89^{bcd}	44.44^{b}
T_6	$(D_2F_3M_1)$	1356.67^{cd}	778.44^{c}	16.53^{cde}	11.33^{efg}	19.11^{bcd}	38.62^{c}
T_7	$(D_3F_1M_1)$	1308.44^{cde}	790.22^{c}	16.7^{cd}	11.33^{efg}	18.56^{cde}	37.89^{cd}
T_8	$(D_3F_2M_1)$	1290.89^{def}	708.00^{d}	16.53^{cde}	11.67^{ef}	15.56^{ghi}	37.32^{cde}
T_9	$(D_3F_3M_1)$	1187.56^{fgh}	702.67^{d}	16.37^{cde}	11.89^{de}	16.33^{fghi}	35.13^{def}
T_{10}	$(D_1F_1M_0)$	1213.33^{efgh}	657.00^{de}	15.77^{def}	11.89^{cdefg}	17.22^{efg}	33.73^{fgh}
T_{11}	$(D_1F_2M_0)$	1175.11^{gh}	612.00^{e}	15.33^{def}	12.11^{cde}	15.78^{ghi}	31.03^{ghi}
T_{12}	$(D_1F_3M_0)$	1107.11^{h}	605.00^{e}	15.17^{def}	12.89^{bcd}	17.56^{def}	30.53^{ij}
T_{13}	$(D_2F_1M_0)$	1002.22^{i}	587.22^{efg}	15.07^{ef}	13.00^{bcd}	15.89^{ghi}	29.17^{ijk}
T_{14}	$(D_2F_2M_0)$	935.78^{ij}	599.11^{ef}	14.83^{fg}	13.11^{bcd}	16.00^{fghi}	28.37^{ijk}
T_{15}	$(D_2F_3M_0)$	890.22^{j}	532.00^{fgh}	13.57^{gh}	13.44^{abc}	15.89^{ghi}	27.23^{jkl}
T_{16}	$(D_3F_1M_0)$	905.00^{ij}	513.33^{h}	13.34^{h}	13.89^{ab}	15.11^{i}	26.40^{kl}
T_{17}	$(D_3F_2M_0)$	840.00^{j}	525.00^{gh}	12.00^{i}	14.67^{a}	15.33^{hi}	26.43^{kl}
T_{18}	$(D_3F_3M_0)$	691.67^{k}	413.56^{i}	11.33^{i}	14.67^{a}	14.67^{i}	24.03^{l}
T_{19}	Control	1225.49^{efg}	680.25^{d}	15.94^{def}	11.42^{efg}	16.96^{efgh}	34.20^{efg}
CD (0.05)		39.67	27.13	0.48	0.40	0.52	1.27
CV %)		2.00	2.22	1.82	2.01	1.82	2.10

The highest total fresh weight (1568.89 g) was observed in T_1 treatment which was at par (1555.56 g) with $T_{3,}$ while the lowest total fresh weight (691.00g) was recorded in T_{18}. Highest head weight (1153.33 g) was recorded in treatment T_1, whereas lowest (413.56 g) was noted in T_{18}. The head diameter was found to be highest (18.73 cm) in T_3 treatment, while minimum head diameter (11.33 cm) was found in T_{18}. In case of number of non-wrapper leaves, minimum leaf no (10.44) was found in T_4 and maximum (14.67) in both T_{17} andT_{18}. Maximum wrapper leaves (21.22) were recorded in T_1 followed by T_3 (20.44) and the minimum (14.67) was noticed in T_{18}. Maximum yield was observed in the treatment T_1 (53.8 t/ha) which was at par with T_3 (53.4 t/ha). Lowest fruit yield of (24.03 t/ha) was observed in T_{18} i.e., unmulched at 50 per cent ET_c with 75 per cent RDF. The increase in yield and yield attributes might be due to the continuous supply of optimum dose of water-soluble fertilizers in available form through fertigation at critical stages of plant growth which resulted in higher uptake and better translocation of assimilates from source to sink (Priya *et al.,* 2023). The yield from plants grown in unmulched condition was significantly lower than those from plants grown with black plastic mulch. Increased temperature inside the soil and efficient utilization of water, fertilizers and nutrients resulting from the use of the plastic mulch might have contributed to higher yield (Deka *et al.,* 2023)

Cost economics

The averaged data pertaining to economic returns of drip based irrigation and fertigation levels obtained during the experiment is given in Table 2. The average selling price of cabbage was considered to be Rs. 15 per kg. Among different levels of fertigation and mulching highest B:C (2.85) ratio was recorded under 30 micron thickness plastic mulch at 100 per cent drip with 75 per cent RDF (T_3). The controlled plot which was unmulched, conventionally irrigated and fertilized through soil application of NPK fertilizers @ 100% RDF exhibited a B: C ratio of (1.96:1). The lower B: C ratio in controlled plot was associated with higher labour cost as well as lesser yield as compared to those which were mulched, well irrigated and fertilized.

Crop water requirement and water applied

The total water requirement for cabbage was calculated during various growth stages at three days intervals (Table 2) for surface irrigation (SI), drip irrigation (DI) and drip with black mulch growing conditions. It was observed that total water requirement per hectare was 9.07 cm, 6.80 cm and 4.54 cm under DI (100% ET_c), DI (75% ET_c), DI (50% ET_c) with mulch, respectively. Under unmulched condition water requirement per hectare was found to be 13.96 cm, 10.47 cm and 6.98 cm under DI (100% ET_c), DI (75% ET_c), DI (50% ET_c), respectively. An effective rainfall of 2.88 cm was noticed during the entire crop growth period which was subtracted from the water requirement value to calculate total irrigation water requirement for different irrigation levels. Under surface irrigation total 28 cm water was applied by 7 irrigations (4 cm in 12 days interval) during entire growing season. It is noted that SI consumed more water than drip irrigation which, in turn, consumed more than drip irrigation with black mulch. Similar data were reported by Deka *et al.* (2023).

Table 2: Cost economics and water use efficiency in cabbage as affected by different levels of drip, fertigation, mulch and without mulch

Treatment	B:C ratio	Water requirement (cm)	Effective rainfall (cm)	Irrigation water requirement (cm)	Water saving (%)	Water use efficiency (q ha^{-1} cm^{-1})
T_1	2.83	9.07	2.88	6.19	74.21	86.91
T_2	2.78	9.07	2.88	6.19	74.21	84.81
T_3	2.85	9.07	2.88	6.19	74.21	86.27
T_4	2.48	6.80	2.88	3.92	83.67	120.23
T_5	2.2	6.80	2.88	3.92	83.67	105.71
T_6	2.06	6.80	2.88	3.92	83.67	98.52
T_7	1.99	4.54	2.88	1.66	93.08	228.25
T_8	1.97	4.54	2.88	1.66	93.08	224.82
T_9	1.88	4.54	2.88	1.66	93.08	211.63
T_{10}	2.12	13.96	2.88	11.08	53.83	30.44
T_{11}	1.97	13.96	2.88	11.08	53.83	28.01
T_{12}	1.96	13.96	2.88	11.08	53.83	27.55
T_{13}	1.84	10.47	2.88	7.59	68.38	38.43
T_{14}	1.8	10.47	2.88	7.59	68.38	37.38
T_{15}	1.75	10.47	2.88	7.59	68.38	35.88
T_{16}	1.66	6.98	2.88	4.10	82.92	64.39
T_{17}	1.68	6.98	2.88	4.10	82.92	64.46
T_{18}	1.54	6.98	2.88	4.10	82.92	58.61
T_{19}	1.96	30.88	2.88	28.00	0.00	12.21

Irrigation water requirement

The irrigation water requirement for cabbage was estimated for different growth stages using the computed values of ET_c, crop spacing (0.60 m × 0.60 m) and wetted area (0.8). The distribution efficiency of drip irrigation was considered to be 80 per cent under mulched condition and 75 per cent under unmulched condition. The total amount of water required for a plant at each growing stages is presented in Table 2. The effective rainfall received from precipitation was considered in estimating the net irrigation water requirement of the crop.

Water use efficiency

It is evident from Table 2 that water requirement and irrigation water requirement was lowest T_7, T_8 and T_9 in which 50 per cent of total water requirement was applied with mulch. The same treatments exhibited highest water saving (93.08 %). In contrary, water requirement and water saving was found to be lowest in T_{10}, T_{11} and T_{12} in which 100 per cent of total water requirement was applied without mulch. The highest water use efficiency (228.25 q ha^{-1} cm^{1}) was recorded in treatment T_7 having 50 per cent drip and 100 per cent RDF under mulched environment. The lowest water use efficiency (12.21 q ha^{-1}) cm^{-1} was recorded in treatment T_{19} (controlled plot) which was unmulched, conventionally irrigated and fertilized through soil application of NPK fertilizers @ 100% RDF.

CONCLUSIONS

The results revealed that application of plastic mulching along with fertigation levels increases the yield and yield attributing characters of cabbage. The maximum cabbage yield of 53.8 t/ha was recorded under 30 micron thickness plastic mulch at 100% drip with 75% recommended dose of fertilizer through fertigation (T_1). However, the yield was at par with 100% drip along with plastic mulching and 75% recommended dose of fertilizer (T_3). The highest B: C ratio was also recorded in (T_3) in comparison to all the treatments. Based on the obtained results it can be concluded that for getting higher production of cabbage over their conventional practice the farmers of Assam can opt for drip irrigation and fertigation with 100% of total water requirement and 75% of recommended dose of fertilizer along with plastic mulching.

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