Composite effect of Drip Irrigation and Mulching of Banana crop in North Bihar Agro-climatic Condition

Comment [I1]: combined

ABSTRACT

The research work entitled "Composite effect of drip irrigation and mulching of Banana crop in North Bihar Agro-climatic Condition" was carried out under three main treatments on drip irrigation namely; 100, 80, and 60% of V volume of water through drip and five sub-treatments, i.e black, blue, red, white color plastic mulch and without mulch (control) with three replications. Variety Basrai of Banana crop was selected. The field layout designed by using split plot design (SPD).

Comment [I2]: volume (V)

The composite effect of drip irrigation and mulching on water saving, vegetative growth, flowering time, bunch emergence time, harvesting time, yield parameters (bunch length, number of hands per bunch, number of finger per bunch, weight per bunch and yield) and quality (length of finger, circumference of finger and weight of finger) of banana frits were found to be better in treatment T_2 (application of 80% of V volume of water through drip irrigation) along with black color of plastic mulch to the tune of 14.95% water saving; 176.15 cm plant height; 60.23 cm plant firth; 17.6 number of functional leaves; 292.0 DAT flowering time; 318.4 DAT bunch emergence time; 391.5 DAT harvesting time; 101.90 cm bunch length; 11.3 number of hands per bunch: 107.97 number of fingers per bunch; 19.77 kg weight of bunch; 879.42 q/ha yield; 14.01 cm length of fingers; 11.90 circumference of fingers and 115.04 g weight of fingers. The water us efficiency in respect of yield was evaluated to be maximum i.e. 26.30 q/ha-cm in treatment T_3 (application of 60% of V volume of water through drip). The maximum soil temperature (23.69^{o}C) and soil moisture (29.29%) were found in treatment T_3 and T_1, respectively along with color plastic mulch. The maximum benefit cost ratio was estimated to the tune of 3.76 in treatment T_2 along with black color plastic mulch.

Key words: Banana, Drip irrigation, Mulching, yield and B: C ratio.

1. Introduction

Banana (*Musa* sp.) is the second most important fruit crop in India next to mango. Its year round availability, affordability, varietal range, taste, nutritive and medicinal value makes it the favourite fruit among all classes of people. It has also good export potential. Hi-tech

cultivation of the crop is an economically viable enterprise leading to increase in productivity, improvement in produce quality and early crop maturity with the produce commanding premium price. Banana and plantains are grown in about 120 countries. Total annual world production is estimated at 86 million tonnes of fruits. India leads the world in banana production with an annual output of about 14.2 million tonnes. Other leading producers are Brazil, Eucador, China, Phillipines, Indonesia, Costarica, Mexico, Thailand and Colombia. In India banana ranks first in production and third in area among fruit crops. It accounts for 13% of the total area and 33% of the production of fruits. Production is highest in Maharashtra (3924.1 thousand tones) followed by Tamil Nadu (3543.8 thousand tones). Within India, Maharashtra has the highest productivity of 65.70 metric t/ha against national average of 30.5 tones/ha, where as the average yield in Bihar is very less it is about 20 t/ha. This might be due to inappropriate package and practices regarding the irrigation and fertigation. The other major banana producing states are Karnataka, Gujarat, Andhra Pradesh and Assam.

Drip irrigation is a controlled method of irrigation, consisting of tubes with emitters. It allows increasing water use efficiencies by providing precise amounts of water directly to the root zone of individual plants (Burt and Styles, 2007). Banana is a perennial crop, depending up on age of plant and climatic parameters, the water requirement varied from 2 lit per plant per day to 8.00 lit per plant per day. The quantity of water requirement per plant per day vaired from 2.3 to 6.7 liter depending on the stage of crop and weather condition Srivanappan et at. (1987).

Fertigation is a technology for application of fertilizer to the crops along with irrigation water through drip or sprinkler irrigation on a continual basis in controlled manner as so as to allow for steady uptake of nutrients by plants and to effect saving in costly inputs of both water and fertilizer (Patel and Rajput 2011). Fertilizer and water use in trickler fertigated potato using different fertilizer application rates, frequencies of application and wetted soil volume were compared with a furrow irrigated and conventionally fertigated crop (Chawla and Narda 2001), results indicated that water and fertilizer saving to the extent of 30 and 70 % respectively with comparable yield levels. Highest yield of 36.29 t/ha of fresh tubers was obtained under trickle irrigation as compared to 21.5 t/ha for the furrow irrigated crop. An experiment was conducted to determine the effect of water soluble fertilizer through drip irrigation on the growth and yield of banana, during 1998 -2000 at Rahuri (Singh 2000). The banana yield was significantly higher with increase in the level of fertilizer and was found maximum 68 t/ha under 100 percent recommended dose. Studies were undertaken to assess

Comment [13]: tons

the effects of fertigation through drip on the growth, yield and quality of banana during 1997-98 with twelve treatments comprising 2 fertilizer sources, 3 fertilizers levels and two planting system. These treatments were also compared with surface irrigation methods using straight fertilizers application (Pawar at al. 2001). The results revealed that the banana fruit yield was significantly higher in normal planting (82.86 t/ha) than paired row planting (75.75 t/ha).The fruit yield increased significantly in water soluble fertilizers (81.01 t/ha) as compared to only N through drip (77.59 t/ha).

Mulching in general is a beneficial practice for crop production. Mulch conserves soil moisture, retains heat as well as it suppress weed growth (Chakarborthy et.al 1994 and Hooda et al.,1999). Color plastic film also affects effective weed seed germination, growth and development under the plastic (Brault et al., 2002). Therefore keeping above observation in mind this work carried out.

Comment [I4]: please write the objective of your experiment

2. Materials and Methods

2.1 Experimental site

The experiment was carried out at Rajendra Agricultural University Pusa Samastipur Bihar in year 2005-06 under "Precision Farming Development Centre (PFDC)". It is situated at $25^0$59'N latitude and $85^0$48'E longitude. Altitude of the site is 52.92 m above mean sea level. Experimental site is under humid sub-tropical climate, greatly influenced by the south-west monsoon. The main characteristic of the climate is hot-dry summer followed by cold winters. Average annual rainfall is 1270 mm, out of which about 1026 mm is received during the monsoon season from June to October. Soil type is sandy clay loam with average available moisture content 12.01%.

2.2. Experimental design and Land preparation for Planting of Banana crop

The field preparation for banana plantation was carried out by two ploughing with mould board plough followed by cross harrowing to make the soil porous. The pits of 60 cm x 60 cm x 60 cm sizes were dug at 1.5m x 1.5m spacing. Before transplanting the banana plantlets, FYM, mustered cake and MOP were mixed in the soil at the rate of 10 kg, 1kg, 200 g per plant, respectively and filled in the pits. Filled pit were left for 15 days to get decompose and mix the manure/fertilizers in the soil thoroughly in this research split plot design adopted. Each treatment was replicated 3 times the details of the treatment and sub-treatment in table.Three irrigation level treated as main treatment and our mulches and control treatment where applied as sub-treatment the total treatment combination 15 and Total replicated plot 45.

Design – Split Plot Design , Replication – 3 , Variety - Grand Naine

Treatment	
T_1	Application of V volume (49.24 cm) of water through drip
T_2	Application of 0.8V volume (39.39cm) of water through drip
T_3	Application of 0.6V volume (29.54 cm) of water through drip
Sub-Treatments	
M_1	Application of black colour plastic mulch
M_2	Application of blue colour plastic mulch
M_3	Application of red colour plastic mulch
M_4	Application of white colour plastic mulch
M_5	No mulch (control)

Drip Irrigation

Drip system consisting of sand filter 10 m^3/h as discharge capacity; 50 mm nominal size; 2 kg/cm^2 nominal pressure with 14-24 mesh; screen filter of 10 m^3/h discharge capacity; 65 mm of nominal size; 2 kg/cm^2 nominal pressure with 120 mesh as the screen size), pipe line (main -63 mm diameter and 21 m length; and sub-main - 63 mm diameter and 11 m as length) and drippers (4 lph) was installed/used under experiment. Cavity type tube well of 2.5 inch diameter suction pipe was used as the water source. A 7.5 HP diesel pump set was used to suck the water from well and supply to the pipe line system through filters. The main and sub-main pipe lines were installed at 40 cm depth from the ground surface. Laterals were installed over the ground surface, row wise passing through banana plantlets below plastic mulch. Drippers were placed on the lateral near banana plantlets. During system operation, the water first goes to the main pipeline, to the sub-main pipeline, to the laterals and lastly to the ground near banana plantlets through drippers.

Mulch

Mulching was performed after one month of banana transplantation. For which, the banana plant rows were formed in the ridge shape of nominal size with outward slope. The laterals equipped with drippers are placed over the ridge shape banana row. After that as per layout, the silver and black colours polythene sheets of 60 micron (0.06) thickness were spread over the ridge. The edges of polythene were covered with the help of loose soil.

Crop Water Requirement

The daily crop water requirement of banana plant was determined as (Anonymous, 1997).

The formula of crop water requirement is given as under:

$$V=E_p \cdot K_c \cdot K_p \cdot W_p \cdot A \quad \ldots (1)$$

Net volume of water Vn, could be expressed as,

$$V_n = V - R_e.A \quad \ldots (2)$$

The total volume of water applied per plant per day is given by,

$$= V_n \text{ x no. of plant} \quad \ldots (3)$$

Where,

V = Water requirement of consumptive use of plant (l/plant/day), V_n = net volume of water, E_p = pan evaporation (mm/day), K_c = crop co-efficient, K_p = pan factor, W_p= wetted area factor, A = spacing of the plant (m^2), R_e = effective rainfall (cm)

In equation (1) the daily pan evaporation values were collected from meteorological observatory located in crop research centre Pusa Farm, Samastipur, Bihar for banana crop period (March, 2009 to March, 2011). The pan factor (K_p) was taken as 0.8 for USWB type pan (Anonymous 1997). The wetted area factor (W_p) was considered as 0.9 for initial stage and 1 for full growth stage (Anonymous, 1997). The value of crop co-efficient (K_c) was taken as 0.8 for initial stage and 1 for full growth stage of banana plants (Anonymous, 1997).

Fertilizer Dose

The recommended dose of fertilizers for banana crop is 200 g nitrogen, 50 g phosphorus and 300 g potash per plant per year. The phosphorus and potash were applied as basal application in two split doses, i.e. first dose at 90 DAT (6^{th} May) and second dose at 180 DAT (7^{th} August). The nitrogen was applied at month interval through fertigation, before commencement of flowers in banana plants.

Water saving

The quantity of water saving under different treatments was evaluated with respect to control treatment, by using following formula:

$$Depth\ of\ water\ saving\ (ds) = d_a - d_{th} \quad \ldots(4)$$

$$Percentage\ water\ saving = \frac{d_s}{d_a} \text{ x } 100 \quad \ldots(5)$$

Where d_a = actual depth of water applied as per treatment (cm)

d_{th}= theoretical depth of water required (cm)

The value of d_a, i'e depth of required water under different treatments is fixed as per crop water requirement e.g. treatment T1 it is 49.24 cm; in treatment T2 39.39 cm and in treatment T3 is 29.54cm.

Growth Parameters

This section deal with various growth parameters the observation of Plant girth , Number of leaves per plant , Flowering time , Fruits per plant , bunch length, weight of bunch were recorded on Banana Plant.

Patterns of Root System

Two banana plants were take into consideration for recorded the radical and vertical spreading (length) of banana roots; for which banana plants were uprooted and cleaned their roots and measured with the help of measuring tape.

Reproductive Parameter

In this flowering time, Bunch emergence time, harvesting time data were collected.

Vegetative growth Parameter

In vegetative growth plant height, plant girth and number of functional leaves per plants were considered as growth parameter.

Mulching Effect on Yield and Growth Parameter of Banana Fruit

The number of hands per bunch, number of fruits per bunch, bunch length, weight of bunch and yield of banana crop were considered as the yield parameters for evaluating the composite effect of drip irrigation and different colours of plastic mulch on crop.

Evaluation of mulching effect on Soil-Plant Environment

The environmental parameters, such as solar radiation, soil moisture and soil temperature were taken into consideration for evaluating the composite effect of drip irrigation and coloured plastic mulch on soil plant environment.

Solar Radiation

The amount of solar radiation absorbed, i.e retained below the plastic mulch of different coloured was measured with the help of solar meter. The measurement was conducted at 8.00 AM, 12.00 noon and 4.00 PM, daily during banana crop period; and averaged together to get average daily value of solar radiation.

Soil Moisture

The available soil moisture content under different plastic mulch was determined by taking soil sample from 30 cm soil depth. Soil samples were taken by using hand augur and followed oven dry method to determine the soil moisture**.**

Soil temperature

The soil temperature under different plastic mulch was determined at 20 cm soil depth by using digital temperature meter. The observations on soil temperature ware taken twice, i.e 8.00 AM and 2.00 PM daily.

Evaluation of Cot-Economics of Banana crop

The cost - economics of banana crop under drip irrigation and mulching treatment was analysed for determining the benefit- cost of banana cultivation. The computation of benefits done by following formula:

$$Benefit\ (Rs./ha) = Income(Rs./ha) - Cost\ of\ cultivation\ (Rs./ha) \quad \ldots (6)$$

The income was determined by multiplying the unit yield and unit price of banana fruit. Unit price ((Rs/ha) was taken into consideration as per local market price of banana.

Benefit cost ratio:

The b/c ratio of banana crop was computed as

$$\frac{b}{c} = \frac{Benefit\ obtained}{Cost\ of\ cultivation} \quad \ldots (7)$$

3. RESULTS AND DISCUSSION

3.1 Effect of mulches on water saving, rooting pattern and vegetative growth of banana plant

3.1.1 Water saving

In treatment T1 is 49.24 cm; in treatment T2 39.39 cm and in treatment T3 29.54 cm. As shown in table, the percentage water saving over control treatment (without mulch) is presented in Table .1. It can be observed that black colour plastic mulch under different irrigation treatment was 13.62% more water saving as compared to control treatment. The water saving increase in red, blue and white colour plastic mulch was 11.01, 9.12 and 3.31%, respectively over control treatment under different irrigations. It can also be seen in Table .1 that CD value of Drip factor is 0.214 , CD value of Mulch factor is 0.7014 and CD value of its interaction factor is 1.218.

Thus, the black colour plastic mulch in drip irrigation is beneficial for water saving in banana crop cultivation.

Comment [I5]: what is the reason for recommending black color mulch for water saving

Table .1 Composite effect of drip irrigation and mulch on water saving (%) under different treatments over control treatment

Sub-treatment (Mulch)	Main treatment (Drip irrigation)			
	T_1	T_2	T_3	(%) Average
M_1	10.30	14.95	15.61	13.62
M_2	7.03	11.40	8.94	9.12
M_3	8.25	12.90	11.88	11.01
M_4	0.68	4.16	4.40	3.31
Mean	6.56	10.85	10.21	

Factor	$S.E_m$	CD	CV
Drip Irrigation (T)	0.072	0.214	2.70
Mulch (M)	0.237	0.7014	7072
M X T	0.41	1.218	

3.1.2 Rooting pattern

3.1.2.1 Horizontal spreading of root

Table .2 illustrates how mulch and drip irrigation work together to affect the horizontal distribution of banana roots under various conditions. The study observed that among different colors of plastic mulch, white plastic mulch (M_4) led to the maximum spreading of banana roots (104.13 cm), while black plastic mulch (M_1) resulted in the minimum spreading (99.51 cm). Blue (M_2) and red (M_3) plastic mulches showed horizontal root spreading of 102.10 cm and 101.20 cm, respectively. Compared to the control treatment (without mulch), there was 7.24%, 4.83%, 5.67%, and 2.94% less horizontal spreading of banana roots in black, blue, red, and white plastic mulch, respectively.

3.1.2.2 Vertical spreading of root

The trend of vertical spreading of banana root was found to be similar as horizontal spreading, i.e. maximum vertical spreading of 70.52 cm was noticed in treatment T_3; 61.99 cm in treatment T_2 and minimum 54.44 cm in treatment T_1 as shown in Table .3. Amongst different colours of plastic mulch, the white colour plastic mulch (M_4) result maximum vertical rooting depth to the tune of 63.29 cm (average), followed by 61.74 cm in blue colour mulch (M_2), 60.79 cm in red colour (M_3) and 59.10 cm in black colour plastic mulch (M_1) as shown in Table 3. As compared to control treatment, the percentage reduction in vertical spreading of banana roots was found to be 12.21, 8.30, 9.71 and 6.00 in sub-treatment M_1, M_2, M_3 and M_4, respectively.

Vertical rooting depth in response to mulches were found to be non - significant whereas effect of amount of drip irrigation was found to be significant at 1% level.

Table .2 Composite effects of drip irrigation and mulch on horizontal spreading of banana roots (cm).

Sub-treatment (Mulch)	Main treatment (Drip irrigation)				
	T_1	T_2	T_3	Sub-treatment mean	Percentage reduction over control
M_1	90.33	98.78	109.38	99.51	7.24
M_2	93.21	101.13	111.95	102.10	4.83
M_3	92.42	100.16	111.01	101.20	5.67
M_4	95.23	104.23	112.86	104.13	2.94
M_5(control)	98.11	108.16	115.56	107.28	-
Main treatment mean	93.88	102.50	112.16	102.83	

Treatment	$S.E_m$	CD (at 5%)	CV
Main treatment (T)	1.131	3.301	4.25
Sub-treatment (M)	2.798	NS	8.16
M X T	4.84	NS	4.84

**: Significant at 1% level.

Table 3 Composite effects of drip irrigation and mulch on vertical spreading of banana roots (cm) under different treatments.

Sub-treatment (Mulch)	Main treatment (Drip irrigation)				
	T_1	T_2	T_3	Sub-treatment mean	Percentage reduction over control
M_1	51.04	59.16	67.10	59.10	12.21
M_2	53.82	61.49	69.89	61.74	8.30
M_3	53.03	60.26	69.08	60.79	9.71
M_4	55.75	63.07	71.04	63.29	6
M_5(control)	58.56	65.97	72.45	66.66	---
Main treatment mean	54.44	61.99	70.52	62.31	

Treatment	S.Em	CD (at 5%)	CV	F-value
Main treatment	1.15	4.53	7.18	48.38**
Sub-treatment	1.87	NS	9.04	2.33

**: Significant at 1% level.

3.3 Effect of Mulch on Soil-Plant Environment

The soil temperature (at 20 cm depth), soil moisture (at 30 cm depth) and solar radiation were considered as the soil-plant environment parameters to explore the effect of mulch. The composite effect of drip irrigation and mulch on soil temperature, soil moisture and solar radiation are shown in Table 4, 5 and .6, respectively.

3.3.1 Soil temperature

As per Table 4, it is found that the soil temperature increase due to decrease in depth of irrigation and vice –versa. Amongst different treatments of drip irrigation ,the average maximum daily soil temperature at 20 cm depth was found to be 23.69^{0}C in treatment T3 (application of 60% of V volume of water through drip) with mulch, while average minimum daily soil temperature was found to be 22.41^{o}C.

Amongst different colours of plastic mulch, the black colour mulch developed maximum soil temperature i.e. 24^{o}C due to absorption of more solar radiation, while white colour plastic mulch developed minimum soil temperature i.e. 21.67^{o}C .The red and blue colours mulch generated the soil temperature to the tune of 22.85 and 22.4^{o}C, respectively during banana crop period. The increase in soil temperature under different plastic mulch was computed to be 15.22 % in sub-treatment M_1, 7.54% in sub-treatment M_2 , 9.70% in sub treatment M_3 and 4.03% in sub-treatment M_4 over control treatment.

The composite effect of drip irrigation (main treatment) and mulch (sub-treatment) on soil temperature was found significant at 1% level with the F-value 47.84 and 4.82, respectively.

Comment [16]: were

Table .4 Composite effect of drip irrigation and mulch on soil temperature (^{o}C) at 20 cm depth during crop period under different treatment.

Sub-treatment (Mulch)	Main treatment (Drip irrigation)				
	T_1	T_2	T_3	Sub-treatment mean	Percentage increase over control
M_1	22.60	24.03	25.36	24.00	15.22
M_2	21.10	22.40	23.70	22.4	7.54
M_3	21.53	22.83	24.20	22.85	9.70
M_4	20.23	21.80	23.00	21.67	4.03
M_5(control)	19.30	21.00	22.20	20.83	----
Main treatment mean	20.95	22.41	23.69	22.35	-----

Treatment	S.Em	CD (at 5%)	CV	F-Value
Main treatment	0.19	0.77	3.43	47.84**
Sub-treatment	0.54	1.59	7.32	4.82**

**: Significant at1% level.

3.3.2 Soil moisture

On comparison from Table .5, it was found that the maximum average monthly soil moisture (29.29%) was in treatment T_1 (application of 100% of volume of water through drip) followed by 26.00% in treatment T_2 (application of 80% V volume

of water through drip) and minimum 23.58% in treatment T_3(application of 60% of V volume of water through drip).

The black colour plastic mulch was found to conserve maximum amount of water in the soil i.e. 28.49% while minimum 25.32% in white colour plastic mulch. The blue and red colours plastic mulch conserved 26.65 and 27.28% moisture content in soil. Overall, the composite effect of black plastic mulch and application of 100% of V volume water through drip (treatment T_1) was found better for water conservation in the soil. The percentage increase in soil moisture due to plastic mulch over control treatment (M_5) was 20.11, 12.35, 15.01 and 6.75% in sub-treatment M_1, M_2, M_3 and M_4, respectively. The reason of more soil moisture conserved in black colour plastic mulch at higher temperature because at higher temperature, more water evaporates from the soil which gets condense and stored in upper soil profiles. As per statically analysis, it was found that the levels of moistures conservation under main and sub – main treatment are highly significant with F- value of 275.99 (main treatment) and 6.58 (sub main-treatment).

Table .5 Composite effect of drip irrigation and mulch on soil moisture (%) at 30 cm depth under different treatments.

Sub-treatment (Mulch)	Main treatment (Drip irrigation)				
	T_1	T_2	T_3	Sub-treatment mean	Percentage increase over control
M_1	31.35	28.92	25.20	28.49	20.11
M_2	29.21	26.86	23.87	26.65	12.35
M_3	29.77	27.45	24.63	27.28	15.01
M_4	28.54	24.22	23.20	25.32	6.75
M_5(control)	27.60	22.55	21.00	23.72	-----
Main treatment mean	29.29	26.00	23.58	26.29	------

Treatment	S.Em	CD (at 5%)	CV	F-Value
Main treatment	0.17	0.67	2.54	275.99**
Sub-treatment	0.71	2.09.	8.17	6.58**

**: Significant at1% level.

3.3.3 Solar radiation

On perusal of Table .6, it was found that there is no effect of change in depth of irrigation on transmission of solar radiation inside the plastic mulch. In all the treatments, i.e. T_1 (application of 100% of V volume of water through drip) T_2 (application of 80% of V volume of water through drip) and T_3 (application of 60% of V volume of water through drip), the transmission solar radiation was recorded to the tune of 35.63 ly/h.

On contrast, the effect of colour mulch was found to be quite significant on transmission of solar radiation. The maximum transmitted solar radiation was noticed inside the white colour plastic mulch (M_4), i.e. 51.15 ly/h (daily average) followed by 36.10 ly/h in

blue colour (M_2);28.44 ly/h in red colour (M_3) and 3.23 ly/h in black colour plastic mulch (M_1). Overall, as compared to control treatment, about 94.55, 39.09, 52.02 and 13.67% more solar radiation was intercepted in black, blue, red and white colour plastic mulch, respectively.

Table 6 Composite effect of drip irrigation and mulch on daily average solar radiation (ly/h) transmitted below the mulch under different treatments

Sub-treatment (Mulch)	Main treatment (Drip irrigation)				
	T_1	T_2	T_3	Sub-treatment mean	Percentage decrease inside the mulch
M_1	3.23	3.23	3.23	3.23	94.55
M_2	36.10	36.10	36.10	36.10	39.09
M_3	28.44	28.44	28.44	28.44	52.02
M_4	51.15	51.15	51.15	51.15	13.67
M_5(control)	59.27	59.27	59.27	59.27	
Main treatment mean	35.63	35.63	35.63		

3.4 Effect on Yield and Quality of Banana

3.4.1 Yield parameters

The parameters, such as length of bunch, number of hands per bunch, number of fingers per bunch, weight of bunch and yield potential of banana were evaluated under different treatments and presented in Tables from .7 to .11.

3.4.1.1 Length of bunch

The composite effect of drip irrigation (main treatment) and mulch (sub-treatment) on length of banana bunch is presented in Table .7, which indicated that amongst different treatments of drip irrigation, the maximum length of banana bunch was found in treatment T_2 (when 80% water was applied through drip) to the tune of 101.90 cm (average), while minimum 92.83 cm in treatment T_3 (i.e. when 60% water was applied through drip). In treatment T_1 (when 100% water was applied through drip) it was 100.71 cm.

In case of different colours of plastic mulch, the maximum bunch length was noticed in sub-treatment M_1 (black colour plastic mulch) to the tune of 102.44 cm (average) and minimum 97.06 cm (average) in sub-treatment M_4 (white colour plastic mulch). In sub-treatments M_2 (blue colour plastic mulch) and M_3 (red colour plastic mulch), the average length of banana bunch was found to be 99.37 and 100.61 cm, respectively. The variations in the length of banana bunch amongst different treatments were estimated to be 10.22, 6.92, 8.25 and 4.43% greater in sub-treatments black, blue, red and white colour plastic mulch, respectively over control treatment. As per statistical analysis, the effect of main treatment (drip irrigation) was found significant at 5% level on length of banana bunch having F – value as 15.71, while effect of mulching treatments was found non-significant.

Table .7 Composite effect of drip irrigation and mulch on length of banana bunch (cm) of banana under different treatments.

Sub-treatment (Mulch)	Main treatment (Drip irrigation)				
	T_1	T_2	T_3	Sub-treatment mean	Percentage increase over control
M_1	103.89	106.21	97.24	102.44	10.22
M_2	101.03	103.09	94.00	99.37	6.92
M_3	102.15	104.33	95.35	100.67	8.25
M_4	99.21	100.93	91.03	97.06	4.43
M_5(control)	97.30	94.97	86.54	92.94	
Main treatment mean	100.71	101.90	92.83	98.48	

Treatment	S.Em	CD (at 5%)	CV	F-Value
Main treatment	1.24	4.88	4.89	15.71*
Sub-treatment	3.18	NS	9.71	1.32

*: Significant at 1% level.

3.4.1.2 Number of hands per bunch

As per Table .8, it was found that the maximum number of hands per bunch was in treatment T_2, i.e. 11.33 (average) amongst different treatments of drip irrigation, followed by 10.86 in treatment T_1 and minimum 8.53 in treatment T_3. Similarly, amongst different colours of plastic mulch, the black colour plastic mulch (M_1) appeared to produce maximum number of hands per bunch (11.37), while white colour (M_4) produced minimum number of hands per bunch (10.00). the other plastic mulches, such as blue (M_2) and red (M_3) colours plastic mulch produced 10.51 and 10.66 (average) number of banana hands per bunch. As compared to control treatment (M_5), the variation in number of hands per bunch of banana was estimated to be 31.29, 21.36, 23.09 and 15.47%, respectively.

The effect of main treatments (drip irrigation) and sub-treatments (mulch) was found to be significant at 1% levels, with their F- value of 134.04 and 5.89, respectively.

Table .8 Composite effect of drip irrigation and mulch on number of hands per bunch of banana under different treatments.

Sub-treatment (Mulch)	Main treatment (Drip irrigation)				
	T_1	T_2	T_3	Sub-treatment mean	Percentage increase over control
M_1	11.77	12.66	9.66	11.37	31.29
M_2	10.89	11.77	8.89	10.51	21.36
M_3	11.00	12.00	9.00	10.66	23.09
M_4	10.66	11.22	8.11	10.00	15.47
M_5(control)	10.00	9.00	7.00	8.66	-
Main treatment mean	10.86	11.33	8.53	10.24	

Treatment	S.Em	CD (at 5%)	CV	F-Value
Main treatment	0.12	0.50	4.89	134.04**
Sub-treatment	0.41	1.21	12.17	5.89**

**: Significant at 1% level.

3.4.1.3 Number of fingers per bunch

On perusal of Table 9, it was observed that the maximum number of banana fingers i.e. 107.97 (average) was in treatment T_2 (when 80% V volume of irrigation water was applied through drip) followed by 105.95 in T_1, (when 100% V volume of water was applied through drip) and minimum 97.58 in treatment T_3 (when 60% V volume of water was applied through drip).

The better effect of mulch on number of banana fingers per bunch was noticed under sub-treatment M_1 (black colour plastic mulch), i.e. 109.26 (maximum average). On contrast the white colour plastic mulch (M_4) produced minimum number of fingers per bunch, i.e. 101.74 (average). The blue (M_2) and red colours plastic mulch (M_3) resulted 105.22 and 106.55 banana fingers per bunch, respectively. Overall, as compared to control treatment, the increase in number of banana fingers per bunch was estimated to be 13.34, 9.15, 10.53 and 5.53%, respectively in sub-treatment M_1, M_2, M_3, and M_4.

The effect of mulch (i.e. sub-treatments) on number of fingers per bunch was found significant at 5% level having 2.79 as F-value.

Table 9 Composite effect of drip irrigation and mulch on number of fingers per bunch of banana under different treatments.

Sub-treatment (Mulch)	Main treatment (Drip irrigation)				
	T_1	T_2	T_3	Sub-treatment mean	Percentage increase over control
M_1	110.00	113.78	104.00	109.26	13.34
M_2	106.00	109.11	100.55	105.22	9.15
M_3	107.33	111.00	101.33	106.55	10.53
M_4	104.44	105.77	95.00	101.74	5.54
M_5(control)	102.00	100.22	87.00	96.40	-
Main treatment mean	105.95	107.97	97.58	104.23	

Treatment	S.Em	CD (at 5%)	CV	F-Value
Main treatment	2.56	NS	9.51	3.58
Sub-treatment	2.84	8.31	8.19	2.79*

*: Significant at 5% level.

3.4.1.4 Weight of bunch

The composite effect of drip irrigation and plastic mulch on weight of banana bunch are shown in Table .10. On perusal, it was found that amongst different treatments of drip irrigation, the treatment T_2 (80% application of V volume of water through drip) resulted maximum bunch weight to be the tune of 19.77 kg (average), while treatment T_3 (60% application of V volume of water through drip) noticed minimum weight of bunch (17.47 kg). In treatment T_1 (100% application of V volume of water through drip), it was 19.42 kg.

Amongst different colours of plastic mulches, the black colour plastic mulch (M_1) appeared to result highest bunch weight, i.e. 20.18 kg (average)followed by 19.6 kg in red colour plastic mulch (M_3); 19.18 kg in blue colour plastic mulch (M_2)and lowest 18.03 kg in case of white colour plastic mulch (M_4). The increase in weight of banana bunch under different sub-treatments over control treatment was computed to be 15.71% in sub-treatment M_1, 9.98% in sub-treatment M_2, 12.39% in sub-treatment M_3 and 3.38% in sub- treatment M_4.

As per statistical analysis the effect of drip irrigation was found significant at 5% level (F-value 6.94) while the effect of mulching was found to be highly significant.

Table .10 Composite effect of drip irrigation and mulch on bunch weight (kg) of banana under different treatments.

Sub-treatment (Mulch)	Main treatment (Drip irrigation)				
	T_1	T_2	T_3	Sub-treatment mean	Percentage increase over control
M_1	20.44	21.16	18.95	20.18	15.71
M_2	19.72	20.28	17.56	19.18	9.98
M_3	19.99	20.66	18.14	19.60	12.39
M_4	18.40	18.78	16.72	18.03	3.38
M_5(control)	18.34	18.00	15.98	17.44	-
Main treatment mean	19.42	19.77	17.47	18.89	

Treatment	S.Em	CD (at 5%)	CV	F-Value
Main treatment	0.47	1.87	9.78	6.94*
Sub-treatment	0.50	1.48	8.09	4.90**

*: Significant at 5% level.

**: Significant at 1% level.

3.4.1.5 Yield

The yield as the ultimate productive parameter of banana crop was also found to be highest in treatment T_2 (application of 80% V volume of water through drip), i.e. 879.42 q/ha (average), while minimum 776.54 q/ha in treatment T_3 (application of 60% V volume of water through drip). In treatment T_1 (application of 100% V volume of water through drip), the average yield of banana was harvested at the rate of 863.09 q/ha (Table .11).

Like other productive parameters, the yield was also noticed to be maximum, i.e. 897.19 q/ha (average) in black colour plastic mulching (M_1), while lowest in white colour mulch to the tune of 801.50 q/ha. In other treatments, such as in blue (M_2) and red colour plastic mulches (M_3), the yield was found to be 853.32 and 871.13 q/ha respectively. Overall, as compared to control treatment (without mulch), the increase in banana yield was estimated to be 15.72% in sub-treatment M_1, 10.07% in sub-treatment M_2, 12.36% in sub-treatment M_3 and 3.38 % in sub-treatment M_4.

The composite effect of drip irrigation (main treatment) and plastic mulch (sub-treatment) on banana yield was found to be significant at 5% (6.94 F-value) and 1% level (4.94 F-value), respectively.

Table.11 Composite effect of drip irrigation and mulch on yield (q/ha) of banana under different treatments.

Sub-treatment (Mulch)	Main treatment (Drip irrigation)				
	T_1	T_2	T_3	Sub-treatment mean	Percentage increase over control
M_1	908.78	940.75	842.04	897.19	15.72
M_2	876.70	902.90	780.37	853.32	10.07
M_3	888.34	918.69	806.38	871.13	12.36
M_4	826.50	834.71	743.31	801.50	3.38
M_5(control)	815.16	800.05	710.63	775.28	-
Main treatment mean	863.09	879.42	776.54	839.69	

Treatment	S.Em	CD (at 5%)	CV	F-Value
Main treatment	21.11	82.88	9.73	6.94*
Sub-treatment	22.60	65.97	8.07	4.94**

*: Significant at 5% level.

**: Significant at 1% level.

3.4.2 Quality parameters

The quality of banana fruits was evaluated on the basis of length of fingers, circumference of fingers and weight of fingers. The composite effect of drip irrigation and mulch on these parameters are presented in Tables from 12 to 14.

3.4.2.1 Length of banana finger

Amongst different treatments of drip irrigation (with mulch), the average length of banana fingers was found to be maximum in treatment T_2 (when 80% of V volume of water was applied through drip) to the tune of 14.01 cm (average), while in treatment T_3 (when 60% of V volume of water was applied through drip) it was 10.77 cm (average). The treatment T_1 (when 100% of V volume of water was applied through drip) resulted 13.33 cm as the average length of banana fingers (Table 12).

Table 12 Composite effect of drip irrigation and mulch on length of banana fingers(cm) under different treatments.

Sub-treatment (Mulch)	Main treatment (Drip irrigation)				
	T_1	T_2	T_3	Sub-treatment mean	Percentage increase over control
M_1	14.61	15.58	12.84	14.34	32.65
M_2	13.28	14.31	11.05	12.88	19.15
M_3	13.88	14.76	11.78	13.47	24.61
M_4	12.81	13.37	9.83	12.00	11.01
M_5(control)	12.06	12.01	8.35	10.81	-
Main treatment mean	13.33	14.01	10.77	12.70	

Treatment	S.Em	CD (at 5%)	CV	F-Value
Main treatment	0.21	0.86	6.69	60.54**
Sub-treatment	0.45	1.31	10.64	9.10**

**: Significant at 1% level.

In case of plastic mulches, the maximum length of banana fingers was harvested in black colour plastic mulch (M_1), i.e. 14.34 cm (average) followed by red colour plastic mulch (M_3) 13.47 cm, blue colour plastic mulch (M_2) 12.88 cm and minimum finger length 12 cm in white colour plastic mulch (M_4). The percentage increase in length of banana fingers under different sub-treatments over control is shown in Table 13, which revealed that percentage increase in length of banana fingers under sub-treatments M_1, M_2, M_3 and M_4 was 32.65, 19.15, 24.61 and 11.01 respectively over control treatment.

Statically, the effect of drip irrigation and mulch for increasing the length of banana fingers was found to be highly significant.

3.4.2.2 Circumference of finger

The composite effect of drip irrigation (main treatment) and mulch (sub-treatment) on circumference of banana fingers is presented in Table 13. on comparison, it was found that amongst different treatment of drip irrigation the maximum circumference, i.e. 11.90 cm (average) was in treatment T_2 (when 80% of V volume of water was applied through drip), while minimum 9.73 cm (average) was in treatment T_3(when 60% of V volume of water was applied through drip). In treatment T_1 (when 100% of V volume of water was applied through drip), the circumference of banana finger was found to be 11.27 cm.

In case of different colours of plastic mulch (sub-treatment), the maximum circumference of banana fingers was noticed in sub-treatment M_1 (black colour plastic mulch) to the tune of 12.04 cm (average), while it was minimum in white colour plastic mulch (M_4) i.e. 10.41 cm (average). In other sub-treatments such as blue colour (M_2) and red colour plastic mulch (M_3), the circumference of banana finger was found to be 11.17 and 11.66 cm respectively. The percentage increase in circumference of banana fingers over control (M_5) was estimated

to be 26.21% in sub-treatment M_1, 17.09% in sub-treatment M_2, 22.22% in sub-treatment M_3 and 9.12% in sub-treatment M_4.

As per statistical analysis, the effect of main treatments (drip irrigation) on circumference of banana was found significant at 5% level with 8.76 as F-value; while effect of sub-treatment (mulch) was significant at 1% (F-value 6.85).

Table 13 Composite effect of drip irrigation and mulch on circumference of banana fingers(cm) under different treatments.

Sub-treatment (Mulch)	Main treatment (Drip irrigation)				
	T_1	T_2	T_3	Sub-treatment mean	Percentage increase over control
M_1	11.91	13.24	10.98	12.04	26.21
M_2	11.33	12.2	9.99	11.17	17.09
M_3	11.75	12.87	10.37	11.66	22.22
M_4	10.96	11.11	9.16	10.41	9.12
M_5(control)	10.41	10.08	8.13	9.54	-
Main treatment mean	11.27	11.90	9.73	10.97	

Treatment	S.Em	CD (at 5%)	CV	F-Value
Main treatment	0.37	1.48	13.33	8.76*
Sub-treatment	0.38	1.11	10.48	6.85**

*: Significant at 5% level.

**: Significant at 1% level.

4.4.2.3 Weight of finger

The effect of black colour plastic mulch (M1) was found better to resulted highest weight of banana fingers, while poor performance was noticed in case of white colour mulch(M4). The effect of blue (M2) and red colours (M3) plastic mulches was slightly inferior to the black colour plastic mulch. Overall, the average weight of banana finger under black, blue, red and white colours plastic mulches was found to be 115.4, 110.95, 111.92 and 108.30 gram respectively. In comparison to control treatment (without mulch) the increase in weight of banana fingers under different sub- treatments was computed to be 10.21% in sub-treatment M1, 5.96% in sub- treatment M2, 6.89% in sub-treatment M3 and 3.43% in sub-treatment M4.

Regarding statistical significance of effect of irrigation (T1, T2 and T3) was found significant at 5% with 6.09 as CD-value while the effect of mulches on weight of banana finger was non-significant.

Table .14 Composite effect of drip irrigation and mulch on weight of banana fingers(g) under different treatments.

Sub-treatment (Mulch)	Main treatment (Drip irrigation)				
	T_1	T_2	T_3	Sub-treatment mean	Percentage increase over control

M_1	116.88	120.82	108.5	115.40	10.21
M_2	113.05	115.94	103.87	110.95	5.96
M_3	114.16	117.43	104.18	111.92	6.89
M_4	111.96	113.06	100.13	108.30	3.43
M_5(control)	110.05	107.97	96.11	104.71	-
Main treatment mean	113.22	115.04	102.56	110.27	

Treatment	S.Em	CD (at 5%)	CV	F-Value
Main treatment	1.55	6.09	5.45	18.87**
Sub-treatment	3.19	NS	8.69	1.57

**: Significant at 1% level.

3.5 Water use efficiency

The computed values of water use efficiencies under different treatments (drip irrigation and mulch) are presented in Table 15. On comparison, it was found that amongst different treatments of drip irrigation, the treatment T_3 (application of 60% of V volume of water was applied through drip) resulted highest water use efficiency to the tune of 26.30 q/ha cm, while treatment T_1 (application of 100% of V volume of water was applied through drip) noticed lowest water use efficiency, i.e. 17.53 q/ha cm, due to supply of full volume of water to the crop. The water use efficiency in treatment T_2 (application of 80% of V volume of water was applied through drip) was 22.32 q/ha cm, which is greater than T_1 but lesser than T_3.

As far as, the effect of different colour plastic mulch on water use efficiency is concerned, the black colour plastic mulch appeared to result highest (23.62 q/ha cm) water use efficiency, while white colour mulch was found inferior (20.31 q/ha cm) for increase water use efficiency in banana crop. Overall, in comparison to control treatment (without mulch) about 16.35, 10.19, 12.70 and 3.64% greater water use efficiency was found in sub-treatments M_1, M_2, M_3 and M_4 respectively.

Table 15 Computed values of water use efficiency (q/ha cm) under different treatments.

Sub-treatment (Mulch)	Main treatment (irrigation)				
	T_1	T_2	T_3	Sub-treatment mean	Percentage increase over control
M_1	18.46	23.88	28.54	23.63	16.35
M_2	17.80	22.92	26.42	22.38	10.19
M_3	18.04	23.32	27.30	22.89	12.70
M_4	16.79	21.19	25.16	21.05	3.64
M_5(control)	16.55	20.31	24.06	20.31	-
Main treatment mean	17.53	22.32	26.30	-	

3.6 Cost economics

The benefit-cost ratios of banana cultivation under different treatment of drip irrigation (T_1,T_2, and T_3) and plastic mulching (M_1,M_2,M_3, and M_4) are presented in Table.16, which revealed that amongst different treatments of drip irrigation, the treatment T_2 (application of

80% V volume of water through drip) generated highest b/c ratio, i.e. 3.76 (average), while lowest 3.36 (average) in treatment T_3 (application of 60% V volume of water through drip). The b/c ratio 3.51 (average) was found in treatment T_1 (application of 100% V volume of water through drip).

Amongst different colours of plastic mulch (sub-treatment) the highest b/c ratio was found in case of black colour plastic mulch (M_1) to the tune of 3.84 (average) followed by 3.70 in sub-treatment M_3 (red colour plastic mulch); 3.60 in sub-treatment M_2 (blue colour plastic mulch) and lowest 3.32 in sub-treatment M_4(white colour plastic mulch). The percentage increase in b/c ratio over control (without mulch) treatment was 17.79, 10.43, 13.50 and 1.84% in sub-treatment M_1, M_2, M_3, M_4 and M_5, respectively.

Table 16 Composite effect of drip irrigation and mulch on benefit-cost ratio under different treatments.

Sub-treatment (Mulch)	Main treatment (irrigation)				
	T_1	T_2	T_3	Sub-treatment mean	Percentage increase over control
M_1	3.74	4.08	3.70	3.84	17.79
M_2	3.58	3.87	3.36	3.60	10.43
M_3	3.64	3.96	3.50	3.70	13.50
M_4	3.31	3.50	3.15	3.32	1.84
M_5(control)	3.26	3.40	3.11	3.26	-
Main treatment mean	3.51	3.76	3.36	-	

Conclusions

The study investigated the combined impact of drip irrigation and different colors of plastic mulch on banana crop growth and yield. It revealed that drip irrigation, especially with 80% of the water volume (T2), significantly improved vegetative growth, yield, and cost-effectiveness. Among the plastic mulch colors, black mulch proved most effective in enhancing soil and plant conditions, growth, and yield parameters, followed by red and blue mulches. Conversely, white plastic mulch yielded inferior results compared to the other colors. Black plastic mulch excelled in conserving water in the soil and raising soil temperature due to its superior solar radiation absorption. White plastic mulch, on the other hand, exhibited the highest transmission of solar radiation. Interestingly, white plastic mulch also promoted the deepest vertical rooting depth. The study found that treatment T2, with 80% water volume through drip, resulted in the highest banana crop yield, while treatment T3, with 60% water volume, produced the lowest yield.

Additionally, black plastic mulch demonstrated the highest water use efficiency and benefit-cost ratio among the different mulch colors. These findings underscore the significant impact of both drip irrigation and plastic mulch color on banana crop growth and yield, highlighting the potential benefits of adopting these practices in banana cultivation.

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