Original Research Article

Assessing the Productivity and Economic Sustainability of Banana Cultivation with Diverse Colored Plastic Mulches in Western Maharashtra Region

Notes: The words with red color words are meaning the words after correction.

Abstract

Aims: In today's perspectives, it is essential to study the crops like banana, which is a heavy feeder of the nutrients with respect to color plastic mulches and irrigation scheduling. In this study, the effect of various colored plastic mulches on the growth and quality parameters of banana crop along with its economic feasibility was assessed.

Study design: This experiment followed a randomized block design with nine treatments (T_1 to T_9), each with three replications.

Place and duration of study: This study was carried out at Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra during 14th December 2021 to 15th December 2022.

Methodology: Different color plastic mulches in combination with varying irrigation schedule were evaluated for growth and yield of banana crop. Various growth parameters of banana crop, yield, micrometeorological parameters, water use efficiency and cost economics of banana production were evaluated for different treatments.

Results: The highest banana yield recorded was 84.45 tons per hectare, and this was achieved using silver-black plastic mulch in conjunction with daily drip irrigation set at 48% of the Pan Evaporation (Ep) rate, referred to as treatment T_3. Treatment T_3 led to 37.24% increase in banana yield compared to surface irrigation with 1.00 Irrigation Water to Cumulative Pan Evaporation (IW/CPE) ratio (treatment T_9). The seasonal water requirement for banana cultivation with treatment T_3 amounted to 1015 mm, resulting in an impressive water use efficiency of 83.18 kg ha^{-1} mm^{-1}. NDVI values exhibited a range from 0.3895 during the initial growth stage of the banana to 0.8918 at the peak growth stage.

Conclusion: From an economic perspective, the utilization of silver-black plastic mulch emerged as the most favorable choice among all treatments, boasting the highest benefit to cost ratio of 2.34 and yielding the maximum net income of ₹ 3,86,286 per hectare.

Keywords: Banana, Color Plastic Mulch, Economic Feasibility, Western Maharashtra

1. Introduction

Banana (*Musa Paradisiaca* L.) is the fourth most important global food crop, trailing only rice, wheat, and maize **(Ahmed et al., 2011).** This energy-rich fruit is a valuable source of vitamins A, C, and B6, along with essential minerals **(Hedge and Srinivas, 1990).** Approximately 90% of the world's banana and plantain production serves local consumption in producing countries, with only 10% earmarked for export **(Dadzie and Orchard, 1997).** Many developing nations rely on banana cultivation as a primary agricultural activity, particularly targeting export markets. Meeting stringent quality standards for fresh banana exports is a key challenge **(Bakhiet, 2006).** Successful banana cultivation hinges on a professional approach and efficient resource management.

Banana, being a tropical crop, thrives with a consistent water supply and insufficient moisture negatively impacts growth and yield **(Pramanik et al., 2014).** The Grandnaine banana variety stands out with a slightly shorter growth cycle, heavier bunches, and longer fingers, resulting in a higher annual yield of extra-large fruit **(Mahmoud and Fatima, 2013).** Globally, Grandnaine is the preferred Cavendish dessert banana in both tropical and subtropical regions **(Ahmed et al., 2010).** In the present context, it is imperative to research crops like banana, which have high nutrient requirements, to identify the most efficient fertilizer application methods to maximize fertilizer use efficiency and net profit.

Irrigated agriculture covers 20% of global agricultural land but contributes 39% of the world's food supply **(Paul et al., 2013).** Drip irrigation is highly efficient, eliminating water channels, expanding irrigation coverage and reducing input costs **(Lewis, 2001).** Mulching, a soil-covering practice, enhances plant growth and crop production **(Csizinszky et al., 1995).** Plastic mulches, used for over 60 years, significantly modify soil temperature and boost marketable yields by up to 65% compared to bare soil **(Singh et al., 2009).** Plastic mulches conserve moisture, control weeds, and prevent soil erosion and direct moisture evaporation. Various advantages of mulching include improved soil moisture, optimal temperature maintenance, reduced erosion and compaction, heavy metal binding, enhanced soil nutrition, better plant growth, seed germination, and reduced pesticide use **(Decoteau et al., 1990).**

Plastic mulches come in different colors, each with unique benefits. Black plastic warms soil early in the season and controls weeds. White plastic cools soil, making it suitable for summer crop establishment **(Kumar and Dey, 2011).** Reflective silver mulches also reduce soil temperature **(Singh et al., 2009).** Different-colored mulches can attract or repel insects, making them useful for "catch crops" **(Mutetwa and Mtaita, 2014).**Thus, there is need to adopt specific colour mulch for particular crop.This study evaluates the suitability of different-colored plastic mulches for banana crops in terms of yield and cost-benefit ratio.

2. Materials and Methods

2.1 Study area

This study was carried out at the research cum demonstration farm of Precision Farming Development Centre (PFDC), Department of Irrigation and Drainage Engineering, Dr. Annasaheb Shinde College of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra during 14th December 2021 to 15th December 2022. The location is at 740°38'00" E longitude and 19°20'00" N latitude, situated at an elevation of 557 meters above sea level. This area falls within the semi-arid and sub-tropical zone, receiving an average annual rainfall of 566.48 mm, with a mean pan evaporation ranging from 3.7 to 12.4 mm day^{-1}. The predominant soil type in this area is clay.

2.2 Experimentdetails

The soil of experimental plot consisted of 18.76% sand, 23.16% silt, and 57.09% clay, with a pH of 8.72 and electrical conductivity of 0.99 dS m^{-1}. Field capacity and permanent wilting point were 40.09% and 17.37%, respectively. Soil deficiencies included 81.53 kg ha^{-1} of available N and 7.40 kg ha^{-1} of P, while K was sufficient at 302.40 kg ha^{-1}. The water class was C_3S_1 (medium salinity, low hazard alkalization) with EC 0.62 dS m^{-1} and pH 7.9. Six plastic mulches (yellow-black, blue-black, silver-black, white-black, red-black, and pervious) measuring 30 microns thick, 7.5 m long, and 2.1 m wide were used in a 43.5 m x 27 m field. The experiment followed a randomized block design with nine treatments (T_1 to T_9), each with three replications. Each plot was 7 m × 3.5 m, and a 1.5 m buffer strip prevented lateral water movement between beds.

2.3 Irrigation scheduling

Treatment T_1 to T_7were consisted of different color mulches and daily drip irrigation was given with 48% of pan evaporation. Pan evaporation data obtained from Auto Weather Station of MPKV, Rahuri was used for irrigation scheduling of treatments T_1 to T_7. Treatment T_8 was given daily drip irrigation with 100% of crop evapotranspiration based on crop coefficient (Kc) values.Treatment T_9 was given surface irrigation with 1.00 IW/CPE ratio.160:32:160 g N:P:K fertilizer dose was applied monthly to banana crop. The developed of crop coefficient curve for obtaining daily crop coefficient values is shown in **Fig. 1.**

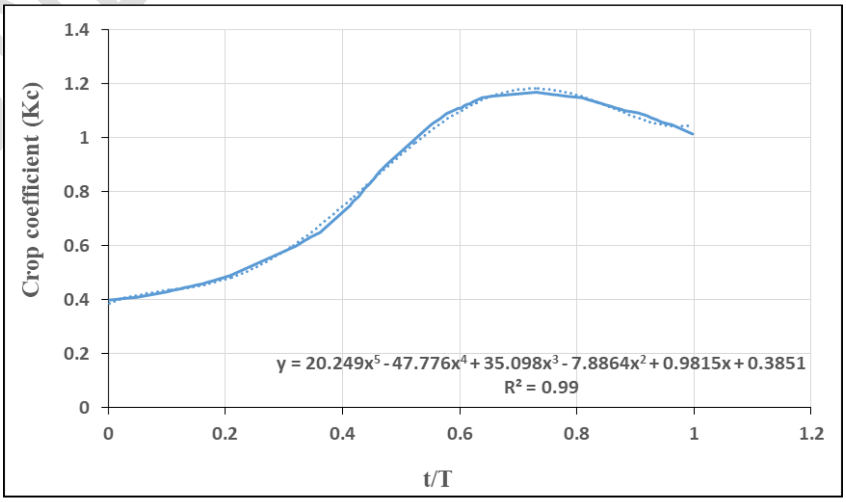

Fig. 1 Crop coefficient curve showing best fit polynomial equation for obtaining daily crop coefficient values

$$Kc_t = 20.249[t/T]^5 - 47.776[t/T]^4 + 35.098[t/T]^3 - 7.8864[t/T]^2 + 0.9815[t/T] + 0.3851 \quad .....(2.1)$$

Where,

Kc_t - Crop Coefficient on t^{th} day

t - Day considered

T - Total period of crop growth from sowing to harvesting, days

This best fit polynomial equation (2.1) was obtained by using Kc values and crop period of initial, mid and late/end season for banana crop from FAO Irrigation and Drainage Paper No. 24 and 56**(Doorenbos and Pruitt, 1977; Allen et al., 1998).**A plot of Kc values against crop period for initial, mid and late/end season given the above best fit polynomial equation which was used for estimation of daily crop coefficient (Kc) values. The reference evapotranspiration (ET_0) multiplied by daily crop coefficient (Kc) gives the value of crop evapotranspiration (ETc) which was used for irrigation scheduling.

In case of surface irrigation 1.00 IW/CPE ratio was used to schedule the irrigation, as per the previous studies carried out at this university. For first three months after planting, 4 cm depth of water was applied at 40 mm CPE. Afterwards 5 cm depth of water was applied at 50 mm CPE till end. As furrow available within paired row planting with surface irrigation was capable of accommodating only 4.1 cm of irrigation depth, only that much of water was applied as against 5 cm depth**(Berad et al., 1998).**

2.4 Biometric and yield observations

Growth observations were recorded for 4 sample plants selected randomly from each replicated treatment. Plant height, stem girth, number of functional leaves, days for flowering, total crop duration, yield per plant and yield (t ha^{-1})were noted at the interval of

60, 120 180, 240, 300 days after transplanting (DAT). Quality parameters such as Total Soluble Solids (TSS) and acidity of fruit were also noted.

2.5 Micro meteorological observations

Photo synthetically active radiation (PAR) (µmol m^{-2} s^{-1})

The photo syntheticallyactive radiation (PAR) is quantum of energy utilized by plants for photosynthesis and is an integrated measurement over spectral range (wavelengths) of 400 to 700 nm.The photo synthetically active radiation (PAR) measured on a clear sky between 11.00 am to 1.00 pm with the LI 191SA Line Quantum Sensor (Li-cor make) at an interval of 15 days.The absorbed photo synthetically active radiation (APAR) calculated by using following formula given by **Gallo and Daughtry (1986).**

$$APAR = [(I_o + R_s) - (T_c + R_c)] \quad \text{….. (2.2)}$$

APAR = [(Intercepted + Reflected from soil) – (Transmitted + Reflected from canopy)]

Soil temperature

Soil temperature was measured by soil thermometer installed in the soil at 10 cm depth. The soil temperature was measured under yellow black plastic mulch, blue black plastic mulch, silver black plastic mulch, white black plastic mulch, red black plastic mulch, pervious mulch and on control treatment (no mulch) daily at the time of 8:30 am and 2:30 pm.

Photosynthesis rate

Plastic mulches affect the plant light environment by altering the wavelength composition and radiation reflected from surface up to the plant canopy. The light color mulches reflect more photosynthetic light. This affected plant light environment, ultimately affected the rate of photosynthesis **(Decoteau et al., 1990).**Photosynthesis rate of banana plant leaves measured on a clear sky between 11.00 am to 1.00 pm with the LI 6400 XT Portable

Photosynthesis System fortnightly. The LI 6400 XT Portable Photosynthesis System directly gave the reading of photosynthesis rate in the unit µmol CO_2 m^{-2} s^{-1} under various treatments.

Normalized Difference Vegetation index (NDVI)

HR 1024 spectroradiometer was used for recording spectral signature of banana crop. The data recorded at the time of field measurements was stored in the form of ASCII file in PDA provided with instrument.The overlay matching of data was performed and data was exported to excel sheet. NDVI was calculated using the following formula.

$$\text{NDVI} = \frac{\text{Near Infrared Band} - \text{Red Band}}{\text{Near Infrared Band} + \text{Red Band}}$$

….. (2.3)

Near infrared band ranges from 700 nm to 1300 nm and red band ranges from 620 nm to 699 nm. By averaging the values of reflectance observed, the NDVI value of the week for particular treatment was calculated.

2.6 Water Use Efficiency (WUE)

The field water use efficiency of different treatments was estimated from the banana yield data and the total depth of water applied, using following equation.

$$Water\ Use\ Efficiency = \frac{Y}{WR}$$

.....(2.4)

Where,

Y = Crop yield, kg ha^{-1}

WR = Total depth of water applied in the field, mm

2.7 Cost economics of banana production

The cost of production was worked out for each treatment. The cost includes paid out cost on hired human labor, plants, fertilizers, water charges, interest on working capital, and interest on fixed capital, depreciation, repair and maintenance for drip irrigation system.

Depreciation

It was calculated by following formula:

$$\text{Depreciation} = \left[\frac{\frac{OC - JV}{L}}{\text{No. of season}}\right]$$

…..(2.5)

Where,

OC = Original cost, ₹

JV = Junk value (10% of OC), ₹

L = Life span, years

Gross monetary returnsand net income

The gross monetary returns per hectare were worked out by considering the fruit yield from different treatments and the prevailing market price of banana. The net income was worked out by subtracting the cost of production from the gross monetary returns in each treatment.

Benefit-cost ratio

The benefit-cost ratio was worked out by dividing the cost of production to the gross returns in each treatment under study. The statistical analysis of data was carried out by statistical method known as "Analysis of variance" (ANOVA) appropriate for the "Random block design". The standard error (S.E.) for each factor and their interaction was worked out. Wherever the results vary significantly, critical difference (C.D.) at 5%level of significance was worked out.

3. Results and Discussion

3.1 Gross depth of water applied to banana crop

In present study drip and surface irrigation method were taken to compare yield of banana in the respective treatments. The gross depth of irrigation water applied is shown in **Table 1.**

Table 1. Total depth of irrigation applied in various treatments for banana crop

Treatment	Gross depth of water applied, mm
T_1{Yellow-black plastic mulch (YBPM), 48% Ep}	1114
T_2 {Blue-black plastic mulch (BBPM), 48% Ep}	1130
T_3 {Silver-black plastic mulch (SBPM), 48% Ep}	1015
T_4 {White-black plastic mulch (WBPM), 48% Ep}	1087
T_5 {Red-black plastic mulch (RBPM), 48% Ep}	1081
T_6 {Pervious plastic mulch (PPM), 48% Ep}	1060
T_7 {No mulch (NM), 48% Ep}	1142
T_8 {No mulch (NM), 100% ETc}	1323
T_9 {Surface irrigation (SI), 1.00 IW/CPE ratio}	2204

The maximum depth of irrigation (2204 mm) was applied for treatment T_9,followed by the treatment T_8 (1323 mm) and minimum (1015 mm) in the treatment T_3. Although the irrigation level for first seven treatments was same i.e. 48% of pan evaporation, the variation in depth of irrigation water applied was due to different total duration of plants under various treatments. The plants under treatment T_3recorded less total duration or completed their life span earlier than those in other treatments, thus recorded less gross depth of water applied.

3.2 Growth parameters of banana

The highest plant height (266.74 cm) was recorded at harvest (320 DAT) in treatment T_3, which was at par with T_6 (252.59 cm). The minimum plant height (194.72 cm) was observed in T_9. The rate of increase in plant height was comparatively maximum in same treatments as compared to control treatments. The rate of increase in plant height reached its maximum during 90-120 DAP in treatments T_1 to T_8, but in treatment T_9 the same was observed during 120-150 DAP. This might be due to suppressed growth of plants in surface irrigated treatment in early growth period due to periodical water and air stress, but rain started after 5 months after planting the plants might have made up their suppressed growth.As in the plant height, stem girth also followed more or less same trend. The maximum stem girth (63.99 cm) was recorded in treatment T_3, followed by treatment T_6 (63.50 cm),T_1 (59.79) and T_4 (59.07 cm), respectively. The minimum stem girth (51.34 cm) was recorded in the treatment T_9. Number of functional leaves were highest (14.08) in treatment T_3,followed by treatment T_6 (13.42) and T_1 (13.33), respectively. The minimum number of leaves (10.83) were observed under treatment T_9.The rate of increase in functional leaves was maximum during the period 60-90 DAP.**Ashrafuzzaman et al. (2011)** also reported the similar results.

Table 2.Growth parameters of banana crop as affected by various treatments

Treatments	Plant height, cm	Stem girth, cm	No. of functional leaves per plant	Mean days to flower	Total duration, days
T_1 (YBPM, 48% Ep)	243.78	59.79	13.33	230.33	347.00
T_2 (BBPM, 48% Ep)	217.54	56.93	12.08	254.67	367.67
T_3 (SBPM, 48% Ep)	266.74	63.99	14.08	220.33	323.33
T_4 (WBPM, 48% Ep)	237.19	59.07	12.92	238.67	352.67
T_5 (RBPM, 48% Ep)	236.32	58.77	12.50	248.67	362.00
T_6 (PPM, 48% Ep)	252.59	63.50	13.42	225.67	339.33
T_7 (NM, 48% Ep)	202.70	52.89	11.50	263.67	373.67
T_8 (NM, 100% ETc)	203.93	54.12	12.00	259.67	369.67
T_9 (SI, 1 IW/CPE ratio)	194.72	51.34	10.83	286.67	377.67
S.E.m±	7.00	1.75	1.67	6.73	9.35
C.D. at 5%	20.99	5.25	7.72	20.17	28.03

The treatment T_3 required minimum number of days (220.33 days) to flower. The earliness in the flowering of plants in treatment T_3 over other treatments could be attributed to better microclimate above and below the mulch with less competition effect resulting in shortening of its vegetative phase and making it to put out earlier flower. Followed by treatment T_3, T_6 (225.67 days)and T_1 (230.33 days), respectively showed earliness to flower. The treatments T_1 to T_8 exhibited their earliness over T_9 in this regard.Treatment T_3 took minimum number of days (323.33 days) to complete its life cycle which was at par with T_6 (339.33 days) and T_1 (347 days), respectively. The treatments T_1 to T_8 observed to be superior over T_9 in this regard also, as they taken less total duration to complete their life cycle than T_9. The plants in the treatment T_9 taken highest 377.67 days to complete their life cycle among all treatments.

The treatment T_3 registered maximum bunch weight of 25.86 kg, which was at par with T_6 (24.75 kg). This may be due to reason that, the mulch changes microclimate beneath the crop canopy by altering the wavelength composition reflected from mulch surface, which may have attributed to improved photosynthesis and improved yield as well. The treatment T_9 recorded lowest bunch weight of 16.23 kg.The data revealed that, the treatment T_3 registered maximum yield (84.45 t ha^{-1}) which was at par with treatment T_6 (81.67 t ha^{-1}). The treatment T_9 recorded lowest yield of 53.00 t ha^{-1}. The treatments T_1 to T_8 was observed to be superior over treatment T_9 in this regard.There was no significant difference in TSS and acidity of fruit pulp of banana under different treatments. The TSS of banana was observed to be about 18.5 and acidity 0.25.

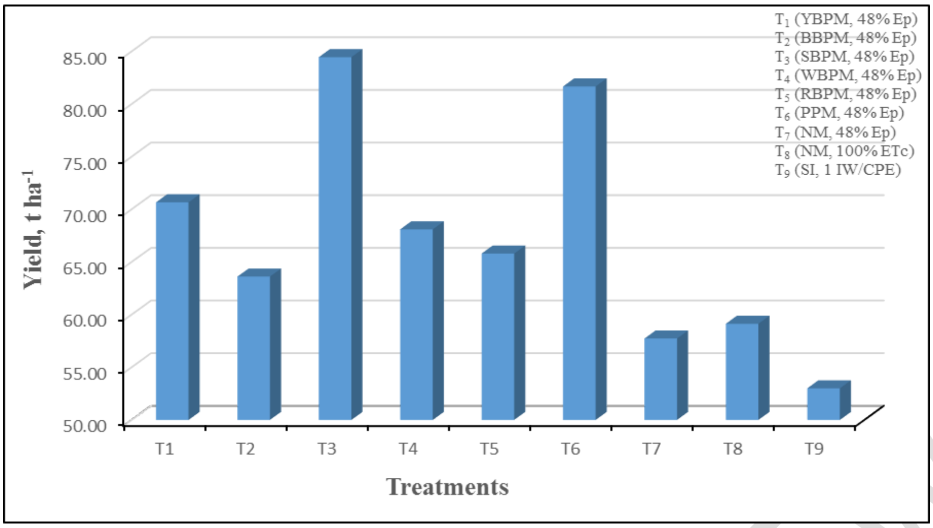

Fig. 2. Yield (t ha^{-1}) of banana as influenced by various treatments

3.3 Micro Meteorological Observations

Photo synthetically Active Radiations (PAR)

The highest photo synthetically active radiation (µmol m^{-2} s^{-1}) was observed in the treatment T_3 at 60, 120, 180, 240, 300 DAT and at 1st harvest (318 DAT), that was 307.67, 573.25, 882.50, 1060.78, 975.55 and 900.27 µmol m^{-2} s^{-1}, respectively. The highest PAR (307.67 µmol m^{-2} s^{-1}) at 60 DAT was observed in treatment T_3 which was followed by treatment T_4 (295.62 µmol m^{-2} s^{-1}) and T_1 (295.09 µmol m^{-2} s^{-1}). Similar trend was observed at 120, 180, 240, 300 DAT and at harvesting stage also. It was observed that, the number of at par treatments to the treatment T_3 increased with increase in days after transplanting (DAT). This may be due to reason that, the weather affected the color of the mulch with time, which reduced the difference in reflected radiations from various colormulches. It was also observed that, light color mulches reflected more photo synthetically active radiation than dark color mulches. These results were matching with results obtained by **Decoteau et al., 1990; Daughtry et al., 1992.**

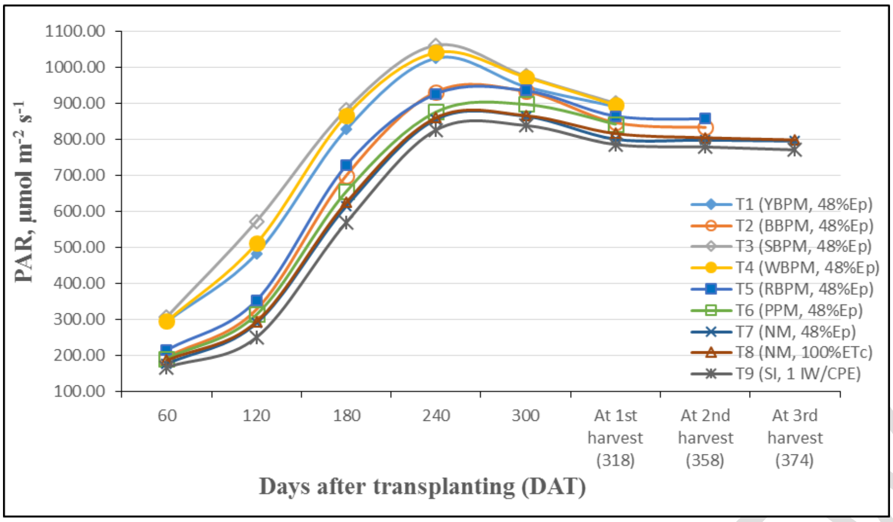

Fig. 3.Photo synthetically active radiation (µmol m^{-2} s^{-1}) for banana crop

Photosynthesis rate (µmol CO_2 m^{-2} s^{-1})

The highest rate of photosynthesis (µmol CO_2 m^{-2} s^{-1}) was observed in treatment T_3 at 60, 120, 180, 240, 300 days after transplanting and at 1st harvest that was 3.63, 7.95, 15.05, 19.72, 29.33 and 28.38 µmol CO_2 m^{-2} s^{-1}, respectively. The similar trend as PAR, observed in the case of photosynthesis rate. The highest rate of photosynthesis (3.63 µmol CO_2 m^{-2} s^{-1}) at 60 DAT was observed in treatment T_3, which was at par with treatment T_4 (3.47 µmol CO_2 m^{-2} s^{-1}). Similar trend was observed at 120, 180, 240, 300 DAT and at harvesting stage also. Similar to the PAR, in case of photosynthesis rate, the number of at par treatments to the treatment T_3 increased with increase in days after transplanting because the weather affected the color of the mulch with time, which reduced the difference in reflected radiations from different color mulches. In response to increased photosynthesis rate, more photosynthetic produced and to store surplus photosynthetic plant adapt itself by producing more yields.

Table 3. Photosynthesis rate (µmol CO_2 m^{-2} s^{-1}) of banana crop

Treatments	Photosynthesis rate (µmol CO_2 m^{-2} s^{-1})					
	60 DAT	120 DAT	180 DAT	240 DAT	300 DAT	At harvest

T_1 (YBPM, 48% Ep)	3.22	6.77	14.26	18.96	28.55	27.33
T_2 (BBPM, 48% Ep)	2.95	6.26	13.70	17.25	27.89	26.23
T_3 (SBPM, 48% Ep)	3.63	7.95	15.05	19.72	29.33	28.38
T_4 (WBPM, 48% Ep)	3.47	7.56	14.58	19.16	29.02	28.16
T_5 (RBPM, 48% Ep)	3.00	7.27	14.30	18.79	28.38	26.44
T_6 (PPM, 48% Ep)	3.16	6.19	12.48	17.13	25.90	24.08
T_7 (NM, 48% Ep)	2.40	5.58	12.11	16.39	25.25	23.87
T_8 (NM, 100% ETc)	2.49	5.60	12.18	16.51	25.32	23.87
T_9 (SI, 1 IW/CPE ratio)	2.07	4.96	11.34	14.55	23.38	22.99
S.E.m±	0.10	0.17	0.36	0.48	0.72	0.67
C.D. at 5%	0.31	0.51	1.07	1.43	2.14	2.02

Soil temperature

The highest monthly average daily soil temperature (30.63 ^{0}C) was observed under treatment T_5 (RBPM, 48%Ep) in the month of May, followed by treatment T_2 (30.50 ^{0}C). This may be due to reason that, the dark color mulches such as red, blue etc. absorb more of incoming solar radiations as compared to light color mulches like white, silver etc. In contrast lighter color mulches reflect more of incident solar radiation, hence temperature under light color mulches observed to be less as compared to dark color mulches. The treatment T_9 (SI, 1.00 IW/CPE ratio) recorded greater soil temperature as compared to treatment T_7 (NM, 48%Ep) and treatment T_8 (NM, 100%ETc), because of more evaporation losses of applied water. The minimum monthly average daily soil temperature (27.63 ^{0}C) in the month of May, was observed in treatment T_4 (WBPM, 48%Ep), which may be due to greater reflectivity of white color mulch. Similar to monthly average daily soil temperature, the highest seasonal average daily soil temperature (26.38 ^{0}C) was observed in treatment T_5, which was followed by treatment T_2 (26.25 ^{0}C). The minimum seasonal average daily soil temperature (24.43 ^{0}C) was observed in treatment T_4 (WBPM, 48%Ep).

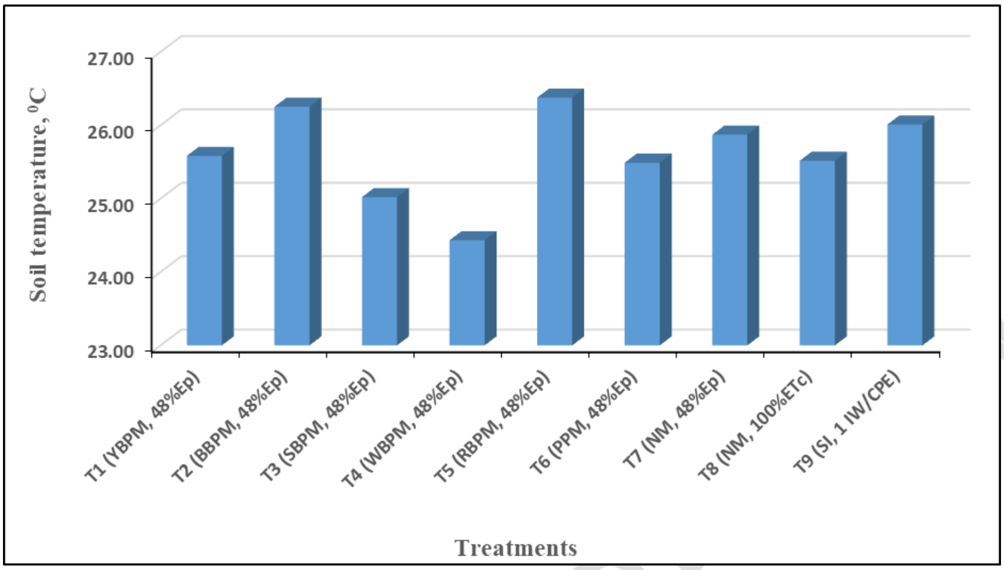

Fig. 4 Seasonal average daily soil temperature under various treatments

NDVI value over growth period of banana

Greater the amount of healthy green vegetation in the field of view of the sensor, the greater the NDVI value. This relationship is deduced from the physiological fact that chlorophyll a and b in the palisade layer of healthy green leaves absorbs most of the incident red radiant flux while the spongy mesophyll leaf layer reflects much of the near infrared radiant flux. This fact is also seen in the NDVI values recorded. In the vegetative and flowering stage, there is more amount of healthy vegetation present.The maximum NDVI value (0.8943) recorded in treatment T_6 at 300 DAT, followed by treatment T_3 (0.8918) and T_4 (0.8765), respectively. The photo synthetically active radiation for these treatments was maximum as compared to other treatments; thus due to denser green canopy, NDVI values recorded for these treatments were maximum. The minimum NDVI value (0.8104) at 300 DAT was recorded in treatment T_9.The NDVI values in all treatments increased continuously during peak growth period of banana crop and decreased slightly in the harvesting stage of the crop.

This may be due to reason that, the banana crop remained green or healthy in the harvesting stage also.

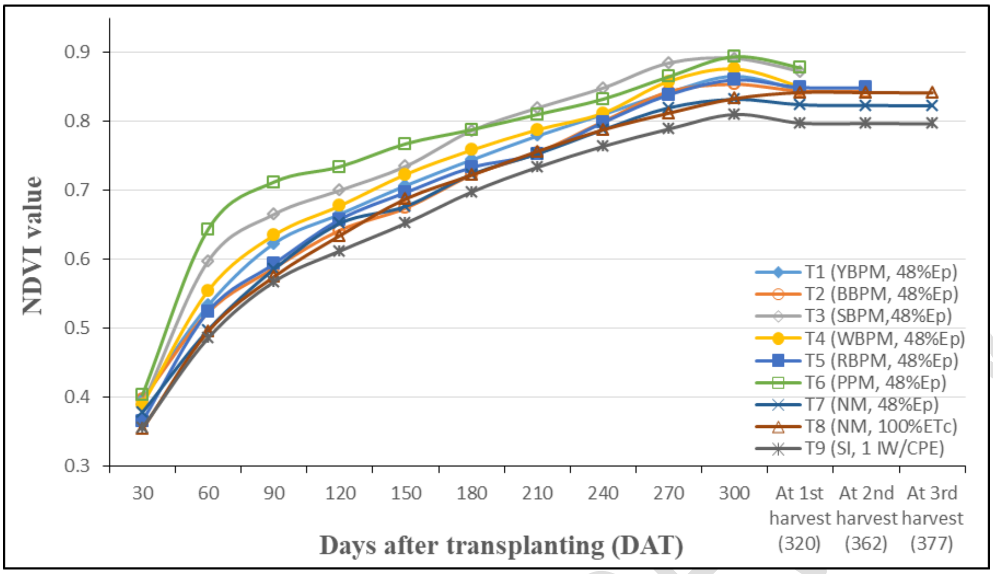

Fig. 5. NDVI values of banana crop as influenced by various treatments

Water use efficiency (WUE)

The highest water use efficiency (81.83 kg ha^{-1} mm^{-1}) obtained in treatment T_3,followed by treatment T_6 (75.90 kg ha^{-1} mm^{-1}) and minimum (26.03 kg ha^{-1} mm^{-1}) in T_9.The highest water use efficiency in treatment T_3 was due to maximum yield and comparatively lower seasonal water requirement. The water use efficiency was lower in surface irrigation amongst all other treatments because of lowest yield and highest seasonal water requirement.

Table 4.Water use efficiency of banana under various treatments

Treatments	Yield, kg ha^{-1}	Seasonal water requirement, mm	Water use efficiency, kg ha^{-1} mm^{-1}
T_1 (YBPM with 48% Ep)	70667	1113.64	63.46
T_2 (BBPM with 48% Ep)	63613	1130.40	56.27
T_3 (SBPM with 48% Ep)	84450	1015.24	83.18
T_4 (WBPM with 48% Ep)	68100	1087.10	62.64

T_5 (RBPM with 48% Ep)	65800	1080.57	60.89
T_6 (PPM with 48% Ep)	81667	1059.50	77.08
T_7 (NM with 48% Ep)	57733	1141.94	50.56
T_8 (NM with 100% ETc)	59129	1323.31	44.68
T_9 (SI, 1.00 IW/CPE ratio)	53000	2204.40	24.04

3.4 Cost Economics of banana production

The cost of cultivation per hectare was maximum (₹ 3,93,487/-) in treatment T_6. The lowest cost of cultivation (₹ 1,36,799/-) was found in treatment T_9 due to surface irrigation (no drip irrigation components) and no plastic mulch used. Amongst all treatments, the maximum of gross monetary returns per hectare (₹ 6,75,463/-) were observed in treatment T_3 due to highest banana yield. It was followed by T_6 (₹ 6,52,000 /-). The minimum gross monetary return per hectare (₹ 1,85,524/-) was experienced with treatment T_9, as it produced lowest yield (53.00 t ha^{-1}). The maximum net income per hectare (₹ 3,86,286 /-) was observed in treatment T_3, followed by treatment T_6 (₹ 2,58,513 /-), as there was highest yield. The lowest net income per hectare (₹ 48,725 /-) was observed in treatment T_9,which was due to lowest yield.The maximum B: C ratio (2.34) was observed in treatment T_3, followed by treatment T_1 (1.82). The minimum B: C ratio (1.36) was recorded in treatment T_9.

Table 5.Cost of cultivation, gross income, net income and benefit cost ratio

Treatment	Total cost of cultivation (₹ ha^{-1})	Total income (₹ ha^{-1})	Net income (₹ ha^{-1})	Benefit cost ratio
T_1 (YBPM with 48% Ep)	289177	527706	238528	1.82
T_2 (BBPM with 48% Ep)	289177	475515	186338	1.64
T_3 (SBPM with 48% Ep)	289177	675463	386286	2.34

T_4 (WBPM with 48% Ep)	289177	510600	221423	1.77
T_5 (RBPM with 48% Ep)	289177	493418	204240	1.71
T_6 (PPM with 48% Ep)	393487	652000	258513	1.66
T_7 (NM with 48% Ep)	242801	375505	132704	1.55
T_8 (NM with 100% ETc)	242801	390780	147979	1.61
T_9 (SI, 1.00 IW/CPE ratio)	136799	185524	48725	1.36

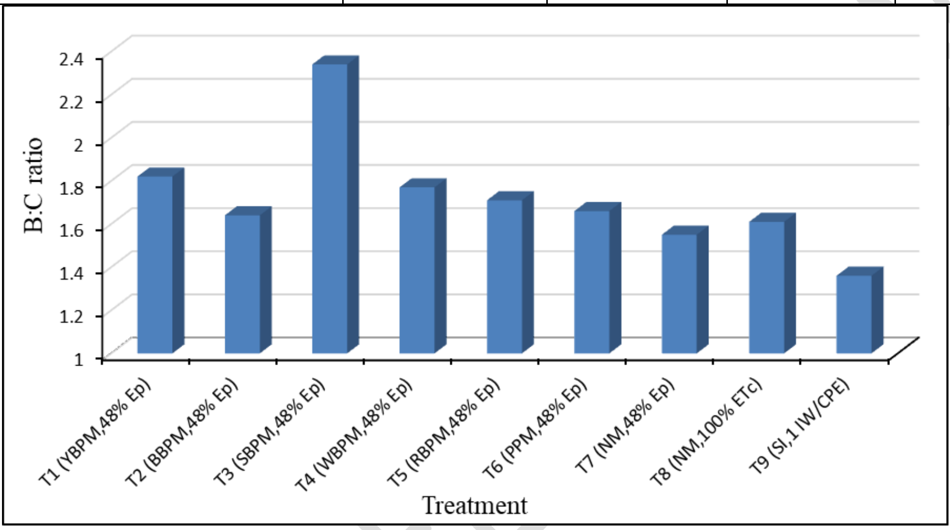

Fig. 6. Benefit cost ratio of banana production under various treatments

The highest B: C ratio (2.34) recorded in treatment T_3, followed by treatment T_1 (1.82). This was due to highest yield obtained in these treatments and comparatively low cost of cultivation. Although the yield in treatment T_6 was at par with that of treatment T_3, the B: C ratio in treatment T_6 was low as compared to that of treatment T_3. This was due to reason that, the cost of cultivation in treatment T_6 was higher due to higher cost of pervious plastic mulch as compared to other mulches. The lowest B: C ratio (1.36) was observed in treatment T_9. This was due to lowest yield obtained in treatment T_9.

3.5 Conclusion

In this study, the effect of various color plastic mulches on growth and quality parameters of banana crop was evaluated. The maximum yield of banana (84.45 t ha^{-1}) was due to silver-black plastic mulch with daily drip irrigation at 48% Ep (treatment T_3), which was at par with that of pervious plastic mulch with irrigation at 48% Ep (treatment T_6).The adoption of silver- black plastic mulch with daily drip irrigation at 48% Ep (treatment T_3) has resulted in 37.24% increase in yield of banana over surface irrigation with 1.00 IW/CPE ratio (treatment T_9).The seasonal water requirement of banana crop cultivated with silver- black plastic mulch at daily drip irrigation with 48% Ep (treatment T_3) was 1015 mm with water use efficiency of 83.18 kg ha^{-1} mm^{-1}.The highest rate of photosynthesis and PAR was observed in treatment T_3.The NDVI values of banana crop in treatment T_3 were in the range of 0.3895 to 0.8918 during the growth period of 323 days. The NDVI value of 0.3895 in initial stage of banana increased to 0.8918 in peak growth stage and again it slightly decreased to 0.8727 in harvesting stage of banana. From the economic point of view, the adoption of silver-black plastic mulch was found to be the best amongst all other treatments, having maximum B: C ratio of 2.34 and maximum net income of ₹ 3,86,286 /- per hectare.

4. References

Ahmed AB, Ali MAand IhsanMI. Effect of drip irrigation on performance of banana under different irrigation regimes in Gezira. African Crop Science Conference Proceedings. 2011;10: 425- 431.

Ahmed BA, Mohammed AAand. IhsanMI. Effect of drip irrigation system and fertigation on growth, yield and quality of banana CV. Grand Nain (Musa AAA). RUFORUM, Uganda.2010; 20- 24.

Allen RG, Pereira LS, Raes D and Smith M. Crop Evapotranspiration-Guidelines for Computing Crop Water Requirements. FAO Irrigation and Drainage Paper 56, FAO, Rome. 1998; 300(9): D05109.

Ashrafuzzaman M, HalimMA,Ismail MR, ShahidullahSMand HossainMA.Effect of Plastic Mulch on Growth and Yield of Chilli (*Capsicum Annuum*L.). Brazilian Archives of Biology and Technology.2011; 54: 321-330.

Berad SM, Shinde SH and Dahiwalkar SD. Effects of drip fertigation and paired planting on productivity and economics of banana. Journal-Maharashtra Agricultural Universities.1998; 23(3): 288-290.

Bakhiet SB. Evaluation of introduced Cavendish banana (Musa AAA) clones grown at Kassala, Sudan. Unpublished Ph.D. (Agri.) Thesis, University of Gezira, Wad Medani, Sudan.2006.

Csizinszky AA, Schuster DJand Kring JB. Colour mulches influence yield and insect pest population in tomatoes. HortScience. 1995; 120(5): 778-784.

Dadzie BK and OrchardJE.Routine post-harvest screening of banana/Plantain Hybrids: Criteria and Methods, Technical Guidelines 2. International Plant Genetic Resources Institute, Rome, Italy.1997.

Daughtry CS, GalloKP, GowardSN, Prince SDand Kustas WP. Spectral estimates of absorbed radiation and phytomass production in corn and soybean canopies. Remote Sensing and Environment.1992; 39: 141-152.

Decoteau DR, KasperbauerMJand HuntPG. Bell pepper plant development over mulches of diverse colours. HortScience.1990; 25(4): 460-462.

Doorenbos J. and Pruitt WO. FAO Irrigation and Drainage Paper 24.Crop Water Requirements, FAO, Roma.156.1977.

Gallo KP and Daughtry CT. Techniques for measuring intercepted and absorbed Photosynthetically Active Radiation in Corn Canopies. Agronomy Journal.1986; 78(4): 752-756.

Hedge DM and SrinivasK. Growth, productivity and water use of banana under drip and basin irrigation in relation to evaporation replenishment.Indian Journal of Agronomy.1990; 35(1-2): 106-112.

Kumar S. and DeyP.Effects of different mulches and irrigation methods on root growth, nutrient uptake, water-use efficiency and yield of strawberry. Journal of Horticultural Sciences.2011; 127: 318-324.

Lewis B. Drip irrigation for row crops. Department of Agriculture Cooperating, New Mexico State University (NMSU), Atlanta.2001.

Mahmoud HH and FatimaYG.Effect of different levels of planting distances, irrigation and fertigation on growth characters of main and ratoon banana crop cv. Grandnaine. Global Journal of Plant Ecophysiology. 2013; 3(2): 104-109.

Mutetwa M and MtaitaT. Effect of different mulch colours on cucumber production. J. Glob. Innov. *Agric. Soc. Sci.,* 2014; 2(4): 178-184.

Paul JC, MishraJN, Pradhan PLand PanigrahiB. Effect of drip and surface irrigation on yield, water- use-efficiency and economics of capsicum (capsicum annum L.) grown under mulch and non-mulch conditions in eastern coastal India. European Journal of Sustainable Development.2013; 2(1): 99-108.

Pramanik S, TripathiSK, Ray Rand BanerjeeH. Economic evaluation of drip-fertigation system in banana cv. Martaman (AAB, Silk) cultivation in new alluvium zone of West Bengal.Agricultural Economics Research Review.2014; 27(1): 103-109.

Rajablariani H, RafeziR, HassankhanF. Using coloured plastic mulches in tomato (*Lycopersiconesculentum* L.) production. IPCBEE 47.2012.

Singh R, KumarS, NangareDDand MeenaMS. Drip irrigation and black polyethylene mulch influence on growth, yield and water-use efficiency of tomato. African Journal of Agricultural Research. 2009; 4(12): 1427-1430.