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Effect of Balanced Fertilization and Mulching on Growth, Yield and Economics of Chilli (*Capsicum annuum* L.) in Odisha, India

Mukhi S.K. [a*], Mishra P [b] and Bar N [a]

[a] Krishi Vigyan Kendra, Kandhamal, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India.
[b] Directorate of Extension Education, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A front-line demonstration was carried out at different farmers' field of Kandhamal district of Odisha to determine the effect of balanced fertilization and mulching on growth, yield and economics of chilli during 2022-23. The experiment was conducted under the international collaborative project on Resilience, Krishi Vigyan Kendra, Kandhamal, OUAT, Bhubaneswar. The demonstration was conducted at ten farmers' field with three treatments *viz.,* T_1 : Farmer's Practice (FYM @ 2 t ha^{-1} & $N:P_2O_5:K_2O$::50:30:30 kg ha^{-1}), without mulching, T_2 : FYM @ 10 t ha^{-1} & $N:P_2O_5:K_2O$ @100:75:75 kg ha^{-1} , foliar application of water soluble fertilizer (19-19-19) and mulching with paddy straw @ 6 t ha^{-1} and T_3: FYM @ 10 t ha^{-1} & $N:P_2O_5:K_2O$ @ 100:75:75 kg ha^{-1} , foliar application of water soluble

**Corresponding author: Email: sujitbbsr1soil@yahoo.co.in;*

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fertilizer (19-19-19) and double coated (black on silver) polythene mulching. The results revealed that significantly higher growth parameters viz., plant height (89.6 cm), number of primary branches per plant (10.4) and plant spread (69.4 cm); yield attributes viz., number of fruits per plant (142.3), fruit length (6.41cm), fresh fruit weight (1.80 g), fruit dry weight (0.69 g), fruit girth (2.73 cm) and fresh fruit yield (178.3 q ha^{-1}) were observed with the treatment T_3 (FYM 10 t ha^{-1},100% RDF, foliar application of water soluble fertilizer and polythene mulching) followed by T_2 (FYM 10 t ha^{-1}, 100% RDF, foliar application of water soluble fertilizer with paddy straw mulching @ 6 t ha^{-1}). The highest number of weeds including grasses and broad leaf weeds (342.6 number of weeds m^{-2}) was recorded in T_1 (Farmer's practice without mulching) plot followed by T_2 (67.5 number of weeds m^{-2}) and the lowest was in T_3 (10.8 number of weeds m^{-2}) indicating black polythene mulching was more effective than paddy straw mulching in suppressing weed growth. The treatments, received FYM 10 t ha^{-1},100% RDF, foliar spray with water soluble fertilizer and polythene mulching (T_3) resulted in higher gross return of Rs. 4,45,750 ha^{-1}, net return of Rs. 3,47,050 ha^{-1} and benefit: cost ratio of 4.5 as compared to T_2 and T_1. Hence, application of FYM @ 10 t ha^{-1}, N:P_2O_5:K_2O @ 100:75:75 kg ha^{-1}, foliar application of water-soluble fertilizer and double coated (black on silver) polythene mulching enhanced the growth parameters, yield attributes, economic parameters and yield of chilli.

Keywords: Chilli; mulching; balanced fertilization; economics; water soluble fertilizer; weed population; yield.

1. INTRODUCTION

"Chilli (*Capsicum annuum* L.) is an important spice essentially used in every Indian cuisine for its pungency, taste, colour and aroma. It is rich in proteins, lipids, carbohydrates, fibres, mineral salts (Ca, P, Fe) and vitamins like A, D, E, C, K, P, B2 and B12 with good medicinal properties. It can be used as medicine to treat asthma, cough and sore throats" (Kanthaswamy & Venkadeswaran, 2020). "India is a leading country in production of chilli in the world. In India, chilli is grown in almost all the states across the length and breadth of the country in an area of 0.79 million ha with a production of 1.2 million tonnes. The major chilli growing states are Andhra Pradesh, Karnataka, Maharashtra, Odisha, Tamil Nadu, Madhya Pradesh and Rajasthan. Chilli is sensitive to water stress and being a long duration and energy rich crop require proper manuring and balanced fertilizers along with sufficient moisture level for higher yield and quality produce" (Tyagi & Kulmi, 2019).

"Weed infestation is one of the limiting factors for chilli production. The presence of weeds in the crop reduces the availability of nutrient and water and thereby photosynthetic efficiency, dry matter production and its distribution to economical parts, reduces sink capacity of crop resulting in poor fruit yield" (Kumari & Jat, 2021; Rani et al., 2015)

"Mulching is referred as spreading various covering materials on the surface of soil to minimize moisture losses and weed population and to enhance crop yield" (Kader *et al.*, 2019).

"Mulching stimulates the microbial activity in soil through improvement of soil Ago-physical properties. It also minimizes the use of N fertilizer, warms the soil, improves the soil physical condition and suppresses weed growth and could account for increased yield" (Sindhu *et al.,* 2023; Tarara, 2000). "Black polythene mulch is the standard plastic mulch used in vegetable production" (Gordon *et al.,* 2010). "Plastic mulch on the surface of the soil causes change in the microclimate on its vicinity. This results in moisture conservation, reduction in frequency of irrigation, less soil compaction and higher CO_2 levels around plants" (Reddy *et al.*, 2016; Zhang et al., 2007). "It also suppresses weed-flora and reduces weed competition with crop for water and nutrients making them available in greater quantities for crop plants. Plastic mulches also reduce attack of few diseases and pests to the crops. Mulching has some role for preventing soil erosion and increasing quality of the produces" (Ansary *et al.,* 2017). The cost of using mulch is compensated by savings in weed removal and reduced irrigation. Chilli is heavy feeder of manure and long duration crop. It requires balanced dose of fertilizer for better yield and quality of produce. Therefore, the present study was carried to ascertain the effect of balanced fertilization and mulching on growth, yield and economics of chilli.

2. MATERIALS AND METHODS

The Kandhamal district is situated within the longitudes of 83^0 30'to 84^0 35' East and latitudes of 19^0 34' to 20^0 34' North and comes under North Eastern Ghat Zone of Odisha. The district

is located in central Odisha and adjoining districts are Boudh in north, Rayagada in south, Ganjam and Nayagarh in east and Kalahandi district in west. The district has a geographical area of 8021 square kilometers.

A front-line demonstration was conducted on ten farmers' field of two villages of the Kandhamal district in Randomized Block Design (RBD) under Resilience project operated at Krishi Vigyan Kendra, Kandhamal, Odisha University of Agriculture and Technology (OUAT), Bhubaneswar. The demonstration was conducted during *Kharif* 2022. The demonstration consisted of three treatments of same chilli variety (Daiya) which was replicated at ten farmers' field. The area of the demonstrated plot was 0.25 ha of each farmer. Twenty-five days old seedlings of chilli hybrid were transplanted on raised bed with a spacing of 0.60 m between row to row and 0.45 m plant to plant. The treatments of the experiment consisted of T_1 : Farmer's Practice (FYM @ 2 t ha^{-1} & $N:P_2O_5:K_2O$::50:30:30 kg ha^{-1}, without mulching), T_2 : FYM @ 10 t ha^{-1} & $N:P_2O_5:K_2O$ @100:75:75 kg ha^{-1}, foliar spray of water soluble fertilizer and mulching with paddy straw @ 6 t ha^{-1} and T_3 : FYM @ 10 t ha^{-1} & $N:P_2O_5:K_2O$ @ 100:75:75 kg ha^{-1} , foliar spray of water soluble fertilizer and double coated (black on silver) polythene mulching. The plastic mulch of 25-micron thickness and 120 cm width were used for this study. The land was prepared by ploughing, weed and crop stubbles removed. The well decomposed farmyard manure (10 tha^{-1}) and the nutrients NPK as per the treatments (RDF @100-75-75 kg $N\text{-}P_2O_5\text{-}K_2O$ ha^{-1}) were applied in the bed at the time of preparation of raised bed. Later foliar spray of water-soluble fertilizer 19:19:19 (N:P: K) was done @ 5g/L at 15 days interval starting from 30 days after planting to T_2 & T_3 plots only. Micronutrient boron as borax was sprayed twice @ 2g/L at 40 DAT (days after transplanting) and 60 DAT to all treated plots. The paddy straw mulch spread on raised bed after transplanting of chilli seedling at a spacing of 0.60 m ×0.45 m in treatment T_2. The polythene mulch was fixed tightly on the raised bed (15 cm high) with both ends and sides are buried properly in the soil up to the depth of 10 cm. The silver side of the double face of the polythene film was above the soil surface while the black side was below. After that the holes were punched with 4 inches PVC pipe and razor blade where seedlings were to be established. Irrigation channels of 0.60 m wide are laid out in between two crop rows. Manual weeding was done in T_1 while, no weeding operation was carried out in case of T_2 and T_3 plots. The observations on weed density, plant height, number of primary branches per plant, average number of fruits per plant, average fresh and dry fruit weight, fresh fruit yield and economic components were recorded. The height of the plant was measured from the base of the plant to the tip of the plant in centimeter. The spreads of plants were recorded at the time of first harvesting with the help of measuring scale. The maximum distance in between two outer leaves were measured in centimeter and averages was calculated which was considered as diameter. Weight of ten randomly selected fresh fruits from each treatment were collected and measured in an electronic balance and the mean was worked out to estimate average fresh fruit weight and was expressed in grams (g). The initial soil samples were collected before planting and the physico-chemical properties were analyzed by following the proper procedure. The initial soil properties of farmers plot were found as soil reaction of 5.02 to 5.38, electrical conductivity (EC) of soil was 0.104 to 0.217 dSm^{-1}, soil organic carbon was 0.32 to 0.45 per cent, available N was 209.3 to 257.8 Kg ha^{-1}, available Bray's P was 11.7 to 17.2 Kg ha^{-1} and available K was 198.3 to 291.6 Kg ha^{-1}. The data obtained on various attributes were statistically analyzed for critical differences using standard procedure. Cost of cultivation was calculated considering the prevailing charges of agricultural operations and local market price of inputs involved. Gross returns were obtained by converting the harvest into monetary terms at the prevailing local market rate during the course of study. The economic parameters were worked out by using the following formulae

$$\text{Gross return (Rs/ha)} = \text{Fresh fruit yield (q/ha)} \times \text{Price of the produce (Rs/q)},$$

$$\text{Net return (Rs/ha)} = \text{Gross return (Rs/ha)} - \text{Cost of cultivation (Rs/ha)} \text{ and}$$

$$\text{Benefit : cost ratio} = \frac{\text{Gross return (Rs/ha)}}{\text{Cost of cultivation (Rs/ha)}}$$

3. RESULTS AND DISCUSSIONS

3.1 Effect on Plant Growth of Chilli

Among the treatments T_3 (FYM 10 t ha^{-1},100% RDF @ 100:75:75 kg N:P_2O_5 : K_2O ha^{-1},, foliar spray with water soluble fertilizer and polythene mulching) produced the maximum plant height (89.6 cm), number of primary branches per plant (10.4) and plant spread (69.4 cm) followed by T_2 (FYM 10 t ha^{-1}, 100% RDF, foliar spray of water soluble fertilizer and paddy straw mulching @ 6 t ha^{-1}) where 77.1 cm plant height, 8.8 primary branches per plant and 65.8 cm plant spread were recorded. The minimum plant height (63.3 cm), number of primary branches per plant (7.6) and plant spread (58.2 cm) were recorded (Table 1) in the treatment T_1 (FYM @ 2 t ha^{-1} & N:P_2O_5:K_2O::50:30:30 kg ha^{-1} without mulching). The increase in plant height, number of primary branches and plant spread might be due to application of balanced nutrition to the crop enhances the better availability of sufficient quantity of nutrients.

"The applied higher dose of NPK responsible for cell division and cell elongation during the vegetative growth and are very essential for the plant growth as they directly or indirectly control the different physiological processes" (Reddy *et al.,* 2016). Further, mulching might have helped in attaining optimum growth through controlling of weeds, conserving soil moisture, reducing infiltration rate, maintaining soil temperature, stimulating soil micro-flora, reducing nutrient leaching and reducing pest infestation. Compared to the plastic mulch organic mulch was probably less effective in checking evaporation loss ultimately maintained less soil moisture content, thus found less vegetative growth of the plants. Das *et al.,* 2022 reported that "mulching enhanced the plant height and number of primary branches in chilli due to sufficient soil moisture near the root zone and minimum evaporation loss. High moisture content may lead to more nutrient and water uptake, which ultimately enhances the proper plant growth and development of plants".

Rani *et al.* (2020) observed in their study that use of mulch improved the micro climatic condition near the root zone which promoted higher plant height and primary branches of chilli. The similar findings were also observed by Ashrafuzzaman *et al.,* (2011), Prajapati *et al*., (2017); Pravakar *et al.,* (2010), Pandey *et al.* (2013) in green chilli, Gordon *et al.,* (2010) in okra and Ranjan *et al.,* (2014) & Christopher *et al.,* (1996) in tomato.

3.2 Yield and Yield Parameters

The fruit characteristics and yield recorded after every five number of pickings and the average values are expressed under different treatments are shown Table 2.

The yield attributes like Number of fruits per plant (142.3), fruit length (6.41cm), fresh fruit weight (1.80 g), fruit dry weigh (0.69), fruit girth (2.73 cm) and fresh fruit yield (178.3 q ha^{-1}) were higher in T_3 (FYM 10 t ha^{-1},100% RDF, foliar spray with water soluble fertilizer and polythene mulching) followed by T_2 where the number of fruits per plant (126.9), fruit length (5.27 cm), fresh fruit weight (1.55 g), dry fruit weight (1.55 g), fruit girth (2.62 cm) and fresh fruit yield (156.8 q ha^{-1}) were observed. The minimum number of fruits per plant (107.6), fruit length (4.38 cm), fresh fruit weight (1.30 g), fruit dry weight

Table 1. Effect of balanced fertilization and mulching on growth parameters of chilli

Treatments		Plant height (cm)	Number of primary branches $plant^{-1}$	Plant spread (cm)
T_1	Farmers Practice (FYM @ 2 t ha^{-1} & N: P_2O_5: K_2O ::50:30:30 kg ha^{-1}), without mulching	63.3	7.6	58.2
T_2	FYM @ 10 t ha^{-1} & N: P_2O_5: K_2O @100:75:75 kg $ha^{-1,}$ foliar spray of water-soluble fertilizer and mulching with paddy straw @ 6 t ha^{-1}	77.1	8.8	65.8
T_3	FYM @ 10 t ha^{-1} & N: P_2O_5: K_2O @ 100:75:75 kg $ha^{-1,}$ foliar spray of water-soluble fertilizer and double coated (black on silver) polythene mulching	89.6	10.4	69.4
SEm±		0.32	0.15	0.24
CD $_{(0.05)}$		0.96	0.46	0.72

Table 2. Effect of balanced fertilization and mulching on yield attributes and yield of chilli

Treatments		Number of fruits per plant	Fruit length (cm)	Fresh fruit weight (g)	Fruit dry weight (g)	Fruit girth (cm)	Fresh fruit yield (q ha^{-1})
T_1	Farmers Practice (FYM @ 2 t ha^{-1} & N: P_2O_5: K_2O ::50:30:30 kg ha^{-1}), without mulching	107.6	4.38	1.30	0.43	2.51	131.6
T_2	FYM @ 10 t ha^{-1} & N: P_2O_5: K_2O @100:75:75 kg $ha^{-1,}$ foliar spray of water-soluble fertilizer and mulching with paddy straw @ 6 t ha^{-1}	126.9	5.27	1.55	0.57	2.62	156.8
T_3	FYM @ 10 t ha^{-1} & N: P_2O_5: K_2O @ 100:75:75 kg $ha^{-1,}$ foliar spray of water-soluble fertilizer and double coated (black on silver) polythene mulching	142.3	6.41	1.80	0.69	2.73	178.3
S Em±		1.43	0.06	0.04	0.03	0.03	1.64
$CD_{(0.05)}$		4.26	0.17	0.08	0.05	0.10	4.88

Table 3. Effect of balanced fertilization and mulching on weed infestation of chilli

Treatments		Weed population (Number of weeds m^{-2}) at 40 DAT		
		Grass	Broad leaf weed	Total
T_1	Farmers Practice (FYM @ 2 t ha^{-1} N: P_2O_5: K_2O :: 50:30:30 kg ha^{-1}), without mulching	222.1	120.5	342.6
T_2	FYM @ 10 t ha^{-1} & N: P_2O_5: K_2O @100:75:75 kg $ha^{-1,}$ foliar spray of water-soluble fertilizer and mulching with paddy straw @ 6 t ha^{-1}	24.7	42.8	67.5
T_3	FYM @ 10 t ha^{-1} & N: P_2O_5: K_2O @ 100:75:75 kg $ha^{-1,}$ foliar spray of water-soluble fertilizer and double coated (black on silver) polythene mulching	4.7	6.1	10.8

Table 4. Effect of balanced fertilization and mulching on economics of chilli

Treatments		Cost of cultivation (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	B:C ratio
T_1	Farmers Practice (FYM @ 2 t ha^{-1} & N: P_2O_5: K_2O ::50:30:30 kg ha^{-1}), without mulching	85900	329000	243100	3.8
T_2	FYM @ 10 t ha^{-1} & N: P_2O_5: K_2O @100:75:75 kg $ha^{-1,}$ foliar spray of water-soluble fertilizer and mulching with paddy straw @ 6 t ha^{-1}	92600	392000	299400	4.2
T_3	FYM @ 10 t ha^{-1} & N: P_2O_5: K_2O @ 100:75:75 kg $ha^{-1,}$ foliar spray of water-soluble fertilizer and double coated (black on silver) polythene mulching	98700	445750	347050	4.5

(0.43 g), fruit girth (2.51 cm) and fresh fruit yield (131.6 q ha^{-1}) were found in T_1 (Farmers' practice, without mulch). These improvement in yield attributes and yield might be due to high availability of soil moisture, balanced nutrition through soil and foliar application with mulching which helped in establishing the roots, initiating more fruiting points, their subsequent retention and development in the plant leading to the higher number of fruits per plant, yield and other parameters. Debbarma *et al.* (2015) and Marichamy *et al.* (2016) reported that the higher yield and yield attributes of crops under mulching achieved due to less weed population, increased photosynthesis and metabolic activities, higher uptake of water and nutrients which facilitated growth and yield of plants. Similar trends of yield and yield attributes were reported by Prabhakar *et al.,* (2010) and Ramachandrappa *et al.,* (2010) in green chilli, Krishnamoorthy & Noorjehan, (2014), Reddy *et al.,* (2016) and Rani *et al.,* (2020) & Das *et al.,* (2022) in chilli and Ansary *et al.,* (2017) in tomato.

3.3 Weed Population

Mulching provides a physical barrier, thus reduces the germination and nourishment of many weeds (Shilpa *et al.*, 2022). In this study weed population were counted at 40 days after transplanting (DAT).

The growth of different weeds under different treatments was presented in Table 3. The highest number of weeds including grasses and broad leaf weeds per square meter (342.6) was recorded in T_1 plot followed by straw mulching (67.5) and the lowest was in black/silver polythene mulch (10.8) indicating black polythene mulching was more effective than paddy straw mulching in suppressing weed growth. In fact, Black/silver polythene mulching produced weeds only through the punch hole and no weed was found above the polythene, which might be due to lack of penetration of light passed through black polythene. A portion of photosynthetic radiation was blocked by the black polythene which suppressed weed growth. About 99 per cent weed control was found under black/silver plastic mulch as reported by Rajablariani *et al.,* (2012) that supported the present findings. Ashrafuzzaman *et al.,* (2011) also recorded lowest number of weeds in black polythene mulch as compared to other mulch. Polythene mulch application is effective for conserving soil moisture and weed control as reported by (Sindhu *et al.,* 2023). Similar findings were reported by Kumari & Jat (2021), Narayan *et al.* (2017) and Sathiyamurthy *et al.* (2017) in chilli.

3.4 Economics

The economics of cultivation of chilli (Table 4) revealed that among the treatments, which received FYM 10 t ha^{-1},100% RDF, foliar spray with water soluble fertilizer and polythene mulching (T_3) resulted in higher gross return of Rs. 4,45,750 ha^{-1}, net return of Rs. 3,47,050 ha^{-1} and benefit: cost ratio of 4.5 as compared to T_2 and T_1.

The lowest economic parameters were recorded in Farmer's practice, without mulch treatment (T_1), where gross return of Rs. 3,29,000 ha^{-1}, net return of Rs. 2,43,100 ha^{-1} and benefit: cost ratio of 3.8 were calculated. Similar findings were also reported by Kumari & Jat, (2021); Tyagi & Kulmi, (2019) and Narayan *et al.,* (2017) in chilli.

4. CONCLUSION

Based on the study results, it could be concluded that application of FYM @ 10 t ha^{-1}, $N:P_2O_5:K_2O$ @ 100:75:75 kg $ha^{-1,}$ foliar application of water-soluble fertilizer and double coated (black on silver) polythene mulching enhanced the growth parameters, yield attributes, economic parameters and yield of chilli. Farmers also earned higher net return and benefit cost ratio due to adopting this technology. Therefore, balanced fertilization with polythene mulching in chilli cultivation could enhance soil moisture retention, suppress weed growth and enhance crop yield.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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