Effect of Natural and Synthetic Mulches on Yield and Yield Attributing Parameters of Chili (Capsicum annuum L. Solanaceae)

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Authors’ contributions

This work was carried out in collaboration among all authors. Authors RN and BA designed the study, wrote the research methodology, conducted the research, performed the statistical analysis, and prepared final version of the manuscript. Author SBN provided guidance in all these steps and helped finalize the manuscript. Authors SP and NO assisted in field research and data collection. Author RHT provided his expertise while finalizing the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Production of chili (Capsicum annuum Linnaeus; Solanaceae) in rain-fed regions of Nepal during the winter is constrained by the limited availability of soil moisture. Mulching has been a proven tool to conserve soil moisture and enhance yield. A field study was conducted in the winter of 2019 to identify the most suitable mulch that enhances the yield and yield attributing parameters of chili.

Study Design: Seven treatments with three replications were evaluated under the randomized complete block design. Among the treatments, rice straw (5 kg/plot) and water reed (5 kg/plot) were used as natural mulches. While, plastic mulches: transparent (25 µ), silver (25 µ), black (25

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µ), and black thick (50 µ) (double thickness) were used as synthetic mulches. Only soil with no mulch was the control.

**Place and Duration of Study:** The study was conducted at Bangau, Dang, Nepal from November 2019 to May 2020.

**Methodology:** We measured soil temperature at 10 cm depth using soil thermometer, and calculated soil moisture through oven dry method. Similarly, weight of ten fresh and ten dry fruits was recorded from each plot using an electronic scale. Number of fruits per plant was also counted. All the data were analyzed using ANOVA and means were separated following a post hoc test.

**Results:** The highest soil moisture (18.38%), number of fruits per plant (24.91), fruit fresh weight per ten fruits (59.86 g), and fruit dry weight per ten fruits (14.65 g) were recorded in black thick plastic mulched plots. Furthermore, the lowest fresh weed weight (95.30 g) was also measured in black thick plastic mulched plots. Whereas, the highest soil temperature (18.92°C) was recorded in transparent plastic mulched plots.

**Conclusion:** This study concludes black thick plastic as the most effective among the treatments tested in this study in enhancing yield and yield attributing parameters of chili.

**Keywords:** Fruit yield; mulching; soil moisture; soil temperature; weed control.

**1. INTRODUCTION**

Chili is one of the notable spices [1] and vegetable crop. In addition to its culinary value, chili is an important source of nutrition for vitamin A, vitamin C, and capsaicin- a widely recognized anti-cancer agent [2]. Chili is also extensively used for medication against metabolic, circulatory, musculoskeletal, and dermatological disorders [3]. Economically, chili is a crucial crop and accounts for more than $1 billion global trade value [4]. Moreover, chili in human cosmetics has now proven safe after the toxicological risk assessment [5]. This benefit provides chili cultivation yet another reason to flourish commercially.

The commercial prosperity of chili demands appropriate and well-timed inputs like fertilizer, irrigation, and plant protection measures, along with the favorable soil microclimate. Soil moisture stress, soil temperature, and weed growth affect soil microclimate and chili production [6]. Mulching, a protective layer laid above the soil surface, can effectively amend the microclimatic soil conditions. Mulch aids in chili growth and development by weed suppression, soil moisture conservation, disease or pest reduction, enhances vitamin C and total soluble solids (TSS) content [7,8].

Mulches of natural origin have been used traditionally, whereas synthetic mulches have been applied commercially since the 1960s [9,10]. Natural mulches such as straws of various crops, leaf litter, and grasses have several advantages. Natural mulch improves organic matter content in the soil and soil tilth [11] and provides a favorable environment for earthworms and other soil microbes [12]. The addition of organic matter by natural mulches ultimately helps ameliorate soil’s physical, chemical, and biological properties [13].

Similarly, polyvinyl chloride (PVC) is widely used as plastic mulch as it permits radiation of greater wavelengths, which helps increase soil temperature [14]. The thickness and color of the plastic mulch are crucial in the determination of chili growth, fruit quality, and quantity. Profound foliage development has been closely linked with the application of transparent and silver- colored mulch films [15]. Chili grown on plastic mulches are found to mature early, produce cleaner fruits, and get a reasonable market price [16]. Moreover, chili fruit yield is found to be increased by two folds under black plastic mulch compared to control [17]. Mulches of varied nature, colors, thickness can improve plant growth, yield, fruit ripening, and fruit quality. Thus, this field study was conducted to identify the most suitable mulch that would enhance the yield and yield attributing parameters of chili. In addition, the effect mulches had on soil physical parameters was also examined.

**2. MATERIALS AND METHODS**

‘Karma 747’, an F₁ hybrid cultivar recommended by the Government of Nepal for Terai and Midhills (60-2500 m above mean sea level) was the plant material selected for this study. A standard 10 g seed packet was acquired from the Nepal Agricultural Research Council. Seeds were sown
in polyethylene bags of (10 cm x 15 cm) at 2 cm depth. After 30 days, seedlings were transplanted on the raised plots of (4.5 m x 1 m x 0.15 m). Seven treatments were used, and they were replicated three times under randomized complete block design (RCBD). The treatments were; rice straw (5 kg/plot), water reed (5 kg/plot), different types of plastic mulch; transparent (25 µ), silver (25 µ), black thin (25 µ), black thick (50 µ), and no mulch/ control.

Irrigation, nutrient, weed, and disease pest control measures were applied whenever necessary. Various parameters of soil, plant growth, yield, and amount of weed incidence were recorded at 35, 70, and 90 days after transplanting (DAT). Soil temperature at 10 cm depth was measured using the thermometer whereas soil moisture was calculated by using the following formula.

\[
\text{Soil Moisture (\%)} = \frac{\text{mass of wet soil} - \text{mass of dry soil}}{\text{mass of dry soil}} \times 100
\]

Similarly, plant height was measured from the base of the stem to the apex of the topmost leaf using a measuring tape. Fruit length was measured using a measuring tape and width were measured using Vernier calipers. Ten fruits, fresh and dry (12% moisture level) were selected per plant of the treatment plots. Fruit weights per ten fruits were then measured using an electronic scale.

Weeds on the plots were out manually ensuring minimal damage to the standing chili plants and mulches. Fresh weed weight was recorded using an electronic scale.

Field data were tabulated in Microsoft Excel version 16.0.6742.2048 (Microsoft Excel, 2019), whereas data analysis was done through RStudio version 3.5.2. (RStudio Team, 2020). Analysis of variance (ANOVA) tool was used to analyze the treatment means and their variations statistically. The variations among the treatment means were tested at a 5% confidence level (\(P \leq 0.05\)). Fisher’s Least Significant Difference (LSD) was conducted as a post hoc test to separate the treatment means.

3. RESULTS AND DISCUSSION

3.1 Soil Moisture

All mulched plots showed significantly higher moisture content compared to the non-mulched control plots. The highest soil moisture was found on black thick plastic mulched plots (18.38%), and the lowest soil moisture was found on control plots (15.95%) (Fig. 1). Similar results were revealed by Malik et al. [18] and Wang [19], who reported the highest percentage of soil moisture on black plastic mulched plots compared to the control plots. McMillen [19] confirms that the soil moisture difference among the mulched and non-mulched plots is due to the relatively lesser evaporation rate. Unlike the control plots, the evaporated moisture in the mulched plots was trapped inside the mulches and returned to the soil.

3.2 Soil Temperature

Soil temperature on the control plot was significantly lower than all the mulched plots. The highest soil temperature was recorded in the transparent plastic mulched plot (19.24°C), whereas the lowest soil temperature was recorded in the control plot (16.86°C) (Fig. 2). Soil temperatures at the mulched plot were higher because mulched plots were able to trap the incoming solar radiation. Transparent plastic mulch was able to transmit more solar radiation into the soil than other treatments. It resulted in heating of the air trapped inside the plastic mulch and created the ‘greenhouse effect’ as reported by Hu [20]. Ultimately this increased the temperature of the soil inside it. This finding is similar to a study by Ashrafuzzaman et al. [21], who reported 67% higher soil heat flux on transparent plastic mulched plots compared to opaque plastic mulched plots. Also, the study reported an increase in soil temperature through plastic mulch. However, soil temperatures between all other mulched plots were statistically similar.

3.3 Fruit Fresh Weight

The highest fruit weight was recorded from black thick mulched plots (59.86 g), whereas the lowest fruit weight was recorded from control plots (40.86 g) (Fig. 3). Fruit weight recorded on the control plot was statistically lower, compared to all other mulched plots. Higher fruit weights on mulched plots can be associated with better growth and development of chili due to more favorable microclimatic conditions. This assertion can be backed up by Phet and Mquat [22], who reported favorably adjusted hydrothermal conditions and enhanced nutrient availability in the plants under mulched...
conditions. Particularly, favorable soil moisture, temperature, accumulation of nutrients on root zones, and lower weed density resulted in improved yield. These results are similar to Khan [23] and Kumara et al. [24], who reported the maximum weight of fruits collected from black plastic mulch plots whereas minimum from the control plot.

3.4 Fruit Dry Weight

Fruit dry weight was higher in plots treated with a mulch compared to control plots. Although, this difference was not significant. The highest dry weight was recorded on fruits harvested from black thick plastic mulched plots (14.65 g), whereas the lowest fruit dry weight was found in control plots (9.79 g) (Fig. 4).

3.5 Number of Fruits

All mulched plots showed a significantly greater number of fruits than the control plots. The highest fruit number per plant was recorded on the black thick mulched plot (25), followed by the transparent plastic mulch plot (21), as shown in Fig. 5. The lowest number of fruits was observed on the control plot (14). Similar results were published by Maida et al. [25] and Tegen et al. [26], who reported a significant increase in the number of fruits on polythene mulched plots compared to control plot.

![Fig. 1. Soil moisture (%) under different mulch treatments](image-url)
Fig. 2. Soil Temperature (°C) under different mulch treatments

Fig. 3. Fruit fresh weight per ten fruits across various mulch treatments
Fig. 4. Fruit dry weight per ten fruits across various mulch treatments

Fig. 5. Fruit number per plant across various mulch treatments
Mulch provided a favorable soil microclimate and soil moisture availability at critical periods of plant growth. Consistent availability of soil moisture during the flowering and fruiting stages as well as the increased temperature might be the reason for the higher number of fruits on the black thick plastic and transparent plastic mulched plots. This result is similar to the study by Holzman et al. [27], who reported that water stress decreases the yield of the crop. Moreover, black thick plastic mulched plots had relatively fewer weeds than transparent mulch plots. Lower weed infestation leads to less competition for nutrients, space, and light in black plastic mulch plots, contributing to an increased number of fruits. This statement can be supported by Amador-Ramirez [28], who reported up to 48% chili yield loss due to weed infestations.

3.6 Weed Fresh Weight

In black thick plastic mulched plots, weed biomass was found to be statistically lowest among the treatments. All the mulch treatments except transparent plastic mulch were found effective in controlling the weed. Weed biomass was found lowest on the black thick plastic mulched plots (95.30 g) and highest on the control plot (151.80 g) (Fig. 6). These results are similar to Narayan et al. [2] and Ashrafuzzaman et al. [6] who also reported maximum weed weight on plots covered with transparent mulch plastics whereas minimum weed weight was recorded on black plastic mulched plots.

The lowest weed biomass on black plastic mulch can be linked to the minimal availability of solar radiation into the mulch. Amare and Desta [29] asserted that black thick plastic mulch blocked solar radiation efficiently, minimized photosynthesis of weed, and caused low vegetative growth of weed. In contrast, transparent plastic mulch lets solar radiation pass through it, resulting in the growth and development of weed through increment in photosynthesis.

4. CONCLUSION

From the study, it can be concluded that both the natural and synthetic mulches had positive impacts on enhancing yield and yield attributing parameters of chili. Among the treatments, black thick plastic mulch and transparent plastic mulch were statistically superior in yield and significant yield attributing parameters. However, transparent plastic didn’t suppress weed growth. In contrast, black thick plastic mulch was the most effective among the mulches in weed control. Additionally, black thick plastic conserved the maximum soil moisture. Thus, this study concludes that black thick plastic mulches most notably altered soil microclimate and ultimately lead to improved yield and yield attributing parameters of chili. In this study, we couldn’t consider double-colored plastic mulches like silver-black and transparent-black which are becoming popular lately. Hence, the performance of chili under such integrated mulches, which have unique properties of their own, can be an attractive research prospect for the future.
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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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