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The Effect of Different Mulches and Bed Sizes on Growth, Yield and Quality of Turmeric (*Curcuma longa* L.) Under the Mid-Hill Zone of Himachal Pradesh

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ABSTRACT

The present investigation was carried out in the Department of Vegetable Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India during *kharif*, May, 2020–January, 2021 to examine the effect of different mulches and bed sizes on the growth, yield and quality of turmeric. The trial was laid out in randomized complete block design (factorial) with 9 treatment combinations, including 3 mulches (silver-black mulching film, pine needles and dry grass) with 3-bed sizes (9×1 m^2, 6×1 m^2 and 3×1 m^2), which were triplicated. Turmeric yield proved to be significantly affected by mulching materials with silver-black mulching film producing the highest yield (32.01 t ha^{-1}) whereas pine needles produced the lowest yield (23.85 t ha^{-1}). Rhizome length and breadth, the number of primary and secondary rhizomes, dry recovery, essential oil, oleoresin and curcumin content were some of the yield and quality characteristics that have been improved by the use of silver-black mulching film. Bed size also provided a significant effect on the yield of turmeric with the highest (29.03 t ha^{-1}) in bed size 9×1 m^2 whereas lowest in 3×1 m^2 (25.75 t ha^{-1}). A combination of silver-black mulching film and 9×1 m^2 bed size provided the significantly highest turmeric yield (33.56 t ha^{-1}). This study recommends that farmers in Himachal Pradesh's mid-hill zone to produce turmeric using silver-black mulching film on beds measuring 9×1 m^2 for better growth, yield and improved quality of turmeric.

KEYWORDS: Bed size, growth, mulch, turmeric, quality, yield

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1. INTRODUCTION

Turmeric (*Curcuma longa* L.) is most precious and sacred spices in the world, belongs to Zingiberaceae family and native to South-East Asia (Aggarwal et al., 2007). It is a perennial herbaceous rhizomatous plant that bears ovate, pyriform or oblong and branched brownish-yellow rhizomes. It is a versatile and lucrative tropics cash crop with applications as a spice, flavouring agent, colourant, dye and in various medical systems (Dev and Sharma, 2022; Iweala et al., 2023). Curcumin, turmeric's key bioactive ingredient, has been proven to have anti-oxidant (Akter et al., 2019), anti-inflammatory (Tomeh et al., 2019), anti-tumor, anti-mutagenic, anti-coagulant, anti-fertility, anti-diabetic and anti-hypertensive effects (Ahmad et al., 2020). It is also known as the 'golden spice' and the 'spice of life' because of its numerous medicinal applications and lack of known side effects (Prasad and Aggrawal, 2011).

India is the world's largest producer of turmeric, accounting for 80% of the global trade (Anonymous, 2021). In India, it is cultivated in 3,49,430 ha and produced 13,34,310 t during the year 2021–22, with Maharashtra leading the way with 1,02,625 ha and a production of 3,67,985 t. In Himachal Pradesh, it is grown on 505 ha and produces 821 t during the same period (Anonymous, 2022). However, production is lagging due to factors like marginal farming, unscientific cultivation practices, post-harvest operations and lack of high-yielding cultivars (Aglawe et al., 2014). To maximize productivity, the current set of agro-technologies need to be location specific, must be improved (Fuentes et al., 2009). Among them, mulch application is a water conservation technique as well as it alters the physico-chemical properties of soil (Thakur and Kumar, 2021) and increasing the population size will increase the net productivity (Zhang et al., 2021).

Mulching is a crucial practice in crop management which enhances growth, development and quality (Shirish et al., 2013). It conserves soil moisture (Kumar et al., 2022) and regulates top soil temperature (Qin et al., 2014), micro-flora and fauna (Bhagat et al., 2016). It also decreases the effect of speedy wind on the soil surface in arid regions, preventing erosion and protecting the soil from splashing raindrops (Iqbal et al., 2020). It has been shown to reduce soil nutrient leaching and to act as a barrier to soil pathogens (Thakur and Kumar, 2021), resulting in higher economic yields and higher quality produce harvests. Natural mulches such as leaf, straw, saw dust, spent materials and crop residues have been used for centuries (Indulekha and Thomas, 2018). However, synthetic materials like plastic mulch have revolutionised the techniques and advantages of mulching in recent years (Kader et al., 2017; Mansoor et al., 2022). This technology modifies the radiation budget and decreasing soil water loss, while maintaining loose, friable and aerated soil (Amare and Desta, 2021).

Turmeric is often planted on a 3×1 m^2 bed with channels that are 30–45 cm wide (Anonymous, 2009), which significantly reduces the net cropped area. If the necessary drainage is maintained, which is not a severe issue in hilly zones of Himachal Pradesh, increasing the bed size results in an increase in the net cropped area, which could lead to a potential increase in productivity (Biswas et al., 2022). The ideal plant population for any crop varies significantly depending on the climate in which it is cultivated and the soil's fertility level (Kaur et al., 2020). Plant population and planting spacing are crucial for greater production because they provide plants with an equal chance of survival and maximize the utilisation of other inputs (Haarhoff and Swanepoel, 2022). In this research, we investigated how mulching and bed size influenced the growth, production and quality of turmeric.

2. MATERIALS AND METHODS

2.1. *Description of study site and climatic conditions*

The experiment was conducted at vegetable research farm, Department of Vegetable Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP) during May, 2020–January, 2021. The field is located at 77° 11' 30" East and 30° 52' 30" North, 13 km away from Solan city with an elevation of 1276 m above mean sea level. The soil of the experimental field was gravelly loam to gravelly clay loam in texture. It falls in the sub-humid, sub-temperate and mid-hill zone of Himachal Pradesh. The maximum ambient temperature varied from 20.33°C–31.93°C and minimum from 0.23°C–20.93°C. January was the coldest, while June was the hottest month. The total rainfall during the growing season was 649.00 mm, with the majority of it falling between July and August (Figure 1).

2.2. *Experimental details*

2.2.1. *Cultivar and experimental layout*

The high yielding annually harvested turmeric cultivar Palam Lalima, which has been developed and recommended by CSK HPKV Palampur (Anonymous, 2017) used in the current study. The planting beds were prepared of size 3×1 m^2, 6×1 m^2 and 9×1 m^2 with drainage channels of 0.5 m were made between them which accommodates 50, 100, and 150 plants bed^{-1}, respectively. The uniform sized turmeric rhizomes were planted during the first fortnight of May with the spacing of 20×30 cm^2. The experiment was laid out in Randomised Complete Block Design (factorial) with nine treatment combinations, including three mulches (silver-black mulching film, pine needles and dry grass) with three-bed sizes (9×1, 6×1 and 3×1 m^2) which were replicated at three times.

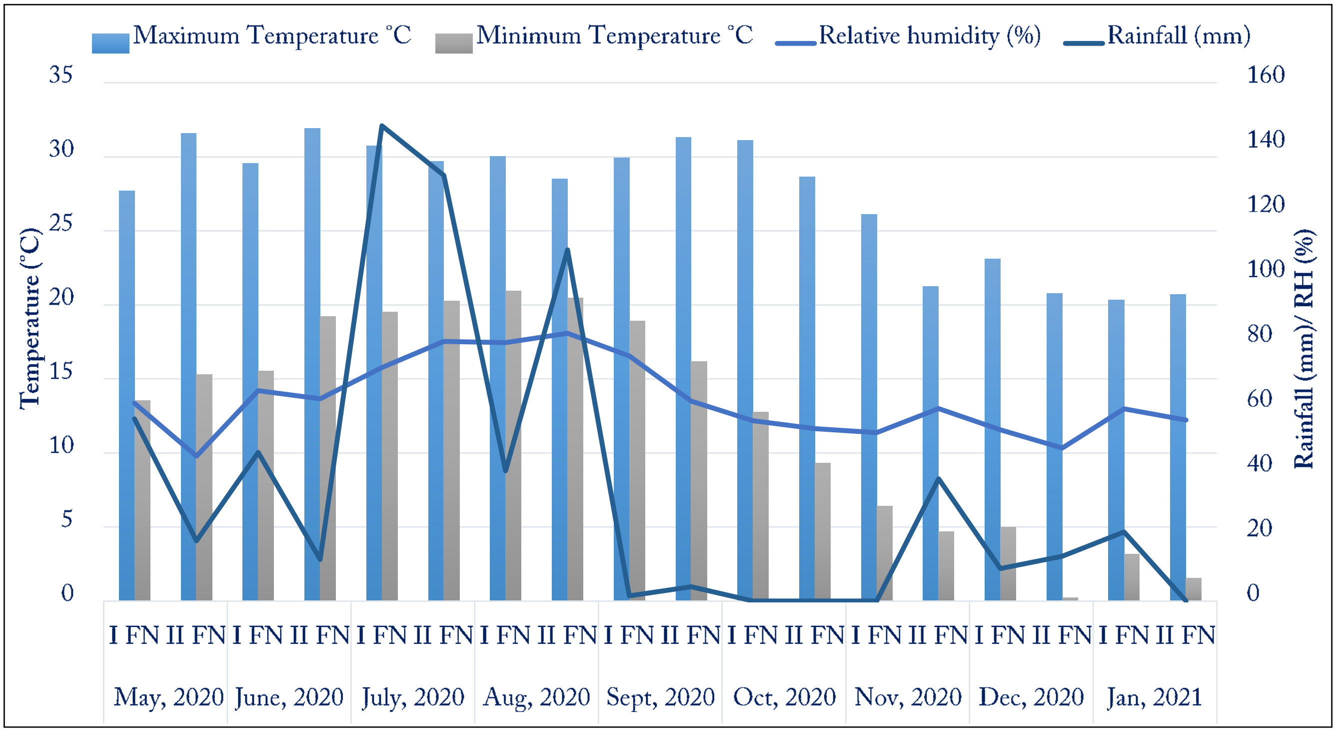

Figure 1: Graphical representation of fortnightly (FN) data pertaining to the temperature, rainfall and relative humidity during the crop season (May, 2020 - January, 2021); Source: Meteorological Observatory, Department of Environmental Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP) - 173 230

2.2.2. The different treatments are as follows

T_1: M_1B_1: Silver-black mulching film with bed size 9×1 m^2; T_2: M_2B_1: Pine needle mulch with bed size 9×1 m^2; T_3: M_3B_1: Dry grass mulch with bed size 9×1 m^2; T_4: M_1B_2: Silver-black mulching film with bed size 6×1 m^2; T_5: M_2B_2: Pine needle mulch with bed size 6×1 m^2; T_6: M_3B_2: Dry grass mulch with bed size 6×1 m^2; T_7: M_1B_3: Silver-black mulching film with bed size 3×1 m^2; T_8: M_2B_3: Pine needle mulch with bed size 3×1 m^2; T_9: M_3B_3 (Control): Dry grass mulch with bed size 3×1 m^2.

2.2.3. Details of cultural operations

All the treatments used both organic and inorganic inputs and they all embraced comparable cultural norms as recommended in the Package of Practices for Vegetable Crops (Anonymous, 2009). According to the treatments, different mulch materials are utilized i.e., silver-black mulching film (50 μ) was employed prior to rhizome planting, whereas pine needles and dry grass mulch were applied instantly after the planting.

2.3. Hydro-thermal studies on soil

2.3.1. Changes in soil moisture (%) under different mulches at 15 cm depth at 15 days interval

Soil moisture content was recorded at 15 cm soil depth by gravimetric method by drying the soil sample in aluminium boxes in the oven at 120°C for 48 hours, the data were recorded at fortnightly intervals. The maximum soil moisture content (7.96–15.41%) was recorded under Dry grass mulch whereas, minimum (8.42–13.21%) was recorded under pine needle mulch. The trend of soil moisture content during high precipitation period were observed maximum under Dry grass mulch and while under Silver-black mulching film in dry period. So, Silver-black mulching film had conserved the sufficient soil moisture content (9.45–13.81%) throughout the growth period of crop (Figure 2).

2.3.2. Changes in soil temperature (°C) under different mulches at 15 cm depth at 7:30 AM and 2:30 PM at 15 days interval on clear sunny days

Soil temperature at 15 cm depth was recorded at fortnightly intervals at 7:30 AM and 2:30 PM for minimum and maximum soil temperature, respectively, throughout the growth period of turmeric crop using digital thermometer. Highest soil temperature (7.30–28.62°C) was observed under Silver-black mulching film and lowest (5.43–27.22°C) in Dry grass mulch at 7:30 AM for minimum soil temperature. At 2:30 PM also, similar trend in the results were observed with highest (14.77–36.61°C) and lowest (13.40–34.48°C) under Silver-black mulching film and Dry grass mulch, respectively for maximum soil temperature (Figure 3).

2.4. Observations recorded

Growth parameters viz., plant height, tiller girth, number

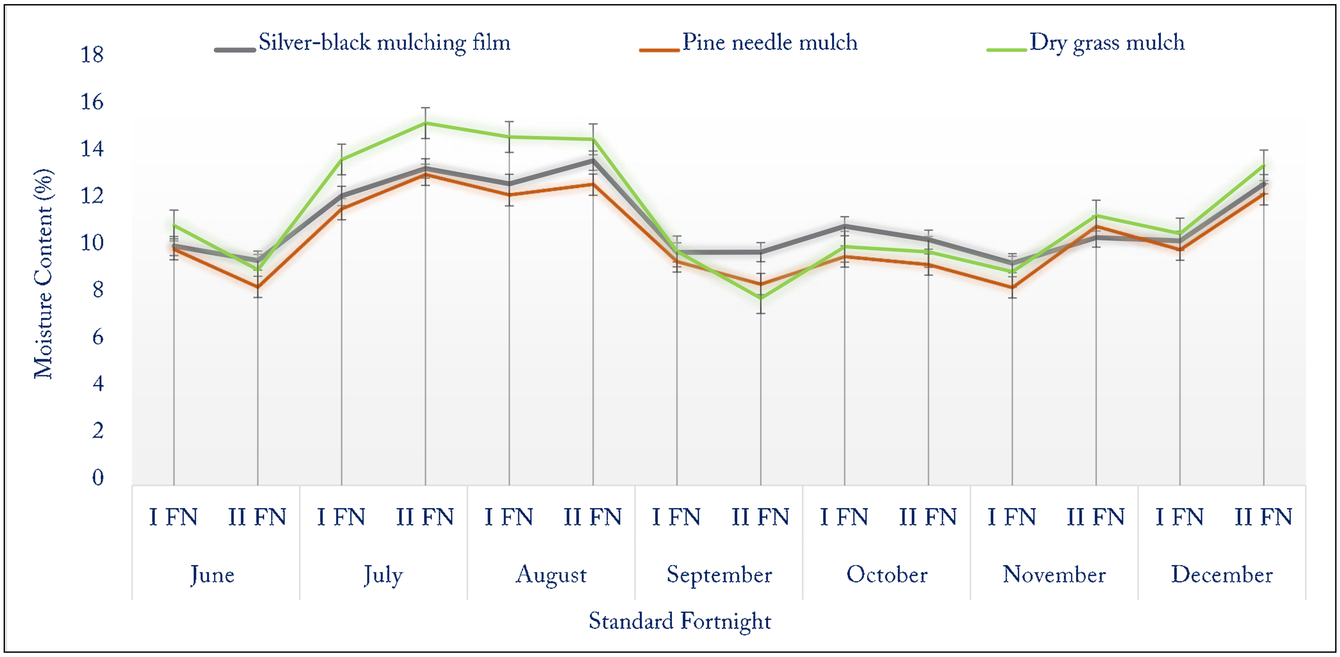

Figure 2: Changes in soil moisture (%) under different mulches at 15 cm depth at 15 days interval

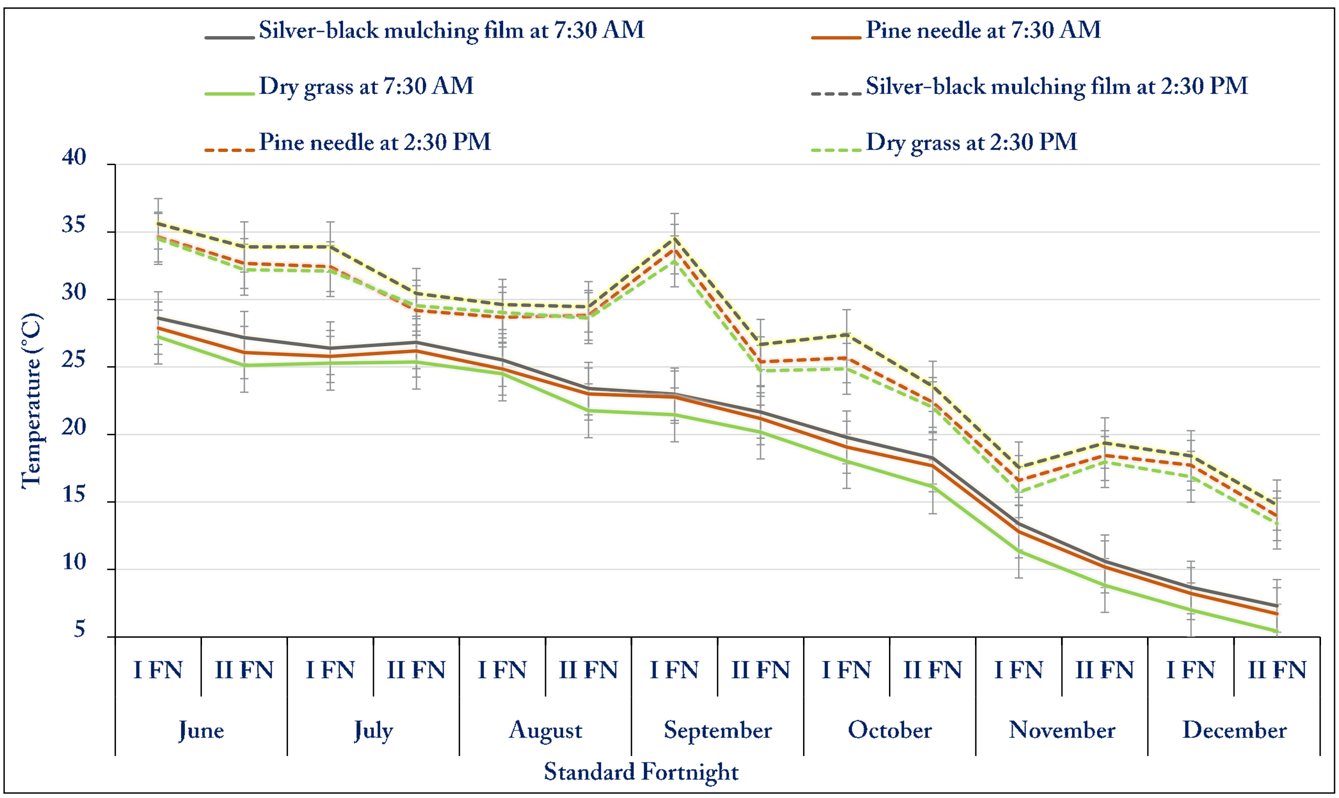

Figure 3: Changes in soil temperature (°C) under different mulches at 15 cm depth at 7:30 AM and 2:30 PM at 15 days

of leaves plant^{-1} and leaf area index were recorded at 180 days after planting (DAP). The crop was harvested in the second fortnight of January and yield parameters viz., length and breadth of rhizome, number of primary and secondary rhizomes, yield per plant and yield per hectare were recorded. The quality parameters viz., dry rhizome recovery, essential oil, oleoresin and curcumin content were estimated as per methods suggested by American Spice Trade Organization (ASTA, 1997). Observations on growth and yield parameters were recorded from ten randomly selected plants in each replication.

2.5. Statistical analysis

The data recorded were analyzed by using MS-Excel & SPSS software. The mean values of data were subjected to analysis of variance as described by Panse and Sukhatme (1957) for Randomized Complete Block Design (Factorial).

3. RESULTS AND DISCUSSION

The experiment was conducted to study two different factors, mulching and bed sizes on the growth, yield and quality of turmeric. The result of each parameter has been discussed and interpreted in this section.

3.1. Growth traits

3.1.1. Plant height (cm)

The effect of mulching on average plant height was found to be significant. The maximum average plant height (182.44 cm) was recorded in plots applied with silver-black mulching film whereas, the minimum was recorded in pine needle mulch (169.64 cm). The effect of bed size was statistically non-significant for plant height. The interaction effect of mulching and bed size had shown a significant influence on plant height. Silver-black mulching film with bed size 9×1 m^2 recorded significant maximum plant height (183.63 cm) which was statistically on par with silver-black mulching film with bed size 6×1 m^2 and silver-black mulching film with bed size 3×1 m^2 whereas, pine needle mulch with bed size 3×1 m^2 recorded a minimum plant height (168.27 cm) (Table 1). According to Verma and Sarnaik (2006) plastic mulch has demonstrated superior performance than the dry grass and palash leaves, supporting the findings of the present study with higher soil moisture content and temperature (Thakur et al., 2019), resulting in nutrient

Table 1: Effect of mulching and bed size of growth characters of turmeric

Particulars	Plant height (cm)	Tiller girth (cm)	No. of leaves $plant^{-1}$	Leaf area index (LAI)	Rhizome length (cm)	Rhizome breadth (cm)	No. of primary rhizomes	No. of secondary rhizomes
Main effect of mulching (M)								
M_1	182.44	11.24	14.81	38.06	16.15	13.71	6.09	13.51
M_2	169.64	10.20	12.42	22.56	13.32	12.17	4.27	9.16
M_3	171.68	10.33	13.48	27.02	14.99	12.86	4.93	10.20
SEm±	1.73	0.11	0.22	0.58	0.19	0.21	0.19	0.21
CD (p=0.05)	5.20	0.33	0.67	1.73	0.62	0.62	0.58	0.64
Main effect of bed size (B)								
B_1	175.23	10.54	13.66	28.66	14.63	12.72	5.00	10.87
B_2	174.72	10.60	13.68	29.31	14.77	12.93	5.07	10.89
B_3	173.81	10.63	13.38	29.66	15.05	13.09	5.22	11.11
SEm±	1.73	0.11	0.22	0.58	0.19	0.21	0.19	0.21
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Interaction between bed size and mulching (B×M)								
B_1M_1	183.63	11.52	15.00	37.46	16.12	13.57	6.20	13.40
B_1M_2	170.03	10.05	12.37	21.95	12.98	11.99	3.93	9.00
B_1M_3	172.03	10.03	13.60	26.56	14.80	12.61	4.87	10.20
B_2M_1	180.87	11.01	14.77	37.95	16.01	13.89	5.93	13.53
B_2M_2	170.63	10.27	12.87	23.26	13.20	12.23	4.33	9.07
B_2M_3	172.67	10.53	13.40	26.73	15.11	12.69	4.93	9.07
B_3M_1	182.83	11.19	14.67	38.66	16.31	13.69	6.13	13.60
B_3M_2	168.27	10.29	12.03	22.46	13.78	12.31	4.53	9.40
B_3M_3	170.33	10.41	13.43	27.78	15.07	13.29	5.00	10.33
SEm±	3.00	0.19	0.39	1.00	0.33	0.36	0.34	0.37
CD (p=0.05)	9.00	0.57	1.16	2.99	1.00	1.07	1.01	1.10

NS: Non-significant

availability and nutrient uptake.

3.2. Tiller girth (cm)

The effect of mulching on tiller girth was found to be significant. The maximum average tiller girth (11.24 cm) was recorded in plots applied with silver-black mulching film whereas, the minimum was recorded in pine needle mulch (10.20 cm). The effect of bed size was statistically non-significant for tiller girth. The interaction effect of mulching and bed size had shown a significant influence on tiller girth. Silver-black mulching film with bed size 9×1 m^2 recorded significantly the maximum tiller girth (11.52 cm) which was statistically on par with silver-black mulching film with bed size 6×1 m^2 and silver-black mulching film with bed size 3×1 m^2 whereas, dry grass mulch with bed size 9×1 m^2 recorded a minimum tiller girth (10.03 cm). The greater moisture retention and stable soil temperature under the plastic mulch (Figure 2 and 3) may be the cause of the turmeric tiller's increased girth (Lalitha et al., 2010). The findings concurrent with those of Reddy et al. (2017) who noted a larger stem girth under the plastic mulching film.

3.1.3. No. of leaves plant^{-1}

The effect of mulching on the number of leaves plant^{-1} was found to be significant. The maximum number of leaves plant^{-1} (14.81) was recorded in plots applied with silver-black mulching film whereas, the minimum was recorded in pine needle mulch (12.42). The effect of bed size was statistically non-significant for the number of leaves plant^{-1}. The interaction effect of mulching and bed size had shown a significant influence on number of leaves plant^{-1}. Silver-black mulching film with bed size 9×1 m^2 recorded a significantly maximum number of leaves plant^{-1} (15.00) which was statistically on par with silver-black mulching film with bed size 6×1 m^2 and silver-black mulching film with bed size 3×1 m^2 whereas, pine needle mulch with bed size 3×1 m^2 recorded the minimum number of leaves plant^{-1} (12.03) (Table 1). As silver coloured polyethene mulch reflects back a significant portion of sunlight towards the plants (Amera and Desta, 2021) may aid in higher availability of light for photosynthesis, producing a greater number of functional leaves. Kushwah et al. (2013) also reported the highest number of leaves under plastic mulch compared to grass mulch in ginger, which were in agreement with our results. However, in contradiction Verma and Sarnaik (2006) observed the minimum number of leaves under plastic mulch compared to other organic mulches in turmeric.

3.1.4. Leaf area index (LAI)

The effect of mulching on LAI was found to be significant. The maximum LAI (38.06) was recorded in plots applied with silver-black mulching film whereas, the minimum was recorded in pine needle mulch (22.56). The effect of bed size was statistically non-significant for LAI. The interaction effect of mulching and bed size had shown a significant influence on LAI. Silver-black mulching film with bed size 3×1 m^2 recorded the significantly maximum LAI (38.66) which was statistically on par with silver-black mulching film with bed size 6×1 m^2 and silver-black mulching film with bed size 9×1 m^2 whereas, pine needle mulch with bed size 9×1 m^2 recorded a minimum LAI (21.95) (Table 1). Utilisation of more sunlight in 3×1 m^2-sized beds, as well as the maximum number of functional leaves in silver-black mulching film, resulting in maximum LAI. Silver-black mulching film modifies the microclimate, which can be more favourable for plant growth with increased light and temperature regulation (Figure 3), encourage the more production of leaves thereby LAI. The findings are consistent with those of Kushwah et al. (2013); Indulekha and Thomas (2018), who observed the highest LAI under plastic mulching in turmeric compared to dry grass mulch and no-mulch application.

3.2. Yield traits

3.2.1. Rhizome length and breadth (cm)

The effect of mulching on rhizome length and breadth was found to be significant. The maximum rhizome length (16.15 cm) and breadth (13.71 cm) was recorded in plots applied with silver-black mulching film whereas, the minimum was recorded in pine needle mulch (13.32 cm and 12.17 cm, respectively). The effect of bed size was statistically non-significant for rhizome length and breadth. The interaction effect of mulching and bed size had shown a significant influence on rhizome length and breadth. Silver-black mulching film with bed size 3×1 m^2 recorded a significantly maximum rhizome length (16.31 cm) which was statistically on par with silver-black mulching film with bed size 6×1 m^2 and silver-black mulching film with bed size 9×1 m^2 and maximum breadth (13.89 cm) in silver-black mulching film with bed size 6×1 m^2 which was statistically on par with silver-black mulching film with bed size 9×1 m^2 and silver-black mulching film with bed size 3×1 m^2 whereas, pine needle mulch with bed size 9×1 m^2 recorded a minimum rhizome length and breadth (12.98 and 11.99 cm, respectively) (Table 1). When compared to other mulches or bare soil, the improved growth of rhizomes under silver-black mulching is due to better soil moisture retention (Figure 2), higher leaf area leading to higher biomass accumulation as well as shoot and root growth (Weraduwage et al., 2015). The results are in support of Reddy et al. (2017), who discovered the maximum rhizome length and breadth under plastic mulch.

3.2.2. No. of primary and secondary rhizomes

The effect of mulching on the number of primary and secondary rhizomes was found to be significant. The maximum number of primary (6.09) and secondary (13.51) rhizomes were recorded in plots applied with silver black mulching film whereas, the minimum was recorded in pine needle mulch (4.27 and 9.16, respectively). The effect of bed size was statistically non-significant for number of primary and secondary rhizomes. The interaction effect of mulching and bed size had shown a significant influence on number of primary and secondary rhizomes. Silver-black mulching film with bed size 9×1 m^2 recorded a significantly maximum number of primary rhizomes (6.20) and which was statistically on par with silver-black mulching film with bed size 6×1 m^2 and silver-black mulching film with bed size 3×1 m^2 as well as silver-black mulching film with bed size 3×1 m^2 for secondary rhizomes (13.60) which was statistically on par with silver-black mulching film with bed size 6×1 m^2 and silver-black mulching film with bed size 9×1 m^2 whereas, pine needle mulch with bed size 9×1 m^2 recorded a minimum number of primary and secondary rhizomes (3.93 and 9.00, respectively) (Table 1). Microclimate modification and improved soil condition i.e., reduced compaction, stabilized moisture level and weed suppression (Kader et al., 2017; Mansoor et al., 2022) facilitate better nutrient uptake which led to increased growth of a greater number of rhizomes under silver coloured polyethene mulches. Similarly, Bharati et al., 2020 recorded highest number tubers under plastic mulch in comparison to saw dust, paddy straw, paddy husk and no-mulch in potato.

3.2.3. Yield plant^{-1} (g) and yield ha^{-1} (t)

The effect of mulching on yield per plant as well as yield ha^{-1} was found to be significant. The maximum yield plant^{-1} (316.80 g) and yield ha^{-1} (32.01 t) was recorded in plots treated applied with silver-black mulching film whereas, the minimum was recorded pine needle mulch (235.77 g and 26.71 t, respectively). The effect of bed size was statistically non-significant for yield plant^{-1} however, observed significantly maximum (29.03 t) yield per hectare in 9×1 m^2 whereas, minimum in 3×1 m^2 sized beds (25.75 t). The interaction effect of mulching and bed size had shown a significant influence on yield plant^{-1} as well as yield ha^{-1}. Silver-black mulching film with bed size 9×1 m^2 recorded significantly maximum yield plant^{-1} (318.87 g) as well as yield ha^{-1} (33.57 t) which were statistically on par with silver-black mulching film with bed size 6×1 m^2 and silver-black mulching film with bed size 3×1 m^2 whereas, pine needle mulch with bed size 3×1 m^2 recorded a minimum yield plant^{-1} and yield ha^{-1} (227.77 g and 21.69 t, respectively) (Table 2).

The higher the plant height, functional leaves and rhizome growth parameters, the higher the turmeric production, which was determined to be high in silver-black mulching film. This could be owing to reduced weed growth, increased water availability to plants and increased nutrient uptake, resulting in less crop-weed competition under silver-black mulching film over dry grass and pine needle mulches. The influence of bed size on yield per plant was non-significant; nevertheless, bed size has a substantial influence on yield per hectare due to an increase in plant population per hectare according to bed size, i.e., 95,238, 1,02,564 and 1,05,263 plants in 3×1 m^2, 6×1 m^2 and 9×1 m^2, respectively. Increased bed length of up to 9 m enhanced net cropping area by 10.53% higher than the 3 m normal bed length. The findings were consistent with Sidhu et al. (2016), who reported the highest fresh rhizome yield under mulching in a sole turmeric crop due to the higher plant population per hectare; Kumar and Gill (2010) reported the highest yield per hectare with higher population density in turmeric and Reddy et al. (2017) reported a 14.70% increase in yield under plastic mulch compared to other treatments.

3.3. Quality traits

3.3.1. Dry rhizome recovery (%)

The effect of mulching on dry rhizome recovery was found to be significant. The highest dry rhizome recovery (25.16%) was recorded in plots with silver-black mulching film whereas, lowest was recorded in pine needle mulch (20.93%). The effect of bed size was statistically non-significant for dry rhizome recovery. The interaction effect of mulching and bed size had shown significant influence on dry rhizome recovery. Silver-black mulching film with bed size 9×1 m^2 recorded significantly highest dry recovery (25.56%) which was statistically on par with silver-black mulching film with bed size 6×1 m^2 and silver-black mulching film with bed size 3×1 m^2 whereas, pine needle mulch with bed size 3×1 m^2 recorded lowest dry rhizome recovery (20.03%) (Table 2). This could be due to higher leaf area under plastic much leading to higher dry matter accumulation under plastic mulch compared to other organic mulches (Choudhary, 2011).

3.3.2. Oleoresin content (%)

The effect of mulching on oleoresin content was found to be significant. The maximum oleoresin content (12.79%) was recorded in plots with silver-black mulching film which was statistically on par with dry grass mulch whereas, minimum was recorded in pine needle mulch (10.83%) (Table 2). The individual effect of bed size as well as was interaction of mulching and bed size was statistically non-significant for oleoresin content turmeric.

3.3.3. Essential oil content (%)

The effect of mulching on essential oil content was found to be significant. The maximum essential oil (5.75%) was recorded in plots mulched with silver-black mulching film whereas, minimum was recorded in pine needle mulch (4.92%). The effect of bed size was statistically non-

Table 2: Effect of mulching and bed size of yield and quality characters of turmeric

Particulars	Yield plant^{-1} (g)	Yield ha^{-1} (t)	Dry rhizome recovery (%)		Oleoresin content (%)		Essential oil content (%)		Curcuminoids content (%)	
Main effect of mulching (M)										
M_1	316.80	32.01	25.16	5.11*	12.79	3.71*	5.75	2.60*	4.96	2.44*
M_2	235.77	23.85	20.93	4.68	10.83	3.44	4.92	2.43	4.15	2.27
M_3	264.52	26.71	21.81	4.78	11.44	3.53	5.28	2.50	4.22	2.28
SEm±	1.98	0.20	(0.05)		(0.06)		(0.03)		(0.05)	
CD (p=0.05)	5.93	0.60	(0.14)		(0.19)		(0.09)		NS	
Main effect of bed size (B)										
B_1	275.76	29.03	23.18	4.91	11.87	3.59	5.44	2.54	4.32	2.30
B_2	271.00	27.80	22.43	4.84	11.78	3.57	5.36	2.52	4.38	2.31
B_3	273.33	25.75	22.29	4.82	11.40	3.51	5.14	2.48	4.64	2.37
SEm±	1.98	0.20	(0.05)		(0.06)		(0.03)		(0.05)	
CD (p=0.05)	NS	0.60	NS		NS		NS		NS	
Interaction between bed size and mulching (B×M)										
B_1M_1	318.87	33.56	25.56	5.15	13.14	3.76	6.08	2.66	4.91	2.43
B_1M_2	247.30	26.02	21.84	4.78	11.08	3.48	4.92	2.43	3.98	2.23
B_1M_3	261.23	27.50	22.16	4.81	11.39	3.52	5.33	2.52	4.07	2.25
B_2M_1	316.80	32.49	24.38	5.04	12.99	3.74	5.67	2.58	4.94	2.44
B_2M_2	232.37	23.83	20.93	4.68	10.72	3.42	5.00	2.45	4.06	2.49
B_2M_3	263.83	27.06	21.97	4.79	11.64	3.55	5.42	2.53	4.14	2.25
B_3M_1	314.73	29.98	25.54	5.15	12.23	3.62	5.50	2.55	5.04	2.46
B_3M_2	227.77	21.69	20.03	4.59	10.68	3.42	4.83	2.41	4.41	2.33
B_3M_3	268.50	25.5.71	21.29	4.72	11.30	3.51	5.08	2.47	4.46	2.33
SEm±	3.42	0.34	(0.08)		(0.11)		(0.05)		(0.09)	
CD (p=0.05)	10.26	1.04	(0.25)		NS		(0.15)		NS	

* Values in the column are square root transformed; NS- Non-significant

significant for essential oil content. The interaction effect of mulching and bed size had shown significant influence on essential oil content. Silver-black mulching film with bed size 9×1 m^2 recorded maximum essential oil (6.08%) which was statistically on par with silver-black mulching film with bed size 6×1 m^2, silver-black mulching film with bed size 3×1 m^2, dry grass mulch with bed size 9×1 m^2 and dry grass mulch with bed size 6×1 m^2 whereas, pine needle mulch with bed size 3×1 m^2 recorded minimum essential oil content (4.83%) (Table 2).

3.3.4. Curcuminoid content (%)

The main effect of mulching as well as bed size was found to be non-significant on total curcuminoid content. The maximum curcuminoids content (4.96%) was recorded in plots mulched with silver-black mulching film whereas, minimum was recorded in pine needle mulch (4.15%). The interaction effect of mulching and bed size also shown non-significant effect on total curcuminoid content. Silver-black mulching film with bed size 3×1 m^2 recorded maximum curcuminoid content (5.04%) whereas, pine needle mulch with bed size 9×1 m^2 recorded minimum curcuminoid content (3.98%) (Table 2). The results corroborate with Kumar et al. (2017) who reported the non-significant effect of mulching on curcumin content in turmeric. Whereas, Kikon (2016) also recorded higher curcumin content under mulches compared to Un-mulched treatment. Antonious and Kasperbauer (2002) found a higher concentration of β-carotene in carrots under yellow and white polythene mulches than in bare soil, suggesting that plastic mulches have an effect on phenolic pigments.

4. CONCLUSION

The highest fresh rhizome yield (33.56 t ha^{-1}) along with improved quality of turmeric cv. Palam Lalima obtained under 9×1 m^2 bed size and silver-black mulching film.

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