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IMPACT OF DIFFERENT MULCHES ON SOIL TEMPERATURE AND PLANT GROWTH IN GUAVA NURSERY UNDER SUBTROPICAL CONDITIONS

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ABSTRACT

The present study was conducted to investigate the effect of organic and inorganic mulches on soil temperature, moisture, weed control efficacy and growth of guava nursery plants. Black polypropylene woven mats were found to be most effective in suppressing the weed growth even after 240 days of application. Weed biomass of 1.4 g/m^2 was recorded in black polypropylene woven mats after 300 days of application as compared to 42.5 g/m^2 in control and 20.5g/m^2 in paddy straw mulch. The biodegradable mulch started degrading after 150 days of application and recorded a weed biomass of 4.8g/m^2 at this stage. Black polypropylene woven mats resulted in 2-3 per cent higher soil temperature during winters and maintained 1.5-2 percent higher moisture content during the month of May-June. The maximum colony count of fungi (34.04 × 10^3 cfu/g of soil), bacteria (42.33 × 10^6 cfu/g of soil) and actinomycetes (34.52 × 10^5 cfu/g of soil) was recorded under paddy straw mulch plots. The highest percentage of buddable plants (84.73%) with maximum plant height (44.26 cm) was also recorded in black polypropylene woven mats. Thus, it was concluded that the black polypropylene woven mats can be applied in the guava nursery plots to control the weed growth effectively as well as to moderate soil temperature and enhance soil microbial population.

Keywords: Biodegradable mulch, Organic mulches, Plant growth, Polypropylene weed mat, Soil properties

Guava (*Psidium guajava* L.) is an important fruit grown in tropical and sub-tropical regions of the world. It originated in tropical America and belongs to family Myrtaceae. It is relatively precocious and prolific in bearing and is a highly remunerative crop. The fruits are highly nutritious; it is a rich source of vitamin 'C' which varies in content from 95.75 to 239.00 mg 100^{-1} g in different cultivars of guava (Singh *et al.,* 2007). Weed infestation in guava nurseries is a big challenge in the subtropics for many nursery producers. The occurrence of weeds in the nurseries effects the growth and establishment of the seedlings. Weeds that are commonly found in the nurseries under sub-tropical conditions are *Cyperus rotundus, Cynodon dactylon, Chenopodium album, Sorghum halepense, Parthenium hysterophorus, Canabis sativa, Rumex dendatus, Anagallis arvensis* and *Phalaris minor* etc. (Brar *et al.* ,2017). Conventional methods used for controlling the weeds are costly and more labour consuming. Currently, pre and post emergence herbicide choices are limited due to number of registered materials and crop safety concerns (Zheljazkov *et al.,* 2007). Moreover, the use of various herbicides results in phytotoxic effect on the young plants as well as they are persistent thereby leaving a long residual effect. Mulching is being proposed as one of the effective technique for conserving soil moisture, suppression of weed growth, improving soil fertility, controlling soil erosion and modifying the thermal pattern of soil. The use of mulches is also an important practice for controlling the weeds in fruit plant nurseries and can provide growers with additional management option for effective and economical production of fruit plant nurseries. Besides, maintaining soil moisture and aeration mulches also maintain the activity of soil microorganisms. Organic mulches are of particular interest since they offer a means not only to improve physical properties of soil but also its nutrient content.Plastic film mulches are widely used in agricultural and horticultural systems (Espi *et al*., 2006) and the black polyethylene mulch is the most widely used in different production systems (Moreno and Moreno, 2008). However, there have been efforts to find an alternative for polyethylene because of the disposal problems.

The biodegradable films can be used in place of the conventional polyethylene films.Thus the effectiveness of various organic and inorganic mulches in controlling weeds may increase their use in agriculture systems with a concomitant decrease in the application of synthetic herbicides. The overall economic benefit of using different types of mulches for the production of sustainable guava nursery plants needs to be studied. Thus, the present study was planned to evaluate the effectiveness of different organic and inorganic mulches on weed control, soil moisture and temperature content and soil health for the production of healthy and good quality guava nursery plants.

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MATERIALS AND METHODS

The present study was carried out in the year 2018-20 at University Seed Farm, Ladhowal and Department of Fruit Science, Punjab Agricultural University, Ludhiana. The experimental site is situated at an altitude of 229 metres above mean sea level and it geographically lies at latitude of 30°58'29"N and longitude of 75°44'10.87"E with an average rainfall of 734 mm of which about 80% is received during the monsoon season. The site has sub-tropical and semi-arid climate with a hot dry summer from March to June, wet monsoon season from late July to mid-September and a cool, dry winter from October to February. The soil of the experimental site from top to 15 cm layer is silt loam in texture with pH 8.3 and electrical conductivity 0.51 dS m^{-1}.There were 5 treatments and each treatment was replicated thrice. The treatment includes paddy straw mulch (T_1), biodegradable plastic mulch (T_2), black polypropylene woven mats (T_3), hand hoeing at monthly intervals (T_4) and without weeding (T5). The field was ploughed properly and levelled before making the experimental plots. One year old seedlings of guava cultivar 'L-49' used as rootstock were planted during the month of July in two square meter plots. The seedlings were planted at a distance of 15 x15 cm in paired rows which were kept 45 cm apart. All the cultural practices like irrigation, plant protection and fertilizer application except weed management were carried out uniformly. The application of plastic mulches was done after taking the required length of film for the plot of size 2x1 square metre per one replication. The polypropylene mulch was spread in the plots by anchoring one end of the mulch film in the soil approximately 4 - 6 inch by using iron pegs and then it was unrolled along the length and width of the plot and finally the other end of the mulch sheet was also firmly buried into the soil. The guava seedlings were planted in the holes made in the mulch sheets at the spacing of 15 cm on tightly laid mulch sheets. The paddy straw mulch 6 cm in thickness was spread @ 4 tons per acre all over the plot i.e. beneath the guava seedlings and in between the rows of seedlings after the transplanting of the seedlings. A control plot was kept for comparison with other treatments in which no weeding was done. The different mulching treatments were also compared with standard practice of weeding at monthly intervals throughout the season. Soil temperature was estimated by inserting soil temperature thermometer at 10 cm depth in the soil and the reading was noted after 30 minutes at weekly intervals and then average monthly temperature was expressed in °C. Soil moisture was assessed by using the gravimetric method for which the soil samples were collected at 15 cm depth in an aluminium box with the help of soil auger from each replicate plot at monthly intervals. The samples were weighed for calculating the wet weight and there after oven dried at 105°C for about 24 hours. After removing from oven, the samples were allowed to cool down and were weighed again for dry weight and the values were calculated and expressed as percent moisture content on weight basis. The sampling for soil moisture content was delayed for 3 to 5 days if rain occurred on the day of sampling. The pattern of rainfall distribution was quite different during the two seasons, with high rain in July 2018 and August 2019, and nearly similar rainfall in September 2018 and 2019 but it was exceptionally low in September 2020 (Fig. 1). A quadrant of 0.25m^2 (0.5 m × 0.5m) was placed inside each mulch treated plot randomly. The weeds in the quadrant were removed from each plot at 30, 60, 90, 120, 150, 180, 210, 240, 270 and 300 days

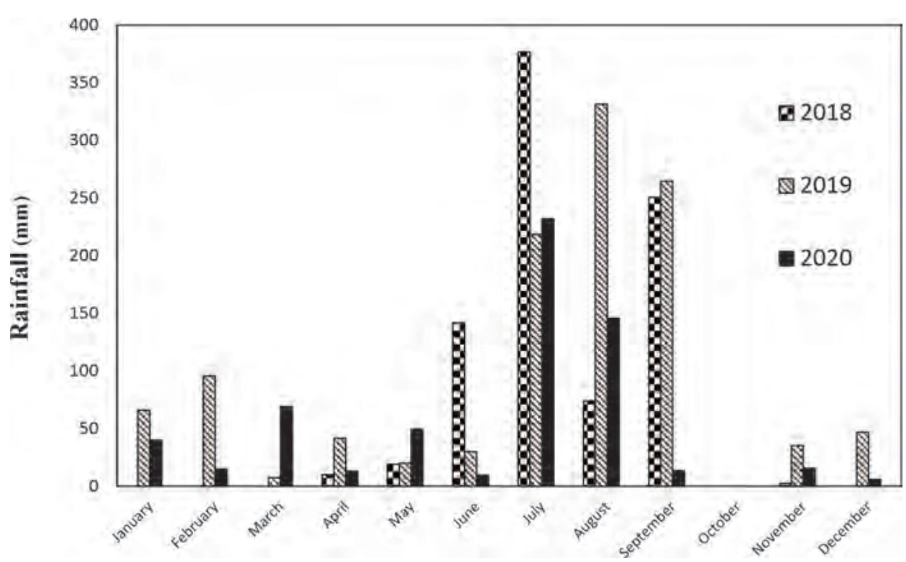

Fig. 1. Monthly mean rainfall during the 2018–19 and 2019-20

after the application of different mulches. The samples were first air-dried and later dried in oven at 65º C and the dry weight of the weed samples was recorded as the total dry weight in grams. The dry weight was finally calculated on per one square meter basis. Serial dilution spread plate technique was used for the counting of bacteria, fungi and actinomycetes colonies. The height of ten seedlings per replication was measured from soil surface to tip in centimetres with a meter scale before the start of budding operation and expressed as average for each recording date in each replication for all the treatments. The percentage of buddable plants was calculated in May with the following formula:

$$\text{Percentage of buddable plants (\%)} = \frac{\text{No. of buddable plants}}{\text{Total no. of seedlings}} \times 100$$

The experiment was laid out as per Randomized Block Design (RBD) with three replications. The data of two years was pooled and subjected to analysis of variance using SAS package (Version 9.3 SAS Institute Inc., USA) to find significance of different treatments at $p \leq 0.05$.The relationship between different factors was subjected to Pearson's correlation to generate a correlation matrix.

RESULTS AND DISCUSSION

Soil temperature

The black polypropylene woven mats consistently maintained significantly higher temperature ($P \leq 0.05$) during winter months. The maximum temperature of 36.3°C was recorded at 10 cm depth during the month of August whereas the minimum temperature of 16.4°C was observed during January in plots which received hand hoeing, which was significantly different as compared to other mulches (Fig. 2). On the other hand, paddy straw-mulched soil when compared with other treatments, recorded lower soil temperature from July to October. However, the soil temperature under paddy straw mulch varied from 24.75°C in April to 17.33°C in January and again rose to 27.24°C in the next April. The soil temperature recorded in biodegradable mulched plots was at par with the hand hoeing treated plots from August to October but maintained higher soil temperature during the subsequent winter months from November to March though it started losing its effectiveness after 150 days of application. No significant differences in soil temperature were recorded among the paddy straw mulched and hand hoeing treatment plots after 300 days of application. Generally, black polypropylene woven mats, followed by biodegradable mulch, maintained the highest soil temperatures. Hamouz *et al.* (2006) recorded an average increase in soil temperature of 1.8°C due to covering with polypropylene fibre mats. The soil temperature in the plots without straw and without covers and under polypropylene fibre mats was higher than in the plots covered with straw alone (Kosterna, 2014).Further, the present investigation shows that the least variation in temperature compared to the control plots was observed in plots mulched with black polypropylene woven mats followed by biodegradable polythene mulches. In the control as well as hand hoeing plots, higher reduction in soil temperature was noticed in the winter months. The black polypropylene woven mats, as well as biodegradable mulches, offered better insulation than the paddy straw mulch and hence significant increase in soil temperature was recorded. The increase in soil temperature may be due to the fact that these types of mats absorb UV, infrared and visible wavelength of the solar radiation (Dvork *et al.,* 2010).Organic mulches significantly decreased the soil temperature. The highest temperature differences

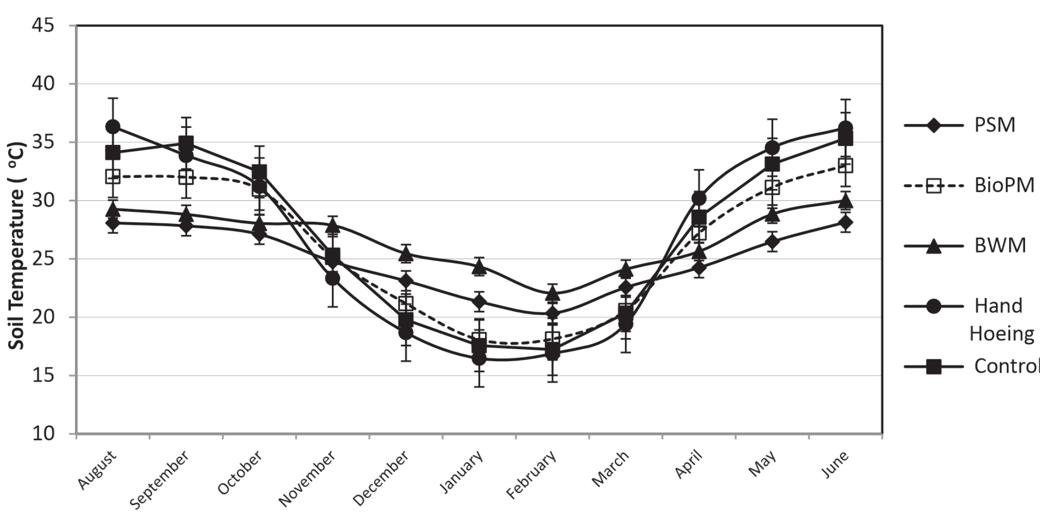

Fig. 2. Effect of different mulching treatments on average monthly soil temperature (^{0}C) in guava nursery

of 0.7 to 1.6°C were observed between plots without mulch and those mulched with straw (Sinkeviciene *et al.,* 2009).

Soil moisture content

The monthly average soil moisture percentage (Fig. 3) in the guava nursery plots under the different mulching treatments fluctuated with rainfall and air temperature over the season. However, maximum fluctuation in soil moisture content was observed in the uncovered plots (no mulching). The soil moisture content was the maximum in September due to higher rainfall, but was less in August due to limited rainfall and higher temperature. The maximum soil moisture content of 17.06 % in the plots mulched with black polypropylene woven mats during the month of September. The minimum soil moisture content of 5.76 % was recorded in the hand hoeing treated plots in the month of December. September being the wettest month recorded the maximum soil moisture content whereas minimum soil moisture was recorded in the month of December. The positive effect of all the mulching treatments was exhibited at the beginning of the study from July to February but thereafter due to the decomposition of paddy straw mulch and disintegration of biodegradable mulch no significant difference in conservation of soil moisture was observed in these mulches. On the other hand, the polypropylene woven fibre mats remained intact and thus exhibited its superiority in preserving the moisture content throughout the season. The monthly variation in moisture content during the season was also dependent on the application of irrigation and rainfall. The July month received the highest average rainfall of 376 mm as compared to 74 mm in August and 250.6 mm in September during the year 2018. The lowest moisture content during the December month was recorded as no irrigation was applied during November and December and the precipitation was almost negligible. Irrigation was applied in the January month to avoid the occurrence of frost damage to the guava nursery plants. Simsek *et al.* (2017) who evaluated different doses and thicknesses of various organic or inorganic mulches to preserve the soil moisture content reported the highest moisture content in 16 t/ha mulch application rate while the lowest was recorded in 0 t/ha mulch application rate. It was further observed that during the months of low or no rainfall, black polypropylene woven mat mulch resulted in better soil moisture retention followed by other mulching materials. Paddy straw mulch was relatively less efficient in retaining soil moisture later in the season which may be attributed to their early decomposable nature. Our results in agreement with the study conducted by Wu *et al.* (2016) who reported that plastic and biodegradable mulches retained 17 mm and 11 mm more water, than straw mulch in fallow and ingrowth period respectively. The high percentage of soil moisture content under mulches resulted in optimum absorption of nutrients and proper translocation of food materials which might have led to increased plant height and stem girth leading to higher percentage of buddable plants in guava nursery. Similarly, George *et al.* (2015) observed maximum soil moisture in black polypropylene woven mats. The intensity of turbulent exchange between the soil water and atmosphere can weaken due to the mulch layer which may results in reduction of evaporation from the soil and decreased the ineffective water consumption (Ramakrishna *et al.,* 2006).

Weed biomass

Weed biomass estimates clearly revealed that the

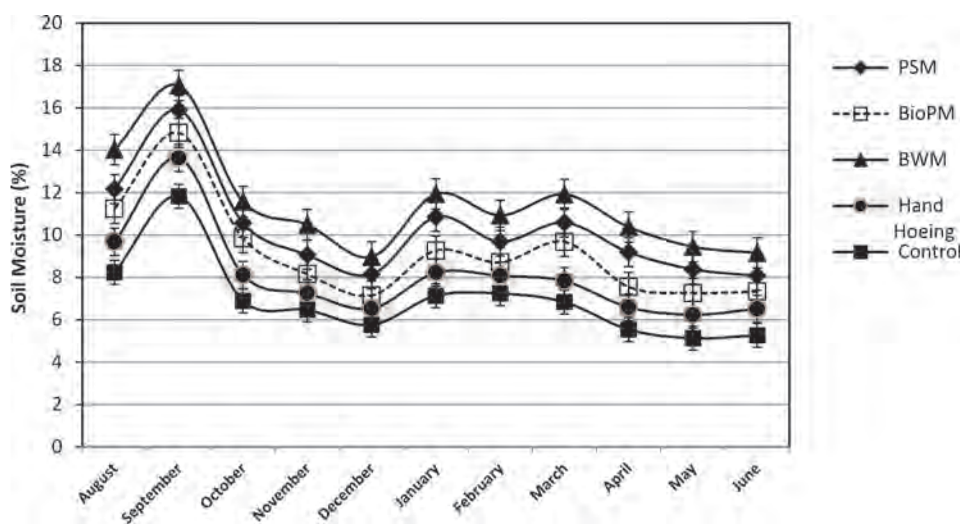

Fig. 3. Effect of different mulching treatments on average monthly soil moisture content (%)in guava nurseryplots

Table 1. Effect of different mulching treatments on weed biomass (g/m^2) in guava nursery plots

Treatment	Weed biomass (g/m^2)					
	30 days	60 days	90 days	150 days	240 days	300 days
Paddy straw mulch	1.94 (3.8)	2.49 (6.2)	2.95 (8.7)	1.76 (3.1)	2.41 (5.8)	4.53 (20.5)
Biodegradable mulch	0.42 (0.2)	1.60 (2.5)	2.15 (4.6)	2.19 (4.8)	2.32 (5.4)	4.95 (24.5)
Black weed mat	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	1.18 (1.4)
Hand hoeing	3.01 (9)	3.54 (12.6)	3.22 (10.4)	2.92 (8.5)	3.22 (10.3)	3.66 (13.4)
No weeding	4.26 (18.1)	5.34 (28.5)	6.97 (48.6)	5.24 (27.5)	6.22 (38.7)	6.52 (42.5)
LSD (p≤0.05)	0.17	0.07	0.10	0.12	0.16	0.27

Weed biomass data subjected to square-root transformation; original values are shown in parentheses.

weed population varied significantly with the application of different mulches (Table 1). Moreover, the type of weeds differed with the change in season over the period of experiment.The most commonly found summer weed species in the entire nursery plots were *Cynodon dactylon, Cyperus rotundus, Elusine indica, Digera arvensis, Euphorbia hirta* and the winter weed species observed in the nursery plots were *Chenpodium album, Anagalis arvensis, Amaranthus viridis, Argemone mexicana.* The dry weight of the weeds decreased markedly after October due to decrease in temperature which limited the weed biomass production. Weed biomass increased effectively after January likely because of the increase in temperature suitable for the growth of winter weeds. The data on weed biomass was recorded upto 300 days after mulching starting from 30 days after mulch application. Weed biomass was nil in black polypropylene woven mats till 240 days after mulch application. However, weed biomass of 1.4 g/m^2 was recorded after 300 days of mulch application. The weed biomass under paddy straw mulch varied from 3.8 to 20.5 g/m^2 whereas it varied from 0.42 to 24.5 g/m^2 under biodegradable mulch as it started losing its integrity after 150 days of application and thus recorded a higher weed biomass thereafter than the 6 cm thick layer of paddy straw mulch. Hand hoeing treatment also recorded significantly lower weed biomass than the control (without weeding) plots. Dvorak *et al.* (2010) observed that black polypropylene woven mats reduce 89 per cent weed biomass as compared to control. Black weed mat reduced the weed biomass significantly as compared to other treatments. As the weeds under black polypropylene woven mats were few right from the initial growth of the guava seedlings so there was less competition for food and space by the weeds which ultimately resulted in lower weed biomass in these plots. The black colour of the polypropylene woven mats absorbed all the radiations itself and results in least light penetration under the mulched soil which ultimately effects the growth and germination of weed seeds and weed biomass and can decrease the use of synthetic herbicides (George *et al.,* 2015).The hindrance to light penetration due to mulching results in lower weed biomass and this may also be due to increased soil temperature. We noticed a significant but negative correlation between weed biomass and guava plant height ($r = -0.946$, $n = 15$, $P = 0.001$, two-tailed; Table 4 and Fig. 4 e). Also, significant but negative correlation between weed biomass and percentage of buddable plants was recorded ($r = -0.895$, $n = 15$, $P < 0.001$, two-tailed) (Table 4 and Fig. 4f).The increased soil temperature might be responsible for killing the embryo of weed seeds. Weed population was practically nil under the black polypropylene woven mats. Polypropylene woven fabric mats worked for a longer time and resulted in better weed control and was very beneficial in the areas of less rainfall (Geyer *et al.,* 2006).

Table 2. Effect of different mulching treatments on soil microbial properties in guava nursery plots

Treatment	Fungi (cfu/g of soil × 10^3)	Bacteria (cfu/g of soil × 10^6)	Actinomycetes (cfu/g of soil × 10^5)
Paddy straw mulch	34.04 ± 2.09^a	42.33 ± 1.98^a	34.52 ± 2.16^a
Biodegradable mulch	19.43 ± 1.24^b	30.52 ± 2.35^b	23.03 ± 1.25^b
Black weed mat	15.61 ± 0.93^c	27.00 ± 1.16^c	21.41 ± 2.29^c
Hand hoeing	13.05 ± 0.58^d	24.71 ± 1.57^d	18.42 ± 0.64^d
No weeding	13.45 ± 0.89^d	24.33 ± 0.90^d	18.14 ± 2.59^e
LSD (p≤0.05)	1.95	2.09	0.04

Table 3. Effect of different mulching treatments on plant height (cm) and percentage of buddable plants in guava nursery plots

Treatments	Plant height (cm)	Percentage of buddable plants (%)
Paddy straw mulch	36.96[c]	75.92[b]
Biodegradable plastic mulch	39.39[b]	69.96[d]
Black weed mat	44.26[a]	84.73[a]
Hand hoeing	33.60[d]	74.26[c]
Control	32.59[d]	10.59[e]
LSD (p≤0.0.5)	1.25	1.63

Soil microbial count

The soil microbial count increased significantly with the application of different types of mulches (Table 2). However, the maximum microbial activity was observed in the paddy straw mulch as compared to other mulches. The highest fungi count (34.04×10^3 cfu/g of soil), bacterial count (42.33×10^6 cfu/g of soil) and actinomycetes count (34.52×10^5 cfu/g of soil) was observed under the plots mulched with paddy straw mulch (34.04×10^3 cfu/g of soil) and minimum of fungi count (13.45×10^3 cfu/g of soil), bacterial count (24.33×10^6 cfu/g of soil) and actinomycetes count (18.14×10^5 cfu/g of soil)was found in control, respectively. Among the inorganic mulches, biodegradable mulch recorded higher fungi count (19.43×10^3 cfu/g of soil), bacterial count (30.52×10^6 cfu/g of soil) and actinomycetes count (23.03×10^5 cfu/g of soil) than the polypropylene woven fibre mats. The decomposition of organic materials influences the fungi and actinomycetes population and a significantly higher fungi and actinomycetes population under all the mulched treatments were reported by Muhammed *et al*. (2015). Tiquia *et al.* (2002) reported increased microbial colonies/population under paddy straw mulch due to increased organic carbon content of the soil due to mulching as it is one of the major constituents of food for the microorganisms. The actinomycetes population may be influenced with the decomposition of organic materials. Das and Dutta (2018) reported the highest microbial population under the paddy straw mulch followed by other mulching treatments while it was lowest under the control. A large number of microbial populations are indicative of better soil health and increased nutrient availability to plant. The activity of microorganism is greatly affected with the soil moisture content. The increase in the population might be due to the favourable soil moisture conditions (Aswathi *et al.,* 2006).

Plant height

The data reveals that height of guava plants in the nursery plots increased significantly with the application of different mulches (Table 3). The maximum plant height (44.26 cm) was recorded in the plots mulched with black polypropylene woven mats. Biodegradable mulch showed superior results in terms of plant height (39.39 cm) as compared to paddy straw mulch (36.96cm) because during the initial period of plant growth biodegradable mulch was intact and helped the plants in attaining good growth by maintaining higher soil moisture and soil temperature as compared to paddy straw mulch. However, minimum plant height was recorded under control (32.59 cm) which was at par with the hand hoeing treatment (33.60cm). Plant height of guava showed a strong and significant positive correlation with soil moisture in nursery ($r = 0.954$, $n = 15$, $P < 0.01$, two-tailed) (Table 4 and Fig. 4b). Similarly, plant height of guava had a strong and significant positive correlation with soil temperature in nursery ($r = 0.550$, $n = 15$, $P < 0.05$, two-tailed) (Table 4 and Fig. 4a). The observation are in confirmation with the results of Kosterna *et al.* (2014) who recorded significantly higher plant height in plots mulched with weed mats in comparison to paddy straw mulch. The increase in plant height was due to higher soil moisture conservation which mitigated water stress whereas Das and Dutta (2010) reported a maximum increase in plant height (7.46 %) under the paddy straw mulch as compared to other treatments.

Table 4. Correlation between soil parameters and weed parameters

Characteristic	Soil temperature	Soil moisture content	Weed biomass
Plant height	0.550*	0.954**	-0.946*
Percentage of buddable plants	0.521*	0.723**	-0.895*

*Correlation is significant at the 0.05 level (two-tailed). **Correlation is significant at the 0.01 level (two-tailed).

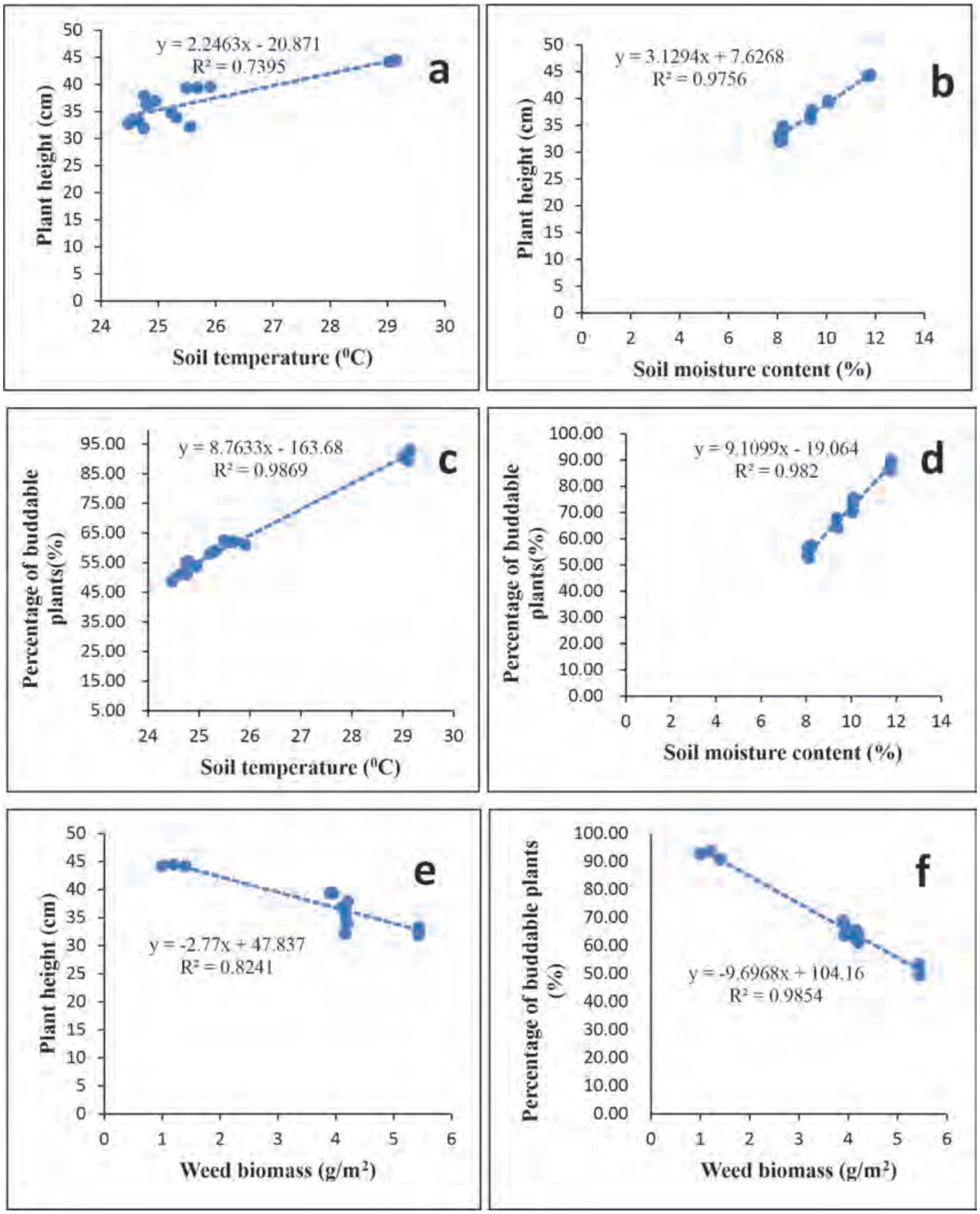

Fig. 4. Relationship between (a) plant height and soil temperature, (b) plant height and soil moisture content (c) percentage of buddable plants and soil temperature (d) percentage of buddable plants and soil moisture content, (e) percentage of buddable plants and weed biomass, (f) plant height and weed biomass in guava nursery plots. The regression coefficient values (R^2) are adjusted.

Buddable plants

The percentage of buddable plants varied significantly with the application of different mulches (Table 3). The highest percentage of buddable plants (84.73%) was recorded in the plots mulched with black polypropylene woven mat. However, the plots mulched with paddy straw (75.92%) produced significantly higher percentage of buddable guava plants as compared to biodegradable mulch (69.96%) and hand hoeing treatment (74.26%). The minimum percentage of buddable plants was recorded in control (10.59%). Percentage of buddable plants of guava had a strong and significant positive correlation with soil moisture in nursery ($r = 0.723$, $n = 15$, $P < 0.01$, two-tailed) (Table

4 and Fig. 4 d). A strong and significantly positive correlation between percentage of buddable plants of guava with soil temperature was observed in nursery (r = 0.521, n = 15, P < 0.05, two-tailed) (Table 4 and Fig. 4 c). Thakur *et al*. (2013) reported that highest percentage of buddable plant was recorded under paddy straw mulch. The increase in the buddable percentage of plants due to the increase in stem girth is due to the mulching treatments. The soil moisture conservation due to mulches and suppression of weeds resulted in highest proportion of buddable plants whereas the reduction in percentage of buddable plants in control plots can be associated with increased competition for nutrients and moisture.

The use of black polypropylene woven mats had a positive effect on soil temperature during winters, which lead to better growth of guava seedlings than control. The buddable seedlings of guava were found to be 84.7 % under black woven mat as compared to only 10.6 % under control. It was further observed that during the months of low or no rainfall, black polypropylene woven mat mulch resulted in better soil moisture retention followed by other mulching materials which can result in lower irrigation requirements. Weed biomass was nil in black polypropylene woven mats till 240 days after mulch application and only 1.4g/m^2 after 300 days of transplanting as compared to 42.5 g/m^2 weed biomass in control. Thus, black polypropylene woven mat mulching can prove efficient tool for weed control in fruit nurseries.

Authors' contribution

Conceptualization and designing of the research work (KKK, GK); Execution of field/lab experiments and data collection (PS); Analysis of data and interpretation (PS, KKK, JSB); Preparation of manuscript (PS, KKK, GK).

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