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Growth and Yield of Summer Squash (*Cucurbita pepo* L.) as Influenced by Different Coloured Plastic Mulches in the *Tarai* Region of Uttarakhand

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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

Summer squash is a short-duration vegetable crop with off-season nature and high economic returns per unit area. However, the early crop growth season encounters a number of abiotic stresses like low temperature and frost, which adversely affect the marketable yield and quality of the fruits. This dependency on natural factors restricts the scope of its profitable cultivation, thereby making it necessary to bring more area under protected cultivation. Coloured plastic mulches are an important component of protected cultivation, which are designed to modify the microclimate at the plant and soil levels so as to increase crop production and productivity, as well as quality of the produce, to meet the demands of the consumers. Keeping these considerations in view, the present field investigation was conducted at the Vegetable Research Centre of G. B. Pant University of Agriculture and Technology, Pantnagar (Uttarakhand) during the rabi season of 2019-20 to study

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the effect of different coloured plastic mulches on the growth and yield of summer squash (*Cucurbita pepo* L.). The experiment comprised nine treatments (bi-coloured plastic mulches) replicated thrice in a randomised block design. Results revealed that use of different coloured plastic films significantly influenced the growth and yield parameters of summer squash. Red coloured plastic mulch (V_1) recorded the maximum values for fruit length (30.78 cm), fruit yield plant^{-1} (1975.8 g), fruit yield plot^{-1} (39.51 kg) and total marketable fruit yield (365.52 q ha^{-1}), while biodegradable film of silver-black colour (V_7) and black plastic mulch (V_4) recorded the maximum plant height (cm) and plant spread (cm), respectively. The maximum diameter of the fruit (110.13 mm) was recorded under black coloured plastic mulch. Considering the prevalent climatic conditions of the *tarai* region of Uttarakhand, red coloured plastic mulch can be recommended for commercial cultivation of summer squash for obtaining higher fruit yields.

Keywords: Coloured plastic; mulch; summer squash; growth; yield; biodegradable film; fruit yield; vegetables.

1. INTRODUCTION

With the increasing demand of vegetables and health consciousness among people, it has become imperative for the growers to produce more as well as good-quality vegetables to sustain in the local, national and international markets. Apart from relying on high yielding varieties (HYVs) and good agricultural practices (GAPs), there is a need to effectively and economically utilise the resources by low-cost technologies. Of late, mulch has become one of the most effective technologies for optimum growth, yield and quality enhancement of vegetable crops besides reducing the cost of production.

The English word “mulch” is derived from the German word “*molsch*” meaning soft, beginning to decay. Mulches may also be defined as materials that are applied to, or grow upon, the soil surface [1]. Mulches have a significant role in improving soil physical, chemical and biological properties, enhancing crop productivity, protecting the crop from freezing and preventing drought stress [2-4]. Mulching is a cropping practice that entails covering the soil around (close to) plants, with organic or synthetic materials, to provide a more favourable environment for their growth and development [5]. Organic mulches, which include straws, husks, wood chips, leaves, grasses and cover crops (live mulches), saw dust, compost and manures [6], are the most commonly utilised mulches in the developing countries; however, they are subjected to decomposition, and are labour-intensive, less efficient and highly dependent upon weather and location.

The development of polyethylene as plastic film in 1938 and its introduction as plastic mulch in the 1950s significantly enhanced commercial vegetable crop production [7]. Different types of coloured plastic mulches are used with different formulations for different purposes. Previously, only black, white and transparent plastic mulches were used for vegetable farming, but the colours known today are black, white, red, brown, silver, yellow and blue. These colours affect crop physiology with their role in light absorption. For instance, black plastic mulch absorbs ultraviolet (UV), visible and infrared wavelengths of solar radiation effectively, thereby increasing soil temperature. White plastic mulch is just the opposite of black mulch; it cools the soil and is mostly used in crops that require less soil temperature [7,8]. Red plastic mulch absorbs solar radiation more efficiently than black, blue, green and yellow plastic mulches. The solar radiation transmittance follows the order of transparent>red>green>yellow>blue>black plastic mulch [9], while as per some studies, red>transparent>green>blue>yellow>black is the order of energy balance [10]. Coloured plastic mulches are designed to modify the microclimate at the plant and soil levels so as to increase crop production and productivity.

Summer squash (*Cucurbita pepo* L.), also known as bush squash, courgette, vegetable marrow, *Chappan Kaddu*, *Vilayati Kaddu*, and commonly known as zucchini, performs well in cool and moist climatic conditions, and requires approximately 16 to 27°C for its proper growth and development [11]. The *tarai* region of Uttarakhand has a great potential for this vegetable owing to its short duration, easier cultivation and off-season nature with higher economic returns per unit area. To achieve high fruit yield, this crop requires adequate soil moisture and high soil temperature during the entire growing period. Surface mulching with plastic films can prove beneficial in terms of improving soil moisture retention, maintaining soil temperature regime (without large fluctuations) and minimising loss of nutrients and water through weeds. Many studies have shown accelerated plant growth and fruit ripening under mulched conditions [12]. Coloured plastic mulches have been shown to significantly affect light absorptivity, light reflectivity, soil water loss, soil temperature, plant morphology and weed control [3]. Therefore, considering the advantages of mulching in vegetable production, keeping in view the open field condition, an investigation was conducted to study the effect of different coloured plastic mulches on the growth and yield of summer squash.

2. MATERIALS AND METHODS

2.1 Location of the Experimental Site

The trial was carried out at the Vegetable Research Centre of G. B. Pant University of Agriculture and Technology, Pantnagar (29°N and 79.30°E, and 243.84 m above msl) during the *rabi* season of 2019-20. The experimental site is located in the sub-mountainous region of the Shivalik, known as *tarai*. The weekly average meteorological data recorded during the cropping period, collected at the nearest observatory (GBPUA&T, Pantnagar), have been graphically presented in Fig. 1.

The physico-chemical properties of the experimental soil were determined by adopting standard analytical methods. The soil was sandy loam in texture, neutral in reaction (pH 7.2), low in available nitrogen (145.50 kg ha^{-1}), high in available phosphorus (21.60 kg ha^{-1}), medium in available potassium (125.13 kg ha^{-1}) and fairly high in organic carbon (0.91%).

2.2 Experimental Design and Cultural Practices

There were a total of nine treatments laid out in a randomised block design. The treatments were replicated three times, giving a total of 27 plots and a net experimental area of 270 m^2.

The seedlings of summer squash 'Cora' (F_1 hybrid) were prepared in polythene bags of 500 g capacity, using vermicompost and soil (3:1) as the growing medium, under polyhouse. The experimental field was prepared by giving one deep ploughing and three harrowings, followed by levelling, and then, divided into plots of specified size. Full doses of P_2O_5 (100 kg through DAP) and K_2O (160 kg through MOP), and half the recommended dose of nitrogen (60 kg through urea), along with well-rotten FYM

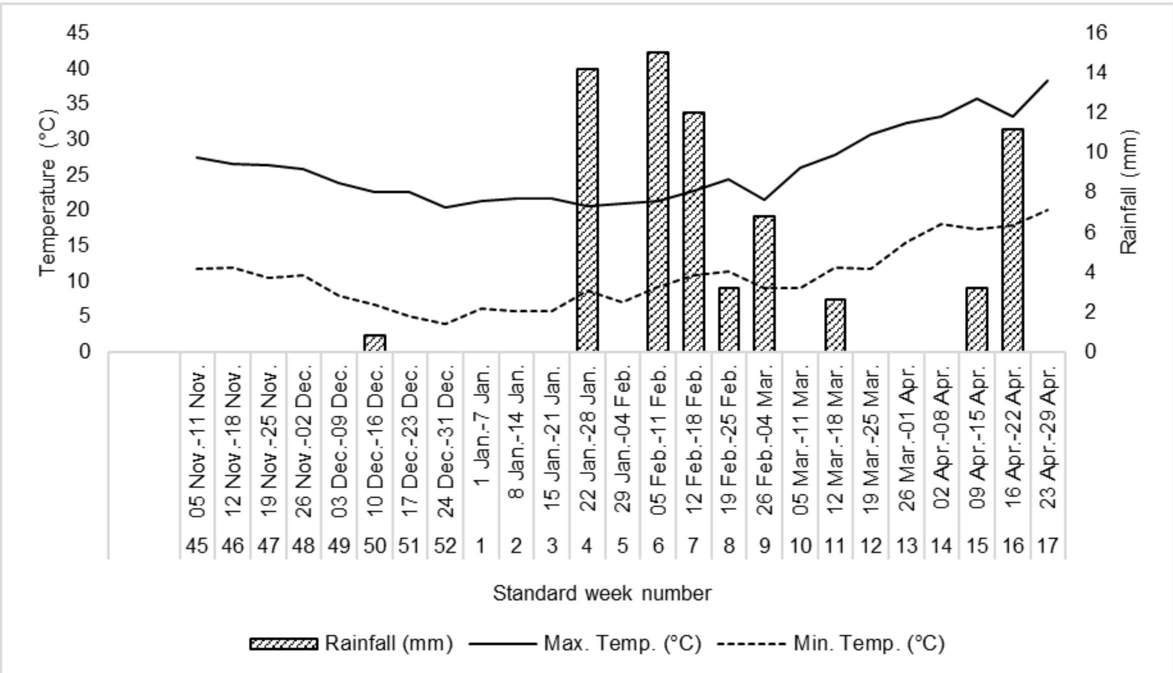

Fig. 1. Weekly average meteorological data obtained during the cropping period

Table 1. Details of the treatments along with the symbols used

Symbols	Treatments
V_1	Plastic film of red-black colour
V_2	Plastic film of silver-black colour
V_3	Plastic film of white-black colour
V_4	Plastic film of black-black colour
V_5	Plastic film of yellow-black colour
V_6	Biodegradable film of white-black colour
V_7	Biodegradable film of silver-black colour
V_8	Transparent film with herbicide application
V_9	Control (Unmulched condition)

@ 20 t ha^{-1} were applied before transplanting. The beds were manured with vermicompost @ 500 g m^{-2}, two days before transplanting.

Different bi-coloured (upper/outer surface, coloured, and lower/inner surface, black) plastic films of 25 µm thickness were applied on the beds as treatments in the present experiment. The details of the treatments have been provided in Table 1.

Holes were made on the films using a hot, thick pipe at a spacing of 90 cm × 60 cm to facilitate transplanting of the seedlings. Healthy seedlings of uniform size (10 to 15 cm in height, having two to four true leaves) were transplanted in the holes by carefully removing them along with the root ball. One light irrigation was given just after transplanting through drip system and the second irrigation was provided one week after transplanting for establishment of the root system. Further irrigations were applied as per crop demand, soil moisture status and climatic condition. The remaining dose of nitrogen (i.e., 60 kg) was applied 40 days after transplanting (DAT) as top-dressing. Recommended sprays of chemicals (fungicides and pesticides) were carried out throughout the cropping period to prevent outbreak of any disease or insect-pest.

2.3 Collection of Data

Randomly selected three plants $plot^{-1}$ were tagged for collecting data on plant height (cm), plant spread (cm) and fruit yield $plant^{-1}$ (g). Fruit length (cm), fruit diameter (mm) and average fruit weight (g) were recorded on three randomly selected fruits harvested at edible maturity. The weights of fruits harvested from all the 20 plants from each treatment of each replication were added and then, the average yield $plot^{-1}$ (kg) was calculated. The total yield of marketable fruits was estimated based on fruit yield $plot^{-1}$ and expressed in q ha^{-1}.

2.4 Statistical Analysis

The data recorded during the course of study were analysed statistically using MS Excel, OP Stat software (designed and developed by the Computer Section, CCS HAU, Hisar) and SPSS v.26 package and the treatment means were compared with CD (P=0.05) values for testing the significance of treatment differences.

3. RESULTS AND DISCUSSION

3.1 Vegetative Growth Traits

Plant height was significantly influenced by the use of different coloured plastic mulches. From the data (Table 2), it is apparent that the maximum plant heights (20.90 cm and 34.79 cm) were recorded under biodegradable silver-black mulch (V_7) at 30 DAT and final harvest, respectively, which was followed by black mulch (V_4). The minimum plant heights (17.21 cm and 27.33 cm) were registered by the transparent mulch (V_8) at both the growth stages. Plant spread was significantly affected by the use of different coloured plastic mulches, as is evident from Table 2. The maximum plant spread was observed under the black plastic mulch (V_4), i.e., 70.40 cm and 87.39 cm, respectively, at 30 DAT and at final harvest, followed by silver mulch (V_2) and red mulch (V_1). The plant spread was recorded minimum (41.59 cm) under unmulched condition (V_9) at 30 DAT, while transparent mulch (V_8) recorded the minimum plant spread (52.17 cm) at final harvest.

It is evident from the results that use of coloured plastic mulch significantly increased plant height and spread in summer squash. Higher plant height under biodegradable silver-black mulch may be attributed to higher photosynthesis as a result of higher uptake of nutrients due to favourable soil temperature and microclimate under plastic mulch, resulting in better growth and development of the plants. Similar findings of better growth of summer squash by the use of plastic mulch were also reported by Bhatt et al. [13] and Singh et al. [14]. Higher soil temperature under black plastic mulch improved the plant microclimate, leading to early growth and development [15]. Singh et al. [16] observed wider plant spread under plastic mulch due to more CO_2 available for photosynthesis (due to chimney effect) as plastic mulches are more impermeable to the gas. All the mulches, except transparent mulch, suppress weed population by restricting the entry of sunlight, thereby reducing the uptake of nutrients by weeds and making more nutrients available for better growth and development of the crop plants. The present finding was also in close conformity with Thapliyal et al. [17].

3.2 Fruit and Yield-Related Attributes

Mulching with different coloured plastic films had no significant effect on fruit length (Table 3). However, the maximum fruit length (30.78 cm) was observed under red plastic mulch (V_1), while transparent mulch (V_8) recorded the minimum fruit length (18.58 cm).

Contrary to fruit length, significant differences were observed among treatments for fruit diameter. The maximum diameter of the fruit (110.13 mm) was recorded under black coloured mulch (V_4), while the minimum fruit diameter (55.68 mm) was registered under transparent mulch (V_8), which was statistically at par with unmulched condition (V_9), i.e., 58.44 mm. Data in Table 3 clearly depict significant differences in average fruit weight w.r.t. different coloured plastic mulches compared to control (unmulched condition). Maximum average fruit weight (1097.67 g) was observed in red coloured plastic mulch (V_1), which was at par with V_2 (1029.00 g), V_4 (1010.17 g), V_7 (907.33 g) and V_5 (886.50 g), while the minimum average fruit weight (449.16 g) was registered in unmulched condition (V_9).

Table 2. Effect of different coloured plastic mulches on plant height (cm) and plant spread (cm) of summer squash

Treatments	Plant height (cm)		Plant spread (cm)	
	At 30 DAT	At final harvest	At 30 DAT	At final harvest
V_1: Plastic film of red-black colour	19.70	33.23	68.62	83.89
V_2: Plastic film of silver-black colour	19.80	32.49	68.91	83.62
V_3: Plastic film of white-black colour	19.62	32.06	57.54	72.54
V_4: Plastic film of black-black colour	20.55	33.77	70.40	87.39
V_5: Plastic film of yellow-black colour	19.00	31.88	60.19	75.19
V_6: Biodegradable film of white-black colour	19.28	31.00	60.01	75.05
V_7: Biodegradable film of white-black colour	20.90	34.79	67.14	82.14
V_8: Transparent film with herbicide application	17.21	27.33	41.59	52.17
V_9: Control (Unmulched condition)	17.26	27.62	40.37	53.82
CD (*P*=0.05)	2.19	4.23	11.03	12.66

Table 3. Effect of different coloured plastic mulches on fruit length (cm), fruit diameter (mm) and average fruit weight (g) of summer squash

Treatments	Fruit length (cm)	Fruit diameter (mm)	Average fruit weight (g)
V_1: Plastic film of red-black colour	30.78	99.40	1097.67
V_2: Plastic film of silver-black colour	26.89	104.94	1029.83
V_3: Plastic film of white-black colour	26.96	100.90	864.33
V_4: Plastic film of black-black colour	22.90	110.13	1010.17
V_5: Plastic film of yellow-black colour	22.44	101.65	886.50
V_6: Biodegradable film of white-black colour	28.22	97.76	724.00
V_7: Biodegradable film of white-black colour	25.56	102.89	907.33
V_8: Transparent film with herbicide application	18.58	83.52	577.66
V_9: Control (Unmulched condition)	19.44	87.66	449.16
CD (*P*=0.05)	NS	12.82	226.62

NS = Non-Significant

Table 4. Effect of different coloured plastic mulches on fruit yield plant^{-1} (g), fruit yield plot^{-1} (kg) and total marketable fruit yield (q ha^{-1}) of summer squash

Treatments	Fruit yield plant^{-1} (g)	Fruit yield plot^{-1} (kg)	Total marketable fruit yield (q ha^{-1})
V_1: Plastic film of red-black colour	1975.80	39.51	365.52
V_2: Plastic film of silver-black colour	1524.15	30.48	281.96
V_3: Plastic film of white-black colour	1253.28	25.06	231.85
V_4: Plastic film of black-black colour	1540.50	30.81	284.99
V_5: Plastic film of yellow-black colour	1296.50	25.93	239.85
V_6: Biodegradable film of white-black colour	959.30	19.18	177.47
V_7: Biodegradable film of white-black colour	1497.10	29.94	276.96
V_8: Transparent film with herbicide application	115.53	2.31	21.37
V_9: Control (Unmulched condition)	162.82	3.25	30.12
CD (*P*=0.05)	57.80	1.105	12.674

The increase in fruit length and fruit diameter may be attributed to the application of water in combination with plastic mulch. The constant favourable soil temperature and moisture provided better soil thermo-moisture regime in the root zone throughout the cropping season, which stimulated better crop growth resulting in increased fruit length and diameter under mulched condition. These results corroborate with the findings of Sezen et al. [18] in bell pepper. Similarly, Nagalakshmi et al. [19] observed the maximum diameter of fruits in chilli with the application of black plastic mulch. The higher value of average fruit weight under plastic mulch was attributed to better plant growth and development under optimum soil microclimate, resulting in better nutrient uptake. Increase in fruit weight due to mulching have also been reported by Awasthi et al. [20] in brinjal and Ambai and Joseph [21] in oriental pickling melon.

The various fruit yield parameters of summer squash were influenced by the use of different coloured plastic mulches (Table 4). Red plastic mulch (V_1) recorded the maximum fruit yield plant^{-1} (1975.8 g), fruit yield plot^{-1} (39.51 kg) as well as total marketable fruit yield (365.52 q ha^{-1}), while the transparent mulch (V_8) registered the lowest values for all the yield parameters.

Fruit number and weight are the principal components which determine fruit yield. Higher number and weight of fruits in red, silver and black plastic mulches might be the result of higher soil temperature with less fluctuation, better thermo-moisture regime of soil (leading to better soil microclimate and enhanced photosynthesis), less loss of water and better uptake of nutrients, collectively. Among all the coloured plastic mulches used, significantly higher fruit yield was recorded under red plastic film as red wavelength reflected form the mulch surface was trapped by the plant canopy, leading to higher photosynthetic efficiency. On the other hand, the reduced yield under transparent mulch may be attributed to abundant weed growth under the mulch surface, leading to reduced nutrient availability and its uptake by the crop. Ansary and Roy [22] observed higher yield of watermelon in mulched treatment as compared to control, due to higher vegetative growth under mulches. Similar results were also recorded by Bhatt et al. [13], Singh et al. [14] and Thapliyal et al. [17] in summer squash; Hedau and Kumar [23] and Singh et al. [24] in tomato; Singh et al. [16] in bitter gourd; Awasthi et al. [20] in brinjal; and Nimah [25] in cucumber.

4. CONCLUSION

Based on the results, it can be concluded that use of red coloured plastic mulch enhanced both growth and yield-attributing characters in summer squash, keeping in view the prevalent climatic conditions of the *tarai* region of Uttarakhand. Besides red coloured plastic film, silver-black, black-black and biodegradable silver-black films also proved effective in increasing yields of the crop. Hence, red coloured plastic mulch can be recommended for commercial open-field cultivation of summer squash for getting higher fruit yields.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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