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Protected strawberry culture at high altitude temperate climate as influenced by planting time, mulching and soil moisture

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ABSTRACT

An experiment was conducted on growing strawberry under polyhouse environment having three planting dates (mid September, mid October and mid November), and three types of mulches (black and clear polyethylene and grass straw (*Cymbopogon martini*) and without mulch as control). Irrigation level/ week was kept constant for each replication. Runners planted in mid September and beds mulched with black polyethylene improved fruit quality with comparatively better size (3.0 cm length, 2.9 cm dia. and 11.7 g) and was also effective in retaining better amount of soil moisture for longer duration even on the 7th day after irrigation with 30.3% in rainy season to 18.4% in summer. This treatment combination also improved plant growth, *i.e.*, 37.0 cm plant spread, 58.4 cm^2 leaf area and 36.5% dry matter and 159.0 g fruit yield/ plant. Grass mulch in combination with September planting time was effective in improving plant growth in terms of plant spread (37.0 cm), leaf number/ plant (19.1), leaf area (62.3 cm^2) and dry matter (36.2%) as well as fruit physico-chemical properties like TSS (10.8^{0}Brix), total sugars (7.5%) and ascorbic acid (44.1%). Moisture retention was the lowest (18.5%) in summer in comparison to rainy season (31.3%) even under black polyethylene mulch irrespective of planting time depicting the seasonal effect on the soil moisture content. Clear polyethylene encouraged weed growth (355.3-362.8 weeds/ bed). Highly significant positive correlations were recorded among soil moisture, plant dry matter and different growth and fruit characters. Leaf area and number of leaves/plant positively influenced fruit size, weight and fruit yield/plant which can be used for prediction of fruit yield of strawberry.

Key words: *Frageria* × *ananassa*, mulching, protected cultivation, plant growth, fruit quality.

INTRODUCTION

Strawberry (*Frageria* × *ananassa* Duch.) is a delicious berry fruit with very good market value for its fresh consumption as well as for processing. However, its cultivation in Uttarakhand, a central Himalayan state in India, is restricted in the low to mid hills, which experience favourable winter and spring weather. The main hurdle for its cultivation in high altitude is inclement weather such as freezing temperature, frost and chilling wind during winter and hail storm accompanied by low temperature. Another important factor is maintenance of optimum level of soil moisture, which is essential at critical growth stages and fruiting of strawberry. Moreover, water shortage is becoming serious problem in the hills during fall, winter and spring period due to change in precipitation/snowfall pattern over the years. Timely irrigation is beneficial not only for better plant growth and yield of quality fruits, but it protects the beds from drought stress, frost damage and extreme heat inside the polyhouse during the strong sunny days. Mulching of strawberry beds with various plastic films or any organic material helps to preserve water in the soil, maintain soil temperature, control weed growth, protect plants from injury caused by soil freezing/ thawing cycles in winter and also protect the delicate berries from any damages (Fernandez, 4).

Apart from these, planting time is very much important as it varies from region to region depending upon agro climate, and accordingly, recommended planting times in different part of India are fall (September to November), spring (March) and even in August (Sharma and Sharma, 13). Physiological disorder like albinism becomes a common problem when growing environment, mulching, planting time, fertilizer and cultural practices are not favourable (Sharma and Sharma, 12). Thus, it becomes very significant to investigate plant growth, fruit yield and quality in relation to soil moisture status, mulching and planting time under protected strawberry production system. Considering the high altitude climatic conditions of central Himalayas and importance of strawberry for crop diversification in the area, the present study was undertaken to examine the suitability of strawberry culture under polyhouse conditions by manipulating planting time and mulching material.

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MATERIALS AND METHODS

The present study was conducted during the years 2007-2010 in polyhouse at the Regional Station, Central Institute of Temperate Horticulture, Mukteshwar, Uttarakhand, India, situated at an altitude of 2,200 m above mean sea level. Healthy bare rooted runners of strawberry cv. Blakemore were planted on raised beds of 1.5 m × 2 m having 16 runners/ bed at spacing of 45 cm × 35 cm. The experiment with two factors, planting date at three levels and mulching at four levels was laid out under Randomized Block Design, which comprised twelve treatments (three replications) namely T_1 = Mid September x Black polyethylene, T_2 = Mid September × Clear polyethylene, T_3 = Mid September × Grass straw (*Cymbopogon martini*), T_4 = Mid September × No mulch, T_5 = Mid October × Black polyethylene, T_6 = Mid October × Clear polyethylene, T_7 = Mid October × Grass straw, T_8 : Mid October × No mulch, T_9 = Mid November × Black polyethylene, T_{10} = Mid November × Clear polyethylene, T_{11} = Mid November × Grass straw, and T_{12} = Mid November × No mulch. Recommended fertilizers at the rate of 34 g/m^2 N, 15 g/m^2 P_2O_5 and 34 g/m^2 K_2O were applied and other cultural operations were performed as per package of practices. Overhead irrigation was applied at interval of 7 days at the rate of 4.5 l/plant (Sturm, 15). Observations on plant growth parameters such as plant spread (cm) and length (cm), primary root numbers/ plant, crown numbers/ plant, crown collar diameter (cm) and average leaf number/ plant were recorded as per standard procedures. Average leaf area (cm^2) per plant was measured by leaf area meter (Li-COR). Three plants per replication were taken for plant dry matter {(dry weight/fresh weight)/100} determination (Al-madhagi *et al*., 1) from the beds, which were separately maintained. Fresh weight of each sample was taken and thereafter, kept in hot air-oven at 60°C over night to take dry weight. Phenological parameters such as bloom duration, peak bloom duration (dates and days), flower trusses/ plant and flowers/ truss as well as fruit set (%) were also recorded. Different physical parameters of fruit such as fruit length (cm), diameter (cm) and weight (g), and chemical parameters such as total soluble solids (°Brix), total sugars (%), ascorbic acid (%) and acidity (%) were estimated as per standard procedures (Anon, 2). Average yield (g/plant) was determined by accumulating weight of fruits harvested at different interval. Harvest duration (days) for each treatment was counted from the first harvesting to last harvesting.

All the damaged fruit were considered as rejected fruits, whereas, fruits affected by physiological disorder albinism were diagnosed on the basis of symptoms. Soil samples for soil moisture determination as per gravimetric method (Black, 3) were collected on 2nd, 4th and 7th day after irrigation every week. Soils were collected by coring upto 15-20 cm depth and sample of each bed was mixed to make a single composite sample. Wet soil samples with boxes were weighted and were dried in hot air oven for 24 h at 105^{0}C and soil dry weight was measured. Soil moisture content in per cent [{(wet soil weight excluding the weight of box - soil dry weight excluding the weight of box)/soil dry weight excluding the weight of box} × 100] for each treatments was recorded. Average soil moisture content for each month and season was calculated, and grouped into Fall (September, October and November), Winter (December, January, February), Spring (March and April), Summer (May and June) and Rainy season (July and August). Three years pooled data were analyzed as per the standard statistical procedure.

RESULTS AND DISCUSSION

Amongst all the treatment combinations of planting time and mulching, early flowering (6th February), extended duration of flowering (149 days) and longer peak bloom period (15 days) were recorded (Table 1) in treatment comprising September planting of runners and black polyethylene mulch (T_1). Grass mulches with September planting (T_3) gave higher flower trusses/ plant, flowers/ truss, higher plant length and spread (11.8, 20.3, 32.0 and 37.0 cm respectively), closely followed by treatment combination of black polyethylene and September planting. These two treatments also resulted in higher fruit set (68.8 and 65.3%) and gave better result for higher number of leaves per plant (19.1 and 18.4) and average leaf area/ plant (62.3 and 58.4 cm^2). Advancement in bloom with appropriate mulch type and planting time under protected conditions was also reported by Pires *et al*. (11). Rooting and plant dry matter of the September planted plants were recorded to be better under black polyethylene mulch with values of 8.4 primary roots, 26.5 cm average root length/plant and 36.5% plant dry matter. Grass mulch on September planted strawberry plants also improved primary roots (7.9) and dry matter (36.2%). September planting and black polyethylene as well as grass mulches (Table 2) were again found to be good for improving fruit quality namely fruit length 3.0 and 3.0 cm, diameter 2.9 and 2.8 cm and weight 11.7 and 10.8 g, TSS 10.2 and 10.8°Brix, total sugars 7.4 and 7.5% and ascorbic acid 44.2 and 44.1%, respectively. September planting along with either black polyethylene and grass mulch were found to be beneficial for higher yield/plant (159.0 and 154.0 g) and extended the harvest duration

Table 1. Reproductive and vegetative parameters of starawberry cv. Blakemore plants as affected by planting dates and mulching.

Treatment	Flowering duration (days)	Flowering duration (date)	Peak bloom (days)	Flower trusses/ plant	Flower/ truss	Fruit set (%)	Plant length (cm)	Plant spread (cm)	Crown Nos./ plant	Crown collar dia. (cm)	Av. leaf Nos./ plant	Leaf area (cm^2)	Primary root Nos./ plant	Av. root length (cm)	Plant dry matter (%)
T1	149	6/2-1/7	15	10.8	19.8	65.3	31.5	36.4	7.1	4.2	18.4	58.4	8.4	26.5	36.5
T2	136	10/2-25/6	11	9.4	18.5	62.5	28.4	33.5	6.9	4.1	17.6	53.7	7.6	25.4	32.4
T3	134	15/2-28/6	13	11.8	20.9	68.8	32.0	37.0	6.8	4.2	19.1	62.3	7.9	25.2	36.2
T4	122	10/3-11/6	8	6.6	11.3	45.6	20.3	24.6	4.1	3.0	12.3	43.5	5.7	17.2	25.1
T5	140	10/2-29/6	11	7.5	16.4	60.4	25.4	33.5	6.6	4.0	18.2	52.4	7.4	22.0	35.8
T6	128	15/2-22/6	10	6.3	15.2	55.4	21.6	28.6	6.5	3.9	15.5	50.5	7.1	20.2	30.2
T7	128	18/2-25/6	11	7.0	16.8	55.2	26.6	32.4	6.8	4.0	18.0	55.6	7.0	23.3	34.3
T8	100	20/3-27/6	9	5.0	9.5	40.3	17.4	22.6	4.0	3.5	12.7	40.6	5.2	15.4	24.3
T9	103	1/3-11/6	9	7.2	16.4	50.3	21.3	30.4	6.0	3.8	17.5	50.5	6.0	21.5	30.5
T10	100	3/3-10/6	10	6.0	15.6	48.5	20.4	28.4	5.5	3.5	14.4	48.7	5.4	20.3	26.3
T11	97	5/3-9/6	8	6.5	16.8	53.4	22.5	30.6	6.0	3.7	15.6	50.5	6.1	22.4	30.0
T12	94	10/3-11/5	8	4.0	8.7	38.5	15.5	16.5	4.0	2.8	10.2	38.6	5.4	15.2	21.8
CD at 5%	0.55	--	0.60	0.50	3.16	5.17	1.23	2.28	0.25	0.40	1.26	2.30	0.25	0.27	1.67

Table 2. Fruit quality parameters of stawberry cv. Blakemore and weed abundance as affected by planting dates and mulching.

Treatment	Fruit length (cm)	Fruit dia (cm)	Fruit wt. (g)	TSS (^{0}B)	Acidity (%)	Total sugars (%)	Ascorbic acid (%)	Yield/ plant (g)	Harvest duration (days)	Rejected fruits (%)	Albinism (%)	Weed abundance (weeds/ bed)
T1	3.0	2.9	11.7	10.2	0.9	7.4	44.2	159.0	69.7	5.4	16.5	3.3
T2	2.8	2.6	10.5	9.9	1.0	6.7	43.1	147.1	50.7	6.1	13.2	362.8
T3	3.0	2.8	10.3	10.8	0.8	7.5	44.1	154.0	75.7	10.1	10.4	152.0
T4	2.4	2.3	6.3	9.6	1.5	5.8	34.3	59.3	45.6	30.3	14.7	402.0
T5	2.8	2.5	9.9	9.6	1.3	7.1	41.2	139.0	60.5	6.9	28.4	4.6
T6	2.3	2.1	7.0	9.3	1.3	6.4	39.0	121.4	48.7	8.9	19.4	349.8
T7	2.9	2.6	8.7	9.8	0.9	7.4	40.1	132.3	62.5	12.6	11.2	149.7
T8	2.3	2.1	6.2	9.5	1.7	5.7	34.2	52.4	42.7	40.4	23.3	426.3
T9	2.6	2.4	7.5	9.7	1.3	7.0	37.4	100.6	50.7	7.1	28.9	3.5
T10	2.7	2.6	7.1	9.2	1.3	6.1	37.2	80.5	47.8	8.6	17.6	355.3
T11	2.5	2.3	7.1	9.7	1.2	7.3	37.1	97.4	56.8	12.9	12.2	163.0
T12	2.2	2.1	5.2	8.9	1.4	5.8	34.1	42.1	35.4	36.9	23.9	411.6
CD at 5%	0.15	0.11	0.15	0.14	0.12	0.11	1.57	4.52	1.12	2.23	1.61	8.34

(69.7 and 75.7 days). All the treatments laid out in the month of October and November as well as no mulch treatments (T_4, T_8 and T_{12}) at three different planting times resulted in comparatively lower values for all the vegetative as well as reproductive parameters irrespective of mulching types. Beneficial effect of black polyethylene mulch on all these parameters of strawberry plant and fruit were also reported by Singh *et al*. (14). Plant dry matter content is always used as measure for productivity of any plant and it's built up and dissemination in different plant organs is dependent on generation and distribution of assimilates as well as growth regulators (Al-madhagi *et al*., 1). Use of black polyethylene as mulch almost completely restricted the weed growth (3.3-4.6 weeds/ bed) irrespective of planting time (Table 2), whereas, maximum weed abundance was recorded in all the beds, which were not mulched (402.0-26.3 weeds/ bed). Clear polyethylene also facilitated comparatively higher number of weeds (349.8-355.3 weeds/bed). Grass straws mulch resulted much less weeds (152.0-163.0 weeds/ bed). Clear polyethylene mulch allows penetration of light, increases soil temperature and abundance of weeds, and has been always reported to be a problem which ultimately competes with strawberry plant growth, yield and fruit quality. Black polyethylene has been always proved to be good mulch material and prevents weed growth (Molinar and Yang, 10). Mulching always protects delicate fruits from any damage and only 5.4% fruits were rejected under black polyethylene mulch on September planted beds, whereas, 30.3-40.4% fruits were rejected when mulch was not applied. However, September planting and grass mulch resulted minimum albinism (10.4%). Higher albinism was recorded in the beds without mulch (23.9%) in November planting. Late planting augmented fruit albinism irrespective of mulching type. Though incidence of albinism was slightly higher under black polyethylene mulch in comparison to grass mulch with September planting combination, however, black polyethylene mulch improved over all plant growth, yield and fruit quality (Kher *et al*., 6). Moreover, good mulching of strawberry beds protects the delicate berries from any damage from direct soil contact apart from modifying microclimate around strawberry plants (Sharma and Sharma, 12; Singh *et al*., 14).

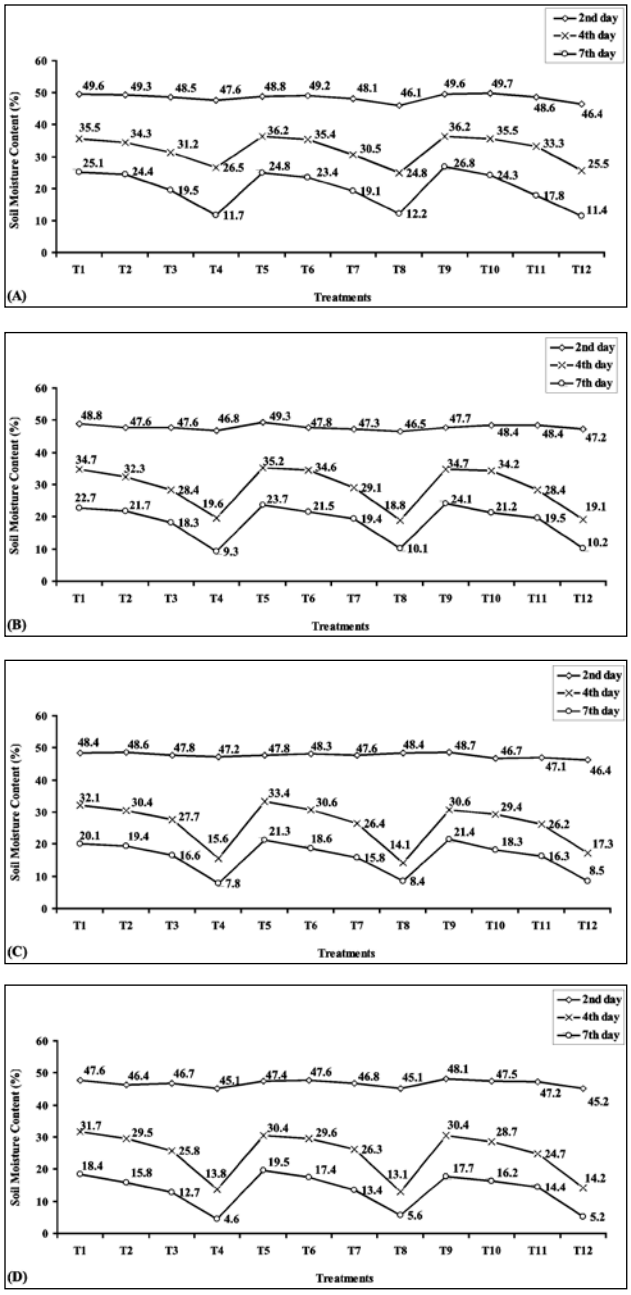

Fig. 1. Soil moisture (%) content in different treatments at three intervals/ week during (A): fall, (B): winter, (C): spring and (D): summer season.

Comparatively sufficient moisture was retained in the soil of mulched beds (Fig. 1A, B, C, D and 2E) than the beds without mulch as days progressed in each week till the beds were again irrigated at weekly interval throughout the year. Black polyethylene was again found to be very effective in conserving soil moisture in successive days as observed on 4th and 7th day after irrigation in each week with range of 41.1% (T_9 in rainy season) to 30.4% (T_5 in summer) and 32.4 (T_5 in rainy season) to 17.7% (T_{10} in summer) respectively. Grass straw mulch also conserved sufficient percentage of moisture (26.2% in T_{11} in rainy season and 12.7% in T_3 in summer) in comparison to beds without mulch which retained only 20.3% (T_4 in rainy season) to 4.6% (T_4 in summer season). This is also very clear (Fig. 2F) that there are significant effects of mulch type and season

on soil moisture status under polyhouse environment. Summer and spring seasons experience comparatively less rainy days in the hills of Uttarakhand and day temperature is relatively higher as a result of which moisture retention in the 7th day after irrigation was very less in both the seasons. In rainy season, reduced rate of evapo-transpiration inside the polyhouse due to frequent rains and continuous cloudy days results higher soil moisture retention under black polyethylene mulch. Improved soil moisture status under appropriate mulches creates favourable soil microclimate and influences biological activities and soil mineralization which have positive effect on plant health. Kruger *et al*. (7) reported that plant water status influences photosynthesis and consequently plant growth, and water deficit has a direct action on metabolic and physiological processes resulting in increased stomata activities. Mingchi *et al*. (9) also clearly indicated that plant height, number of leaves, fruit weight, fruit diameter, fruit number and yield gradually decreased with the decreasing trend of soil moisture, and physico-chemical properties of fruit also differed under different soil moisture levels. Beneficial effect of black polyethylene and grass mulch along with optimum soil moisture status on the strawberry yield as well as fruit size, sugar content and TSS/acid ratio has been also been reported by Kumar *et al*. (8).

Correlation analysis (Table 3) among different parameters gave a very close relationship among the vegetative and reproductive parameters for better plant growth and higher production of quality fruits. Soil moisture, plant dry matter, leaf area, plant length, plant spread, average root length, primary root numbers, flowers/truss, fruit set, fruit weight, fruit diameter and fruit yield (g/ plant) were significantly positively interrelated among themselves with correlation coefficient (r-values) range of 0.51 (soil moisture and flowers/ truss) to 0.96 (leaf area and plant spread). More specifically, leaf area was highly significantly correlated with fruit set (r = 0.96) and fruit yield (r = 0.94) and with other vegetative characters namely plant length (r = 0.92), plant spread (r = 0.96) and root length (r = 0.94). Hortynski *et al*. (5) also reported that fruit size is mainly depended on micro-environment such as air and soil temperature, humidity as well as rainfall apart from plant physiological and genetic nature. Positive correlation among soil moisture, fruit size, fruit diameter, fruit weight, total or average yield, leaf area and inflorescence quality was also observed by Mingchi *et al*. (9). In the present study, positive effect of larger leaves and higher leaf area on fruit yield and quality may be due to development of better photosynthetic area and sugars are translocated from leaf to other plant organs and maturing fruits. Moreover, sugars are converted into starch in roots for winter storage. Thus, leaf area or number of leaves per plant, especially in fall or early winter, ultimately positively influence fruit size, weight and fruit yield/plant which can used for prediction of fruit yield per plant of strawberry in the spring.

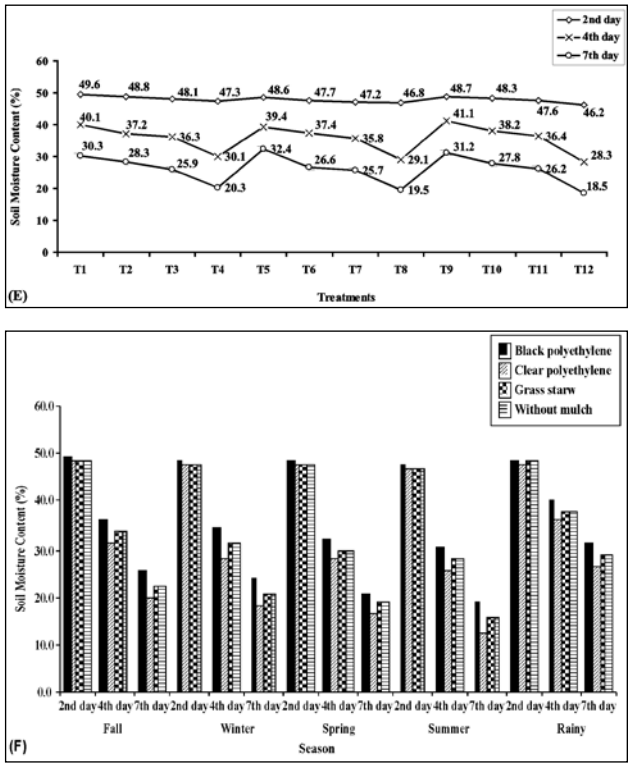

Fig. 2. (E): Soil moisture (%) content in different treatments at three intervals/ week during rainy season, and (F): mulching and seasonal effect on soil moisture content (%) under polyhouse.

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Table 3. Correlation (r values) among soil moisture, different vegetative and reproduction parameters of strawberry cv. Blakemore.

Parameter	Soil moisture (%)	Plant dry matter (%)	Leaf area (cm^2)	Plant length (cm)	Plant spread (cm)	Av. root length (cm)	Primary root No./ plant	Flowers/ truss	Fruit set (%)	Fruit wt. (g)	Fruit dia. (cm)
Plant dry matter (%)	0.76										
Leaf area (cm^2)	0.68	0.90									
Plant length (cm)	0.55	0.86	0.92								
Plant spread (cm)	0.74	0.93	0.96	0.91							
Av. root length (cm)	0.72	0.90	0.94	0.89	0.94						
Primary root No./ plant	0.62	0.92	0.87	0.89	0.85	0.86					
Flowers/ truss	0.51	0.80	0.89	0.95	0.87	0.87	0.85				
Fruit set (%)	0.70	0.92	0.96	0.93	0.95	0.93	0.93	0.91			
Fruit wt. (g)	0.63	0.91	0.89	0.93	0.91	0.91	0.92	0.92	0.93		
Fruit dia. (cm)	0.63	0.71	0.81	0.84	0.80	0.81	0.68	0.83	0.76	0.83	
Fruit yield (g/ plant)	0.74	0.95	0.94	0.90	0.92	0.94	0.92	0.88	0.90	0.94	0.74

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