

Mulch type influences plant growth, albinism disorder and fruit quality in strawberry (*Fragaria × ananassa* Dusch.)

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Mulch type influences plant growth, albinism disorder and fruit quality in strawberry (*Fragaria × ananassa* Dusch.).

Abstract — Introduction. Albinism is a serious physiological disorder of strawberries in which fruits appear bloated, develop poor color and flavor, and become susceptible to fruit rot during storage. Many factors have been reported to be associated with albinism, but vigorous vegetative growth of the plants is considered as the primary factor. Mulching is the most important cultural practice in strawberry, which is known to influence plant growth, yield and fruit quality. Our studies aimed at observing the influence of different types of mulch materials on strawberry growth and albinism disorder. **Materials and methods.** Studies were conducted with five cultivars (Sweet Charlie, Chandler, Douglas, Fern and Etna) cultivated with three types of mulch materials (black polyethylene, white polyethylene and paddy straw). No mulch was used as a control. Observations were recorded on plant growth parameters, albinism incidence and fruit quality parameters of five cultivars under different mulch materials. **Results and discussion.** All growth parameters were better with mulching than with control. Among the different types of mulch materials, plants had the best growth with black polyethylene, but the fruits were more affected by albinism as compared with those cultivated with paddy straw mulch. Among the cultivars, the plants of Etna showed the most vigorous growth, but their fruits had the highest incidence of albinism (49.88%); those of Sweet Charlie had the lowest incidence (20.74%), primarily because of the close relationship between plant growth and albinism. **Conclusion.** Black polyethylene mulch favored better plant growth in strawberry, but enhanced the incidence of albinism in a sub-tropical climate as compared with paddy straw. Thus, paddy straw is the best option for use as mulch for strawberry in warmer localities.

India / *Fragaria ananassa* / mulches / plastic film / straw mulches / growth / albinism / quality

Effet du type de couverture du sol sur la croissance des plants, l'albinisme et la qualité du fruit chez le fraisier (*Fragaria × ananassa* Dusch.).

Résumé — Introduction. L'albinisme est une anomalie physiologique sérieuse qui induit, chez la fraise, un fruit boursoufflé, de couleur pâle et de pauvre saveur, supportant mal le stockage. De nombreux facteurs seraient associés à cette anomalie, mais le principal d'entre eux serait une forte croissance végétative des plants. Le paillage des fraisiers est une technique essentielle pour cette culture ; elle est connue pour influencer la croissance des plants, le rendement et la qualité du fruit. Nos travaux ont donc cherché à étudier l'influence, sur l'albinisme, de différents types de matériaux de couverture du sol. **Matériel et méthodes.** Les traitements ont permis de tester cinq cultivars de fraisiers (Sweet Charlie, Chandler, Douglas, Fern et Etna) cultivés sur trois types de couverture du sol (polyéthylène noir, polyéthylène blanc et paille de riz). Le traitement témoin a été constitué par une culture des fraisiers sur sol nu. Les observations ont porté sur des paramètres de croissance des plantes et de qualité du fruit, ainsi que sur l'incidence de l'albinisme pour les cinq cultivars testés sur les différents types de couverture. **Résultats et discussion.** Tous les paramètres de croissance ont été meilleurs avec les plants cultivés sur paillage que sur ceux mis sur sol nu. Parmi les différents matériaux utilisés, c'est le polyéthylène noir qui a permis la meilleure croissance des plants, mais les fruits ont alors été davantage affectés par l'albinisme que ceux obtenus sur sol recouvert de pailles de riz. Parmi les cultivars testés, les plants d'Etna ont eu la croissance la plus vigoureuse, mais leurs fruits ont eu le taux d'albinisme le plus élevé (49,88 %) ; ceux de Sweet Charlie ont eu le taux d'anomalie le plus bas (20,74 %), principalement du fait de la corrélation entre croissance des plants et albinisme. **Conclusion.** Le polyéthylène noir a favorisé la meilleure croissance des fraisiers, mais, sous climat subtropical, cette couverture a augmenté l'incidence de l'albinisme par rapport à l'utilisation de la paille de riz. De ce fait, la paille de riz pourrait être le meilleur matériau de couverture pour la culture de fraisiers dans les régions les plus chaudes de l'Inde.

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Received 7 December 2002
Accepted 13 February 2003

Fruits, 2003, vol. 58, p. 221–227
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DOI: 10.1051/fruits:2003010

RESUMEN ESPAÑOL, p. 227

Inde / *Fragaria ananassa* / mulch / film plastique / paillis / croissance / albinisme / qualité

1. Introduction

Strawberry is one of the most delicious and refreshing fruits in the world, which is cherished in gardens for its beautiful, attractive fruit that has a tantalizing aroma. Though it is a major fruit of temperate climates, it also grows profitably well in sub-tropical plains of India [1]. It suffers from many disorders, but albinism is considered as the most serious disorder of its fruits, occurring primarily at the time of ripening. It is particularly serious in greenhouse-grown strawberries, which has reached an alarming situation in the USA, Belgium and the Netherlands [2, 3], though Sharma and Sharma [4] have also observed its incidence in field-grown strawberries under sub-tropical climates. Fruit suffering from albinism appears bloated and develops white or pink areas on its surface and its pulp remains pale. It has a poor flavor and tends to be more acidic than a normal fruit. Similarly, the affected fruit does not ripen uniformly, is liable to be severely damaged during harvesting, and is highly susceptible to fruit-rot during storage [2–5]. The marketing of such a fruit is very difficult, and, if marketed, it fetches a very poor price, giving to farmers fewer returns for their investment [1, 5]. Albinism may be due to many reasons, but excessive growth due to heavy N fertilization or otherwise is considered as the most important of them [5, 6].

In strawberry cultivation, mulching is considered as the most important cultural practice which affects plant growth, fruit yield and fruit quality [1, 5, 6]. As albinism has a direct relationship with plant growth, and to check if different types of mulch materials influence albinism or not, systematic studies regarding mulch materials were conducted with five commercial strawberry varieties under a sub-tropical climate.

2. Materials and methods

The studies were conducted in the Division of Fruits and Horticultural Technology, IARI, New Delhi, India, during 2000 and 2001.

Five varieties, viz., Sweet Charlie, Chandler, Douglas, Fern, and Etna, collected from IARI, Regional Horticultural Research Station, Shimla (Himachal Pradesh), were planted on raised beds (300 cm × 60 cm × 15 cm in size) at 20 cm × 30 cm distance, during the last week of October in both the years. Three mulch materials, viz., black polyethylene (BP), white polyethylene (WP) and paddy straw (PS) were applied 15 d after planting and no mulch (NM) was applied to control plants. Each treatment consisted of five beds, replicated three times.

Observations on the growth parameters: crown height (cm), crown spread (cm), leaf number and area (cm²), and fruit number were recorded in twenty randomly selected plants per bed. Thus, observations were recorded in 100 plants per treatment, replicated three times.

Standard procedures were adopted for recording plant height (cm) and spread (cm). Twenty plants per bed were taken for recording data on fruit number and albinism incidence. For incidence of albinism, the total healthy (normal) and albino fruits were counted in the selected plants and represented as a percentage (%) which was transformed as per arcsin values before analysis. Quality parameters of normal and albino fruits were estimated as per standard procedures [7] in twenty randomly selected fruits per treatment, replicated three times. The data of two years were pooled and analyzed following a factorial randomized block design [8].

3. Results

3.1. Plant growth parameters

All plant growth parameters, viz., crown height, plant spread, leaf number and leaf area were influenced invariably by the different mulch materials. Irrespective of cultivar, plants with black polyethylene had maximum crown height (9.41 cm), crown spread (20.98 cm), leaf number (29.10), and leaf area (40.97 cm²), which were

Table I.
Effect of mulch materials on plant growth parameters for strawberry cultivated under a sub-tropical climate.

Cultivar	Crown height (cm)					Crown spread (cm)					Leaf number					Leaf area (cm ²)				
	Bp	Wp	Ps	No mulch	Mean	Bp	Wp	Ps	No mulch	Mean	Bp	Wp	Ps	No mulch	Mean	Bp	Wp	Ps	No mulch	Mean
Sweet Charlie	8.33	7.42	6.56	6.22	7.13	18.90	17.20	15.75	14.90	16.69	22.34	21.62	19.46	17.35	20.19	32.81	30.20	26.46	23.95	28.36
Chandler	10.3	9.86	8.18	7.40	8.96	22.80	20.96	19.48	17.85	20.27	34.22	32.85	30.62	28.50	31.80	46.62	44.70	42.92	39.36	43.40
Douglas	8.82	7.80	6.62	6.15	7.35	19.76	17.80	15.70	14.30	16.89	23.27	21.93	20.25	18.20	20.91	34.33	32.92	30.32	28.20	41.47
Fern	8.86	8.29	7.36	6.85	7.84	20.23	19.36	17.12	15.92	18.16	28.42	27.25	25.50	23.30	26.12	42.55	38.51	35.23	32.80	37.27
Etna	10.6	9.96	8.32	7.72	9.16	23.20	21.62	19.76	18.40	20.75	36.24	34.36	32.72	30.81	33.53	48.56	45.75	42.90	40.20	44.35
Mean	9.41	8.67	7.41	6.88	-	20.98	19.39	17.56	16.27	-	29.10	27.60	25.71	23.63	-	40.97	38.42	35.57	32.907	-

Bp = black polyethylene; Wp = white polyethylene; Ps = paddy straw; no mulch = control.
 For the crown height parameter, critical values are 0.19 for mulch, 0.26 for cultivar and 0.49 for the interaction [mulch × cultivar] ($p \leq 5\%$).
 For the crown spread parameter, critical values are 0.22 for mulch, 0.58 for cultivar and 0.47 for the interaction [mulch × cultivar] ($p \leq 5\%$).
 For the crown height parameter, critical values are 1.16 for mulch, 2.08 for cultivar and 1.76 for the interaction [mulch × cultivar] ($p \leq 5\%$).

significantly lower with white polyethylene, paddy straw or when no mulch (control) was used. Plants grown with no mulch had the least crown height (6.87 cm), crown spread (16.27 cm), leaf number (23.63) and leaf area (32.90 cm²) (table I).

Among the cultivars, Etna had the maximum crown height (9.16 cm), crown spread (20.75 cm), leaf number (33.53) and leaf area (44.35 cm²), followed by Chandler, the present day commercial cultivar in sub-tropical plains of India, and Douglas had the minimum growth. Sweet Charlie, the cultivar recently introduced from the USA, exhibited a semi-vigorous type of growth under a sub-tropical climate. Further, the interaction [mulch × cultivar] was also significant for all growth parameters (table I).

3.2. Incidence of albinism

Incidence of albinism, a serious physiological disorder, was observed to be close to 31% in field-grown strawberries under a sub-tropical climate, and it was significantly influenced by mulching.

Among the different types of mulch materials tested, the incidence was the

highest with black polyethylene (38.60%) and the lowest with paddy straw mulch (22.45%) (table II).

Among the different cultivars, the incidence of albinism was the highest in Etna fruits (49.88%) and the lowest in Sweet Charlie fruits (20.74%), non-significantly followed by Fern fruits (22.52%) (table II). The interaction [mulch × cultivar] for albinism incidence was also significant.

3.3. Fruit size and quality parameters

Interestingly, albino fruits, though low in weight (12.4 g) and TSS (7.9%), and high in acidity (0.268%), were not significantly inferior to normal fruits, except that they had a poor color development. Irrespective of cultivar, fruits with the highest weight (14.4 g) and TSS (8.9%) and lowest in acidity (0.245%) were harvested when black polyethylene was used as mulch, and fruits of normal size and good fruit quality were harvested when paddy straw was used (tables III–V). Among the cultivars, Chandler produced the biggest fruit (16.1 g), but the desirable quality parameters such as TSS (9.7%) and acidity (0.245%) were the highest and the lowest in Sweet Charlie

Table II.

Incidence of albinism (%) in strawberry fruits as influenced by different types of mulch materials.

Cultivar	Black polyethylene	White polyethylene	Paddy straw	No mulch (control)	Mean
Sweet Charlie	28.40 (32.20)	20.30 (26.78)	11.75 (20.03)	22.50 (28.32)	20.74 (27.06)
Chandler	46.56 (43.03)	40.56 (39.55)	32.75 (34.91)	44.62 (41.90)	41.12 (39.87)
Douglas	30.34 (33.40)	22.98 (28.62)	12.65 (20.83)	25.75 (30.50)	22.93 (28.59)
Fern	30.92 (33.77)	21.22 (27.42)	11.35 (19.68)	26.60 (31.05)	22.52 (28.32)
Etna	56.76 (48.88)	48.39 (44.06)	43.75 (41.41)	50.60 (45.34)	49.88 (44.92)
Mean	38.60 (38.41)	30.69 (33.62)	22.45 (28.28)	33.09 (34.42)	31.21 (33.96)

Figures in brackets are the corresponding arcsin transformed values.

Critical difference values are 1.98 for mulch, 1.95 for cultivar and 2.66 for the interaction [mulch × cultivar] ($p \leq 5\%$).**Table III.**

Fruit weight (g) of normal and albino fruits of strawberry as influenced by different types of mulch materials.

Cultivar	Normal fruits					Albino fruits					Overall mean
	Bp	Wp	Ps	No mulch	Mean	Bp	Wp	Ps	No mulch	Mean	
Sweet Charlie	15.6	14.8	14.5	11.2	14.0	14.9	14.4	14.2	11.0	13.6	12.4
Chandler	18.5	17.3	16.8	12.0	16.2	18.0	17.1	16.8	11.6	15.9	16.1
Douglas	13.6	12.5	12.2	09.2	11.9	13.2	12.4	12.0	08.9	11.6	11.8
Fern	09.9	09.0	08.8	06.3	08.5	09.3	08.6	08.5	06.0	08.1	08.3
Etna	14.5	14.0	13.8	11.2	13.4	14.0	13.6	13.5	10.8	13.0	13.2
Mean	14.4	13.5	13.2	10.0	12.8	13.8	13.2	13.0	09.7	12.4	–

Bp = black polyethylene; Wp = white polyethylene; Ps = paddy straw; no mulch = control.

Critical difference values are 0.62 for fruit weight, 0.73 for cultivar, 0.31 for mulch, 0.56 for the interaction [fruit weight × cultivar], 0.66 for the interaction [fruit weight × mulch], 0.63 for the interaction [cultivar × mulch], 1.12 for the interaction [fruit weight × mulch × cultivar] ($p \leq 5\%$).

(tables III–V). The interactions [fruit × cultivar], [fruit × mulch], [cultivar × mulch], and [fruit × mulch × cultivar] for fruit size, TSS and acidity were also significant.

4. Discussion

4.1. Growth parameters

Different types of mulch materials have been found to significantly influence the plant growth parameters of strawberry. The significant and positive influence of

mulching on plant growth may be due to conservation of moisture, regulation in temperature and suppression of weeds [9–11]. Among the different types of mulch materials, black polyethylene was observed to be the best for improving the strawberry plant growth over white polyethylene, paddy straw and control because of better moisture and temperature regulation and suppression of weeds over other mulch materials and control [12–16]. Due to these significant effects, black polyethylene has been recommended as the best mulch material for strawberry in temperate climates [10, 15, 16]. Among the cultivars, Etna

Table IV.

Total soluble solids (%) of normal and albino fruits of strawberry as influenced by different types of mulch materials.

Cultivar	Normal fruits					Albino fruits					Overall mean
	Bp	Wp	Ps	No mulch	Mean	Bp	Wp	Ps	No mulch	Mean	
Sweet Charlie	10.5	10.0	10.0	8.6	9.8	10.0	9.8	9.8	8.3	9.5	9.7
Chandler	8.3	8.0	8.0	6.3	7.7	7.9	7.6	7.5	6.0	7.3	7.5
Douglas	8.0	7.8	7.6	7.5	7.7	7.6	7.2	7.2	6.8	7.2	7.5
Fern	10.2	9.8	9.5	8.2	9.4	9.5	9.2	9.6	7.2	8.9	9.2
Etna	7.3	6.8	6.3	5.1	6.4	7.0	6.8	6.5	6.0	6.6	6.8
Mean	8.9	8.5	8.3	7.1	8.2	8.4	8.1	8.1	6.9	7.9	–

Bp = black polyethylene; Wp = white polyethylene; Ps = paddy straw; no mulch = control.

Critical difference values are 0.42 for fruit TSS, 0.53 for cultivar, 0.22 for mulch, 0.44 for the interaction [fruit TSS × cultivar], 0.51 for the interaction [fruit TSS × mulch], 0.62 for the interaction [cultivar × mulch], 1.11 for the interaction [fruit TSS × mulch × cultivar] ($p \leq 5\%$).

Table V.

Juice acidity (%) of normal and albino fruits of strawberry as influenced by different types of mulch materials.

Cultivar	Normal fruits					Albino fruits					Overall mean
	Bp	Wp	Ps	No mulch	Mean	Bp	Wp	Ps	No mulch	Mean	
Sweet Charlie	0.226	0.230	0.235	0.260	0.238	0.240	0.250	0.253	0.260	0.251	0.245
Chandler	0.246	0.253	0.258	0.266	0.256	0.258	0.268	0.272	0.285	0.271	0.264
Douglas	0.256	0.268	0.272	0.280	0.269	0.260	0.273	0.282	0.298	0.278	0.274
Fern	0.233	0.240	0.246	0.252	0.243	0.240	0.258	0.266	0.272	0.259	0.251
Etna	0.266	0.275	0.281	0.292	0.279	0.270	0.278	0.288	0.296	0.283	0.281
Mean	0.245	0.253	0.259	0.270	0.257	0.254	0.265	0.272	0.282	0.268	–

Bp = black polyethylene; Wp = white polyethylene; Ps = paddy straw; no mulch = control.

Critical difference values are 0.06 for fruit juice acidity, 0.018 for cultivar, 0.02 for mulch, 0.026 for the interaction [fruit juice acidity × cultivar], 0.033 for the interaction [fruit juice acidity × mulch], 0.035 for the interaction [cultivar × mulch], 0.039 for the interaction [fruit juice acidity × mulch × cultivar] ($p \leq 5\%$).

showed vigorous growth in all parameters, followed by Chandler; Sweet Charlie exhibited a semi-vigorous type of growth. This variability in growth behavior under a subtropical climate may be attributed to genotypic variability existing in the cultivars [1, 5, 6].

4.2. Incidence of albinism

Albinism occurred in nearly 31% of fruits. To our knowledge, our work is the first

report describing the incidence of albinism in field-grown strawberries under a subtropical climate. Albinism incidence was influenced by mulching, being significantly higher with black polyethylene and much less with paddy straw mulch, which may probably be due to the better growth of plants under black polyethylene mulch, as Lieten [2, 3] and Sharma and Sharma [4] have reported that the vigor of the plant has a direct relationship with albinism in strawberry. Further, the convective heat

released by the polyethylene might have favored the development of albino fruits because black polyethylene has the capacity to absorb higher solar radiation as compared with other mulch materials such as white polyethylene and paddy straw. Further, black polyethylene mulch is also known to promote N mineralization, which might have also favored the incidence of albinism [2, 3, 5]. Thus, all these factors might have played a contributory role in the development of albino fruits, as a result of which albinism was very high with black polyethylene, compared with white polyethylene or paddy straw mulch. The albinism incidence was much less with paddy straw (22.45%), signifying its importance for use as mulch in warmer areas.

Wider variability in respect to albinism incidence was observed among the different cultivars in a warmer climate. In general, cultivars that had vigorous growth had a higher incidence of albinism and *vice versa*. Etna had the highest incidence (49.88%) and Sweet Charlie the lowest (20.74%), non-significantly followed by Fern (22.52%). Thus, genetic variability related to the vigor of plants may be responsible for variable incidence of albinism in different cultivars [1, 4–6].

4.3. Fruit size and quality parameters

Our observations, according to which albino fruit size and quality were not significantly inferior to normal fruits, except for poor color development, are contradictory to the reports of earlier authors, except that of Lieten and Marcelle [2, 3]. Fruits with the best weight and TSS and the lowest acidity were in black polyethylene mulch (*tables III–V*). This significant influence of black polyethylene over the other mulch materials or no mulch observed on fruit size and quality may be attributed to a better vegetative growth of plants due to better microclimate modifications and partly due to depletion of less nutrients, owing to better weed control [12–16]. Wider variability was observed in respect to fruit weight, TSS and acidity among the cultivars, which may be due to genetic variability existing among the cultivars [1, 5, 6]. Similarly, the significant

influence of different interactions between fruit, cultivar and mulch materials may be due to synergistic and interactive influence [1].

5. Conclusions

Our studies indicated that the plants have better growth and produce fruits with better weight and TSS when cultivated under black polyethylene mulch, but the fruits then have a higher incidence of albinism, a serious disorder under a sub-tropical climate where the temperature is comparatively high during the fruit maturity and ripening stages. Paddy straw, which not only reduced the incidence of albinism but is also easily and cheaply available, can be the best choice for use as mulch for strawberry in the warmest localities.

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Efecto del tipo de cobertura del suelo en el crecimiento de las plantas, el albinismo y la calidad de la fruta en el fresal (*Fragaria x ananassa* Dusch.).

Resumen — Introducción. El albinismo es una seria anomalía fisiológica que induce, en la fresa, un fruto hinchado, de color pálido, sabor pobre y que soporta mal el almacenamiento. Habría muchos factores asociados a esta anomalía, pero el principal de ellos sería un fuerte crecimiento vegetativo de las plantas. El acolchado de los fresales es una técnica esencial para este cultivo; conocida por influir en el crecimiento de las plantas, el rendimiento y la calidad de la fruta. El objetivo de nuestros estudios consistió en estudiar la influencia de los distintos tipos de materiales de cobertura del suelo en el albinismo. **Material y métodos.** Los tratamientos permitieron probar cinco cultivares de fresa (Sweet Charlie, Chandler, Douglas, Fern, y Etna) cultivados con tres tipos de cobertura del suelo (polietileno negro, polietileno blanco y paja de arroz). El tratamiento testigo estaba constituido por un cultivo de fresas en suelo desnudo. Las observaciones se refirieron a parámetros de crecimiento de las plantas y de calidad de la fruta así como a la incidencia del albinismo en los cinco cultivares probados con los distintos tipos de cobertura. **Resultados y discusión.** Todos los parámetros de crecimiento fueron mejores en las plantas con acolchado que en las cultivadas en suelo desnudo. Entre los distintos materiales utilizados, el polietileno negro permitió el mejor crecimiento de las plantas, pero con frutos que se vieron más afectados por el albinismo que los obtenidos en suelo cubierto de paja de arroz. Dentro de los cultivares probados, las plantas de Etna mostraron el crecimiento más vigoroso, pero sus frutos presentaron la tasa de albinismo más alta (49,88%); los Sweet Charlie presentaron la tasa de anomalía más baja (20,74%), principalmente debido a la correlación entre crecimiento de las plantas y albinismo. **Conclusión.** El polietileno negro favoreció el mejor crecimiento de los fresales, pero, en clima subtropical, esta cobertura aumentó la incidencia del albinismo con respecto a la utilización de la paja de arroz. Por ello, la paja de arroz podría constituir el mejor material de acolchado para el cultivo de fresas en las regiones más cálidas de la India.

India / *Fragaria ananassa* / material orgánico de cobertura / película plástica / cobertura con paja / crecimiento / albinismo / calidad