Effects of Mulch and Cultivar on Strawberry Productivity under Tropical Highland Conditions

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Abstract

A study was conducted to determine effects of four mulches (cut grass, clear polyfilm, black polyfilm, and none) on productivity of four strawberry (Fragaria x ananassa Duch.) cultivars (Pajaro, Aiko, Fern and Douglas) under tropical highland conditions. It was hypothesized that polyfilm would hasten growth and increase yield more than cut stargrass (Cynodon dactylon), or no mulch, through warming soil, improving nutrient uptake and conserving moisture. The experiment was set up as split plots in randomised complete block design; mulches were assigned to main plots, whereas cultivars were assigned to sub-plots. Each of the sixteen treatments was replicated three times. Cultivars were planted at the beginning of long rains in March 2002. Data were recorded from the fourth month after planting (MAP) and analysed. Polyfilm hastened growth from 2 to over 5 stolons, 18 to 30 leaves, 31cm to 35cm diameter at 4 MAP, and increased flowering and yield from 9 to 12 flower stalks, 22 to 29 berries, and 30 g to 35 g berry fresh weight at 9 MAP. Most of the time, black polyfilm growth and yield parameters were higher than those for cut grass or no mulch. Positive effects of cut grass mulch developed slowly, while those of clear polyfilm mulch diminished over time. Nine months after planting, black polyfilm gave significantly ($P<0.05$) higher yields, and hence is recommended. Clear polyfilm is recommended only for hastening plant growth. 'Douglas' was often inferior in all response variables compared to the other three cultivars and hence is least recommended for growing under tropical highland conditions. Mulch did not significantly ($P>0.05$) interact with cultivar, implying that it does not alter the potential of cultivars grown under tropical highland conditions.

Keywords: Growth, mulching, productivity, strawberry cultivar, tropical highlands

Introduction

Strawberry is a herbaceous, perennial plant with a compressed stem called the crown; leaves, flowers and stolons originate from the crown (Edmond et al., 1977). Although it is a native of temperate-zones, it has been introduced to other climatic regions, where it grows and yields quite successfully upon adaptation. It also adapts readily under protected cropping conditions in many regions of the world. Strawberry growth and development is influenced by cultural, climatic and physiological factors, and productivity in native lands is naturally controlled by distinct climatic changes (Galletta and Himelrick, 1990). Determining precise cultural requirements for strawberry could enable growers to produce it extensively in new regions.

The choice of a strawberry cultivar to grow depends on a combination of factors such as prevailing climate, pest pressure and consumer preferences. The most important factor, however, is photoperiod. The cultivar fern exhibits day neutral photoperiodic response, whereas 'Pajaro', 'Aiko', and 'Douglas' require short days to stimulate flowering (Galletta and Himelrick, 1990). Plastic mulches (polyfilms) are often used in raised-bed culture of strawberry to warm the soil, conserve moisture, control weeds and keep fruits clean (Kasperbauer, 2000). The most commonly used polyfilm is black, which promotes the best root growth, water use efficiency, and nutrient uptake, compared to clear (transparent) and organic mulches. Gupta and Acharya (1993) observed that transparent polyfilm raises

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maximum soil temperature significantly, whereas organic mulch reduces it. Kasperbauer (2000) reported that yield per plant and size per berry was greater over red than over black polyfilm. Red plastic reflected a higher far-red to red photon ratio that regulated photosynthate allocation into fruits to increase yield. In the study of Gupta and Acharya (1993) black polyfilm increased yield by 56%, compared to no mulch, and the fruits were larger and had higher total soluble solids (sugar content) and lower acidity, compared to those from plants mulched with other materials.

Therefore, the current research was conducted to determine effects of mulch on growth, yield and quality of four strawberry cultivars grown under tropical highland conditions.

Materials and Methods

The current study was conducted on a farm situated at latitude 0°23' south, longitude 35°35' east, and altitude of 2200 m above sea level (asl). Tests revealed that soils at the site were well-drained sandy loams, with pH 6.6, 0.32% total nitrogen and 1.6% carbon. The rainfall received at the site ranges from 500 to 1000 mm per annum and is bimodal; long rains fall from March to August and short rains from October to December. Temperatures at the site range from 15 to 26°C (Jaetzold and Schmidt, 1983).

The experiment was laid out as a split plot arrangement in a randomised complete block design; blocking was based on the slope of the land. Mulches (none, cut stargrass, clear polyfilm and black polyfilm) were assigned to main plots, whereas cultivars (Pajaro, Aiko, Fern and Douglas) were assigned to subplots. Each treatment was replicated three times.

Land was ploughed and harrowed to a fine tilth, followed by manual construction of beds. Main plots, measuring 1 m wide and 15 m long each, were marked, and an equivalent of 18 tonnes ha^{-1} of farmyard manure (Anonymous, 1977) and 34 kg ha^{-1} of phosphorous (Galletta and Himelrick, 1990) uniformly broadcasted on the surface and incorporated into the soil by digging with a hoe to a depth of 20 cm. Bed edges were raised to10 cm above ground, followed by laying of a drip irrigation tube at the centre of each bed and applying mulch. Subplots, measuring 1 m wide by 3 m long each, were marked on the beds. A distance of 1 m separated adjacent subplots, 50 cm paths separated main plots, and 1.5 m paths separated replications. The spacing between suckers in a single row system was 30 cm, giving 10 suckers per subplot. Holes were opened in the mulches to facilitate insertion of suckers into the soil. The suckers were planted in March 2002. Cut stargrass was applied to a height of 5 cm above the bed surface and new grass was added every two months to ensure the soil underneath was never exposed.

During periods of no rain all plots were equally irrigated through the drip tubes, but during rainy periods only beds mulched with polyfilm were irrigated to balance the moisture content in the soils. Weeding was done every month in and around the entire experimental site. The most common pests (red spider mites, aphids, powdery mildew on leaves and gray mold on fruits) were sprayed at recommended rates and timings using dicofol, dimethoate, benomyl and tebuconazole, respectively (Galletta and Himelrick, 1990). Current stolons, flowers and senescing leaves were pruned monthly to facilitate optimal crown growth. Excess mature leaves were pruned from all plants just before the sixth month after planting to prevent their competition with reproductive growth. Pruning of flowers was stopped after six months to allow maturation of berries.

Data recording commenced from the fourth month after planting and continued for six months. Data recorded included number of stolons, stolon dry weight, number of leaves, leaf dry weight, canopy diameter, number of whole flower stalks, as well as berry number, fresh weight, diameter and brix index. Data were recorded monthly except berries, which were harvested every one to two weeks before they perished. All data were calculated per plant except diameter and brix, which were calculated per berry and leaf dry weight was expressed per leaf.

Dry weight of stolons per plant was derived from harvesting all current stolons per treatment, drying in an oven at 70°C for two days, weighing and dividing the total dry weight by the number of plants contributing the stolons. Subsequent stolons developing on the plants were harvested and handled similarly at the end of every month. Dry weight per leaf was derived from randomly picking one mature leaf from each plant, putting all leaves per treatment in a bag, drying, weighing and dividing the total dry weight by the number of leaves. All data were analysed as a two-way factorial arrangement in a randomised complete block design.

Results and Discussion

Stolon growth and dry weight

The number of stolons decreased as plants grew older. Significantly ($P<0.05$) more stolons developed under clear and black polyfilms than under both cut grass and no mulch throughout the season (Table 1). This response was probably attributed to the effect of polyfilm in raising temperature and promoting growth, and that of organic mulch in reducing temperature and suppressing growth (Gupta and Acharya, 1993). After nine months, stolon growth almost ceased, indicating a shift from vegetative to reproductive growth. Stolons on cultivars were significantly ($P<0.05$) different only after six months (Table 1). The results are explained by the fact that the effect of photoperiod is less pronounced in the tropics than in temperate-zones (Westwood, 1993).

Mulch significantly ($P<0.05$) influenced stolon dry weight at four and eight months (Table 1). Stolon dry weight for both polyfilms was often higher than that for both cut grass and no mulch. This trend was similar to that for the number of stolons (Table 1). The effect of cultivar on stolon dry weight was significant ($P<0.05$) at four and five months only. Throughout the season, stolon dry weight for 'Douglas' was lower than that for the other three cultivars (Table 1). This response indicates that this cultivar is poorly suited to growing under the tested tropical highland conditions.

Table 1. Effects of mulch and cultivar on number of stolons and stolon dry weight [1]

Time (months)	Mulch					Cultivar				
	None	Cut grass	Clear polyfilm	Black polyfilm	$LSD_{0.05}$	Pajaro	Aiko	Fern	Douglas	$LSD_{0.05}$
(a) Number of stolons per plant										
4	2.1^{b}	1.9^{b}	6.1^{a}	5.4^{a}	0.6	4.1	4.3	4.0	3.4	NS
5	2.4^{c}	2.3^{bc}	3.3^{ab}	3.7^{a}	1.0	2.7	3.4	3.1	2.4	NS
6	0.0^{c}	0.4^{a}	0.4^{a}	0.2^{bc}	0.2	0.5^{a}	0.2^{b}	0.3^{ab}	0.1^{b}	0.3
7	0.3^{b}	0.1^{b}	1.5^{a}	0.4^{b}	0.7	0.8	0.3	0.7	0.5	NS
8	0.1^{c}	0.3^{bc}	1.6^{a}	0.7^{b}	0.5	0.7	0.7	0.7	0.6	NS
9	0.0	0.1	0.4	0.3	NS	0.2	0.2	0.2	0.1	NS
b) Stolon dry weight (g/plant)										
4	0.7^{b}	0.6^{b}	1.9^{a}	1.7^{a}	0.4	1.6^{a}	1.3^{ab}	1.1^{ab}	0.9^{b}	0.4
5	0.9	0.7	1.5	1.3	NS	1.1^{ab}	1.4^{a}	1.2^{ab}	0.8^{b}	0.4
6	0.0	0.1	0.1	0.1	NS	0.1	0.1	0.1	0.0	NS
7	0.2	0.1	0.5	0.1	NS	0.3	0.1	0.3	0.2	NS
8	0.1^{c}	0.1^{bc}	0.5^{a}	0.2^{b}	0.1	0.2	0.2	0.2	0.2	NS
9	0.0	0.1	0.2	0.1	NS	0.1	0.2	0.1	0.1	NS

[1] Values followed by the same letter, or no letter, within each row of mulch or cultivar are not significantly (NS) different at $P \leq 0.05$.

Table 2. Effects of mulch and cultivar on number of leaves and leaf dry weight [1]

Time	Mulch					Cultivar				
(months)	None	Cut grass	Clear polyfilm	Black polyfilm	$LSD_{0.05}$	Pajaro	Aiko	Fern	Douglas	$LSD_{0.05}$
(a) Number of leaves per plant										
4	18^b	21^b	30^a	30^a	5	27^a	22^a	27^a	23^{ab}	4
5	30^b	34^b	42^a	43^a	8	41	35	38	36	NS
6	21^b	24^b	29^a	30^a	5	27	25	26	25	NS
7	37^b	37^b	45^{ab}	51^a	9	43	42	43	42	NS
8	44^b	47^b	59^a	58^a	10	55^a	51^{ab}	54^{ab}	49^b	5
9	46^b	48^b	58^a	62^a	10	57^a	55^a	53^{ab}	49^b	4
b) Leaf dry weight (g/plant)										
4	1.3	1.2	1.3	1.2	NS	1.2	1.3	1.2	1.2	NS
5	1.2	1.1	1.2	1.3	NS	1.2^{ab}	1.3^a	1.2^{ab}	1.1^b	0.1
6	0.7^a	0.6^b	0.6^b	0.6^b	0.1	0.6^b	0.7^a	0.6^b	0.6^b	0.1
7	0.8	0.7	0.6	0.6	NS	0.7	0.7	0.7	0.6	NS
8	0.8^a	0.8^a	0.7^b	0.7^b	0.1	0.7^b	0.8^a	0.7^b	0.7^b	0.1
9	0.9	0.9	0.7	0.8	NS	0.9	0.9	0.8	0.8	NS

[1] Values followed by the same letter, or no letter, within each row of mulch or cultivar are not significantly (NS) different at $P \leq 0.05$.

Leaf growth and dry weight

The effect of mulch on number of leaves was significant ($P<0.05$) and consistent throughout the season. The number of leaves increased steadily over the season from a low of 18 to a high of 62 (Table 2). The number of leaves produced by plants under clear and black polyfilms was always similar and higher than that produced by plants under both cut grass and no mulch. The increased leaf growth under both polyfilms was attributed to the promotion of soil warming, root growth and nutrient uptake by these polyfilms (Gupta and Acharya, 1993). The effect of cultivar on leaves was significant ($P<0.05$) at four, eight and nine months. Often, 'Douglas' produced the lowest number of leaves (Table 2).

The leaf dry weight produced earlier in the season was higher than that produced later in the season (Table 2). The decrease was attributed to the increase in the number of leaves that developed and competed for photosynthates as the season progressed (Faust, 1989).

The effect of mulch on leaf dry weight was significant ($P<0.05$) at six and eight months. Later in the season, leaf dry weight for non-mulched and cut grass plants was higher than that for plants under either polyfilm (Table 2). The difference was attributed to the high number of stolons, flowers and leaves that competed for photosynthates, resulting in little assimilates being partitioned to individual leaves of plants under polyfilms (Faust, 1989)

Table 3. Effects of mulch and cultivar on canopy diameter and number of flower stalks [1]

Time (months)	Mulch					Cultivar				
	None	Cut grass	Clear polyfilm	Black polyfilm	$LSD_{0.05}$	Pajaro	Aiko	Fern	Douglas	$LSD_{0.05}$
(a) Canopy diameter (cm)										
4	31[b]	31[b]	34[a]	35[a]	1.8	33	33	32	32	NS
5	32	33	36	36	NS	35	34	34	33	NS
6	25	23	25	25	NS	25	25	25	23	NS
7	29	28	30	29	NS	29[ab]	30[a]	30[a]	28[b]	1.6
8	31	31	33	32	NS	33[a]	32[a]	32[a]	30[b]	1.5
9	32	33	33	35	NS	34[a]	34[a]	34[a]	31[b]	1.9
(b) Number of flower stalks per plant										
4	0	0	0	0	NS	0	0	0	0	NS
5	1[a]	0[b]	0[b]	1[a]	0.1	0	0	0	0	NS
6	1	1	1	1	NS	2	1	1	1	NS
7	3[bc]	2[c]	5[a]	4[ab]	1.1	3	3	4	4	NS
8	7[b]	7[b]	9[a]	9[a]	1.3	8	8	8	7	NS
9	9[b]	10[b]	10[b]	12[a]	1.7	11	11	11	10	NS

[1] Values followed by the same letter, or no letter, within each row of mulch or cultivar are not significantly (NS) different at $P \leq 0.05$.

Table 4. Effects of mulch and cultivar on number and fresh weight of berries [1].

Time (months)	Mulch					Cultivar				
	None	Cut grass	Clear polyfilm	Black polyfilm	$LSD_{0.05}$	Pajaro	Aiko	Fern	Douglas	$LSD_{0.05}$
(a) Berry fresh weight (g/plant)										
6	35[b]	28[b]	46[a]	53[a]	10	41	41	43	37	NS
7	37[b]	52[a]	24[c]	38[b]	11	40	40	38	33	NS
8	22[b]	31[a]	14[c]	23[b]	5	22	24	23	20	NS
9	30	28	30	35	NS	31	31	34	27	NS
Total	123[b]	139[ab]	114[c]	149[a]	24	134	136	138	117	NS
b) Number of berries per plant										
6	24[b]	17[c]	37[a]	38[a]	6	29	27	31	27	NS
7	34[b]	43[a]	24[c]	38[ab]	7	36	36	38	30	NS
8	21[b]	27[a]	14[c]	23[b]	4	21	23	22	20	NS
9	22	18	25	29	NS	23	23	27	21	NS
Total	101[b]	105[b]	99[b]	128[a]	6	109	108	116	98	NS

[1] Values followed by the same letter, or no letter, within each row of mulch or cultivar are not significantly (NS) different at $P \leq 0.05$.

The effect of cultivar on leaf dry weight was significant ($P<0.05$) at five, six and eight months (Table 2). The difference was attributed to the variation in the rate of senescence of the cultivars (Galletta and Himelrick, 1990). 'Aiko' senesced at a slower rate compared to the other cultivars, and hence could be suitable for longer cultivation periods prevailing under tropical highland conditions.

Canopy development

The effect of mulch on canopy diameter was significant ($P<0.05$) only at four months, when plants under clear and black polyfilms had wider canopies than plants under both cut grass and no mulch (Table 3). At the early growth stages, polyfilms could have promoted faster canopy growth than cut grass or no mulch through their effects in warming the soil, optimising water use efficiency, and enhancing root growth and nutrient uptake (Gupta and Acharya, 1993). Canopy diameter is important because it indicates the area covered by a plant, thereby guiding proper spacing for increased land use efficiency (Faust, 1989). The constant canopy diameter after four months indicated that all plants had attained comparable and maximum light interception capabilities.

The effect of cultivar on canopy diameter was significant ($P<0.05$) during the last three months, when 'Douglas' developed the narrowest canopy, compared to the other three cultivars, which developed similar wider canopy diameters (Table 3). The significant difference implies that canopy diameter probably mediated performance of the cultivars. The plateau in canopy diameter (leaf production and growth) from 8 to 9 MAP (with increased age of strawberry leaves and plants) could symbolize the end of useful life of old leaves and plants, when pruning and renovating would be necessary, respectively (Galletta and Himelrick, 1990). Thus, 'Douglas' proved to be a cultivar that could attain such a growth stage earlier than the other three cultivars.

Flower development

Plants started flowering consistently at four months. Flower growth increased as the season progressed (Table 3). At seven months, the number of flowers increased and the effect of mulch became significant ($P<0.05$). Clear polyfilm resulted in the highest number of flower stalks per plant (5), followed by black polyfilm (4). This trend was maintained until at nine months stage, when plants under no mulch produced the lowest number of flower stalks (9), compared to the highest (12) for plants under black polyfilm mulch (Table 4). The increase in flower initiation and growth on mulched plants was attributed to the positive nutritional and warming effects of organic and inorganic mulches, respectively (Gupta and Acharya, 1993; Kasperbauer, 2000).

The effect of cultivar on the number of flower stalks was not significant ($P>0.05$) during the entire season and all cultivars responded similarly in flowering, regardless of their photoperiodic orientation (Table 3). The results agree with the fact that photoperiodic effect is not very strong in the tropics, because day and night hours are almost constant throughout the year.

Number and fresh weight of berries

At six months, yields for both polyfilm mulches were highest, but at seven and eight months, grass mulch took over the top position (Table 4). However, at nine months, there was no significant ($P>0.05$) difference due to mulches. Total yield at nine months for black polyfilm (149 g/plant) and cutgrass (139 g/plant) were significantly ($P<0.05$) higher than for clear polyfilm (117 g/plant) and no mulch (123 g/plant). Black polyfilm and cut grass increased total fresh weight by 21% and 13%, respectively, compared to no mulch. In contrast, clear polyfilm decreased total fresh weight by 7% compared to no mulch. The productivity trend for number of berries was the same as for fresh weight.

The higher yields produced by plants mulched with black polyfilm was attributed to moisture conservation and increased minimum soil temperature (Kasperbauer, 2000). Black polyfilm in particular probably mediated its effects through promotion of better root growth, water use efficiency, and nutrient uptake (Gupta and Acharya, 1993). Later in the season, clear polyfilm could have raised maximum soil temperature excessively, thereby increasing respiration and decreasing fixed photosynthates that went into yields (Gupta and Acharya, 1993). Black and organic mulches most likely had the opposite effect, which favoured higher yields. Organic mulches also add nutrients to the soil as they decompose, thereby benefiting plant performance later in the season.

The effect of cultivar on fresh weight and number of berries was not significant ($P>0.05$) throughout the season, although the day neutral cultivar, Fern yielded slightly higher than the other cultivars (Table 4). 'Douglas' produced the lowest yields throughout the season and this performance corresponded to other previously described growth attributes.

Berry size (diameter) and brix index

In the current study, the effect of cultivar on berry diameter and brix index was consistent, but not significant (Table 5). Mulch produced a significant ($P<0.05$) effect on the diameter of berries in the middle of the fruiting season, whereby berries for both polyfilm mulches were smaller than those for cut grass and no mulch (Table 5). Berry size ranged from 1.3 cm to 1.7 cm. The small berry diameter for black polyfilm corresponded to the high number of berries, probably translating into competition, and for clear polyfilm to high temperatures, probably raising catabolism (Faust, 1989). Thus, the response of berry diameter to mulching contrasted with that of fresh weight and number of berries (Table 4).

The effect of mulch on brix index, which ranged from 7% to 11%, was significant ($P<0.05$); no mulch and clear polyfilm gave the highest indices (Table 5). Probably, there was less dilution of sugars in the berries for no mulch where little moisture was conserved (Gupta and Acharya, 1993). These results contrasted with those of Gupta and Acharya (1993), where fruits from plants mulched with black polyfilm were largest, with highest total soluble solids (sugar content) and lowest acidity, when compared to those from plants mulched with other materials. Mostly likely, the different cultivar (Tioga) tested in their study and other growth conditions caused the difference in results.

Table 5. Effects of mulch and cultivar on berry diameter and brix index [1]

Time	Mulch					Cultivar				
(Months)	None	Cut grass	Clear polyfilm	Black polyfilm	$LSD_{0.05}$	Pajaro	Aiko	Fern	Douglas	$LSD_{0.05}$
(a) Berry diameter (cm/berry)										
6	1.8	1.8	1.7	1.8	NS	1.8	1.8	1.8	1.7	NS
7	1.5^{a}	1.5^{a}	1.3^{bc}	1.4^{ab}	0.1	1.5	1.4	1.4	1.4	NS
8	1.5^{a}	1.5^{a}	1.3^{bc}	1.4^{ab}	0.1	1.4	1.4	1.4	1.4	NS
9	1.7	1.8	1.6	1.7	NS	1.6	1.7	1.7	1.7	NS
b) Brix index (% sugar)										
6	11	10	10	9	NS	10	10	10	10	NS
7	10^{ab}	9^{b}	11^{a}	9^{b}	1	10	9	10	9	NS
8	9^{a}	8^{b}	9^{a}	9^{a}	1	9	8	9	10	NS
9	9^{ab}	7^{c}	9^{ab}	8^{bc}	1	9	8	8	8	NS

[1] Values followed by the same letter, or no letter, within each row of mulch or cultivar are not significantly (NS) different at $P \leq 0.05$.

Conclusions and Recommendations

In the current study mulching with either clear or black polyfilm hastened growth of most vegetative plant parts. Organic mulch also had positive effects, but these developed slowly compared to those of polyfilm mulches. Photoperiodic response was not critical in determining productivity of the three best-performing cultivars.

Thus, it is recommended that to hasten growth and take advantage of the other general benefits of mulching, either black or clear polyfilm could be used for strawberry grown under tropical highland conditions. Where the cost of polyfilm mulch material is prohibitive, and speeding up growth is not a priority, organic mulch could be used. Since mulches often influenced productivity significantly more weight should be placed on choosing and managing them, rather than on cultivars, under tropical highland conditions. 'Douglas', however, is least recommended for growing under tropical highland conditions, whereas any of the other three cultivars is recommended for adoption.

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