Agricultural Journal 6 (6): 340-346, 2011
ISSN: 1816-9155


# The Interaction Effect of Photoperiod and Exogenous Hormone on the Dry Matter of Strawberry (*Fragaria x ananassa* Duch)

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**Abstract:** The effect of interaction among exogenous hormones auxin (IBA), Gibberellins Acid (GA3) and cytokinin (6-BA), photoperiod and cultivars on the total dry matter of strawberry plant was investigated in Cameron Highland, Pahang, Malaysia. The five factorials experiment with three replications was designed in a split plot factorial Randomized Completed Block Design (RCBD). A total of 864 plants involve and were placed under 400 $m^2$ plastic rain-shelter. Two Malaysian commercial strawberry cultivars, Camarosa and Camaroga, were used. The plants were exposed to three photoperiod levels (12 (normal day length of Cameron Highland), 15 and 18 h) and sprayed with 0 and 50 ppm IBA, GA3 and 6-BA. The results showed that only GA3 gave the significant effect on the dry matter of strawberry by its own action where, 17.06% dry matter content was produced under application of 50 ppm GA3. The result demonstrated that the photoperiod, variety, IBA and 6-BA factors do not act individually on the production of strawberry dry matter but rather by the mutual interaction among them. It was found that the highest, 21.2%, dry matter content of the strawberry was produced by Camaroga cultivar grown under 15 h photoperiod and treated with 50 ppm IBA and GA3 and thus such combined treatment is recommended as the best condition for increasing productivity of strawberry in Cameron Highland.

**Key words:** *Fragaria x ananassa*, photoperiod, exogenous hormone, dry matter, strawberry, Malaysia

## INTRODUCTION

Strawberry (*Fragaria x ananassa* Duch.) belongs to the Rosaceae family. Now-a-days, the commercial variety of strawberry is widely grown not only in its original cold sub-tropical and temperate region but also in the high-latitude of tropical region (FAO, 2007; Hancock, 1999). Presently, it is cultivated in 69 countries including Malaysia. In 2007, the estimated world production and area of strawberry was about 3,824,678 ton and 254,027 ha, respectively (FAO, 2007).

Dry matter content is always used to measure productivity in plant. Its dissemination in plant is partly determined by the balanced distribution of assimilates from the source organ to the other various organs. Under its original climatic condition, strawberry plant accumulates dry matter (starch) in root and crown and becomes dormant during Short Day (SD) in autumn and winter seasons (Maas, 1986; Durner *et al*., 1984). It was found that the dry matter of four strawberry varieties (i.e., Aromas, Quinalt, Fort Laramie and Tribute) were greater under 16 h (LD) than under 8 h (SD) photoperiod where their parents show the different response to photoperiod which *F. chiloeniss* was higher under LD while *F. virginiana* no significant under both SD and LD (Serce and Hancock, 2005). Meanwhile, the dry matter of other variety (i.e., Allstar, Chandler and Honeoye) was significant different under duration short day (8-11 h), the dry matter was even not significantly affected by the photoperiod but rather by the cultivars of the plant (Serce and Hancock, 2005).

The effect of growth regulators on the dry matter of strawberry are varies depending on the type and concentration of the hormones, time and season of application and Cultivars (Engels and Ebert, 1988; Fouad *et al*., 1991; Shou-Ming *et al*., 2007). Aerial dry matter of strawberry are most significantly increased when GA3 are used (Engels and Ebert, 1988). It was reported

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that the application of GA3 during the late autumn caused the aerial dry matter of strawberry either reduces or increases depending on the GA3 concentration and cultivars used. Meanwhile, root, crown and foliage dry matter in certain variety such as Raritan was not affected by the application of the hormones (Weidman and Stang, 1983). It was reported that cytokine (BA) had also affected on the root and aerial dry matter of strawberry (Archbold and Strang, 1986).

Meanwhile, Shou-Ming *et al*. (2007) indicated that the combined application of GA3, IAA and 6-BA with various proportions can significantly affected the dry matter of shoots and roots of strawberry. However, the interaction between the type of exogenous hormone and photoperiod on strawberry dry matter has not been thoroughly investigated. Therefore, a study was conducted under Cameron highland climatic condition with the following objectives:

- To assess the interaction effect of variety, photoperiod, auxin, gibberellin and cytokinin on the total dry matter of strawberry
- To determine the best combination of exogenous hormones (auxin, gibberellin and cytokine), photoperiod and variety application in maximizing strawberry effectively dry matter in Cameron highland

## MATERIALS AND METHODS

**Experimental layout:** The experiment was conducted at the Malaysian Agricultural Research and Development Institute (MARDI) Station in Cameron Highland, Malaysia located at an altitude of 10,000 m above sea level, latitude 4°28'6.75"N and longitude 101°23'6.83"E. Two strawberry cultivars, Camarosa and Camaroga, were used. The uniform plantlets runner cuttings obtained from the adult plants were rooted in nursery. A total of 864 rooting plantlets of 3.5 leaves stage were planted in 15 cm diameter plastic pots containing mixed growing media of coco peat and perlite at 9:1 ratio. All plants were placed under 400 $m^2$ plastic rain-shelter, watered and fertilized trough the fertigation system. Pest and disease control were made using the standard practice applied in Cameron highland. The plants were exposed to three photoperiod levels, 12 (normal day length of Cameron highland), 15 and 18 h by using 100 w fluorescent bulbs with overall light density of approximately 50 lux. Three types of hormone, auxin (IBA) [indolyl-3-butyric acid (Merck KGaA, Darmstadt, Germany)], cytokinin (6-BA) ($N^6$-benzyladenine (R&M , UK)] and Giberralic acid (GA3) (Merck-Schuchardt CHG, 85662 Hohenbrunn, Germany)] each with two levels of concentrations, 0 and 50 ppm (Single or combination as total eight treatment) were treated once on the plants via foliage application. Thus, 48 treatments each containing 6 plants were involved. Each treatment contains three replications. The experiment was arranged in a split plot factorial Randomized Completed Block Design (RCBD) with IBA, GA3, 6-BA and cultivars as spilt plots on main factor of photoperiod. Samples for dry matter measurement were taken randomly from three plants of each replication. The samples were washed, freshly weighted and dried in oven at 60°C until the weight stables and then the percentage of the dry matter were calculated as the following:

$$\text{DryMatter(DM)(\%)} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

**Statistical analysis:** The data were analyzed as a split plot factorial RCBD with IBA, GA3, 6-BA and cultivars as the spilt plots on photoperiod. Analysis of Variance (ANOVA) was analyzed using the program GinStat 5 and was used to determine the significant difference among the treatments means. The multiple range test of Duncan for the significant separation of means among the treatments was calculated by using the MSTAT-C program.

## RESULTS AND DISCUSSION

The effect of different treatments from each individual factors, cytokinin (6-BA), auxine (IBA), gibberellin (GA3), photoperiod and cultivars on the percentage of total dry matter of strawberry are shown in Fig. 1. The result exhibited that only GA3 which producing 17.06% dry matter with a concentration of 50 ppm had significant affected on the dry matter of strawberry (Fig. 1b). Whereas the different between the treatments level of the other individual factor did not show any significant effect on the dry matter of strawberry (Fig. 1). Figure 2 shows the interaction effect of two factors (pair-wise interaction) on the percentage total dry matter of strawberry.

This shows that the total dry matter content of strawberry had significantly decreased under the interaction of GA3×6-BA where the dry matter was lowest (16.77%) in the plant treated with 50 ppm GA3+50 ppm 6-BA (Fig. 2a). Oppositely, the dry matter had increased significantly under the interaction of GA3×IBA where the plants with 50 ppm IBA+0 ppm GA3 treatment gave the highest dry matter content (17.9%) (Fig. 2c). The interaction of variety×IBA had also gave a significant

effect on the dry matter of strawberry where the highest content (18.05%) was given by Camaroga variety after treated with 50 ppm IBA. The other pair-wise interactions did not show any significant different among the treatments (Fig. 2).

The interaction effect among the three factors on the total dry matter is shown in Table 1. It indicated that the interaction of GA3×IBA×6-BA did not significantly affect on the dry matter of strawberry (Table 1a, b). However, the interaction of variety×6-BA×IBA and variety×IBA×GA3 had significantly affected on the plant dry matter where in the former interaction, Camaroga cultivar gave the highest dry matter content (18.5%) when treated with 50 ppm IBA+0 ppm 6-BA and in the later interaction, the same cultivar also gave the highest content (18.21%) when treated with 50 ppm 6-BA+0 ppm GA3 (Table 1 a, d). The dry matter contents were also significantly affected by the interactions of photoperiod ×GA3×6-BA and photoperiod×IBA×6-BA where the treatment of the 12 h +0 ppm GA3 and 6-BA and 15 h

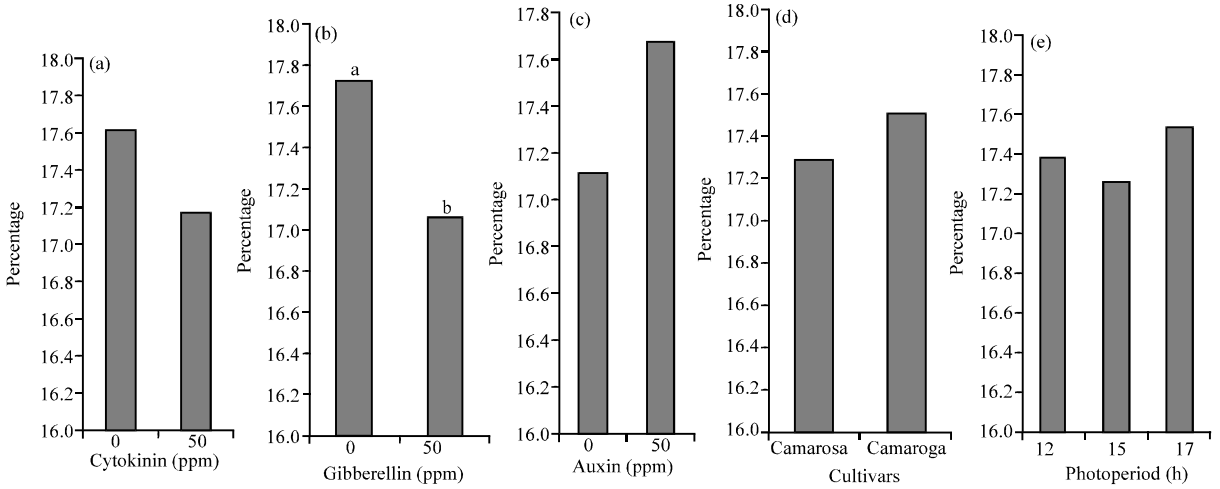


Fig. 1: Means comparisons among different treatments of each individual factor, a) cytokinin (6-BA); b) Gibberellin (GA3); c) Auxin (IBA); d) cultivars; e) photoperiod on the percentage (%) total dry matter of strawberry. Means with different letters in same figure indicate significant differences ($p<0.05$)

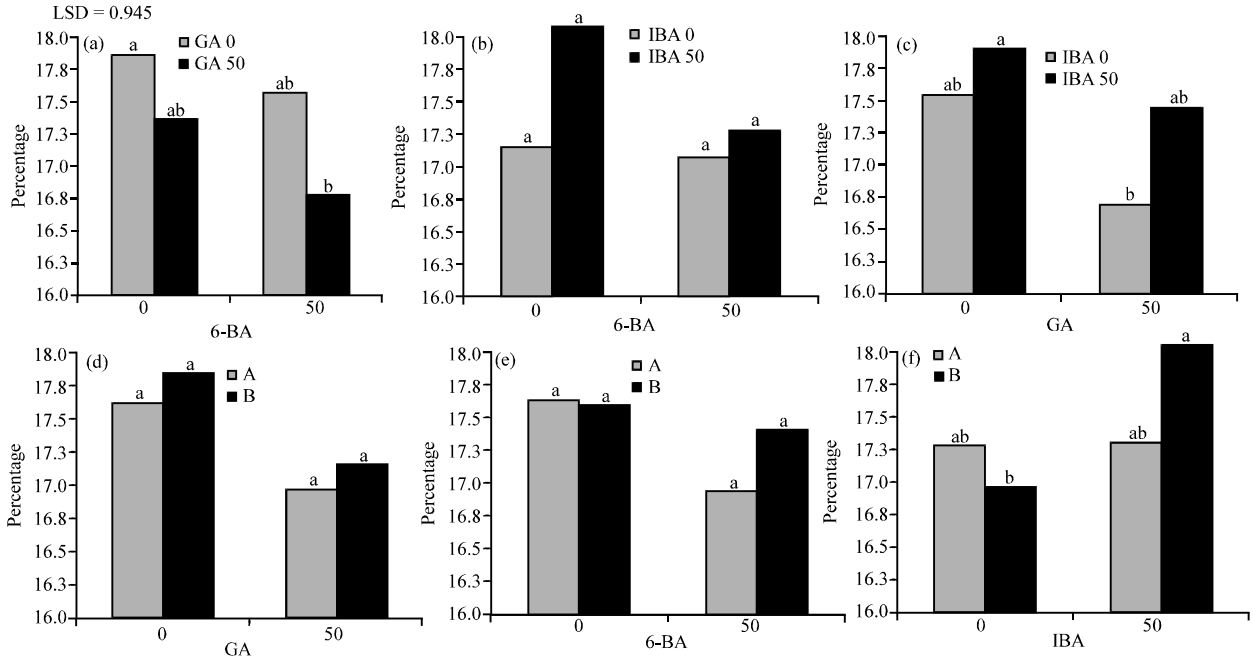


Fig. 2: Continued

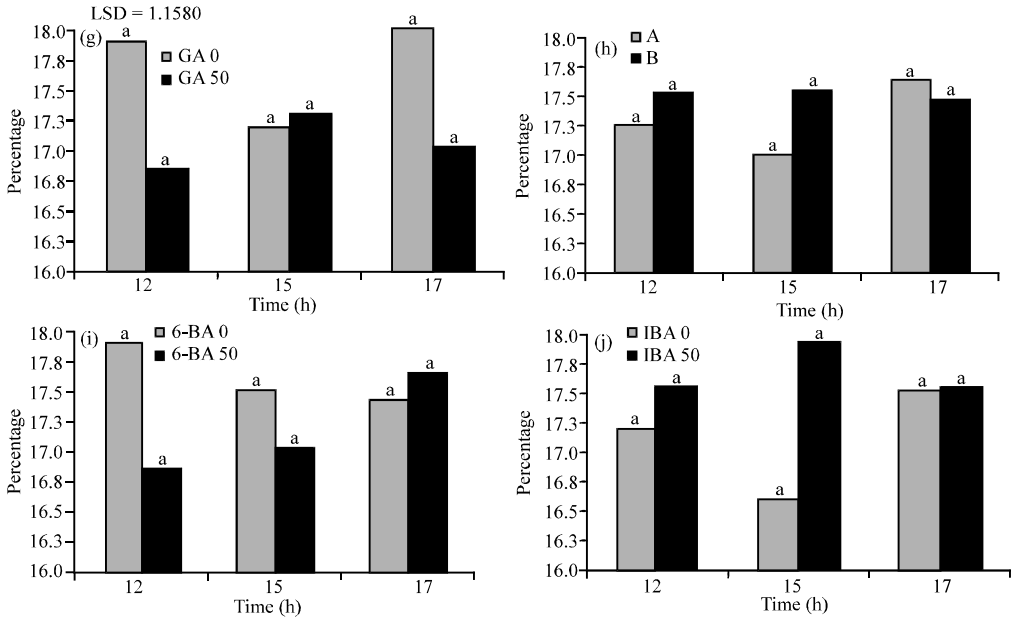


Fig. 2: Means comparisons of the total dry matter percentage of strawberry as revealed by two factors interaction. A = Camarosa, B = Camaroga. Means with different letters in same figure indicate significant differences ($p<0.05$)

+50 ppm IBA+0 ppm 6-BA gave the highest content of 18.64 and 19.12%, respectively (Table 1 e, f). The interactions of the photoperiod×variety×6-BA and the photoperiod× variety×GA3 had also significantly affected on the strawberry productivity. The dry matter content also reaches the highest level in the treatments of the 12 h photoperiod+Camarosa+0 ppm 6-BA and 15 h photoperiod+Camarosa+0 ppm GA3 with 18.59 and 18.34%, respectively (Table 1 h, i).

The effect of the interaction among four factors is shown in Table 2. It exhibits that all interactions gave a significant effect on the dry matter of strawberry. In the interaction of variety×6-BA×IBA×GA3, the dry matter was highest (19.01%) in variety Camaroga treated with 50 ppm GA3 and IBA and 0 ppm 6-BA (Table 2a). Interaction of photoperiod×6-BA×IBA×GA3 produces the highest dry matter content (19.26%) in plants grown under 15 h photoperiod and treated with 50 ppm IBA and GA3 and 0 ppm 6-BA (Table 2b).

The highest dry matter from the interaction of photoperiod×variety×GA3×6-BA was 19.53% that was revealed by Camaroga variety grown under 12 h with 50 ppm 6-BA and 0 ppm GA3 treatment (Table 2c). Camaroga variety also received the highest content of dry matter (20.07%) from the interaction of photoperiod ×variety×IBA×6-BA but under 15 h photoperiod with 50 ppm IBA and 0 ppm 6-BA treatment (Table 2d). Nevertheless, the interaction of photoperiod× variety×IBA×GA3 has allowed Camaroga variety produces the highest dry matter content (19.09%) when grown under 18 h photoperiod with 0 ppm IBA and GA3 applications (Table 2e). The interaction effect among five factors, photoperiod×variety×IBA×GA3×6-BA on the dry matter percentage of strawberry is shown in Table 3. The analysis revealed that the interactions of the five factors gave a great significant different among the treatments. Through this analysis, the highest dry matter content was 21.20% which was obtained in Camaroga variety grown under the 15 h photoperiod and treated with 50 ppm GA3 and IBA and 0 ppm 6-BA.

Meanwhile, the lowest dry matter content (14.31%) was found in Camarosa variety grown under 12 h photoperiod and treated with 50 ppm 6-BA and 0 ppm of each GA3 and IBA (Table 3).

Gibberellin or in combination with either auxin or cytokinin caused the reduction of the total dry matter in strawberry. This may be due to the reason that gibberellin reduced the rate of photosynthesis in plant (Tafazoli and Shaybany, 1978; Fouad *et al*., 1991). In general, the treatment of exogenous auxin and cytokinin alone or in combination did not deliver any significant affect on the dry mater but become effective when a particular cultivar is used as in according with the other reports (Archbold and Strang, 1986; Serce and Hancock, 2005). This result also confirms that the application of exogenous gibberellin led to the reduction of plant productivity (Engels and Ebert, 1988). The researchers also found that the effect of photoperiod on the dry

Table 1: Means comparisons of the percentage of total dry matter of strawberry as revealed by three factors interaction analysis

| | GA3 (0) | | GA3 (50) | | |
|---|---|---|---|---|---|
| 6-BA | 0 | 50 | 0 | 50 | LSD |
| **(a)** | | | | | |
| IBA0 | 17.63$^{a}$ | 17.44$^{a}$ | 16.66$^{a}$ | 16.70$^{a}$ | 1.337 |
| IBA50 | 18.10$^{a}$ | 17.70$^{a}$ | 18.05$^{a}$ | 16.83$^{a}$ | - |
| **(b)** | | | | | |
| Camarosa | 18.18$^{a}$ | 17.03$^{a}$ | 17.07$^{a}$ | 16.85$^{a}$ | 1.337 |
| Camaroga | 17.54$^{a}$ | 18.12$^{a}$ | 17.65$^{a}$ | 16.68$^{a}$ | - |
| | IBA (0) | | IBA (50) | | |
| 6-BA | 0 | 50 | 0 | 50 | LSD |
| **(c)** | | | | | |
| Camarosa | 17.60$^{ab}$ | 16.94$^{b}$ | 17.65$^{ab}$ | 16.94$^{b}$ | 1.337 |
| Camaroga | 16.69$^{b}$ | 17.20$^{ab}$ | 18.50$^{a}$ | 17.60$^{ab}$ | - |
| | IBA (0) | | IBA (50) | | |
| GA3 | 0 | 50 | 0 | 50 | LSD |
| **(d)** | | | | | |
| Camarosa | 17.62$^{ab}$ | 16.92$^{ab}$ | 17.59$^{ab}$ | 17$^{ab}$ | 1.337 |
| Camaroga | 17.45$^{ab}$ | 16.44$^{b}$ | 18.21$^{a}$ | 17.89$^{ab}$ | - |
| | 6-BA (0) | | 6-BA (50) | | |
| GA3 (h) | 0 | 50 | 0 | 50 | LSD |
| **(e)** | | | | | |
| 12 | 18.64$^{a}$ | 17.17$^{abc}$ | 17.18$^{abc}$ | 16.53$^{c}$ | 1.637 |
| 15 | 17.49$^{abc}$ | 17.51$^{abc}$ | 16.94$^{abc}$ | 17.11$^{abc}$ | - |
| 17 | 17.46$^{abc}$ | 17.40$^{abc}$ | 18.61$^{ab}$ | 16.67$^{bc}$ | - |
| | IBA (0) | | IBA (50) | | |
| IBA (h) | 0 | 50 | 0 | 50 | LSD |
| **(f)** | | | | | |
| 12 | 18.01$^{ab}$ | 17.79$^{abc}$ | 16.38$^{bc}$ | 17.32$^{abc}$ | 1.637 |
| 15 | 15.88$^{c}$ | 19.12$^{a}$ | 17.33$^{abc}$ | 16.72$^{bc}$ | - |
| 17 | 17.54$^{abc}$ | 17.31$^{abc}$ | 17.5$^{abc}$ | 17.77$^{abc}$ | - |
| | GA3 (0) | | GA3 (50) | | |
| IBA (h) | 0 | 50 | 0 | 50 | LSD |
| **(g)** | | | | | |
| 12 | 17.49$^{a}$ | 18.33$^{a}$ | 16.91$^{a}$ | 16.79$^{a}$ | 1.637 |
| 15 | 16.82$^{a}$ | 17.60$^{a}$ | 16.38$^{a}$ | 18.23$^{a}$ | - |
| 17 | 18.29$^{a}$ | 17.77$^{a}$ | 16.75$^{a}$ | 17.31$^{a}$ | - |
| | Camarosa | | Camaroga | | |
| Cultivars | | | | | |
| 6-BA (h) | 0 | 50 | 0 | 50 | ISD |
| **(h)** | | | | | |
| 12 | 18.59$^{a}$ | 15.89$^{b}$ | 17.22$^{ab}$ | 17.81$^{ab}$ | 1.637 |
| 15 | 17.13 | 16.85 | 17.86 | 17.19 | - |
| 17 | 17.16 | 18.07 | 17.7 | 17.20 | - |
| | GA3 (0) | | GA3 (50) | | |
| Cultivars (h) | A | B | A | B | ISD |
| **(i)** | | | | | |
| 12 | 17.14$^{abc}$ | 18.68$^{a}$ | 17.35$^{abc}$ | 16.35$^{c}$ | 1.637 |
| 15 | 17.34$^{abc}$ | 17.08$^{abc}$ | 16.64$^{bc}$ | 17.97$^{abc}$ | - |
| 17 | 18.34$^{ab}$ | 17.73$^{abc}$ | 16.89$^{abc}$ | 17.17$^{abc}$ | - |
| | Camarosa | | Camaroga | | |
| Cultivars | | | | | |
| IBA (h) | 0 | 50 | 0 | 50 | ISD |
| **(j)** | | | | | |
| 12 | 17.27$^{a}$ | 17.21$^{a}$ | 17.12$^{a}$ | 17.90$^{a}$ | 1.637 |
| 15 | 16.62$^{a}$ | 17.36$^{a}$ | 16.59$^{a}$ | 18.47$^{a}$ | - |
| 17 | 17.92$^{a}$ | 17.31$^{a}$ | 17.12$^{a}$ | 17.78$^{a}$ | - |

Means with different letters in same figure indicate significant differences ($p<0.05$)

matter of strawberry had not much influenced by the other factors (Table 1). This is probably because the light received by the plant for photosynthesis was sufficient. However, the interaction effect from the variety, auxin and

Table 2: Means comparisons of the total dry matter percentage of strawberry as revealed by four factors interaction analysis

| | GA3 (0) | | | | GA3 (50) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | IBA (0) | | IBA (50) | | IBA (0) | | IBA (50) | | |
| 6-BA | 0 | 50 | 0 | 50 | 0 | 50 | 0 | 50 | LSD |
| **(a) V** | | | | | | | | | |
| Camarosa | 18.16$^{ab}$ | 17.08$^{ab}$ | 18.21$^{ab}$ | 16.97$^{ab}$ | 17.04$^{ab}$ | 16.8$^{ab}$ | 17.09$^{ab}$ | 16.90$^{ab}$ | 1.891 |
| Camaroga | 17.10$^{ab}$ | 17.80$^{ab}$ | 17.98$^{ab}$ | 18.44$^{ab}$ | 16.28$^{b}$ | 16.6$^{b}$ | 19.01$^{a}$ | 16.77$^{ab}$ | - |
| | IBA (0) | | | | IBA (50) | | | | |
| | GA3 (0) | | GA3 (50) | | GA3 (0) | | GA3 (50) | | |
| 6-BA (h) | 0 | 50 | 0 | 50 | 0 | 50 | 0 | 50 | LSD |
| (b) **Pd** | | | | | | | | | |
| 12 | 18.55$^{abcd}$ | 16.42$^{abcd}$ | 17.47$^{abcd}$ | 16.34$^{bcd}$ | 18.72$^{abc}$ | 17.93$^{abcd}$ | 16.87$^{abcd}$ | 16.71$^{abcd}$ | 2.316 |
| 15 | 16.01$^{cd}$ | 17.64$^{abcd}$ | 15.75$^{d}$ | 17.01$^{abcd}$ | 18.96$^{ab}$ | 16.24$^{bcd}$ | 19.26$^{a}$ | 17.20$^{abcd}$ | - |
| 17 | 18.32$^{abcd}$ | 18.26$^{abcd}$ | 16.77$^{abcd}$ | 16.74$^{abcd}$ | 16.60$^{abcd}$ | 18.94$^{abcd}$ | 18.03$^{abcd}$ | 16.59$^{abcd}$ | - |
| | Camarosa | | | | Camaroga | | | | |
| | GA3 (0) | | GA3 (50) | | GA3 (0) | | GA3 (50) | | |
| Cultivars | | | | | | | | | |
| 6-BA (h) | 0 | 50 | 0 | 50 | 0 | 50 | 0 | 50 | LSD |
| (c) Pd | | | | | | | | | |
| 12 | 19.45$^{ab}$ | 14.82$^{e}$ | 17.73$^{abcd}$ | 16.97$^{abcde}$ | 17.82$^{abcd}$ | 19.53$^{a}$ | 16.61$^{bcde}$ | 16.09$^{de}$ | 2.316 |
| 15 | 17.45$^{abcde}$ | 17.23$^{abcde}$ | 16.82$^{abcde}$ | 16.46$^{cde}$ | 17.52$^{abcde}$ | 16.64$^{bcde}$ | 18.20$^{abcd}$ | 17.75$^{abcd}$ | - |
| 17 | 17.65$^{abcd}$ | 19.02$^{abc}$ | 16.66$^{bcde}$ | 17.13$^{abcde}$ | 17.28$^{abcde}$ | 18.19$^{abcd}$ | 18.13$^{abcd}$ | 16.20$^{cde}$ | - |
| | Camarosa | | | | Camaroga | | | | |
| | IBA (0) | | IBA (50) | | IBA (0) | | IBA (50) | | |
| Cultivars | | | | | | | | | |
| 6-BA (h) | 0 | 50 | 0 | 50 | 0 | 50 | 0 | 50 | LSD |
| (d) Pd | | | | | | | | | |
| 12 | 18.65$^{ab}$ | 15.9$^{bc}$ | 18.53$^{ab}$ | 15.89$^{bc}$ | 17.38$^{abc}$ | 16.87$^{bc}$ | 17.05$^{bc}$ | 18.75$^{ab}$ | 2.316 |
| 15 | 16.11$^{bc}$ | 17.13$^{bc}$ | 18.16$^{abc}$ | 16.56$^{bc}$ | 15.66$^{c}$ | 17.52$^{abc}$ | 20.07$^{a}$ | 16.87$^{bc}$ | - |
| 17 | 18.05$^{abc}$ | 17.8$^{abc}$ | 16.26$^{bc}$ | 18.36$^{abc}$ | 17.04$^{bc}$ | 17.21$^{bc}$ | 18.37$^{abc}$ | 17.18$^{bc}$ | - |
| | Camarosa | | | | Camaroga | | | | |
| | IBA (0) | | IBA (50) | | IBA (0) | | IBA (50) | | |
| Cultivars | | | | | | | | | |
| GA3 (h) | 0 | 50 | 0 | 50 | 0 | 50 | 0 | 50 | LSD |
| (e) Pd | | | | | | | | | |
| 12 | 16.70$^{ab}$ | 17.84$^{ab}$ | 17.57$^{ab}$ | 16.85$^{ab}$ | 18.27$^{ab}$ | 15.97$^{b}$ | 19.08$^{a}$ | 16.73$^{ab}$ | 2.316 |
| 15 | 17.07$^{ab}$ | 16.17$^{b}$ | 17.62$^{ab}$ | 17.11$^{ab}$ | 16.58$^{ab}$ | 16.59$^{ab}$ | 17.58$^{ab}$ | 19.35$^{a}$ | - |
| 17 | 19.09$^{a}$ | 16.76$^{ab}$ | 17.58$^{ab}$ | 17.03$^{ab}$ | 17.50$^{ab}$ | 16.75$^{ab}$ | 17.97$^{ab}$ | 17.59$^{ab}$ | - |

Table 3: Means comparisons of the total dry matter percentage of strawberry as revealed by five factors interaction analysis

| | IBA (0) | | | | IBA (50) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | GA3 (0) | | GA3 (50) | | GA3 (0) | | GA3 (50) | | |
| 6-BA | 0 | 50 | 0 | 50 | 0 | 50 | 0 | 50 | LSD |
| **Cultivars (Pd)** | | | | | | | | | |
| **12 h** | | | | | | | | | |
| Camarosa | 19.10$^{abcde}$ | 14.31$^{f}$ | 18.20$^{abcdef}$ | 17.49$^{abcdef}$ | 19.80$^{abc}$ | 15.34$^{def}$ | 17.26$^{abcdef}$ | 16.44$^{abcdef}$ | 3.2750 |
| Camaroga | 18.01$^{bcdef}$ | 18.54$^{abcdeF}$ | 16.74$^{abcde}$ | 15.20$^{bcdef}$ | 17.63$^{aF}$ | 20.52$^{abcdef}$ | 16.47$^{ab}$ | 16.99$^{bcdef}$ | - |
| **15 h** | | | | | | | | | |
| Camarosa | 15.91$^{cdef}$ | 18.23$^{abcdef}$ | 16.30$^{cdef}$ | 16.04$^{cdeF}$ | 19.00$^{abcde}$ | 16.24$^{cdef}$ | 17.33$^{abcdef}$ | 16.89$^{bcdef}$ | - |
| Camaroga | 16.12$^{cdef}$ | 17.04$^{bcdef}$ | 15.20$^{ef}$ | 17.99$^{abcdef}$ | 18.93$^{abcde}$ | 16.23$^{cdef}$ | 21.20$^{a}$ | 17.51$^{abcdeF}$ | - |
| **17 h** | | | | | | | | | |
| Camarosa | 19.47$^{abcd}$ | 18.71$^{abcde}$ | 16.63$^{bcdef}$ | 16.88$^{bcdef}$ | 15.83$^{cdef}$ | 19.34$^{abcde}$ | 16.69$^{bcdef}$ | 17.37$^{abcdef}$ | - |
| Camaroga | 17.17$^{bcdef}$ | 17.82$^{abcdef}$ | 16.90$^{bcdef}$ | 16.60$^{bcdef}$ | 17.38$^{abcdef}$ | 18.55$^{abcde}$ | 19.36$^{abcd}$ | 15.81$^{cdef}$ | - |

Means with different letters in same figure indicate significant differences ($p<0.05$)

cytokine on the photoperiod is rather noticeable, particularly on Camaroga variety where under the 15 h photoperiod, the plant had significantly increased the dry matter content (Table 2d). This result confirms that

the application of exogenous hormones can increase the productivity of strawberry but only when grown under the long day photoperiod.

## CONCLUSION

The study showed that the dry matter content of strawberry was significantly affected by the joint interaction among factors of photoperiod, variety, auxin, gibberellin and cytokinin. It is believed that the production of strawberry in Cameron highland is not control by a single factor but rather by the mutual interactions of the five or more factors. It could be mentioned that var. Camaroga is a good variety of strawberry in Cameron Highland that can give a high production when grown under 12 or 15 h long day and supplemented with 50 ppm of gibberellin and auxin.

## REFERENCES

Archbold, D.D. and J.G. Strang, 1986. Effect of BA on growth and yield of Redchief strawberry. HortScience, 21: 1377-1379.

Durner, E.F., J.A. Barden, D.G. Himelrick and E.B. Poling, 1984. Photoperiod and temperature effects on flower and runner development in day-neutral, Junebearing and everbearing strawberries. J. Am. Soc. Hortic. Sci., 109: 396-400.

Engels, B. and G. Ebert, 1988. Effect of combined application of GA4+7 and BA on photosynthesis, transpiration and leaf growth in strawberry cultivar Korona (*Fragaria ananassa* Duch.). Erwerbsobstbau, 30: 183-185.

FAO, 2007. FAOSTAT agricultural statistics database. http://www.fao.org.

Fouad, M., H.J. Swartz and J.G. Buta, 1991. The role of abscisic acid and plant growth regulators in tissue culture-induced rejuvenation of strawberry *ex vitro*. Plant Cell Tissue Organ Cult., 25: 75-84.

Hancock, J.F., 1999. Strawberries. CAB International Publishing, New York, USA., pp: 237.

Maas, J.L., 1986. Photoperiod and temperature effects on starch accumulation in strawberry roots. Adv. Strawberry Prod., 5: 22-24.

Serce, S. and J.F. Hancock, 2005. The temperature and photoperiod regulation of flowering and runnering in the strawberries, *Fragaria chiloensis*, *F. virginiana* and *F. ananassa*. Sci. Hortic., 103: 167-177.

Shou-Ming, S., L. Guo-Jie, L. Shao-Hua and M. Peng-Fei, 2007. Effects of IAA, GA3 and 6-BA applied in autumn on plant quality of strawberry. J. Fruit Sci., 24: 545-548.

Tafazoli, E. and B. Shaybany, 1978. Influence of nitrogen, deblossoming and growth regulator treatments on growth, flowering and runner production of the Gem everbearing strawberry. J. Am. Soc. Hortic. Sci., 103: 372-374.

Weidman, R.W. and E.J. Stang, 1983. Effects of gibberllins ($GA_{4+7}$), 6-benzyladenine (6-BA) and promalin ($GA_{4+7}$ $^{+}$6-BA) plant growth regulators on plant growth, branch crown and flower development Scott and Raritan strawberries. Adv. Straw. Prod., 2: 15-17.