# การใช้หลอดฟลูออเรสเซ็นต์เพื่อประหยัดพลังงานในการเลี้ยงเนื้อเยื่อพืช

Fluorescent Lamps for Energy Saving in Plant Tissue Culture

**รมณีย์ เจริญทรัพย์**[1] อภิชัย กฤษณามระ[1]

Rommanee Charoensub[1] Apichai Kritsanamara[1]

## บทคัดย่อ

เพื่อศึกษาการลดค่าใช้จ่ายของการใช้ไฟฟ้าในการเพาะเลี้ยงเนื้อเยื่อ จึงได้นำหลอดฟลูออเรสเซ็นต์ ชนิด 36 วัตต์ (T8) ที่ใช้บัลลาสขดลวดแบบเก่า และ ชนิด 28 วัตต์ (T5) ที่ใช้ชุดบัลลาสอิเล็กทรอนิกส์มา ติดตั้งบนชั้นเลี้ยงเนื้อเยื่อ แล้วตรวจสอบผลของความเข้มแสงและสีของแสงของหลอดฟลูออเรสเซ็นต์ชนิดให้แสง daylight, cool white และ warm white ต่อการเจริญเติบโตของเนื้อเยื่อต้นเจตมูลเพลิงแดงและต้นกล๊อกซิเนีย ผลการศึกษาพบว่าหลอด T5 ที่ใช้ชุดบัลลาสอิเล็กทรอนิกส์ใช้ไฟฟ้า 26.66% ของหลอด T8 แต่ให้ความเข้มแสงต่ำกว่า การนำหลอด T5 ติดตั้งร่วมกับหลอด T8 ชนิด cool white บนชั้นเลี้ยงเนื้อเยื่อให้ค่าความเข้มแสงใกล้เคียงกับหลอด T8 ชนิด daylight แต่สามารถลดค่าใช้จ่ายได้ประมาณ 38% และผลการเจริญเติบโตของพืชทั้งสองชนิดภายใต้แสงจากหลอดชนิดต่างๆไม่มีความแตกต่างทางสถิติ

## ABTRACT

To save electricity cost for tissue culture laboratory, fluorescent lamps 36 watt (T8) with conventional solid-ballast and 28 watt (T5) with electronic ballast set installed on the culture shelf were investigated. The intensity and light colors, daylight, cool white and warm white were examined on growth of *in vitro* plantlets of rose-colored leadwort and gloxinia. The results indicated that T5 lamps with electronic ballast set consumed electricity by 26.66% of T8 lamps, resulted in lower light intensity generated capacity. The combination of T5 and T8 cool white lamps on shelf gave the similar light intensity but cost ca 38% of energy less than T8 daylight. In addition, the growths of both plantlets culture under all type of lamps were non-significantly different.

**Keywords:** energy saving, fluorescent lamp, light intensity, plant micropropagation

**e-mail address:** rdirmc@ku.ac.th

[1] ฝ่ายเครื่องมือและวิจัยทางวิทยาศาสตร์ สถาบันวิจัยและพัฒนาแห่งมหาวิทยาลัยเกษตรศาสตร์ กรุงเทพ 10900

[1] Instrumentation and Scientific Research Division, Kasetsart University Research and Development Institute, Bangkok 10900

# INTRODUCTION

Light plays an important role in influencing growth and development of the *in vitro* culture plants. High sucrose and salt containing media, low light level and carbon dioxide concentration in the culture vessel are some of the important limiting factors among various physical microenvironmental factors which influence photosynthesis of *in vitro* cultured plants (Fujiwara and Kozai, 1995). Beside photosynthesis, light, both quantity and quality, is involved in several processes of plant development such as photomorphogenensis and photoperiodism (Hopkins, 1999) and the expression of many genes is affected by light (Hopkins, 1995). Control of light spectrum and light cycle can also be used in plant tissue culture to regulate growth and development, improve plant quality and increase rate of growth in plants leading to improved plant yields (Economou and Read, 1987). As the importance of light in the plant growth, artificial light sources are used in plant tissue culture laboratory to provide all the light a plant needs. Thus the energy requirement and their cost are main expenditure of the laboratory as much as or more than the cost of manpower and others.

In recent years, many kinds of artificial light sources have evolved and been available for vary utilization which are energy and cost effective. Though the light emitting diodes (LEDs) can specify wavelength and less energy consuming but it requires special installation so that the fluorescent lamps are still popular as a light source for commercial micropropagation. Moreover, now they have variety color of light to select. Since the light quality is as important for plant development as the light quantity, the photosynthetic reaction of plants is driven predominantly by light at wavelengths in the near-ultraviolet (300-380 nm), blue (430-490 nm), red (640-700 nm) and far-red (700-760 nm) regions (Kozai *et al*., 1992). Though the aquarium light fluorescent lamps are recommended for plant tissue culture, their high price and required special order to buy are limited the decision for commercial. Fluorescent lamps that produce series of white light include daylight, cool white and warm white light for general lighting use are generally find in hardware stores as the tube diameter size, T8 (1 inch diameter) and T5 (0.5 inch diameter). As we know that the length and diameter of the tube enter into the calculation of how much power the lamp will consume and how much light it can generate, thus those lamps are alternative choice of light source for reducing cost of energy consumed.

However, the effects on growth of *in vitro* plantlets by comparison with energy consumption are not clarify, this investigation attended to indicate the cost reduction of energy saving and compare the effective of T8 lamp and T5 lamp on the growth of plantlets which will be the primary guide line for the choices of energy saving in laboratory.

# MATERIALS AND METHODS

## Energy saving

Fluorescent lamp 36 watt (T8) lamp with conventional ballast (starter and solid ballast) and 28 watt (T5) lamp with electronics-ballast set, were selected to compare the electricity consumption. The electricity current uses for individual lamp at 220 volt was measured by Amp meter then calculated the electricity consumed.

The electricity consumption of tissue culture shelf was also measured and compared among using fluorescent lamp daylight, cool white color type 1) T8 36 watt lamp with conventional ballast, 2) T8 36 watt lamp with electronics ballast set and 3) T5 28 watt lamp with electronics ballast set. Each shelf contained 8 lamps, 10 h photoperiod at room temperature 25$^{\circ}$C. The electricity consumption was measured by Watt Hour Meter.

## Quality of light

To compare the intensity of light produced from daylight, cool white and warm white type of fluorescent T8 and T5 lamps. Light intensity on the white Formica floor of the empty shelf, were measured on 28 point along the length of 2.4 m-long and 5 point along the width of 1.2 m-wide of the same white color oil painting ceiling shelf by LUX meter. Eight fluorescent lamps were installed along the length of shelf. Each lamp was 30 cm apart.

## Plant growth

*In vitro* plantlets of rose-colored leadwort (*Plumbago indica* Linn) and gloxinia (*Gloxinia sp.*) were used as plant material for growth developed observation. Plantlets were culture on semi-solidify MS (Murashige and Skoog, 1962) medium supplemented with 0.1 mg/l 6-benzylaminopurine (BAP), 30g/l sucrose and 6.7 g/l agar pH 5.6, 10 h photoperiod at 25$^{\circ}$C. After culture for one month, the pieces of single node 5 mm-long without leaf of rose-colored leadwort and single node 3 mm-long with a pair of leaves of gloxinia were cut off and used as started plant material. They were subculture on to the semi-solidify MS medium supplemented with 0.1 mg/l BAP and 6.7 g/l agar pH 5.6, 10 h photoperiod at 25$^{\circ}$C. Each culture tube (Pyrex® No. 9825) contained 10 ml of the medium, one piece of plant material per tube. The light source were compare using different kinds of fluorescent lamps, T8 (36 watt) and T5 (28 watt), which were daylight, cool white and warm white color type. The experiment was set on the white color oil painting ceiling shelf.

Each treatment consisted of ten replications. The numbers of new leaves, new leaves size and color, number of new shoot, new shoot length, fresh weight and dry weight of plantlets were recorded after culture for 5 weeks.

The experimental data were analyzed by variance analysis (ANOVA), followed by LSD test at 5% level of probability for mean comparison.

## RESULTS AND DISCUSSION

### Energy saving

The electric current of the individual lamp at 220 volt consumed by the 36 watt fluorescent lamp (T8) with conventional ballast is 450 mA (0.45 A) per lamp while the 28 watt fluorescent lamp (T5) with electronics-ballast set is 120 mA (0.12 A) per lamp. The calculated electricity power of T8 lamp is 99 W or consumed 0.099 unit/h and of T5 lamp is 26.4 W or consumed 0.0264 unit/h. It showed that T5 lamp consumed approximately 26.66 % of T8 lamp.

The tissue culture shelf contained 8 lamps of T8 daylight and cool white type with conventional ballast consumed the same level of electricity, while T8 lamps and T5 lamps with electronic-ballast sets have lower electricity consumption than T8 lamps with conventional ballasts, especially T5 lamps showed the lowest electricity consumption (Table 1). T5 lamps consumed approximately 24.2% of T8 lamps with conventional ballast and 62.99% of T8 lamps with electronic-ballast sets.

**Table 1** The average electricity consumption in kWh per 8 lamps.

| Type of lamp | Day | Photoperiod | Unit consumed |
|---|---|---|---|
| T8 daylight type with conventional ballast | 1 | 10 h | 7.33 kWh |
| | 5 | 50 h | 36.63 kWh |
| T8 cool white type with conventional ballast | 1 | 10 h | 7.33 kWh |
| | 5 | 50 h | 36.36 kWh |
| T8 daylight type with electronic-ballast set | 1 | 10 h | 2.79 kWh |
| | 5 | 50 h | 13.97 kWh |
| T5 daylight type with electronic-ballast set | 1 | 10 h | 1.76 kWh |
| | 5 | 50 h | 8.80 kWh |

The results of the measurement, the calculation of the electricity consumption and the cost of energy requirement (Table 2) showed that if we changed the T8 to T5 lamp of one shelf with 40 lamps, it can reduce the electricity cost about 2,298.91 Baht per month or 74.7 % of T8 lamp cost. The cost reduction can cover the cost of new T5 lamps with electronic-ballast set in the first 5.05 months. In the other hand, the use of T8 lamps but changed the conventional ballast to electronic-ballast could reduce the electricity cost about 1,903.44 Baht per month or 61.86% of the conventional ballast cost, not included the payment for the installation of new ballast. The cost reduction can cover the cost of new electronic-ballast in the first 4.62 months. However, T5 lamp can change easier, just only buy the new ones and no need of any installation of new equipment as T8 lamp with electronic-ballast needs.

Table 2 Energy saving comparison

| content | ballast | | electronic-ballast set | |
|---|---|---|---|---|
| | T8 daylight | T8 cool white | T8 | T5 |
| Electric current (A) per 8 lamps | 3.33 | 3.33 | 1.27 | 0.80 |
| Electric power (W) per 8 lamps | 732.60 | 732.60 | 279.40 | 176.00 |
| unit/h per 1 sub-shelf 8 lamps (kWh) | 0.73 | 0.73 | 0.28 | 0.18 |
| unit/h per 1 shelf 40 lamps (kWh) | 3.66 | 3.66 | 1.40 | 0.88 |
| Electricity cost[1] per 40 lamps 10 h/day (Baht) | 102.56 | 102.56 | 39.12 | 25.93 |
| Electricity cost per 40 lamps 10 h/day/month (Baht) | 3,076.92 | 3,076.92 | 1,173.48 | 778.01 |
| Electricity cost saving per month (Baht) | - | - | 1,903.44 | 2,298.91 |
| Electricity cost saving per year (Baht) | - | | 22,841.28 | 27,586.94 |
| Cost of lamp and electronic-ballast[2]/40 lamps (Baht) | 1,520.00 | 1,880.00 | 8,800.00 | 11,600.00 |
| Time to cover the cost of new equipment (month) | - | | 4.62 | 5.05 |
| Net electricity cost saving in the first year (Baht) | | | 14,041.28 | 15,986.94 |

Note: 1. The electricity cost factor used 2.80 Baht/ kWh, not included Ft value (Fuel Adjustment Charge)

2. A T5 lamp included electronic-ballast was 290 Baht/set and an electronic-ballast without T8 lamp was 220 Baht/set (whole sale price)

## Quality of light

The intensity of light produced from daylight, cool white and warm white fluorescent T8 and T5 lamps showed that T8 lamp cool white type produced higher average intensity (LUX) than T8 lamp daylight type. However, T5 lamps daylight, cool white and warm white type produced lower intensity than both T8 daylight and cool white. The conversion of illuminance (LUX) to photosynthetic photon flux density (PPFD: µmol $m^{-2}s^{-1}$) (Hoshi,1999), of both T8 and T5 cool white type showed higher average PPFD than T8 daylight and T5 daylight and warm white type (Figure 1).

As a benefit of the energy saving property of T5 lamps, it should be save the cost of electricity consumption by nearly 75%. However, T5 lamps produced lower intensity for both illuminance (LUX) and PPFD (µmol $m^{-2}s^{-1}$). Hence, to enhance the efficiency of light in addition to energy saving, T8 cool white type which gave higher intensity, were installed in combination with T5 daylight or cool white or warm white type. The T8 lamps were placed alternated with the T5 lamps along the length of shelf then recorded the intensity as the former observation. It showed that the combination of T8 cool white type and T5 all color type gave similar intensity as T8 daylight which was the original lamps of the shelf. The combination of T8 and T5 cool white type gave the nearest intensity (Figure 1) and can reduce the electricity cost by 38% of T8 daylight type which are generally used in laboratory.

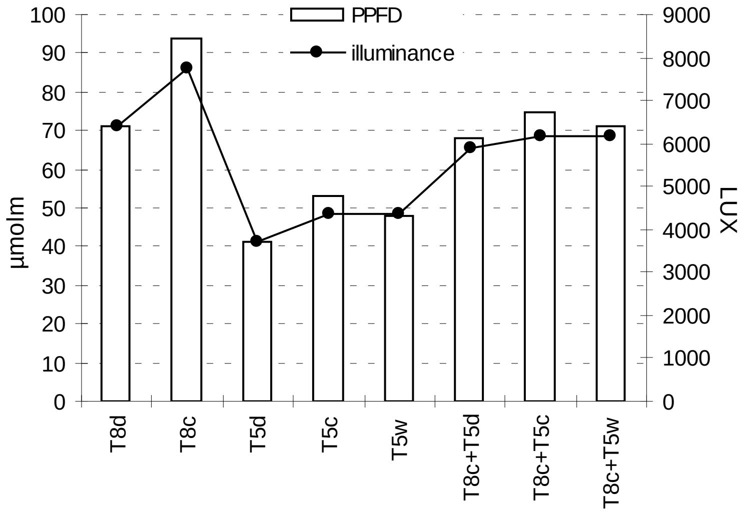


**Figure 1** The average illuminance (LUX) and average PPFD (µmol $m^{-2}s^{-1}$) of T8 daylight type (T8d), T8 cool white type (T8c), T5 daylight type (T5d), T5 cool white type (T5c), T5 warm white type (T5w) and the combination of T8 cool white type with T5 daylight (T8c+T5d), cool white (T8c+T5c) and warm white (T8c+T5w) type.

### Plant growth

Because of the result of light intensity measurement, plantlets of rose-colored leadwort and gloxinia were culture under selected kinds of fluorescent lamps consisted of T8 daylight and cool white type, T5 cool white and warm white type and the combination of T8 and T5 cool white type. After culture for 5 weeks, growth and development of *in vitro* plantlets of rose-colored leadwort and gloxinia, on the same medium with the same size and weight of initial explants, were examined which showed non-significantly different in all type of light sources provided. The average numbers of new leaves, new leaves size and color, number of new shoot, new shoot length, fresh weight, dry weight and increasing fresh weight of both plantlets were non-significantly different (Figure 2, 3 and 4).

Since, Plantlets under *in vitro* conditions have been considered to have little or no photosynthetic ability to provide a positive carbon balance and hence require sugar as a carbon and energy source for heterotrophic or mixotrophic growth (Kozai *et al.*, 1990). There was report of the growth of *in vitro* bananas, in air tight vessels and in continuously $CO_2$ flushed vessels under two different PPFD, low and high, 30 and 240 µmol $m^{-2}s^{-1}$ respectively. The results showed that under low irradiance it is the low light intensity that limits photosynthetic activity and under high light intensity, the $CO_2$ availability becomes the limiting factor for photosynthesis during several hours in the light period (Navarro *et al.*, 1994). In our experiments, light intensity exposed to the plantlets were ranged approximately 50 – 90 µmol $m^{-2}s^{-1}$ (Figure 1). It was not such a high intensity but as normal as used for tissue culture works which approximately 50 µmol $m^{-2}s^{-1}$ (Taji *et al.*, 1995). Consequently, the different intensity cause by different type of our investigated fluorescent lamps were not enough to influence the alternative growth of both kinds of plantlets in the air tight culture vessel.

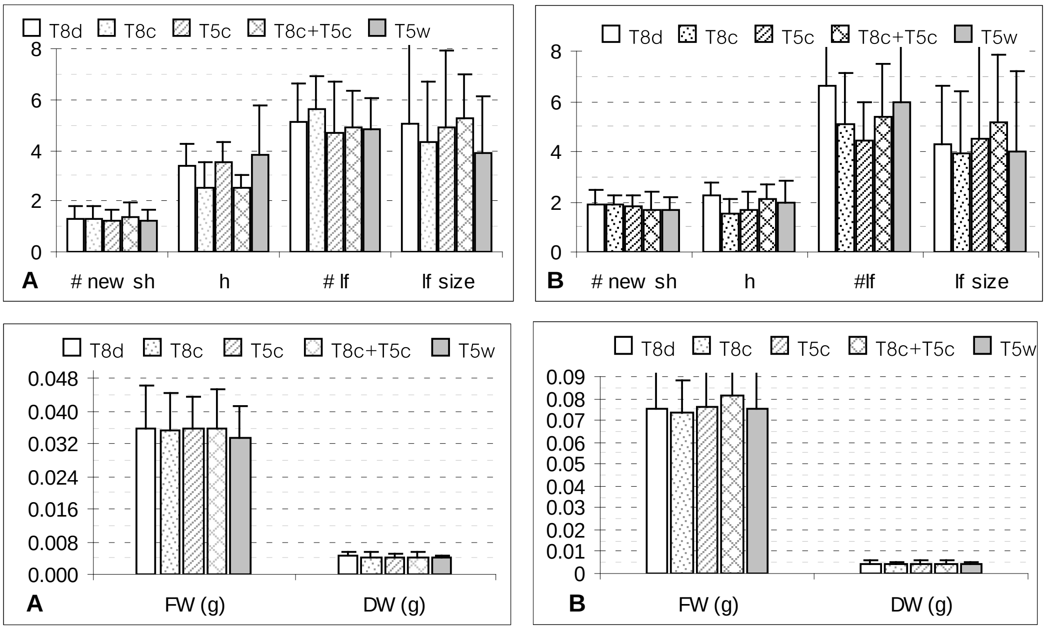


**Figure 2** Growth and development of *in vitro* plantlets of rose-colored leadwort (A) and gloxinia (B) culture under 36 watt lamps, T8 daylight (T8d) and cool white (T8c) and under 28 watt lamps, T5 cool white (T5c) and warm white (T5w) and under the combination of T8 cool white and T5 cool white (T8c+T5c) after 5 weeks 10 h photoperiod. [# new sh: number of new shoots, h: height of new shoot in mm, #lf: number of new leaves, lf size: size of new leaves in $mm^2$ per leaf, FW: fresh weight in g, DW: dry weight in g, per plantlet.]

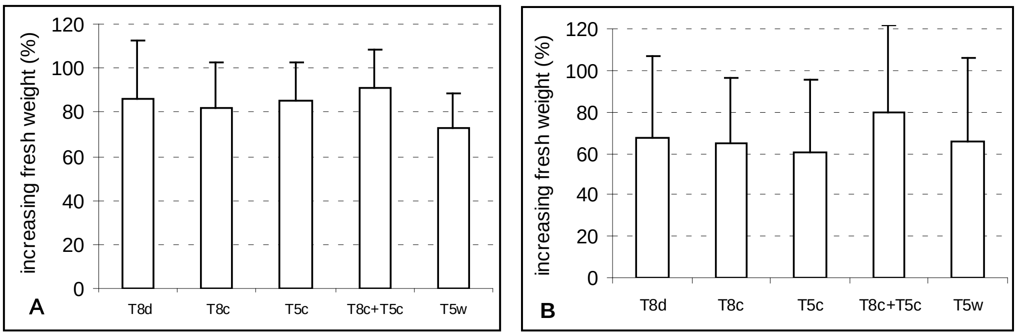


**Figure 3** The increasing fresh weight (%) of *in vitro* plantlets of rose-colored leadwort (A) and gloxinia (B) culture under 36 watt lamps, T8 daylight (T8d) and cool white (T8c) and under 28 watt lamps, T5 cool white (T5c) and warm white (T5w) and under the combination of T8 cool white and T5 cool white (T8c+T5c) after 5 weeks 10 h photoperiod.

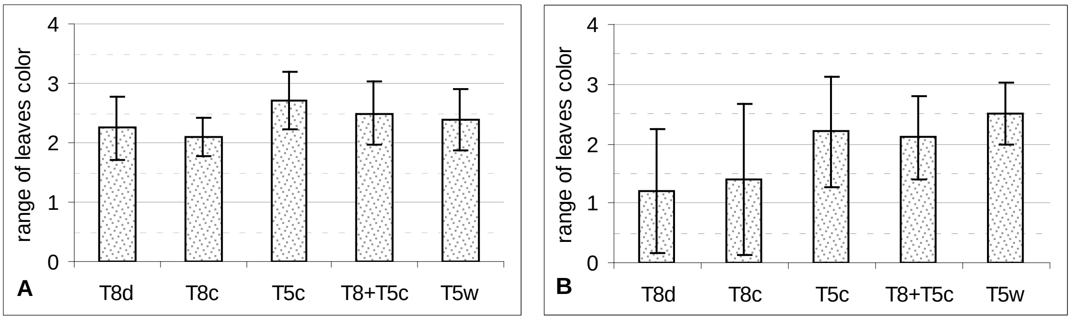


**Figure 4** The ranging number of leaves color of *in vitro* plantlets of rose-colored leadwort (A) and gloxinia (B) culture under 36 watt lamps, T8 daylight (T8d) and cool white (T8c) and under 28 watt lamps, T5 cool white (T5c) and warm white (T5w) and under the combination of T8 cool white and T5 cool white (T8c+T5c) after 5 weeks 10 h photoperiod. Ranging number referred, 0: yellow, 1: light green, 2: green, 3: dark green

## CONCLUSION

For the energy saving, the 28 watt T5 lamps reduced cost of electricity consumption by approximately 75%, however, T5 lamps produced lower intensity both illuminance (LUX) and PPFD (µmol $m^{-2}s^{-1}$). The combination of T5 and T8 cool white lamps on shelf gave the similar light intensity but cost ca 38% of energy less than T8 daylight. In addition, the growths of both plantlets culture under all type of lamps were non-significantly different. It may conclude that in normal condition of culture with air tight vessel, all kinds of fluorescent lamps that we observed can produce the similar quality of plantlets. However, there are other limiting factors which do not observed in this investigation, the further experiment should be conduct.

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