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COMPACT 3U AS A NOVEL ARTIFICIAL LIGHTING SOURCE FOR GLOXINIA (*SINNINGIA* SPP.) AND POTATO (*SOLANUM TUBEROSUM*) MICROPROPAGATION

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ABSTRACT

An efficient lighting system (Compact 3U) was successfully applied to the micropropagation of gloxinia and potato plants. To compare the *in vitro* growth of plantlets under Neon and Compact 3U lighting systems, gloxinia and potato shoots were cultured on suitable media at different light intensities: (1) 45 μmol $m^{-2}s^{-1}$ (under Neon lighting system as a control); (2) 45 μmol $m^{-2}s^{-1}$, (3) 60 μmol $m^{-2}s^{-1}$, and (4) 75 μmol $m^{-2}s^{-1}$ (under Compact 3U lighting systems). The results obtained after 3 weeks of *in vitro* culture and 6 weeks of acclimatization in a greenhouse showed that the growth of plantlets cultured under the Compact 3U system was better than that under Neon lighting system. The Compact 3U lighting source had a highly significant effect on the growth and development of gloxinia and potato plantlets. Besides, the data in our study also indicated that gloxinia and potato plantlets adapted differently to different lighting sources and light intensities.

Keywords: Compact 3U, gloxinia, Neon, potato

1. INTRODUCTION

In vitro multiplication is a primary method to rapidly propagate horticultural plants. In many cases, this technique gives some superior transplant qualities to seedling production and conventional vegetative production, and billions of micropropagated plantlets are produced annually worldwide [1]. The widespread use of micropropagation for major crops in agriculture and horticulture has been restricted because of its relatively high production cost caused by high labor cost [2] and especially electrical energy consumption.

Plant growth and development are affected by many factors, such as light quality, photoperiod, temperature, humidity, exogenous growth regulators, and mechanical stresses [3]. Among these, light conditions, in particular, have a significant impact on the growth and morphology of *in vitro* and *ex vitro* plants [2, 3].

Light affects on plant growth and development due to photoperiodic effects, photosynthesis and photomorphogenesis [4, 5].

Although light requirements of the *in vitro* plantlets are less than those of *in vivo* plants, it is important to regulate the photomorphogenic process in tissue culture in terms of duration, intensity, and spectral quality [6].

Light intensity regulates the size of leaves and stem as well as their morphological pathway and

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is involved in pigment formation and hyperhydricity of *in vitro* plantlets [7, 8]. Each plant requires different optimal light intensity according to its species, culture medium, growth and developmental stage, etc. Appelgren (1991) found that exposure of *Pelargonium* shoot cultures for 18 h/day for 6 to 8 weeks to red light at 30 μmol $m^{-2}s^{-1}$ remarkably increased stem elongation as compared to white and incandescent lights at the same light intensity [9].

The total quantity of light received by plant directly influences on photosynthesis, plant growth and yield [10].

However, it is surprising that the most commonly used fluorescent lamps in micropropagation were developed for human lighting applications while the photoreceptors of plants differ from those of human. Therefore, the lighting sources previously developed and used for human lighting usage have various limitations, consequently, may not be optimal for *in vitro* produced shoots or plants [11]. Moreover, the amount of photosynthetically active radiation (PAR) energy received by shoots or plantlets *in vitro* is only a small portion of the total energy released from the lighting source [12] while illumination expenses are one of the major factors determining production cost.

In our study, we used the Compact 3U lamp as a promising lighting source for *in vitro* propagating gloxinia and potato plantlets. In this report, we focused on the effects of two different lighting sources (Compact 3U and Neon) as well as some different light intensities of Compact 3U lamps (45, 60 or 75 μmol $m^{-2}s^{-1}$, respectively) on the growth and morphology of *in vitro* plantlets compared to Neon lamp (with cool white emission) as a control system.

Compact 3U lamps (Fig. 1) consuming less 80% energy than incandescent lamps, have a compact size, a long life (> 6,000 h), and reach one-fifth of the brightness of conventional incandescent lamps. Therefore, the use of these lamps in micropropagation could reduce the plant production cost.

Fig. 1: *Compact 3U lamp*

2. MATERIALS AND METHODS

2.1 Plant materials

Sinningia shoots, about 3 cm in height, derived from shoots multiplicated on MS medium [23]

(supplemented with 0.1 mg/l NAA, 0.3 mg/l BA, 30 g/l sucrose and 8 g/l agar), were cultured on ½ MS medium plus 20 g/l sucrose and 8 g/l agar.

Solanum tuberosum cv. 07 internodes, about 0.5 cm in length, derived from *in vitro* plantlets, were cultured on MS medium supplemented with 0.1 mg/l NAA, 0.1 mg/l GA_3, 0.5 mg/l adenine-sulphate, 0.5 g/l activated charcoal, 10% coconut water, 20 g/l sucrose and 8 g/l agar.

For all experiments, 250 ml vessels content 60 ml of media were used. pH was adjusted to 5.7 before autoclaving at 121^{o}C, 1 atm for 30 min.

2.2 Lighting system

Cool white fluorescent lamps (Neon tubes) (40 W each; Rang Dong Light Source & Vacuum Flask Co., Vietnam, FL-40W/T10) and warm white fluorescent lamps (Compact 3U lamps, Fig. 1) (18 W each; Rang Dong Light Source & Vacuum Flask Co., Vietnam, CFH-3U18W) were used as lighting sources in each treatment.

Light intensities were 45 μmol $m^{-2}s^{-1}$ under Neon light or 45, 60, 75 μmol $m^{-2}s^{-1}$ for Compact 3U (Fig. 2) according to each experiment. Photosynthetic photon flux density (PPFD) was measured with an illumination meter (Tokyo photoelectric Co., LTD., Japan, ANA-F11) on the empty culture shelf.

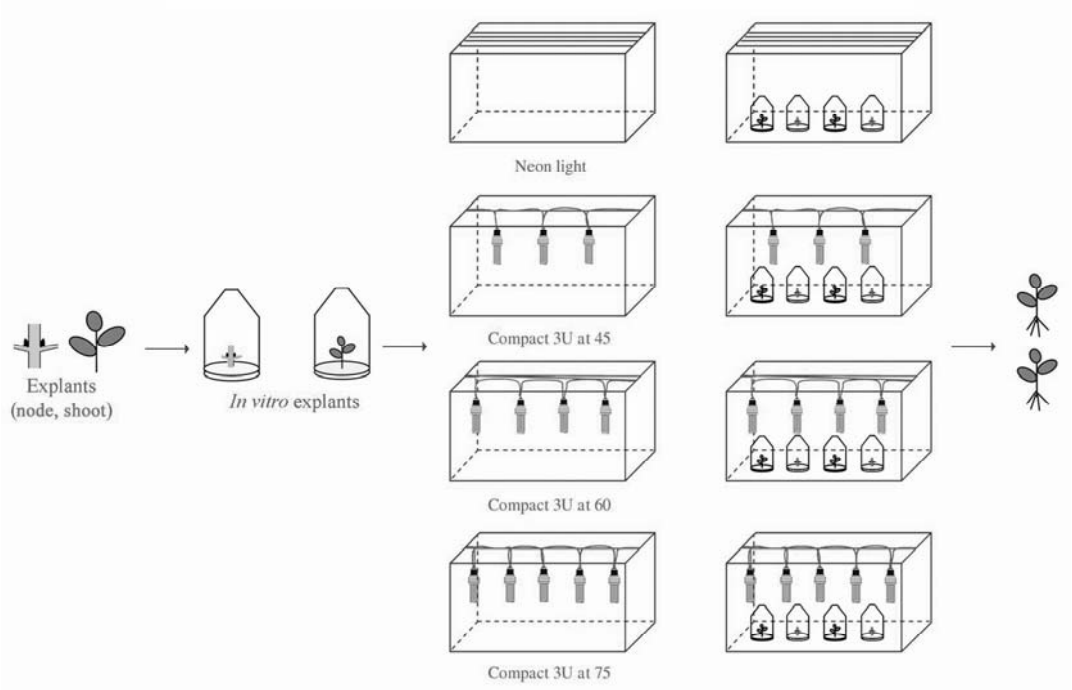

Fig. 2: *Setting up the Compact 3U and Neon lighting sources for studying in vitro growth and development of gloxinia and potato plantlets*

2.3 Effects of different light intensities of Compact 3U on the *in vitro* growth and development of gloxinia and potato plantlets

Five shoots from a plant (gloxinia or potato) were cultured in each vessel (10 vessels per shelf). There were 4 shelves under different light intensities: three shelves with the Compact 3U

lighting system which the distance from 3U lamps to the surface of shelf is 16 cm with 3 lamps/shelf, 4 lamps/shelf and 5 lamps/shelf for gaining the intensities at 45, 60 or 75 μmol $m^{-2}s^{-1}$ respectively and the remaining shelf with Neon lighting system at 45 μmol $m^{-2}s^{-1}$. After 3 weeks of culture, some morphological parameters of potato plantlets (plant height, number of nodes, root length, internode length, leaf area, plant fresh weight, and number of lateral buds) as well as those of gloxinia plantlets (plant height, number of nodes, leaf area, root length, and plant fresh weight) were recorded.

To estimate the effect of Compact 3U lighting system on growth and development of plantlets in greenhouse, the *in vitro* potato plantlets were chosen to transplant to greenhouse and its growth and development were observed after 8 weeks of culture. The acclimatization of plantlets in the greenhouse is described in details in the acclimatization section. All the *in vitro* cultures and *ex vitro* plantlets were cultured under culture conditions described as the below culture conditions section.

The process to set up the Compact 3U and Neon lighting sources for studying *in vitro* growth and development of potato and gloxinia plantlets was generally described in Fig. 2.

2.4 Acclimatization

After 3 weeks of culture, potato plantlets were transplanted to greenhouse, and sprayed with 5 g/l antifungal mixture containing Manozeb 80 WP (Materials for plant protection II Co., Vietnam), Zodiac 80 WP (Vinh Thanh Ltd., Co., Vietnam) and Atonick 18 DD (Asatti Chemical Co., Japan) twice a week. In addition, these plantlets were sprayed with a pesticide solution containing 150 g/l Sumi alpha (Omo Chemical Ltd., Co., Japan) once a week and fertilizer solution containing 100 g/l NPK, 50 g/l Komix BFC 201 (Thien Sinh Biochemical Agriculture and Trade Co., Vietnam) and 15 g/l Miracle Fort (Phu Hung Foundation, Vietnam) once a week. In addition, they were also watered twice daily.

2.5 Culture conditions

The *in vitro* cultures were incubated at 25 ± 2^{o}C under a 10-hour photoperiod and 75 - 80% relative air-humidity under different lighting systems according to experimental purposes.

The *in vitro* plantlets, after being collected data, were transplanted into greenhouse at 25 ± 2^{o}C with 80 - 85% relative air-humidity and under 6 h/day with supplemental Compact 3U lighting source. They were sprayed with solutions at dosages and periods as described in the acclimatization above.

2.6 Data collection

2.6.1 In vitro

After 3 weeks of culture, plant height, number of nodes, root length, internode length, leaf area, plant fresh weight, and number of lateral buds of potato plantlets as well as plant height, number of nodes, leaf area, root length, and plant fresh weight of gloxinia plantlets were recorded.

2.6.2 Ex vitro

The subsequent growth and development of potato plantlets under 6 h/day supplemental Compact 3U lighting source in the greenhouse at night were observed. After 8 weeks of culture, plant height, number of leaves and tubers, plant fresh weight, and tuber fresh weight of *Solanum tuberosum* cv. 07 plants were collected.

2.7 Statistical analyses

Each treatment was repeated 3 times and the data was recorded after 3 week of culture. Explants in experiments were arranged in a randomized complete block design with 5 shoots per treatment and three blocks. The data were analyzed for significance by analysis of variance with the mean separation by Duncan's multiple range tests [13].

3. RESULTS AND DISCUSSION

3.1 Effects of different light intensities of Compact 3U lighting source on the *in vitro* growth and development of gloxinia and potato plantlets after 3 weeks of culture

3.1.1 Solanum tuberosum cv. 07

The effects of different light intensities of Compact 3U on the *in vitro* growth and development of *Solanum tuberosum* cv. 07 are described in Table 1. There was a significant difference in plant height, internode length, leaf area, plant fresh weight and number of lateral buds per plant in both lighting systems (Fig. 3a).

Table 1: *Effects of different light intensities of Compact 3U lighting source on the in vitro growth and development of Solanum tuberosum cv. 07 plantlets after 3 weeks of culture*

Light intensity (μmol $m^{-2}s^{-1}$)	**Plant height (cm)**	**Number of nodes**	**Root length (cm)**	**Internode length (cm)**	**Leaf area (mm^2)**	**Plant fresh weight (mg)**	**Number of lateral buds**
Neon (45)	6.2c[x]	5.5d	5.2b	1.4c	5.6d	160d	3.3a
Compact 3U (45)	8.3a	6.3c	6.7a	2.1a	11.9b	220b	2.8b
Compact 3U (60)	7.8b	6.5b	6.7a	1.7b	6.5c	270a	3.2a
Compact 3U (75)	8.5a	6.8a	6.8a	1.7b	13.3a	190c	1.9c

[x]Different letters within a column indicate significant differences at P = 0.05 by Duncan's multiple range test.

The plant height, internode length and leaf area of plantlets cultured under Compact 3U system at 45 μmol $m^{-2}s^{-1}$ were considerably higher than those under Neon lighting system at the same light intensity. However, the number of lateral buds per plant under Neon lighting system was greater than that of Compact 3U lighting system at 45 μmol $m^{-2}s^{-1}$. Besides, there was no significant difference in the number of nodes and root length of potatoes in both lighting systems. In general, these results showed that the growth and development of potatoes cultured under Compact 3U lighting source were better than those grown under Neon lighting source when compared at the same intensity at 45 μmol $m^{-2}s^{-1}$.

In addition, except for root length, different intensities (45, 60, 75 μmol $m^{-2}s^{-1}$) among the 3U lighting systems affected on some plant growth characteristics such as plant height, number of nodes, internode length, leaf area, plant fresh weight and number of lateral buds. The plant height, number of nodes and leaf area were highest when cultured under Compact 3U light intensity at 75

μmol $m^{-2}s^{-1}$. But the plant fresh weight, number of lateral buds was highest when cultured at 60 μmol $m^{-2}s^{-1}$ and the internode length was highest at 45 μmol $m^{-2}s^{-1}$. In general, the best growth and development of potato were obtained when it was cultured under Compact 3U light intensity at 75 μmol $m^{-2}s^{-1}$.

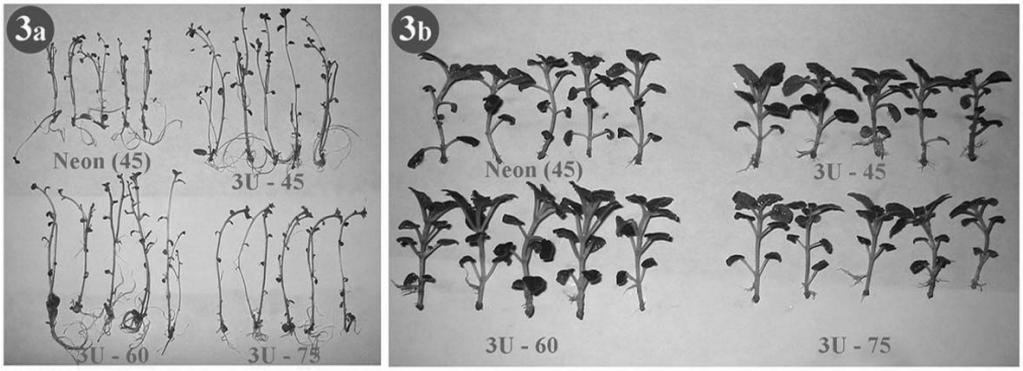

Fig. 3: *Potato and gloxinia plants cultured under Compact 3U at different light intensities. (3a) Potato cultured under Compact 3U at different light intensities after 3 weeks of culture. Potato cultured under Neon light at 45 μmol (top left), Compact 3U at 45 μmol $m^{-2}s^{-1}$ (top right), 60 μmol $m^{-2}s^{-1}$ (bottom left), or 75 μmol $m^{-2}s^{-1}$ (bottom right). (3b) Gloxinia cultured under Compact 3U at different light intensities after 3 weeks of culture. Gloxinia cultured under Neon light at 45 μmol (top left), Compact 3U at 45 μmol $m^{-2}s^{-1}$ (top right), 60 μmol $m^{-2}s^{-1}$ (bottom left), or 75 μmol $m^{-2}s^{-1}$ (bottom right)*

3.1.2 Sinningia spp.

Table 2: *Effects of different light intensities of Compact 3U lighting source on the in vitro growth and development of gloxinia plantlets after 3 weeks of culture*

Light intensity (Compact 3U) (μmol $m^{-2}s^{-1}$)	**Plant height (cm)**	**Number of nodes**	**Leaf area (mm^2)**	**Root length (cm)**	**Plant fresh weight (mg)**
Neon (45)	4.4a[y]	4.7a	33.2d	5.1d	240c
Compact 3U (45)	3.6b	4.7a	68.7a	8.3c	300a
Compact 3U (60)	4.4a	4.8a	61.5b	9.7a	290b
Compact 3U (75)	3.6b	4.2b	53.0c	9.0b	190d

[y]Different letters within a column indicate significant differences at P = 0.05 by Duncan's multiple range test.

The results in Table 2 showed that the Compact 3U lighting source had a significant effect on leaf area, root length and plant fresh weight of gloxinia plantlets. These morphological parameters of *Sinningia* spp. plantlets cultured under Compact 3U lighting systems were higher than those under Neon lighting system (except for plant height and the number of nodes) (Fig. 3b).

Different light intensities of Compact 3U lighting systems differently affected the growth and development of gloxinia. Leaf area and plant fresh weight decreased proportionally with the decrease of light intensities and were highest at 45 μmol $m^{-2}s^{-1}$. However, the plant height, number of nodes and root length were highest at 60 μmol $m^{-2}s^{-1}$.

These results suggested that gloxinia shoots should be cultured at 60 μmol $m^{-2}s^{-1}$ which was also the most appropriate intensity for inducing vigorous growth of the plantlets.

3.2 Effect of Compact 3U lighting system on growth and development of *Solanum tuberosum* plantlets in greenhouse

The data in Table 3 and Fig. 4 showed that some morphologic parameters of Compact 3U-derived potato plants (except for number of tubers) in the greenhouse after one month and a half under 6 h/day under Compact 3U lighting source at night were higher than those of Neon-derived plants. These results suggested that using Compact 3U lighting system for culturing potato *in vitro* could save electric energy consumption as well as induce vigorous growth of plantlets. The survival rate of potato plantlets cultured under Compact 3U lamps in greenhouse is 90% and is similar to which of those plantlets untreated with light. Hence, this parameter is not considered in this experiment.

Table 3: *Subsequent growth of Compact 3U-derived potato plants in the greenhouse after two months and a half under 6 h/day with Compact 3U lighting source*

Lighting systems (μmol $m^{-2}s^{-1}$)	Plant height (cm)	Number of leaves	Number of tubers	Plant fresh weight (g)	Tuber fresh weight (mg)
Neon	16.0b[z]	9.4b	36a	1.1b	590b
Compact 3U	17.6a	10.3a	31b	1.4a	640a

[z]Different letters within a column indicate significant differences at P = 0.05 by Duncan's multiple range test.

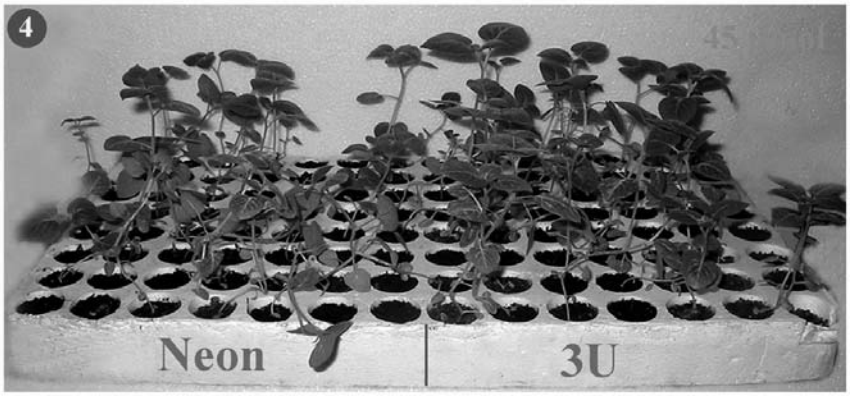

Fig. 4. *Potato plants in spongy tray after transplanted to greenhouse 8 weeks. Potato derived from Neon light (left) or Compact 3U (right) at 45 μmol $m^{-2}s^{-1}$*

In summary, the Compact 3U lighting source had a significantly positive effect on the growth and development of gloxinia and potato plantlets. The Compact 3U lighting source had a positive effect on the plant height and the number of roots of potato as well as the plant fresh weight of potato and gloxinia plantlets. The results obtained in this study showed that Compact 3U lighting source affected on the morphology of gloxinia and potato plantlets, increased their biomass, and enhanced the plantlet growth before transplanting to the greenhouse.

In most cases, different Compact 3U light intensities had no clear effect on plantlet growth and development as compared to those of Neon light. Different light intensities affected on potato and gloxinia leaf area and plant fresh weight, and potato internode length. In these plants, a lower light intensity gave a higher plant quality. Except for the leaf area of potato, the remaining cases showed that plantlets grew and developed well under lower intensities (45 or 60 μmol $m^{-2}s^{-1}$). Consequently, Compact 3U lighting source has considered having the positive effect on the growth and development of *in vitro* plantlets before transplanting to greenhouse.

The results of this study were similar to those of Economou and Read (1987), Warrington and Michell (1976), Morgan and Smith (1981), Smith (1982), Tibbitts et al. (1983), Mortensen and Stromme (1987), and Agrawal (1992) who all confirmed the significant effects of light quality (related to different lighting sources) on the *in vitro* and *ex vitro* growth and plant morphology [5, 14 - 19]. The effects of light intensity of different lighting sources on the growth and development of plants were also the concern of some studies of Gilslerod and Mortensen (1997), Miyashita et al. (1997), and Nhut (2002) [20 - 22]. In these studies, higher light intensities gave the best plant growth. But in this report, we suggest using lower intensities (45 or 60 μmol $m^{-2}s^{-1}$) of Compact 3U for plant growth due to the electrical energy consumption saving as well as increasing the growth and development of gloxinia and potato plants.

4. CONCLUSIONS

The Compact 3U lighting source had a highly significant effect on the growth and development of gloxinia and potato plants. Plant quality was better under the Compact 3U system. In most cases, different light intensities of Compact 3U had no clear effect on the growth and development of the plantlets as compared to Neon light. The Compact 3U at lowest intensity resulted in slow growth.

Hence, having a suitable light spectrum, resulting in good, high quality plants, saving 75 - 80% of electrical energy consumption as compared to incandescent lamps, being cheap, and subsequently retrieving initial investments quickly, the Compact 3U are expected to be a novel and promising lighting system for micropropagation and subsequent growth of gloxinia and potato plants.

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