Journal of Agricultural Technology 2012 Vol. 8(4): 1461-1468
Available online http://www.ijat-aatsea.com
ISSN 1686-9141

Vertical mobile planting system consistent with the pattern of solar radiation and effects of system on light exposure and growth of Gerbera cut flowers (*Gerbera jamesonii* cv. Antibes), in greenhouse culture

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Shahla Mahdavi, Mohsen Kafi, Rouhangiz Naderi and Toktam Sadat Taghavi (2012) Vertical mobile planting system consistent with the pattern of solar radiation and a study on effects of system on light exposure and growth of Gerbera cut flowers (*Gerbera jamesonii* cv. Antibes), in greenhouse culture. Journal of Agricultural Technology 8(4): 1461-1468.

One of the problems encountering plant production in greenhouses is decreasing yield from strategies employed for economic efficiency. Vertical culture presents the possibility for increased yield in greenhouses, but light availability becomes a problem. This research has been done, after much investigation, to construct a mobile vertical planting system. A fixed vertical system was also constructed to compare effects with the moving system. Gerbera plants cv. Antibes was cultured in both systems and on the ground. The effect of the vertical mobile system on yield enhancement of *Gerbera jamesonii* cv. Antibes was measured and compared with the two other culture systems. Results showed that the vertical culture systems were effective on raising yield in greenhouse production due to increasing the number of plants per m^2. The mobile vertical system was effective on light exposure to plant surfaces, and those plants cultured on a mobile vertical system received more light than plants in other systems. System type had significant effect on leaf number of plants and plants on the mobile vertical system had higher leaf number. Increased light and plant growth on the mobile vertical system would be concerned the movement of the system consistent with solar radiation. Use of this system of vertical culture, through increased plant number per m^{2,} compared to ground plants and the quality of properties, would be presented a way to enhance quality and yield in greenhouse production.

Key words: *Gerbera jamesonii*, overcast, yield, vertical mobile planting system

Introduction

One way to enhance yield in greenhouse production is with a vertical culture system (Stapleton *et al.*, 2001). Vertical culture is a method for plant

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culture that using the height of a greenhouse in addition to the ground space and this can increase the number of plants and thus enhance yield. Vertical culture systems are used worldwide for example, in USA, Japan, Australia and European countries such as Italy (Paraskevopoulou *et al*., 1995). Other benefits of vertical culture include more economic use of water and nutrition, easy harvesting and a reduction in labor costs. Stapleton *et al.,* (2001) investigated some vegetables such as aruguia (*Eruca vesicaria*), basil (*Ocimum basilicum*), Purple basil (*Ocimum basilicum*), chervil (*Anthriscus cerefolium*), dill (*Anethom graveolens*), lemon balm (*Melissa officinalis*), sweet marjoram (*Origanum majorana*), oregano (*Origanum vulgare*), parsley (*Petroselinum crispum*), Italian (flat leaf) parsley (*Petroselinum crispum*), sage (*Salvia officinalis*) and thyme (*Thymus vulgaris*) in vertical culturing systems.

Excellent growth vigor was reported in vertical culturing systems. A study done in 2010, Al-Raisy *et al*. investigated the effect of four media in strawberry vertical cultures and reported the best yield, fruit quality and leaf ion concentration in media with around 6 pots. Yuan *et al.* (2004) reported on vertical culture in strawberry and determined water and herbicide use decreased, fruit produce was cleaner, it ripened faster and yield was enhanced. Liu *et al.* (2005) measured vertical culture in cylindrical columns and reported that this enhanced yield of vegetables twice or threefold per m^2. In addition, vertical culture has been found to be preferable for enhanced yield, but existing vertical systems have some disadvantages such as light restriction and the problem that pots shade to each other, nutrition composition changes from upper pots to those positioned at lower levels, problems with transmission of disease and salt aggregation have also been reported. Hence, this new system with efficiency requirements would be higher than current systems which aimed to eliminate these aforementioned problems.

Gerbera and its hybrids are well known for their variable shape and color of their flowers and are one of the ten most popular commercial cut flowers in the world (Flower council of Holand; Solgi *et al*., 2009). *Gerbera jamesonii* L. is currently a major cut flower crop worldwide. This plant is a member of the Asteraceae family (Mercurio, 2007). ‘Antibes’ is a new cultivar of standard gerberas that has been produced in the Netherlands. It has red flowers of about 12 cm diameter and the vase life of this cultivar is estimated to be about 10 days.

The main aim of this research was to invent a system for optimization of vertical culture for gerbera plant (*Gerbera jamesonii* cv. Antibes) in greenhouse. Effects of the vertical mobile system (as an invented system) in comparison to a fixed vertical system and common ground culture were evaluated on growth and yield of Gerbera.

Materials and methods

The new type of vertical system was made to resolve the problem of shade in current vertical culture systems. It is created with a rotor motor system to rotate during the day (mobile vertical system) to be consistent with movement of the sun's radiation, as an attempt to increase plants' exposure to light during daytime. In the vertical culturing system, structures were made from galvanized tubes with pots hanging from them. To prevent water shed, saucers adjoined pots were made by hooks and wires. In terms of the pitch of irrigation drippers, tubes were perforated at specific demarcation points. Spacing of pores was ordered to minimize shading of pots at different heights. After making the structure, drippers were adjoined to tubes. All pots had a system for simultaneous irrigation and nutrition that used one timing device. Tubes had two roles; one as a retentive structure and another for transmission of water and nutrition. The vertical system was mobilized by one gearwheel, one spiral gearbox, one step motor and Programmable Logic Controller (PLC), it could move consistent with the solar radiation, plants were standing in maximum amounts of sunlight and the least shade (picture 1). Plans of sunrise and sundown were plotted to excel and the PLC was programmed for consistency with them. After measuring the maximum angle of sunshine during the day in the greenhouse with one staple wood, the necessary medium angle of the system's movement was obtained. Per retentive structure was made of the three main arms and the step motor moved one of them, then the movement was shifted to the two other arms with one clamp.

Two micro switches controlled the start and end of a movement angle to determine two ends of a movement angle to prevent damage to the arms.

Design and making movement strength

Movement strength used in the system was made of one, two phase texture step motor with 5 N/m power to create low deal movement by programming with a PLC that received pulses induced by a 1.8 degree movement. A step motor transformed these electronically received pulses to mechanical movement with transmission of 0 & 1 bytes. In fact a one step motor is a mixture of a one DC electrical motor and one solenoid, that can rotate very slowly (step means a one degree rotation), to create movement consistent with sun's radiation as well as being a soft movement, a step motor was chosen as the most suitable device. One spiral gearbox with 1 relation by 7.5 with one orbit of spiral gearbox, gearwheel are just rotated by 7.5 degrees to overcome any limitation of motor power. One stand was made that could undergo the weight and parity of the system. Also tree yataghan was used to control rotation, as it was soft and easy.

Electrical used equipment characterization

Due to the possibility of programming and use in an industrial environment and also its ability to collect data, a mini-PLC model: TECO was used for sending pulses in defined seconds. Moreover one industrial board was used for conversion, for sending pulses from the PLC to the step motor, as it needed pulses with specific voltage. In this project two micro switches were used to determine the start and end points of morning and afternoon movements. PLC transmitted a written computer program to contactors and controls mechanisms.

Control system and plants

A system for vertical culture, exactly like the mobile system was invented and constructed, but it was immobile. Moreover, in current systems of greenhouse culture pots are put on the ground, this technique was used as a control for both vertical systems. Little plants of *Gerbera jamesonii* cv. Antibes were bought from Netherlands and cultured to the 3-6 leaf stage in white cubic pots with Pitmoss and Perlite composition ratio of 40 % and 60 % respectively. From initial days after planting they were maintained with a nutrition formula of Savvas (2002). After approximately two months when plants were almost at the stage of initial flowering, then the measurements were taken.

Exposition of measurements

Value of received light per pot in all systems was measured twice with luxmeter model: LutronLX. Leaf cholorophyl content was measured with Spadmeter model: Minolta (Spad-502). Leaf number and flower number for each plant were counted. Finally statistical significance between mean values was assessed using analysis of variance and a conventional Duncan's Multiple Range Test at $p \leq 0.01$&0.05 using SAS (9.1) statistical software.

Results and discussion

Plant number per m^2 in both vertical systems (fixed and mobile) increased in testing with Gerbera plant (*Gerbera jamesonii* cv. Antibes). Pot numbers, (one plant per pot) per m^2 in the vertical system in 9 m^2, was 54 pots that could increase to 90 pots, but number of ground pots per 9 m^2 was a maximum of approximately 36 pots. This result showed a yield enhancement per m^2. System type (vertical mobile system, vertical immobile system and common culture) had significantly affected on amount of light received by plant surfaces ($P<0.05$) of which, plants in the mobile vertical system received more light than others, probably because of movement consistent with the sun's solar radiation and a decrease in areas of shade. Liu *et al.* (2005) stated that the measurement of vertical culture in cylindrical columns enhanced yield of vegetables twice or threefold per m^2. Whereas system type had no significant effect on chlorophyll content and flower number of plants, but the mobile vertical system had significant effect on leaf number. With this, Stapleton *et al.* (2001) reported that the yield in greenhouse production has enhanced with a vertical culture system. It seem reasonable to assume that light enhancement, due to the mobile vertical system, had a significant effect on gerbera plant quality and this result is consistentwith Paradikovic *et al.* (2008) showed that an increase of gerbera plant quality in exposure to more light. In conclusion, these results demonstrated quality of plants cultured in the mobile vertical system which better than those grown on the ground. Furthermore, because there were more plants on the vertical system, yield per m^2 was enhanced to demonstrate the benefit of this system of greenhouse culture (Table 1, Figs.1-7). Moreover, Al-Raisy *et al.* (2010) confirmed the effect of four media in strawberry vertical cultures and reported the best yield, fruit quality and leaf ion concentration in media. In this research finding, Gerbera plant cv. Antibes significantly increased in plant number per m^2 in both vertical systems (fixed and mobile).

Table 1. Influence of system type on light continent, leaf and flower number, Chlorophyll content of *Gerbera jamesonii* cv. Antibes

System	Light content	Leaf number	Flower number	Chlorophyll content
Vertical mobile system	30703 A	15.444 A	1.750 A	65.945 A
Fixed vertical system	18193 B	10.750 B	1.777 A	65.827 A
Control (ground culture)	19475 B	12.750 AB	2.222 A	65.188 A

∗$P < 0.05$, ∗∗$P < 0.01$, All treatments even control contained 6% sucrose.
Means in the same column followed by the same letters are not significantly different using Duncan test.

Fig. 1. Picture of vertical mobile system in greenhouse

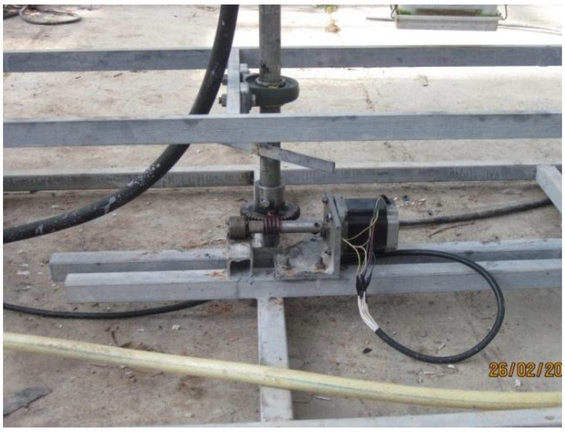

Fig. 2. Moving parts of the mobile vertical system; including stepmotor, spiral gearbox, gearweel, yataghan.

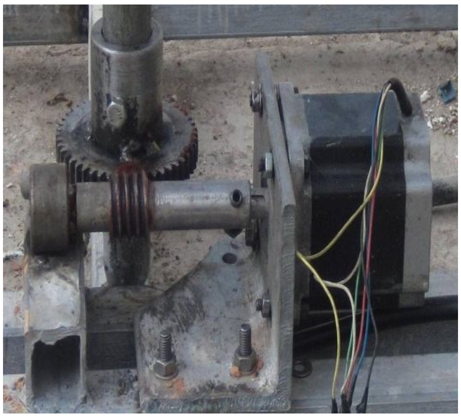

Fig. 3. Close up picture of the stepmotor and gearweel and the spiral gearbox.

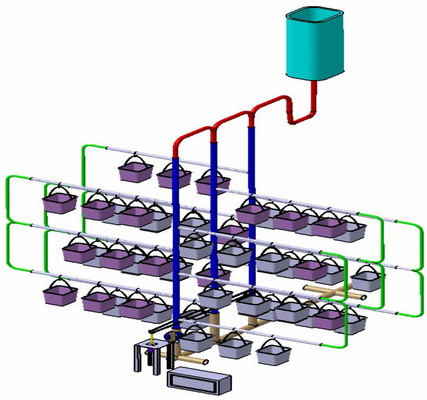

Fig. 4. software system depicted picture CATIA

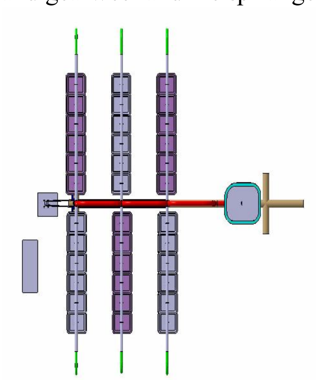

Fig. 5. Isometeric System picture from overhead

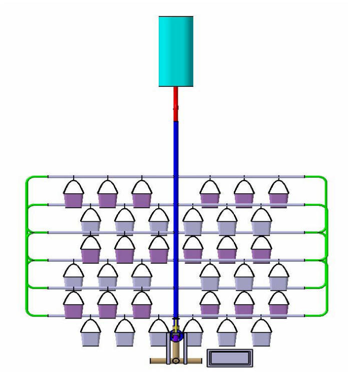

Fig. 6. Depicted isometric picture of vertical mobile system from opposite CATIA showing the pot design in layers designed to be without overlap and shading.

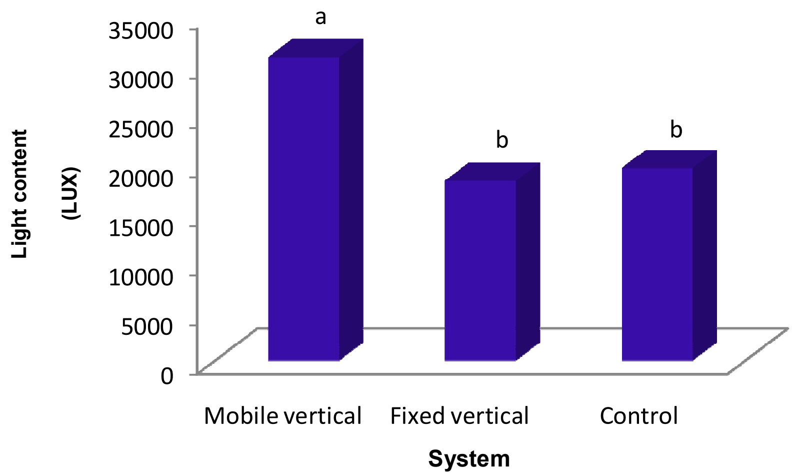

Fig. 7. The received light content of plants in vertical mobile and vertical fixed system and ground culture

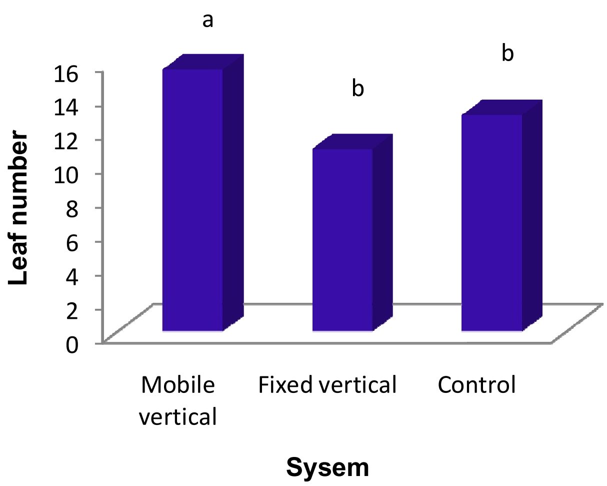

Fig. 8. Comparison of leaf number in plants of vertical mobile and vertical fixed system and ground culture

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(Published in July 2012)