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Disbudding effects on growth analysis of Celosia (*Celosia cristata*)

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Key words: Celosia cristata, disbudding, growth analysis.

Abstract: Experiments to investigate the effects of disbudding on growth analysis of two celosia cultivars, 'Carmine' and 'Chief Gold', were carried out on the field in 2009 and 2010 at the Sinna Garden of Department of Crop Science, University of Ghana, Legon, Accra, Ghana. The treatments consisted of disbudding once, disbudding twice, and no disbudding, as control, and were arranged in a 3x2 split plot in a randomized complete block design with four replications in 2009 (experiment 1) and three in 2010 (experiment 2). The two cultivars were harvested weekly during the growing period and separated into the various plant parts and oven-dried for dry weights, using appropriate formulae to calculate the various growth parameters. Analysis of variance (ANOVA) was used to analyse the data and a correlation coefficient matrix showed relationships among growth parameters. Disbudding resulted in increased leaf area index, leaf area ratio, leaf area duration, relative growth rate, and harvest index, but reduced crop growth rate and net assimilation rate. 'Chief Gold' had a higher harvest index than 'Carmine'. Disbudding plants once gave the best flower head size and weight result. 'Carmine' gave the best flower yield and quality results in experiment 1 and 'Chief Gold' in experiment 2.

1. Introduction

Celosia, a C_3 plant, belongs to the Amaranthaceae family and is of tropical origin. In Ghana, Celosias are not only grown as a cut flower crop, but also as bedding plants, pot plants, and vegetable crops (Norman, 2004).

In this study, disbudding entailed the removal of axillary buds or bud breaks on a single stem, leaving the terminal flower bud intact and able to develop into a large flower head. This practice is reported to be a standard operation in the cultivation of roses, carnations, chrysanthemums and celosias (Machin and Scopes, 1978; Janick, 1986; Dole and Wilkins, 1999; Norman, 2004). Celosia requires one stem as a cut flower; here developing flower buds on a flowering shoot must be disbudded in order to improve the quality of the terminal flower (Norman, 2004). Reports indicate that disbudding increases plant height in dahlias (Parshall, 2007) and in Celosias reduces the number and size of undesirable side (or axillary) shoots on the flower stem and thus resulting in increased plant height, flower stem length and flower head size (Norman *et al.,* 2009). Also, disbudding induces early harvesting and a more concentrated harvesting period (Norman, 2004).

Growth analysis has been widely used to study yield-influencing factors and plant development as net photosynthates accumulation over time (Gardner *et al*., 1985). This approach uses simple primary data in the form of weights, areas, volumes and contents of plant components to investigate processes within and involving the whole plant (Hunt, 1990).

The leaf area index (LAI) of a crop at a particular growth stage indicates its photosynthetic potential or the level of its dry matter accumulation. The greater the LAI, the higher the dry matter accumulation potential of the crop and vice versa (Rasheed *et al.,* 2003). Its value can vary with environmental and cultivation conditions (Board and Harville, 1992). The leaf area and its duration (LAD) are measurements of growth of plants and plant physiological processes (Miralles *et al*., 1997). LAI and LAD control the total production of dry matter and subsequently yield and yield attributes (Jirali *et al*., 1994). Crop growth rate (CGR) is a prime factor in determining crop yield because it reflects the capacity of assimilates production and affects dry matter accumulation. There is a close association between maximum dry matter production and maximum CGR (Ball *et al*., 2000). The analysis of CGR has been shown to be important in evaluating treatment differences among crop species or cultivars with species in relation to yield (Fageria *et al*., 2006).

Relative growth rate (RGR) is described as the rate of increase of total dry weight per plant (Hunt, 2003). Relative growth rate curves of crops are in opposition to DM accumulation during the life cycle of crops (Fageria *et al*.,

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2006). Results from the studies of Medhet *et al*. (2000) on growth analysis of sunflower, *Helianthus annuus*, under drought conditions indicated a reduction of RGR value from early growth stages to final stages. However, recent reports by Fageria *et al*. (2006) indicate that values of RGR are generally higher during early growth stages of the crop and decrease with age.

Measurement of net assimilation rate (NAR) is important to detertmine the efficiency of plant leaves for DM production. NAR values decrease with crop growth due to both the shedding of leaves and reduced photosynthetic efficiency of older leaves (Fageria *et al*., 2006). Similarly, Law-Ogbomo and Egharevba (2008) reported that abscission with plant growth of the lower leaves in tomato causes a decrease in NAR.

However, there is no detailed information on the quantitative growth aspects and growth analysis of *Celosia cristata* grown for cut flower production. The only previous reference to growth characteristics is that of *Celosia argentea* (grown as a leafy vegetable crop) by Ojo (2001) who reported a positive relationship between yield and leaf area, which was enhanced by increasing population density and cutting height. The present experiment was therefore undertaken to investigate the effects of disbudding on the growth indices of two cultivars (Carmine and Chief Gold) of *Celosia cristata* and to identify relationships between these indices (parameters) and flower yield.

2. Materials and Methods

Experimental site

The study was conducted at the Sinna Garden, Department of Crop Science, University of Ghana, Legon, between July and September 2009 for experiment 1 and December 2009 to February 2010 for experiment 2. The soil at the experimental site is of the Adenta series (Brammer, 1960) and classified as Ferric Acrisol (FAO/UNESCO, 1990). The soil is sandy loam and moderately well drained with moderate levels of organic matter. Climatological data during the experimental period are shown in Table 1.

Experimental design

A randomized complete block design with split plot arrangement and cultivars as the main plots and disbudding as the subplots were used for the experiment. There were four replications in experiment 1 and three in experiment 2. The disbudding treatments were: disbudding once; disbudding twice; and no disbudding (as control). The cultivars used were 'Carmine' and 'Chief Gold'. The plants were established at a spacing of 15 x 9 cm. There were 90 plants (experiment 1) and 96 plants (experiment 2) per sub-plot in which five plants were sampled weekly for dry weights and 10 plants were tagged for field data collection.

Cultivation practices

In experiment 1, seeds were first sown in seed boxes using sandy soil on 17 July 2009 and the germinated seedlings were planted in the field on 7 August 2009. Before planting, each sub-plot (0.9 x 1.5 m) received an application of 15-15-15 NPK fertilizer at the rate of 674 kg/ha on 6 August 2009. In experiment 2, cow dung was incorporated into the plots at 25 t/ha on 8 December 2009. Seeds were sown in plastic seed trays on 16 December 2009 using peat as the soil mix and the germinated seedlings were pricked out into plastic seed trays on 30 December 2009. The seedlings were planted in the field on 13 January 2010. A day before planting, each sub-plot (0.99 x 1.65 m) received an application of 15-15-15 NPK fertilizer at the rate of 600 kg/ha.

In each experiment, hand watering was done twice a day. Routine weed control was carried out either by hand-picking of weeds or by hoeing when necessary. Diseases and insect pests were controlled by spraying of insecticide and fungicide. Dithane M45 was sprayed on 19 August 2009 and 11 February 2010, in both experiments respectively, to control leaf spot diseases. On 2 September 2009, 28 January and 3 February 2010, in both experiments respectively, Cydim Super was also sprayed to control grasshoppers and whiteflies. In experiment 1, plants were side-dressed four weeks after planting with potassium nitrate at

Table 1 - Climatological data during experimental period

Month	Mean maximum temperature (°C)	Mean minimum temperature (°C)	Total rainfall (mm)	Mean maximum relative humidity (%)	Mean minimum relative humidity (%)
Experiment 1 - 2009					
July	28.3	23.3	91.5	94	77
August	28.3	23.0	11.5	92	74
September	30.5	23.2	6.3	91	69
Experiment 2 - 2009					
December 2010	33.4	24.8	10.3	92	64
January	33.3	25.0	49.6	94	65
February	33.7	25.4	57.2	94	66

Source: Meteorological Services of Ghana, Mempeasem, Accra, Ghana.

a rate of 100 kg/ha while in experiment 2, side-dressing was done at three weeks after planting at the same rate.

Disbudding

Disbudding was carried out as follows:

1. Disbudding once: Axillary flower heads and side shoots were removed on all the plants in the field except the control plants at 22 days after planting (DAP) on 29 August 2009 and at 18 DAP on 1 February 2010.
2. Disbudding twice: The removal of axillary flower heads and side shoots was undertaken on only the plants designated for this treatment at 27 DAP on 3 September 2009 and at 25 DAP on 8 February 2010.

Sampling

Sampling started two weeks after planting and every week thereafter until the sixth week in experiment 1; in experiment 2 it started a week after planting and every week thereafter until the fifth week. Five plants were randomly sampled from each sub-plot, carefully dug up and the roots washed of soil particles. The leaf area was calculated using a leaf area meter (Model AM 100 by Analytical Development Company Limited, England). The plant parts (leaves, flower heads, flower stems, side shoots, axillary flowers and roots) were separated and chopped into pieces and put in different sampling envelopes and oven-dried to a constant weight of 80°C for 48 hr to determine their dry matter.

Two types of measurements are needed for growth analysis: the plant weight, usually the oven dry weight (g); and the size of the assimilating system, usually in terms of leaf area (cm^2). The crop growth rate, net assimilation rate (NAR), relative growth rate (RGR), leaf area index, leaf area ratio (LAR), leaf area duration and harvest index were calculated as follows.

Leaf area index (LAI)

Leaf area index is defined as leaf area per unit area of land. It is a dimensionless ratio (Watson, 1947) and calculated with the formula:

$$\text{Leaf area index} = \frac{\textit{Total Leaf Area}}{\textit{Land Area}}$$

Crop growth rate (CGR)

Crop growth rate is defined as the increase in plant dry matter per unit of time per land area unit (Radford, 1967) with the formula:

$$\text{CGR (gm}^{-2}\text{ day}^{-1}\text{)} = \frac{W_2 - W_1}{t_2 - t_1}$$

Relative growth rate (RGR)

Relative growth rate is the increase of plant material per time unit. It was calculated for each interval between sampling with the formula given by Radford (1967). The RGR of the first harvest could not be calculated because there was no dry weight before the first harvest.

$$\text{RGR (mgg}^{-1}\text{ day}^{-1}\text{).} = \frac{\ln W_2 - \ln W_1}{t_2 - t_1}$$

Net assimilation rate (NAR)

The net assimilation (NAR) is the increase of plant material per unit of the assimilating material per unit of time. It was calculated for each interval between two samplings with the formula described by Watson (1947) and Radford (1967). The NAR of the first harvest could not be calculated because there was no leaf area value before the first harvest.

$$\text{NAR (gm}^{-2}\text{ day}^{-1}\text{)} = \frac{(W_1)(W_2)}{LAD}$$

Leaf area duration (LAD)

Leaf area duration is the photosynthetic potential of a plant, i.e. a measurement of the entire opportunity for assimilation a plant possesses during a growth period (Watson, 1947). This was calculated using the formula:

$$\text{LAD} = \frac{(LAI_1 + LAI_2) \times (t_2 - t_1)}{2}$$

Leaf area ratio (LAR)

Leaf area ratio of a plant at an instant in time (t) is the ratio of the assimilatory material per unit of plant material present. The LAR was calculated with the following formula:

$$\text{LAR (cm}^2\text{/g)} = \frac{(LAI_1) - (LAI_2)}{(W_1)(W_2)}$$

Harvest index (HI)

The harvest index is the ratio of economic yield (flower head and stem) to biological yield (Donald and Hamblin, 1976). Its computation uses the following formula:

$$\text{Harvest index (HI)} = \frac{\textit{Economic yield (Flower head and stem)}}{\textit{Biological yield (Total dry weight)}} \times 100$$

Where W_2 and W_1 = dry weight at second and first harvest, t_2 and t_1= time corresponding to second and first harvest.

Leaf chlorophyll content

Leaf chlorophyll content was measured using a chlorophyll meter (model SPAD, Minolta, Japan).

Flower head size index

This was calculated as the product of the vertical and horizontal lengths of the flower head divided by 2.

Number of side shoots

This was obtained by stripping off side shoots on the flower stem and counting.

Harvesting

Harvesting of the 10 tagged plants of each plot started 60 days after sowing for experiment 1 and 63 days after sowing for experiment 2. 'Carmine' was harvested two days earlier than 'Chief Gold'.

Statistical analysis

The data collected were analysed using analysis of variance (ANOVA) (GenStat, ver. 9). Significant differences among treatment means were determined using the least significant difference (LSD) test at P = 0.05.

Correlation analysis

Correlation analysis for flower quality parameters and other measured growth variables was also determined using Spearman's rank correlation coefficient.

3. Results and Discussion

Flower head dry weight and size

Tables 2 and 3 show the effects of disbudding and cultivar on flower head dry weight and size. Disbudding significantly influenced flower head size production. In experiment 1, disbudding twice produced the heaviest flower heads with the control producing the lightest. Plants subjected to disbudding once produced the heaviest flower heads with the control producing the lightest in experiment 2. Larger flower heads were also produced by disbudding-once plants followed by disbudding-twice, with the control producing the smallest flower heads. 'Carmine' produced significantly larger flower heads than 'Chief Gold' in experiment 1. However, the opposite was true in experiment 2.

Flower head size has the potential to increase when the sink-source ratio is reduced, i.e. when the number of competing sinks for assimilates is reduced or the source activity is increased (Cockshull, 1982; Lee *et al*., 2001). In the present study, disbudding increased flower head size significantly. Similar observations were made by Carvalho *et al*. (2006) in chrysanthemums and Norman *et al*. (2009) in celosia. In a celosia plant, the axillary flower heads, roots, leaves and side shoots compete with the flower stem and head for assimilates. As the number of flower heads per plant increases, the flower head size tends to decrease. Reducing the number of flower heads on a flower stem allows the plant to distribute assimilates to the terminal flower that then attains a larger size. Competition among the terminal flowers as well as between the flower and the vegetative plant parts for available assimilates explains the smaller and lighter flower heads produced by the control plants. These experienced a high intra-plant competition for photosynthetic radiation, thus influencing the assimilate allocation to the terminal flower. An increased in the number of small flowers has also been reported in Chrysanthemum by Carvalho *et al*. (2006) as a result of removal of the terminal flower bud.

Crop growth rate (CGR)

Figure 1 shows the effects of disbudding and cultivar on CGR of celosia plants. Significant interactions were observed but showed no differences among treatments at 3 WAP in experiment 1. However, in experiment 2, disbudding significantly affected CGR with the control plants recording the highest CGR and this was significantly different from the other treatments. Significant

Table 2 - Effects of disbudding on flower head dry weight and size of two celosia varieties at harvest. Experiment 1

	Flower head dry weight (g)			Flower head size index (cm)		
Treatment	'Carmine'	'Chief gold'	Mean	'Carmine'	'Chief Gold'	Mean
Disbudding once	2.08	2.20	2.34	21.7	19.7	20.7
Disbudding twice	2.48	1.81	1.94	18.9	15.0	17.0
Control	1.09	0.84	0.97	12.2	9.5	10.9
Mean	1.89	1.62		17.6	14.7	
$LSD_{(5\%):CULTIVAR}$	NS			NS		
$LSD_{(5\%):DISB}$	0.56			7.20		
$LSD_{(5\%):CULTIVAR\ x\ DISB}$	1.22			9.65		

Table 3 - Effects of disbudding on flower head dry weight and size of two celosia varieties at harvest. Experiment 2

	Flower head dry weight (g)			Flower head size index (cm)		
Treatment	'Carmine'	'Chief gold'	Mean	'Carmine'	'Chief Gold'	Mean
Disbudding once	2.21	2.47	2.34	16.9	23.9	20.4
Disbudding twice	2.11	2.13	2.12	18.1	20.2	19.1
Control	1.43	1.02	1.08	11.9	10.2	11.1
Mean	1.82	1.87		15.7	18.1	
$LSD_{(5\%):CULTIVAR}$	NS			NS		
$LSD_{(5\%):DISB}$	0.36			3.50		
$LSD_{(5\%):CULTIVAR\ x\ DISB}$	0.41			4.30		

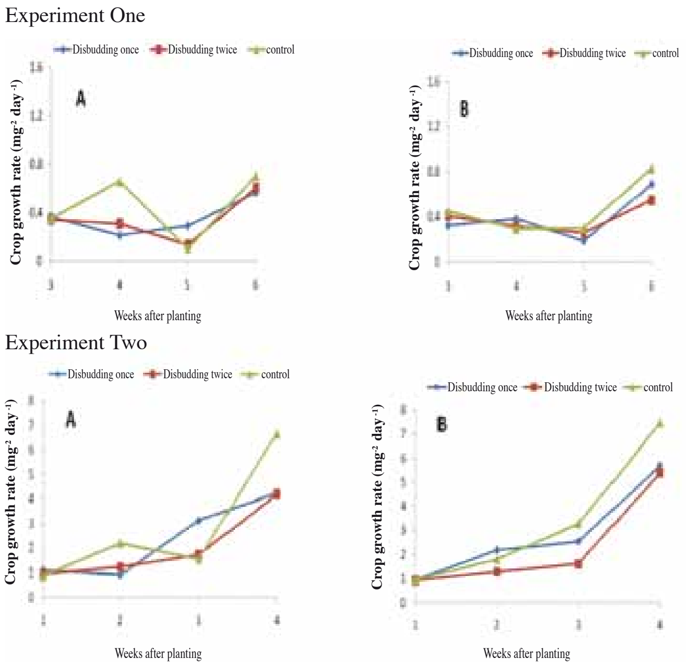


Fig. 1 - Crop growth rate as affected by disbudding and cultivar: 'Carmine' (A) and 'Chief' Gold (B).

interactions were observed with 'Chief Gold' having significantly higher CGR than 'Carmine' at the 3 WAP. Crop growth rate was observed to increase with plant development (Fig. 1A and B). An increase in CGR was recorded for both experiments at the final sampling (5-6 WAP). Crop growth rate is a prime factor in determining crop yield because it reflects the capacity of assimilates production and affects dry matter accumulation. There is a close association between maximum dry matter production and maximum CGR (Ball *et al.*, 2000). The observed significant and positive correlation between total aboveground biomass and CGR (r = 0.241*) and (r = 0.245*) in both experiments, respectively, supports this hypothesis. Celosia plants produced a lot of side shoots and axillary flower heads during growth. Therefore, it can be speculated that the DM accumulated in these organs, in addition to the other plant organs, accounted for the higher CGR and also enhanced NAR in the control plants (Fig. 2A and B). Crop growth rate was significantly and positively correlated with flower stem dry weight (r = 0.3*).

Leaf area index (LAI)

Disbudding did not significantly affect LAI at the initial growth stages. Leaf area index was significantly different among the various treatments (Fig. 3A and B) and at harvesting (5-6 WAP), disbudding significantly affected LAI in both experiments. In experiment 1, plants disbudded twice had the highest LAI (2.47) followed by those disbudded once (2.43); the control plants produced the lowest (1.55). In experiment 2, plants disbudded once had the highest LAI (2.58) followed by those disbudded twice (2.52), while the control plants had the lowest LAI (1.83). All disbudded treatments had a significantly higher LAI than the control treatments. 'Carmine' produced a lot of leaves in experiment 1, and they were broader than the ones of 'Chief Gold', hence 'Carmine' had a higher LAI. 'Chief Gold' responded earlier to disbudding than 'Carmine' in LAI as the control plants recorded lower values right from the initial stages.

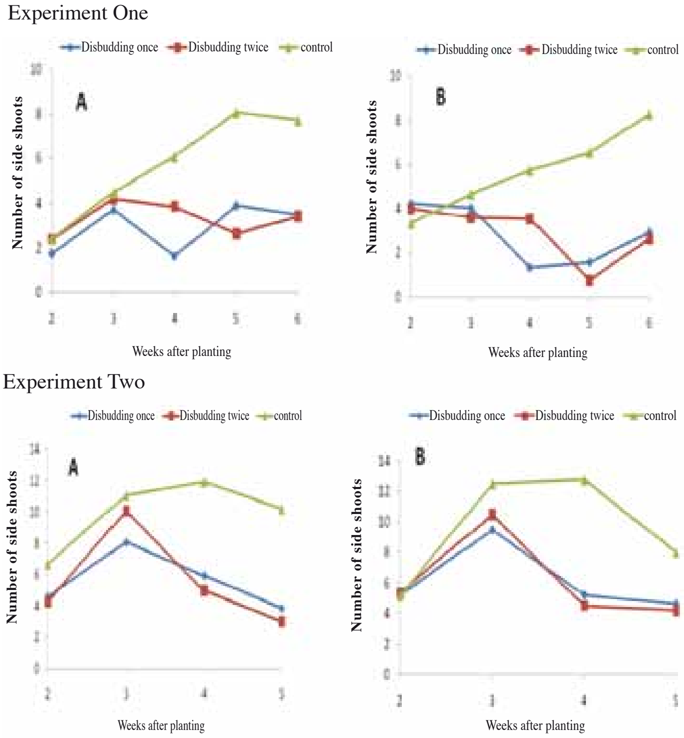


Fig. 2 - Effects of disbudding and cultivar on side shoot production: 'Carmine' (A) and Chief Gold' (B) cultivars of celosia over the growing period in both experiments.

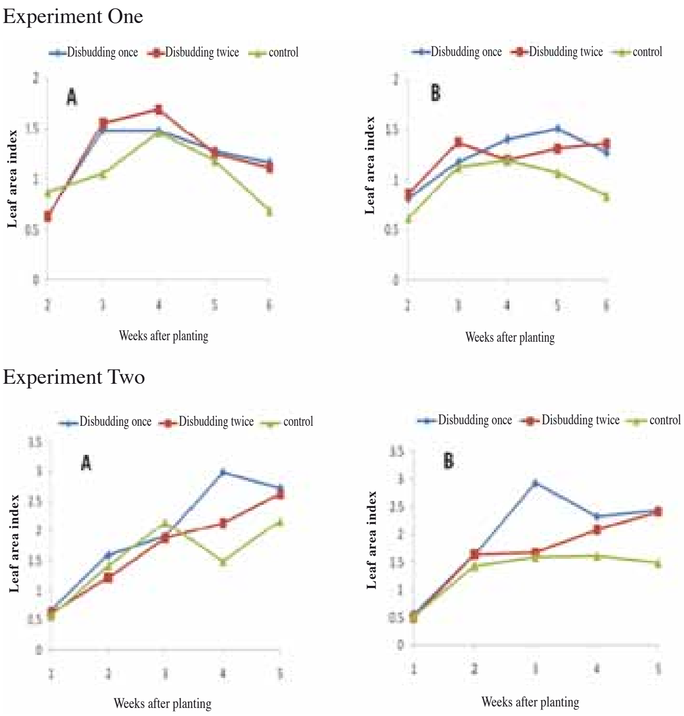


Fig. 3 - Leaf area index as affected by disbudding and cultivar: 'Carmine' (A) and 'Chief Gold' (B).

The LAI determines the photosynthetic capacity of a crop. The higher LAI of the disbudded treatments means that there were more (expanded) leaves per plant for higher radiant energy interception for photosynthesis and, therefore, more dry matter partitioning into the economic yield. This assertion is supported by the significant positive correlation between chlorophyll content and LAI in experiment 1 (r = 0.040*). A significantly higher number of leaves per plant was produced by 'Carmine' (17.44) than 'Chief Gold' (12.82) (Fig. 4). The lower LAI induced by the control treatments might be due to a lower leaf number and area which might have resulted from the competition among the various plant parts for assimilate partitioning. Maximum DM production is achieved at an optimal LAI. The optimal LAI obtained for disbudded plants in celosia is between 2 and 2.5. Although the control plants had a lower LAI, they had the highest CGR. Previous reference to growth characteristics of *Celosia argentia* was made by Ojo (2001) who reported a positive relationship between yield and leaf area. The results of experiment 2 confirm what reported above this. A linear relationship was observed between total aboveground biomass and LAI (r = 0.040*). However, total aboveground biomass had a significantly negative relationship with LAI (r = -0.343*) in experiment 1. LAI had a positive and significant association with flower stem dry weight (r = 0.04*) and flower head dry weight (r = 0.07*).

Relative growth rate (RGR)

In both experiments, RGR decreased linearly during the early growth and increased towards maturity (Fig. 5A and B). In experiment 1, plants disbudded twice exhibited a higher RGR than control and disbudded-once plants. However, in experiment 2, plants disbudded once had a higher RGR than the other treatments. 'Carmine' exhibited a higher RGR in experiment 1 than 'Chief Gold' in experiment 2. The observed decrease in RGR may be attributed to the decreasing trend in leaf area ratio (LAR) with plant growth as indicated by the linear relationship between LAR and RGR (r = 0.343*), (r = 0.168*) in both experiments, respectively. Relative growth rate had a positive and significant association with flower stem dry weight (r = 0.12*) and flower head dry weight (r = 0.39*). Increased RGR due to disbudding also resulted in increased flower yield. Relative growth rate also had a significant negative relationship with CGR (r = -0.04*).

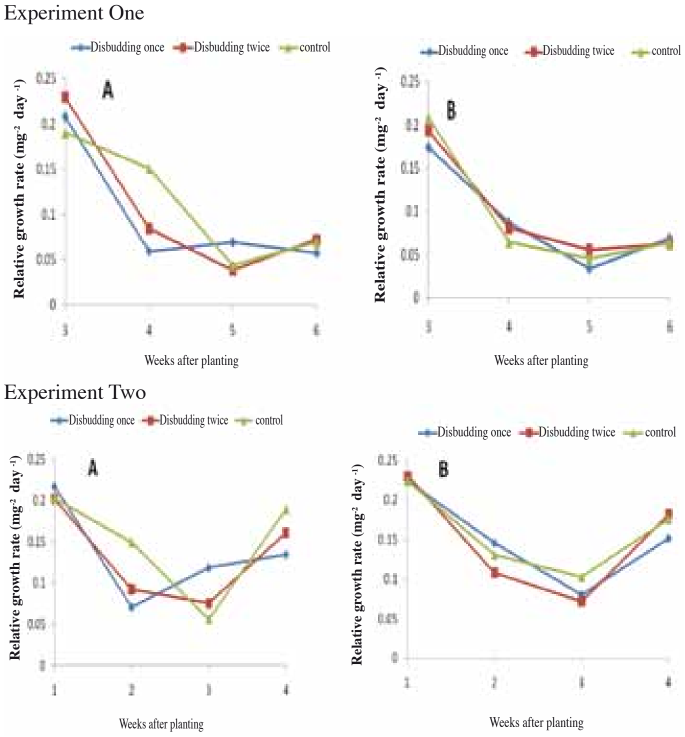


Fig. 5 - Relative growth rate as affected by disbudding and cultivar: 'Carmine' (A) and 'Chief Gold' (B).

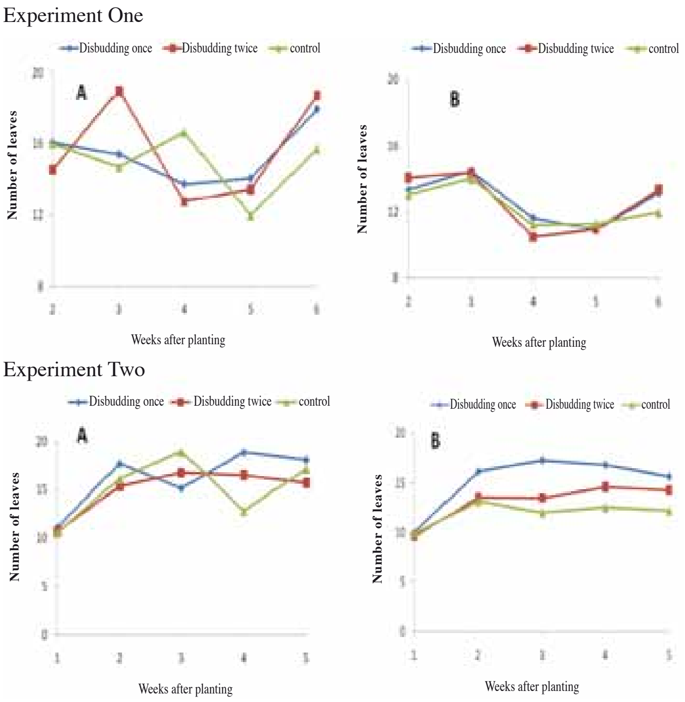
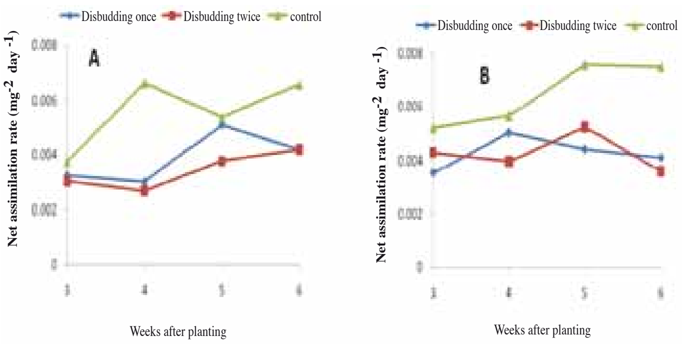


Fig. 4 - Leaf growth as influenced by disbudding and cultivar: 'Carmine' (A) and 'Chief Gold' (B) cultivars of celosia.

Net assimilation rate (NAR)

Net assimilation rate showed no significant differences among treatments at 3 WAP in experiment 2 (Fig. 6A and B). In experiment 1, disbudding did not affect NAR significantly; in experiment 2 disbudding lowered NAR significantly. Correlation analysis shows that NAR had a negative and significant correlation with flower head dry weight (r = -0.05*) and flower stem dry weight (r = -0.02*) in experiment 1 but correlated positively and significantly with flower head dry weight (r = 0.13*) in experiment 2. Thus, the lower NAR observed in experiment 2 was compensated for bigger flower head production. Generally, 'Chief Gold' had a higher NAR than 'Carmine'. The decline in NAR with plant growth observed in experiment 2 after disbudding might be due to both the shedding of leaves and reduced photosynthetic efficiency of older leaves (Fageria *et al*., 2006). Similarly, Law-Ogbomo and Egharevba (2008) reported that the abscission of the lower leaves with plant growth in tomato causes a decline in NAR.

Experiment One



Experiment Two

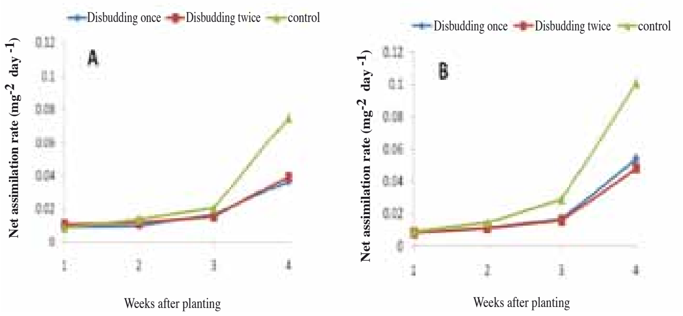


Fig. 6 - Net assimilation rate as affected by disbudding and cultivar: 'Carmine' (A) and 'Chief Gold' (B).

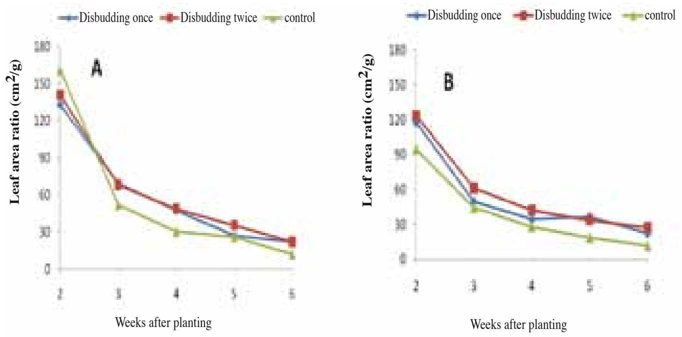
Leaf area ratio (LAR)

Leaf area ratio decreased for both cultivars in both experiments with plant age. From 3-6 WAP, disbudding significantly affected LAR (Fig. 7A and B). The disbudded plants had a significantly higher LAR than the control plants. Since LAR indicates how much leaf area a plant produces per gram of dry matter, a high LAR indicates that a plant is efficient at producing leaf area. Since leaf area determines light interception, which is also an important parameter affecting plant growth, a high LAR would be expected to result in a high growth rate (Kang and Van Iersel, 2004). This further explains the linear relationship between LAR and RGR (r = 0.343*), (r = 0.168*) in both experiments, respectively. Leaf area ratio correlated negatively and significantly with flower stem dry weight (r = -0.05*) and flower head dry weight (r = -0.02*).

Leaf area duration (LAD)

The effect of disbudding and cultivar on LAD is shown in figure 8A and B. Disbudding affected LAD but this was significant. However at harvesting (5-6 WAP), significant differences were observed among disbudded treatments. Significant interactions were also observed with all disbudded plants of 'Carmine' producing a higher LAD than that of 'Chief Gold' (Fig. 8A and B). According to Gifford and Evans (1981),

Experiment One



Experiment Two

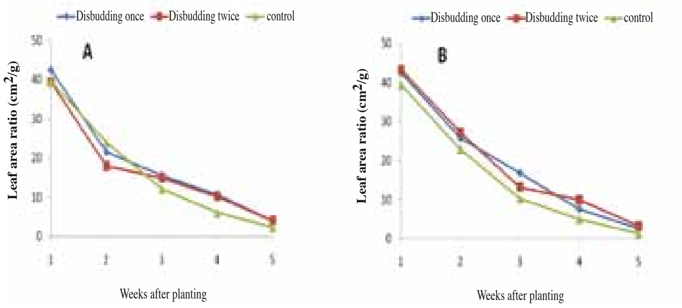
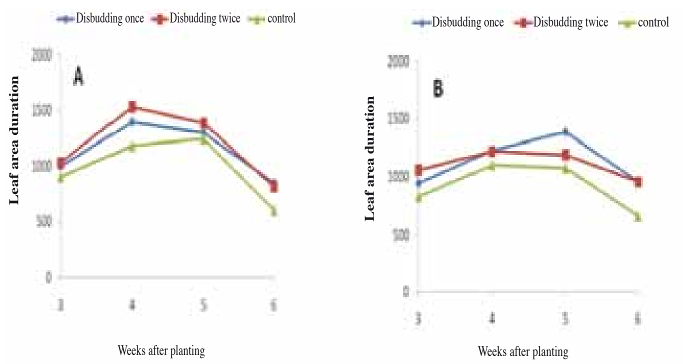


Fig. 7 - Leaf area ratio as affected by disbudding and cultivar: 'Carmine' (A) and 'Chief Gold' (B).

Experiment One



Experiment Two

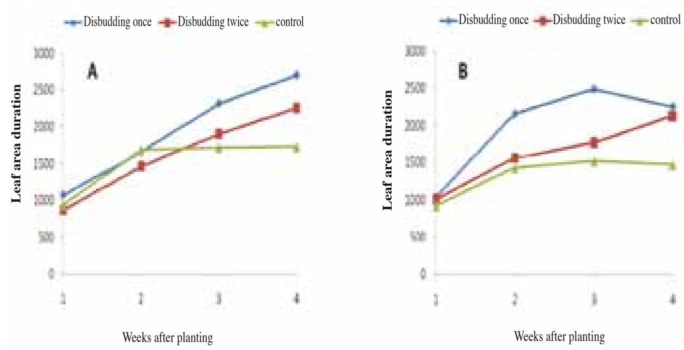


Fig. 8 - Leaf area duration as affected by disbudding and cultivar: 'Carmine' (A) and 'Chief Gold' (B).

LAD is more important for determining the final yield. However, in the current study, the higher LAD of 'Carmine' in both experiments did not lead to a yield advantage since 'Chief Gold' had a higher yield in terms of both the flower head and flower stem (economic sinks).

The most likely explanation for this disagreement is the inefficiency of 'Carmine' to use its entire LAD for DM production even though flower heads were harvested before they were fully matured (market requirement) for both cultivars. A positive linear association was observed between LAD and flower head dry weight (r = 0.02*) and flower stem dry weight (r = 0.04*).

Harvest index (HI)

The effects of cultivar and disbudding on mean harvest index are presented in Table 4. Disbudding significantly influenced HI. All disbudded plants had a higher HI than the control plants (Table 4). Cultivars did not differ significantly in mean HI. Significant disbudding and cultivar interactions were also observed. The HI for the disbudded 'Chief Gold' plants was relatively higher than that of 'Carmine', indicating that 'Chief Gold' had a more efficient translocation system compared to 'Carmine'. Differences in HI may be related to differences in the pattern of allocation of photosynthate (Gent and Kiyomoto, 1989). 'Chief Gold' had higher HI than 'Carmine', which indicates that 'Carmine' is less efficient in converting DM to flower stem and head yield (flower yield). HI showed linear associations with LAI (r = 0.131*), LAR (r = 0.154), NAR (r = 0.019*) and RGR (r = 0.010*).

4. Conclusions

The overall result of the present study shows the effect of variations in disbudding on growth and development of the two considered cultivars. Disbudding increased leaf area index, leaf area ratio, leaf area duration, relative growth rate, and harvest index, but reduced crop growth rate and net assimilation rate. 'Chief Gold' had a higher harvest index than 'Carmine'. Disbudding plants once gave the best flower yield and quality in terms of flower head size and weight. In addition, 'Carmine' gave the best flower yield and quality results in experiment 1 and 'Chief Gold' in experiment 2. Disbudding once is therefore a highly recommended technique for celosia cut flower growers.

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Table 4 - The effects of cultivar and disbudding on mean harvest index of two celosia cultivars in both experiments

Treatment	Mean harvest index					
	'Carmine'		'Chief gold'		Mean	
	Epx 1	Exp 2	Epx 1	Exp 2	Epx 1	Exp 2
Disbudding once	36.99	29.34	39.26	29.34	38.12	29.34
Disbudding twice	37.41	37.03	42.90	28.49	40.15	27.76
Control	21.35	15.58	20.10	15.47	20.73	15.53
Mean	31.92	23.99	34.09	24.44		
$LSD_{(5\%):CULTIVAR}$	NS	NS				
$LSD_{(5\%):DISB}$	4.35	4.04				
$LSD_{(5\%):CULTIVAR\ x\ DISB}$	5.48	4.87				

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