EFFECTS OF GA_3, BA AND NAA ON DRY MATTER PARTITIONING AND RHIZOME DEVELOPMENT IN TWO CULTIVARS OF *ACHIMENES LONGIFLORA* DC, UNDER THREE LEVELS OF IRRADIANCE.

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Abstract

Two cultivars of *Achimenes longiflora* DC., 'Flamenco' and 'Hilda' were placed at 21°C and 16 h light of 3 irradiance levels 35, 18 and 10 W m^{-2} for 16 weeks after being sprayed with gibberelic acid (GA_3), benzyladenine (BA) or a-naphthalenacetic acid (NAA), alone and in combination.

Increasing irradiance levels increased dry weight of aerial parts and number and dry weight of rhizomes. GA_3 increased plant height; the elongation effect was more prominent at lower irradiances.The combination of GA_3 with BA or/and NAA increased weight of aerial parts and lowered the percentage of dry matter incorporated in the rhizomes (RWR). BA combined with NAA increased dry weight and number of rhizomes; however responses to growth regulator treatments depended on the cultivar; 'Flamenco' was more responsive than 'Hilda'.

1.Introduction

Earlier work demonstrated that rhizome development in Achimenes is ennanced by a higher level of irradiance. Application of 100 mg l^{-1} BA compared to 100 mg l^{-1} GA_3 increased fresh weight of rhizomes (Vlahos,1985). The last conclusion is in agreement with Deutche (1974), who found that cytokinins promoted and gibberellins suppressed tuberization of leaf and stem cuttings in Achimenes.

It is well established that plant growth and development are affected by several growth substances or their combinations; endogenous auxins are known to interact with cytokinins and gibberellins in the promotion of transport of assimilates and also influence uptake of assimilates by sink tissue (Wareing,1978). Furthermore, environmental factors and/or treatments with growth regulators can induce changes in the ratio of roots or tubers to shoot weights or influence sink-source relationships in several plants (Thomas,1978; Menzel,1980;Melis &v.Staden,1984).It seems likely that growth substances would affect the distribution of assimilates in Achimenes.Thus a study was carried out to determine if exogenously applied growth regulators influence the formation and development of rhizomes in two cultivars under different levels of irradiance.

The cultivars used, although morphologically similar, are known to differ considerably in the development of their aerial parts and rhizomes (Vlahos,unpublished).The growth regulators gibberellic acid (GA_3),benzyladenine (BA) and a-naphthalenacetic acid (NAA) were used in this investigation; the first two were also used in a previous study and NAA was prefered to IAA because the latter caused epinasty in the plants during preliminary experiments.

2.Material and methods

2.1. Plant material

Two commercial cultivars were used,'Flamenco' and 'Hilda Michelssen' (referred to as 'Hilda'). Stem cuttings from sprouted rhizomes were obtained from a commercial grower in April 1984. They were placed in a greenhouse to root and become established. Plantlets with an average height of 10 cm and 5 to 6 leaf whorls were selected and potted in 10 cm plastic pots using a standard potting medium on May 8,1984. Flower buds were already visible in the axils of the upper leaf whorls in both cultivars.

2.2. Light and growth regulator treatments

Plants were placed in a growth room at 21°C day and night temperature and 16 h light. Illumination was provided by Philips sodium (SON/T) and mercury (HPI/T) lamps of 250 and 400 W respectively.Three light regimes were provided: the high irradiance (hi) of 35 W m^{-2},the reduced irradiance (ri) of 18 W m^{-2} and the low irradiance (li) of 10 W m^{-2}. The 50% and 70% reduction in light intensity was achieved by shading the ri group with a double layer of white cheese cloth and the li group with 4 single layers of the same material. Plants, under each irradiance level,were sprayed to run off with 7.10^{-5}M GA_3, 14.10^{-5} M NAA, 21.10^{-5} M BA and their combinations;the concentrations used were determined from earlier and preliminary experiments. Controls were sprayed with water. Two weeks later the same applications were repeated. Solutions were made on the day of application, pH was brought to 7 and Tween 20 was added as a surfactant at the rate of 0.1 ml l^{-1}. The experimental design was a split-plot with 2 replications, 3 irradiance levels (main plots) ,and 2 cultivars (sub-plots).
There were 8 growth regulator treatments randomized within each sub-plot. 2 plants per replication were the experimental unit. Plants were fertilized regularly and sprayed with Vydate-L four times during the experimental period.

2.3. Recording of data

At the end of the 16 week period, on September 4,1984 plant height and fresh weight of the aerial plant parts were recorded. Rhizomes were harvested,counted and both their fresh and dry weight were recorded. Dry weights were determined after the plant parts had been dried at 70°C for 48 h. The weight of rhizomes was divided by the number of rhizomes to determine the weight per rhizome, which was related to their size. The ratio of rhizome dry weight to the total dry weight (aerial parts and rhizomes) was estimated in order to find out if treatments influenced the amount of dry matter incorporated into rhizomes. This ratio will be referred to as rhizome weight ratio, RWR. Data were analysed according to analysis of variance and Tukey's (1953) honestly significant difference (HSD) was used to evaluate differences among means of the various treatments at the 1% level of significance.

3. Results

Results indicated that cultivars responded differently to the growth regulator treatments and that there were interactions between irradiance and growth regulator treatments. All comparisons are with the control, unless stated otherwise.

3.1. Effects of cultivar

Table 1 shows those characteristics of each cultivar that were independent from either irradiance or growth regulator treatments. Fresh and dry weight of rhizomes, RWR and fresh weight per rhizome were significantly higher in 'Flamenco'.Height ,fresh and dry weight of aerial parts were greater in ' Hilda'.

3.2. Effects of irradiance

Table 2 shows the main effects of irradiance on the two cultivars, averaged over the 8 growth regulator treatments since irradiance and growth regulator treatments were independent. As irradiance levels increased, dry weight of aerial parts and rhizomes increased in both cultivars.

3.3 Interaction effects

Table 3 shows the interaction effects between cultivar and growth regulators. Dry weight of aerial parts in 'Flamenco' increased with GA_3 alone or in combination with BA and/or NAA and BA alone; in 'Hilda' only the combination BA+GA_3 increased dry weight whereas NAA or BA alone or combined decreased it. Dry weight of rhizomes was enhanced by the application of GA_3 or the combination BA+NAA in 'Flamenco' and was supressed by NAA alone in 'Hilda'. Data for fresh weights were similar to those of dry weight thus are not shown in Table 3. Percentage of dry matter incorporated into rhizomes (RWR) was not influenced by any of the treatments in 'Hilda'; in 'Flamenco' however,NAA alone increased RWR whereas the combinations GA_3+NAA, BA+GA_3 and BA+NAA+GA_3 decreased it (Fig.1).

Table 4 shows the interaction effects between irradiance and growth regulators averaged over the two cultivars as they did not influence the interaction. Plant height increased, under any of the 3 irradiances, by treating plants with GA_3 alone or in combination with BA and/or NAA. Among the 3 irradiance levels,the difference in plant height was more pronounced when plants were sprayed with GA_3 alone. Number of rhizomes was influenced by a three way interaction (Table 5). Under hi, the combinations BA+NAA and GA_3+NAA increased number of rhizomes in 'Flamenco'. In 'Hilda', GA_3 alone or in combination with NAA and/or BA and NAA alone decreased it. Treatments under ri or li had no effect on the number of rhizomes. As the average of means (X) indicates ,number of rhizomes in both cultivars increased as levels of irradiance increased. The size of rhizomes,as it was related to the dry weight per rhizome, was also affected by a threeway interaction. 'Hilda' had bigger rhizomes when treated with NAA alone under hi (551 mg compared to 96 mg of control) whereas under li had the smallest rhizomes (31 mg). 'Flamenco' was not affected. These data are not shown in tables.

4. Discussion and Conclusions

Results indicate that partitioning of assimilates differed in the two cultivars. Vegetative and generative growth is limited whereas rhizome development is enhanced in 'Flamenco' in comparison to 'Hilda'. Differences in the levels of endogenous hormones may be responsible for this difference. Gibberellins are known to supress and cytokinins to promote tuberization (Deutche,1974;Esashi & Leopold,1968). It could be that 'Flamenco' produces higher levels of endogenous cytokinins or that the ratio of cytokinins to gibberellins is higher than in 'Hilda'. Increased levels of endogenous gibberellins could be responsible for increased top growth, at the expense of rhizome production in 'Hilda' as compared to 'Flamenco'. An investigation on the endogenous hormone levels would have answered these assumptions but such a study was not undertaken in this experiment.

It has been shown that irradiance influences number of rhizomes (Vlahos,1985). Data from this study confirm these finding and further indicate that when level of irradiance decreases dry weight of aerial parts and rhizomes also decreases. Mortensesn & Ulsaker (1985) reported similar effects of irradiance on growth of begonia. It is a fact that at higher light intensities photosynthesis is enhanced and production of assimilates increases; accumulation of assimilates in the aerial and the underground parts of the plant account for increased top growth and flowering (Thijn,1954) and tuber development in the potato (Bodtander,1963).

The present results in Achimenes are in agreement with those findings as the higher the level of irradiance the higher the dry weight of the top and the rhizomes (Table 2) .The effect of growth regulators depended on cultivar and/orirradiance. Application of solutions with GA_3 and its combinations increased dry weight of aerial parts and reduced RWR in 'Flamenco (Table 3, Fig.1). These results are in agreement with reports that GA_3 inhibits tuberization and increases haulm weight in potato (Menzel,1983) and that sink strength of the tuber is reduced (Mares et al,1981). The increased rhizome dry weight in 'Flamenco' treated with GA_3 alone can be explained as an indirect effect resulting from translocation of increased assimilates from the highly developed aerial parts. However, when NAA or BA was combined with GA_3 even though it enhanced top growth, rhizome weight was not affected. This could be an indication that the aerial sink was strengthened in relation to that of rhizomes when BA or NAA was used, as auxins and cytokinins are known to attract metabolites at the site of application (Luckwill,1981;Wareing & Patrick, 1975). In 'Flamenco' the combination of BA with NAA increased dry weight of rhizomes and NAA alone increased RWR (Fig.1). Furthermore the combinations GA3+NAA and BA+NAA significantly increased number of rhizomes under the hi regime (Table 5).

One may speculate that as NAA is known to induce endogenous ethylene production (Luckwill,1981) and given that ethylene was reported to increase rhizome number and weight in Achimenes (Runger,1984) it seems then probable that NAA combined with either BA or GA_3 resulted in increased rhizome formation and development. Vreugdenhil et al,(1984) reported a similar effect of IAA with BA increasing radial growth and ethylene production in tubers of radish resulting in increased dry weight of tubers. Gibberellic acid relates almost exclusively to stem elongation (Leopold & Krieseman,1975); in both cultivars height of the main stem increased significantly under any of the irradiance regimes when plants were sprayed with a solution containing GA_3. However, a high irradiance level (hi) was antagonistic to the effect of GA_3 as under either li or ri elongation was more pronounced. Furthermore,under li, the marked elongation effect of GA_3 alone was reduced when either NAA or/and BA were incorporated in the mixture. (Table 4).

'Hilda' was affected quite differently from 'Flamenco' by the growth regulator treatments. Application of NAA alone was not favourable as number of rhizomes and dry weight of both aerial parts and rhizomes decreased (Tables 3 and 5) ; GA_3 alone or combined with NAA and/or BA decreased number of rhizomes only under the hi regime (Table 5).

It is clear that 'Flamenco and 'Hilda' differ in their pattern of growth and assimilate partitioning suggesting possible differences in the levels of endogenous hormones. High light intensities are needed for satisfactory growth and development of both the aerial and underground plant parts of Achimenes. The use of gibberellins alone or in combination with auxin and cytokinin is not recommended as plants obtain an undesirable elongation of the main stem. However, in 'Flamenco', the combination of NAA with either GA_3 or BA can increase number of rhizomes under high light intensities, which can be useful to growers of Achimenes rhizomes.

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Table 1. Main characteristics of two cultivars of Achimenes treated with GA_3, NAA and BA and grown under three levels of irradiance at 21°C and 16 h light. Values are means of 96 plants[z]. Numbers on the same horizontal row are different at the 1% level of significance (HSD).

	cv Flamenco	cv Hilda
Height of main stem(cm)	31.2	41.0
Top fresh weight (g)	20.5	34.2
Top dry weight (g)	2.6	4.2
Rhizome fresh weight (g)	2.4	1.1
Rhizome dry weight (mg)	848	387
Fresh weight per rhizome (g)	0.50	0.25
Rhizome weight ratio (RWR)	26	7

z
2 replications, 3 irradiance levels, 8 chemical treatments and a 2-plant experimental unit.

Table 2. Effect of 3 levels of irradiance on dry weight of aerial parts and rhizomes in 2 cultivars of Achimenes grown at 21°C and 16 h light for 16 weeks. Values are means of 32 plants[x]. Numbers on the same row followed by different letters are significantly different at 1% level(HSD).

	Levels of irradiance (W m^{-2})		
	ll (10)	rl (18)	hl (35)
Dry weight of			
Aerial parts (g)			
'Flamenco'	1.70a	2.50b	3.74c
'Hilda'	2.76a	3.90b	4.99c
Rhizomes (mg)			
'Flamenco'	396a	491b	1658c
'Hilda'	141a	313b	707c

x 2 replications, 8 treatments and 2-plant experimental unit.

Table 3. The effect of GA_3, NAA and BA alone or in combination on dry weight of aerial parts and rhizomes in 2 cultivars of Achimenes grown at 3 irradiance levels at 21° and 16 h light for 16 weeks. Values are means of 12 plants.[y] Numbers on the same row marked with an * are significantly different from control at the 1% level (HSD).

	Top dry weight(g)		Rhizome dry weight(mg)	
	'Flamenco'	'Hilda'	'Flamenco'	'Hilda'
control	1.65	4.54	706	487
GA_3	3.64*	5.28	1165*	352
NAA	1.37	2.65*	839	218*
GA_3+NAA	3.43*	4.95	766	248
BA	2.72*	3.40	764	461
BA+GA_3	2.98*	5.71*	653	431
BA+NAA	1.95	2.98	980*	587
BA+GA_3+NAA	3.42*	3.87	916	313
$\bar{X}$	2.64	4.17	848	387

[y] 2 replicants, 3 irradiance levels and a 2-plant experimental unit.

Table 4. Interaction effect of growth regulators and irradiance on plant height in 2 cultivars of Achimenes grown at 21°C and 16 h light for 16 weeks. Values are means of 8 plants.[w] Numbers on the same column marked with an * are significantly different from control at the 1% level (HSD).

	Plant height (cm)		
	ll (10 W m^{-2})	rl (18 W m^{-2})	hl (35 W m^{-2})
control	21.0	31.0	27.0
GA_3	54.6*	45.7*	37.9*
NAA	22.0	24.6	31.6
GA_3+NAA	49.5*	48.9*	40.2*
BA	24.1	29.6	28.7
BA+GA_3	49.4*	44.7*	35.0*
BA+NAA	27.7	29.2	30.9
BA+GA_3+NAA	49.4*	47.1*	36.5*
$\bar{X}$	37.2	37.6	33.5

[w] 2 replications, 2 cultivars and a 2-plant experimental unit.

Table 5. Interactions of growth regulator treatments and irradiance on number of rhizomes in 2 cultivars of Achimenes, grown at 21°C and 16 h light for 16 weeks. Values are means of 4 plants.[z] Numbers on the same column marked with an * are significantly different from the control at the 1% level (HSD).

	Number of rhizomes					
	ll (10 W m^{-2})		rl (18 W m^{-2})		hl (35 W m^{-2})	
	'Flamenco'	'Hilda'	'Flamenco'	'Hilda'	'Flamenco'	'Hilda'
control	3.2	2.5	4.0	4.7	4.5	10.0
GA_3	2.7	2.2	6.0	5.2	6.5	5.2*
NAA	1.7	2.2	3.7	4.0	6.2	3.2*
GA_3+NAA	3.7	2.2	3.7	3.5	8.7*	4.2*
BA	4.2	2.5	5.7	3.2	6.0	10.7
BA+GA_3	3.7	3.2	4.2	5.5	4.5	6.0*
BA+NAA	3.5	3.7	3.7	4.5	8.5*	12.3
BA+GA_3+NAA	4.7	2.2	4.2	4.0	6.2	5.7*
$\bar{x}$	3.4	2.6	4.4	4.4	6.4	7.2

[z] 2 replications and a 2-plant experimental unit.

Fig. 1. The effect of GA_3, BA, NAA and their combinations on percentage of dry matter incorporated into rhizomes (RWR) on two cultivars of *Achimenes* The vertical bar represents HSD (0.01).