J. Bamboo and Rattan, Vol. 3, No. 2, pp. 91–97 (2004)

Also available online - www.vsppub.com

Growth and proliferation of bamboo (*Dendrocalamus strictus* Roxb.) seedlings influenced by various growth regulators

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Abstract—Growth and proliferation behaviour of bamboo (*Dendrocalamus strictus*) seedlings was studied under varying concentrations of different growth regulators, i.e. cycocel, ethrel, GA_3 and maleic hydrazide. Fresh and dry biomass were significantly increased with foliar spray of cycocel (100 mg/l), while maleic hydrazide (10 mg/l) was recorded most effective growth retardant. Ethrel (10 mg/l) promoted height of plants but had negative effect on the proliferation parameters. In the case of photosynthetic efficiency (chlorophyll fluorescence) GA_3 (100 mg/l) promoted all fluorescence parameters over control except F_0 but non-significantly, while cycocel (1000 mg/l) decreased all fluorescence parameters significantly except F_0. Cycocel (100 mg/l), ethrel (1 mg/l) and maleic hydrazide (10 mg/l) also had negative effect on some chlorophyll fluorescence parameters.

Key words: Bamboo; growth regulators; biomass; proliferation; chlorophyll fluorescence.

INTRODUCTION

Bamboos form one of the very important natural resources playing a major role in the livelihood of the rural people and in the rural industry. Due to its heavy global demand bamboo stock decreases very fast, so necessary steps are required urgently in this direction. Plantation programmes should be prioritised to meet the present problem. Due to long seeding cycle, seed availability is also a big problem in this field; so much pressure creates on current planting stock. For fast multiplication of the planting stock some treatments and practices may offer some good positive results.

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Fluorescence studies have been used to test the photosynthetic efficiency of the plants [1, 2] and, hence, a quantum yield can be correlated with the net photosynthesis rate. Therefore, the factors which affect the quantum yield certainly will affect the photosynthesis rate also. Different factors are reported in literature, which are responsible for affecting the rate of photosynthesis. Among these, growth regulators have been reported very commonly. In general, various reports were found in the literature on the effect of various growth regulators on chlorophyll fluorescence parameters in different plant species, e.g. gibberellic acid, ethrel and cycocel as promoter [3–7], as neutralisant [8, 9] and as retardant [10–13]. In the case of bamboos such literature is not available so far. The present study was undertaken to study the effect of various growth regulators on growth, proliferation and photosynthetic efficiency (chlorophyll fluorescence) of bamboo seedlings.

MATERIALS AND METHODS

The experiment was conducted in April–September 2001 at the nursery of Plant Physiology Branch, Forest Research Institute, Dehra Dun, India, under natural environmental conditions. About 40-day-old seedlings of *Dendrocalamus strictus* were used for the study. The growth regulators and their concentrations used in the experimentation were: cycocel: 100 and 1000 mg/l; gibberellic acid (GA_3): 10 and 100 mg/l; ethrel: 1 and 10 mg/l and maleic hydrazide (MH): 1 and 10 mg/l. A total of fifteen plants were taken per treatment and arranged in completely randomised design (CRD).

Preparation of solution

According to the concentration of solution, the total quantity of chemical in mg (in case of solid) and in μl (in case of liquid) was weighed or measured and dissolved in a few ml of distilled water. This was made to the requisite volume by adding more distilled water. In case of GA_3, the solution was prepared by dissolving the GA_3 powder in a few drops of absolute alcohol; to which distilled water was added for making up the necessary volume.

Foliar spray with chemicals

A small amount of detergent (tepol), 1 ml per litre of solution, was mixed with the solution before spraying. It served as a wetting agent. The solutions were sprayed by hand sprayer on leaves. The treatments were applied at an interval of 15 days. Total 5 spray treatments were applied. Each plant received about 5.0 ml of the test solution. Plants were sprayed with the solution in the evening hours (at about 17.00 h).

OBSERVATIONS

Growth and proliferation studies

The observations on growth and proliferation were recorded after four months from the date of first spray. After completion of the experiment, plants were sampled and following observations were recorded.

Morphological parameters

Number of culms per clump (NOC), mean height of culms (HOC), mean basal diameter of culms (BDC), mean number of leaves (NOL), number of rhizome sub-units (NORSU).

Biomass parameters

Fresh weight of culms (FWC), fresh weight of leaves (FWL), fresh weight of rhizome (FWRZ), fresh weight of roots (FWRT), dry weight of culms (DWC), dry weight of leaves (DWL), dry weight of rhizome (DWRZ), dry weight of roots (DWRT).

Chlorophyll fluorescence measurements

Young fully expanded leaves (youngest leaves of the youngest culm) of plants were darkened with leaf clips for 20 min (as this time (the length) of dark adaptation was found appropriate) before the measurement of chlorophyll fluorescence characteristics (F_0 = low level fluorescence, F_m = maximum fluorescence, F_v = variable fluorescence and F_v/F_m = photochemical efficiency of photosystem 2 with a portable Hansatech Plant Efficiency Analyzer (Hansatech, King's Lynn, UK). Observations were recorded on three leaves per plant and three plants per treatment. The observations were recorded after 3 days of each foliar spray treatment. The mean of all five observations was calculated and the data was statistically analysed using SPSS.

RESULTS

Growth and proliferation studies

The data on growth and proliferation are presented in Table 1. The results of ANOVA reveal that various growth regulators affected different morphological and biomass parameters significantly except NOC, BDC, NORSU, FWRT and DWRZ ($P \leqslant 0.05$). Results indicate that highest values of all studied parameters were recorded in plants sprayed with 100 mg/l cycocel, except HOC and BDC. The latter reached maximum values in plants sprayed with 10 mg/l ethrel and 1000 mg/l cycocel, respectively.

Minimum values of all parameters were recorded in plants sprayed with 10 mg/l maleic hydrazide, except NOC, NOL and NORSU. The lowest proliferation (NOC

Table 1.
The effect of growth regulators on the growth and proliferation of *D. strictus* seedlings

Treatment (mg/l)	NOC	HOC (cm)	BDC (mm)	NOL	NORSU	FWC (g)	FWL (g)	FWRZ (g)	FWRT (g)	TFW (g)	DWC (g)	DWL (g)	DWRZ (g)	DWRT (g)	TDW (g)
Control	4.33	57.57	2.40	52.89	7.56	10.53	6.47	8.61	4.31	29.93	4.65	2.91	1.94	0.89	10.40
Cycocel 100	5.89	59.84	2.53	58.78	9.22	13.18	7.75	10.52	5.36	36.82	5.57	3.32	2.35	1.02	12.26
Cycocel 1000	4.33	59.21	2.65	47.11	6.67	10.59	5.96	7.46	4.35	28.36	4.12	2.70	1.75	0.86	9.43
Ethrel 1	4.11	51.60	2.29	43.39	5.78	8.37	5.21	5.73	3.48	22.79	3.44	2.35	1.25	0.72	7.76
Ethrel 10	3.33	66.91	2.29	45.11	5.22	9.25	6.06	6.86	4.35	26.53	3.79	2.65	1.36	0.78	8.58
GA_3 10	4.89	55.51	2.19	45.00	7.00	8.92	5.67	7.85	4.59	27.03	3.74	2.64	1.77	0.90	9.05
GA_3 100	4.22	59.41	2.17	43.44	6.89	8.13	4.68	7.75	4.33	24.88	3.37	2.10	1.67	0.82	7.97
MH 1	4.22	49.69	2.20	41.44	7.56	7.56	4.97	5.90	4.99	23.42	3.03	2.16	1.42	0.87	7.48
MH 10	4.44	48.44	1.96	52.22	6.78	7.18	4.36	4.83	2.69	19.06	2.80	1.91	1.03	0.49	6.22
$CD_{(0.05)}$	NS	10.88	NS	NS	NS	3.02	1.59	2.95	NS	7.61	2.17	0.66	NS	0.27	2.17

NOC = number of culms, HOC = height of culms, BDC = basal diameter of culms, NOL = number of leaves, NORSU = number of rhizome sub-units, FWC = fresh weight of culms, FWL = fresh weight of leaves, FWRZ = fresh weight of rhizomes, FWRT = fresh weight of roots, TFW = total fresh weight, DWC = dry weight of culms, DWL = dry weight of leaves, DWRZ = dry weight of rhizomes, DWRT = dry weight of roots, TDW = total dry weight and MH = maleic hydrazide.

Table 2.
Effect of growth regulators on different chlorophyll fluorescence parameters in *D. strictus* seedlings

Treatment (mg/l)	F_0	F_m	F_v	F_v/F_m
Control	1055.3	3849.0	2793.7	0.73
Cycocel 100	1357.3	3229.0	1871.7	0.58
Cycocel 1000	1490.7	2717.7	1227.0	0.44
Ethrel 1	1500.7	3653.0	2152.3	0.59
Ethrel 10	0961.3	3593.7	2632.3	0.73
GA_3 10	1204.3	3755.7	2551.3	0.68
GA_3 100	0940.3	3966.0	3025.7	0.76
Maleic hydrazide 1	1042.0	3882.3	2843.3	0.73
Maleic hydrazide 10	1405.3	3245.0	1839.7	0.56
$CD_{(0.05)}$	NS	666.5	614.7	0.13

CD = critical differences.

and NORSU) was recorded in plants treated with 10 mg/l ethrel, while minimum NOL was observed in 1 mg/l maleic hydrazide treatment (Table 1).

Chlorophyll fluorescence studies

The observations revealed that the foliar spray with different growth regulators affected all fluorescence parameters, except F_0 (Table 2). In general, GA_3 in 100 mg/l concentration promoted all parameters of chlorophyll fluorescence over control but non-significantly, while cycocel 1000 mg/l decreased all parameters, significantly over control, except F_0. The other treatments like cycocel 100 mg/l, ethrel 1 mg/l and maleic hydrazide 10 mg/l also decreased the values of F_m and F_v/F_m significantly over control.

DISCUSSION

Cycocel, ethrel and maleic hydrazide are well known chemical inhibitors of plant growth whereas gibberellic acid generally promotes the rate of elongation of numerous plant species [14]. In the present study, cycocel significantly increased fresh weight of rhizome and culm, dry weight of leaf and root, and total dry weight of seedlings of *D. strictus.* Ethrel increased culm height. Gibberellic acid decreased leaf dry weight and total dry weight of seedlings, but maleic hydrazide was a general inhibitor.

The reports of Dutta and Ramadas [15] and Phulekar [16] support the findings of present study, as they have reported that cycocel increases height, number of leaves and leaf weight in different plant species, while, in contrast, Wilfret [17] has reported that cycocel treatment did not reduce the height of cultivars of Glory and Gross Supjibi. Similarly, Bisen [18] has reported that ethrel at 200 and 400 ppm concentrations resulted in increased growth and yield of garden pea. Hence, these retardants can act as growth promoters also, in specific cases.

In the present study none of the chemical treatments produced any statistically significant effect on the proliferation rate of the seedlings as judged by their ineffectiveness on the number of culms or rhizome subunits of the seedlings. Perhaps studies using other concentrations/higher frequency of spray and increased number of replicates may yield statistically significant findings.

Maleic hydrazide treatment decreased significantly, the growth of culm, fresh weight of culm, leaf and rhizome and, total fresh and dry weights of seedlings. The inhibitory effect of maleic hydrazide on plant growth has been reported by other workers [16, 19]. They have reported that spray of 1000 ppm maleic hydrazide caused height reduction in *Dendranthema grandiflora*, and that of 500 and 1000 ppm caused a reduction in the total dry weight production in *Arachis hypogea*. However, reduction of culm growth in *D. strictus* seedlings did not show a statistically significant ($P \leqslant 0.05$) relation with an increase in culm or rhizome sub-unit number, indicating thereby, that the reduction of culm growth may not always result in an increase in the proliferation rates. Therefore, other factors like total dry matter production and its preferential diversion towards new culm and new rhizome sub-unit formation have also to be considered.

Results of the study on chlorophyll fluorescence indicate that gibberellic acid generally promotes all the fluorescence parameters, although no report is available on this aspect in bamboos. Ballantyne [3] and Bishnoi and Krishnamoorthy [5] have reported that gibberellic acid was effective in stimulating the photosynthetic efficiency in *Rhododendron* varieties and *Arachys hypogaea*, respectively. But Little and Loach [8] observed that GA_3 did not promote the rate of photosynthesis in *Abies balsamea*, whereas Sharma and Singh [10] and Fouad *et al.* [11] reported that gibberellic acid reduced the rate of photosynthesis in some plant species. So, it is clear that GA_3 influences photosynthetic efficiency of different plant species differently.

In general, cycocel, ethrel and maleic hydrazide decreased the rate of photosynthesis, which is supported by the observations of Dayal *et al.* [4], Subrahmanyam and Rathore [9] and Crafts-Brandner and Sutton [13] in different species. But Bishnoi *et al.* [5] and Kumar *et al.* [7] reported the promotive effect of these treatments on rate of photosynthesis. Therefore, the effect of growth regulatory substances on photosynthetic efficiency is still far from clear, and still more research is needed establish their role in this regard.

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