Effect of seaweed concentrate on the growth of the seedlings of three species of *Eucalyptus*

J. van Staden, R.P. Beckett* and M.J. Rijkenberg

NU Research Unit for Plant Growth and Development, Department of Botany, University of Natal Pietermaritzburg, Private Bag X01, Scottsville, 3209 Republic of South Africa

Received 10 January 1995; revised 21 February 1995

The effect of the seaweed concentrate Kelpak on the growth of seedlings of three species of *Eucalyptus* was investigated. A preliminary experiment showed that foliar sprays of Kelpak significantly increased the growth of seedlings of *E. nitens* and *E. macarthurii*. The main experiment was carried out on *E. grandis*, and studied the best method of applying the seaweed concentrate and the best time of application. Results showed that both foliar sprays and root flushes increased root and shoot growth. For both methods of application, a single dose early in the life of the seedling was optimal. There was little benefit in applying Kelpak after transplantation. Results clearly showed that seaweed concentrate can improve seedling growth in *Eucalyptus* species.

Die effek van die seewierkonsentraat Kelpak op die groei van saailinge van drie *Eucalyptus* spesies is bestudeer. 'n Voorlopige eksperiment het getoon dat blaarbespuitings van Kelpak die groei van *E. nitens* en *E. macarthurii* saailinge betekenisvol verhoog het. Die hoofeksperiment met *E. grandis* het die beste metode van seewierkonsentraat-aanwending bestudeer. Beide blaarbespuiting en wortelbenatting het wortel- en stingelgroei bevorder. Vir beide aanwendingsmetodes was 'n enkele toediening vroeg in die lewe van die saailinge optimaal. Daar was weinig voordeel om Kelpak met uitplanting aan te wend. Die resultate het duidelik getoon dat seewierkonsentraat die groei van *Eucalyptus*-saailinge kan bevorder.

Keywords: *Eucalyptus*, seaweed concentrate, seedling establishment.

*To whom correspondence should be addressed.

Introduction

Seaweed concentrates have many beneficial effects on plants (Metting *et al.* 1990). However, little is known about the effects of seaweed concentrates on the growth of seedlings. The commercial exploitation of *Eucalyptus* species in southern Africa recently has expanded greatly. Stand establishment is a major cost in producing a crop. To reduce nursery costs (e.g. of water, fertilizers, pesticides and space) it is desirable to produce high-quality seedlings as quickly as possible. Larsen *et al.* (1986) reported that pine seedlings with high root-to-shoot ratios and large root masses had the best chances of survival. Crouch & van Staden (1991) showed that the seaweed concentrate Kelpak promotes root formation in a variety of plants; this may be because it contains relatively high concentrations of indoles (Crouch *et al.* 1992). Seasby & Selby (1990) proved that the application of NAA greatly increased root production in eight conifer species. Recently, Atzmon & van Staden (1994) showed that seaweed concentrate can improve the growth of seedlings of *Pinus pinea*. The aim of the present investigation was, therefore, to test the potential for using seaweed concentrates to improve the growth of seedlings of species of *Eucalyptus*. The seaweed concentrate used in this study was Kelpak, which is manufactured by Kelp Products Pty. Ltd., Cape Town, from the stipes and laminae of the brown alga *Ecklonia maxima* (Osbeck) Papenfuss using a cell-burst process. This process does not involve the use of heat, chemicals or dehydration, which could detrimentally affect the organic components of the concentrate (Featonby-Smith 1984). A preliminary experiment investigated the effect of a foliar spray of Kelpak on the growth of *E. nitens* and *E. macarthurii*. As the results were encouraging, the main experiment described here examined the effect of timing and method of application of seaweed concentrate on *E. grandis*. The possible benefit of applying Kelpak immediately after transplantation was also studied.

Materials and Methods

Growing conditions

Seeds were obtained from the Institute of Commercial Forestry Research (Private Bag X01, Scottsville, 3209) and were sown in pine bark growing medium in Speedling 128 trays stryrodipped in Plazdip, a Cu-based, chemical root-pruning agent. After germination, the seedlings were thinned to one per cavity and grown in a thermostatically controlled greenhouse. Temperatures were maintained between 10° and 35°C, and typical midday light intensities ranged from 600 to 800 μmoles m^{-2} s^{-1}. Seedlings were watered daily with tap water. From the end of the first week they were fertilized on alternate weeks with a 1-g l^{-1} solution of a hydroponic powder containing 6.5% N, 2.7% P and 13% K. In all experiments each treatment comprised 12 plants arranged in a randomized block design.

Treatment with seaweed concentrate

Plants treated with a root flush each received 4 ml of seaweed concentrate solution. Plants treated with a foliar spray received just enough solution to wet the leaves without causing run-off. All solutions contained 0.02% Tween 20 wetting agent, and control plants were given only distilled water and wetting agent.

Preliminary experiment

In a preliminary experiment, seedlings of *E. nitens* and *E. macarthurii* were treated with a foliar spray of 0.2%, 1% and 10% seaweed concentrate, respectively. Plants were sprayed 2, 4, 8 and 10 weeks after planting. They were harvested after 12 weeks, and seedling height and leaf number measured. Leaf surface area was determined electronically using a LI-COR Model LI-3000 leaf area meter. All plant parts were then dried at 80°C to constant mass (after *ca.* 48 h) and weighed.

Main experiment

In this, the effect of root flush and foliar applications of seaweed concentrate on seedling growth was determined after 12 weeks in *E. grandis*. Seaweed extracts were applied after two weeks (one application), after two and six weeks (two applications) and after two, six and 10 weeks (three applications). The concentrations of Kelpak in the root-flush treatments were the same as those used in the preliminary experiment. However, the concentrations used in the foliar *Eucalyptus* seedlings and seaweed concentrate spray treatments were increased to 20%, 30% and 50%. Concentrations were increased to test if costs could be reduced by applying Kelpak once, rather than several times. After 12 weeks' growth, parameters were determined as above, except that roots were separated into the main tap root and lateral roots and measured separately. In addition, this experiment tested the effect of applying the seaweed concentrate immediately after transplanting. Replicate plants that had received root-flush treatments identical to those outlined above were transferred after 12 weeks to 1 500-ml plastic pots containing pine bark medium. They were then left untreated, or immediately given a root flush of seaweed concentrate at the same concentration as the applications before transplanting. After a further two weeks, plants were harvested as above, except that in addition, root length was measured using a Comair root length scanner.

Statistical analysis of data

All data were subjected to analysis of variance, and the least significant difference (L.S.D.) calculated at the 95% level.

Results and Discussion

The preliminary experiment showed that foliar sprays of Kelpak significantly increased the growth of both *E. nitens* and *E. macarthurii* (Table 1). For *E. nitens*, all concentrations of Kelpak increased growth, but 0.2% and 10% gave the best results. There was no apparent reason why 1% Kelpak was less effective. In *E. macarthurii*, the benefits increased with increasing concentrations of Kelpak, except that 10% was less effective at increasing leaf number than 0.2% and 1%. The preliminary results therefore indicated that seaweed concentrates can improve the growth of *Eucalyptus* seedlings.

Table 1 The effect of a foliar spray of 0.2, 1 and 10% seaweed concentrate on the growth of 12-week-old seedlings of *Eucalyptus nitens* and *E. macarthurii*. Plants were sprayed 2, 4, 8 and 10 weeks after planting

Seaweed concentrate (%)	Seedling height (mm)	Leaf area (cm^2)	Leaf number	Shoot dry mass (mg)	Root dry mass (mg)
Eucalyptus nitens					
Control	163	44	14.5	540	58
0.2	201	61	18.0	800	74
1	183	55	17.0	690	62
10	192	62	16.1	810	76
L.S.D.	12	8	1.8	90	10
Eucalyptus macarthurii					
Control	188	34	14.3	420	84
0.2%	194	39	16.6	580	117
1%	225	49	16.8	630	106
10%	232	50	15.0	610	107
L.S.D.	14	4	1.2	60	10

The aim of the first part of the main experiment was to determine the best method of applying seaweed concentrate and the optimal time of application. Full results are presented in Table 2. Both root flush and foliar sprays increased the growth of *E. grandis*, suggesting that growers can use either application method. Interestingly, one early root-flush application of 10% Kelpak was

Table 2 The effect of (A) root flush (0.2, 1 and 10%) and (B) foliar applications (20, 30 and 50%) of seaweed concentrate on seedling growth after 12 weeks in *Eucalyptus grandis*. Seaweed extracts were applied after two weeks (one application), two and six weeks (two applications) and two, six and 10 weeks (three applications)

Seaweed concentrate (%)	Seedling height (mm)	Total plant fresh mass (g)	Collar diameter (mm)	Leaf area (cm^2)	Leaf number	Shoot dry mass (mg)	Lateral root dry mass (mg)
A. Root flush							
Control	11	2.0	1.4	37	13.1	198	57
One application							
0.2	12	2.0	1.8	43	16.7	190	77
1	12	2.1	1.7	54	15.4	235	65
10	21	2.9	2.2	66	13.8	355	84
Two applications							
0.2	13	2.2	2.1	45	13.5	223	76
1	14	2.2	1.9	47	12.3	198	67
10	20	3.1	2.7	72	14.6	351	95
Three applications							
0.2	14	2.5	2.2	45	13.5	243	74
1	16	2.0	2.3	48	9.2	256	62
10	20	2.9	2.5	67	13.0	367	81
L.S.D.	1	0.5	0.3	7	3.7	57	20
B. Foliar spray							
Control	12	2.1	1.9	42	11.1	233	53
One application							
20	17	2.4	2.3	55	11.9	359	58
30	18	2.8	2.1	54	12.8	335	68
50	15	2.2	2.1	44	14.6	306	59
Two applications							
20	16	2.0	1.9	41	9.0	261	47
30	13	2.2	2.0	44	14.3	269	68
50	15	2.1	2.0	46	13.4	286	49
Three applications							
20	19	2.6	2.1	56	11.7	290	64
30	15	2.6	2.0	57	13.6	322	67
50	13	1.9	1.8	47	10.9	241	52
L.S.D.	1	0.4	0.3	12	3.8	70	16

as effective at increasing growth as three applications. Increasing the frequency of application was only beneficial when plants received low concentrations of Kelpak, and then only for leaf area and number, and lateral root dry mass. If Kelpak is to be applied as a root flush, we recommend one early application of a high concentration (10%).

For plants receiving foliar sprays of seaweed concentrate, all dosage strengths of Kelpak increased growth to a similar extent. The only exceptions were plants receiving three applications of the highest concentration of Kelpak (50%). These plants resembled the controls, suggesting that the Kelpak doses were supra-optimal. Our recommendation for foliar spraying is a single early application of a low concentration (20%).

Some workers have reported that seaweed concentrates are particularly effective for increasing root growth (Blunden & Wildgoose 1977; Featonby-Smith & van Staden 1983; Nelson & van Staden 1984). Recently, Atzmon & van Staden (1994) showed that foliar application of Kelpak to *Pinus pinea* seedlings increased total plant mass by increasing shoot mass, whereas a root flush increased the mass of lateral roots without significantly increasing total plant mass. In contrast, in this study, both methods of applying Kelpak increased the size and mass of the whole plants in all three species, and had no significant effect on the root-to-shoot ratio (data not shown). However, many treatment combinations increased the mass of lateral roots produced, especially when Kelpak was applied as a root flush. Lateral root production is particularly beneficial for seedling establishment (Deans *et al.* 1990; Geisler & Ferriel 1984; Struve 1990).

Table 3 The effect of the application of a root flush (0.2, 1 and 10%) of seaweed concentrate before and immediately after transplanting on the growth of 14-week-old seedlings of *E. grandis*. Seaweed concentrate applications before transplant-ation were as for Table 2. Plants were transplanted after 12 weeks, then left untreated or immediately given a root flush of seaweed concentrate at the same concentration as the applications before transplanting

	Applications before transplanting	Applications after transplanting	Concentration of seaweed concentrate (%)	Root length (m)	Root dry mass (g)	Shoot dry mass (g)
Control	0	–	0	4.0	0.50	1.11
	1	–	0.2	5.3	0.50	0.98
	1	+	0.2	6.1	0.64	1.41
	1	–	1	7.1	0.41	0.86
	1	+	1	6.2	0.52	1.02
	1	–	10	6.3	0.75	1.64
	1	+	10	4.9	0.77	1.79
	2	–	0.2	5.9	0.43	0.96
	2	+	0.2	4.5	0.61	1.11
	2	–	1	5.8	0.45	0.96
	2	+	1	6.5	0.46	1.00
	2	–	10	5.5	0.66	1.38
	2	+	10	4.7	0.60	1.59
	3	–	0.2	5.5	0.40	0.75
	3	+	0.2	5.9	0.52	1.34
	3	–	1	5.9	0.47	1.27
	3	+	1	4.1	0.51	1.25
	3	–	10	7.4	0.63	1.64
	3	+	10	5.7	0.68	1.63
L.S.D.				1.0	0.09	0.19

The application of seaweed concentrate in our experiments appeared to increase collar diameter, particularly when Kelpak was applied as a root flush (Table 2). Collar diameter is a good indication of the potential for seedlings to survive and grow well after transplantation (Thompson 1985). One way to increase wood production in the forestry industry is to increase the diameter of plants, and one may assume that seedlings with a larger collar diameter will possess an immediate advantage.

Table 3 presents the effect of applying a root flush of seaweed concentrate at the time of transplantation, on seedling size two weeks later. There appeared to be little benefit in applying seaweed concentrate at transplantation if plants received a single early application of 10% Kelpak, as indicated above. The only plants that benefitted were those that had received 0.2% Kelpak before transplanting. For other concentrations of Kelpak, treating plants following transplantation tend-ed to reduce root length, although the reduction was not always significant. Reduced root length is unlikely to improve the performance of transplanted seedlings. We therefore concluded that an additional application of seaweed concentrate following transplantation is unnecessary.

The results presented above clearly show that seaweed concentrates increased the overall growth of all three *Eucalyptus* species, but did not specifically increase root growth. Burdett *et al.* 1983 has shown that increased overall growth in nursery plants affords them a greater chance of survival and establishment after transplantation. This also means that nursery workers can transplant younger seedlings of the same size, thus cutting costs and increasing turnover. We suggest that foresters could use seaweed concentrates to improve seedling growth in *Eucalyptus* species.

Acknowledgments

The FRD and the University of Natal Research Fund are thanked for financial support.

References

ATZMON, N. & VAN STADEN, J. 1994. The effect of seaweed concentrate on the growth of *Pinus pinea* seedlings. *New Forests* 8: 279–288.

BLUNDEN, G. & WILDGOOSE, P.B. 1977. The effects of aqueous seaweed extract and kinetin on potato yields. *J. Sci. Fd Agric.* 28: 121–125.

BURDETT, A.N., SIMPSON, D.G. & THOMPSON, C.F. 1983. Root development and plantation establishment success. *Pl. Soil* 116: 103–110.

CROUCH, I.J. & VAN STADEN, J. 1991. Evidence for rooting factors in a seaweed concentrate prepared from *Ecklonia maxima*. *J. Pl. Physiol.* 137: 297–300.

CROUCH, I.J., SMITH, M.T., VAN STADEN, J., LEWIS, M.J. & HOAD, G.V. 1992. Identification of auxins in a commercial seaweed concentrate. *J. Pl. Physiol.* 139: 590–594.

DEANS, J.D., LUNDERG, C., CANNELL, M.G.R., MURRAY, M.B. & SHEPPARD, L.J. 1990. Root system fibrosity of sitka spruce transplants: Relationship with root growth potential. *Forestry* 63: 1–7.

FEATONBY-SMITH, B.C. 1984. Cytokinins in *Ecklonia maxima* and the effect of seaweed concentrate on plant growth. Ph.D. thesis, University of Natal, Pietermaritzburg.

FEATONBY-SMITH, B.C. & VAN STADEN, J. 1983. The effect of seaweed concentrate and fertilizer on the growth of *Beta vulgaris*. *Z. PflPhysiol.* 112: 155–162.

GEISLER, D. & FERRIEL, D.C. 1984. Response of plants to root pruning. *Hort. Rev.* 6: 155–187.

LARSEN, H.S., SOUTH, D.B. & BOYER, J.M. 1986. Root growth potential, seedling morphology and bud dormancy correlate with survival of loblolly pine seedlings planted in December in Alabama. *Tree Physiol.* 1: 253–263.

METTING, B., ZIMMERMAN, W.J., CROUCH, I.J. & VAN STADEN, J. 1990. Agronomic uses of seaweed and microalgae. In: Introduction to Applied Phycology, ed. Katsuka, I.A., pp. 269–306. SPB Academic Publishing, The Hague.

NELSON, W.R. & VAN STADEN, J. 1984. The effect of seaweed concentrate on wheat culms. *J. Pl. Physiol.* 115: 433–437.

SEASBY, D.A. & SELBY, C. 1990. Enhanced seedling root development in eight conifer species induced by naphthalene acetic acid. *Forestry* 63: 197–207.

STRUVE, D.K. 1990. Root regeneration in transplanted deciduous nursery stock. *HortScience* 25: 266–270.

THOMPSON, B.E. 1985. Seedling morphology evaluation – what you can tell by looking. In: Proceedings: Evaluating Seedling Quality: principles, procedures, and predictive ability of major tests. Workshop held 16–18 October 1984, Forestry Research Laboratory, Oregon State University, Corvallis, ed. Duryea, M.L., pp. 59–71. Oregon State University, Corvallis.