THE USE OF GROWTH KINETICS IN THE DEVELOPMENT OF A PREDICTIVE MODEL FOR THE GROWTH OF EICHHORNIA CRASSIPES (MART.) SOLMS IN THE FIELD

by

Charles Frank Musil

Volume 2
(Tables and Figures)

LIST OF TABLES AND FIGURES

PHOSPHORUS GROWTH RATE LIMITATION

DISCUSSION

CHAPTER 4 TESTING THE MODEL UNDER FIELD CONDITIONS

FIELD DATA

COMPARISON OF PREDICTED AND MEASURED SPECIFIC GROWTH RATES

CORRECTION OF U MAX FOR RELATIVE HUMIDITY

CHAPTER 6 PREDICTING GROWTH RATES FROM THE NUTRIENT CONCENTRATIONS IN THE PLANTS

FIELD DATA

COMPARISON OF PREDICTED AND MEASURED SPECIFIC GROWTH RATES

CHAPTER 2

METHODS

Table 2.1 Criteria used by various researchers for selecting uniform **E. crassipes** plants for culture.

Growth in preliminary culture weeks	No of pseudo-laminae per plant	dry mass g	height cm	Reference
-	-	-	-	Minshall and Scarth (1952)
-	-	-	-	Bock (1969)
-	-	-	-	Chadwick and Obeid (1966)
-	-	-	-	Gosset and Norris (1971)
1	4 or 5	-	-	Sutton and Blackburn (1971)
-	-	-	10 to 18	Haller and Sutton (1973)
-	-	7,5	-	Haller **et al.** (1974)
-	-	-	-	Dunigan et al. (1975a)
4	-	2,75	-	Wolverton and McKown (1976)
-	-	-	-	Pieterse **et al.** (1976)
-	-	-	-	Freidel **et al.** (1978)
-	-	-	-	Tag El Seed (1978)
0	2	0,20 to 0,60	-	This study

- not reported.

Table 2.2 Summary of methods used by various researchers for measuring growth of *E.* **crassipes** in culture.

Parameter used for measuring growth	Growth period or measuring interval (days)	No replicates per treatment	Statistical treatment	Reference
Total dry mass Log_{10} mean dry mass off= sets Log_{10}, numbers of offsets	28	4	Analysis of variance	Chadwick and Obeid (1966)
% wet mass increase	21	3	-	Bock (1969)
Total dry mass	7	4	Duncans multiple range test	Sutton and Blackburn (1971)
Total dry mass	28	3	Duncans multiple range test	Haller and Sutton (1973)
Total dry mass	28	4	Duncans multiple range test	Haller **et al.** (1974)
Number of offsets	28	4	-	Freidel **et al.** (1978)
Total dry mass	140	3	-	Tag El Seed (1978)
Change in fresh mass	2 to 4	16 to 20	Analysis of variance	This study

- not reported

Table 2.3 Numbers of plants (sample sizes) required to give a standard error in measurement of mass of 10% of the mean (n = SE 0,1 $\bar{x}$) as estimated from the fresh and dry masses of 20 marginal plants possessing 2 pseudolaminae sampled from a loosely crowded population in the field.

Plant No.	dry mass/g	fresh mass/g
1	0,30	5,4
2	0,33	6,0
3	0,44	10,8
4	0,41	9,7
5	0,35	7,0
6	0,27	4,2
7	0,39	8,6
8	0,34	6,8
9	0,28	4,3
10	0,38	8,3
11	0,23	4,6
12	0,52	11,3
13	0,35	7,4
14	0,34	6,0
15	0,65	13,2
16	0,37	7,1
17	0,23	4,0
18	0,48	10,8
19	0,42	9,3
20	0,24	4,1
Mean	0,37	7,44
Standard deviation	0,1039	2,7314
n = SE 0,1 $\bar{x}$	8	14

Table 2.4 Types of vessels used by various researchers for culturing **E. crassipes**.

Type	Capacity litres	Composition	Reference
Museum jar	6	glass	Minshall and Scarth (1952)
7 lb. tinned vessels	3	lined with poly=ethylene bags	Chadwick and Obeid (1966)
Beakers	0,5	glass	Bock (1969)
-	2	-	Gosset and Norris (1971)
Jar	0,9	glass	Sutton and Blackburn (1971)
Container	11	polyethylene	Haller and Sutton (1973)
Container	11,4	glass	Haller **et al.** (1974)
Pots	6	glazed clay	Dunigan **et al.** (1975a)
Beakers	1	glass	Wolverton and McKown (1976)
Trays (45 x 30 x 80 cm)	108	polyethylene	Pieterse **et al.** (1976)
Container (25 x 25 x 25 cm)	15,6	metal	Freidel **et al.** (1978)
Container	3	plastic	Tag El Seed (1978)
Buckets	5	polyethylene	This study

- not reported

Table 2.5 Types of culture solutions used by various researchers for growing **E. crassipes**.

Culture solution	Reference
20% Shives R_4 C_2 solution	Minshall and Scarth (1952)
20% Standard Long Ashton solution	Chadwick and Obeid (1966)
20% Hoaglands solution	Bock (1969)
100% Hoaglands solution	Gosset and Norris (1971)
50% Hoaglands solution	Sutton and Blackburn (1971)
50% Hoaglands solution	Haller and Sutton (1973)
Pond water + 3 mg NO_3 l^{-1}; 1 mg P_2O_5 l^{-1}; 1 mg K_2O l^{-1}	Haller **et al.** (1974)
20% Standard Long Ashton solution	Pieterse **et al.** (1976)
Tap water + "OrthoGro" plant solution containing 480 mg N l^{-1}; 240 mg P l^{-1}; 250 mg K l^{-1}	Wolverton and McKown (1976)
20% Standard Long Ashton solution	Tag El Seed (1978)
-	Freidel **et al.** (1978)
Modified culture solution based on Hamner, Lyon and Hamner (1942)	This study

- not reported.

Table 2.6 Chemical composition and ionic concentration of culture solution used for growing **E. crassipes** in this study.

Solution No	Salt	Cations	x10^3 ugl^{-1}	x10^3 ueq l^{-1}	Anions	x 10^3 ug l^{-1}	x10^3 ueq l^{-1}
1	K NO_3	K	8,41	0,215	NO_3	13,33	0,215
	$Ca(NO_3)_2.4H_2O$	Ca	4,31	0,215	NO_3	13,33	0,215
	$Mg(NO_3)_2.6H_2O$	Mg	2,61	0,215	NO_3	13,33	0,215
2	KH_2 PO_4	K	8,05	0,206	PO_4	20,00	0,206
3	K_2 SO_4	K	8,14	0,208	SO_4	10,00	0,208
	Mg $SO_4.7H_2O$	Mg	2,53	0,208	SO_4	10,00	0,208
4	KCl	K	15,40	0,394	Cl	13,97	0,394
5	$CaCl_2$	Ca	35,69	1,781	Cl	63,15	1,781
6	Mg Cl_2 $6H_2O$	Mg	34,86	2,867	Cl	101,63	2,867
7	NaCl	Na	20,00	0,869	Cl	30,84	0,869
		Total		7,718			7,718
8	Fe EDTA	Fe	0,40				
9	Cu $SO_4.5H_2O$	Cu	0,03				
	Mn $SO_4.H_2O$	Mn	0,27				
	Zn $SO_4.7H_2O$	Zn	0,13				
	H_3 BO_3	B	0,27				
	$(NH_4)_6Mo_7O_{24}.4H_2O$	Mo	0,01				

Table 2.7 Ionic concentrations of culture solutions used by various researchers for growing **E. crassipes**.

Ion	Ionic concentration x 10^3 ug l^{-1}				
	1	2	3	4	5
NO_3	40,0	20,0	42,0	28,0 - 56,8	28,0
PO_4	20,0	9,5	6,2	8,2	37,0
SO_4	20,0	40,0	12,8	9,6	96,0
Na	20,0	-	-	6,0	9,0 - 25,0
K	40,0	22,0	46,8	26,0 - 59,0	140,0
Ca	40,0	30,0	40,0	26,8 - 60,0	40,0
Mg	40,0	7,4	9,6	7,2	72,0
Fe	0,40	-	-	0,56 - 1,12	0,56
Mn	0,27	-	0,10	0,56	0,50
Cu	0,03	-	0,014	0,064	0,02
Zn	0,13	-	0,01	0,065	0,05
B	0,27	-	0,10	0,50	0,15
Mo	0,01	-	0,016	0,05	0,01

- absent or not reported.

1 = modified culture solution based on Hamner, Lyon and Hamner (1942) used in this study.

2 = 20% Standard Long Ashton solution according to Chadwick and Obeid (1966).

3 = 20% Hoaglands solution used by Bock (1969); ionic concen= tration as reported by Hewitt (1966).

4 = 20% Standard Long Ashton solution used by Pieterse **et al.** (1976); Tag El Seed (1978); ionic concentration as reported by Hewitt (1966).

5 = 20% Shives R_4 C_2 solution used by Minshall and Scarth (1952); ionic concentration as reported by Hewitt (1966).

Table 2.8 Air and water temperatures used by various researchers for growing **E. crassipes** in culture.

Temperature °C		Reference
Day	Night	
-	-	Minshall and Scarth (1952)
-	-	Chadwick and Obeid (1966)
4,4 to 26,7	4,4 to 26,7	Bock (1969)
-	-	Gosset and Norris (1971)
-	-	Sutton and Blackburn (1971)
-	-	Haller and Sutton (1973)
-	-	Haller **et al.** (1974)
27 ± 2	27 ± 2	Pieterse **et al.** (1976)
24 to 25	24 to 25	Wolverton and McKown (1976)
25 to 40	20 to 25	Freidel **et al.** (1978)
-	-	Tag El Seed (1978)
25 to 31	21 to 25	This study.

- not reported.

Table 2.9 Light intensities and daily photoperiods used by various researchers for growing **E. crassipes** in culture.

Growth situation	Light source	Light intensity	Daily photoperiod hours	Reference
Greenhouse	Daylight and artificial	- Artificial source: 300 Watt incandes= cent lamps	-	Minshall & Scarth (1952)
Rakouba	Daylight	-	-	Chadwick & Obeid (1966)
Growth chamber	Artificial	-	8 and 16	Bock (1969)
Greenhouse	Daylight	-	-	Gosset & Norris (1971)
Greenhouse	Daylight	-	-	Sutton & Blackburn (1971)
Greenhouse	Daylight	-	-	Haller & Sutton (1973)
Screened shade house	Daylight	-	-	Haller **et al.** (1974)
Greenhouse	Daylight and artificial	Artificial source: white fluo= rescent tubes 12 000 ergs $cm^{-2}sec^{-1}$	24	Pieterse **et al.** (1976)
Greenhouse	Daylight	-	-	Wolverton & McKown (1976)
Growth chamber	Artificial	30 000 to 60 000 lux	12	Freidel **et al.** (1978)
Greenhouse	Daylight	-	-	Tag El Seed (1978)
Greenhouse	Daylight	-	12 to 14	This study.

- not reported.

Table 2.10 Treatment differences between experiments designed to determine kinetic coefficients for **E. crassipes** growing under N and P growth rate limitation in culture.

Ex= peri= ment No	N growth rate limitation			Ex= peri= ment No	P growth rate limitation		
	No of plants as inoculum	N added $\times 10^3$ ug N $5l^{-1}$	No of replica= tes per treatment		No of plants as inoculum	P added $\times 10^3$ ug P $5l^{-1}$	No of replica= tes per treatment
1	2	0; 11,29; 22,58; 33,87; 45,16; 56,45	20	6	2	0; 1,30; 2,61; 3,91; 5,22	20
2	1	0; 4,52; 9,03; 18,06; 27,10; 36,13	16	7	1	0; 0,65; 1,63; 2,61; 3,91; 5,22	16
3	1	0; 4,52; 9,03; 18,06; 27,10; 36,13	16	8	1	0; 1,30; 3,26; 5,22; 7,83; 10,44	18
4	1	0, 9,03; 18,06; 28,10; 36,13; 45,16	18				
5	1	0; 9,03; 18,06; 28,10; 36,13; 45,16	18				

Table 2.11 Criteria used by various researchers for selecting uniform **E. crassipes** plants for field investigations.

Mean area m^2	Mean dry mass g	Other	Reference
-	-	Free-floating healthy plants possessing no offsets	Bock (1969)
-	-	-	Scarsbrook & Davis (1971)
-	-	Plants of uniform size	Wahlquist (1972)
-	-	Individual plants without stolons or offsets	Rushing (1974)
18		Young plants	Ornes & Sutton (1975)
-	8,8	-	Boyd & Scarsbrook (1975)
-	-	-	Wooten & Dodd (1976)
-	1,79	-	Boyd (1976)
-	0,4 to 1,20	Marginal plants pos= sessing 3 pseudolaminae	This study
-	2,5 to 6,0	Central plants possess= ing 3 pseudolaminae	This study

- not reported.

Table 2.12 Types of enclosures used by various researchers for containing **E. crassipes** plants in the field.

Type	Area m^2	Construction	Reference
Enclosure formed by other water hyacinths	-		Bock (1969)
Wooden rafts (floating)	46	12,54 x 15,24 cm pine boards nailed together to form a square (6,7 x 6,7 m); held stationary by pine boards driven into the sediment and nailed to rafts	Wahlquist (1972)
Bamboo frame (floating)	4	Side of frame 2 bamboo rungs deep, each rung with diam. of 10 cm. Rungs laced together with nylon chord and nailed at joints. Frames anchored to concrete blocks	Rushing (1974)
Polyvinylchloride frames (floating)	4	PVC pipe (5,08 cm in diam.) used to construct 2,0 x 2,0 m frames, tied to metal posts anchored in sediment	Boyd & Scarsbrook (1975)
Bottomless barrels	-	Barrels painted with inert epoxy paint and set firmly in sediment	Dunigan **et al.** (1975a)
Polyvinylchloride rafts (floating)	20	PVC pipe (5,08 cm in diam.) used to construct 3,2 x 6,4 m enclosures, tied to metal posts anchored in sediment	
Cylindrical enclosure	**ca** 0,8 to 6,0	Plastic coated wire mesh **ca** 1,5m high held in place by metal fencing posts driven into the sediment	This study

Table 2.13 Summary of methods used by various researchers for measuring growth of E. **crassipes** in the field.

Parameters used for measuring growth	No replicates per treatment	Growth period or measuring interval weeks	Reference
Increase in fresh and dry mass and plant numbers	-	2	Bock (1969)
Increase in fresh and dry masses	3	11	Scarsbrook & Davis (1971)
Mean fresh mass in= crease	3	2	Wahlquist (1972)
Increase in mean fresh mass and plant numbers	3	1 to 2	Rushing (1974)
Dry mass yield on half surface area produced	8	1	Ornes & Sutton (1975)
Increase in fresh mass, plant nos; shoot height; root length, based on 0,25 m^2 quadrat samples. Dry mass estimated on subsamples of 500 to 700 g	1	2 to 2,5	Boyd & Scarsbrook (1975)
Increase in fresh and dry masses based on 1 m^2 quadrat samples	5	14,5	Wooten & Dodd (1976)
Increase in fresh mass based on 0,25 m^2 quadrat samples. Dry mass estimated on subsamples	3	2 to 4	Boyd (1976)
Change in fresh mass	30 to 40	**ca** 2	This study.

- not reported.

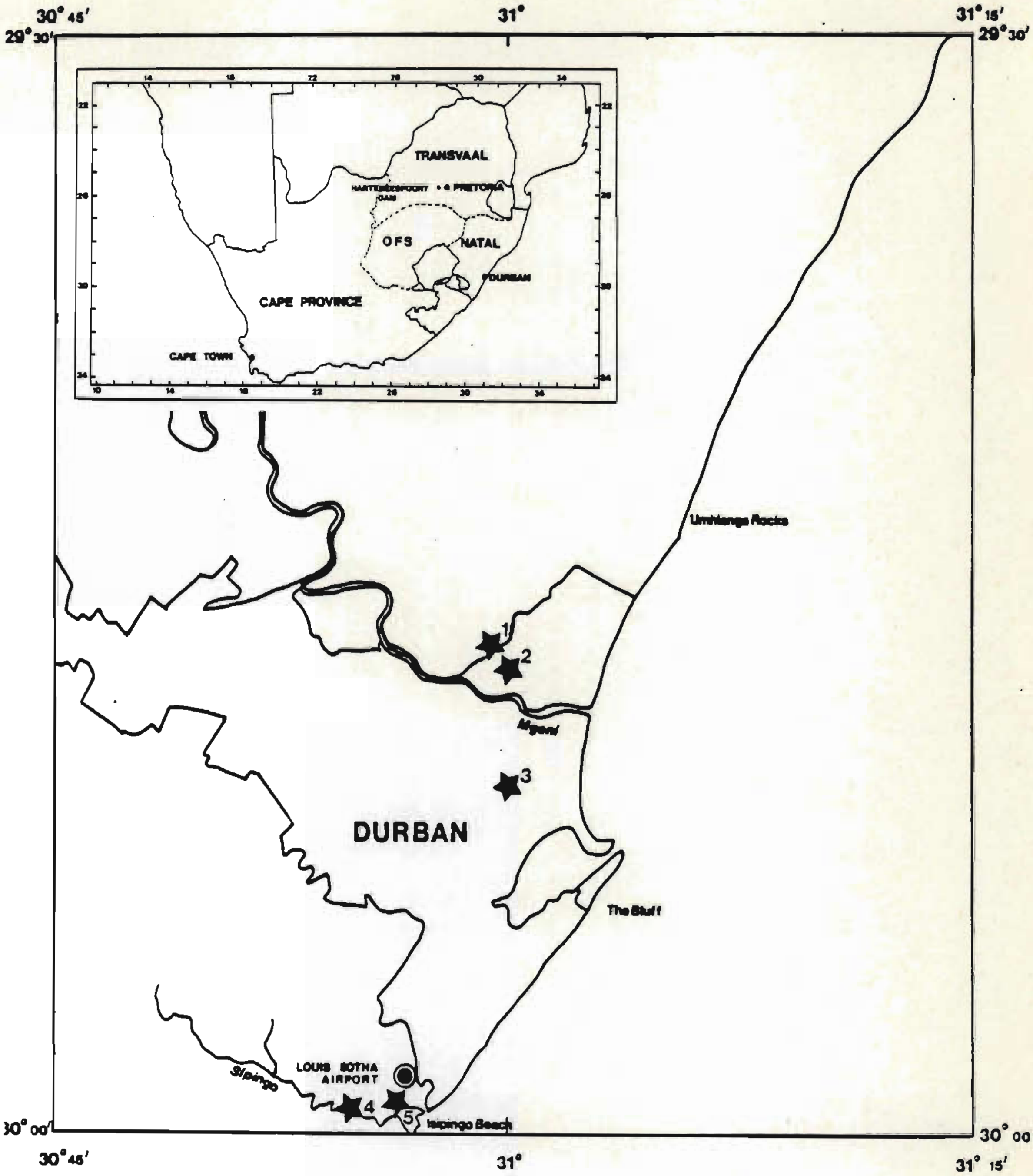


Figure 2.1 Location of field sites. 1. Maturation pond, Northern sewage treatment works. 2 Discharge Canal, Northern sewage treat= ment works. 3. Botanic Gardens Lake. 4. Isipingo Lake. 5. Isipingo Canal. The Hartbeespoort Dam site in the Transvaal is shown in the inset.

CHAPTER 3

EXPERIMENTAL DETERMINATION OF KINETIC COEFFICIENTS

Table 3.1 Average daily air and water temperatures and relative humidities recorded in the greenhouse during growth of E. **crassipes** in N deficient cultures.

Experiment No	Growth in N deficient culture (days)	Air and water temperature °C			Relative humidity %		
		Max	Mean	Min	Max	Mean	Min
1	18	25	24	23	80	67	55
2	39	30	28	26	72	62	53
3	57	28	25	22	76	66	56
4	21	24	21	19	81	70	59
5	17	30	25	21	72	63	55

Table 3.2 Mean fresh masses (g), excluding dead mass, and standard deviations of groups of **E. crassipes** plants to comprise each treatment in each experiment at spiking.

Treatment No	Experiment No				
	1	2	3	4	5
1	17,25±4,45	32,43±13,94	35,81± 8,71	17,92±5,21	25,05±5,77
2	20,51±6,43	38,60±10,14	43,26±11,75	25,92±9,40	24,43±7,43
3	22,83±6,48	35,06± 8,09	39,60±10,99	25,41±7,02	22,39±6,12
4	18,07±5,93	34,26± 8,23	38,51±10,41	22,96±6,59	25,86±9,02
5	19,50±6,51	39,35± 6,48	34,90± 5,72	20,56±6,79	24,23±8,20
6	17,33±6,72	37,55±13,62	34,31±10,38	20,14±7,15	27,02±7,10

Analysis of Variance

Variance ratio (F value)	2,47	1,07	1,91	3,53	0,82
Degrees of freedom (n-1)	119	95	95	107	107
Significance level %	NS (P = 0,05)	NS (P = 0,05)	NS (P = 0,05)	NS (P = 0,05)	NS (P = 0,05)

NS = not significant

Table 3.3 Experiment 1, treatment 4. Specific growth rates (g fresh mass g^{-1} d^{-1}) determined for **E. crassipes** between each weighing interval after the addition of N at a concentration of 6,77 x 10^3 ug N l^{-1}.

Plant	Number of days after the addition of N					
No	2	5	7	10	12	15
1	0,0181	0,0459	0,0723*	0,0416	0,0292	0,0356
2	0,0774	0,0411	0,0932*	0,0444	0,0148	0,0147
3	0,0337	0,0380	0,0796*	0,0312	0,0276	0,0408
4	0,0541	0,0421	0,0633*	0,0396	0,0214	0,0357
5	0,0583	0,0348	0,0702*	0,0496	0,0376	0,0028
6	0,0548	0,0478	0,0559*	0,0458	0,0053	0,0194
7	0,0885*	0,0342	0,0383	0,0488	0,0270	0,0253
8	0,0522	0,0361	0,0716*	0,0463	0,0291	0,0237
9	0,0216	0,0866*	0,0669	0,0322	0,0135	0,0228
10	0,0391	0,0433	0,0713*	0,0399	0,0268	0,0309
11	0,0267	0,0347	0,0758*	0,0329	0,0389	0,0083
12	0,0657	0,0525	0,0945*	0,0050	0,0351	0,0237
13	0,0485	0,0409	0,0731*	0,0422	0,0355	0,0131
14	0,0581	0,0467	0,0793*	0,0344	0,0250	0,0381
15	0,0386	0,0547	0,0759*	0,0357	0,0377	0,0188
16	0,0686	0,0402	0,0744*	0,0544	0,0319	0,0206
17	0,0711*	0,0520	0,0699	0,0485	0,0368	0,0198
18	0,0709*	0,0521	0,0605	0,0195	0,0306	0,0238
19	0,0523	0,0504	0,0744*	0,0339	0,0213	0,0492
20	0,0599	0,0339	0,0689*	0,0582	0,0159	0,0414

* Highest specific growth rate (maximum growth rate) attained by each plant after the addition of N.

Table 3.4 Statistical analysis of regressions of 1/U against 1/N for **E. crassipes** grown under N growth rate limitation in culture.

Experiment No	Correlation coefficient (r)	Degrees of freedom (n-1)	Significance level %	Analysis of Variance: Variance ratio (F value)	Analysis of Variance: Significance level %
1	0,6877	99	0,1	78,19	0,1
2	0,4258	79	0,1	9,49	1,0
3	0,7018	79	0,1	79,06	0,1
4	0,5697	89	0,1	22,37	0,1
5	0,5578	89	0,1	20,51	0,1

Table 3.5 Maximum specific growth rates (Umax) and half saturation coefficients (Ksn) determined for **E. crassipes** under N growth rate limitation in culture.

Experiment No	Growth in N deficient culture (days)	Umax g fresh mass g^{-1} d^{-1}	Umax 95% confidence limits	Ksn ug N l^{-1}	Air and water temperature °C Max	Mean	Min	Relative humidity % Max	Mean	Min
1	18	0,0886	± 0,0064	1 505,6	25	24	23	80	67	55
2	39	0,0537	± 0,0028	399,8	31	28	25	71	62	53
3	57	0,0613	± 0,0089	1 085,3	30	26	23	73	63	54
4	21	0,0713	± 0,0042	914,0	28	24	21	76	66	56
5	17	0,0812	± 0,0050	975,5	30	26	22	72	63	55

Table 3.6 Quantities of N analyzed in 3 culture solution samples taken at random from each treatment in 3 experiments after fresh mass recordings had been terminated. A. Quantity of N (ug N $5l^{-1}$) remaining in culture solution. B. Quantity of N remaining in culture solution as % of that initially added. ND = not determinable, N content < 5ug N $5l^{-1}$.

Treatment No	Experiment No					
	1		2		3	
	A	B	A	B	A	B
N added ug N $5l^{-1}$	0		0		0	
	ND	-	ND	-	ND	-
1	ND	-	ND	-	ND	-
	ND	-	ND	-	ND	-
N added ug N $5l^{-1}$	11 290		4 520		4 520	
	ND	-	ND	-	ND	-
2	5	0,04	ND	-	ND	-
	5	0,04	ND	-	ND	-
N added ug N $5l^{-1}$	22 580		9 030		9 030	
	10	0,04	5	0,05	ND	-
3	5	0,02	ND	-	ND	-
	ND	-	5	0,05	5	0,05
N added ug N $5l^{-1}$	33 870		18 060		18 060	
	15	0,04	5	0,03	10	0,05
4	5	0,01	10	0,05	10	0,05
	10	0,03	ND	-	5	0,03
N added ug N $5l^{-1}$	45 160		27 100		27 100	
	20	0,04	5	0,02	10	0,04
5	30	0,07	15	0,05	10	0,04
	15	0,03	5	0,02	15	0,05
N added ug N $5l^{-1}$	56 450		36 130		36 130	
	25	0,04	25	0,07	20	0,05
6	15	0,03	10	0,03	5	0,01
	40	0,07	10	0,03	25	0,07

Table 3.7 Statistical analysis of regressions relating total fresh mass yields of **E. crassipes** to quantities of N supplied in culture.

Experi= ment No	Correlation coefficient (r)	Degrees of freedom (n-1)	Significance level %	Analysis of Variance: Variance ratio (F value)	Analysis of Variance: Significance level %
1	0,7636	59	0,1	81,16	0,1
2	0,8141	95	0,1	184,72	0,1
3	0,7954	95	0,1	161,91	0,1

Table 3.8 Yield coefficients, Ycn, (g of fresh mass yield of plant mate= rial per g of N absorbed by plants) determined for **E. crassipes** under N growth rate limitation in culture. Yield coefficients (dry mass basis) are estimated from the mean water contents of plants determined in each experiment.

Experi= ment No	Growth in N defi= cient culture (days)	Ycn (fresh mass basis)	Mean water content, plants: %	Mean water content, plants: Standard deviation	Ycn (dry mass basis)
1	18	1 981,1	95,05	± 0,85	98,1
2	39	1 664,9	94,78	± 0,93	86,9
3	57	1 659,6	94,72	± 0,83	87,6

Analysis of Variance

Variance ratio (F value)	3,26
Degrees of freedom (n-1)	311
Significance level %	NS (P = 0,05)

NS = not significant

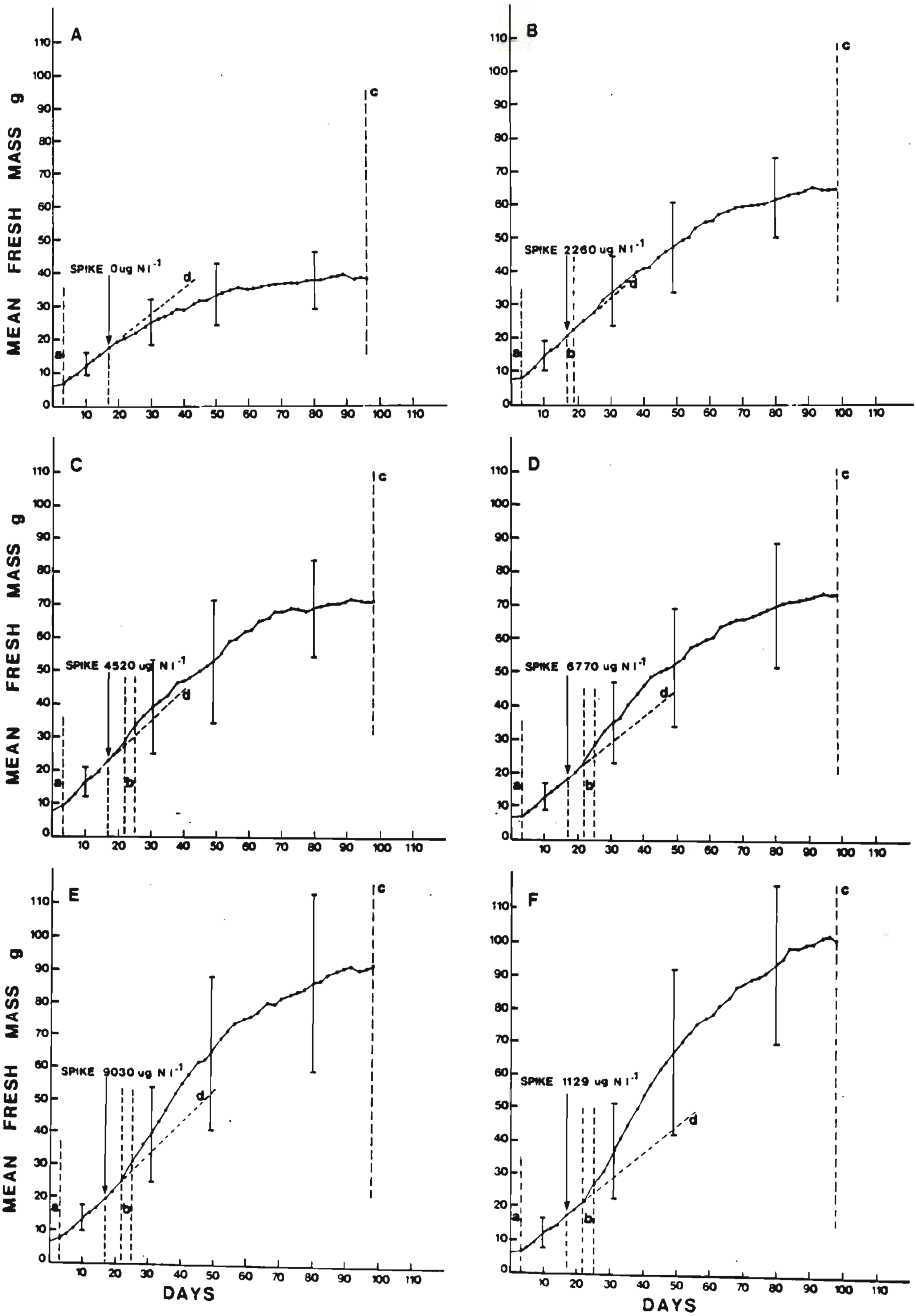
Table 3.9 Minimum N concentrations, % dry mass, (means of 3 batches) ana= lyzed in **E. crassipes** harvested from culture.

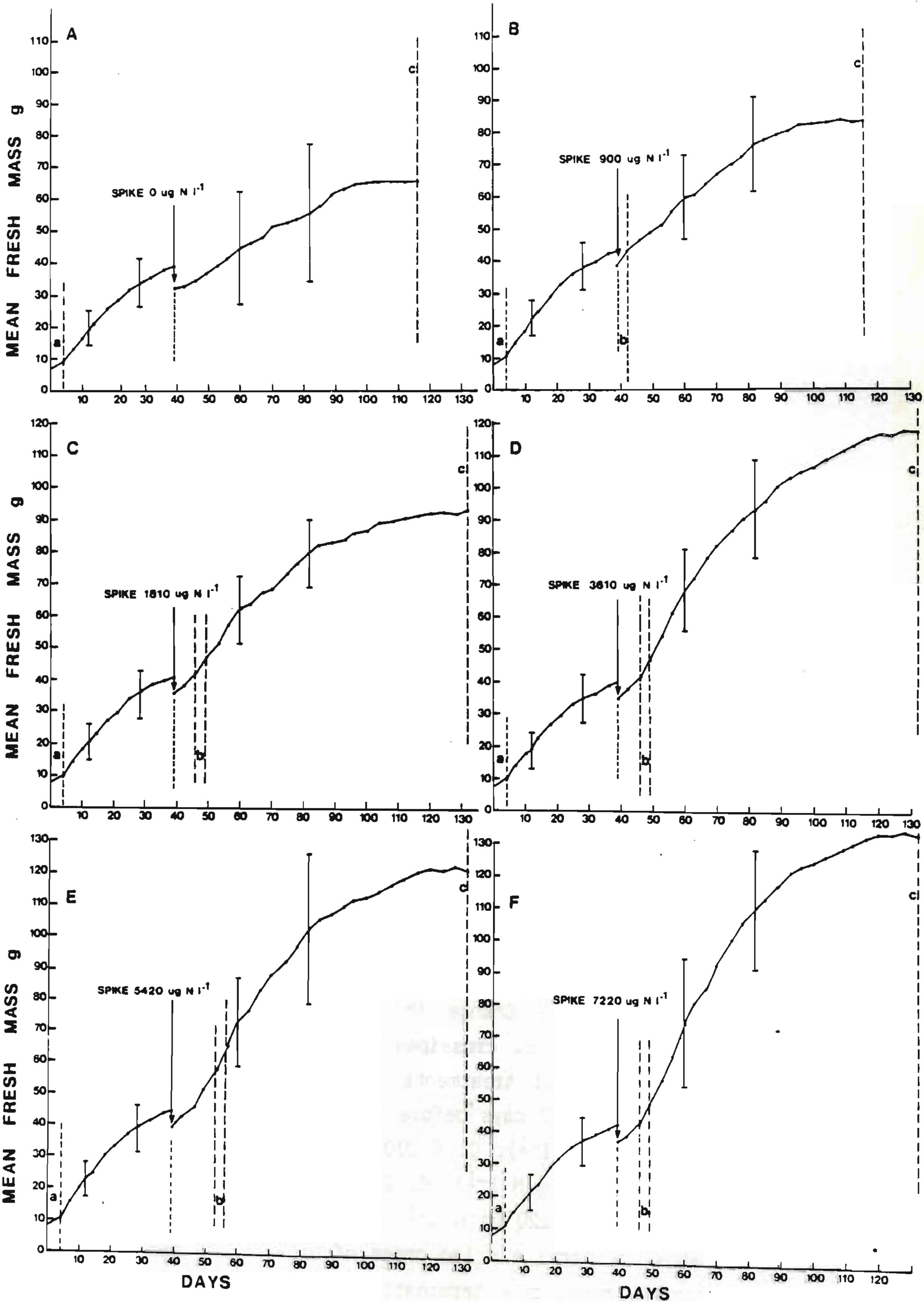
Treatment No	Experiment No		
	1	2	3
1	0,94	0,98	1,08
2	1,02	1,07	1,00
3	1,01	1,27	1,07
4	1,08	1,09	1,11
5	1,28	1,10	1,08
6	1,20	1,18	1,03
Means	1,091	1,117	1,063

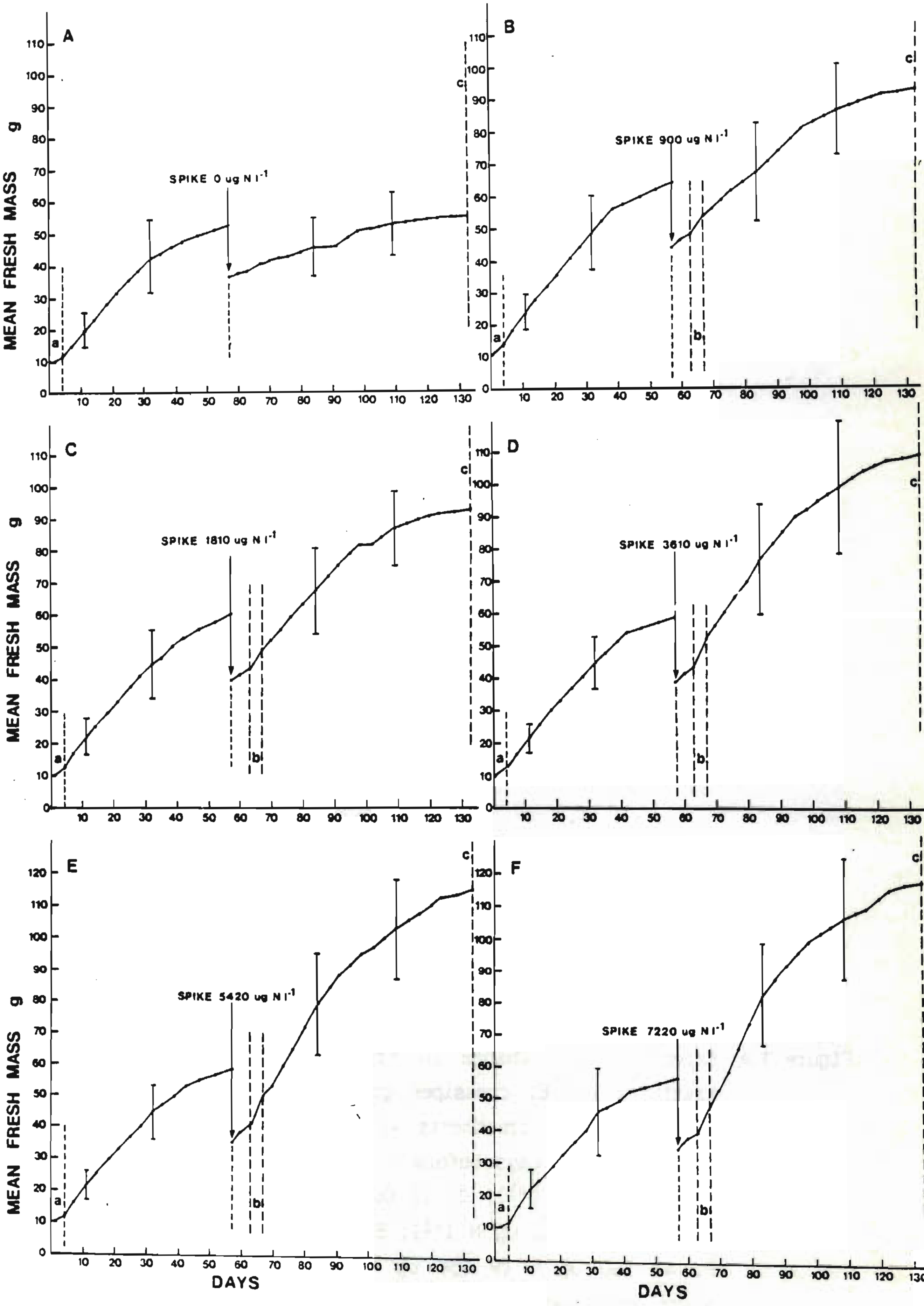
Analysis of Variance

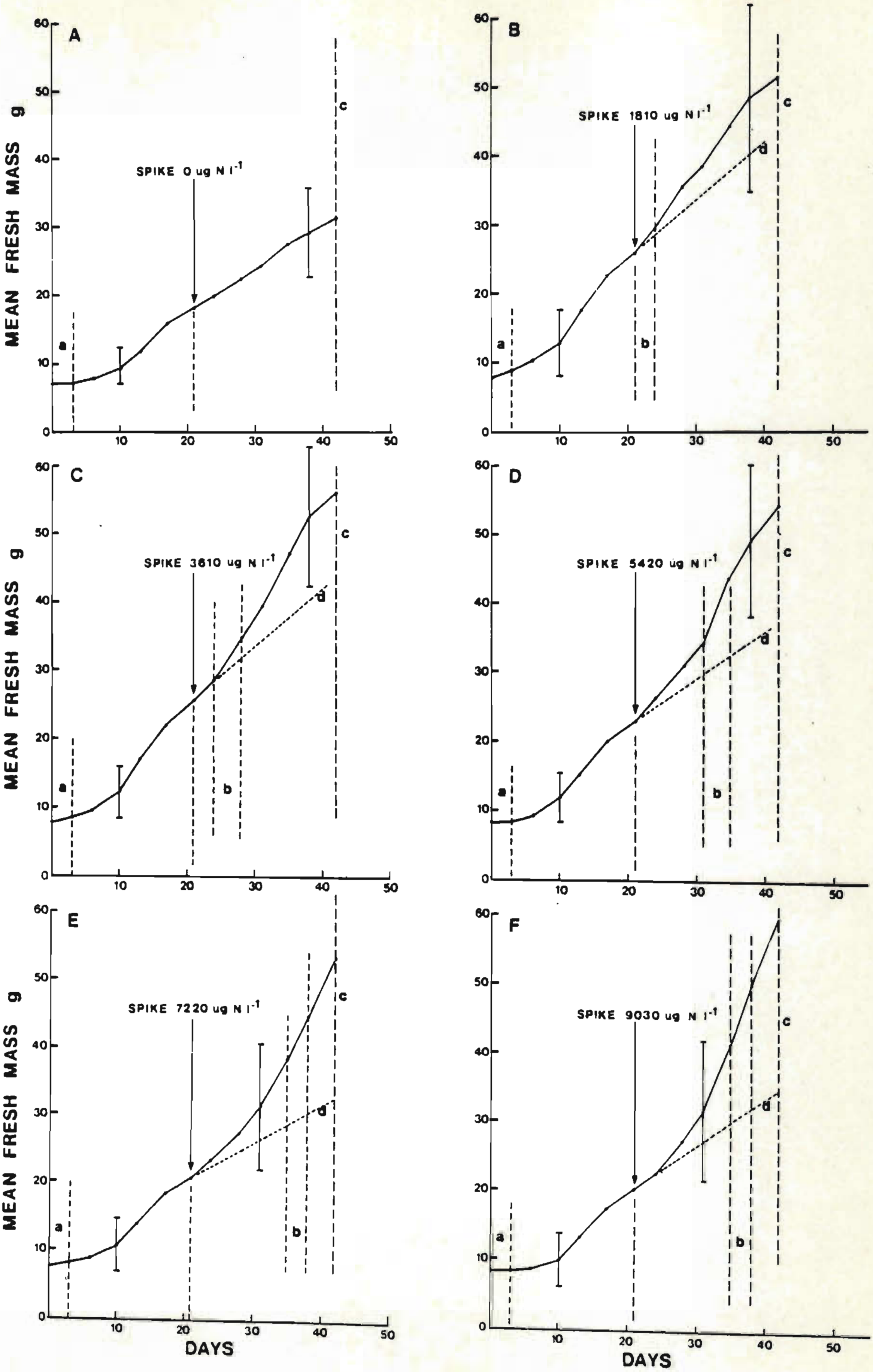
Variance ratio (F value)	0,48
Degrees of freedom (n-1)	53
Significance level %	NS (P = 0,05)

NS = not significant


A
B
C
D
E
F
SPIKE 0ug N l⁻¹
SPIKE 2260 ug N l⁻¹
SPIKE 4520 ug N l⁻¹
SPIKE 6770 ug N l⁻¹
SPIKE 9030 ug N l⁻¹
SPIKE 1129 ug N l⁻¹
MEAN FRESH MASS g
DAYS
a
b
c
d


A
SPIKE 0 ug N l-1
B
SPIKE 900 ug N l-1
C
SPIKE 1810 ug N l-1
D
SPIKE 3610 ug N l-1
E
SPIKE 5420 ug N l-1
F
SPIKE 7220 ug N l-1
a
b
c
MEAN FRESH MASS g
DAYS


A
SPIKE 0 ug N l-1
B
SPIKE 900 ug N l-1
C
SPIKE 1810 ug N l-1
D
SPIKE 3610 ug N l-1
E
SPIKE 5420 ug N l-1
F
SPIKE 7220 ug N l-1
MEAN FRESH MASS g
DAYS
a
b
c


A
SPIKE 0 ug N l-1
B
SPIKE 1810 ug N l-1
C
SPIKE 3610 ug N l-1
D
SPIKE 5420 ug N l-1
E
SPIKE 7220 ug N l-1
F
SPIKE 9030 ug N l-1
MEAN FRESH MASS g
DAYS
a
b
c
d

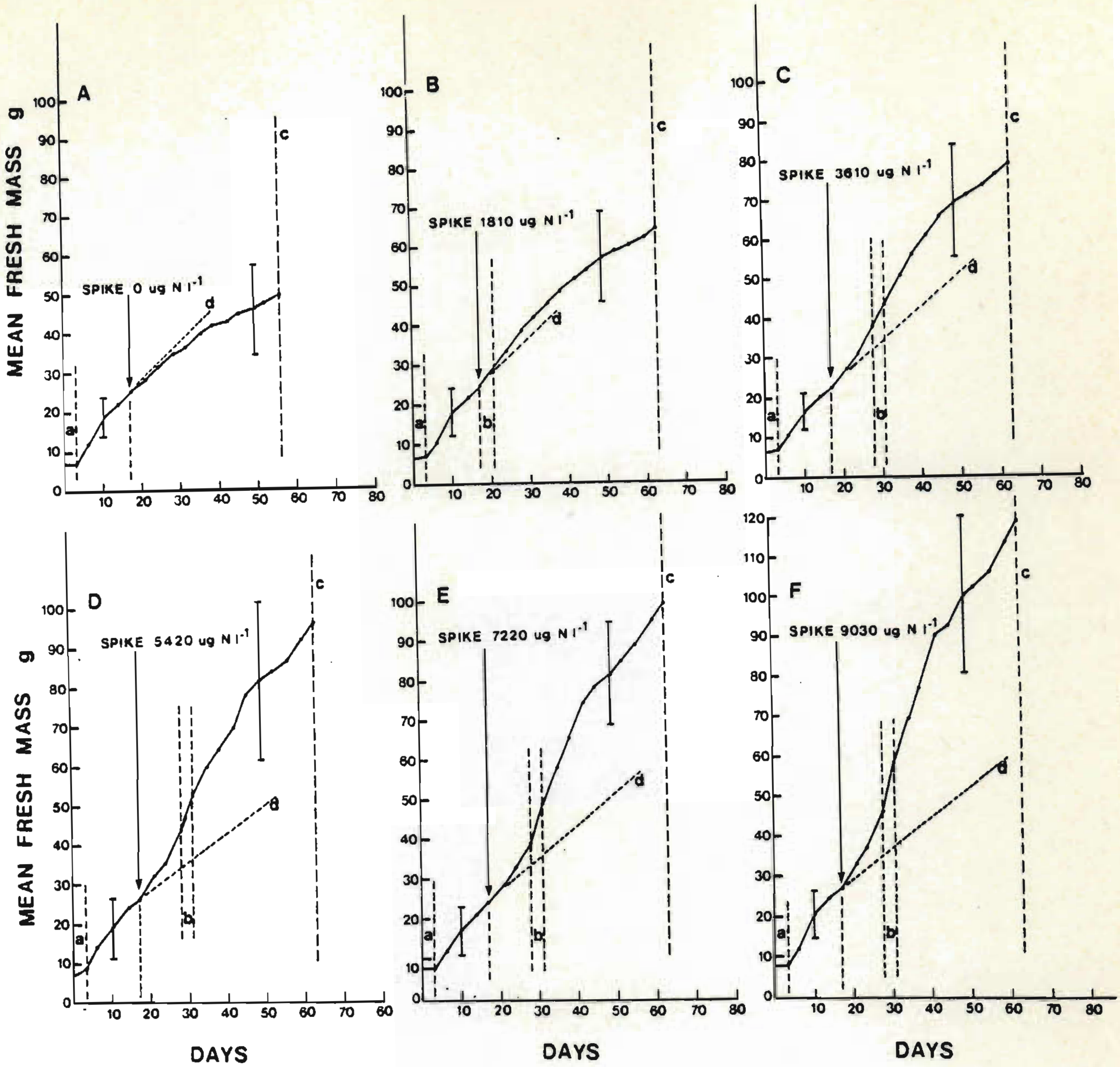


Figure 3.5 Experiment 5. Change in fresh mass (means of 18 plants/ treatment) of **E. crassipes** grown under varying conditions of N supply. All treatments were grown under N deficient con= ditions for 17 days before N was added. A. No N; B. 9 030 ug N (1 810 ug N l^{-1}); C. 18 060 ug N (3 610 ug N l^{-1}); D. 28 100 ug N (5 420 ug N l^{-1}); E. 36 130 ug N (7 220 ug N l^{-1}); F. 45 160 ug N (9 030 ug N l^{-1}). Standard deviations of means are shown by bars: a = lag phase of growth; b = period of maximum growth rate; c = termination of fresh mass recordings; d = projected growth in the absence of N.

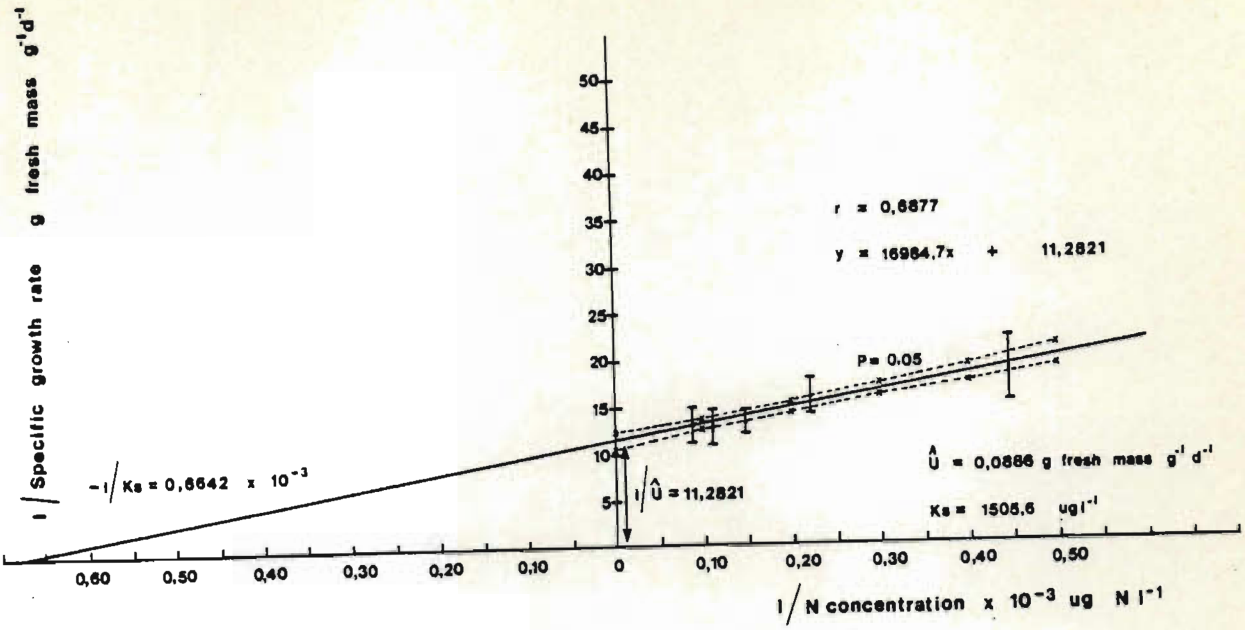


Figure 3.6 Experiment 1. A Lineweaver-Burk plot of the specific growth rates of E. **crassipes** (means of 20 plants/treatment) against the levels of N supplied in culture. Broken lines show 95% confidence limits on either side of the regression line. Standard deviations of means are shown by bars. $\hat{U}$ = Umax.

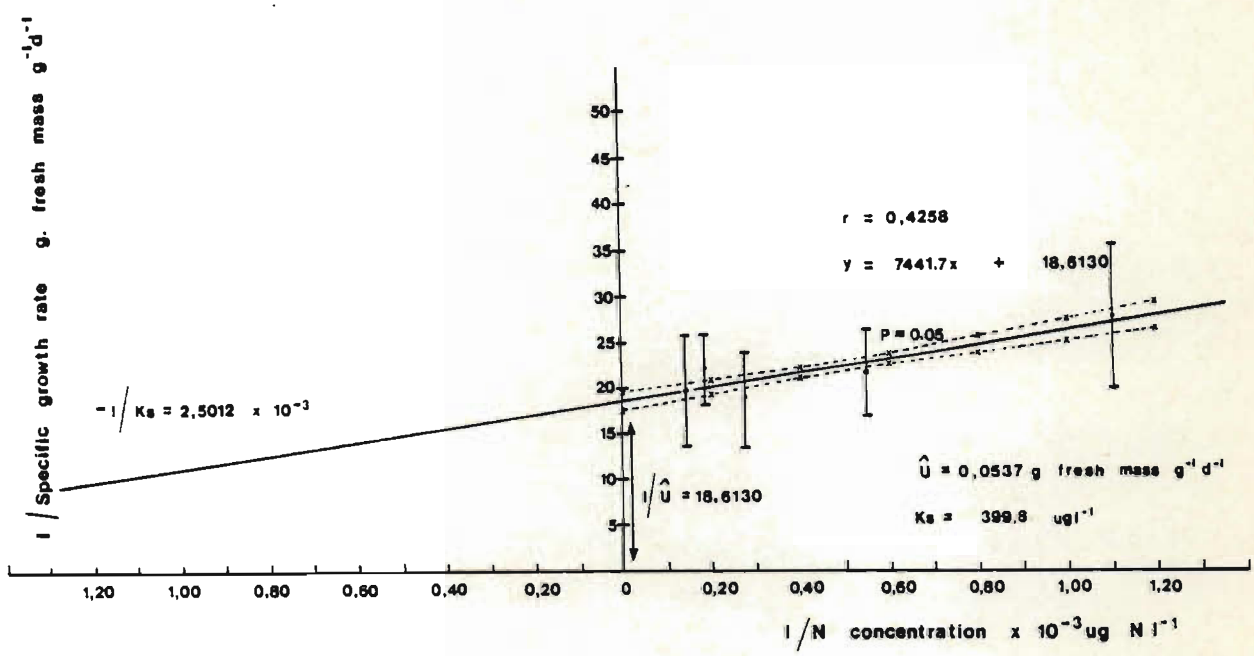


Figure 3.7 Experiment 2. A Lineweaver-Burk plot of the specific growth rates of E. **crassipes** (means of 16 plants/treatment) against the levels of N supplied in culture. Broken lines show 95% confidence limits on either side of the regression line. Standard deviations of means are shown by bars. $\hat{U}$ = Umax.

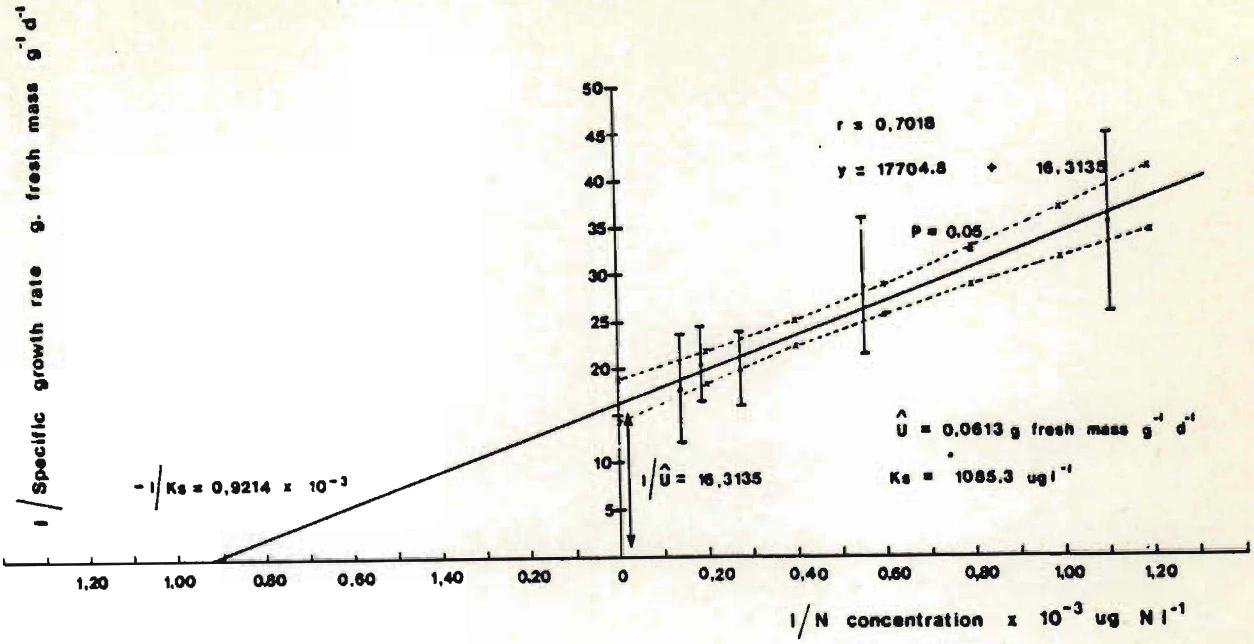


Figure 3.8 Experiment 3. A Lineweaver-Burk plot of the specific growth rates of E. **crassipes** (means of 16 plants/treatment) against the levels of N supplied in culture. Broken lines show 95% confidence limits on either side of the regression line. Standard deviations of means are shown by bars. $\hat{U}$ = Umax.

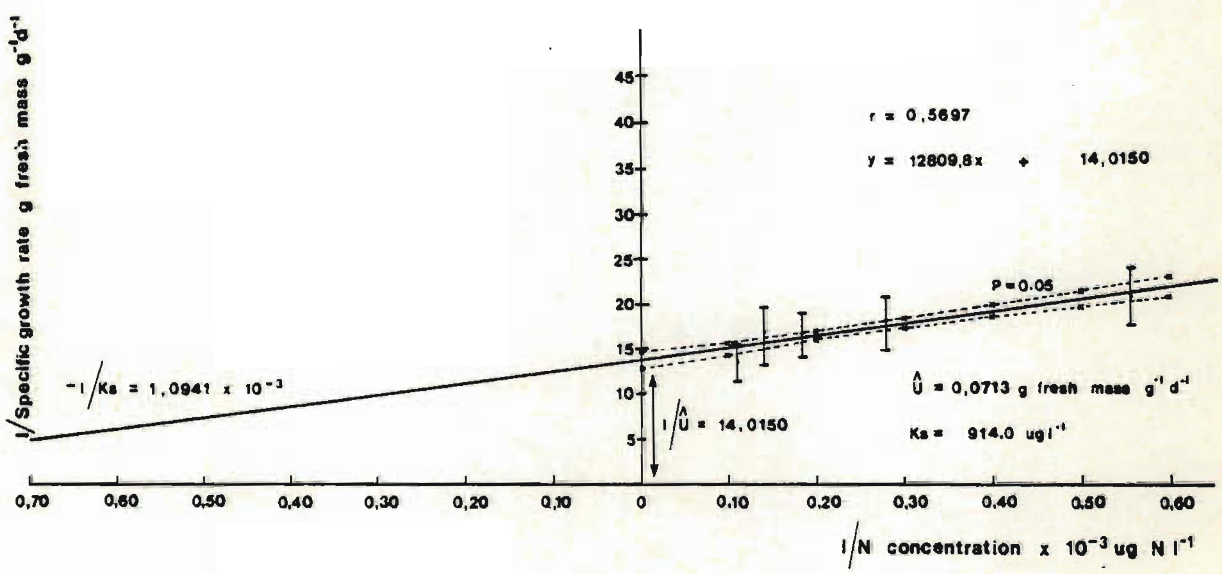


Figure 3.9 Experiment 4. A Lineweaver-Burk plot of the specific growth rates of E. **crassipes** (means of 18 plants/treatment) against the levels of N supplied in culture. Broken lines show 95% confidence limits on either side of the regression line. Standard deviations of means are shown by bars. $\hat{U}$ = Umax.

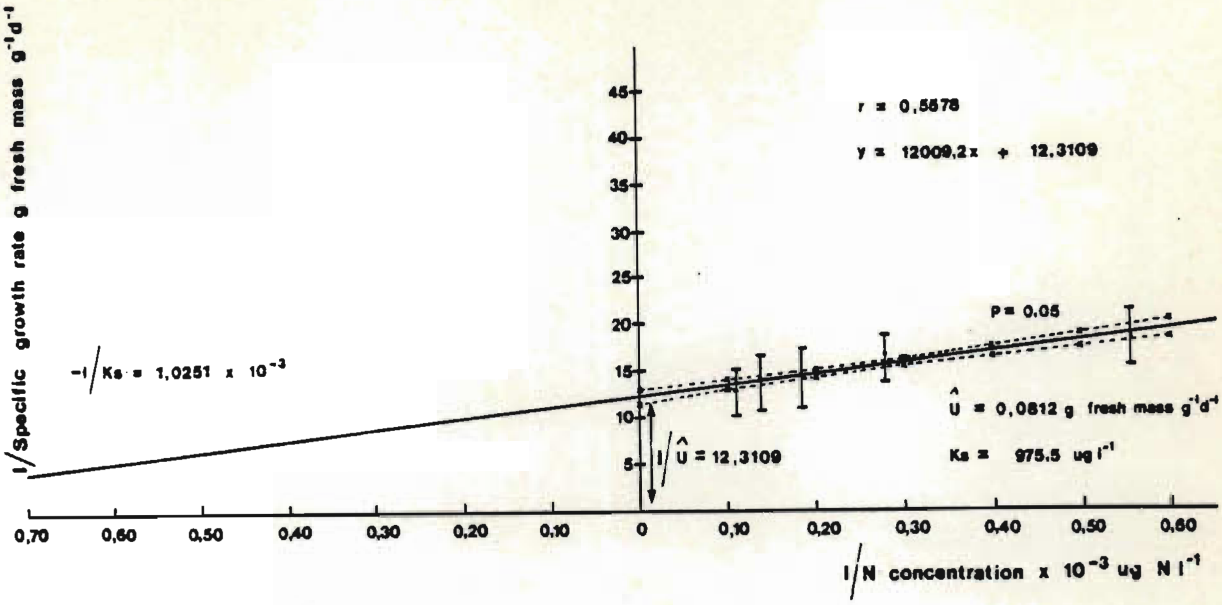


Figure 3.10 Experiment 5. A Lineweaver-Burk plot of the specific growth rates of **E. crassipes** (means of 18 plants/treatment) against the levels of N supplied in culture. Broken lines show 95% confidence limits on either side of the regression line. Standard deviations of means are shown by bars. $\hat{U}$ = Umax.

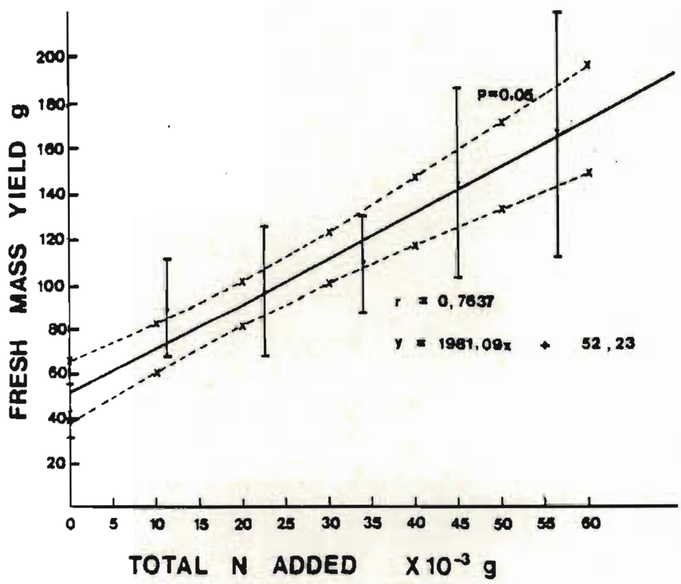


Figure 3.11 Experiment 1. The relationship between the total fresh mass yields of **E. crassipes** (means of 20 plants/treatment) and the quantities of N supplied in culture. Broken lines show 95% confidence limits on either side of the regression line. Standard deviations of means are shown by bars.

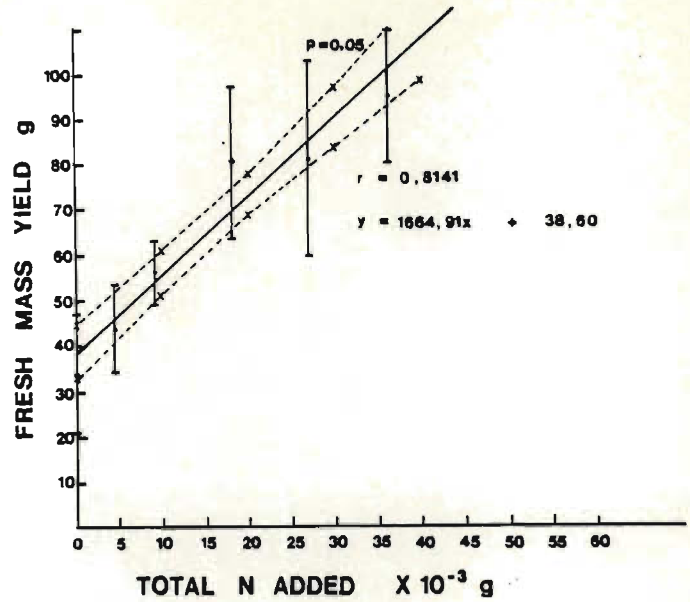


Figure 3.12 Experiment 2. The relationship between the total fresh mass yields of **E. crassipes** (means of 16 plants/treatment) and the quantities of N supplied in culture. Broken lines show 95% confidence limits on either side of the regression line. Standard deviations of means are shown by bars.

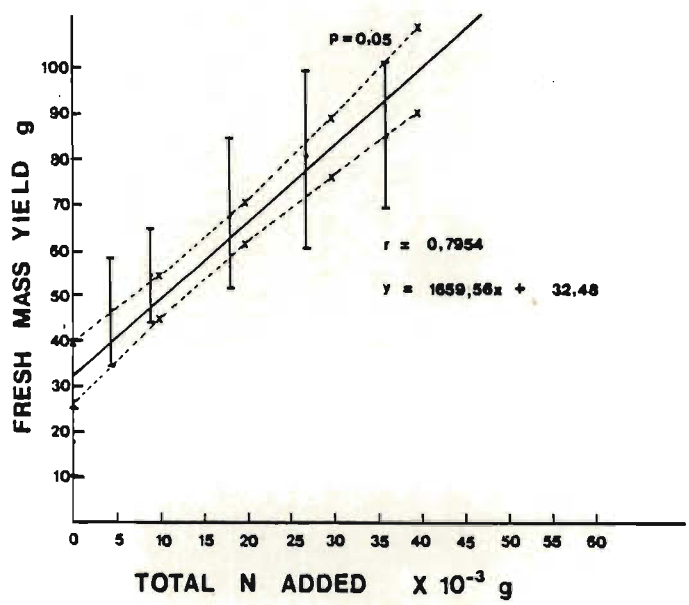


Figure 3.13 Experiment 3. The relationship between the total fresh mass yields of **E. crassipes** (means of 16 plants/treatment) and the quantities of N supplied in culture. Broken lines show 95% confidence limits on either side of the regression line. Standard deviations of means are shown by bars.

Table 3.10 Average daily air and water temperatures and relative humidi= ties recorded in the greenhouse during growth of **E. crassipes** in P deficient cultures.

Experiment No	Growth in P deficient culture (days)	Air and water temperature °C			Relative humidity %		
		Max	Mean	Min	Max	Mean	Min
6	17	31	28	25	70	60	55
7	39	30	28	26	71	62	54
8	38	30	25	21	72	64	56

Table 3.11 Mean fresh masses (g), and standard deviations of groups of **E. crassipes** plants to comprise each treatment in each experiment at spiking.

Treatment No	Experiment No 6	7	8
1	17,71$\pm$ 5,64	43,33$\pm$ 8,21	69,03$\pm$20,92
2	23,50$\pm$10,58	38,48$\pm$14,49	84,92$\pm$15,47
3	19,37$\pm$ 7,79	43,48$\pm$ 8,09	80,28$\pm$19,98
4	20,17$\pm$ 6,74	41,58$\pm$ 8,84	89,82$\pm$18,52
5	24,44$\pm$ 8,39	42,93$\pm$ 6,51	81,12$\pm$22,79
6	-	41,18$\pm$11,62	80,32$\pm$20,83
Analysis of Variance			
Variance ratio (F value)	1,26	0,57	2,16
Degrees of freedom (n-1)	99	95	107
Significance level %	NS (P = 0,05)	NS (P = 0,05)	NS (P = 0,05)

NS = not significant

Table 3.12 Experiment 7, treatment 6. Specific growth rates (g fresh mass g^{-1} d^{-1}) determined for **E. crassipes** between each weighing interval after the addition of P at a concentration of 1,04 x 10^3 ug P l^{-1}.

Plant	Number of days after the addition of P					
No	3	7	10	14	17	21
1	0,0116	0,0296	0,0531*	0,0508	0,0150	0,0388
2	0,0049	0,0317	0,0451	0,0555*	0,0529	0,0393
3	0,0010	0,0372	0,0420	0,0473*	0,0125	0,0325
4	0,0071	0,0153	0,0679*	0,0404	0,0356	0,0269
5	0,0184	0,0178	0,0209	0,0257*	0,0233	0,0078
6	0,0057	0,0020	0,0533*	0,0529	0,0010	0,0219
7	0,0010	0,0308	0,0415	0,0570*	0,0207	0,0407
8	0,0162	0,0127	0,0423*	0,0395	0,0282	0,0359
9	0,0291	0,0357	0,0544	0,0605*	0,0575	0,0556
10	0,0010	0,0280	0,0495*	0,0490	0,0213	0,0327
11	0,0010	0,0305	0,0401	0,0540*	0,0241	0,0312
12	0,0049	0,0355	0,0343	0,0454*	0,0209	0,0334
13	0,0088	0,0147	0,0579	0,0632*	0,0545	0,0369
14	0,0161	0,0283	0,0262	0,0331*	0,0187	0,0281
15	0,0056	0,0166	0,0526*	0,0386	0,0285	0,0295
16	0,0145	0,0127	0,0299	0,0484*	0,0436	0,0377

* Highest specific growth rate (maximum growth rate) attained by each plant after the addition of P.

Table 3.13 Statistical analysis of regressions of 1/U against 1/P for **E. crassipes** grown under P growth rate limitation in culture.

Experi= ment No	Correlation coefficient (r)	Degrees of freedom (n-1)	Significance level %	Analysis of Variance: Variance ratio (F value)	Analysis of Variance: Significance level %
6	0,3463	79	1	4,57	5
7	0,3799	79	0,1	9,73	1
8	0,4769	89	0,1	13,51	0,1

Table 3.14 Maximum specific growth rates (Umax) and half saturation coefficients (Ksp) determined for **E. crassipes** under P growth rate limitation in culture.

Experi= ment No	Growth in P defi= cient culture (days)	Umax: g fresh mass g^{-1} d^{-1}	Umax: 95% confidence limits	Ksp ug P l^{-1}	Air and water temperature °C: Max	Mean	Min	Relative humidity %: Max	Mean	Min
6	17	0,1089	± 0,0045	79,5	31	28	25	70	61	52
7	39	0,0453	± 0,0016	41,1	30	27	25	72	62	53
8	38	0,0451	± 0,0030	161,8	30	26	22	73	64	55

Table 3.15 Quantities of P analyzed in 3 culture solution samples taken at random from each treatment in 3 experiments after fresh mass recordings had been terminated. A. Quantity of P (ug P $5l^{-1}$) remaining in culture solution. B. Quantity of P remaining in culture solution as % of that initially added. ND = not determinable, P content < 5ug P $5l^{-1}$.

Treatment No	Experiment No					
	6		7		8	
	A	B	A	B	A	B
P added ug P $5l^{-1}$	0		0		0	
	ND	-	ND	-	ND	-
1	ND	-	ND	-	ND	-
	ND	-	ND	-	ND	-
P added ug P $5l^{-1}$	1 300		650		1 300	
	ND	-	ND	-	ND	-
2	ND	-	ND	-	ND	-
	ND	-	ND	-	ND	-
P added ug P $5l^{-1}$	2 610		1 630		3 260	
	ND	-	ND	-	ND	-
3	ND	-	ND	-	ND	-
	ND	-	ND	-	ND	-
P added ug P $5l^{-1}$	3 910		2 610		5 220	
	ND	-	ND	-	5	0,09
4	ND	-	ND	-	ND	-
	ND	-	ND	-	ND	-
P added ug P $5l^{-1}$	5 220		3 910		7 830	
	5	0,09	ND	-	5	0,06
5	ND	-	ND	-	ND	-
	ND	-	ND	-	5	0,06
P added ug P $5l^{-1}$			5 220		10 440	
			ND	-	5	0,05
6			5	0,09	10	0,09
			5	0,09	10	0,09

Table 3.16 Statistical analysis of regressions relating total fresh mass yields of **E. crassipes** to quantities of P supplied in culture.

Experi= ment No	Correlation coefficient (r)	Degrees of freedom (n-1)	Significance level %	Analysis of Variance: Variance ratio (F value)	Analysis of Variance: Significance level %
6	0,8259	49	0,1	49,34	0,1
7	0,8224	95	0,1	192,20	0,1
8	0,8458	107	0,1	196,25	0,1

Table 3.17 Yield coefficients, Ycp, (g of fresh mass yield of plant mate= rial per g of P absorbed by plants) determined for **E. crassipes** under P growth rate limitation in culture. Yield coefficients (dry mass basis) are estimated from the mean water contents of plants determined in each experiment.

Experi= ment No	Growth in P defi= cient culture (days)	Ycp (fresh mass basis)	Mean water content, plants: %	Mean water content, plants: Standard deviation	Ycp (dry mass basis)
6	17	18 670,6	94,75	± 0,87	980,2
7	39	16 431,2	94,72	± 0,96	867,6
8	38	16 642,2	94,79	± 0,92	867,1

Analysis of Variance

Variance ratio (F value)	2,72
Degrees of freedom (n-1)	303
Significance level %	NS (P = 0,05)

NS = not significant

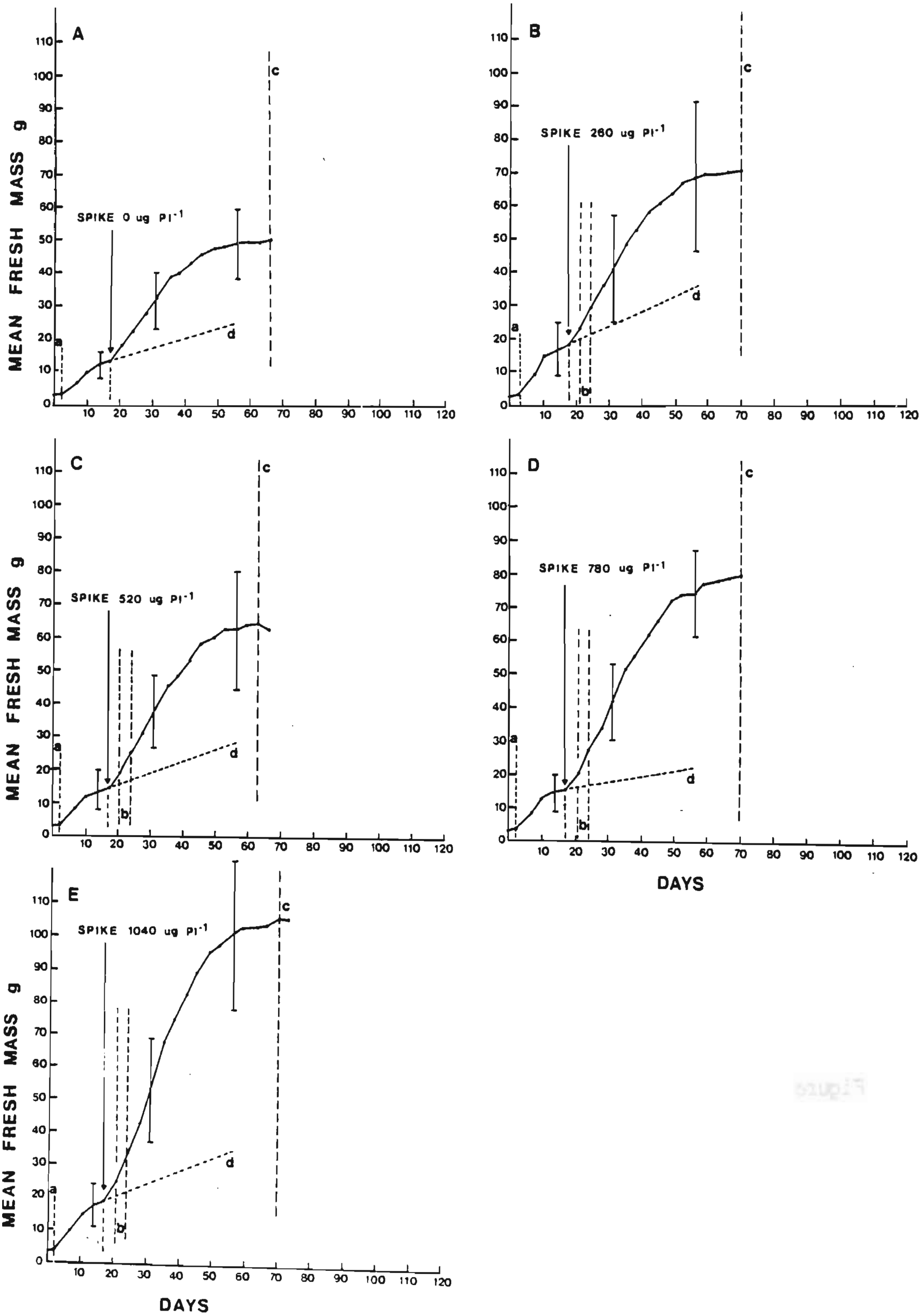
Table 3.18 Minimum P concentrations, % dry mass, (means of 3 batches) ana= lyzed in E. **crassipes** harvested from culture.

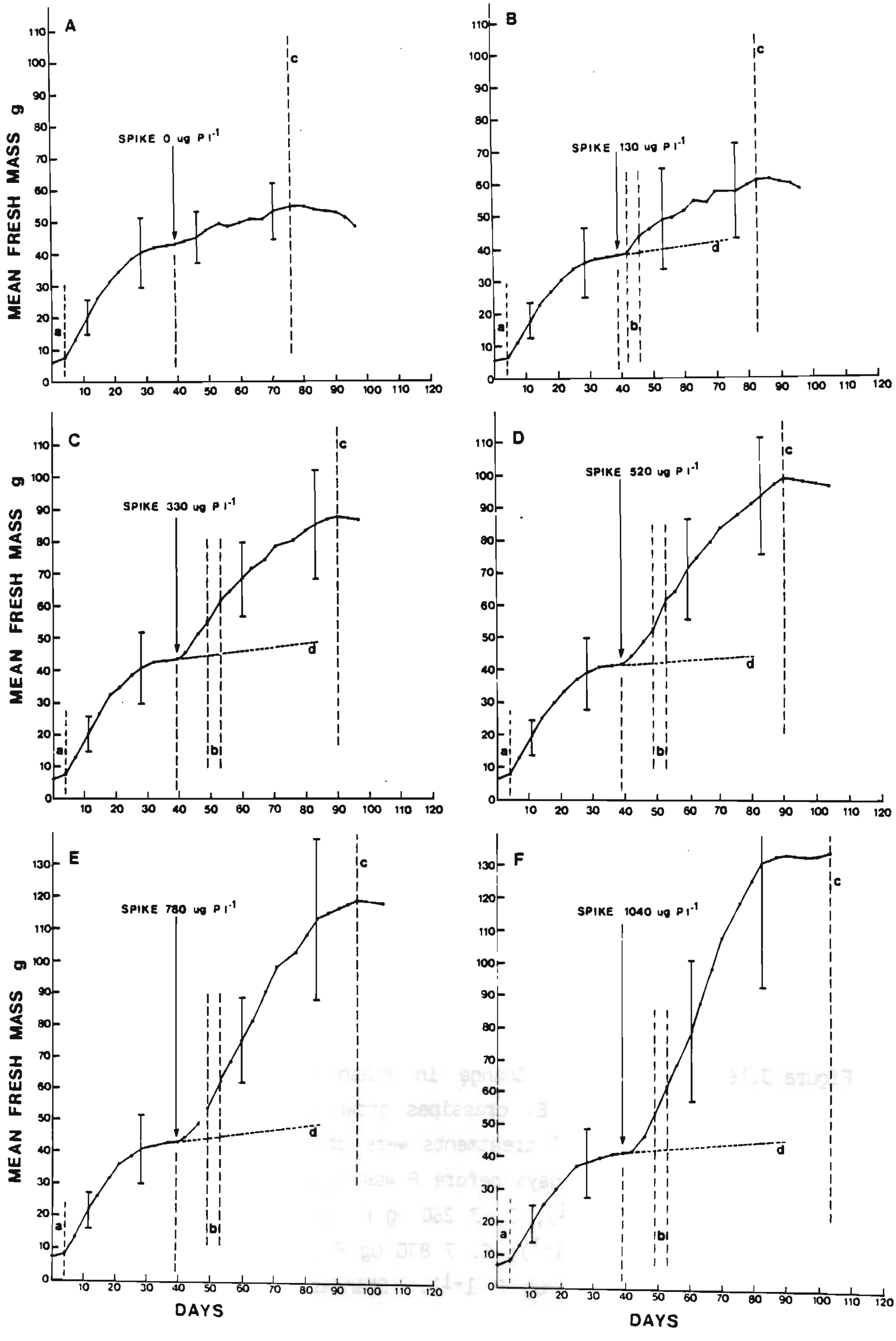
Treatment No	Experiment No		
	6	7	8
1	0,10	0,09	0,10
2	0,11	0,10	0,11
3	0,10	0,11	0,12
4	0,12	0,12	0,12
5	0,13	0,12	0,14
6		0,13	0,12
Means	0,11	0,11	0,12

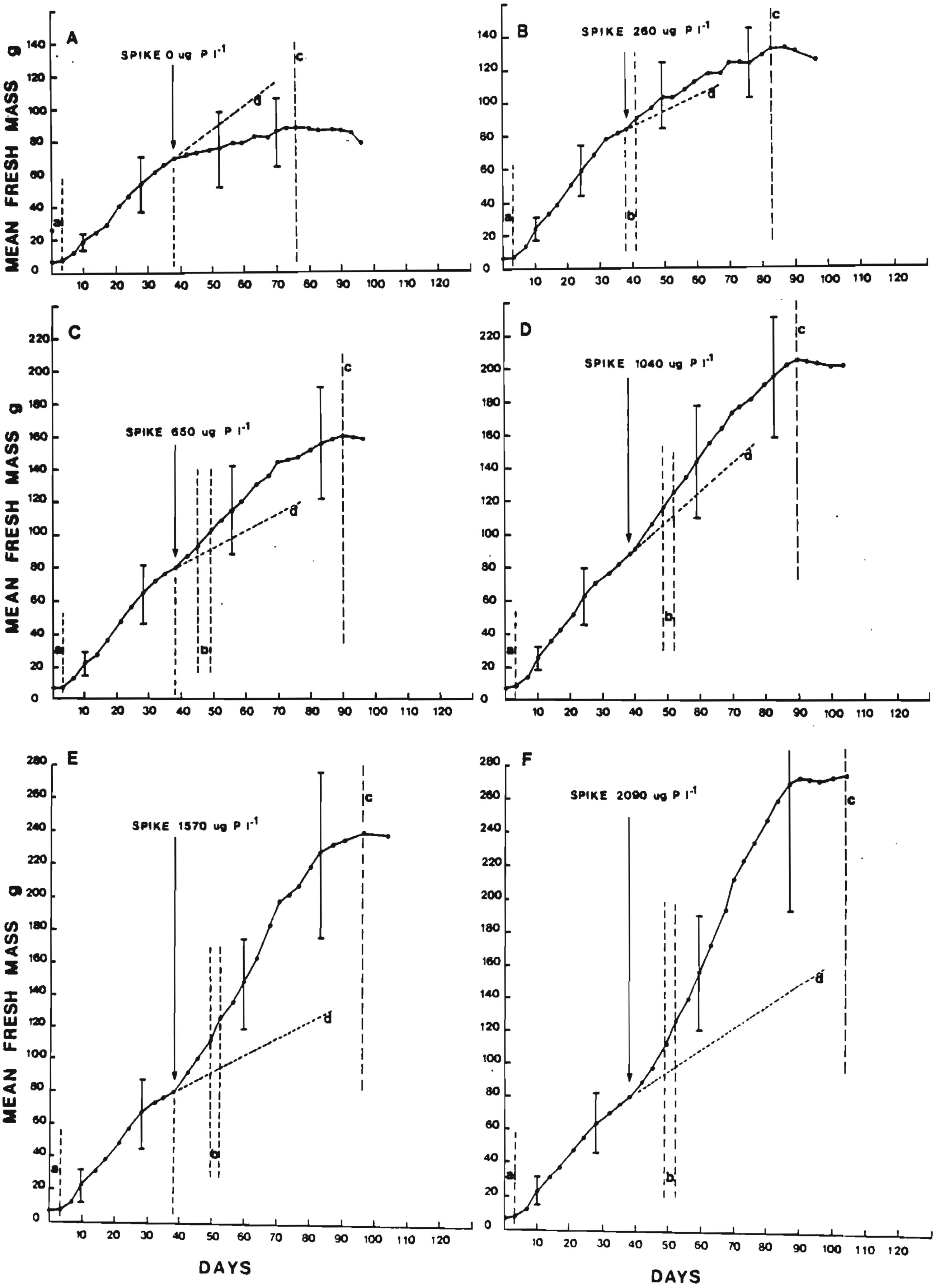
Analysis of Variance

Variance ratio (F value)	0,73
Degrees of freedom (n-1)	50
Significance level %	NS (P = 0,05)

NS = not significant


A
SPIKE 0 ug Pl^{-1}
B
SPIKE 260 ug Pl^{-1}
C
SPIKE 520 ug Pl^{-1}
D
SPIKE 780 ug Pl^{-1}
E
SPIKE 1040 ug Pl^{-1}
a
b
c
d
MEAN FRESH MASS g
DAYS


A
SPIKE 0 ug P l-1
B
SPIKE 130 ug P l-1
C
SPIKE 330 ug P l-1
D
SPIKE 520 ug P l-1
E
SPIKE 780 ug P l-1
F
SPIKE 1040 ug P l-1
MEAN FRESH MASS g
DAYS
a
b
c
d


A
SPIKE 0 ug P l-1
B
SPIKE 260 ug P l-1
C
SPIKE 650 ug P l-1
D
SPIKE 1040 ug P l-1
E
SPIKE 1570 ug P l-1
F
SPIKE 2090 ug P l-1
MEAN FRESH MASS g
DAYS
a
b
c
d

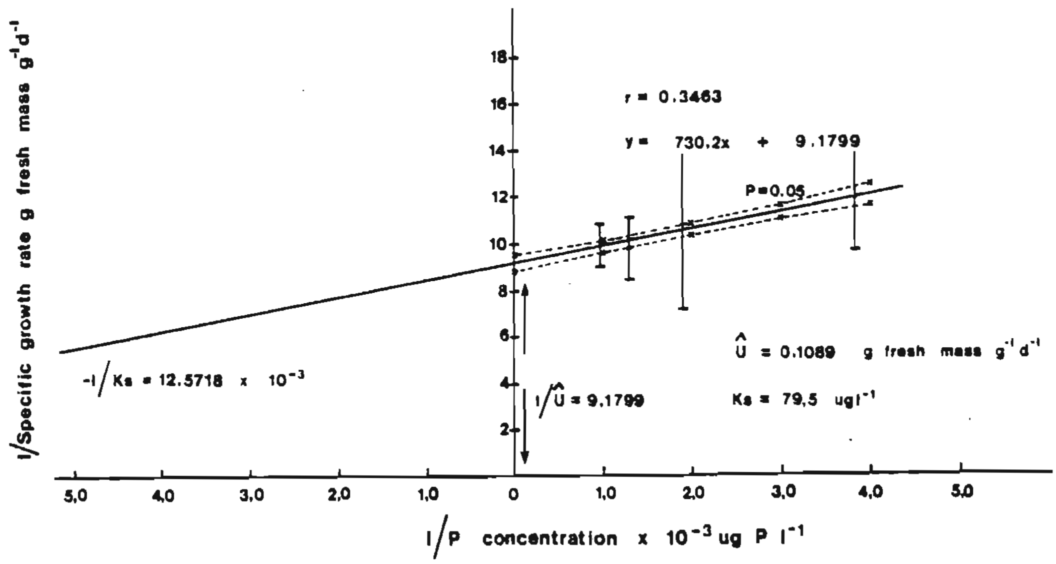


Figure 3.17 Experiment 6. A Lineweaver-Burk plot of the specific growth rates of **E. crassipes** (means of 20 plants/treatment) against the levels of P supplied in culture. Broken lines show 95% confidence limits on either side of the regression line. Standard deviations of means are shown by bars. $\hat{U}$ = Umax.

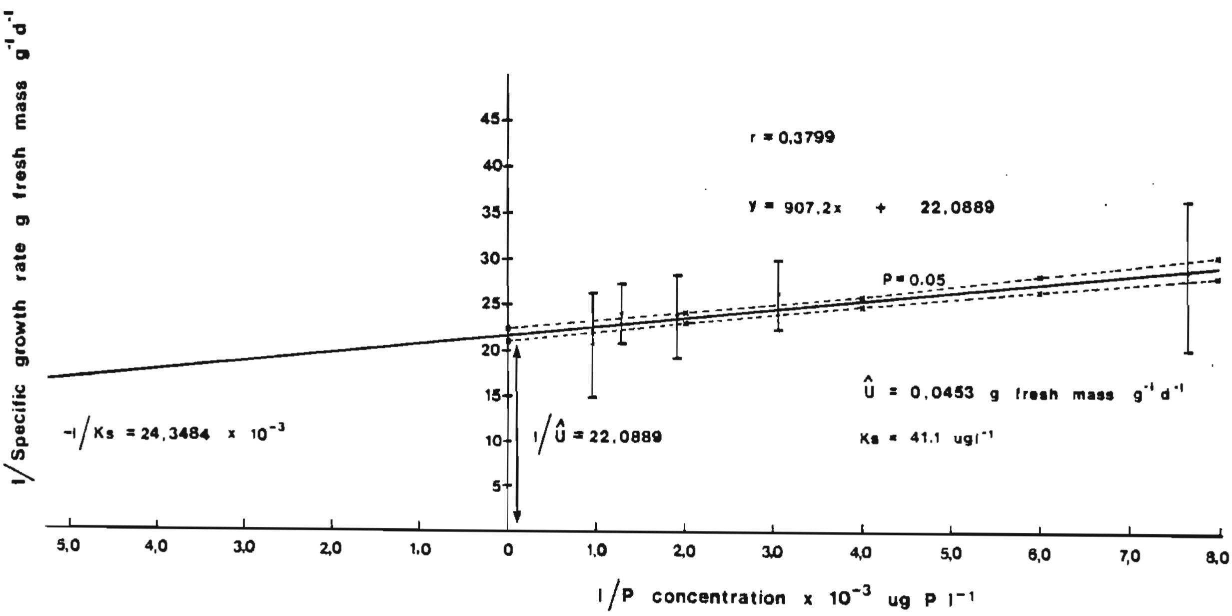


Figure 3.18 Experiment 7. A Lineweaver-Burk plot of the specific growth rates of **E. crassipes** (means of 16 plants/treatment) against the levels of P supplied in culture. Broken lines show 95% confidence limits on either side of the regression line. Standard deviations of means are shown by bars. $\hat{U}$ = Umax.

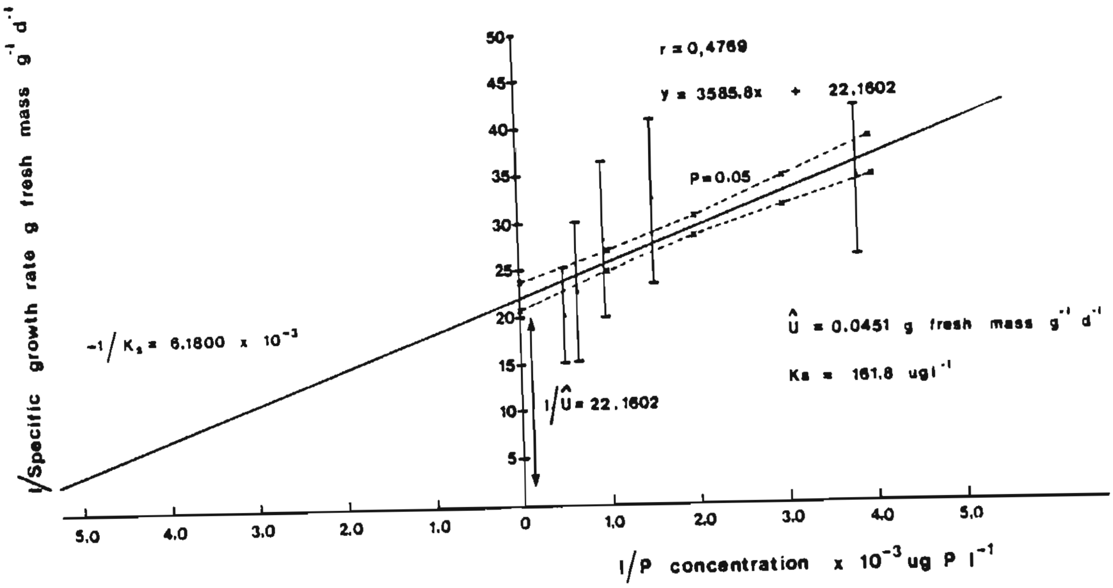


Figure 3.19 Experiment 8. A Lineweaver-Burk plot of the specific growth rates of **E. crassipes** (means of 18 plants/treatment) against the levels of P supplied in culture. Broken lines show 95% confidence limits on either side of the regression line. Standard deviations of means are shown by bars. $\hat{U}$ = Umax.

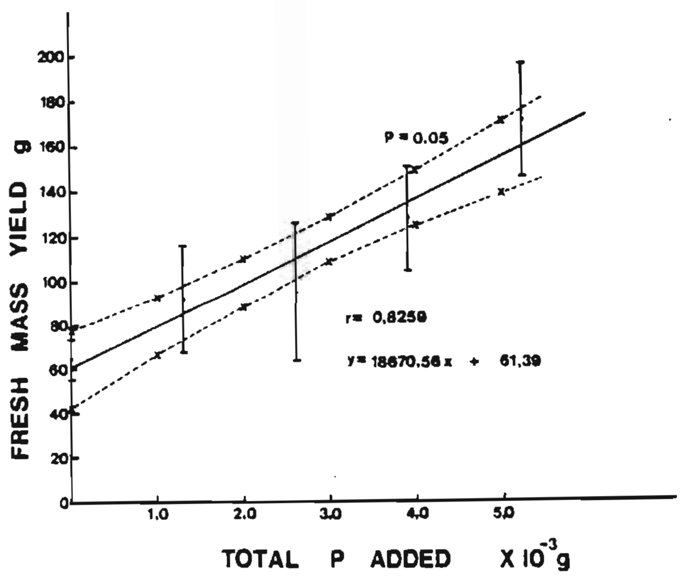


Figure 3.20 Experiment 6. The relationship between the total fresh mass yields of **E. crassipes** (means of 20 plants/treatment) and the quantities of P supplied in culture. Broken lines show 95% confidence limits on either side of the regression line. Standard deviations of means are shown by bars.

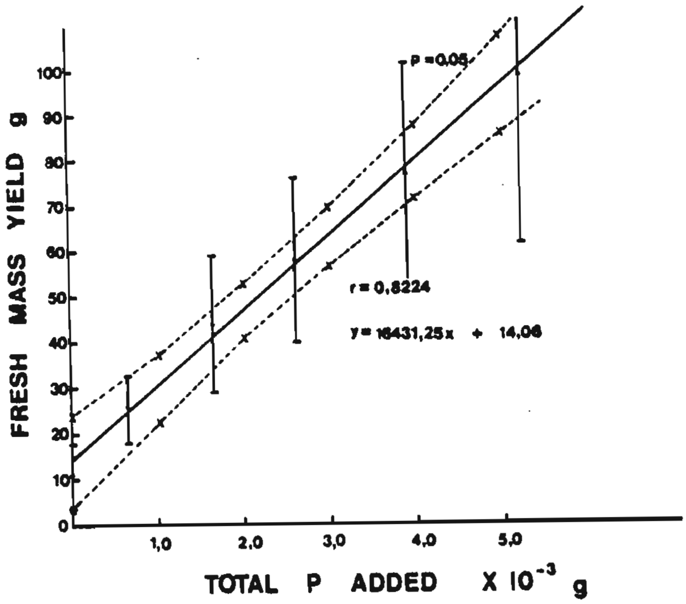


Figure 3.21 Experiment 7. The relationship between the total fresh mass yields of E. **crassipes** (means of 16 plants/treatment) and the quantities of P supplied in culture. Broken lines show 95% confidence limits on either side of the regression line. Standard deviations of means are shown by bars.

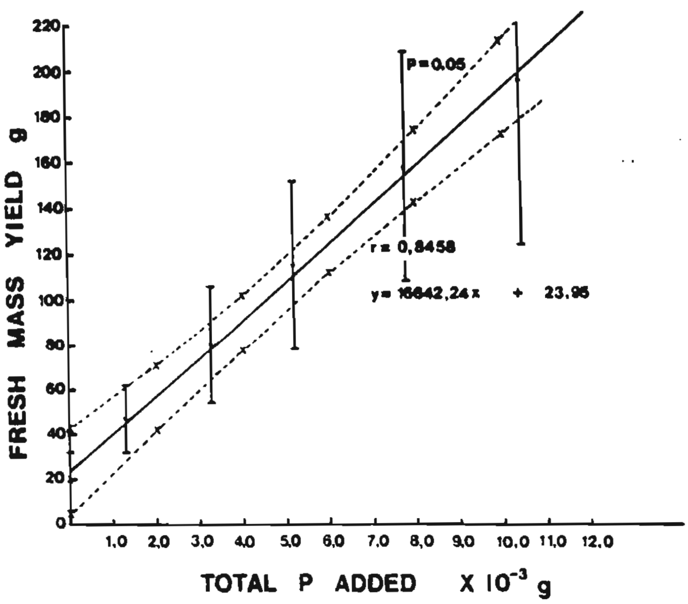


Figure 3.22 Experiment 8. The relationship between the total fresh mass yields of E. **crassipes** (means of 18 plants/treatment) and the quantities of P supplied in culture. Broken lines show 95% confidence limits on either side of the regression line. Standard deviations of means are shown by bars.

Table 3.19 The error with which the specific growth rate (U) of **E. crassipes** would be predicted as estimated from the highest and lowest maximum specific growth rates (Umax) determined for this plant under N and P growth rate limitation respectively in culture. The differences between the predicted specific growth rates estimate the error.

Growth rate limit= ing nutrient	Umax (measured) * % d^{-1}	$S/(Ks + S)$	U (predicted) * % d^{-1}	Difference * % d^{-1}
N	8,86	0,95	8,42	2,60
N	6,13	0,95	5,82	
N	8,86	0,50	4,43	1,37
N	6,13	0,50	3,06	
N	8,86	0,20	1,77	0,54
N	6,13	0,20	1,23	
P	10,89	0,95	10,34	6,06
P	4,51	0,95	4,28	
P	10,89	0,50	5,44	3,19
P	4,51	0,50	2,25	
P	10,89	0,20	2,18	1,28
P	4,51	0,20	0,90	

* % d^{-1} = g fresh mass g^{-1} d^{-1} X 100

Table 3.20 The error with which the specific growth rate (U) of **E. crassipes** would be predicted as estimated from the highest and lowest half saturation coefficients (Ks) determined for this plant under N and P growth rate limitation respectively in culture. Estimates are based on the highest maximum specific growth rates (Umax) determined in culture. The differences between the predicted specific growth rates estimate the error.

Growth rate limiting nutrient	Concentration in water ug l^{-1}	Ks ug l^{-1}	Umax (measured) * % d^{-1}	U (predicted) * % d^{-1}	Difference * % d^{-1}
N	20 000	399,8	8,86	8,69	0,45
N	20 000	1 505,6	8,86	8,24	
N	200	399,8	8,86	2,95	1,91
N	200	1 505,6	8,86	1,04	
P	2 000	41,1	10,89	10,67	0,60
P	2 000	161,8	10,89	10,07	
P	20	41,1	10,89	3,56	2,36
P	20	161,8	10,89	1,20	

* % d^{-1} = g fresh mass g^{-1} d^{-1} X 100

Table 3.21 Half saturation coefficients (Ksn) reported for various species of algae compared with those determined for **E. crassipes.**

Organism	Growth rate limiting nutrient	Ksn ug N l^{-1}	Reference
Chlorella pyrenoidosa*	N	1 400 - 3 000	Shelef **et al.** (1968)
Chlorella pyrenoidosa**	N	700 - 14 000	Shelef **et al.** (1968)
Mixed algae	N	450	Shelef **et al.** (1968)
Selenastrum gracile	N	150	Middlebrooks **et al.** (1971)
Eichhornia crassipes	N	399,8 - 1 505,6 (mean : 976)	This study

* High temperature strain

** Emersion strain

Table 3.22 Half saturation coefficients (Ksp) reported for various species of algae compared with those determined for **E. crassipes.**

Organism	Growth rate limiting nutrient	Ksp ug P l^{-1}	Reference
Chlorella pyrenoidosa*	P	55	Zabat **et al.** (1970)
Chlorella pyrenoidosa**	P	21 - 29	Zabat **et al.** (1970)
Selenastrum gracile	P	10	Middlebrooks **et al.** (1971)
Selenastrum capricornutum	P	3,7 - 5,7	Toerien **et al.** (1971)
Eichhornia crassipes	P	41,1 - 161,8 (mean : 94,1)	This study

* High temperature strain

** Emersion strain

Table 3.23 Yield coefficients, Ycp, (g of dry mass yield of plant material per g of P absorbed by plants) reported for various species diatoms and other algae compared with those determined for **E. crassipes.**

Organism	Growth rate limiting nutrient	Ycp (dry mass basis)	Reference
Selenastrum capricornutum	P	805	Toerien **et al.** (1971)
Microcystis aeruginosa	P	833 - 909	Gerloff and Skoog (1954)
Chlorella pyrenoidosa	P	312 - 374	Zabat **et al.** (1970)
Nitzchia elliptica	P	845	Coetzer **et al.** (1977)
Nitzchia perpusilla	P	455	Coetzer **et al.** (1977)
Nitzchia pelliculosa	P	177	Coetzer **et al.** (1977)
Nitzchia palea	P	171	Coetzer **et al.** (1977)
Eichhornia crassipes	P	867,1 - 980,2 (mean : 904,9)	This study

Table 3.24 Yield coefficients, Ycn, (g of dry mass yield of plant material per g of N absorbed by plants) reported for various species diatoms and other algae compared with those determined for **E. crassipes.**

Organism	Growth rate limiting nutrient	Ycn (dry mass basis)	Reference
Selenastrum capricornutum	N	35,0	Steyn (1973)
Microcystis aeruginosa	N	31,7	Gerloff and Skoog (1954)
Chlorella pyrenoidosa	N	20,0	Shelef **et al.** (1968)
Chlorella sorokiniana	N	17,9	Richardson **et al.** (1969)
Nitzchia perpusilla	N	23,6	Coetzer **et al.** (1977)
Nitzchia elliptica	N	20,0	Coetzer **et al.** (1977)
Nitzchia pelliculosa	N	15,6	Coetzer **et al.** (1977)
Nitzchia palea	N	15,0	Coetzer **et al.** (1977)
Eichhornia crassipes	N	86,9 - 98,1 (mean : 90,9)	This study

Table 3.25 Minimum N concentrations in **E. crassipes** estimated from the yield coefficients (Ycn), determined under N growth rate limi= tation in culture, compared with the minimum N concentrations analyzed in plants harvested from culture.

Experiment No	Ycn (dry mass) basis)	Minimum N concentration (1/Ycn x 100) % dry mass	Minimum N concentrations in plants harvested from culture (means of 6 treatments) % dry mass
1	98,1	1,02	1,09
2	86,9	1,15	1,11
3	87,6	1,14	1,06
Mean	90,9	1,10	1,09

Table 3.26 Minimum P concentrations in **E. crassipes** estimated from the yield coefficients (Ycp), determined under P growth rate limi= tation in culture, compared with the minimum P concentrations analyzed in plants harvested from culture.

Experiment No	Ycp (dry mass) basis)	Minimum P concentration (1/Ycp x 100) % dry mass	Minimum P concentrations in plants harvested from culture (means of 6 treatments) % dry mass
6	980,2	0,10	0,11
7	867,6	0,11	0,11
8	867,1	0,11	0,12
Mean	904,9	0,11	0,11

CHAPTER 4

TESTING THE MODEL UNDER FIELD CONDITIONS

Table 4.1 A statistical comparison of specific growth rates measured for marginal plants at the Botanic Gardens Lake (BGL) and Matura= tion Pond 3 (MP3) sites during 1978.

Growing interval Dates	Specific growth rate g fresh mass g^{-1} d^{-1} BGL	MP3	F value for 79 degrees of freedom	Significance level %
1978				
1/2 - 16/2	0,1158	0,1498	68,03	0,1
17/2 - 1/3	0,1227	0,1698	106,74	0,1
2/3 - 14/3	0,0996	0,1534	102,52	0,1
16/3 - 29/3	0,0675	0,1481	89,22	0,1
31/3 - 12/4	0,0689	0,1146	62,31	0,1
14/4 - 26/4	0,0601	0,0936	16,01	0,1
28/4 - 9/5	0,0645	-	-	-
12/5 - 24/5	0,0478	0,1084	109,35	0,1
26/5 - 7/6	0,0493	0,0987	262,13	0,1
9/6 - 21/6	0,0305	0,0693	98,67	0,1
23/6 - 5/7	0,0313	0,0526	37,39	0,1
7/7 - 19/7	0,0527	0,0859	114,19	0,1
20/7 - 2/8	0,0443	0,1041	184,19	0,1
4/8 - 16/8	0,0635	0,1082	238,13	0,1
18/8 - 30/8	0,0651	0,0981	100,61	0,1
1/9 - 13/9	0,0615	0,1036	125,02	0,1
15/9 - 27/9	0,0867	0,1179	45,09	0,1
29/9 - 12/10	0,0843	0,1239	89,46	0,1
13/10 - 24/10	0,1162	0,1358	12,62	0,1
25/10 - 8/11	0,1064	0,1223	9,89	1,0
10/11 - 22/11	0,0963	0,1147	7,62	1,0
24/11 - 6/12	0,1207	0,1292	1,60	NS (P=0,05)

NS = not significant

Table 4.2 A statistical comparison of specific growth rates measured for marginal and central plants at the Discharge Canal (DC) and Maturation Pond 3 (MP3) sites during 1977 and 1978.

Growing interval Dates	Site	Specific growth rate g fresh mass g^{-1} d^{-1} Marginal	Central	F value for 69 degrees of freedom	Significance level %
1977					
3/11 - 16/11	DC	0,0965	0,0379	49,42	0,1
18/11 - 30/11	DC	0,1035	0,0526	46,06	0,1
1/12 - 14/12	DC	0,0940	0,0338	63,96	0,1
1977					
3/11 - 16/11	MP3	0,1668	0,0559	238,48	0,1
18/11 - 30/11	MP3	0,1544	0,0573	235,16	0,1
1/12 - 14/12	MP3	0,1214	0,0659	15,36	0,1
1978					
1/2 - 16/2	MP3	0,1498	0,0324	443,01	0,1
17/2 - 1/3	MP3	0,1698	0,0357	650,79	0,1
2/3 - 14/3	MP3	0,1534	0,0259	317,35	0,1
16/3 - 29/3	MP3	0,1481	0,0312	184,33	0,1
31/3 - 11/4	MP3	0,1146	0,0403	156,91	0,1
14/4 - 26/4	MP3	0,0936	0,0231	57,12	0,1
28/4 - 10/5	MP3	-	0,0202	-	-
12/5 - 24/5	MP3	0,1084	0,0203	224,85	0,1
26/5 - 7/6	MP3	0,0987	0,0242	366,64	0,1
15/9 - 27/9	MP3	0,1179	0,0248	421,91	0,1
29/9 - 12/10	MP3	0,1239	0,0262	508,72	0,1
13/10 - 24/10	MP3	0,1358	0,0299	611,03	0,1
25/10 - 8/11	MP3	0,1223	0,0268	292,59	0,1
10/11 - 22/11	MP3	0,1147	0,0255	195,76	0,1
24/11 - 6/12	MP3	0,1292	0,0271	123,84	0,1

Table 4.3 Correlation coefficients and Q_{10} values calculated from the regressions relating the specific growth rates (U) of marginal and central plants (Log_e) to the reciprocals of the Absolute mean daily air and water temperatures at the Maturation Pond 3 (MP3) and Botanic Gardens Lake (BGL) sites over the period February to December, 1978.

Site	Environmental factor	Correlation coefficient (r)	Degrees of freedom (n - 1)	Significance level %	Q_{10} 15°C - 25°C
MARGINAL PLANTS					
MP3	U vs. Air temp.	0,8089	20	0,1	2,14
MP3	Water temp.	0,8469	20	0,1	1,80
BGL	U vs. Air temp.	0,7442	21	0,1	2,95
BGL	Water temp.	0,8629	21	0,1	2,58
CENTRAL PLANTS					
MP3	U vs. Air temp.	0,6531	14	1	1,71
MP3	Water temp.	0,5479	14	5	1,42

Table 4.4 The percentage of the maximum specific growth rate (% Umax) that **E. crassipes** would achieve at the average total N and total P concentrations in the water at 6 field sites. Estima= tes are based on the mean Ks concentrations of 976 ug N l^{-1} and 94,1 ug P l^{-1} determined for this plant under N and P growth rate limitation respectively in culture.

Dates	Site	Water			% Umax	
		total N ug N l^{-1}	total P ug P l^{-1}	total N / total P	N	P
1977						
11/8 - 7/9	IL	2248	586	3,8	69,7*	86,2
8/9 - 26/10	IC	2071	315	6,6	67,9*	76,9
3/11 - 14/12	DC	5884	2483	2,4	85,8*	96,3
28/9 - 22/12	HD	3099	171	18,1	76,0	64,5*
1/9 - 14/12	MP3	17979	7921	2,3	94,8*	98,8
1978						
1/2 - 6/12	MP3	20746	6569	3,1	95,5*	98,6
1/2 - 6/12	BGL	10206	150	68,0	91,3	61,4*

* Growth rate limiting nutrient

IL = Isipingo Lake
IC = Isipingo Canal
DC = Discharge Canal
HD = Hartbeespoort Dam
MP3 = Maturation Pond 3
BGL = Botanic Gardens Lake

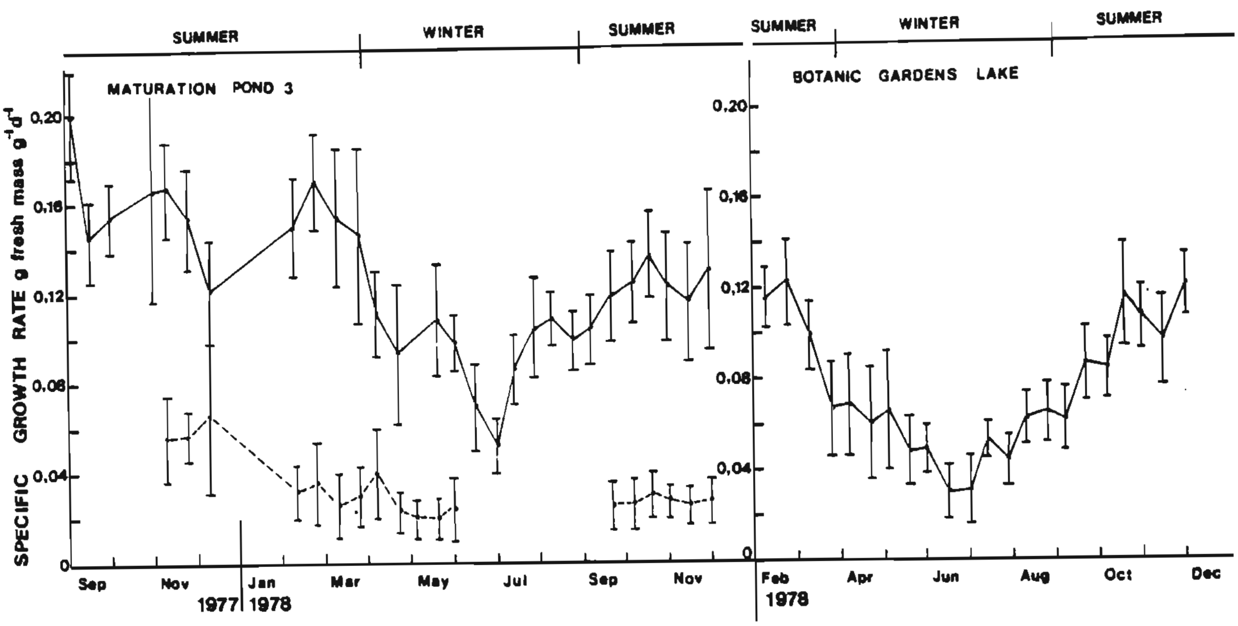


Figure 4.1 Average specific growth rates measured for **E. crassipes**, over each growing interval at 2 sites. Solid line = marginal plants growing in loosely crowded field populations (means of 40 replicates). Broken line = central plants growing in densely crowded field populations (means of 30 replicates). No plants of the central growth form were produced during June, July and August. Standard deviations of means are shown by bars.

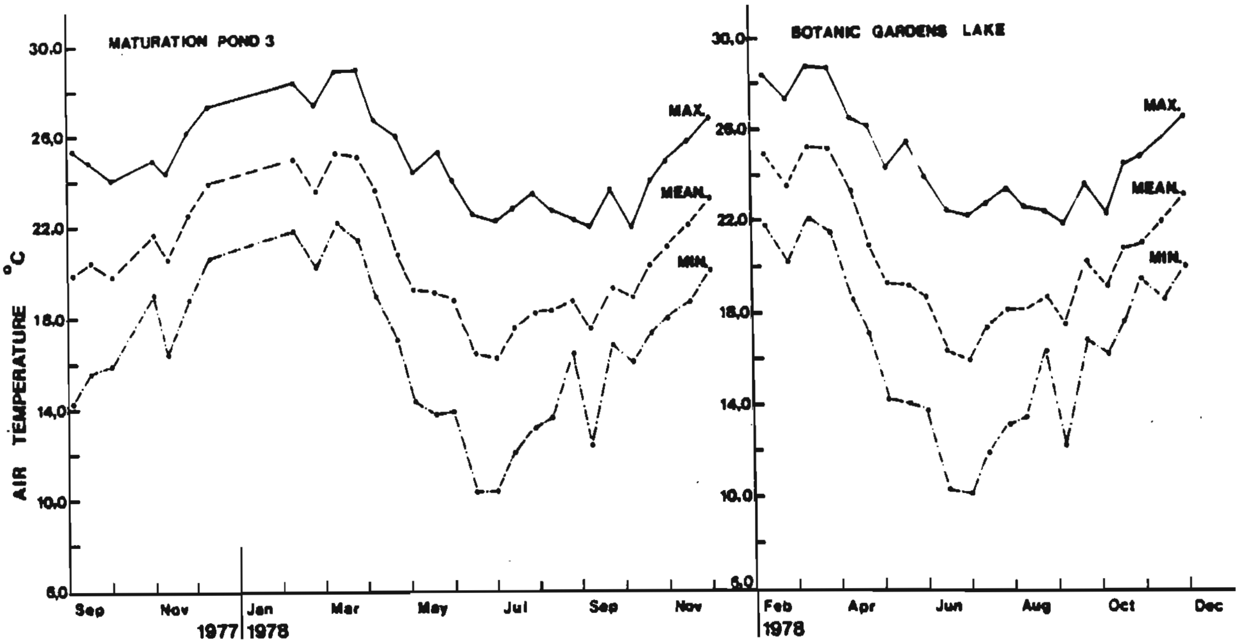


Figure 4.2 Average daily air temperatures recorded over each growing interval of marginal plants at 2 sites.

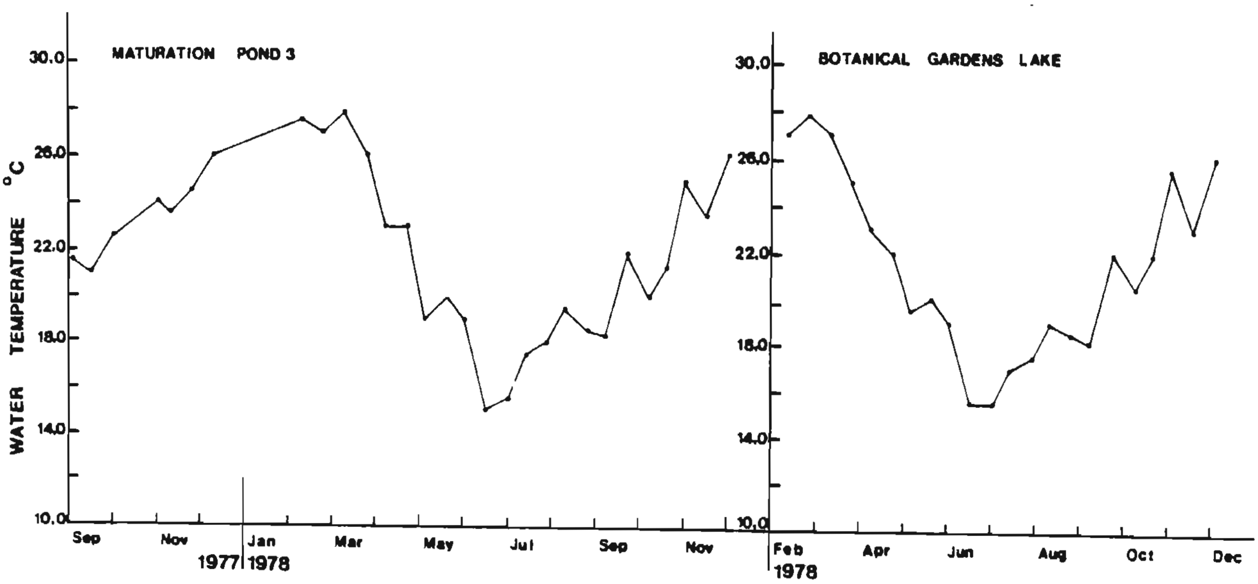


Figure 4.3 Average daily water temperatures recorded over each growing interval of marginal plants at 2 sites.

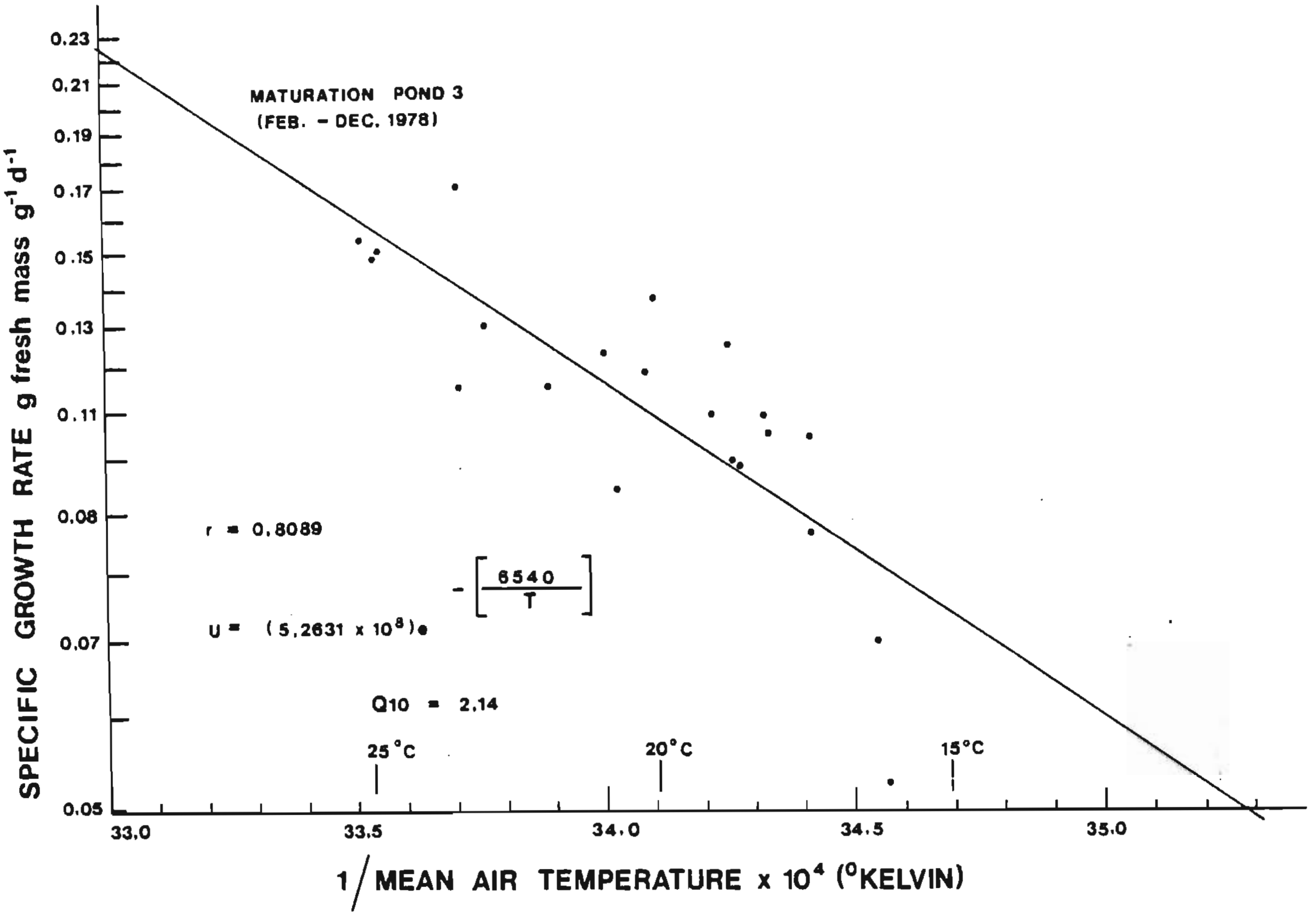


Figure 4.4 An Arrhenius plot of the specific growth rates (Log_e) of marginal plants against the reciprocals of the Absolute mean daily air temperatures at the Maturation Pond 3 site.

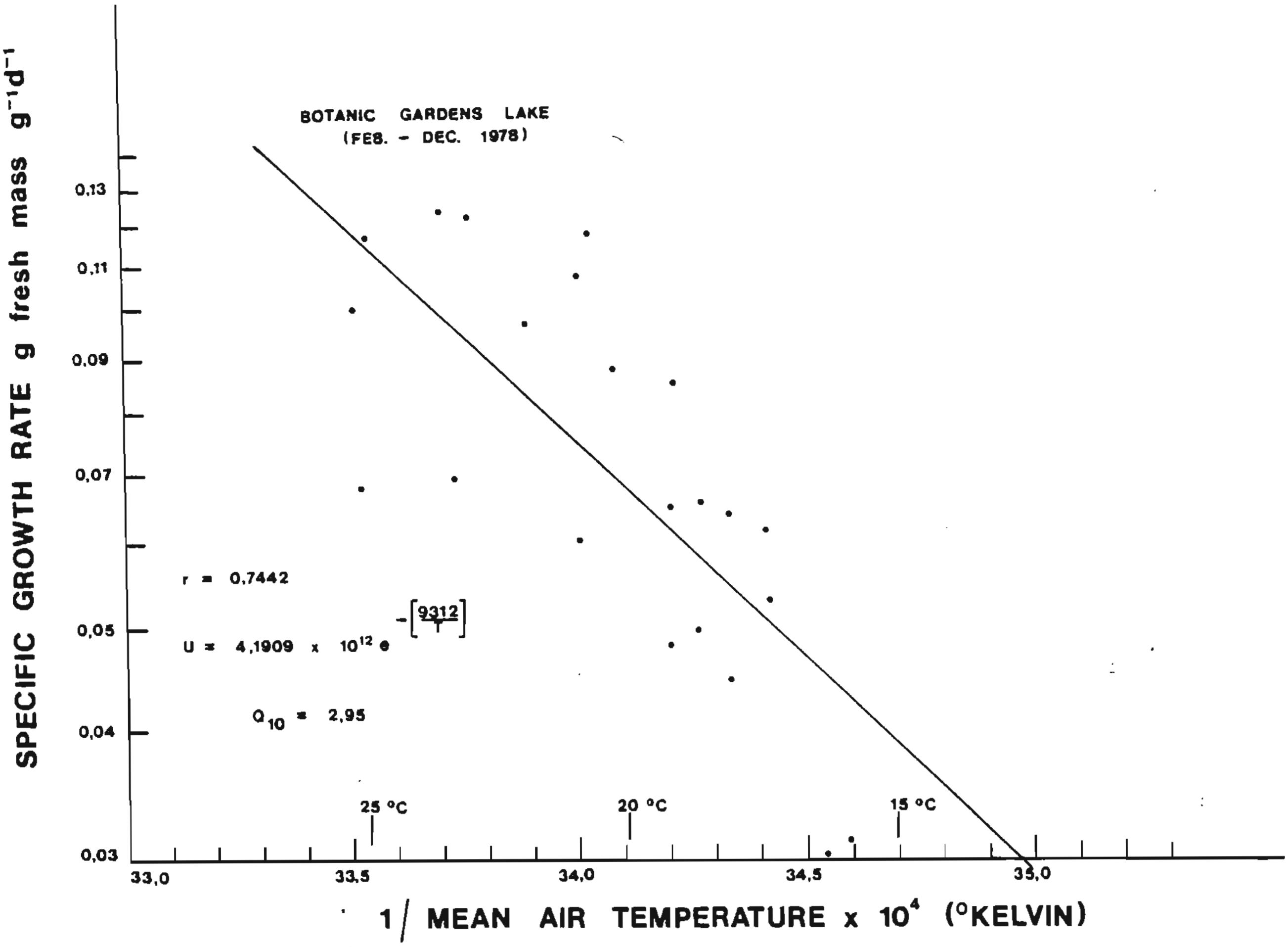


Figure 4.5 An Arrhenius plot of the specific growth rates (Log_e) of marginal plants against the reciprocals of the Absolute mean daily air temperatures at the Botanic Gardens Lake site.

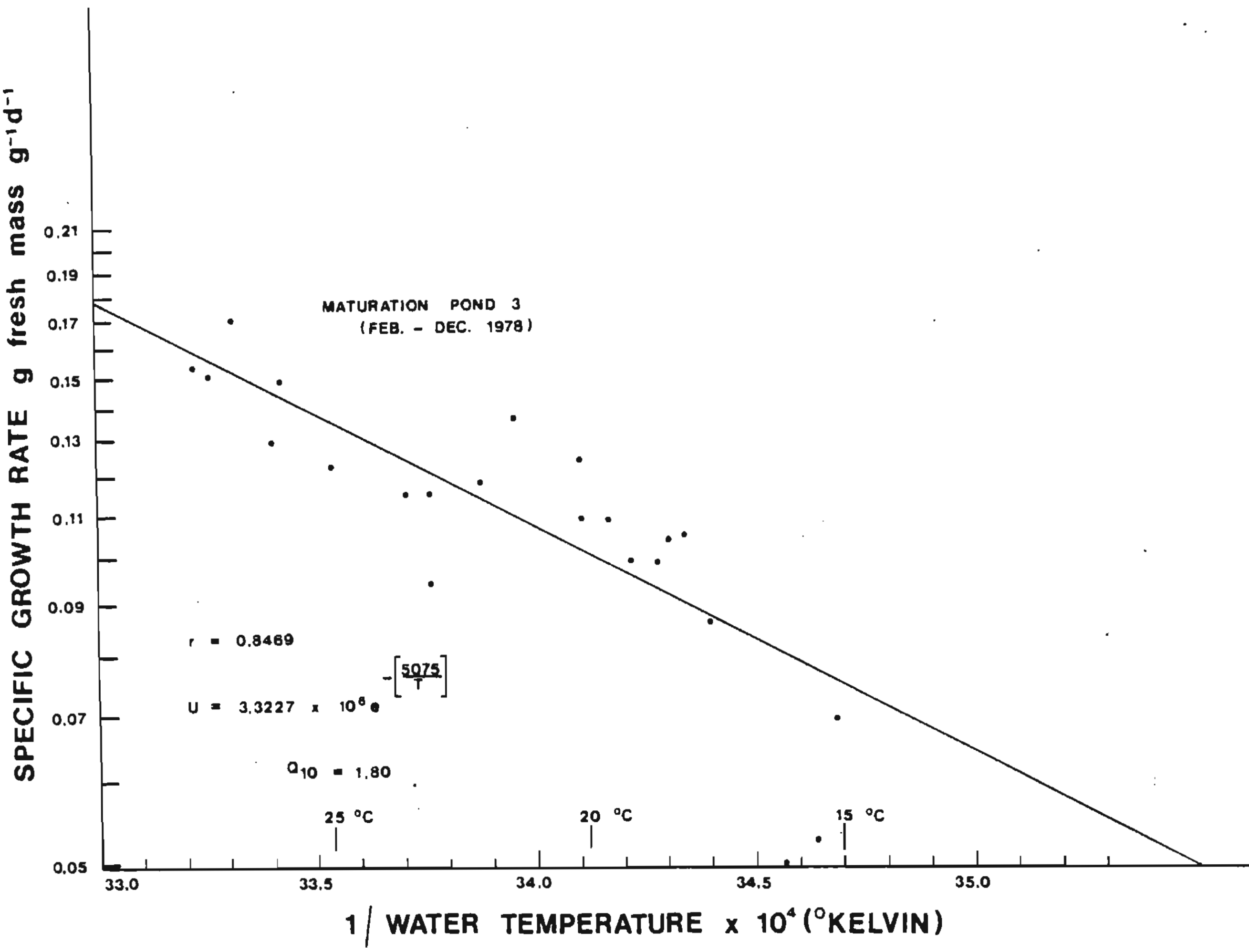


Figure 4.6 An Arrhenius plot of the specific growth rates (Log_e) of marginal plants against the reciprocals of the Absolute mean daily water temperatures at the Maturation Pond 3 site.

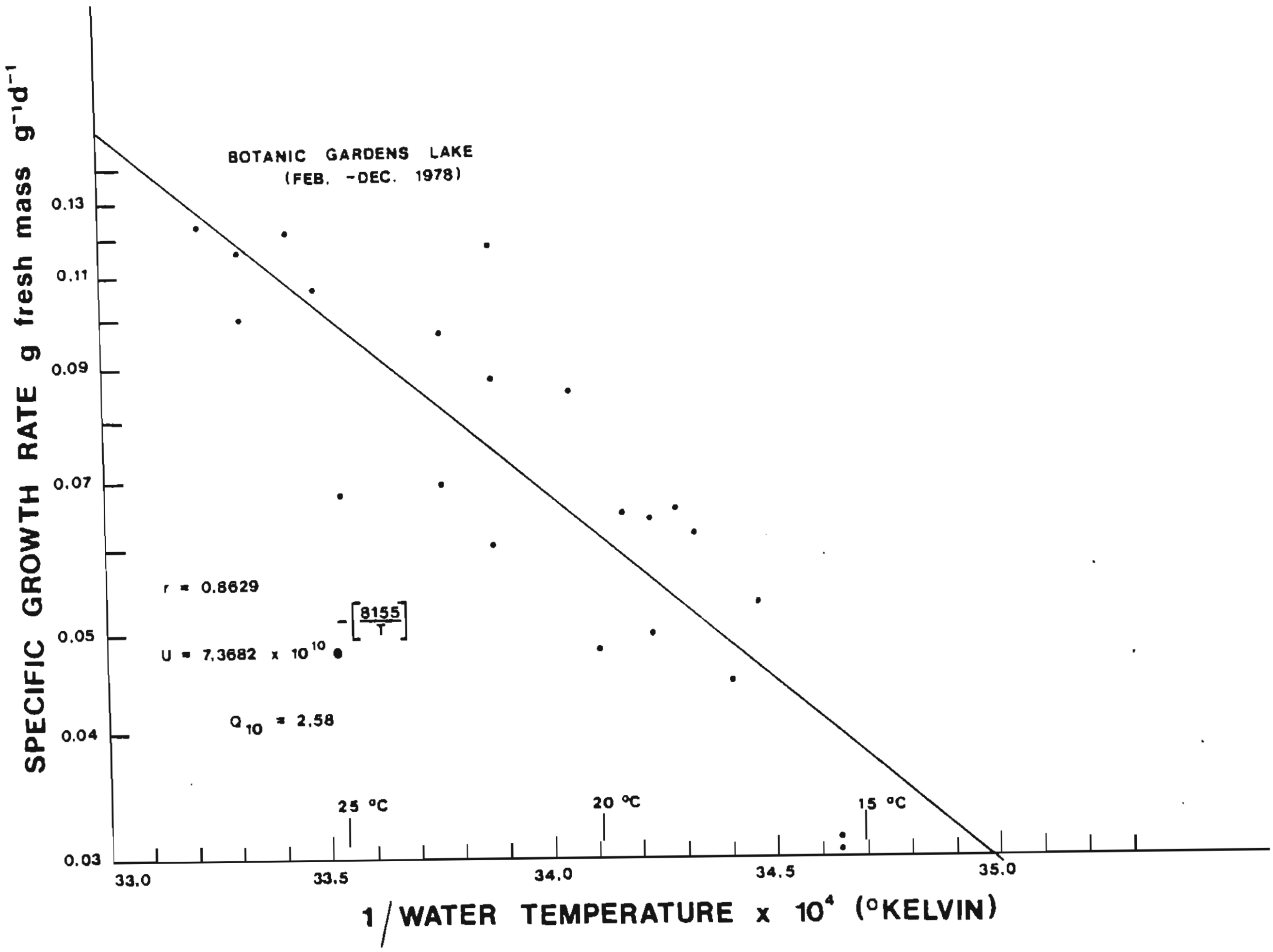


Figure 4.7 An Arrhenius plot of the specific growth rates (Log_e) of marginal plants against the reciprocals of the Absolute mean daily water temperatures at the Botanic Gardens Lake site.

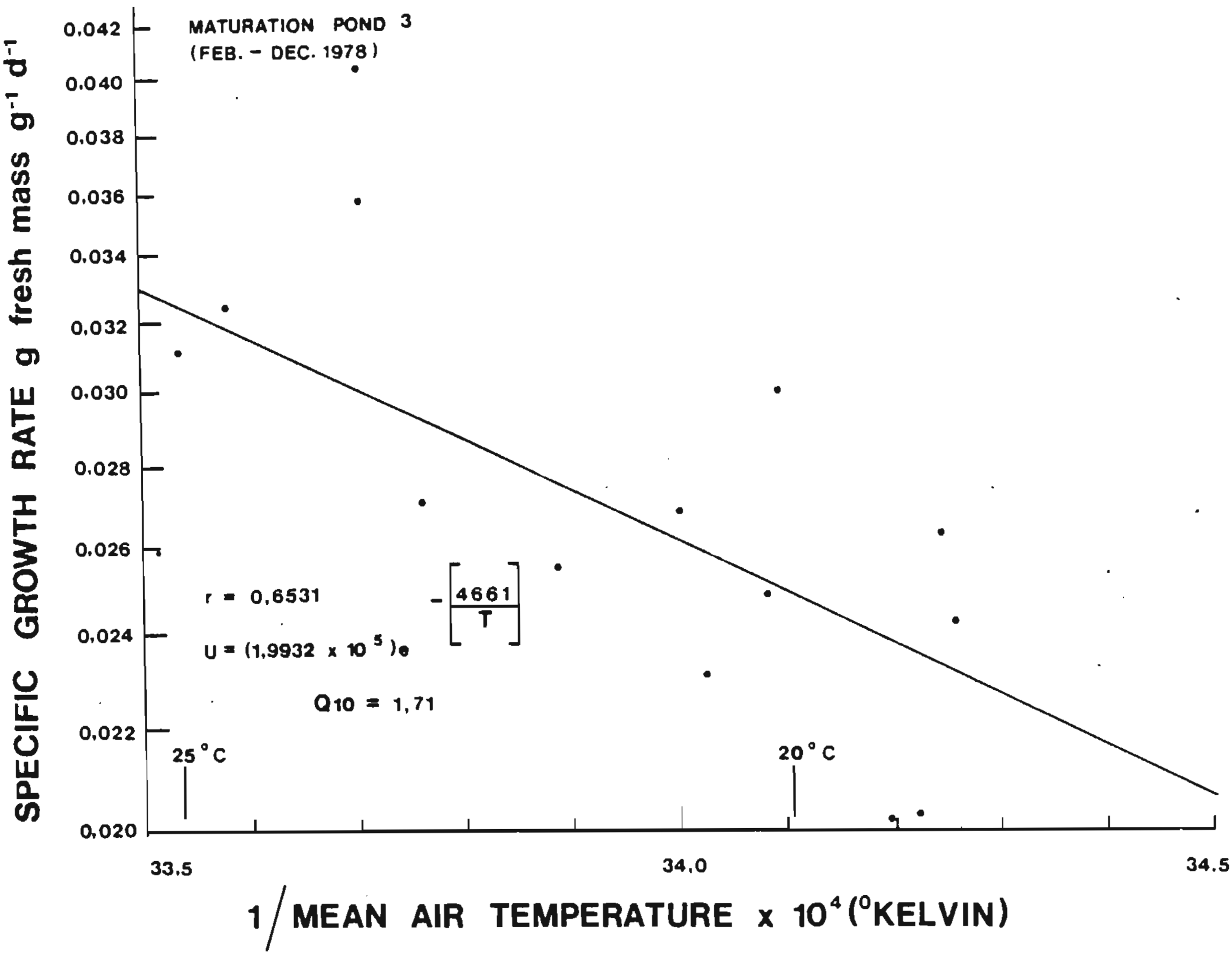


Figure 4.8 An Arrhenius plot of the specific growth rates (Log_e) of central plants against the reciprocals of the Absolute mean daily air temperatures at the Maturation Pond 3 site.

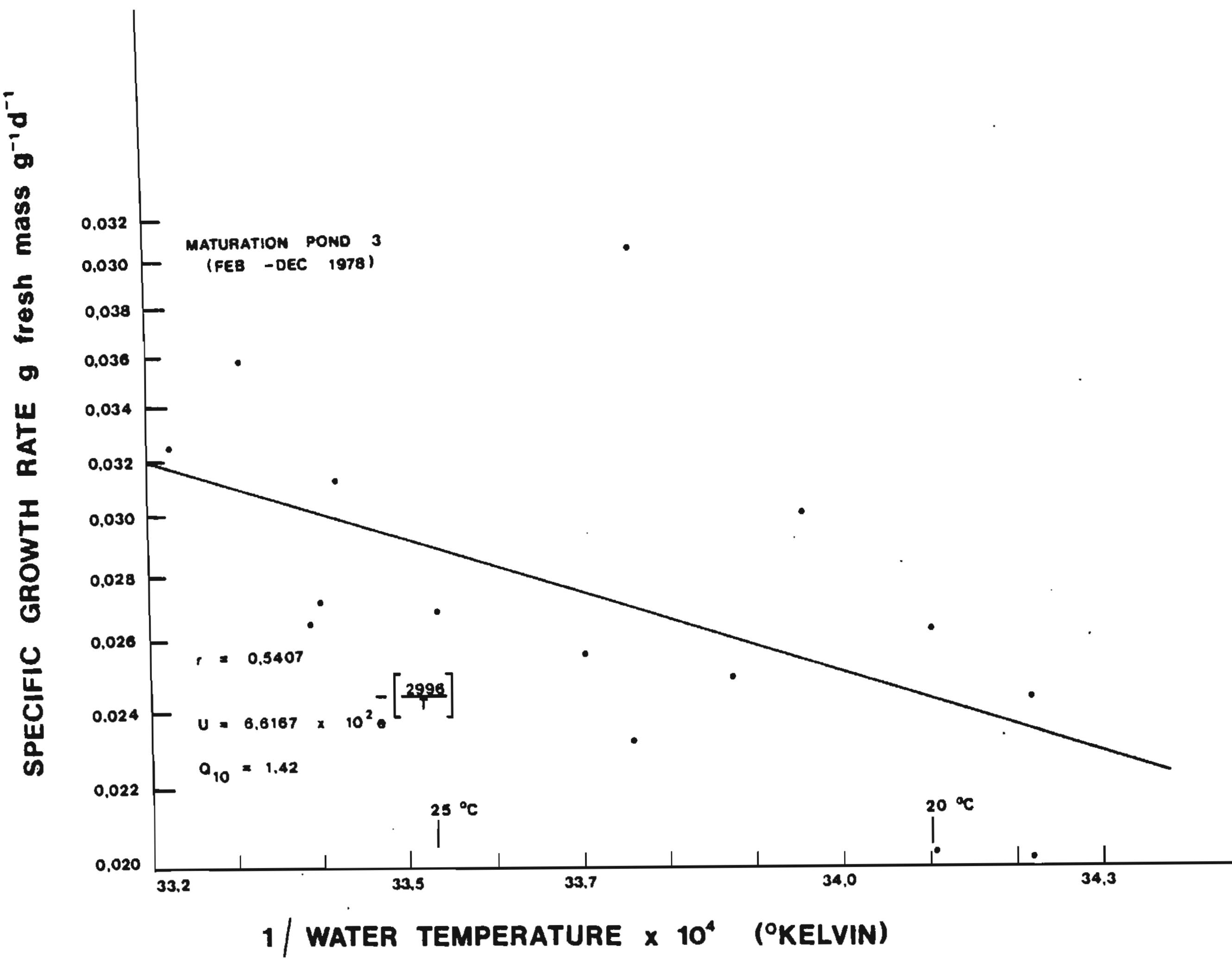


Figure 4.9 An Arrhenius plot of the specific growth rates (Log_e) of central plants against the reciprocals of the Absolute mean daily water temperatures at the Maturation Pond 3 site.

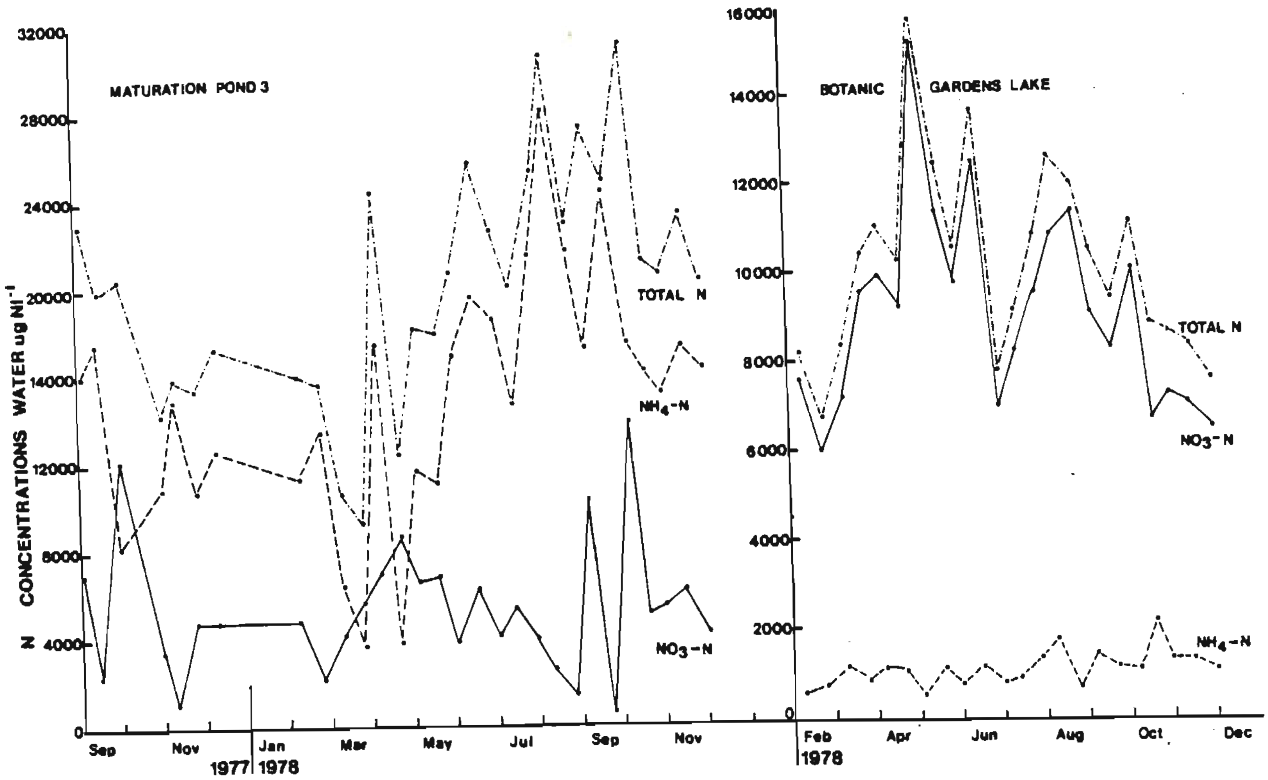


Figure 4.10 Average nitrogen (NO_3-N, NH_4-N and total N) concentrations analyzed in the water, over each growing interval, from the vicinity of the marginal plant populations enclosed at 2 sites.

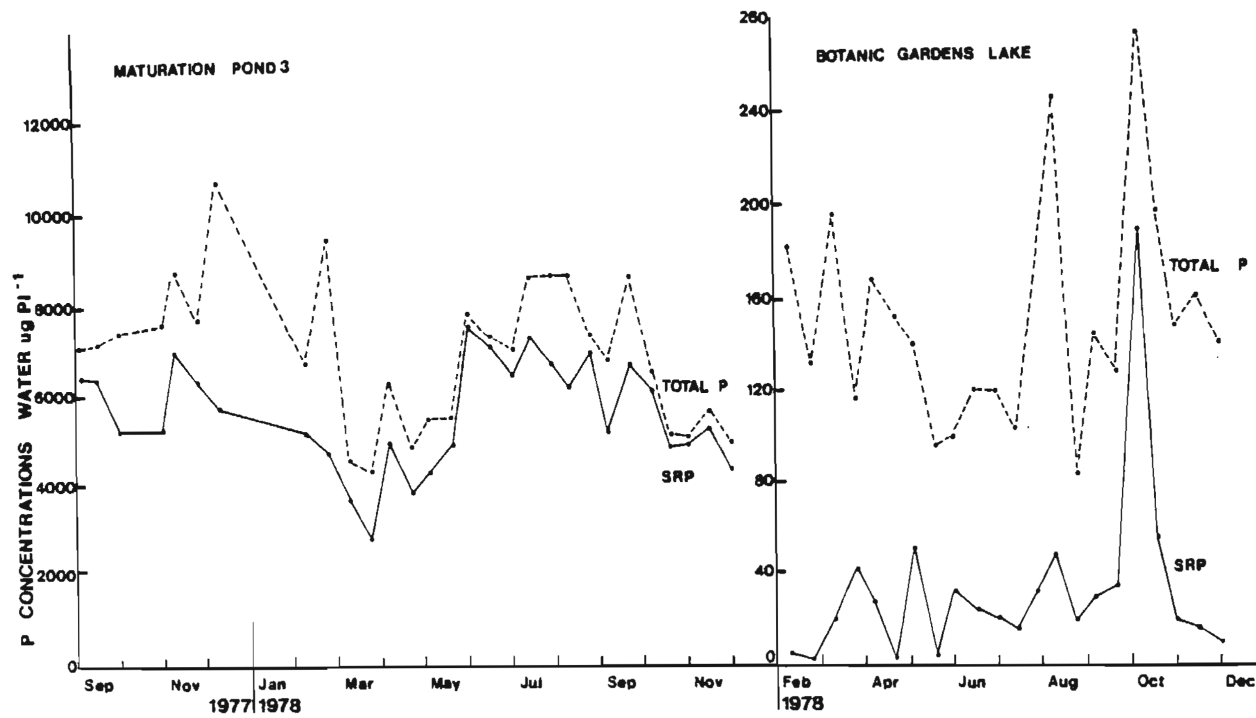


Figure 4.11 Average phosphorus (SRP and total P) concentrations analyzed in the water, over each growing interval, from the vicinity of the marginal plant populations enclosed at 2 sites.

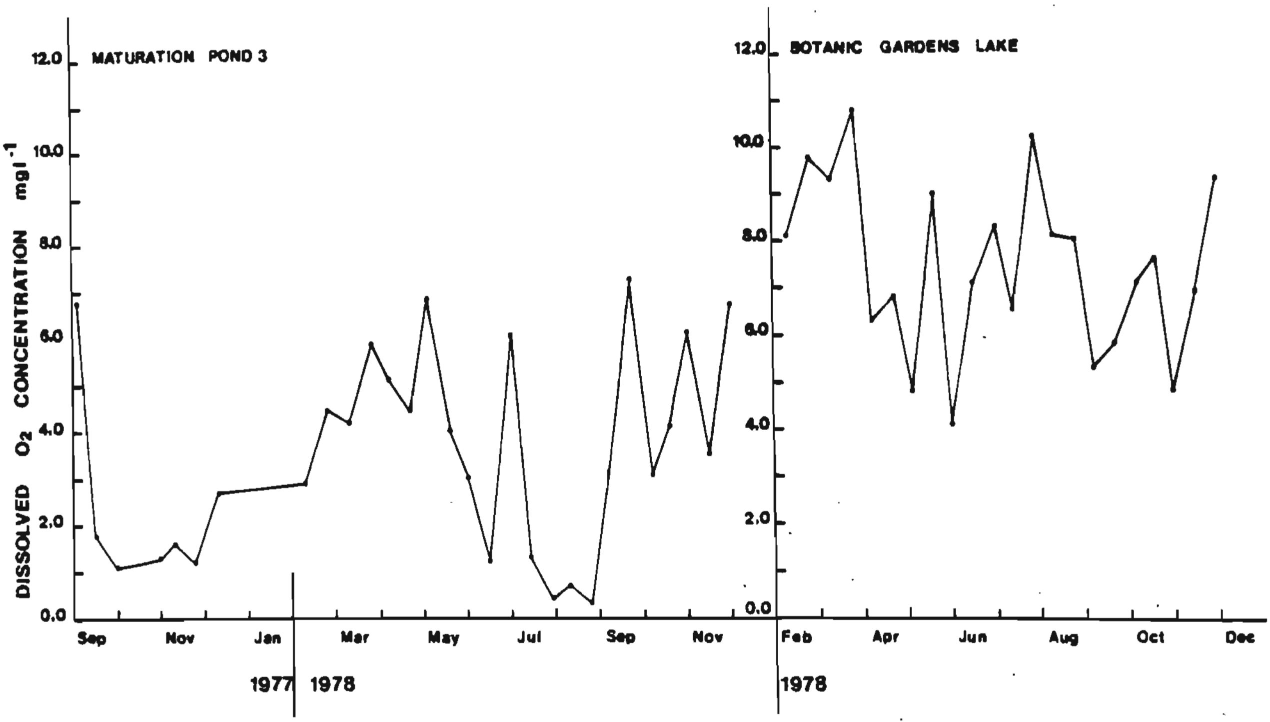


Figure 4.12 Average dissolved oxygen concentrations recorded in the water, over each growing interval, from the vicinity of the marginal plant populations enclosed at 2 sites.

Table 4.5 Maximum specific growth rates (Umax) predicted for **E. crassipes** for various temperatures according to the van't Hoff rule. Predictions were based on the Umax value of 0,0886 g fresh mass g^{-1} d^{-1} determined for this plant at a mean daily air and water temperature of 24°C under N growth rate limitation in culture.

Mean daily temperature °C	1/T x 10^4 °K	Umax g fresh mass g^{-1} d^{-1}
24	33,6473	0,0886
21	33,9904	0,0723
19	34,2231	0,0630
17	34,4589	0,0548
14	34,8189	0,0443

Table 4.6 Specific growth rates (U) predicted for **E. crassipes** from the N (NO_3-N, NH_4-N and total N) concentrations in the water, over each growing interval, at the Maturation Pond 3 site compared with those measured for marginal plants, growing in loosely crowded populations at this site. Maximum specific growth rates (Umax) predicted for **E. crassipes**, over each growing interval, according to the van't Hoff rule using a Umax value determined for this plant under N growth rate limitation in culture.

Growing interval	Predicted values				Measured values	
	Umax g fresh mass g^{-1} d^{-1}	U g fresh mass g^{-1} d^{-1}			U g fresh mass g^{-1} d^{-1}	Standard deviation
Dates		NO_3-N	NH_4-N	total N		
1977						
1/9 - 7/9	0,0671	0,0588	0,0632	0,0644	0,1991	±0,0263
8/9 - 21/9	0,0694	0,0492	0,0657	0,0661	0,1450	±0,0165
23/9 - 4/10	0,0666	0,0617	0,0595	0,0635	0,1542	±0,0163
28/10 - 2/11	0,0759	0,0590	0,0696	0,0710	0,1662	±0,0491
3/11 - 16/11	0,0699	0,0354	0,0656	0,0658	0,1668	±0,0211
18/11 - 30/11	0,0801	0,0664	0,0734	0,0753	0,1544	±0,0221
1/12 - 14/12	0,0880	0,0729	0,0816	0,0833	0,1214	±0,0236
1978						
1/2 - 16/2	0,0941	0,0780	0,0866	0,0887	0,1498	±0,0227
17/2 - 1/3	0,0857	0,0586	0,0799	0,0806	0,1698	±0,0214
2/3 - 14/3	0,0960	0,0776	0,0831	0,0878	0,1534	±0,0312
16/3 - 29/3	0,0947	0,0806	0,0745	0,0856	0,1481	±0,0395
31/3 - 11/4	0,0857	0,0751	0,0811	0,0824	0,1146	±0,0191
14/4 - 26/4	0,0709	*0,0637	0,0559	*0,0657	0,0936	±0,0314
28/4 - 9/5	0,0639	0,0555	0,0589	0,0606	-	-
12/5 - 24/5	0,0630	0,0550	0,0578	0,0597	0,1084	±0,0249
26/5 - 7/6	0,0617	0,0491	0,0583	0,0589	0,0987	±0,0128
9/6 - 21/6	0,0522	0,0450	*0,0497	*0,0503	0,0693	±0,0196
23/6 - 5/7	0,0514	*0,0413	*0,0488	*0,0492	0,0526	±0,0126
7/7 - 19/7	0,0564	0,0476	0,0528	0,0537	0,0859	±0,0155
20/7 - 2/8	0,0592	0,0474	0,0566	0,0570	0,1041	±0,0220
4/8 - 16/8	0,0596	0,0431	0,0576	0,0577	0,1082	±0,0125
18/8 - 30/8	0,0613	0,0358	0,0586	0,0588	0,0981	±0,0129
1/9 - 13/9	0,0564	0,0514	0,0533	0,0544	0,1036	±0,0150
15/9 - 27/9	0,0685	0,0249	0,0658	0,0659	0,1179	±0,0198
29/9 - 12/10	0,0622	0,0580	0,0588	0,0603	0,1239	±0,0186
13/10 - 24/10	0,0680	0,0569	0,0641	0,0650	0,1358	±0,0194
25/10 - 8/11	0,0718	0,0608	0,0673	0,0685	0,1223	±0,0241
10/11 - 22/11	0,0769	0,0661	0,0727	0,0738	0,1147	±0,0261
12/11 - 6/12	0,0828	0,0667	0,0780	0,0790	0,1292	±0,0357

* Predicted specific growth rates falling within standard deviations of measured specific growth rates

Table 4.7 Specific growth rates (U) predicted for **E. crassipes** from the N (NO_3-N, NH_4-N and total N) concentrations in the water, over each growing interval, at 3 sites compared with those measured for marginal plants, growing in loosely crowded populations, at these sites. Maximum specific growth rates (Umax) predicted for E. **crassipes**, over each growing interval, according to the van't Hoff rule using a Umax value determined for this plant under N growth rate limitation in culture.

Growing interval	Predicted values				Measured values	
	Umax g fresh mass g^{-1} d^{-1}	U g fresh mass g^{-1} d^{-1}			U g fresh mass g^{-1} d^{-1}	Standard deviation
Dates		NO_3-N	NH_4-N	total N		
Isipingo Lake						
1977						
11/8 - 17/8	0,0592	0,0259	*0,0422	*0,0453	0,0641	±0,0227
17/8 - 25/8	0,0556	0,0098	*0,0362	*0,0375	0,0506	±0,0195
25/8 - 1/9	0,0592	0,0021	0,0368	0,0371	0,0745	±0,0222
1/9 - 17/9	0,0671	0,0003	0,0461	0,0461	0,1247	±0,0314
Discharge Canal						
1977						
3/11 - 16/11	0,0699	0,0578	0,0419	0,0603	0,0965	±0,0236
18/11 - 30/11	0,0801	0,0667	0,0386	0,0685	0,1035	±0,0269
1/12 - 14/12	0,0880	*0,0731	0,0432	*0,0752	0,0940	±0,0280
Isipingo Canal						
1977						
8/9 - 23/9	0,0704	0,0298	0,0408	0,0478	0,1201	±0,0197
23/9 - 4/10	0,0666	0,0231	0,0424	0,0460	0,1115	±0,0155
5/10 - 26/10	0,0704	0,0293	0,0399	0,0471	0,1167	±0,0132

* Predicted specific growth rates falling within standard deviations of measured specific growth rates.

Table 4.8 Specific growth rates (U) predicted for **E. crassipes** from the N (NO_3-N, NH_4-N and total N) concentrations in the water, over each growing interval, at 2 sites compared with those measured for central plants, growing in densely crowded populations, at these sites. Maximum specific growth rates (Umax) predicted for **E. crassipes**, over each growing interval, according to the van't Hoff rule using a Umax value determined for this plant under N growth rate limitation in culture.

Growing interval	Predicted values				Measured values	
	Umax g fresh mass g^{-1} d^{-1}	U g fresh mass g^{-1} d^{-1}			U g fresh mass g^{-1} d^{-1}	Standard deviation
Dates		NO_3-N	NH_4-N	total N		
Discharge Canal						
1977						
3/11 - 16/11	0,0699	0,0578	*0,0419	0,0603	0,0379	±0,0170
18/11 - 30/11	0,0801	*0,0667	*0,0386	*0,0685	0,0526	±0,0174
1/12 - 14/12	0,0880	0,0731	*0,0432	0,0752	0,0338	±0,0124
Maturation Pond 3						
1977						
3/11 - 16/11	0,0699	0,0354	*0,0656	*0,0658	0,0559	±0,0190
18/11 - 30/11	0,0801	*0,0664	0,0734	0,0753	0,0573	±0,0116
1/12 - 14/12	0,0880	*0,0729	*0,0816	*0,0833	0,0659	±0,0353
1978						
3/2 - 16/2	0,0941	0,0780	0,0866	0,0887	0,0324	±0,0121
17/2 - 1/3	0,0857	0,0586	0,0799	0,0806	0,0357	±0,0184
2/3 - 14/3	0,0960	0,0776	0,0831	0,0878	0,0259	±0,0139
16/3 - 29/3	0,0947	0,0806	0,0745	0,0856	0,0312	±0,0137
31/3 - 11/4	0,0857	0,0751	0,0811	0,0824	0,0403	±0,0203
14/4 - 26/4	0,0709	0,0637	0,0559	0,0657	0,0231	±0,0088
28/4 - 10/5	0,0639	0,0555	0,0589	0,0606	0,0202	±0,0079
12/5 - 24/5	0,0630	0,0550	0,0578	0,0597	0,0203	±0,0089
26/5 - 7/6	0,0617	0,0491	0,0583	0,0589	0,0242	±0,0144
15/9 - 27/9	0,0685	*0,0249	0,0658	0,0659	0,0248	±0,0108
29/9 - 12/10	0,0622	0,0580	0,0588	0,0603	0,0262	±0,0115
13/10 - 24/10	0,0680	0,0569	0,0641	0,0650	0,0299	±0,0101
25/10 - 8/11	0,0718	0,0608	0,0673	0,0685	0,0268	±0,0077
10/11 - 22/11	0,0769	0,0661	0,0727	0,0738	0,0255	±0,0083
24/11 - 16/12	0,0828	0,0667	0,0780	0,0790	0,0271	±0,0101

* Predicted specific growth rates falling within standard deviations of measured specific growth rates.

Table 4.9 Maximum specific growth rates (Umax) predicted for **E. crassipes** for various temperatures according to the van't Hoff rule. Predictions were based on the Umax value of 0,1089 g fresh mass g^{-1} d^{-1} determined for this plant at a mean daily air and water temperature of 28°C under P growth rate limitation in culture.

Mean daily temperature °C	1/T x 10^4 °K	Umax g fresh mass g^{-1} d^{-1}
28	33,2005	0,1089
25	33,5345	0,0889
23	33,7609	0,0774
21	33,9904	0,0673
18	33,3406	0,0544

Table 4.10 Specific growth rates (U) predicted for **E. crassipes** from the P (SRP and total P) concentrations in the water, over each growing interval, at the Botanic Gardens Lake site compared with those measured for marginal plants, growing in loosely crowded populations, at this site. Maximum specific growth rates (Umax) predicted for **E. crassipes**, over each growing interval, according to the van't Hoff rule using a Umax value determined for this plant under P growth rate limitation in culture.

Growing interval	Predicted values			Measured values	
	Umax g fresh mass g^{-1} d^{-1}	U g fresh mass g^{-1} d^{-1}		U g fresh mass g^{-1} d^{-1}	Standard deviation
Dates		SRP	total P		
1978					
1/2 - 15/2	0,0883	0,0044	0,0583	0,1158	±0,0130
17/2 - 1/3	0,0802	0,0017	0,0468	0,1227	±0,0187
2/3 - 14/3	0,0901	0,0158	0,0609	0,0996	±0,0155
16/3 - 28/3	0,0895	0,0276	*0,0494	0,0675	±0,0208
31/3 - 12/4	0,0790	0,0176	*0,0506	0,0689	±0,0220
14/4 - 25/4	0,0669	0,0014	*0,0413	0,0601	±0,0254
28/4 - 9/5	0,0593	0,0211	0,0355	0,0645	±0,0257
12/5 - 23/5	0,0593	0,0024	0,0299	0,0478	±0,0147
26/5 - 6/6	0,0572	0,0145	0,0295	0,0493	±0,0104
9/6 - 20/6	0,0481	0,0098	*0,0269	0,0305	±0,0121
23/6 - 4/7	0,0467	0,0082	*0,0261	0,0313	±0,0156
7/7 - 18/7	0,0517	0,0071	0,0270	0,0527	±0,0080
20/7 - 2/8	0,0548	0,0136	*0,0355	0,0443	±0,0109
4/8 - 15/8	0,0548	0,0185	0,0395	0,0635	±0,0116
18/8 - 29/8	0,0568	0,0091	0,0266	0,0651	±0,0132
1/9 - 13/9	0,0521	0,0123	0,0315	0,0615	±0,0146
15/9 - 27/9	0,0636	0,0169	0,0366	0,0867	±0,0157
29/9 - 11/10	0,0589	0,0392	0,0431	0,0843	±0,0131
13/10 - 23/10	0,0659	0,0240	0,0445	0,1162	±0,0229
25/10 - 7/11	0,0669	0,0112	0,0409	0,1064	±0,0139
10/11 - 22/11	0,0717	0,0104	0,0451	0,0963	±0,0206
24/11 - 6/12	0,0774	0,0074	0,0464	0,1207	±0,0138

* Predicted specific growth rates falling within standard deviations of measured specific growth rates.

Table 4.11 Specific growth rates (U) predicted for **E. crassipes** from the P (SRP and total P) concentrations in the water, over each growing interval, at the Hartbeespoort Dam site compared with those measured for marginal plants, growing in loosely crowded populations, at this site. Maximum specific growth rates (Umax) predicted for **E. crassipes**, over each growing interval, according to the van't Hoff rule using a Umax value determined for this plant under P growth rate limitation in culture.

Growing interval	Predicted values			Measured values	
	Umax	U g fresh mass g^{-1} d^{-1}		U	Standard
	g fresh mass			g fresh mass g^{-1} d^{-1}	deviation
Dates	g^{-1} d^{-1}	SRP	total P		
1977					
28/9 - 11/10	0,0589	*0,0303	*0,0311	0,0313	±0,0209
14/10 - 27/10	0,0619	0,0323	0,0339	0,0207	±0,0070
3/11 - 11/11	0,0678	*0,0467	*0,0477	0,0375	±0,0149
18/11 - 25/11	0,0717	*0,0463	*0,0484	0,0672	±0,0362
14/12 - 22/12	0,0702	*0,0478	*0,0488	0,0410	±0,0157

* Predicted specific growth rates falling within standard deviations of measured specific growth rates.

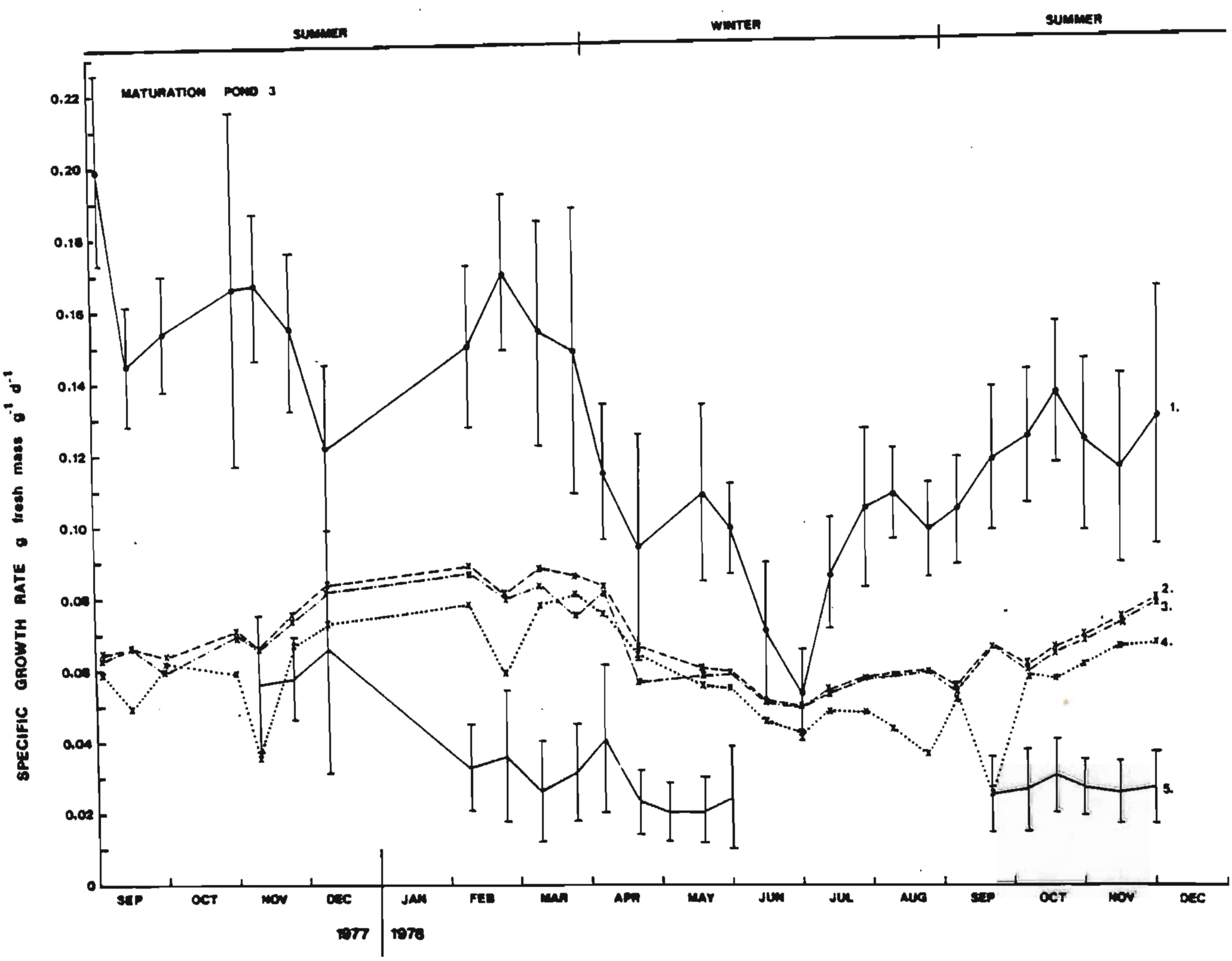


Figure 4.13 Specific growth rates predicted for E. **crassipes** from 2. the total N, 3. the NH_4-N and 4. the NO_3-N concentrations in the water, over each growing interval, at the Maturation Pond 3 site compared with those measured for 1. marginal plants, growing in loosely crowded populations and 5. central plants, growing in densely crowded populations. Standard deviations of measured specific growth rates are shown by bars. The predicted specific growth rates were calculated using kinetic coefficients, generated for this plant under N growth rate limitation in culture, in the Monod model.

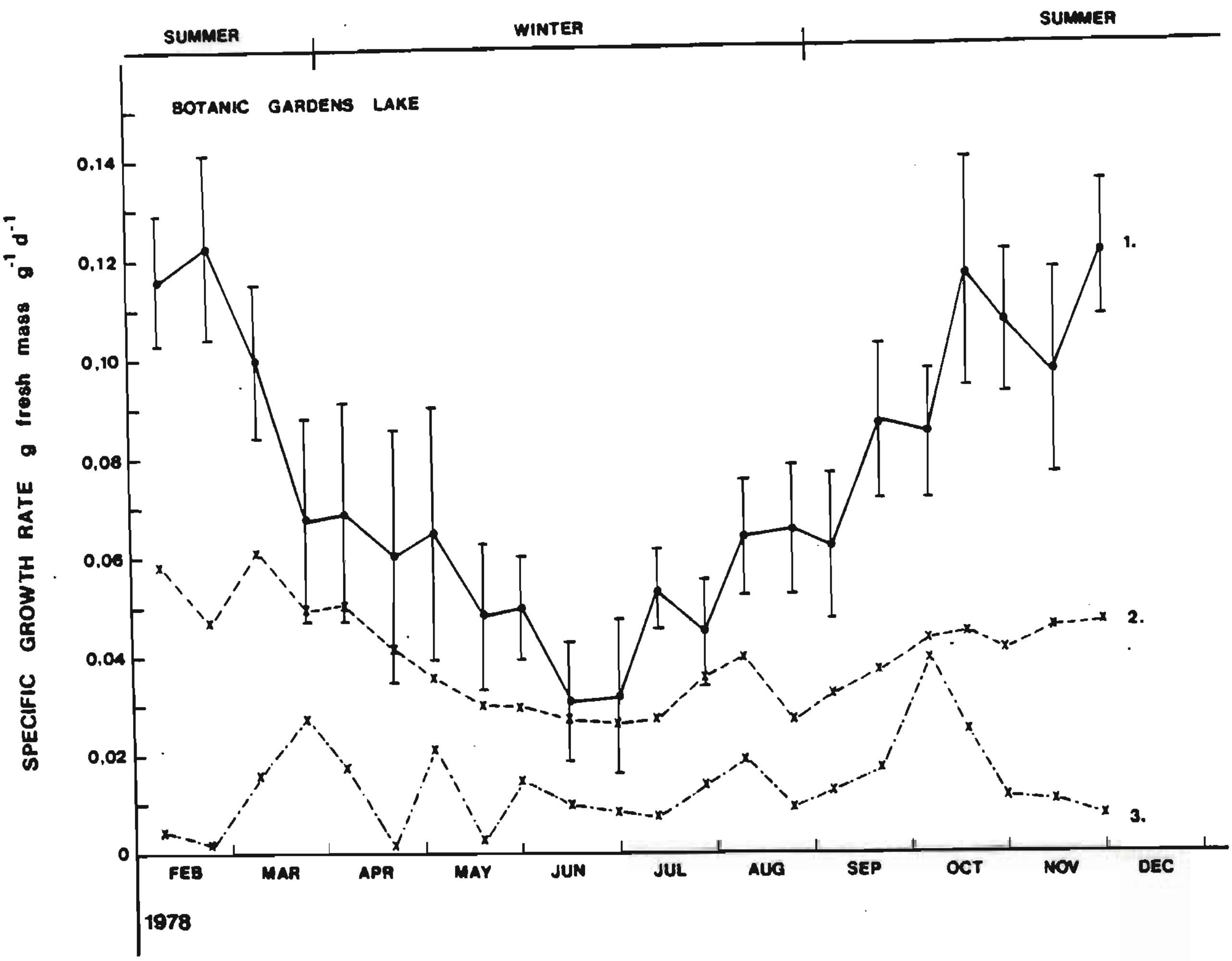


Figure 4.14 Specific growth rates predicted for **E. crassipes** from 2. the total P and 3. the SRP concentrations in the water, over each growing interval, at the Botanic Gardens Lake site compared with those measured for 1. marginal plants, growing in loosely crowded populations. Standard deviations of measured specific growth rates are shown by bars. The predicted specific growth rates were calculated using kinetic coefficients, generated for this plant under P growth rate limitation in culture, in the Monod model.

CHAPTER 5

REFINING THE MODEL UNDER FIELD CONDITIONS

Table 5.1 Specific growth rates (U) predicted for marginal plants from the P (SRP and total P) concentrations in the water, over each growing interval, at the Botanic Gardens Lake site compared with the measured specific growth rates. Maximum specific growth rates (Umax) predicted for marginal plants, over each growing interval, using the regression equation relating the assumed Umax's of marginal plants in the field exponentially to the reciprocals of the Absolute mean daily air temperatures.

Growing interval	Predicted values			Measured values	
	Umax g fresh mass g^{-1} d^{-1}	U g fresh mass g^{-1} d^{-1}		U g fresh mass g^{-1} d^{-1}	Standard deviation
Dates		SRP	total P		
1978					
1/2 - 15/2	0,1560	0,0079	*0,1030	0,1158	±0,0130
17/2 - 1/3	0,1407	0,0029	0,0821	0,1227	±0,0187
2/3 - 14/3	0,1595	0,0279	*0,1078	0,0996	±0,0155
16/3 - 28/3	0,1584	*0,0489	*0,0874	0,0675	±0,0208
31/3 - 12/4	0,1386	0,0309	*0,0888	0,0689	±0,0220
14/4 - 25/4	0,1158	0,0024	*0,0715	0,0601	±0,0254
28/4 - 9/5	0,1017	0,0362	*0,0608	0,0645	±0,0257
12/5 - 23/5	0,1017	0,0041	*0,0513	0,0478	±0,0147
26/5 - 6/6	0,0979	0,0248	*0,0504	0,0493	±0,0104
9/6 - 20/6	0,0813	0,0165	0,0456	0,0305	±0,0121
23/6 - 4/7	0,0788	0,0138	*0,0440	0,0313	±0,0156
7/7 - 18/7	0,0879	0,0121	*0,0459	0,0527	±0,0080
20/7 - 2/8	0,0935	0,0232	0,0605	0,0443	±0,0109
4/8 - 15/8	0,0935	0,0316	*0,0675	0,0635	±0,0116
18/8 - 29/8	0,0972	0,0156	0,0455	0,0651	±0,0132
1/9 - 13/9	0,0886	0,0209	*0,0536	0,0615	±0,0146
15/9 - 27/9	0,1098	0,0291	0,0633	0,0867	±0,0157
29/9 - 11/10	0,1010	0,0673	*0,0738	0,0843	±0,0131
13/10 - 23/10	0,1141	0,0416	0,0771	0,1162	±0,0229
25/10 - 7/11	0,1158	0,0194	0,0708	0,1064	±0,0139
10/11 - 22/11	0,1249	0,0181	*0,0786	0,0963	±0,0206
24/11 - 6/12	0,1356	0,0130	0,0813	0,1207	±0,0138

* Predicted specific growth rates falling within standard deviations of measured specific growth rates.

Table 5.2 Specific growth rates (U) predicted for marginal plants from the P (SRP and total P) concentrations in the water, over each growing interval, at the Hartbeespoort Dam site compared with the measured specific growth rates. Maximum specific growth rates (Umax) predicted for marginal plants, over each growing interval, using the regression equation relating the assumed Umax's of marginal plants in the field exponentially to the reciprocals of the Absolute mean daily air temperatures.

Growing interval	Predicted values			Measured values	
	Umax g fresh mass g^{-1} d^{-1}	U g fresh mass g^{-1} d^{-1}		U g fresh mass g^{-1} d^{-1}	Standard deviation
Dates		SRP	total P		
1977					
28/9 - 11/10	0,1010	*0,0520	0,0533	0,0313	±0,0209
14/10 - 27/10	0,1065	0,0556	0,0583	0,0207	±0,0070
3/11 - 11/11	0,1175	0,0810	0,0826	0,0375	±0,0149
18/11 - 25/11	0,1248	*0,0807	*0,0843	0,0672	±0,0362
14/12 - 22/12	0,1221	0,0832	0,0849	0,0410	±0,0157

* Predicted specific growth rates falling within standard deviations of measured specific growth rates.

Table 5.3 Specific growth rates (U) predicted for marginal plants from the N (NO_3-N, NH_4-N and total N) concentrations in the water, over each growing interval, at 3 sites compared with the measured specific growth rates. Maximum specific growth rates (Umax) predicted for marginal plants, over each growing interval, using the regression equation relating the assumed Umax's of marginal plants in the field exponentially to the reciprocals of the Absolute mean daily air temperatures.

Growing interval	Predicted values				Measured values	
	Umax	U g fresh mass g^{-1} d^{-1}			U	Standard
	g fresh mass				g fresh mass g^{-1} d^{-1}	deviation
Dates	g^{-1} d^{-1}	NO_3-N	NH_4-N	total N		
Isipingo Lake						
1977						
11/8 - 17/8	0,0935	0,0409	*0,0667	*0,0716	0,0641	±0,0227
17/8 - 25/8	0,0872	0,0154	*0,0567	*0,0588	0,0506	±0,0195
25/8 - 1/9	0,0935	0,0032	*0,0581	*0,0586	0,0745	±0,0222
1/9 - 7/9	0,1073	0,0005	0,0736	0,0737	0,1247	±0,0314
Discharge Canal						
1977						
3/11 - 16/11	0,1123	*0,0929	0,0673	*0,0969	0,0965	±0,0236
18/11 - 30/11	0,1306	*0,1088	0,0630	*0,1118	0,1035	±0,0269
1/12 - 14/12	0,1449	*0,1203	*0,0711	0,1238	0,0940	±0,0280
Isipingo Canal						
1977						
8/9 - 23/9	0,1132	0,0479	0,0657	0,0769	0,1201	±0,0197
23/9 - 4/10	0,1065	0,0340	0,0679	0,0735	0,1115	±0,0155
5/10 - 26/10	0,1132	0,0471	0,0642	0,0757	0,1167	±0,0132

* Predicted specific growth rates falling within standard deviations of measured specific growth rates.

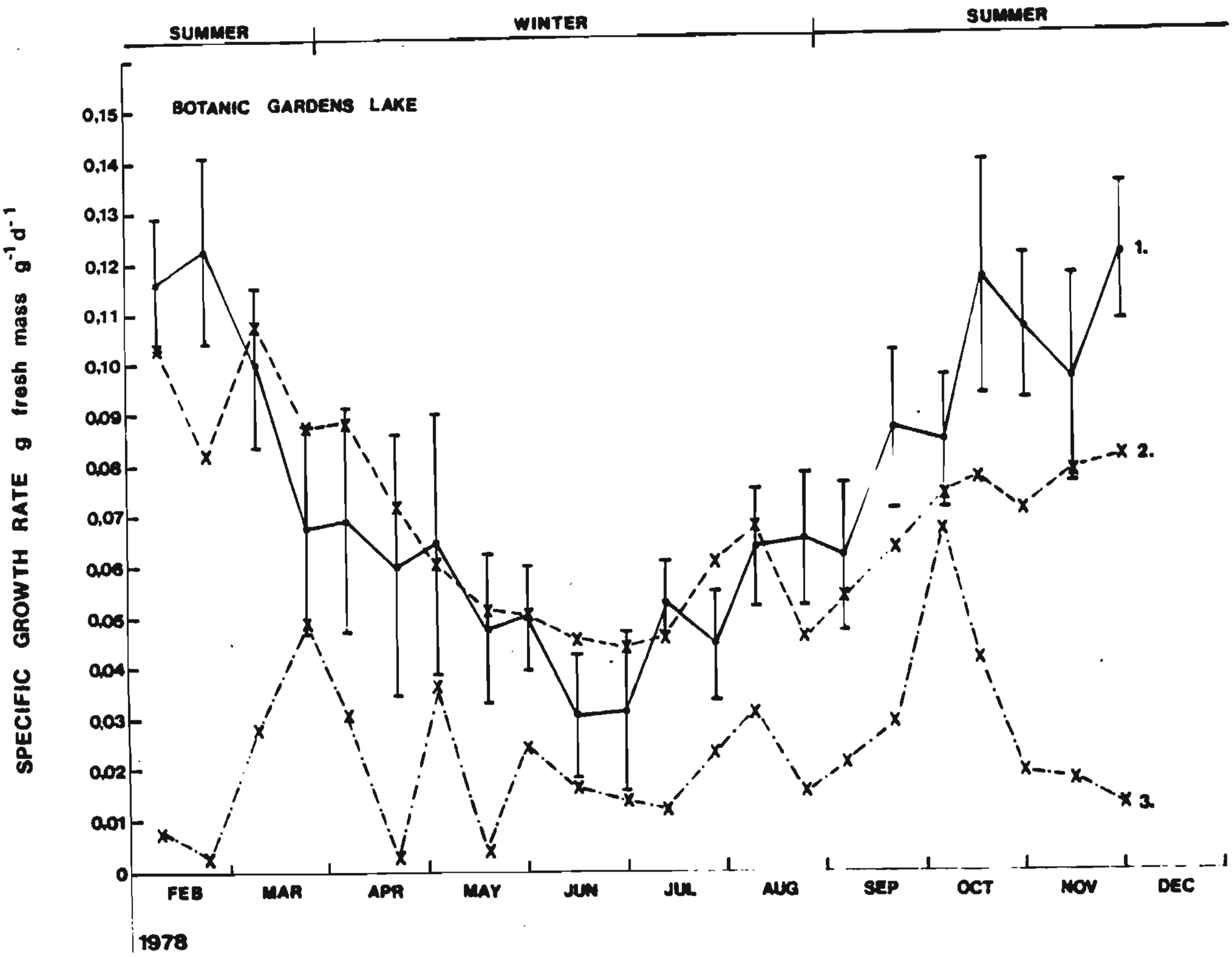


Figure 5.1 Specific growth rates predicted for marginal plants from 2. the total P and 3. the SRP concentrations in the water, over each growing interval, at the Botanic Gardens Lake site compared with 1. the measured specific growth rates. Standard deviations of measured specific growth rates are shown by bars. The predicted values were calculated using Umax values corrected for the mean daily air temperature, derived for marginal plants in the field, and the mean Ksp concentration of 94,1 ug P l^{-1}, generated for E. **crassipes** under P growth rate limitation in culture, in the Monod model.

Table 5.4 Measured and predicted specific growth rates (U) of marginal plants and those normalized to 15°C ($U_{15°C}$) at the Maturation Pond 3 site. The predicted specific growth rates were calcu= lated from the regression equation relating the specific growth rates of marginal plants exponentially to the reciprocals of the Absolute mean daily air temperatures. The normalized specific growth rates were calculated from a formula incorpo= rating the measured and predicted specific growth rates.

Growing interval Dates	Mean daily air temperature °C	Measured U g fresh mass g^{-1} d^{-1}	Predicted U g fresh mass g^{-1} d^{-1}	Normalized $U_{15°C}$ g fresh mass g^{-1} d^{-1}
1978				
1/2 - 16/2	24,9	0,1498	0,1559	0,0704
17/2 - 1/3	23,5	0,1698	0,1405	0,0886
21/3 - 14/3	25,2	0,1534	0,1593	0,0706
16/3 - 29/3	25,0	0,1481	0,1570	0,0691
31/3 - 11/4	23,5	0,1146	0,1405	0,0598
14/4 - 26/4	20,7	0,0936	0,1139	0,0602
12/5 - 24/5	19,0	0,1084	0,1001	0,0794
26/5 - 7/6	18,7	0,0987	0,0978	0,0740
9/6 - 21/6	16,3	0,0693	0,0812	0,0625
23/6 - 5/7	16,1	0,0526	0,0800	0,0482
7/7 - 19/7	17,4	0,0859	0,0885	0,0711
20/7 - 2/8	18,1	0,1041	0,0934	0,0817
4/8 - 16/8	18,2	0,1082	0,0941	0,0843
18/8 - 30/8	18,6	0,0981	0,0970	0,0741
1/9 - 13/9	17,4	0,1036	0,0885	0,0858
15/9 - 27/9	20,2	0,1179	0,1097	0,0788
29/9 - 12/10	18,8	0,1239	0,0986	0,0921
13/10 - 24/10	20,1	0,1358	0,1088	0,0915
25/10 - 8/11	20,9	0,1223	0,1156	0,0775
10/11 - 22/11	21,9	0,1147	0,1247	0,0674
24/11 - 6/12	23,0	0,1292	0,1354	0,0699
	15,0	-	0,0733	-

Table 5.5 Specific growth rates (U) predicted for marginal plants from the P (SRP and total P) concentrations in the water, over each growing interval, at the Botanic Gardens Lake site compared with the measured specific growth rates. Maximum specific growth rates (Umax) predicted for marginal plants, over each growing interval, using the regression equation relating the assumed Umax's of marginal plants in the field exponentially to the products of the reciprocals of the Absolute mean daily air temperatures and diffuse radiant fluxes.

Growing interval	Predicted values			Measured values	
	Umax g fresh mass g^{-1} d^{-1}	U g fresh mass g^{-1} d^{-1}		U g fresh mass g^{-1} d^{-1}	Standard deviation
Dates		SRP	total P		
1978					
1/2 - 15/2	0,1433	0,0072	0,0946	0,1158	±0,0130
17/2 - 1/3	0,1561	0,0032	0,0911	0,1227	±0,0187
2/3 - 14/3	0,1378	0,0241	*0,0931	0,0996	±0,0155
16/3 - 28/3	0,1189	0,0367	*0,0656	0,0675	±0,0208
31/3 - 12/4	0,1019	0,0227	*0,0653	0,0689	±0,0220
14/4 - 25/4	0,1151	0,0024	*0,0711	0,0601	±0,0254
28/4 - 9/5	0,0767	0,0273	*0,0459	0,0645	±0,0257
12/5 - 23/5	0,0940	0,0038	*0,0475	0,0478	±0,0147
26/5 - 6/6	0,0806	0,0204	*0,0415	0,0493	±0,0104
9/6 - 20/6	0,0807	0,0164	0,0452	0,0305	±0,0121
23/6 - 4/7	0,0799	0,0140	*0,0446	0,0313	±0,0156
7/7 - 18/7	0,0901	0,0124	*0,0471	0,0527	±0,0080
20/7 - 2/8	0,0958	0,0237	0,0620	0,0443	±0,0109
4/8 - 15/8	0,0921	0,0311	*0,0665	0,0635	±0,0116
18/8 - 29/8	0,1046	0,0168	0,0490	0,0651	±0,0132
1/9 - 13/9	0,1010	0,0238	*0,0611	0,0615	±0,0146
15/9 - 27/9	0,1309	0,0347	*0,0754	0,0867	±0,0157
29/9 - 11/10	0,1207	*0,0804	*0,0882	0,0843	±0,0131
13/10 - 23/10	0,1526	0,0556	*0,1031	0,1162	±0,0229
25/10 - 7/11	0,1328	0,0223	0,0812	0,1064	±0,0139
10/11 - 22/11	0,1236	0,0179	*0,0778	0,0963	±0,0206
24/11 - 6/12	0,1432	0,0137	0,0859	0,1207	±0,0138

* Predicted specific growth rates falling within standard deviations of measured specific growth rates.

Table 5.6 Specific growth rates (U) predicted for marginal plants from the P (SRP and total P) concentrations in the water, over each growing interval, at the Hartbeespoort Dam site compared with the measured specific growth rates. Maximum specific growth rates (Umax) predicted for marginal plants, over each growing interval, using the regression equation relating the assumed Umax's of marginal plants in the field exponentially to the products of the reciprocals of the Absolute mean daily air temperatures and diffuse radiant fluxes.

Growing interval	Predicted values			Measured values	
	Umax g fresh mass g^{-1} d^{-1}	U g fresh mass g^{-1} d^{-1}		U g fresh mass g^{-1} d^{-1}	Standard deviation
Dates		SRP	total P		
1977					
28/9 - 11/10	0,1254	0,0646	0,0661	0,0313	±0,0209
14/10 - 27/10	0,1023	0,0534	0,0560	0,0207	±0,0070
3/11 - 11/11	0,1121	0,0773	0,0788	0,0375	±0,0149
18/11 - 25/11	0,1317	*0,0851	*0,0889	0,0672	±0,0362
14/12 - 22/12	0,1477	0,1006	0,1027	0,0410	±0,0157

* Predicted specific growth rates falling within standard deviations of measured specific growth rates.

Table 5.7 Specific growth rates (U) predicted for marginal plants from the N (NO_3-N, NH_4-N and total N) concentrations in the water, over each growing interval, at 3 sites compared with the measured specific growth rates. Maximum specific growth rates (Umax) predicted for marginal plants, over each growing interval, using the regression equation relating the assumed Umax's of marginal plants in the field exponentially to the products of the reciprocals of the Absolute mean daily air temperatures and diffuse radiant fluxes.

Growing interval	Predicted values				Measured values	
	Umax g fresh mass g^{-1} d^{-1}	U g fresh mass g^{-1} d^{-1}			U g fresh mass g^{-1} d^{-1}	Standard deviation
Dates		NO_3-N	NH_4-N	total N		
Isipingo Lake						
1977						
11/8 - 17/8	0,0841	0,0368	*0,0600	*0,0644	0,0641	±0,0227
17/8 - 25/8	0,0947	0,0167	*0,0616	*0,0639	0,0506	±0,0195
25/8 - 1/9	0,1153	0,0040	*0,0716	*0,0722	0,0745	±0,0222
1/9 - 7/9	0,1108	0,0006	0,0761	0,0761	0,1247	±0,0314
Discharge Canal						
1977						
3/11 - 16/11	0,1391	*0,1151	*0,0834	*0,1200	0,0965	±0,0236
18/11 - 30/11	0,1362	*0,1135	0,0657	*0,1165	0,1035	±0,0269
1/12 - 14/12	0,1410	*0,1171	*0,0692	*0,1204	0,0940	±0,0280
Isipingo Canal						
1977						
8/9 - 23/9	0,1270	0,0537	0,0737	0,0862	0,1201	±0,0197
23/9 - 4/10	0,1315	0,0420	0,0838	0,0907	0,1115	±0,0155
5/10 - 26/10	0,1323	0,0551	0,0750	0,0885	0,1167	±0,0132

* Predicted specific growth rates falling within standard deviations of measured specific growth rates.

Table 5.8 A comparison of the differences between measured specific growth rates and those predicted for marginal plants from the growth rate limiting total N or total P concentrations in the water at 3 sites, where the predicted values were calculated using Umax values, in the Monod model, corrected for:

A the mean daily air temperature,

B the mean daily air temperature and diffuse radiant flux.

Growing interval Dates	Differences g fresh mass g^{-1} d^{-1} A	B	Growing interval Dates	Differences g fresh mass g^{-1} d^{-1} A	B
Botanic Gardens Lake			**Isipingo Lake**		
1978			**1977**		
1/2 - 15/2	*0,0128	0,0212	11/8 - 17/8	0,0075	*0,0003
17/2 - 1/3	0,0406	*0,0316	17/8 - 25/8	*0,0082	0,0133
2/3 - 14/3	0,0082	*0,0065	25/8 - 1/9	0,0159	*0,0023
16/3 - 28/3	0,0199	*0,0019	1/9 - 7/9	0,0510	*0,0486
31/3 - 12/4	0,0199	*0,0036			
14/4 - 25/4	0,0114	*0,0110			
28/4 - 9/5	*0,0037	0,0186	**Discharge Canal**		
12/5 - 23/5	0,0035	*0,0003			
26/5 - 6/6	*0,0011	0,0078	**1977**		
9/6 - 20/6	0,0151	*0,0147	3/11 - 16/11	*0,0004	0,0235
23/6 - 4/7	*0,0127	0,0133	18/11 - 30/11	*0,0083	0,0130
7/7 - 18/7	0,0068	*0,0056	1/12 - 14/12	0,0298	*0,0264
20/7 - 2/8	*0,0162	0,0177			
4/8 - 15/8	0,0040	*0,0030			
18/8 - 29/8	0,0196	*0,0161			
1/9 - 13/9	0,0079	*0,0004			
15/9 - 27/9	0,0234	*0,0113	* smallest difference		
29/9 - 11/10	0,0105	*0,0039			
13/10 - 23/10	0,0391	*0,0131			
25/10 - 7/11	0,0356	*0,0252			
10/11 - 22/11	*0,0177	0,0185			
24/11 - 6/12	0,0394	*0,0348			

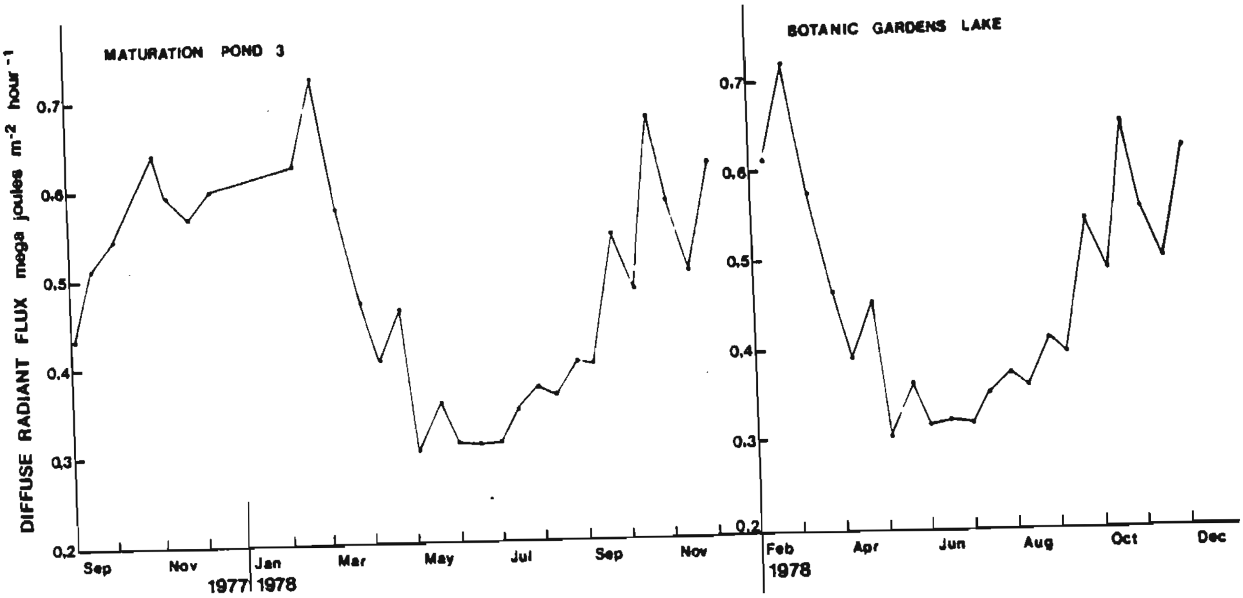


Figure 5.2 Average diffuse radiant fluxes recorded over each growing interval of marginal plants at 2 sites.

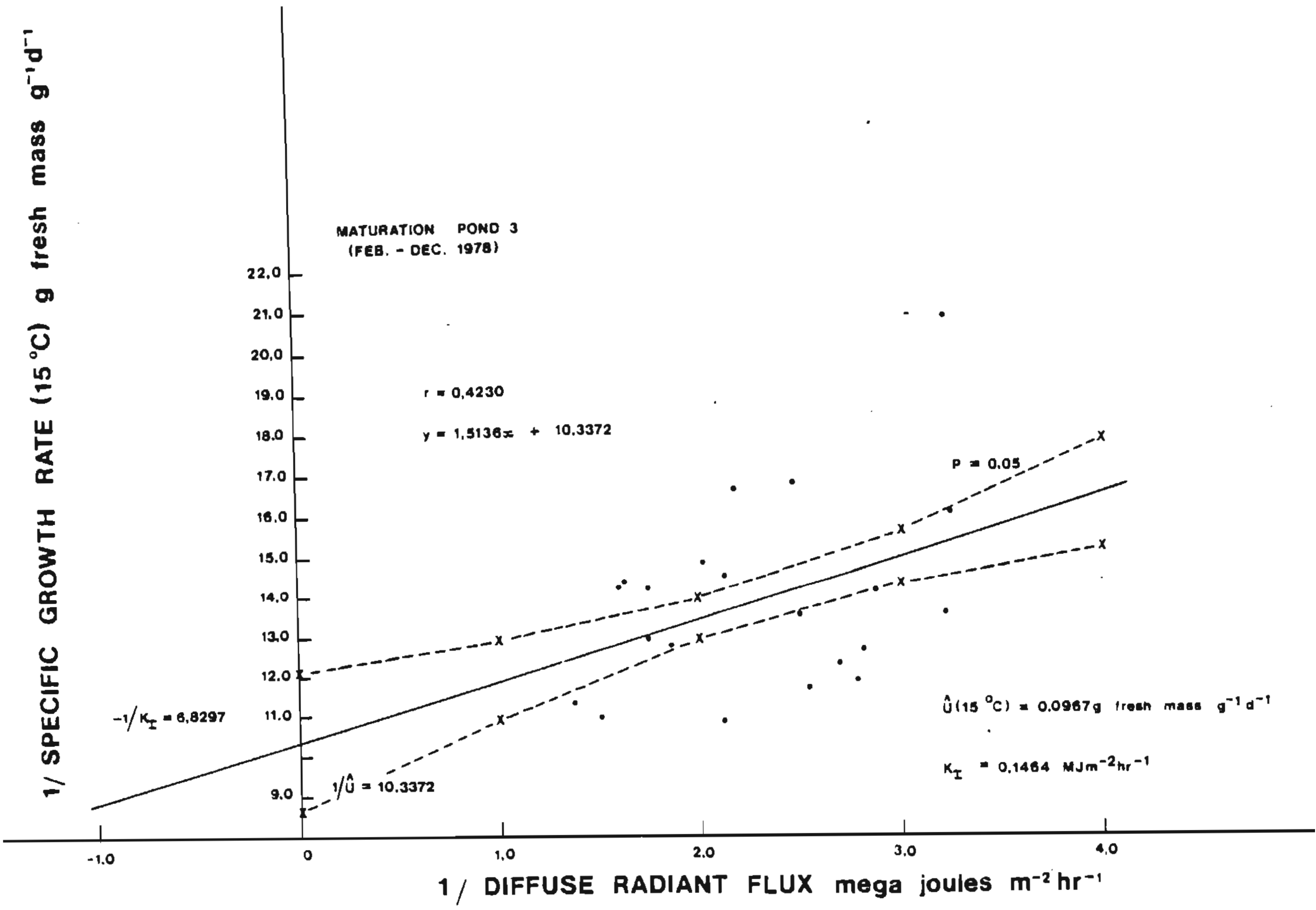


Figure 5.3 A Lineweaver-Burk plot of the specific growth rates (assumed Umax's) of marginal plants normalized to 15°C ($U_{15^\circ C}$) against the diffuse radiant fluxes at the Maturation Pond 3 site over the period February to December, 1978. $\hat{U} = \hat{U}max$.

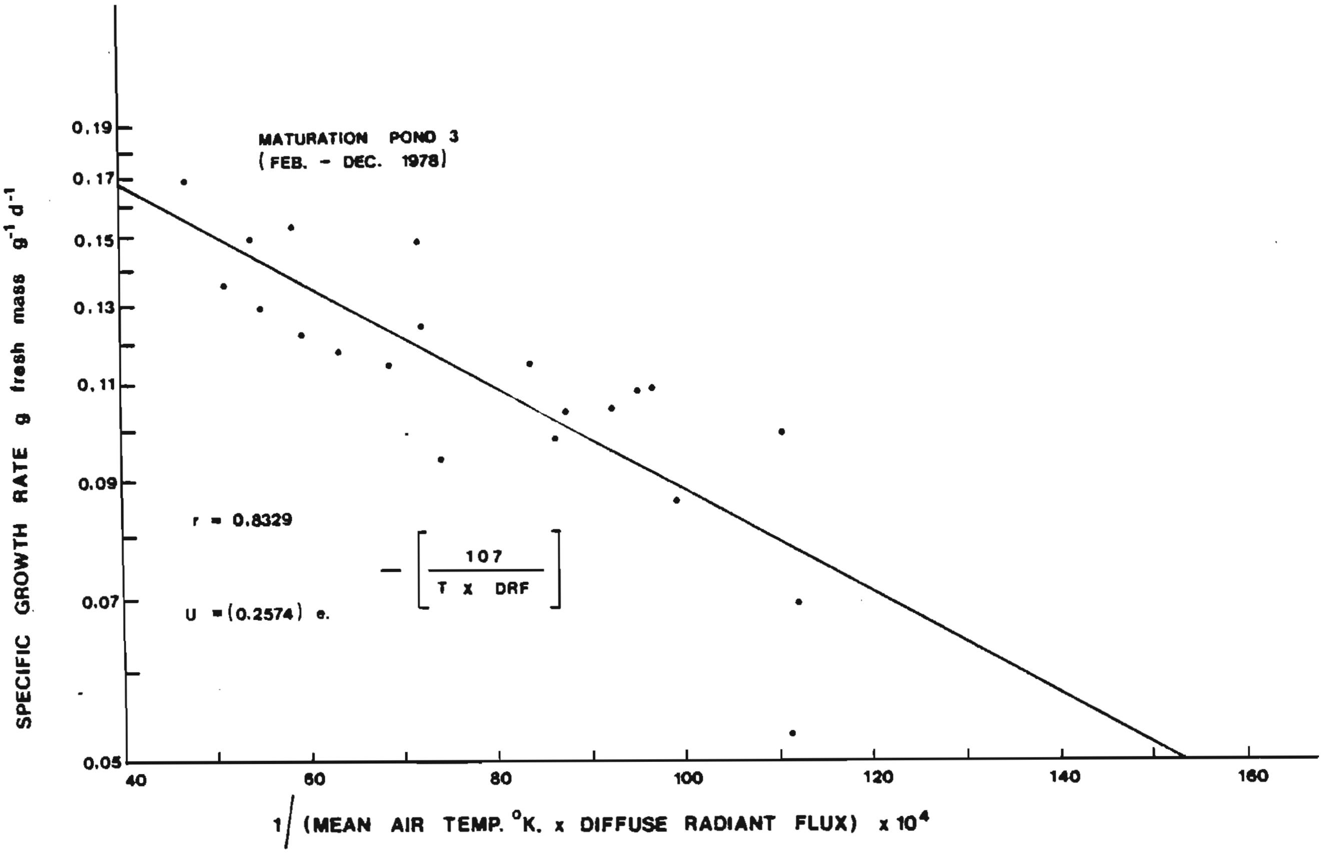


Figure 5.4 An Arrhenius plot of the specific growth rates (assumed Umax's) of marginal plants (Log_e) against the products of the reciprocals of the Absolute mean daily air temperatures and diffuse radiant fluxes at the Maturation Pond 3 site over the period February to December, 1978.

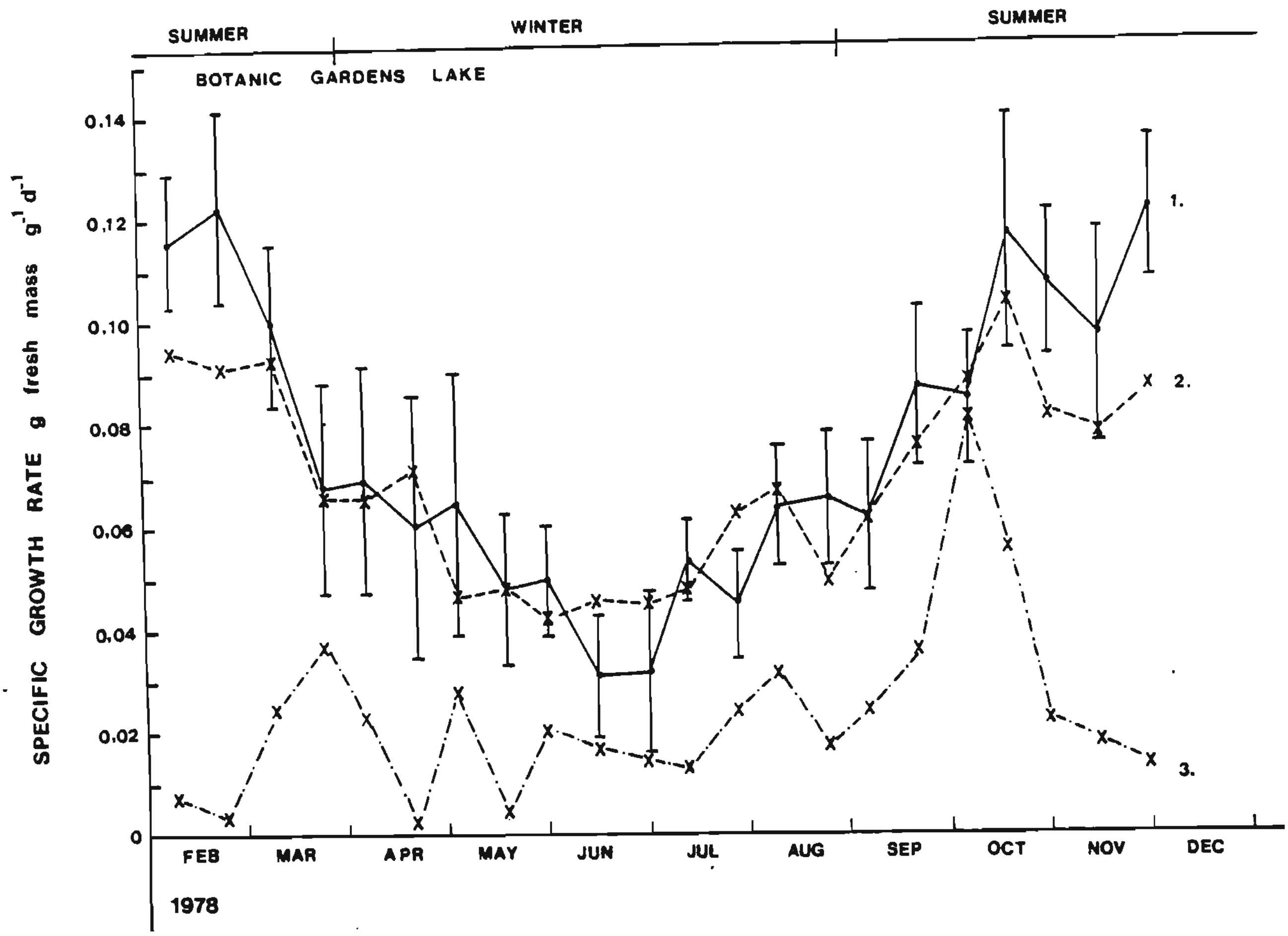


Figure 5.5 Specific growth rates predicted for marginal plants from 2. the total P and 3. the SRP concentrations in the water, over each growing interval, at the Botanic Gardens Lake site compared with 1. the measured specific growth rates. Standard deviations of measured specific growth rates are shown by bars. The predicted values were calculated using Umax values corrected for the mean daily air temperature and diffuse radiant flux, derived for marginal plants in the field, and the mean Ksp concentration of 94,1 ug P l^{-1}, generated for E. **crassipes** under P growth rate limitation in culture, in the Monod model.

Table 5.9 Specific growth rates (U) predicted for marginal plants from the P (SRP and total P) concentrations in the water, over each growing interval, at the Botanic Gardens Lake site compared with the measured specific growth rates. Maximum specific growth rates (Umax) predicted for marginal plants, over each growing interval, using the regression equation relating the assumed Umax's of marginal plants in the field exponentially to the products of the reciprocals of the Absolute mean daily air temperatures, diffuse radiant fluxes and mean daily relative humidities.

Growing interval	Predicted values			Measured values	
	Umax g fresh mass g^{-1} d^{-1}	U g fresh mass g^{-1} d^{-1}		U g fresh mass g^{-1} d^{-1}	Standard deviation
Dates		SRP	total P		
1978					
1/2 - 15/2	0,1416	0,0071	0,0935	0,1158	±0,0130
17/2 - 1/3	0,1501	0,0031	0,0876	0,1227	±0,0187
2/3 - 14/3	0,1365	0,0239	*0,0922	0,0996	±0,0155
16/3 - 28/3	0,1222	0,0377	*0,0675	0,0675	±0,0208
31/3 - 12/4	0,1012	0,0226	*0,0649	0,0689	±0,0220
14/4 - 25/4	0,1134	0,0024	*0,0700	0,0601	±0,0254
28/4 - 9/5	0,0748	0,0266	*0,0447	0,0645	±0,0257
12/5 - 23/5	0,0933	0,0038	*0,0471	0,0478	±0,0147
26/5 - 6/6	0,0827	0,0210	*0,0426	0,0493	±0,0104
9/6 - 20/6	0,0686	0,0139	*0,0384	0,0305	±0,0121
23/6 - 4/7	0,0776	0,0136	*0,0433	0,0313	±0,0156
7/7 - 18/7	0,0899	0,0124	*0,0470	0,0527	±0,0080
20/7 - 2/8	0,0981	0,0243	0,0635	0,0443	±0,0109
4/8 - 15/8	0,1019	0,0344	*0,0735	0,0635	±0,0116
18/8 - 29/8	0,1133	0,0182	*0,0531	0,0651	±0,0132
1/9 - 13/9	0,0983	0,0231	*0,0594	0,0615	±0,0146
15/9 - 27/9	0,1319	0,0350	*0,0760	0,0867	±0,0157
29/9 - 11/10	0,1191	*0,0794	*0,0871	0,0843	±0,0131
13/10 - 23/10	0,1503	0,0548	*0,1015	0,1162	±0,0229
25/10 - 7/11	0,1334	0,0224	0,0815	0,1064	±0,0139
10/11 - 22/11	0,1242	0,0180	*0,0782	0,0963	±0,0206
24/11 - 6/12	0,1407	0,0135	0,0844	0,1207	±0,0138

* Predicted specific growth rates falling within standard deviations of measured specific growth rates.

Table 5.10 Specific growth rates (U) predicted for marginal plants from the P (SRP and total P) concentrations in the water, over each growing interval, at the Hartbeespoort Dam site compared with the measured specific growth rates. Maximum specific growth rates (Umax) predicted for marginal plants, over each growing interval, using the regression equation relating the assumed Umax's of marginal plants in the field exponentially to the products of the reciprocals of the Absolute mean daily air temperatures, diffuse radiant fluxes and mean daily relative humidities.

Growing interval	Predicted values			Measured values	
	Umax g fresh mass g^{-1} d^{-1}	U g fresh mass g^{-1} d^{-1}		U g fresh mass g^{-1} d^{-1}	Standard deviation
Dates		SRP	total P		
1977					
28/9 - 11/10	0,0940	*0,0484	*0,0496	0,0313	±0,0209
14/10 - 27/10	0,0780	0,0408	0,0427	0,0207	±0,0070
3/11 - 11/11	0,0724	*0,0499	*0,0509	0,0375	±0,0149
18/11 - 25/11	0,1108	*0,0716	*0,0748	0,0672	±0,0362
14/12 - 22/12	0,1306	0,0889	0,0908	0,0410	±0,0157

* Predicted specific growth rates falling within standard deviations of measured specific growth rates.

Table 5.11 Specific growth rates (U) predicted for marginal plants from the N (NO_3-N, NH_4-N and total N) concentrations in the water, over each growing interval, at 3 sites compared with the measured specific growth rates. Maximum specific growth rates (Umax) predicted for marginal plants, over each growing interval, using the regression equation relating the assumed Umax's of marginal plants in the field exponentially to the products of the reciprocals of the Absolute mean daily air temperatures, diffuse radiant fluxes and mean daily relative humidities.

Growing interval Dates	Predicted values Umax g fresh mass g^{-1} d^{-1}	U g fresh mass g^{-1} d^{-1} NO_3-N	NH_4-N	total N	Measured values U g fresh mass g^{-1} d^{-1}	Standard deviation
Isipingo Lake						
1977						
11/8 - 17/8	0,0900	0,0394	*0,0642	*0,0689	0,0641	±0,0227
17/8 - 25/8	0,0961	0,0169	*0,0625	*0,0648	0,0506	±0,0195
25/8 - 1/9	0,1156	0,0040	*0,0718	*0,0724	0,0745	±0,0222
1/9 - 7/9	0,1128	0,0006	0,0774	0,0775	0,1247	±0,0314
Discharge Canal						
1977						
3/11 - 16/11	0,1349	*0,1116	*0,0809	*0,1164	0,0965	±0,0236
18/11 - 30/11	0,1344	*0,1119	0,0648	*0,1150	0,1035	±0,0269
1/12 - 14/12	0,1357	*0,1127	*0,0666	*0,1159	0,0940	±0,0280
Isipingo Canal						
1977						
8/9 - 23/9	0,1261	0,0534	0,0732	0,0856	0,1201	±0,0197
23/9 - 4/10	0,1306	0,0417	0,0832	0,0901	0,1115	±0,0155
5/10 - 26/10	0,1321	0,0549	0,0749	0,0884	0,1167	±0,0132

* Predicted specific growth rates falling within standard deviations of measured specific growth rates.

Table 5.12 A comparison of the differences between measured specific growth rates and those predicted for marginal plants from the growth rate limiting total N or total P concentrations in the water at 3 sites, where the predicted values were calculated using Umax values, in the Monod model, corrected for:

A the mean daily air temperature and diffuse radiant flux,

B the mean daily air temperature, diffuse radiant flux and mean daily relative humidity.

Growing interval Dates	Differences g fresh mass g^{-1} d^{-1} A	B
Botanic Gardens Lake		
1978		
1/2 - 15/2	*0,0212	0,0223
17/2 - 1/3	*0,0316	0,0351
2/3 - 14/3	*0,0065	0,0074
16/3 - 28/3	0,0019	*0,0000
31/3 - 12/4	*0,0036	0,0040
14/4 - 25/4	0,0110	*0,0099
28/4 - 9/5	*0,0186	0,0198
12/5 - 23/5	*0,0003	0,0007
26/5 - 6/6	0,0078	*0,0067
9/6 - 20/6	0,0147	*0,0079
23/6 - 4/7	0,0133	*0,0120
7/7 - 18/7	*0,0056	0,0057
20/7 - 2/8	*0,0177	0,0192
4/8 - 15/8	*0,0030	0,0100
18/8 - 29/8	0,0161	*0,0120
1/9 - 13/9	*0,0004	0,0021
15/9 - 27/9	0,0113	*0,0107
29/9 - 11/10	0,0039	*0,0028
13/10 - 23/10	*0,0131	0,0147
25/10 - 7/11	0,0252	*0,0249
10/11 - 22/11	0,0185	*0,0181
24/11 - 6/12	*0,0348	0,0363
Isipingo Lake		
1977		
11/8 - 17/8	*0,0003	0,0048
17/8 - 25/8	*0,0133	0,0142
25/8 - 1/9	0,0023	*0,0021
1/9 - 7/9	0,0486	*0,0472
Discharge Canal		
1977		
3/11 - 16/11	0,0235	*0,0199
18/11 - 30/11	0,0130	*0,0115
1/12 - 14/12	0,0264	*0,0219

* smallest difference

Table 5.13 A comparison of the differences between measured specific growth rates and those predicted for marginal plants from the growth rate limiting total P concentrations in the water at the Hartbeespoort Dam site, where the predicted values were calculated using Umax values, in the Monod model, corrected for:

A the mean daily air temperature,

B the mean daily air temperature and diffuse radiant flux,

C the mean daily air temperature, diffuse radiant flux and mean daily relative humidity.

Growing interval Dates	Differences g fresh mass g^{-1} d^{-1} A	B	C
1977			
28/9 - 11/10	0,0220	0,0348	*0,0183
14/10 - 27/10	0,0376	0,0353	*0,0220
3/11 - 11/11	0,0451	0,0413	*0,0134
18/11 - 25/11	0,0171	0,0217	*0,0076
14/12 - 22/12	*0,0439	0,0617	0,0498

* smallest difference

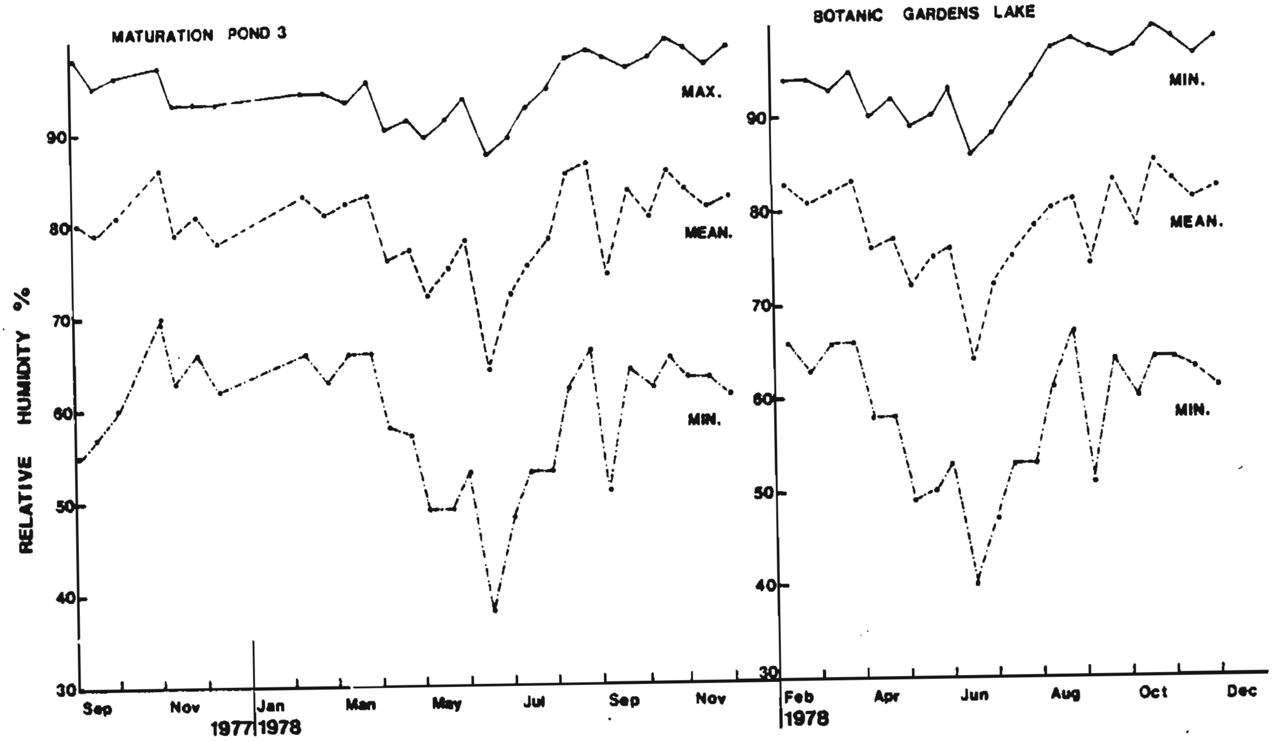


Figure 5.6 Average daily relative humidities recorded over each growing interval of marginal plants at 2 sites.

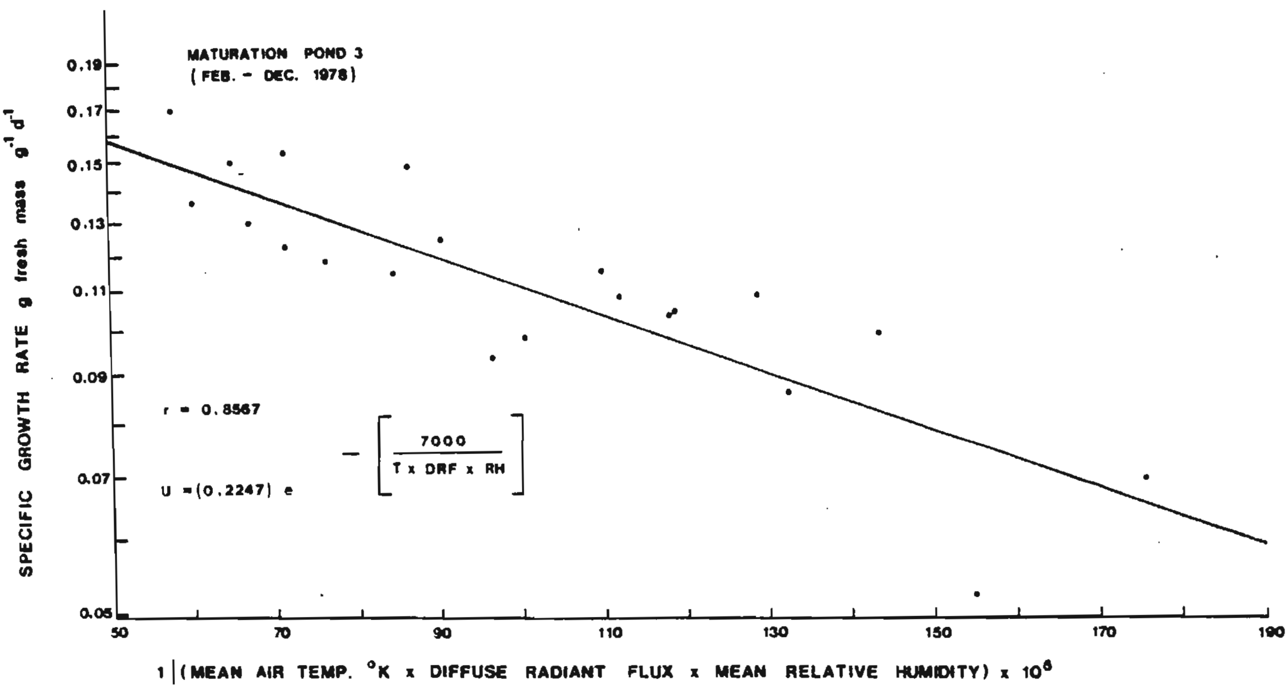


Figure 5.7 An Arrhenius plot of the specific growth rates (assumed Umax's) of marginal plants (Log_e) against the products of the reciprocals of the Absolute mean daily air temperatures, diffuse radiant fluxes and mean daily relative humidities at the Maturation Pond 3 site over the period February to December, 1978.

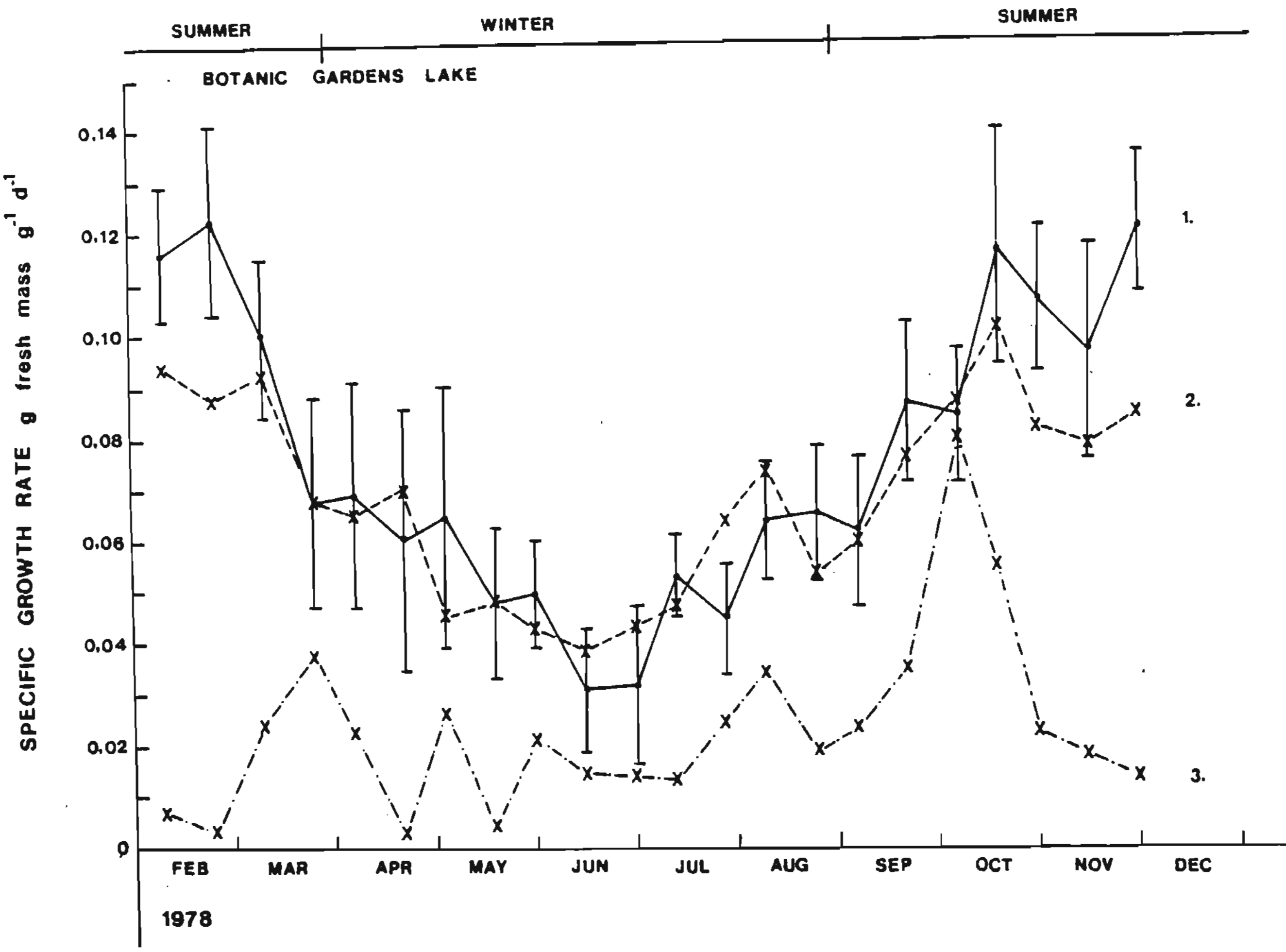


Figure 5.8 Specific growth rates predicted for marginal plants from 2. the total P and 3. the SRP concentrations in the water, over each growing interval, at the Botanic Gardens Lake site compared with 1. the measured specific growth rates. Standard deviations of measured specific growth rates are shown by bars. The predicted values were calculated using Umax values corrected for the mean daily air temperature, diffuse radiant flux and mean daily relative humidity, derived for marginal plants in the field, and the mean Ksp concentration of 94,1 ug P l^{-1}, generated for E. **crassipes** under P growth rate limitation in culture, in the Monod model.

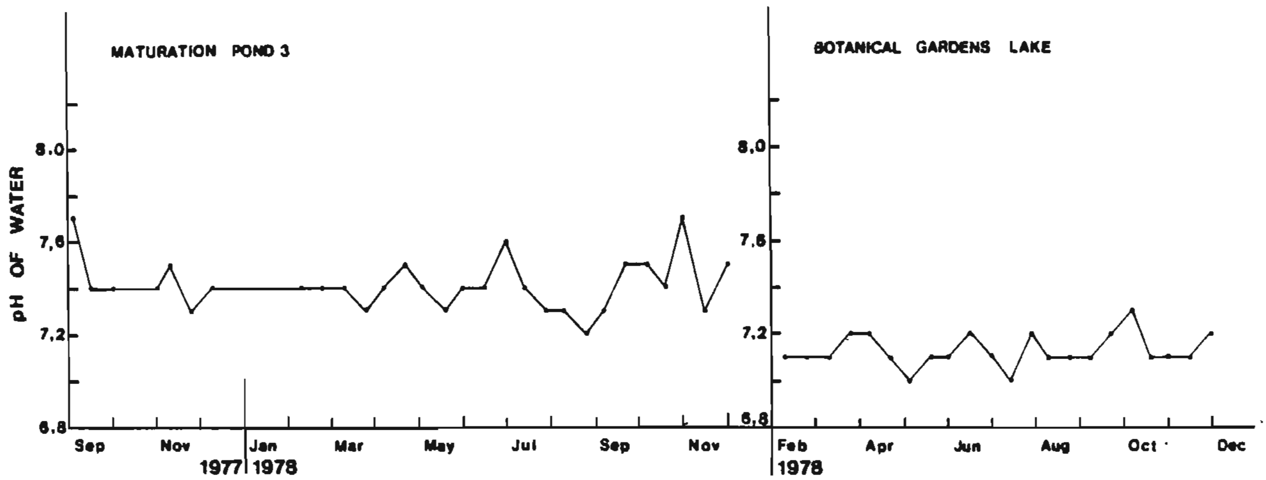


Figure 5.9 Average pH values recorded in the water, over each growing interval, from the vicinity of the marginal plant populations enclosed at 2 sites.

CHAPTER 6

PREDICTING GROWTH RATES FROM THE NUTRIENT CONCENTRATIONS IN THE PLANTS

Table 6.1 A statistical comparison of the N and P concentrations analyzed in marginal plants at the Botanic Gardens Lake (BGL) and Maturation Pond 3 (MP3) sites (means over the period 1/2/78 to 6/12/78).

Site	Nutrient concentration % dry mass N	Nutrient concentration % dry mass P
MP3	4,72	1,19
BGL	3,34	0,51
Analysis of Variance		
Variance ratio (F value)	46,90	55,93
Degrees of freedom (n-1)	128	128
Significance level %	0,1	0,1

Table 6.2 Correlation coefficients calculated between the N and P concentrations in marginal and central plants and the various N and P fractions in the water at the Maturation Pond 3 (MP3) and Botanic Gardens Lake (BGL) sites over the period February to December, 1978.

Site	Chemical factor		Correlation coefficient (r)	Degrees of freedom (n - 1)	Significance level %
MARGINAL PLANTS					
MP3	N content plants vs.	NO_3-N	0,1136	20	NS (P = 0,05)
MP3		NH_4-N	0,6859	20	0,1
MP3		total N	0,6544	20	0,1
MP3	P content plants vs.	SRP	0,4507	20	5,0
MP3		total P	0,3724	20	NS (P = 0,05)
BGL	N content plants vs.	NO_3-N	0,1943	21	NS (P = 0,05)
BGL		NH_4-N	0,1784	21	NS (P = 0,05)
BGL		total N	0,2309	21	NS (P = 0,05)
BGL	P content plants vs.	SRP	0,0184	21	NS (P = 0,05)
BGL		total P	0,1739	21	NS (P = 0,05)
CENTRAL PLANTS					
MP3	N content plants vs.	NO_3-N	0,1556	14	NS (P = 0,05)
MP3		NH_4-N	0,7612	14	0,1
MP3		total N	0,6615	14	1,0
MP3	P content plants vs.	SRP	0,8395	14	0,1
MP3		total P	0,4873	14	NS (P = 0,05)

NS = not significant

Table 6.3 A statistical comparison of the N and P concentrations analyzed in marginal and central plants at the Maturation Pond 3 (MP3) site (means over the period 3/11/77 to 6/12/78, but excluding the winter period 7/6/78 to 15/9/78 when no plants of the central growth form were produced).

Growth form	Nutrient concentration % dry mass	
	N	P
Marginal	4,61	1,15
Central	3,47	0,99
Analysis of Variance		
Variance ratio (F value)	19,41	4,26
Degrees of freedom (n-1)	104	104
Significance level %	0,1	5,0

Table 6.4 The percentage of the maximum specific growth rate (% Umax) that marginal and central plants would achieve at the average N and P concentrations in the plants at 6 field sites. Estimates are based on the average minimum N and P concentrations of 1,10% N and 0,11% P in **E. crassipes**, derived from the mean Yc values (dry mass basis) determined for this plant under N and P growth rate limitation respectively in culture.

Dates	Site	Plant tissue N (% dry mass)	Plant tissue P (% dry mass)	N/P	% Umax N	% Umax P
MARGINAL PLANTS						
1977						
11/8 - 7/9	IL	2,40	0,40	6,0	54,2*	72,5
8/9 - 26/10	IC	2,75	0,22	12,5	60,0	50,0*
3/11 - 14/12	DC	3,02	0,70	4,3	63,6*	84,3
28/9 - 22/12	HD	2,89	0,49	5,9	61,9*	77,5
1/9 - 14/12	MP3	4,79	1,20	4,0	77,0*	90,8
1978						
1/2 - 6/12	MP3	4,72	1,19	4,0	76,7*	90,8
1/2 - 6/12	BGL	3,34	0,51	6,5	67,1*	78,4
CENTRAL PLANTS						
1977						
3/11 - 14/12	DC	2,53	0,47	5,4	56,5*	76,6
3/11 - 14/12	MP3	3,63	1,22	3,0	69,7*	91,0
1978						
1/2 - 6/12	MP3	3,44	0,94	3,6	68,0*	88,3

* growth rate limiting nutrient

IL = Isipingo Lake
IC = Isipingo Canal
DC = Discharge Canal
HD = Hartbeespoort Dam
MP3 = Maturation Pond 3
BGL = Botanic Gardens Lake

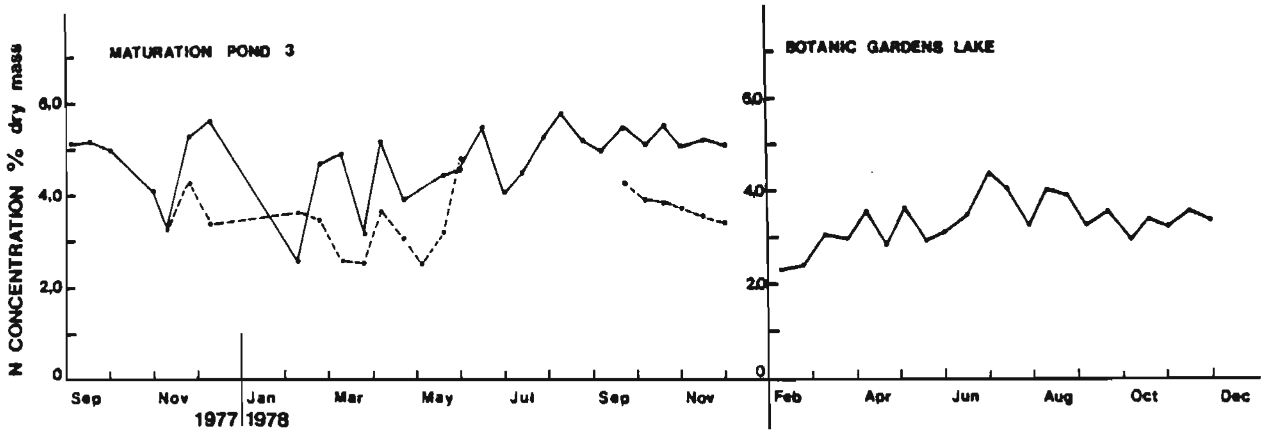


Figure 6.1 Nitrogen concentrations (means of 3 batches) analyzed in **E. crassipes** harvested after each growing interval at 2 sites. Solid line = marginal plants growing in loosely crowded field populations. Broken line = central plants growing in densely crowded field populations. No plants of the central growth form produced during June, July and August.

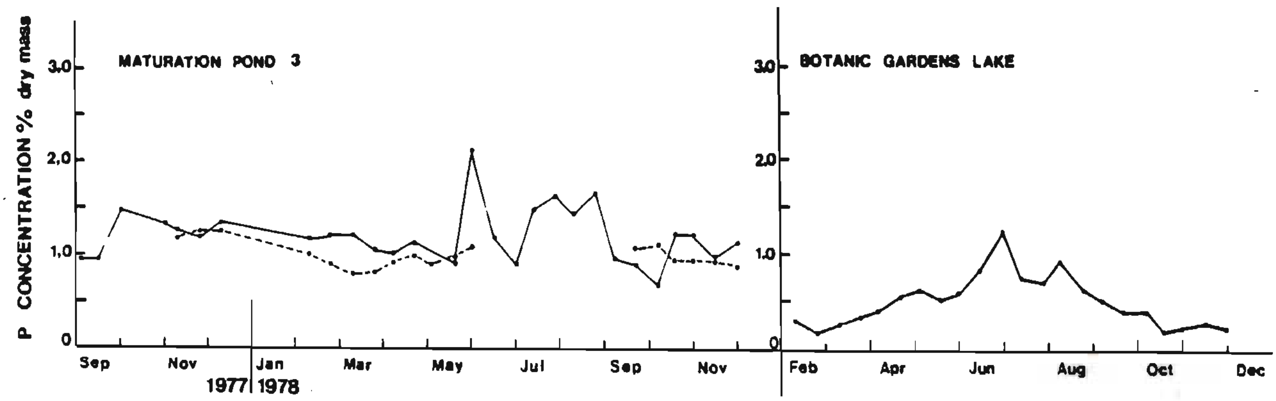


Figure 6.2 Phosphorus concentrations (means of 3 batches) analyzed in **E. crassipes** harvested after each growing interval at 2 sites. Solid line = marginal plants growing in loosely crowded field populations. Broken line = central plants growing in densely crowded field populations. No plants of the central growth form produced during June, July and August.

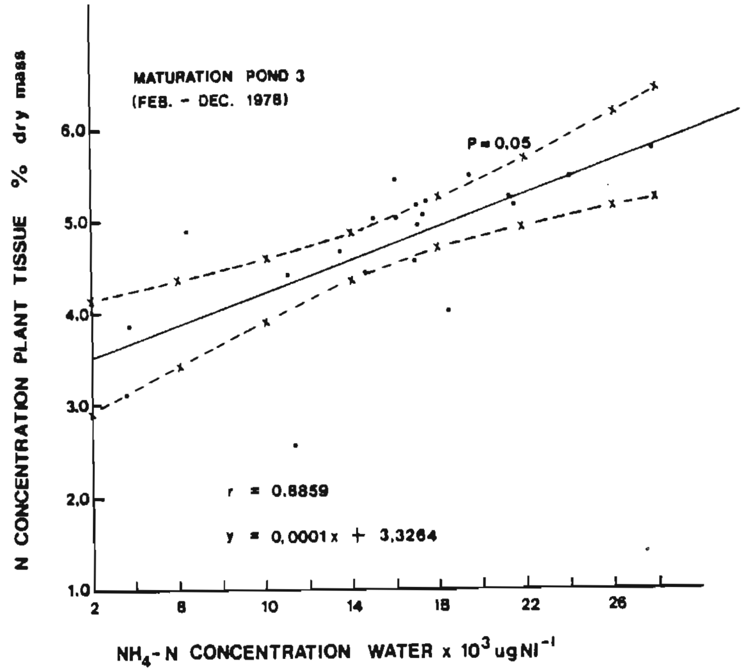


Figure 6.3 The relationship between the N concentrations in marginal plants and the NH_4-N concentrations in the water at the Maturation Pond 3 site over the period February to December, 1978. Broken lines show 95% confidence limits on either side of the regression line.

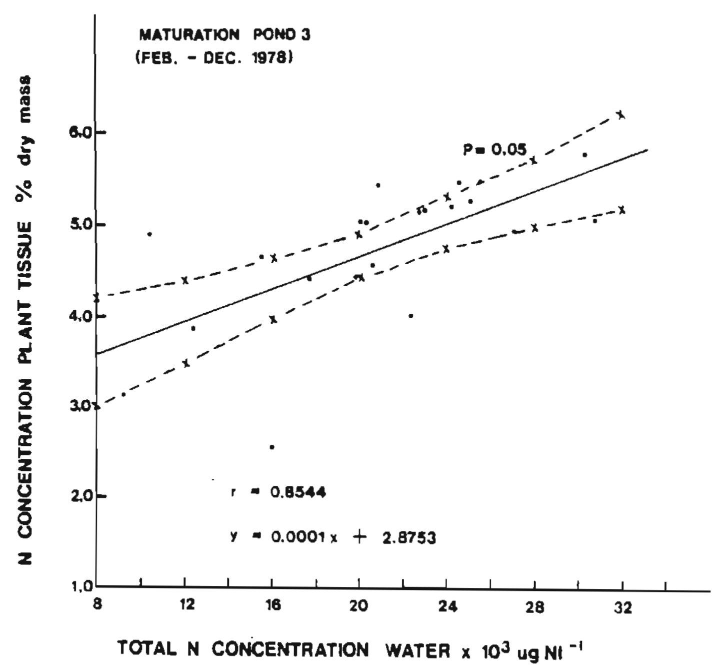


Figure 6.4 The relationship between the N concentrations in marginal plants and the total N concentrations in the water at the Maturation Pond 3 site over the period February to December, 1978. Broken lines show 95% confidence limits on either side of the regression line.

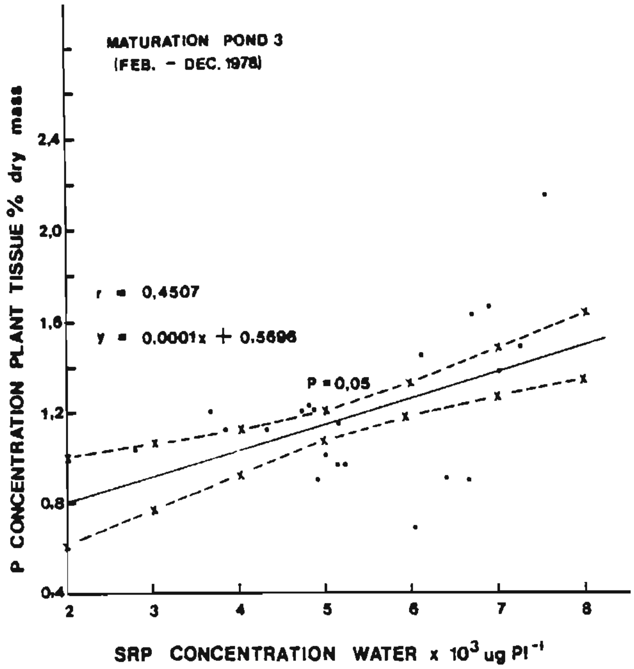


Figure 6.5 The relationship between the P concentrations in marginal plants and the SRP concentrations in the water at the Maturation Pond 3 site over the period February to December, 1978. Broken lines show 95% confidence limits on either side of the regression line.

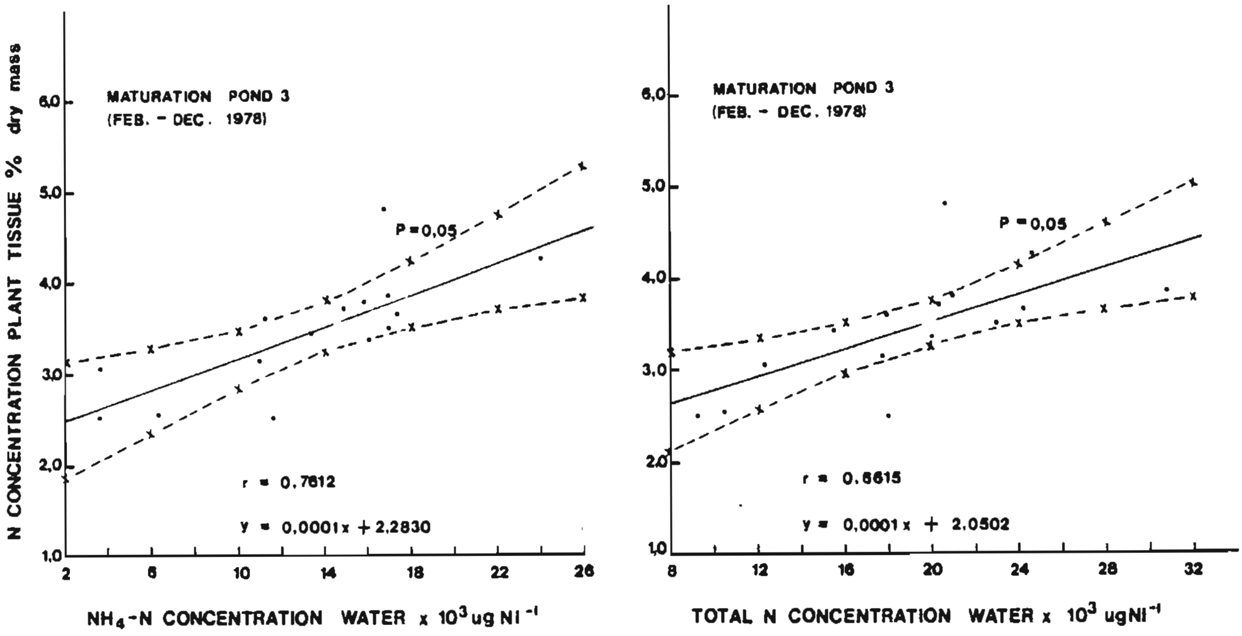


Figure 6.6 The relationship between the N concentrations in central plants and the NH_4-N and total N concentrations in the water at the Maturation Pond 3 site over the period February to December, 1978. Broken lines show 95% confidence limits on either side of the regression line.

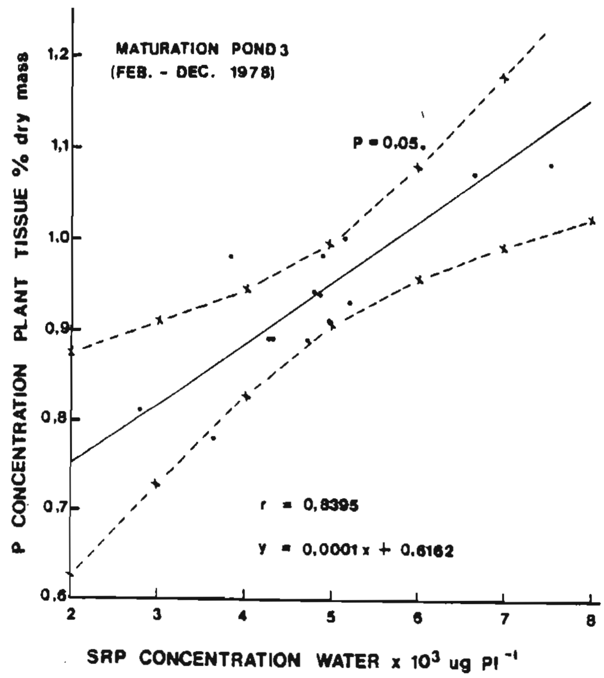


Figure 6.7 The relationship between the P concentrations in central plants and the SRP concentrations in the water at the Maturation Pond 3 site over the period February to December, 1978. Broken lines show 95% confidence limits on either side of the regression line.

Table 6.5 Specific growth rates (U) predicted for marginal plants from the N concentrations in the plants, over each growing interval, at the Botanic Gardens Lake site compared with the measured specific growth rates. Maximum specific growth rates (Umax) predicted for marginal plants, over each growing interval, using the regression equation relating the assumed Umax's of marginal plants in the field exponentially to the products of the reciprocals of the Absolute mean daily air temperatures, diffuse radiant fluxes and mean daily relative humidities.

Growing interval	Predicted values		Measured values	
	Umax	U	U	Standard
	g fresh mass	g fresh mass	g fresh mass	deviation
Dates	g^{-1} d^{-1}	g^{-1} d^{-1}	g^{-1} d^{-1}	
1978				
1/2 - 15/2	0,1416	0,0747	0,1158	±0,0130
17/2 - 1/3	0,1501	0,0816	0,1227	±0,0187
2/3 - 14/3	0,1365	*0,0879	0,0996	±0,0155
16/3 - 28/3	0,1222	*0,0771	0,0675	±0,0208
31/3 - 12/4	0,1012	*0,0698	0,0689	±0,0220
14/4 - 25/4	0,1134	*0,0692	0,0601	±0,0254
28/4 - 9/5	0,0748	*0,0524	0,0645	±0,0257
12/5 - 23/5	0,0933	*0,0583	0,0478	±0,0147
26/5 - 6/6	0,0827	*0,0533	0,0493	±0,0104
9/6 - 20/6	0,0686	0,0468	0,0305	±0,0121
23/6 - 4/7	0,0776	0,0582	0,0313	±0,0156
7/7 - 18/7	0,0899	0,0654	0,0527	±0,0080
20/7 - 2/8	0,0981	0,0649	0,0443	±0,0109
4/8 - 15/8	0,1019	*0,0743	0,0635	±0,0116
18/8 - 29/8	0,1133	0,0813	0,0651	±0,0132
1/9 - 13/9	0,0983	*0,0653	0,0615	±0,0146
15/9 - 27/9	0,1319	*0,0912	0,0867	±0,0157
29/9 - 11/10	0,1191	*0,0750	0,0843	±0,0131
13/10 - 23/10	0,1503	*0,1018	0,1162	±0,0229
25/10 - 7/11	0,1334	0,0881	0,1064	±0,0139
10/11 - 22/11	0,1242	*0,0859	0,0963	±0,0206
24/11 - 6/12	0,1407	0,0948	0,1207	±0,0138

* Predicted specific growth rates falling within standard deviations of measured specific growth rates.

Table 6.6 Specific growth rates (U) predicted for marginal plants from the N concentrations in the plants, over each growing interval, at 3 sites compared with the measured specific growth rates. Maximum specific growth rates (Umax) predicted for marginal plants, over each growing interval, using the regression equation relating the assumed Umax's of marginal plants in the field exponentially to the products of the reciprocals of the Absolute mean daily air temperatures, diffuse radiant fluxes and mean daily relative humidities.

Growing interval	Predicted values		Measured values	
	Umax	U	U	Standard deviation
Dates	g fresh mass g^{-1} d^{-1}	g fresh mass g^{-1} d^{-1}	g fresh mass g^{-1} d^{-1}	
Isipingo Lake 1977				
11/8 - 17/8	0,0900	*0,0529	0,0641	±0,0227
17/8 - 25/8	0,0961	*0,0536	0,0506	±0,0195
25/8 - 1/9	0,1156	*0,0553	0,0745	±0,0222
1/9 - 7/9	0,1128	0,0593	0,1247	±0,0314
Discharge Canal 1977				
3/11 - 16/11	0,1349	*0,0772	0,0965	±0,0236
18/11 - 30/11	0,1344	*0,0876	0,1035	±0,0269
1/12 - 14/12	0,1357	*0,0910	0,0940	±0,0280
Hartbeespoort Dam 1977				
28/9 - 11/10	0,0940	0,0563	0,0313	±0,0209
14/10 - 27/10	0,0780	0,0503	0,0207	±0,0070
3/11 - 11/11	0,0724	*0,0464	0,0375	±0,0149
18/11 - 25/11	0,1108	*0,0671	0,0672	±0,0362
14/12 - 22/12	0,1306	0,0787	0,0410	±0,0157

* Predicted specific growth rates falling within standard deviations of measured specific growth rates.

Table 6.7 Specific growth rates (U) predicted for marginal plants from the P concentrations in the plants, over each growing interval, at the Isipingo Canal site, compared with the measured specific growth rates. Maximum specific growth rates (Umax) predicted for marginal plants, over each growing interval, using the regression equation relating the assumed Umax's of marginal plants in the field exponentially to the products of the reciprocals of the Absolute mean daily air temperatures, diffuse radiant fluxes and mean daily relative humidities.

Growing interval	Predicted values		Measured values	
	Umax	U	U	Standard deviation
Dates	g fresh mass g^{-1} d^{-1}	g fresh mass g^{-1} d^{-1}	g fresh mass g^{-1} d^{-1}	
1977				
8/9 - 23/9	0,1261	0,0683	0,1201	±0,0197
23/9 - 4/10	0,1306	0,0508	0,1115	±0,0155
5/10 - 26/10	0,1321	0,0715	0,1167	±0,0132

Table 6.8 A comparison of the differences between measured specific growth rates and those predicted for marginal plants from:

A the growth rate limiting nutrient (total N or total P) concentrations in the water,

B the growth rate limiting nutrient (N or P) concentrations in the plants,

at 3 sites. In both cases, the predicted values were calculated using Umax values, in either the Monod model or Droop's simplified hyperbolic equation, corrected for the mean daily air temperature, diffuse radiant flux and mean daily relative humidity.

Growing interval Dates	Differences g fresh mass g^{-1} d^{-1} A	B
Botanic Gardens Lake		
1978		
1/2 - 15/2	*0,0223	0,0411
17/2 - 1/3	*0,0351	0,0411
2/3 - 14/3	*0,0074	0,0117
16/3 - 28/3	*0,0000	0,0096
31/3 - 12/4	0,0040	*0,0009
14/4 - 25/4	0,0099	*0,0091
28/4 - 9/5	0,0198	*0,0121
12/5 - 23/5	*0,0007	0,0105
26/5 - 6/6	0,0067	*0,0040
9/6 - 20/6	*0,0079	0,0163
23/6 - 4/7	*0,0120	0,0269
7/7 - 18/7	*0,0057	0,0127
20/7 - 2/8	*0,0192	0,0206
4/8 - 15/8	*0,0100	0,0108
18/8 - 29/8	*0,0120	0,0162
1/9 - 13/9	*0,0021	0,0038
15/9 - 27/9	0,0107	*0,0045
29/9 - 11/10	*0,0028	0,0093
13/10 - 23/10	0,0147	*0,0144
25/10 - 7/11	0,0249	*0,0183
10/11 - 22/11	0,0181	*0,0104
24/11 - 6/12	0,0363	*0,0259

Growing interval Dates	Differences g fresh mass g^{-1} d^{-1} A	B
Isipingo Lake		
1977		
11/8 - 17/8	*0,0048	0,0112
17/8 - 25/8	0,0142	*0,0030
25/8 - 1/9	*0,0021	0,0192
1/9 - 7/9	*0,0472	0,0654
Discharge Canal		
1977		
3/11 - 16/11	0,0199	*0,0193
18/11 - 30/11	*0,0115	0,0159
1/12 - 14/12	0,0219	*0,0030

* smallest difference

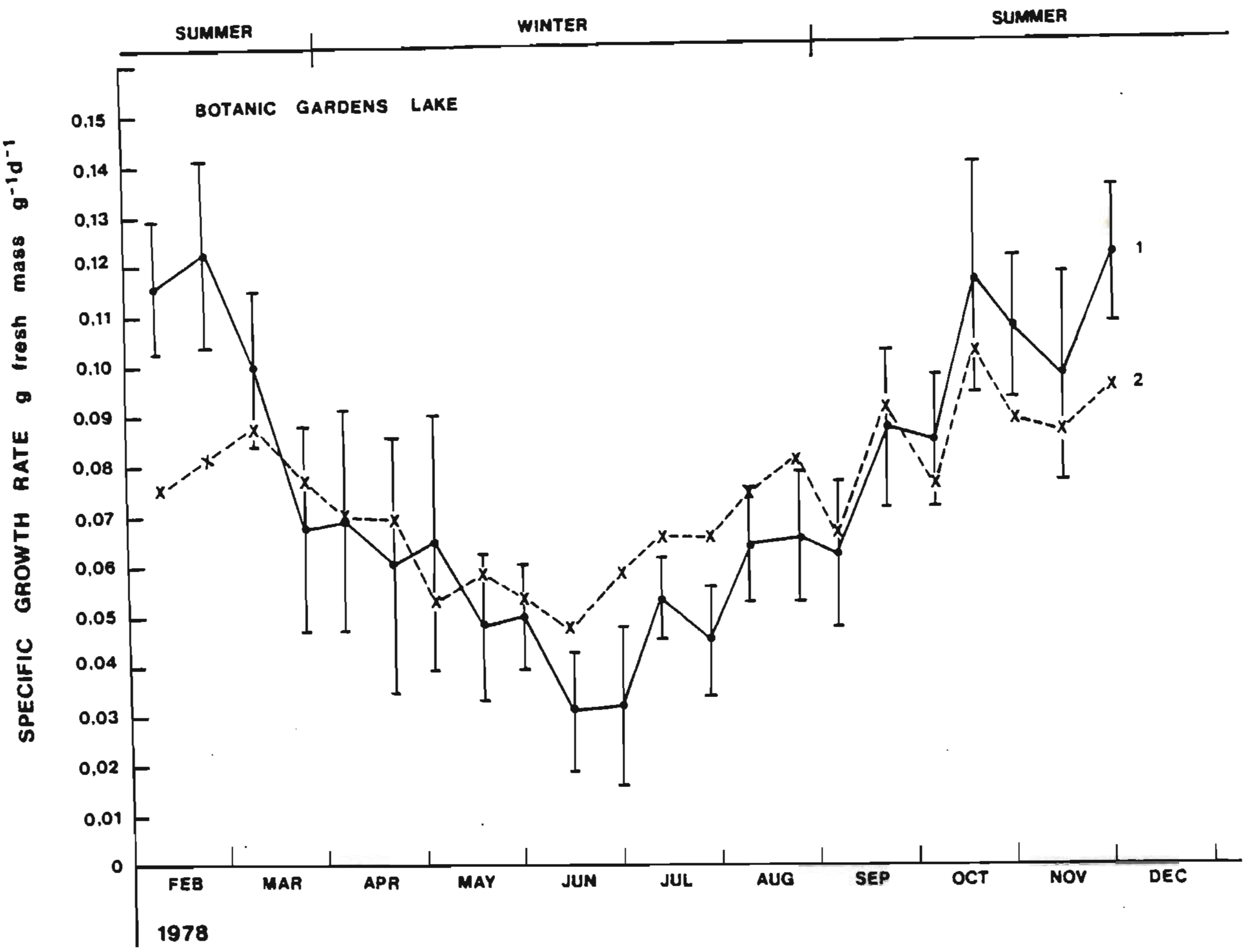


Figure 6.8 Specific growth rates predicted for marginal plants from 2. the N concentrations in the plants, over each growing interval, at the Botanic Gardens Lake site compared with 1. the measured specific growth rates . Standard deviations of measured specific growth rates are shown by bars. The predicted values were calculated using Umax values corrected for the mean daily air temperature, diffuse radiant flux and mean daily relative humidity, derived for marginal plants in the field, and the average minimum N concentration of 1,10% N in E. **crassipes**, derived from the mean Yc value for this nutrient, in Droop's simplified hyperbolic equation.

CHAPTER 7

GENERAL CONCLUSIONS AND APPLICATION OF REFINED MODEL

Table 7.1 Application of the refined model for predicting yields, growth rates and harvesting frequencies for **E. crassipes** growing in loosely crowded field populations in a hypothetical culturally eutrophied water body in the Durban area of Natal in which N is the growth rate limiting nutrient.

N concentration of effluent ug N l^{-1}		2 000	4 000	6 000	8 000	10 000
Annual growth poten= tial of effluent metric tonnes		282,96	565,92	848,88	1131,84	1414,80
Average daily growth potential of effluent metric tonnes		0,7752	1,5505	2,3257	3,1009	3,8762
Specific growth rate g fresh mass g^{-1} d^{-1}	Summer	0,0894	0,1069	0,1144	0,1185	0,1212
	Winter	0,0626	0,0749	0,0802	0,0831	0,0849
Minimum standing crop to produce average daily growth poten= tial of effluent metric tonnes	Summer	8,2891	13,7431	19,1889	24,6475	30,0830
	Winter	12,0000	19,9344	27,8527	35,7865	43,7445
Area of minimum standing crop ha ($\times 10^4$ m^2)	Summer	0,2658	0,4407	0,6153	0,7903	0,9646
	Winter	0,3848	0,6392	0,8931	1,1475	1,4027
Harvesting interval days **i.e.** number of days for each minimum standing crop to pro= duce an additional 47 metric tonnes	Summer	21,2	13,9	10,8	9,0	7,8
	Winter	25,4	16,2	12,3	10,1	8,6

Table 7.2 Stand densities (dry mass basis) reported for **E. crassipes** growing in loosely and densely crowded field populations.

Loosely crowded populations		Densely crowded populations	
Stand density $g\ m^{-2}$	Reference	Stand density $g\ m^{-2}$	Reference
221	Boyd and Scarsbrook (1975)	2130	Boyd and Scarsbrook (1975)
224	Steward (1970)	2500	Knipling **et al.** (1970)

APPENDIX I

PILOT STUDIES

Table I Average specific growth rates (U), means of 6 replicates, of **E. crassipes** grown over a 4 week growth period at different N concentrations in culture at a mean daily air temperature of 25°C day and 23°C night and a 12 hour daily photoperiod.

N concentration in culture x 10^3 ug N l^{-1}	NO_3 concentration in culture x 10^3 ug NO_3 l^{-1}	U g fresh mass g^{-1} d^{-1}
3,61	16	0,0319
5,42	24	0,0391
6,32	28	0,0471
7,22	32	0,0484
8,13	36	0,0544
9,03	40	0,0573
9,93	44	0,0567
10,84	48	0,0569
11,74	52	0,0567
12,64	56	0,0563
		LSD (0,05) = 0,0075
		LSD = least significant difference

Table II Chemical composition and ionic concentrations of cation stock solutions.

Solution No	Salt	Ionic concentration: Cations x 10^3 ug l^{-1}		Anions x 10^3 ug l^{-1}	
1 **K stock solution**					
	KNO_3	K	25,26	NO_3	40,00
	KH_2PO_4	K	8,05	PO_4	20,00
	K_2SO_4	K	8,13	SO_4	10,00
2 **Ca stock solution**					
	$Ca\ (NO_3)_2.4H_2O$	Ca	12,94	NO_3	40,00
	$Ca\ HPO_4$	Ca	8,35	PO_4	20,00
	$Ca\ SO_4$	Ca	4,17	SO_4	10,00
	$Ca\ Cl_2$	Ca	14,54	Cl	25,72
3 **Mg stock solution**					
	$Mg\ (NO_3)_2.6H_2O$	Mg	7,86	NO_3	40,00
	$Mg\ HPO_4$	Mg	5,07	PO_4	20,00
	$Mg\ SO_4$	Mg	2,53	SO_4	10,00
	$Mg\ Cl_2.6H_2O$	Mg	24,54	Cl	71,54
4 **Trace element solution**					
	Na Cl	Na	20,00	Cl	30,84
	Fe EDTA	Fe	0,40		
	$Cu\ SO_4.\ 5H_2O$	Cu	0,03		
	$Mn\ SO_4.\ H_2O$	Mn	0,27		
	$Zn\ SO_4.\ 7H_2O$	Zn	0,13		
	$H_3\ BO_3$	B	0,27		
	$(NH_4)_6\ Mo_7O_{24}.4H_2O$	Mo	0,01		

Trace element stock solution was prepared at 1000 times the concentration of the final solution. One ml of trace element stock solution was added to each litre of final culture solution derived from combining the cation stock solutions.

Table III Relative proportions at which stock solutions were combined to give 28 cation combination treatments (One unit = 4,4 x 10^3 ug l^{-1}).

K

0,9,0

1,7,1

3,6,0 0,6,3

3,5,1 2,5,2 1,5,3

3,4,2 2,4,3

6,3,0 5,3,1 4,3,2 3,3,3 2,3,4 1,3,5 0,3,6

5,2,2 4,2,3 3,2,4 2,2,5

7,1,1 5,1,3 3,1,5 1,1,7

9,0,0 6,0,3 3,0,6 0,0,9

Ca **Mg**

Table IV Average specific growth rates (g fresh mass g^{-1} d^{-1}), means of 6 replicates, of **E. crassipes** grown over a 4 week growth period at various cation combination treatments in culture at a mean daily air temperature of 25°C day and 23°C night and a 12 hour daily photoperiod.

K

0,0394

0,0594

0,0581 0,0409

0,0632 0,0613 0,0547

0,0595 0,0586

0,0561 0,0575 0,0633 0,0606 0,0596 0,0540 0,0217

0,0599 0,0606 0,0587 0,0546

0,0585 0,0589 0,0541 0,0515

0,0448 0,0485 0,0515 0,0224

Ca **Mg**

LSD (0,05) = 0,0071 LSD = least significant difference

Table V Specific growth rates (U) of **E. crassipes** grown over 3 week growth period in aerated and unaerated cultures at a mean daily air temperature of 25°C day and 23°C night and a 12 hour daily photoperiod.

Aerated cultures 10 min hr^{-1}				Unaerated cultures			
Plant No	U g fresh mass g^{-1} d^{-1}	Plant No	U g fresh mass g^{-1} d^{-1}	Plant No	U g fresh mass g^{-1} d^{-1}	Plant No	U g fresh mass g^{-1} d^{-1}
1	0,0539	16	0,0602	1	0,0685	16	0,0765
2	0,0650	17	0,0623	2	0,0733	17	0,0776
3	0,0624	18	0,0604	3	0,0790	18	0,0742
4	0,0591	19	0,0560	4	0,0687	19	0,0664
5	0,0572	20	0,0595	5	0,0696	20	0,0684
6	-	21	0,0573	6	0,0682	21	0,0662
7	-	22	0,0596	7	0,0681	22	0,0632
8	0,0506	23	0,0622	8	0,0669	23	0,0688
9	0,0569	24	0,0482	9	0,0759	24	0,0705
10	0,0527	25	0,0543	10	0,0608	25	0,0641
11	0,0531	26	0,0520	11	0,0649	26	0,0673
12	0,0510	27	0,0597	12	0,0653	27	0,0712
13	0,0586	28	0,0561	13	0,0677	28	0,0673
14	0,0571	29	0,0592	14	0,0649	29	0,0538
15	0,0476	30	0,0625	15	0,0720	30	0,0671
Means			0,0569				0,0685

Analysis of Variance

Variance ratio (F value)	82,46
Degrees of freedom (n - 1)	57
Significance level %	0,1

Table VI Nutrient concentrations analyzed in water samples taken from the vicinity of marginal and central plant populations at 3 sites (means of 3 replicates).

Growth form	Sites	Nutrient concentrations ug l^{-1}						
		Na	K	Ca	Mg	NO_3-N	NH_4-N	SRP
	Isipingo Canal	120 000	10 700	29 000	25 000	550	862	537
Marginal	Umlaas River	64 500	2 600	16 000	14 000	337	162	2
	Enseleni River	26 500	3 900	8 000	3 000	812	212	4
	Isipingo Canal	130 000	11 500	28 000	24 000	400	1 500	800
Central	Umlaas River	66 000	2 200	16 000	14 000	250	250	4
	Enseleni River	28 000	3 500	6 000	2 000	800	312	7

Table VII Nutrient concentrations analyzed in whole **E. crassipes** plants (means of 3 batches).

Sites	Nutrient concentrations % dry mass					
	Na	K	Ca	Mg	P	N
Isipingo Canal	0,395	3,633	1,032	0,524	0,729	-
Umlaas River	0,189	2,861	1,085	0,526	0,355	2,957
Enseleni River	0,251	2,811	1,167	0,736	0,215	-

Table VIII Variance ratios (F values) for data on chemical analysis of **E. crassipes** plant tissue.

Nutrient	1	2	3	4	Interactions		
	Batches	Sites	Plants parts	Growth form	3/4	2/4	2/3
Na	0,35	**23,29	**63,91	**50,06	**10,89	*3,85	*5,53
K	0,35	1,40	**22,47	**12,04	** 7,18	1,32	1,68
Ca	1,60	1,39	**27,69	0,00	1,08	1,36	2,01
Mg	0,39	**13,58	**24,89	**19,78	** 7,76	0,01	0,29
P	1,02	**68,81	**16,19	* 4,74	2,99	1,44	1,07
N	0,19	-	**58,23	**16,30	* 5,07	-	-

* Significant at P = 0,05
** Significant at P = 0,01
\- no data obtained

Table IX Nutrient concentrations analyzed in various plant parts of **E. crassipes** (means of 3 batches).

Plant part	Nutrient concentrations % dry mass					
	Na	K	Ca	Mg	P	N
Roots	0,178	1,417	0,767	0,481	0,309	1,789
Petioles	0,479	5,072	1,368	0,784	0,423	2,171
Pseudolaminae	0,178	2,817	1,149	0,521	0,567	4,911

Table X Nutrient concentrations analyzed in whole marginal and central plants (means of 3 sites).

Growth form	Nutrient concentrations % dry mass					
	Na	K	Ca	Mg	P	N
Marginal	0,368	2,322	1,094	0,680	0,393	3,122
Central	0,189	3,881	1,095	0,511	0,474	2,793

Table XI Nutrient concentrations (% dry mass) analyzed in various parts of marginal and central plants (means of 3 sites).

Nutrient	Growth form	Plant part		
		Roots	Petioles	Pseudolaminae
Na	Marginal	0,197	0,642	0,264
	Central	0,159	0,318	0,091
K	Marginal	1,222	3,089	2,655
	Central	1,611	7,055	2,978
Ca	Marginal	0,831	1,357	1,095
	Central	0,702	1,379	1,204
Mg	Marginal	0,641	0,897	0,503
	Central	0,321	0,672	0,539
P	Marginal	0,311	0,321	0,547
	Central	0,308	0,525	0,588
N	Marginal	1,806	2,503	5,057
	Central	1,774	1,839	4,765

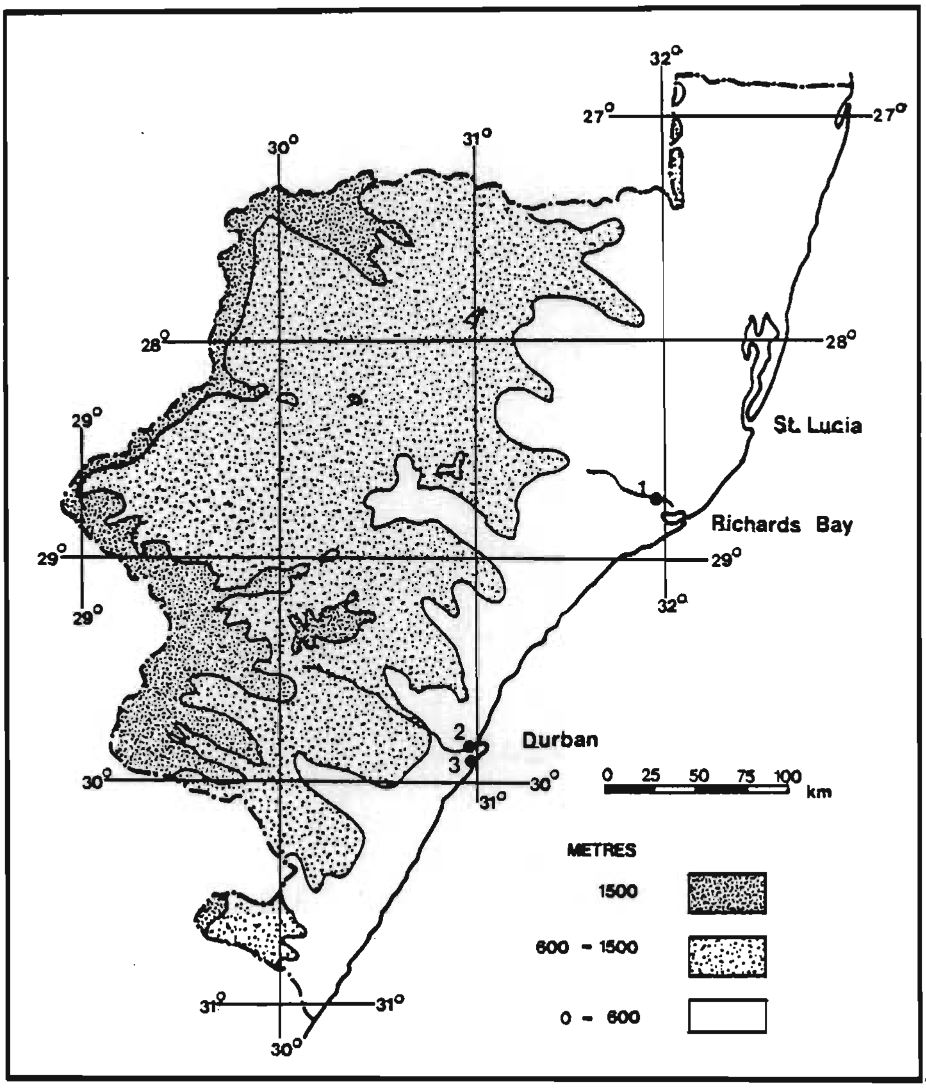


Figure I Sites of collection of E. **crassipes**. 1. Enseleni River 2. Umlaas River 3. Isipingo Canal.

APPENDIX II FIELD DATA

Table I Field data collected during growth of marginal plants.

	PLANTS		CHEMICAL ANALYSES				
Growing interval	*SGR g fresh mass g^{-1} d^{-1}	Standard deviation *n = 40	Plants % dry mass		Water ug l^{-1}		
Dates			N	P	NO_3-N	NH_4-N	total N
MATURATION POND 3							
1977							
1/9 - 7/9	0,1991	± 0,0263	5,13	0,94	6894	16024	22918
8/9 - 21/9	0,1450	± 0,0165	5,16	0,94	2377	17510	19887
23/9 - 4/10	0,1542	± 0,0163	4,97	1,47	12249	8150	20399
28/10 - 2/11	0,1662	± 0,0491	4,08	1,32	3422	10806	14228
3/11 - 16/11	0,1668	± 0,0211	3,23	1,25	1000	14840	15840
18/11 - 30/11	0,1544	± 0,0221	5,28	1,18	4730	10620	15350
1/12 - 14/12	0,1214	± 0,0236	5,66	1,33	4735	12500	17235
Means	**0,1581**	**± 0,0250**	**4,79**	**1,20**	**5058**	**12921**	**17979**
1978							
1/2 - 16/2	0,1498	± 0,0227	2,55	1,15	4740	11230	15970
17/2 - 1/3	0,1698	± 0,0214	4,66	1,20	2116	13360	15476
2/3 - 14/3	0,1534	± 0,0312	4,89	1,20	4120	6320	10440
16/3 - 29/3	0,1481	± 0,0395	3,12	1,04	5580	3600	9180
31/3 - 11/4	0,1146	± 0,0191	5,18	1,00	6919	17313	24232
14/4 - 26/4	0,0936	± 0,0314	3,86	1,12	8640	3652	12292
28/4 - 9/5	-	-	-	-	6480	11520	18000
12/5 - 24/5	0,1084	± 0,0249	4,39	0,89	6700	10974	17674
26/5 - 7/6	0,0987	± 0,0128	4,54	2,13	3796	16830	20626
9/6 - 21/6	0,0693	± 0,0196	5,46	1,17	6150	19382	25532
23/6 - 5/7	0,0526	± 0,0126	4,00	0,90	4000	18391	22391
7/7 - 19/7	0,0859	± 0,0155	4,43	1,47	5280	14560	19840
20/7 - 2/8	0,1041	± 0,0220	5,24	1,62	3914	21173	25087
4/8 - 16/8	0,1082	± 0,0125	5,74	1,44	2549	27786	30335
18/8 - 30/8	0,0981	± 0,0129	5,13	1,65	1369	21389	22758
1/9 - 13/9	0,1036	± 0,0150	4,92	0,96	10088	16980	27068
15/9 - 27/9	0,1179	± 0,0198	5,44	0,89	559	24035	24594
29/9 - 12/10	0,1239	± 0,0186	5,03	0,68	13600	17155	30755
13/10 - 24/10	0,1358	± 0,0194	5,43	1,22	4990	15890	20880
25/10 - 8/11	0,1223	± 0,0241	5,01	1,21	5372	14900	20272
10/11 - 22/11	0,1147	± 0,0261	5,14	0,96	5980	16973	22953
24/11 - 6/12	0,1292	± 0,0357	5,02	1,12	4050	16000	20050
Means	**0,1144**	**± 0,0217**	**4,72**	**1,19**	**5318**	**15428**	**20746**
Range	**0,0526** to **0,1698**	**± 0,0125** to **± 0,0395**	**2,55** to **5,74**	**0,68** to **2,13**	**559** to **13600**	**3600** to **27786**	**9180** to **30755**

*SGR = specific growth rate *n = number of replicates

Table I (continued)

CHEM. AN.(cont.)		PHYSICAL ANALYSES											
Water(cont.)		Water			Atmosphere								
ug l^{-1}		pH	*DO	Temp	Temp. °C			Rel. humidity %			Photo-	*DRF	
SRP	total P		mg l^{-1}	°C	Mean	Max	Min	Mean	Max	Min	period (hrs)	megajoules m^{-2} hr^{-1}	
MATURATION POND 3													
1977													
6403	7096	7,7	6,8	21,5	19,9	25,3	14,3	80	98	55	12,0	0,4333	
6344	7183	7,4	1,8	21,0	20,4	24,8	15,6	79	95	57	12,0	0,5126	
5272	7435	7,4	1,1	22,5	19,8	24,1	15,9	81	96	60	11,9	0,5440	
5286	7627	7,4	1,3	24,0	21,7	24,9	19,0	86	97	70	12,8	0,6400	
6995	7210	7,5	1,6	23,5	20,5	24,3	16,4	79	93	63	13,8	0,5918	
6300	7200	7,3	1,2	24,5	22,5	26,1	18,8	81	93	66	13,8	0,5685	
5720	11680	7,4	2,7	26,0	23,9	27,3	20,6	78	93	62	13,7	0,5987	
6046	**7921**	**7,4**	**2,3**	**23,3**	**21,2**	**25,2**	**17,2**	80	95	**62**	**12,8**	**0,5555**	
1978													
5140	6700	7,4	2,9	27,5	24,9	28,3	21,8	83	94	66	13,3	0,6243	
4712	9435	7,4	4,5	27,0	23,5	27,3	20,2	81	94	63	12,8	0,7215	
3648	4552	7,4	4,2	27,8	25,2	28,8	22,1	82	93	66	11,9	0,5741	
2770	4288	7,3	5,9	26,0	25,0	28,8	21,4	83	95	66	12,0	0,4686	
4970	6298	7,4	5,1	23,0	23,5	26,6	18,9	76	90	58	11,7	0,4039	
3830	4832	7,5	4,4	23,0	20,7	25,9	17,0	77	91	57	11,5	0,4592	
4270	5449	7,4	6,8	19,0	19,2	24,3	14,3	72	89	49	11,0	0,3024	
4880	5523	7,3	4,0	20,0	19,0	25,2	13,7	75	91	49	10,2	0,3548	
7532	7821	7,4	3,0	19,0	18,7	23,9	13,8	77	93	53	10,1	0,3105	
7055	7281	7,4	1,2	15,1	16,3	22,4	10,3	64	87	38	10,0	0,3074	
6404	6986	7,6	6,1	15,5	16,1	22,1	10,3	72	89	48	10,0	0,3101	
7246	8565	7,4	1,3	17,5	17,4	22,7	12,0	75	92	53	10,0	0,3467	
6673	8587	7,3	0,4	18,0	18,1	23,3	13,1	78	94	53	9,9	0,3716	
6100	8609	7,3	0,7	19,5	18,2	22,6	13,5	85	97	62	10,7	0,3610	
6900	7230	7,2	0,3	18,5	18,6	22,2	16,4	86	98	66	11,1	0,3977	
5128	6737	7,3	3,1	18,3	17,4	21,8	12,2	74	97	51	11,8	0,3936	
6654	8533	7,5	7,2	22,0	20,2	23,5	16,7	83	96	64	11,9	0,5393	
6030	6496	7,5	3,0	20,0	18,8	21,8	15,9	80	97	62	11,9	0,4747	
4800	5088	7,4	4,1	21,3	20,1	23,8	17,1	85	99	65	12,6	0,6685	
4860	5012	7,7	6,1	25,0	20,9	24,7	17,9	83	98	63	12,8	0,5741	
5210	5590	7,3	2,5	23,5	21,9	25,5	18,5	81	96	63	13,3	0,4942	
4300	4910	7,5	6,7	26,2	23,0	26,5	19,9	82	98	61	13,8	0,6158	
5414	**6569**	**7,4**	**3,8**	**21,5**	**20,3**	**24,6**	**16,2**	79	94	58	**11,5**	**0,4579**	
2770	4288	**7,2**	**0,3**	**15,1**	**16,1**	**21,8**	10,3	64	87	38	**9,9**	**0,3024**	
to	to	to	to	to	to	to	to	to	to	to	to	to	
7532	9435	**7,7**	**7,2**	**27,8**	**25,2**	**28,8**	**22,1**	86	98	66	**13,8**	**0,7215**	

*DO = dissolved oxygen *DRF = diffuse component of radiant flux

Table II Field data collected during growth of marginal plants.

Growing interval	PLANTS		CHEMICAL ANALYSES				
	*SGR g fresh mass g^{-1} d^{-1}	Standard deviation *n = 40	Plants % dry mass		Water ug l^{-1}		
Dates			N	P	NO_3-N	NH_4-N	total N
BOTANIC GARDENS LAKE							
1978							
1/2 - 15/2	0,1158	± 0,0130	2,33	0,30	7650	574	8224
17/2 - 1/3	0,1227	± 0,0187	2,41	0,18	6014	740	6754
2/3 - 14/3	0,0996	± 0,0155	3,09	0,26	7230	1144	8374
16/3 - 28/3	0,0675	± 0,0208	2,98	0,34	9600	836	10436
31/3 - 12/4	0,0689	± 0,0220	3,55	0,40	9954	1132	11086
14/4 - 25/4	0,0601	± 0,0254	2,82	0,56	9260	1044	10304
28/4 - 9/5	0,0645	± 0,0257	3,68	0,63	15200	524	15724
12/5 - 23/5	0,0478	± 0,0147	2,93	0,51	11350	1125	12475
26/5 - 6/6	0,0493	± 0,0104	3,10	0,57	9775	798	10537
9/6 - 20/6	0,0305	± 0,0121	3,47	0,84	12492	1170	13662
23/6 - 4/7	0,0313	± 0,0156	4,41	1,26	6985	805	7790
7/7 - 18/7	0,0527	± 0,0080	4,04	0,75	8248	908	9156
20/7 - 2/8	0,0443	± 0,0109	3,25	0,71	9544	1340	10884
4/8 - 15/8	0,0635	± 0,0116	4,06	0,93	10841	1772	12613
18/8 - 29/8	0,0651	± 0,0132	3,90	0,64	11336	679	12015
1/9 - 13/9	0,0615	± 0,0146	3,28	0,53	9083	1428	10511
15/9 - 27/9	0,0867	± 0,0157	3,57	0,40	8267	1152	9419
29/9 - 11/10	0,0843	± 0,0131	2,97	0,40	10030	1092	11122
13/10 - 23/10	0,1162	± 0,0229	3,41	0,20	6700	2173	8873
25/10 - 7/11	0,1064	± 0,0139	3,24	0,24	7287	1332	8619
10/11 - 22/11	0,0963	± 0,0206	3,57	0,29	7000	1310	8310
24/11 - 6/12	0,1207	± 0,0138	3,37	0,24	6520	1105	7625
Means	**0,0752**	**± 0,0160**	**3,34**	**0,51**	**9107**	**1099**	**10206**
Range	**0,0305 to 0,1227**	**± 0,0080 to ± 0,0257**	**2,33 to 4,41**	**0,18 to 1,26**	**6014 to 15200**	**524 to 2173**	**6754 to 15724**

*SGR = specific growth rate *n = number of replicates

Table II (continued)

CHEM. AN.(cont.) Water(cont.) ug l^{-1} SRP	total P	pH	PHYSICAL ANALYSES Water *DO mg l^{-1}	Temp °C	Atmosphere Temp. °C Mean	Max	Min	Rel. humidity % Mean	Max	Min	Photo-period (hrs)	*DRF megajoules m^{-2} hr^{-1}
BOTANIC GARDENS LAKE												
1978												
5	183	7,1	8,1	27,0	24,9	28,4	21,8	83	94	66	13,3	0,6127
2	132	7,1	9,8	27,8	23,5	27,3	20,2	81	94	63	12,8	0,7215
20	196	7,1	9,3	27,0	25,2	28,8	22,1	82	93	66	11,9	0,5741
42	116	7,2	10,8	25,0	25,1	28,7	21,5	83	95	66	12,0	0,4643
27	168	7,2	6,3	23,0	23,3	26,5	18,6	76	90	57	11,7	0,3896
2	152	7,1	6,8	22,0	20,9	26,1	17,1	77	92	57	11,4	0,4522
52	140	7,0	4,8	19,5	19,2	24,3	14,3	72	89	49	11,0	0,3024
4	96	7,1	9,0	20,0	19,2	25,4	14,0	75	90	50	10,2	0,3632
32	100	7,1	4,1	19,0	18,7	23,9	13,7	76	93	53	10,1	0,3156
24	120	7,2	7,1	15,5	16,3	22,4	10,3	64	86	40	10,0	0,3186
20	119	7,1	8,3	15,5	15,9	22,1	10,1	72	88	47	10,0	0,3165
15	103	7,0	6,5	17,0	17,3	22,6	11,9	75	91	53	10,0	0,3510
31	173	7,2	10,2	17,5	18,1	23,3	13,1	78	94	53	9,9	0,3716
48	244	7,1	8,1	19,0	18,1	22,5	13,4	85	97	61	10,7	0,3575
18	83	7,1	8,0	18,5	18,6	22,3	16,3	86	98	67	11,0	0,4072
29	144	7,1	5,3	18,2	17,4	21,8	12,2	74	97	51	11,8	0,3936
34	128	7,2	5,8	22,0	20,2	23,5	16,7	83	96	64	11,9	0,5393
188	256	7,3	7,1	20,5	19,1	22,2	16,1	78	97	60	11,9	0,4835
54	196	7,1	7,6	22,0	20,7	24,4	17,5	85	99	64	12,6	0,6964
19	148	7,1	4,8	25,5	20,9	24,7	19,3	83	98	64	12,8	0,5498
16	160	7,1	6,9	23,0	21,9	25,5	18,5	81	96	63	13,3	0,4942
10	141	7,2	9,3	26,0	23,0	26,5	19,9	82	98	61	13,8	0,6158
31	**150**	**7,1**	**7,4**	**21,4**	**20,3**	**24,7**	**16,3**	**79**	**94**	**58**	**11,5**	**0,4587**
2	**83**	**7,0**	**4,1**	**15,5**	**15,9**	**21,8**	**10,1**	**64**	**86**	**40**	**9,9**	**0,3024**
to	**to**	**to**	**to**	**to**	**to**	**to**	**to**	**to**	**to**	**to**	**to**	**to**
188	**256**	**7,3**	**10,8**	**27,8**	**25,2**	**28,8**	**22,1**	**86**	**99**	**66**	**13,8**	**0,7215**

*DO = dissolved oxygen *DRF = diffuse component of radiant flux

Table III Field data collected during growth of marginal plants.

Growing interval Dates	PLANTS: *SGR g fresh mass g^{-1} d^{-1}	PLANTS: Standard deviation *n = 40	CHEMICAL ANALYSES: Plants % dry mass N	Plants % dry mass P	Water ug l^{-1} NO_3-N	Water ug l^{-1} NH_4-N	Water ug l^{-1} total N
ISIPINGO LAKE							
1977							
11/8 - 17/8	0,0641	± 0,0227	2,67	0,39	759	2432	3191
17/8 - 25/8	0,0506	± 0,0195	2,49	0,43	209	1816	2025
25/8 - 1/9	0,0745	± 0,0222	2,11	0,42	35	1601	1636
1/9 - 7/9	0,1247	± 0,0314	2,32	0,36	5	2137	2142
Means	**0,0785**	**± 0,0239**	**2,40**	**0,40**	**252**	**1996**	**2248**
ISIPINGO CANAL							
1977							
8/9 - 23/9	0,1201	± 0,0197	2,78	0,24	716	1350	2066
23/9 - 4/10	0,1115	± 0,0155	2,74	0,18	458	1716	2174
5/10 - 26/10	0,1167	± 0,0132	2,74	0,24	696	1277	1973
Means	**0,1161**	**± 0,0161**	**2,75**	**0,22**	**623**	**1448**	**2071**
DISCHARGE CANAL							
1977							
3/11 - 16/11	0,0965	± 0,0236	2,57	0,69	4680	1461	6141
18/11 - 30/11	0,1035	± 0,0269	3,16	0,81	4880	910	5790
1/12 - 14/12	0,0940	± 0,0280	3,34	0,61	4780	940	5720
Means	**0,0980**	**± 0,0262**	**3,02**	**0,70**	**4780**	**1104**	**5884**
HARTBEESPOORT DAM							
1977							
28/9 - 11/10	0,0313	± 0,0209	2,74	0,46	2360	253	2613
14/10 - 27/10	0,0207	± 0,0070	3,10	0,54	2090	605	2695
3/11 - 11/11	0,0375	± 0,0149	3,07	0,47	4300	350	4650
18/11 - 25/11	0,0672	± 0,0362	2,79	0,46	2390	360	2750
14/12 - 22/12	0,0410	± 0,0157	2,77	0,50	2680	250	2930
Means	**0,0395**	**± 0,0177**	**2,89**	**0,49**	**2764**	**335**	**3099**

*SGR = specific growth rate *n = number of replicates

Table III (continued)

CHEM. AN. (cont.)			PHYSICAL ANALYSES									
Water (cont.)			Water		Atmosphere							
ug l^{-1}		pH	*DO	Temp	Temp. °C			Rel. humidity %			Photo-	*DRF
SRP	total P		mg l^{-1}	°C	Mean	Max	Min	Mean	Max	Min	period (hrs)	megajoules m^{-2} hr^{-1}
ISIPINGO LAKE												
1977												
27	750	7,4	5,4	17,5	18,1	23,1	12,5	80	99	52	11,4	0,3285
22	912	7,4	5,8	17,7	17,2	21,9	12,1	77	98	51	11,5	0,3686
39	352	7,2	6,2	19,5	18,1	22,8	12,4	79	98	56	12,0	0,4575
43	330	7,3	5,2	21,0	19,9	25,3	14,3	80	98	55	12,0	0,4333
33	**586**	**7,3**	**5,6**	**18,9**	**18,3**	**23,3**	**12,8**	**79**	**98**	**53**	**11,7**	**0,3969**
ISIPINGO CANAL												
1977												
118	404	7,6	6,0	21,8	20,6	24,9	16,0	80	96	58	12,0	0,5158
18	216	7,6	6,4	22,0	19,8	24,1	15,9	81	96	60	11,9	0,5440
117	324	7,6	6,2	27,3	20,6	24,6	16,8	82	97	64	12,5	0,5471
84	**315**	**7,6**	**6,2**	**23,7**	**20,3**	**24,5**	**16,2**	**81**	**96**	**61**	**12,1**	**0,5356**
DISCHARGE CANAL												
1977												
2000	2380	7,7	9,6	23,7	20,5	24,3	16,4	79	96	63	13,8	0,5918
2220	2910	7,6	8,4	25,3	22,5	26,1	18,8	81	93	66	13,8	0,5685
1890	2160	7,7	6,6	25,7	23,9	27,3	20,6	78	93	62	13,7	0,5987
2037	**2483**	**7,7**	**8,2**	**24,9**	**22,3**	**25,9**	**18,6**	**79**	**94**	**64**	**13,8**	**0,5863**
HARTBEESPOORT DAM												
1977												
100	105	7,3	7,0	21,0	19,1	25,6	13,5	54	79	35	12,0	0,5091
103	114	7,3	6,0	24,0	19,8	26,3	14,2	57	89	30	12,1	0,3960
209	223	7,1	6,0	24,0	21,1	27,4	15,8	48	78	25	13,7	0,4376
172	196	7,3	5,0	26,0	21,9	28,2	16,9	62	88	40	13,7	0,5413
201	215	7,5	10,0	27,0	21,6	27,2	17,8	67	92	45	13,9	0,6535
157	**171**	**7,3**	**6,8**	**24,4**	**20,7**	**26,9**	**15,6**	**58**	**85**	**35**	**13,1**	**0,5075**

*DO = dissolved oxygen *DRF = diffuse component of radiant flux

Table IV Field data collected during growth of central plants.

Growing interval Dates	PLANTS: *SGR g fresh mass g^{-1} d^{-1}	PLANTS: Standard deviation *n = 40	CHEMICAL ANALYSES: Plants % dry mass N	P	Water ug l^{-1} NO_3-N	NH_4-N	total N
MATURATION POND 3							
1977							
3/11 - 16/11	0,0559	± 0,0190	3,26	1,17	1000	14840	15840
18/11 - 30/11	0,0573	± 0,0116	4,29	1,23	4730	10620	15350
1/12 - 14/12	0,0659	± 0,0353	3,34	1,25	4735	12500	17235
Means	**0,0597**	**± 0,0219**	**3,63**	**1,22**	**3488**	**12653**	**16142**
1978							
3/2 - 16/2	0,0324	± 0,0121	3,60	1,00	4740	11230	15970
17/2 - 1/3	0,0357	± 0,0184	3,43	0,88	2116	13360	15476
2/3 - 14/3	0,0259	± 0,0139	2,54	0,77	4120	6320	10440
16/3 - 29/3	0,0312	± 0,0137	2,50	0,81	5580	3600	9180
31/3 - 11/4	0,0403	± 0,0203	3,63	0,91	6919	17313	24232
14/4 - 26/4	0,0231	± 0,0088	3,05	0,98	8640	3652	12292
28/4 - 10/5	0,0202	± 0,0079	2,49	0,89	6480	11520	18000
12/5 - 24/5	0,0203	± 0,0089	3,14	0,98	6700	10974	17674
26/5 - 7/6	0,0242	± 0,0144	4,78	1,08	3796	16830	20626
15/9 - 27/9	0,0248	± 0,0108	4,22	1,07	559	24035	24594
29/9 - 12/10	0,0262	± 0,0115	3,84	1,10	13600	17155	30755
13/10 - 24/10	0,0299	± 0,0101	3,79	0,94	4990	15890	20880
25/10 - 8/11	0,0268	± 0,0077	3,69	0,94	5372	14900	20272
10/11 - 22/11	0,0255	± 0,0083	3,49	0,93	5980	16973	22953
24/11 - 6/12	0,0271	± 0,0101	3,35	0,89	4050	16000	20050
Means	**0,0276**	**± 0,0118**	**3,44**	**0,94**	**5576**	**13317**	**18893**
Range	**0,0202 to 0,0403**	**± 0,0077 to ± 0,0203**	**2,49 to 4,78**	**0,77 to 1,10**	**559 to 13600**	**3600 to 24035**	**9180 to 30755**
DISCHARGE CANAL							
1977							
3/11 - 16/11	0,0379	± 0,0170	2,71	0,37	4680	1461	6141
18/11 - 30/11	0,0526	± 0,0174	2,69	0,48	4880	910	5790
1/12 - 14/12	0,0338	± 0,0124	2,18	0,55	4780	940	5720
Means	**0,0414**	**± 0,0156**	**2,53**	**0,47**	**4780**	**1104**	**5884**

*SGR = specific growth rate *n = number of replicates

Table IV (continued)

CHEM. AN.(cont.)		PHYSICAL ANALYSES										
Water(cont.)		Water			Atmosphere							
ug l^{-1} SRP	total P	pH	*DO mg l^{-1}	Temp °C	Temp. °C Mean	Max	Min	Rel. humidity % Mean	Max	Min	Photo-period (hrs)	*DRF megajoules m^{-2} hr^{-1}
MATURATION POND 3												
1977												
6995	7210	7,5	1,6	23,5	20,5	24,3	16,4	79	96	63	13,8	0,5918
6300	7200	7,3	1,2	24,5	22,5	26,1	18,8	81	93	66	13,8	0,5685
5720	11680	7,4	2,7	26,0	23,9	27,3	20,6	78	93	62	13,7	0,5987
6338	**8703**	**7,4**	**1,8**	**24,7**	**22,3**	**25,9**	**18,6**	**79**	**94**	**64**	**13,8**	**0,5863**
1978												
5140	6700	7,4	2,9	27,5	24,6	28,0	21,9	83	94	67	13,3	0,6699
4712	9435	7,4	4,5	27,0	23,5	27,3	20,2	81	94	63	12,8	0,7215
3648	4552	7,4	4,2	27,8	25,2	28,8	22,1	82	93	66	11,9	0,5741
2770	4288	7,3	5,9	26,0	25,0	28,8	21,4	83	95	66	12,0	0,4686
4970	6298	7,4	5,1	23,0	23,5	26,6	18,9	76	90	58	11,7	0,4039
3830	4832	7,5	4,4	23,0	20,7	25,9	17,0	77	91	57	11,5	0,4592
4270	5449	7,4	6,8	19,0	19,2	24,8	14,2	72	89	49	11,0	0,2925
4880	5523	7,3	4,0	20,0	19,0	25,2	13,7	75	91	49	10,2	0,3548
7532	7821	7,4	3,0	19,0	18,7	23,9	13,8	77	93	53	10,1	0,3105
6654	8533	7,5	7,2	22,0	20,2	23,5	16,7	83	96	64	11,9	0,5393
6030	6496	7,5	3,0	20,0	18,8	21,8	15,9	80	97	62	11,9	0,4747
4800	5088	7,4	4,1	21,3	20,1	23,8	17,1	85	99	65	12,6	0,6685
4860	5012	7,7	6,1	25,0	20,9	24,7	17,9	83	98	63	12,8	0,5741
5210	5590	7,3	2,5	23,5	21,9	25,5	18,5	81	96	63	13,3	0,4942
4300	4910	7,5	6,7	26,2	23,0	26,5	19,9	82	98	61	13,8	0,6158
4907	**6035**	**7,4**	**4,7**	**23,3**	**21,6**	**25,7**	**17,9**	**80**	**94**	**60**	**12,0**	**0,5081**
2770	**4288**	**7,3**	**2,5**	**19,0**	**18,7**	**21,8**	**13,7**	**72**	**89**	**49**	**10,1**	**0,2925**
to	**to**	**to**	**to**	**to**	**to**	**to**	**to**	**to**	**to**	**to**	**to**	**to**
7532	**9435**	**7,7**	**7,2**	**27,8**	**25,2**	**28,8**	**22,1**	**85**	**99**	**67**	**13,8**	**0,7215**
DISCHARGE CANAL												
1977												
2000	2380	7,7	9,6	23,7	20,5	24,3	16,4	79	96	63	13,8	0,5918
2220	2910	7,6	8,4	25,3	22,5	26,1	18,8	81	93	66	13,8	0,5685
1890	2160	7,7	6,6	25,7	23,9	27,3	20,6	78	93	62	13,7	0,5987
2037	**2483**	**7,7**	**8,2**	**24,9**	**22,3**	**25,9**	**18,6**	**79**	**94**	**64**	**13,8**	**0,5863**

*DO = dissolved oxygen *DRF = diffuse component of radiant flux