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The Water Outlay by *Eichhornia crassipes* and Observations on the Plant Chemical Control

By

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With 5 Figures

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Introduction

It has been well realized that the water hyacinth, *Eichhornia crassipes* SOLMS, could be a dangerous water pest when conditions for growth are favourable. Its growth rate is so rapid, the plant could form a complete cover on the surface of canals, drains and stagnant water areas; it may even chock water channels.

In interest of water economy, realization of the magnitude of the water outlay by the plant, as well as the plant chemical control, this paper is allocated.

It presents a set of the author's observations on plant growth, on evapo-transpiration and transpiration rates of plants from tanks under conditions much comparable to a natural stand. Observations on this aquatic weed control by chemicals are presented together with the responses in respect to transpiration and growth of the chemically treated plants.

Materials and methods

A representative stand of *Eichhornia crassipes* was inspected in four seasons of 1966. The stand was an area of el-Gindi canal, a stream supplied from Ismailia Canal near Amyria, north of Cairo. Plant density, vigor and growth of 1 m^2 water surface was examined.

E. crassipes was regularly transmitted from the fresh water channel to big fresh water tanks in the open in the neighbourhood of the laboratory with a layer of soil at the bottom of the tanks. Frequent renewal of water and pumping fresh air were kept. Density and growth of the plants in the tanks were kept comparable to those in the natural stand.

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Evapotranspiration: Daily evapotranspiration rates (E_{TR}) from tanks of *E. crassipes* with the same plant density as by its natural stand were measured at the different seasons. Evaporation from a comparable free water surface (E_0) was regularly measured.

Transpiration: The daily march of transpiration rate was determined in the four seasons of the year. Transpiration rate was measured, on two hour intervals, using a modification of HUBER's 1927 quick weighing method. The time of exposure was three minutes; exposure simulated greatly the natural position of cut shoot. A checking test of the behavior of stomata during the three minutes after detachment was made using the porometer of ALVIM 1963. No temporary opening of stomata of considerable extent was observed.

Stomatal march: The daily march of stomata was followed in different seasons. The stomatal width of a large number of ethanol fixed stomata on both leaf surfaces was measured.

Leaf water content: The daily and seasonal fluctuations in leaf water content were followed.

Chemical control of the plant and effects on the water outlay and growth: Three herbicides, namely, 2,4-D amine, paraquat and dalapon (Na salt of 2,2 dichloropropionic acid) were used in the chemical control experiments. Small water tanks with a layer of soil at the bottom, were used and comparable samples of the plant were kept floating on water, the water surface being covered by a 4-mm layer of paraffin oil. Renewal of fresh water was made regularly. Open water surface tanks were kept for evaporation (E_0) data. Spraying with aqueous solutions of the herbicides of concentrations: 1000, 500, 100, 50 and 10 ppm was performed in the early morning. Comparable amounts of liquid spray was used in all cases (rate of 0.1 litre of spray soln./m^2 appr.). Control plants were kept and samples were constantly duplicated. The daily water outlay was determined by daily measurement of change in height of water level in millimeters. The daily march of water outlay was expressed in relative transpiration (T/E) percentage values. Notes on the plant responses were taken.

In aquaria experiments, plants were grown on soil extract well aerated water cultures. Growth responses of shoot and root systems were noticed after spraying the shoot with 100, 10 and 1 ppm 2,4-D amine solutions or growing the plants in 1.0—0.001 ppm 2,4-D amine solutions.

Results

Density and Vigor of *Eichhornia crassipes* in 1 m^2 Plant Cover: The data presented in Table 1, of a natural stand in 1966, denotes the vigorous growth of the plant. Of interest is the transpiring area which

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may be produced as high as 5.4, 13.2 and 15.5 times as much as the water surface in April, June and September, respectively.

Table 1

Density and vigor of *E. crassipes* on 1 m² water surface (el Gindi canal, Amyria) 1966

	No. of rosettes	No. of mature leaves	Average plant height (cm)	Transpiring area (m²)	Shoot fresh weight (kg)
January	108	552	5	3.1	1.48
April	116	522	14	5.4	2.35
June	102	378	40	13.2	4.12
September	84	280	45	15.5	5.15

Evapotranspiration: As shown from Table 2, the measured evapatranspiration (E_{TR}) from *E. crassipes* tanks was slightly higher than evaporation (E_0) of free water surface in January but was 1.5 to 2.6 times the values of E_0 from April to September.

Table 2

Measured evapotranspiration (East Cairo), as compared with Agrometeorological Station data (Giza)

	East Cairo		Agrometeorological Station Giza		
	Evaporation free water surface (E_0)	Evapotranspiration (E_{TR}) *Eichhornia* tank	Evaporation Piche	Pan Class A	Potential evapotranspiration (E_{TP}) *Lippia*
	mm/day	mm/day	mm/day	mm/day	mm/day
January	3.0	3.8	7.9	3.25	1.8
April	7.9	11.8	17.7	9.74	6.3
June	9.3	24.8	19.6	13.00	8.3
September	7.6	19.8	9.0	10.51	6.1

A comparison of evapotranspiration from *E. crassipes* water tanks with the potential evapotranspiration of irrigated soil covered with *Lippia* herb at Giza Agrometeorological Station shows that E_{TR} values for *E. crassipes* amount to almost two times E_{TP} values from *Lippia* cover in January and April and almost three times in June and Septem-

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ber. While E_{TP} determined from *Lippia* cover was always lower than E_0 (Pan Class A), E_{TR} from *E. crassipes* cover was always higher than E_0 (tank free water surface).

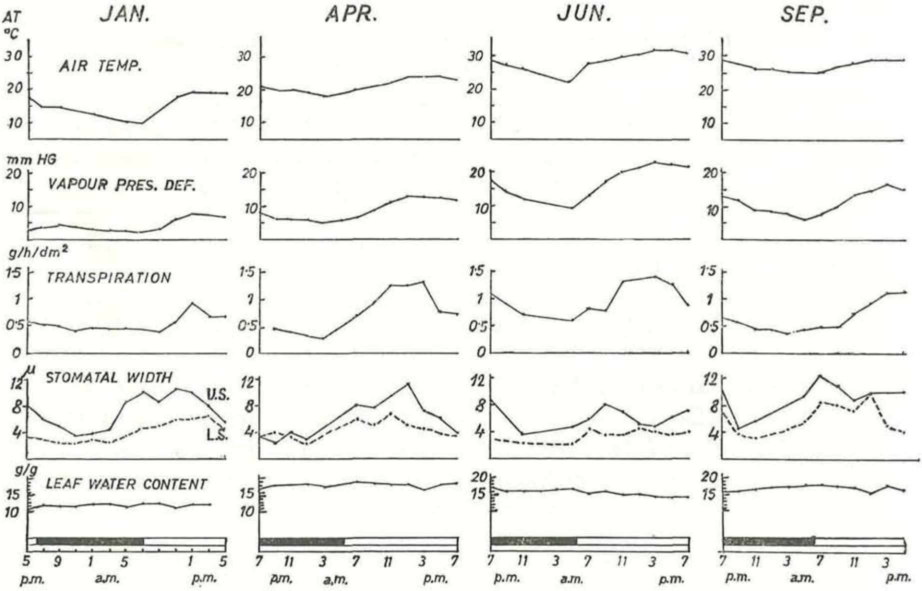

Fig. 1. The daily march of transpiration rate, stomatal width and leaf water content together with the march of air temperature and vapour pressure deficit of the atmosphere along seasons of the year.

The Daily March of Transpiration: A glance to Fig. 1 shows that the daily march of transpiration of *E. crassipes* followed to a great extent the march of the atmospheric factors especially that of the vapour pressure deficit of the atmosphere. Transpiration proceeded at appreciable rates during night, rose in the morning and reached maximal rates in the afternoon, the same as the atmospheric factors. The transpiration curve is characterized by absence of sharp peak but instead there is a flat maximum.

Minimal and Maximal Transpiration Rates: Minimal transpiration rates of the magnitude of 0.401, 0.351, 0.805 and 0.405 g/h/dm² corresponding to 9, 16, 26 and 20 g/h/100 g. fr. wt. were recorded in the four successive experiments from January to September. The maximal transpiration rates amounted to 0.956, 1.331, 1.832 and 1.010 g/h/dm² corresponding to 23, 28, 53 and 50 g/h/100 g. fr. wt. in the respective four successive experiments.

The Seasonal March of Transpiration: It is evident from Table 3 that transpiration followed a similar march to the atmospheric evaporat-

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ing factors especially the vapour pressure deficit. It rose from January to April, attained a maximum in June, and declined by September and furthermore to January.

Table 3

The seasonal march of transpiration rate of *E. crassipes*

	Air temp.	Vapour pressure deficit	Transpiration rate	
	°C	mm/Hg	mg/h/dm²	mg/h/100 g. fr. wt.
January	15.2	4.5	548	13.6
April	21.7	9.4	810	16.8
June	29.7	18.8	1208	37.2
September	27.4	11.5	668	31.8

Stomatal and Leaf Water Deficit Factors: The stomata of *E. crassipes* are bigger in size on the upper than on the lower surface of the leaf. Stomata on both leaf surfaces are continually open day and night. Stomatal width may reach maximal values amounting to 12.6 μ for the upper and 10.0 μ for the lower surface (September, Fig. 1). The stomata showed a closing tendency by night but they never reached complete closure. Minimal width amounted to 2 μ which is as high as maximal width on some land plants. Stomata are commonly open over 40% of maximum.

Fluctuations in leaf water content did not show any appreciable water deficit to be endowed by the plant which many exert a regulating action on transpiration even in the midday hours in summer.

Effect of Herbicides on Plant Growth and Transpiration: Results of the effect of spraying *E. crassipes* plants with aqueous solutions of 2,4-D amine, paraquat and dalapon on plant growth and transpiration activity are represented in Figs. (2—4). 2,4-D amine proved to be the most effective of all herbicides tested. Spraying the plant with aqueous solution of a strength as low as 50 ppm has caused complete death of the plant by eleven days after spray. Prominent depression of transpiration intensity occurred from the first day after spray with 50 ppm and stronger solutions. With 10 ppm 2,4-D amine, a survival rise occurred from the 4 th to the 7 th day after spraying followed by a decline. Paraquat is also effective by 100 ppm aqueous solution (Fig. 3). Dalapon was effective only at 500 and 1000 ppm. *E. crassipes* plants tolerated 100 ppm spray of dalapon. The rises in relative

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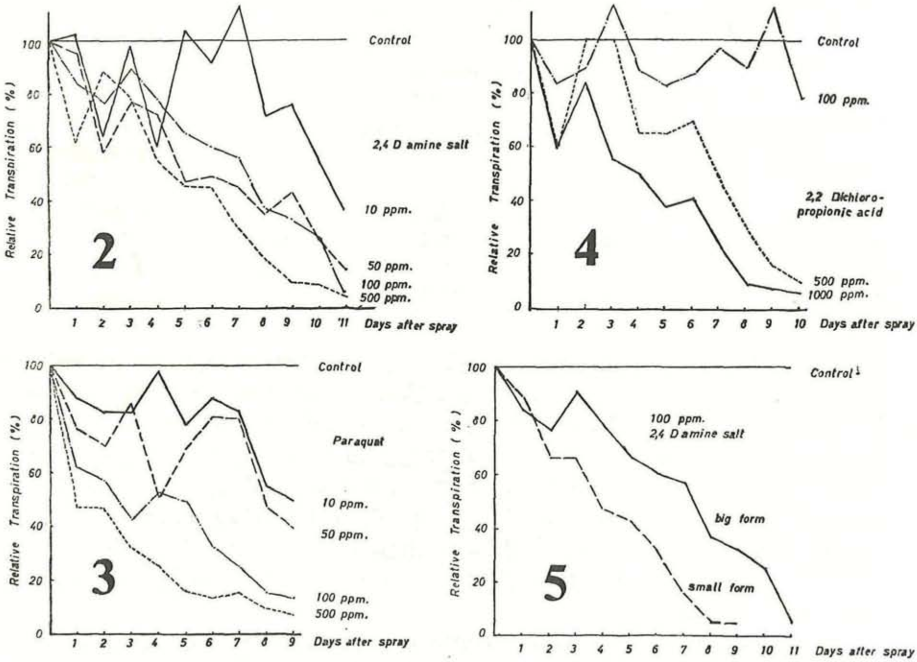
transpiration observed with this treatment are due to survival activity and transpiration of newly formed leaves (Fig. 4).

Effectiveness of 2,4-D amine on *E. crassipes* plants varied sligthly with age and form of the plant. Small forms of growth of *E. crassipes* are susceptible to the kill effect of 100 ppm 2,4-D amine spray three days earlier than bigger form of growth (Fig. 5).



Figs. 2—5. The effect of chemicals on the relative transpiration of *Eichhornia crassipes*. — Fig. 2. The effect of 2,4-D amine spray solns. (0—500 ppm). — Fig. 3. The effect of paraquat spray solns. (0—500 ppm). — Fig. 4. The effect of dalapon (Na salt of 2,2 dichloropropionic acid) spray solns. (0—1000 ppm). — Fig. 5. The effect of 2,4-D amine spray soln. (100 ppm) on big and small forms of the plant.

In aquaria experiments, complete kill of *E. crassipes* was recorded by 5 ppm 2,4-D, amine solution in 10 days. It is evident from Table 4 that 2,4-D, amine greatly affects root growth. Root elongation has practically stopped by concentrations above 0.01 ppm. Spraying 100 ppm 2,4-D amine solution has stopped root growth completely while spraying with lower concentrations diminished the rate of elongation of the root as compared with the control. Shoot growth has been slightly stimulated by 2,4-D amine (0.1 ppm spray) and 0.001 ppm water culture medium only.

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Table 4

Effect of 2,4-D amine as shoot spray and in aquaria water on shoot growth and root elongation

			shoot			Root		
			No. of healthy leaves and inflorescence axes			Maximum lenghth (cm)		
Control			initial	10 days	20 days	initial	10 days	20 days
2,4-D	100	ppm	10	12	13	29.0	31.0	35.5
amine	10	ppm	10	dead	dead	23.0	—	—
as spray	1	ppm	10	10 +infl.	11+infl.	28.2	28.5	30.2
	0,1	ppm	10	12 + 2 infl.	15 + 2 infl.	28.5	29.5	32.6
2,4-D	5.0	ppm	10	2	dead			
amine	1.0	ppm	10	9	8	29.5	29.5	29.5
in culture	0.1	ppm	10	11	11	26.0	26.0	26.0
	0.01	ppm	10	11+infl.	13+infl.	27.0	27.0	27.0
	0.001	ppm	10	11+infl.	13+infl.	27.0	29.0	30.0

Discussion

The tremendous amounts of water outlay through *E. crassipes* together with its high growth rate on water surfaces point out to this species as an evil water spend thrift plant. Evapotranspiration from *E. crassipes* water surface surpassed the potential evapotranspiration rates from a grass covered irrigated land as presented by the Agro-meteorological Office at Giza, as well as free water surface evaporation. This is attributed to differences in heat exchange between free air and the evaporating surfaces, either free water surface or plant surface. The role played by the plant cover is different in case of *E. crassipes* and *Lippia* with respect to the albedo of the exchange surface and to stomatal regulation. The stomata in *E. crassipes* are continually open, a condition which is not found in *Lippia*. Potential evapotranspiration (E_{TP}) as a climatic factor could be measured on a fairly large space scale only, (BOUCHET 1963). Some attempts have been proposed to evaluate E_{TP} on the basis of measured screen evaporation, (PENMAN 1948 and BOUCHET 1963). The measured rates of evapotranspiration (E_{TR}) from *E. crassipes* water surfaces could be taken, in a micro-climate concept, to represent the potential evapotranspiration (E_{TP}) for plant cover over water surfaces, e.g. swampy areas.

Transpiration rate in *E. crassipes* has been shown to be much correlated with climatic factors and it followed diurnal and seasonal

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fluctuations corresponding to changes in the atmospheric factors. There seems complete absence of transpiration control by stomatal closure or a leaf water deficit.

Two of the herbicides used in the present investigation have shown good promise for utilization in chemical control of *E. crassipes*. The problem of control of the plant in some other countries from water channels and reservoirs has been confronted and solved successfully; WUNDERLICH 1963, GALLAGHER 1960, RAYNES 1964, ROBINSON 1963, TILLEY 1966 and VAN VULPIN 1966. In the present investigation it has been shown that 2,4-D amine is the most effective of the herbicides tested.

As has been seen from aquaria the effect is clearly manifested on the root meristems. CRAFTS & HARVEY 1950, as example has shown that roots were from 10—100 times as sensitive to injury from 2,4-D than shoots. With regards to maturity stage, young *E. crassipes* are more susceptible than older plant. The successful toxicant effect of 2,4-D could be explained as it is readily absorbed from sprays, quickly translocated to other parts and affects specially the meristems. Death results from derangements of metabolism especially in meristems. BROWN 1946 has shown that after application of 2,4-D in herbicidal quantities the rate of photosynthesis is slightly decreased. At the same time there is a steady loss in total dry weight most clearly traced to a steady decline in weight of starch and starch like substances. In the present investigation, the transpiration rate has shown a steady decline from the time of application of the herbicide onwards. The rate of decline depended on the concentration of 2,4-D amine in the spray solution.

Paraquat has proved also to be effective in controlling *E. crassipes* by 100 ppm spray. It may be mentioned in this respect that paraquat at 0.25 ppm controlled *Lemna minor* and *Spirodela polyrhiza* in small ponds, (BLACKBURN & WELDON 1965). Dalapon (Na salt of dichloropropionic acid) though a selective grass herbicide, was less effective in control of *E. crassipes* than 2,4-D amine or paraquat. PRASAD & BLACKMAN 1965 have shown that in *Lemna minor*, dalapon entered the plant through both root and frond and largely in the ionic form. Their results did not support the view that the primary action of dalapon is to interfere with the biosynthesis of coenzyme A.

The water outlay from the chemically treated plants could be taken as indication of the plant viability as affected by the herbicide. 10 ppm 2,4-D amine and 100 ppm dalapon sprays were tolerated by the plant while higher concentrations were untolerable. At lower concentrations production of new leaves may occur at the same time while older leaves are seriously damaged. One 100 ppm spray of 2,4-D amine is efficient in killing *E. crassipes* plants whether of the vigorous summer form or the smaller winter or spring form.

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Summary

A study of the natural growth of *Eichhornia crassipes* in a water channel, northern Cairo, was made in 1966 previous to eradication of the plant. Evapotranspiration and transpiration studies were made. Daily evapotranspiration rates in *E. crassipes* water surface were 1.3—2.6 times evaporation rates from open water surfaces. Measured evapotranspiration rates (E_{TP}) from *E. crassipes* tanks are 2—3 times higher than potential evapotranspiration (E_{TP}) from *Lippia*- covered irrigated land. Measured (E_{TP}) of *E. crassipes* could be highly correlated to a microclimatic character i. e. potential evapotranspiration from plant cover over water surfaces. The plant is devoid of complete stomatal closure and water deficits of considerable extents. Transpiration followed a daily and seasonal march correlated with the atmospheric evaporating factors.

Experiments on the effect of 2,4-D amine, paraquat and dalapon on the plant was made and indications of change in relative transpiration after spraying with solutions of different concentrations were considered. 2,4-D amine proved most suitable for the plant control by 100 ppm spray solution, paraquat was also of value, while dalapon needed higher concentration. Observations on growth in shoot, and root elongation with more dilute solutions were represented.

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