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Effect of 2,4-D and Gibberellic Acid on Waterhyacinths under Operational Conditions[1]

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ABSTRACT

The effects of combinations of gibberellic acid (GA_3) and 2,4-dichlorophenoxyacetic acid (2,4-D) on waterhyacinths (*Eichhornia crassipes* (Mart.) Solms) were evaluated to determine if GA_3 increased waterhyacinth sensitivity to 2,4-D under operational conditions. Evaluations were conducted during late summer of 1982 in a dense population of mature, non-bulbous leafed, waterhyacinths in the St. Johns River, Florida. Small plot treatments (27.6 m^2) consisted of combinations of GA_3 at 0.0, 23.5, 47.0, and 94.0 g/ha and 2,4-D at 0.0, 0.56, 1.12, 2.24, and 4.48 kg/ha. Large scale treatments on three 0.4 ha plots consisted of 0.84 kg/ha 2,4-D, 0.84 kg/ha 2,4-D plus 94.0 g/ha GA_3, and 2.24 kg/ha 2,4-D. Results indicate the use of GA_3 to significantly reduce rates of 2,4-D used to control waterhyacinths on an operational basis was not justified from either an increased efficacy or economic standpoint.

Key words: growth regulation, biomass, density, economics, efficacy.

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INTRODUCTION

Various public agencies routinely utilize 2,4-dichlorophenoxyacetic acid (2,4-D) for the control of waterhyacinth in the United States. The U.S. Army Corps of Engineers, Jacksonville District, annually utilizes approximately 8,200 kg of 2,4-D at a rate of 2.24 kg/ha in a 934 l/ha aqueous solution to control waterhyacinths on the St. Johns River, Florida (2). Pieterse and Roorda (1982) reported a ten-fold enhancement of sensitivity of waterhyacinths to 2,4-D when the plants were simultaneously treated with GA_3 at 6 to 8 g/ha under greenhouse conditions. Pieterse and Roorda (1982) also suggested that such a reduction in the amount of 2,4-D needed for control would lower the risk of damage to nearby crops and vegetation. It would also be attractive from an economical point of view due to the large reduction in the amount of 2,4-D required to control waterhyacinths. To test this possibility, the following investigations were conducted: 1) various treatment rates were evaluated in small plots in a natural stand of dense waterhyacinths; 2) a selected rate of 2,4-D and GA_3 was evaluated under actual waterhyacinth control operational conditions; and 3) and economic analysis of the use of GA_3 in conjunction with 2,4-D was performed assuming that GA_3 would reduce the amount of 2,4-D required for waterhyacinth control by a factor of 10.

METHODS

Field applications were conducted during July-August, 1982, on Lake Dexter, one of a chain of lakes located on the St. Johns River, 6.7 km southeast of Astor, Florida. The waterhyacinths appeared free of any disease, but did exhibit evidence of moderate feeding by waterhyacinth weevils, *Neochetina* spp. The plants were growing in a mixed stand with *Nuphar luteum* which prevented movement of the waterhyacinths during the treatment period.

Field evaluations were conducted in two phases. In phase one, fifty-one 9.2m x 3.0m experimental plots were established with each plot separated by an untreated plot of similar size. Prior to treatment, three random 0.33 m^2 samples were taken from the plots to be treated. Plants within the 0.33 m^2 samples were counted, drained of excess water, and weighed to the nearest 0.05 kg in order to determine pretreatment biomass and number per m^2. In phase two, experimental plots were laid out as three separate 0.40 ha plots each separated by an untreated strip of waterhyacinths. Pretreatment biomass determinations were not made because the efficacy of treatments was based on visual evaluations of individual plants to obtain a proportion of dead plants per plot.

In phase one, the 51 individual plots were treated with an airboat mounted tank-mix spray system calibrated to deliver a spray volume of 467 l/ha. Each plot was treated twice to obtain a spray volume of 934 l/ha. Applications were made with a fixed boom equipped with a single Delavan Type-D20 flooding nozzle. The boom was adjusted to approximately 45 cm above the plant canopy such that the swath width was equal to 3.0 m. Treatments consisted of simultaneous applications of combinations of gibberellic acid (Asgrow Florida Company, EPA Accession No. 08728) and 2,4-D amine (Union Carbide Corporation EPA Registration No. 264-2AA) at the following rates: 0.0, 23.5, 47.0, and 94.0 g/ha gibberellic acid and 0.0, 0.56, 1.12, and 2.24 kg/ha 2,4-D. An additional 2,4-D treatment at a rate of 4.48 kg/ha without GA_3 was made due to the high waterhyacinth biomass present in the field plots. Treatments were replicated three times.

In phase two, three 0.40 ha-plots were treated by an airboat mounted tank mix, spray system calibrated to deliver 934 l/ha through a hand-held spray gun equipped with a Delavan Type DFA Dela-foam nozzle. The application was made by a spray crew employed by the U.S. Army Corps of Engineers, Jacksonville District. The crew was instructed to treat each plot in the same manner in which they conduct routine control operations. Treatments consisted of 0.84 kg/ha 2,4-D; 0.84 kg/ha 2,4-D plus 94.0 g/ha gibberellic acid; and 2.24 kg/ha 2,4-D. These rates of 2,4-D and gibberellic acid were chosen based on results of other evaluations and results of the phase one study.

Experimental plots were examined weekly for evidence of treatment effects. Phase one efficacy evalutions were conducted 25 days after treatment since plots treated with 2.24 kg/ha and 4.48 kg/ha 2,4-D appeared to exhibit 100% control. Phase one efficacy evaluations consisted of harvesting the plants in three random 0.33 m^2 samples from each treatment plot, counting the number of viable plants, removing obvious necrotic tissue, and weighing the remaining plant material to the nearest 0.05 kg in order to determine post treatment biomass. Results of phase one were analyzed for the mean percent change in fresh weight and mean percent change in number of plants from initial pretreatment levels. The means of the percent change by treatment were analyzed for the presence of significant differences utilizing Waller-Duncan procedure for the comparison of multiple means.

Phase two efficacy evaluations of visual assessment of the presence of viable meristematic tissue in the treated plots (5). At the conclusion of 22 days post-treatment, plants treated with 2.24 kg/ha 2,4-D appeared to exhibit near 100 percent control and efficacy evaluations were conducted on day 24 post-treatment. Thirty plants randomly selected on three transects through the treated plots were examined and the proportion of dead plants per plot calculated. Proportions of dead plants per treatment plot were analyzed for significant differences utilizing a method described by Walpole and Myers (1978).

An economic evaluation of the use of 2,4-D was performed by calculating the costs of converting the waterhyacinth control operation conducted by the U.S. Army Corps of Engineers on the St. Johns River, Florida, to a control program utilizing various combination of GA_3 and lower than normal rates of 2,4-D. No costs were included for labor, conversion of the spray equipment to allow the use of GA_3, or for increased storage and transportation of GA_3.

RESULTS AND DISCUSSION

Mean pretreatment biomass (fresh weight) of the Lake Dexter waterhyacinth population was 21.98 kg/m^2 (standard error 0.67) and the mean pretreatment number of plants per m^2 was 70.76 (standard error 2.92). These means are within the ranges reported by Center and Spencer (1981) for mature stands of waterhyacinths in a North-Central Florida lake during August. At the conclusion of phase one, mean fresh weight and mean number of plants per m^2 of the control plots were not significantly different from the pretreatment levels ($\alpha = 0.05$) which suggests that the plants were physiologically mature and had become space-limited as reported by Richards (1980) and Center and Spencer (1981).

Tables 1 and 2 summarize the results of the phase one evaluations of the 17 treatment combinations of GA_3 and 2,4-D in terms of mean percent change in fresh weight and mean percent change in number due to treatment, respectively.

Comparisons of Table 1 and 2 reveals that within 2,4-D rates of 0.56 and 1.12 kg/ha and any rate of GA_3, the mean percent change in fresh weight per m^2 was always greater than the mean percent change in number of plants per m^2. This was a reflection of the morphological response of the waterhyacinths to the treatments. At the lower rate of 2,4-D, the older leaves became necrotic at the base and readily separated from the plant, such that the only remaining viable tissue was the meristem, youngest leaves, and roots. However, the plants remained viable and retained the abil-

TABLE 1. MEAN PERCENT CHANGE IN FRESH WEIGHT OF WATERHYACINTHS/m² IN LAKE DEXTER, FLORIDA, TREATED WITH COMBINATIONS OF GIBBERELLIC ACID AND 2,4-D.

Treatment 2,4-D (kg/ha)	Rate GA (g/ha)	Waller-Duncan Grouping[1]	Mean	Min.	Max.	Std. Error
0.00	23.5	A	32.1	15.9	44.5	8.5
0.00	94.0	A	25.9	9.6	51.7	13.1
0.00	47.0	A	21.8	10.8	37.0	7.9
0.00	0.0	B	1.2	−7.1	7.4	4.3
0.56	94.0	C	−81.3	−84.0	−79.0	1.5
0.56	47.0	C D	−82.3	−88.2	−74.8	4.0
0.56	0.0	C D E	−86.4	−89.1	−82.7	1.9
0.56	23.5	C D E	−88.2	−88.9	−87.8	0.4
1.12	0.0	C D E	−94.3	−95.5	−93.2	0.7
1.12	47.0	D E	−96.6	−97.4	−95.5	1.6
1.12	94.0	E	−97.4	−98.0	−96.9	0.3
1.12	23.5	E	−99.1	−99.8	−98.6	0.4
2.24	23.5	E	−99.2	−99.8	−98.5	0.4
2.24	0.0	E	−99.4	−99.9	−98.9	0.2
2.24	94.0	E	−99.5	−100.0	−98.6	0.5
2.24	47.0	E	−99.7	−100.0	−99.5	0.2
4.48	0.0	E	−100.0	−100.0	−100.0	0.0

[1]Mean with the same letter are not significantly different ($\alpha = 0.05$).

ity to reinfest the plot. For this reason, the percent change in number would appear to be a more realistic estimator of efficacy on an operational basis.

According to the Waller-Duncan multiple range test, there was no significant difference in the mean change in weight or number between the three treatment rates of GA_3 (2,4-D rate = 0.0 kg/ha). There was a significant increase in the mean weight change of the three levels of GA_3 (2,4-D rate = 0.0 kg/ha) when compared to the control plots; however, the GA_3 treatments did not affect the mean number of plants per m² when compared to the control plot. Tables 1 and 2 indicate that there were no significant ($\alpha = 0.05$) increases in the efficacy of any fixed rate of 2,4-D when combined with any of the four levels of GA_3.

Table 3 presents the results of the large scale application of 2,4-D and gibberellic acid to a dense stand of waterhyacinths (phase two). Plot 3, which received 2.24 kg/ha 2,4-D, and no GA_3, had the highest percentage (80.4) of dead waterhyacinth plants per transect. The next highest percent dead plants was plot 2 which received 0.84 kg/ha 2,4-D, and 94.1 g/ha GA_3, with 34.7 percent, followed by plot 1 which received 0.84 kg/ha 2,4-D, and 0.0 g/ha GA_3, with 24.2 percent dead plants per transect. The proportions of dead plants in plots 1 and 2 were not significantly different from each other at $\alpha = 0.05$; however, the percent of dead plants in plot 3 was significantly different from plots 1 and 2 at $\alpha = 0.05$. A visual inspection of the phase two plots was conducted 63 days post-treatment. Quantitative evaluations were not possible due to disturbance of the plots by wind, currents, and the 24-day post-treatment sampling procedure. However, the visual evaluation did indicate that the waterhyacinth populations in plot 3 had been: 1) reduced to a non-problematic level and replaced by a monoculture of water lettuce, (*Pistia stratiotes* L.); and 2) plots 2 and 3 still contained problematic levels of waterhyacinth and were in need of retreatment.

TABLE 2. MEAN PERCENT CHANGE IN NUMBER OF WATERHYACINTHS/m² IN LAKE DEXTER, FLORIDA, TREATED WITH COMBINATIONS OF GIRRERELLIC ACID AND 2,4-D.

Treatment 2,4-D (kg/ha)	Rate GA (g/ha)	Waller-Duncan Grouping[1]	Mean	Min.	Max.	Std. Error
0.00	0.0	A	3.5	−15.7	15.5	9.7
0.00	94.0	A	1.7	−16.1	12.5	9.0
0.00	47.0	A	1.3	−9.3	20.0	9.4
0.00	23.5	A	−12.2	−39.6	1.6	13.7
0.56	47.0	B	−51.5	−67.7	−36.0	9.2
0.56	0.0	B	−54.4	−57.9	−51.1	2.0
0.56	23.5	B	−55.7	−68.4	−45.3	6.8
0.56	94.0	B D	−64.8	−80.0	−51.9	8.2
1.12	0.0	B D	−67.0	−76.6	−59.6	5.0
1.12	47.0	B D	−70.6	−73.8	−68.8	1.6
1.12	94.0	C D	−82.7	−82.8	−82.4	0.1
1.12	23.5	C D	−85.1	−93.5	−73.0	6.2
2.24	0.0	C	−94.9	−95.5	−94.2	0.4
2.24	23.5	C	−96.1	−98.9	−94.1	1.4
2.24	94.0	C	−96.6	−100.0	−90.9	2.9
2.24	47.0	C	−99.2	−100.0	−98.6	0.4
4.48	0.0	C	−100.0	−100.0	−100.0	0.0

[1]Means with the same letter are not significantly different ($\alpha = 0.05$).

Table 4 presents a cost comparison for use of a combination of GA_3 and 2,4-D for control of waterhyacinths on the St. Johns River, Florida, as conducted by the U.S. Army Corps of Engineers, Jacksonville District. Based on an average of 3642 ha of waterhyacinths treated per year, the normal application rate of 2,4-D (2.24 kg/ha) results in an annual herbicide cost of $27,096. With the use of GA_3 at 8.0 g/ha and a ten-fold reduction in the amount of 2,4-D required for an equivalent level of control (0.224 kg/ha), as suggested by Pieterse and Roorda (1982), the annual herbicide costs would be $35,947 or 32.7 percent higher than the current rate. Based on the results of the field application at Lake Dexter, Florida (Table 2), the lowest combination of rates of GA_3 and 2,4-D which would provide a level of control (number per m²) not significantly different from 2.24 kg/ha, 2,4-D was 23.5 g/ha and 1.12 kg/ha, respectively. This option would result in an annual herbicide cost of $111,117 or 310% higher than the current rate. The results of the field test of various treatment rates of 2,4-D and GA_3 indicated that on an operational basis, GA_3 does not enhance the effect of 2,4-D on waterhyacinths to a significant degree. The additional costs of using GA_3 and 2,4-D at the relative levels suggested by Pieterse and Roorda (1982) are not justified from an economic standpoint at the current market prices of GA_3 and 2,4-D. However, the use of these combinations under differing field conditions, stage of growth of the treated plants, and/or a significant change

TABLE 3. EFFECT OF LARGE-SCALE OPERATIONAL APPLICATION OF 2,4-D AND GIBBERELLIC ACID (GA_3) TO WATERHYACINTHS; 24 DAYS POST-TREATMENT.

Plot No.	Treatment Rate 2,4-D (kg/ha)	GA (g/ha)	Proportion of Dead Plants per Plot
1	0.84	0.0	0.242 b
2	0.84	94.1	0.347 b
3	2.24	0.0	0.804 a

Proportions followed by the same letter are not significantly different at ($\alpha = 0.05$).

TABLE 4. COSTS COMPARISON FOR THE USE OF A COMBINATION OF GA_3 AND 2,4-D COMPARED TO NORMAL APPLICATION RATES OF 2,4-D FOR THE CONTROL OF WATERHYACINTHS ON THE ST. JOHNS RIVER, FLORIDA.

Option A: Normal rate of 2,4-D (2.24 kg/ha)
1982 2,4-D costs[a] = \$3.32/kg x 2.24 kg/ha = \$7.44/ha
Annual cost = \$7.44/ha x 3642 h/yr[a] = \$27,096/yr

Option B: 8.0 g/ha GA_3 and 0.10 of normal application rate of 2,4-D (0.224 kg/ha)[b]
1982 2,4-D costs = \$3.32/kg x 0.224 kg/ha = \$0.75
1982 GA_3 costs[c] = \$1.14/g x 8.0 g/ha = \$9.12
Total \$9.87/ha

Annual costs = \$9.87/ha x 3642 ha/yr = \$35,947/yr

Option C: 23.5 g/ha GA_3 and 1.12 kg (a.e.)/ha[d]
1982 2,4-D costs = \$3.32/kg x 1.12 kg/ha = \$ 3.72/ha
1982 GA_3 costs = \$1.14/g x 23.5 g/ha = \$26.79/ha
Total \$30.51/ha

Annual costs = \$30.51/ha x 3642 ha/yr = \$111,117/yr

[a]Current bid price (McGehee, 1982).
[b]Pieterse and Roorda (1982).
[c]1982 market price (Asgrow Florida, Inc.).
[d]Lowest rates which produced a level of control which was not significantly different from 2,4-D at 2.24 kg/ha (see Table 2).

in the cost or regulatory status of 2,4-D or GA_3 may alter this situation.

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