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Title: THE EFFECTS OF N-1-NAPHTHYLPHTHALAMIC ACID ON GROWTH OF YELLOW NUTSEDGE AND ITS CONTROL WITH N-PHOSPHONOMETHYL GLYCINE

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Dr. Arnold P. Appleby

Greenhouse and growth chamber experiments were conducted with the following objectives: (a) to study the effects of N-1-naphthylphthalamic acid (naptalam) on shoot and tuber production, rhizome transformation, and growth of yellow nutsedge (Cyperus esculentus L.) plants; (b) to study the effects of N-phosphonomethyl glycine (glyphosate) on nutsedge plants at different stages of growth and on tubers that are produced after glyphosate application; and (c) to investigate the influence of naptalam on glyphosate toxicity to yellow nutsedge plants.

The application of naptalam to yellow nutsedge plants increased the number of new shoots produced by the weed when the herbicide was applied to the soil, through a liquid growth medium, or as a topical spray. The increase in the number of new shoots in naptalam-treated plants was due to the transformation of rhizomes to shoots and to an increase in the number of rhizomes produced. Growth of naptalam-treated plants was inhibited.

Split topical applications of naptalam proved to be more effective in producing new shoots than single topical applications. There was no difference in the number of new shoots produced by plants treated with either single or split soil applications except at the highest concentration where the split application resulted in more new shoots than the single application.

Results of experiments conducted in growth chambers showed that naptalam-treated plants produced more new shoots than untreated plants when grown under a 20-hour photoperiod. Growing the plants under short day conditions (10 to 12-hour photoperiod) induced tuber production but this was inhibited by naptalam application. The application of nitrogen to naptalam-treated plants grown under long day conditions increased the dry weight of new shoots produced by the plants. Naptalam was more effective in inducing the production of new shoots in younger plants than in older ones.

Glyphosate was more effective for reduction of shoot growth of younger yellow nutsedge plants than of older ones. There were no significant differences in dry weights of shoots of the plants when split and single topical applications were compared.

Tubers produced by glyphosate-treated plants sprouted less than tubers produced by the untreated plants. Glyphosate appeared to make the tubers dormant at the lower rates and to kill many of them at the

higher rates. However, over 50 percent of the tubers were not killed and were still capable of regeneration.

It was more advantageous to apply glyphosate to yellow nutsedge plants after naptalam treatment than to apply the two herbicides simultaneously. Simultaneous application of naptalam and glyphosate delayed the production of naptalam-induced new shoots because glyphosate was preferentially translocated to the rhizomes that were being transformed to shoots and inhibited their growth. On the other hand, application of glyphosate 1 to 4 weeks after naptalam treatment resulted in a synergistic effect on the yellow nutsedge plants.

The application of naptalam followed by glyphosate was superior to either glyphosate or naptalam alone in reducing the number of tubers produced by regrowth of yellow nutsedge plants. There was a marked reduction in the total number of rhizomes and tubers of plants treated with naptalam followed by glyphosate indicating that most of the rhizomes that were transformed to shoots by the naptalam treatment were killed by the glyphosate spray.

Based on the findings of this study, a spray program using naptalam and glyphosate to provide improved control of yellow nutsedge appears possible.

The Effects of N-1-Naphthylphthalamic Acid on Growth of Yellow Nutsedge and Its Control With N-Phosphonomethyl Glycine

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INTRODUCTION

Yellow nutsedge (Cyperus esculentus L.) is a serious perennial weed in many parts of the world (5, 6, 16, 22, 43). In the United States, the area infested by this weed had been increasing (56). It was reported as a serious weed in 12 Northeastern states in 1962 (6) but a more recent survey indicated that the weed existed in all the contiguous states of the United States (55). The increase in extent and intensity of its infestation has been partly due to the current methods of weed control (16, 17, 26). The removal of susceptible annual weed species by chemical control has resulted in reduced competition and has encouraged the growth and spread of this weed. The situation may be further aggravated by the greater tendency towards reduced tillage operations.

Propagation by tubers is the major means of spread of yellow nutsedge in cultivated areas (6). Most of the tubers are produced in the upper 15 to 20 cm of soil but some are produced as deep as 45 cm in the soil (6, 52). The weed has a tremendous reproductive potential by tubers and these tubers may not be reached by the herbicides that are applied. These are some of the reasons why the weed is difficult to control.

Herbicides that are currently used to control yellow nutsedge in crops are short persistence and do not provide long-lasting control. Some of them act by inducing dormancy of tubers (2, 6, 23, 57) while others allow the tubers to sprout but kill the shoots after they have emerged (6, 23). Thus, for effective results, these herbicides must persist in the soil in the vicinity of the tubers for an extended period of time to prevent the tubers from sprouting or to kill the shoots when they emerge. This is usually accomplished by repeated applications or by applying high rates of the herbicide which may have an adverse effect on succeeding crops or result in undesirable effects on the environment.

The center of vegetative growth and propagation in yellow nutsedge is the basal bulb (6, 14). The basal bulbs produce numerous rhizomes which may differentiate into either tubers or new shoots. Since the rhizomes produced by the basal bulbs are the source of the tubers that will be produced, a possible approach to control or eradication of yellow nutsedge would be to prevent rhizomes from being transformed to tubers. The system would require the use of a chemical that would transform most of the rhizomes into shoots thereby reducing the amount of tubers that will be produced and at the same time, inducing the newly-formed shoots to emerge from the ground. An application of a rapidly-translocated herbicide following the first

treatment would be needed to kill both the main shoots and the newly-formed shoots.

Naptalam (N-1-napthylphthalamic acid) is a herbicide that has been reported to transform yellow nutsedge rhizomes into shoots (7). Glyphosate (N-phosphonomethyl glycine) has been observed to be rapidly translocated in some perennial weeds (34, 35). These two herbicides might be used in the system previously described, to bring about a more lasting control of yellow nutsedge.

The experiments reported in this study were conducted with the following objectives:

1. To study the effects of naptalam on rhizome, shoot, and tuber production as well as on growth of yellow nutsedge and determine some factors that would enhance rhizome transformation into shoots in naptalam-treated yellow nutsedge plants.
2. To study the effects of glyphosate on yellow nutsedge at different stages of growth of the weed, to determine its effects on tubers that are produced after treatment, and to compare single and split applications of the herbicide.
3. To investigate the effects of simultaneous application of naptalam and glyphosate, and the application of naptalam

followed by glyphosate on growth of the weed and on subsequent regrowth of yellow nutsedge plants from tubers and rhizomes.

LITERATURE REVIEW

Growth and Development of Yellow Nutsedge

Many aspects of the biology of yellow nutsedge have been studied. When a yellow nutsedge tuber sprouts, it produces one or more rhizomes from its apical end. As the rhizomes approach the soil surface and are exposed to light, each forms a basal bulb which develops into a new plant (6, 20, 40). The ascending rhizomes from the parent tubers may attain a length of several centimeters before forming the basal bulb or may be extremely short so that the basal bulb appears to originate from the tuber (20). The basal bulbs send out numerous rhizomes which may be transformed to either new shoots or tubers or remain as an indeterminate rhizome.

Shoot and Tuber Production and Factors Affecting Them

Jansen (20) reported that long photoperiods promoted shoot formation while short photoperiods promoted tuber production in yellow nutsedge. He also found that the active vegetative shoot and rhizome proliferation was competitive with tuberization. The transformation of rhizomes to tubers was promoted by short photoperiods, high temperature, and low nitrogen levels while rhizome transformation to shoots was promoted by long photoperiods, high levels of nitrogen, and

high temperatures (14).

Stoller (39) found that tubers of yellow nutsedge were more tolerant of low soil temperature than tubers of purple nutsedge (Cyperus rotundus L.) and suggested that this may be the reason for the differential distribution of the two weed species in the United States. Fewer yellow nutsedge tubers survived in a cool, dry atmosphere than in a cool, moist atmosphere indicating that they were susceptible to desiccation (44).

The viability of yellow nutsedge tubers is not affected by their size. Tubers which differed about five-fold in weight did not differ in percentage germination (40). However, they found that large tubers produced larger plants.

Yellow nutsedge tubers may remain viable in the soil for nearly two years (6, 39, 41). Taylorson (41) found that tillage encouraged sprouting of tubers. Recently, Stoller et al. (40) observed that yellow nutsedge tubers were capable of repeated regrowth but regrowth after the initial sprouting left the tubers with lower food reserves and resulted in less vigorous plants with each successive regrowth.

Naptalam

Naptalam is a selective preemergence herbicide for the control of a wide range of annual broadleaf and grassy weeds in soybeans,

cucumbers, squash, melons, pumpkins, peanuts, potatoes, and corn (9, 13, 24, 58).

Yaklich and Devlin (61) studied the uptake and translocation of naptalam in the cranberry plant (Vaccinium macrocarpon var. Early Black) when introduced through the nutrient solution. They reported that the greatest concentration of the herbicide was found in the roots. Lesser amounts of the herbicide were translocated to the stems and shoots.

The effect of naptalam on geotropism has long been known (15, 50). Naptalam is an effective inhibitor of auxin transport (1, 8, 25, 45, 46, 47). The herbicide also has been shown to inhibit dipeptidase activity in squash cotyledons (3, 49). Recently, it was reported that gibberellic acid or benzyladenine counteracted the inhibitory effect of naptalam on dipeptidase activity in squash cotyledons (48). Since gibberellic acid and benzyladenine have been known to induce synthesis of the dipeptidase enzyme, they suggested that naptalam inhibited the synthesis of the dipeptidase enzyme in squash cotyledons by interfering with the hormonal control mechanism of enzyme synthesis.

Parker and Dean (29) reported that naptalam induced moderate sprouting of isolated purple nutsedge tubers. Their data also showed that naptalam stimulated sprouting of intact tubers when purple nutsedge plants were treated with the herbicide either as a foliar spray or

by dipping the underground parts of the plants into the herbicide solution.

Glyphosate

Glyphosate is a broad-spectrum herbicide which has demonstrated effective control of many perennial weeds (36). The effectiveness of the herbicide is greatly influenced by temperature and relative humidity. Preconditioning quackgrass (Agropyron repens (L.) Beauv.) and johnsongrass (Sorghum halepense (L.) Pers.) at 16 to 32 C two weeks prior to treatment did not influence the response of the weeds to the herbicide (54) but low temperatures (10 to 25 C) after treatment enhanced its toxicity (10, 28, 30, 54, 59). High relative humidity after glyphosate application also resulted in increased toxicity of the herbicide (10, 28, 59).

Jaworski (21) found that glyphosate inhibited the growth of the aquatic flowering plant, Lemna gibba L. and the bacterium, Rhizobium japonicum but the addition of L-phenylalanine to the nutrient medium in the former, and L-phenylalanine and L-tyrosine in the latter, alleviated growth inhibition. He postulated that glyphosate interferes with the biosynthesis of phenylalanine and more specifically, with the metabolism of chorismic acid in the aromatic amino acid biosynthetic pathway.

Glyphosate lacks residual soil activity (4, 35, 36). Rieck, et al. (31) reported that the addition of montmorillonite, organic material, or aluminum sulfate nullified the toxic effect of the herbicide to 6-week-old corn plants. However, they indicated that adsorption could not account for all the reduction in toxicity of the herbicide. Sprankle, et al. (33) found that soils with high phosphate levels bound less of the herbicides. They indicated that the initial inactivation of glyphosate in the soil involved the binding of the herbicide to the soil constituents and that subsequent microbial degradation of the glyphosate molecule occurred rapidly.

Maximum control of purple nutsedge occurred when the plants were exposed to low temperature (25 C) and high relative humidity (100%) for 7 days after treatment (59). Furthermore, application of glyphosate to purple nutsedge reduced the number of tubers that were produced by regrowth of plants (27, 42, 62).

Glyphosate has been reported to effectively control the topgrowth of yellow nutsedge (4, 53). Sprankle, et al. (34) studied the movement of labelled glyphosate, applied to a lanolin enclosure on leaves of yellow nutsedge, by radioautography. They found that the herbicide moved acropetally and basipetally in the treated leaves. There was also evidence for movement of the herbicide in the phloem to the roots and the developing leaves.

GENERAL MATERIALS AND METHODS

The experiments reported in this study were conducted either in the greenhouse or in growth chambers from November, 1972 to October, 1974. In the greenhouse, temperature was between 20 and 35 C. The temperature in the growth chambers was controlled and will be specified in individual experiments.

Yellow nutsedge plants that were utilized in the earlier experiments were grown from tubers taken from a heavily-infested farm near Canby, Oregon. The plants that were grown from these tubers were verified by the Herbarium, Botany Department, Oregon State University as Cyperus esculentus L. var leptostachyus Boeck. (Costa, 1974). As the research progressed, it became necessary to have a continuous supply of yellow nutsedge tubers. Therefore, some of the plants from the original tubers were grown in large pots filled with a mixture of one-third sand and two-thirds soil. The plants were watered regularly by sprinkle irrigation and received liquid fertilizer as needed. They were the source of the tubers that were used in the later experiments. The tubers produced by these plants were washed, placed in plastic bags, and stored in the refrigerator at 5 C.

Yellow nutsedge tubers were wrapped with a wet cloth and placed in plastic pans to induce sprouting. The plastic pans were placed in the growth chamber at 30 C and 12-hour photoperiod. The cloth was

kept moist by regular watering. Yellow nutsedge tubers with sprouts measuring from 4 to 8 cm were transplanted into plastic pots measuring approximately 10 x 10 x 10 cm containing sandy loam soil, sand-soil mixture, or white sand. The plants were set in a rectangular galvanized tray on the greenhouse bench and watered by sub-irrigation.

The young yellow nutsedge plants were grown in the greenhouse for 1 to 4 weeks after they were transplanted. For each experiment, the number of young plants that were transplanted were always in excess of the number of plants needed to allow selection of uniform plants. Experimental plants were arranged in blocks according to height, amount of foliage, and vigor.

The growth medium used varied with each experiment. The sandy loam soil and the soil or sand in the sand-soil mixture were sieved to exclude large particles.

The naptalam (N-1-naphthylphthalamic acid) used in this study was the liquid formulation of the sodium salt containing 2.0 pounds acid equivalent per gallon. Glyphosate (N-phosphonomethyl glycine) formulated as the isopropylamine salt containing 3.0 pounds acid equivalent per gallon was the other herbicide used in this study. All glyphosate treatments were applied postemergence over the top of yellow nutsedge plants with an overhead, variable speed, track-mounted sprayer in 374 liters of herbicide solution per hectare. The

method of application of naptalam varied with the different experiments.

In experiments where examination of the underground parts of the yellow nutsedge plants was needed, the underground parts of the plants were carefully separated from the growth medium with the aid of running water. Rhizomes transformed to shoots, rhizomes transformed to tubers, and untransformed rhizomes were then carefully detached from the parent plants and counted.

Fresh and dry weights of main shoots, new shoots, or tubers of yellow nutsedge were determined using a balance sensitive to the nearest 0.1 mg. For dry weight determinations, the main shoots, new shoots, or tubers of yellow nutsedge plants were placed in paper bags and dried in the oven at 60 C for 72 hours. The plant materials were weighed after cooling the paper bags at room temperature.

Additional information is provided in the materials and methods section of each experiment.

SECTION I

EFFECTS OF NAPTALAM ON SHOOT AND TUBER PRODUCTION, RHIZOME TRANSFORMATION, AND GROWTH OF YELLOW NUTSEDGE PLANTS

Experiment 1: Effect of Naptalam on Growth and Shoot Production

Materials and Methods:

Yellow nutsedge plants (4 to 6 cm tall) were transplanted into plastic pots measuring approximately 10 x 10 x 10 cm with one plant per pot. The plastic pots were filled with sandy loam soil. Twenty-five days after transplanting, the plants were treated with naptalam. The herbicide solution was applied to the soil. Each pot was treated with 50 ml of 100 or 200 parts per million naptalam solution. Fifty ml of 100 parts per million naptalam solution was calculated to be equivalent to 5.6 kg/ha. Untreated plants were maintained for comparison. At the time of naptalam application, the yellow nutsedge plants were at the six to eight leaf stage and were 23 to 36 cm tall. The experiment was conducted using a randomized block design. Each treatment was replicated eight times. The yellow nutsedge plants were watered regularly by sprinkle irrigation and were fertilized as needed.

Data on height of plants and on number of new shoots produced per plant were taken at 15, 30, and 45 days after treatment with nap-

talam. Dry weights of main shoots and new shoots were determined 45 days after naptalam treatment. The data were statistically analyzed and differences among treatments were tested with Duncan's multiple range test (37).

Results and Discussion:

The results are presented in Table 1. The application of naptalam increased the number of new shoots produced per plant. A similar observation was reported by Bendixen (7). The number of new shoots formed by plants treated with 100 and 200 parts per million naptalam were comparable at 15 and 30 days after treatment but more shoots were produced at the higher concentration of naptalam 45 days after treatment. However, the shoots formed were small. No significant differences were noted in the height of plants at treatment time but growth inhibition of naptalam-treated plants was discernable 15 days after treatment. Naptalam-treated plants were small and dark green. Succeeding leaves failed to elongate and gave the plants a stubby appearance (Figure 1). This inhibition of growth is clearly shown by the data on dry weight of main shoots.

Table 1. Effect of naptalam on new shoot production and growth of yellow nutsedge.

Treatment	Number of new shoots/plant After Treatment			Average Height of Plants (cm)				Dry weight of main shoot 45 days after treatment (g)
	15 days	30 days	45 days	At Treatment time	After Treatment 15 days	30 days	45 days	
Untreated	0.62b[1/]	2.12b	2.12c	29.00a	44.37a	48.00a	54.00a	1.60a
Naptalam (100 ppm)	3.50a	7.87a	8.62b	28.62a	37.37b	37.75b	40.50b	0.80b
Naptalam (200 ppm)	3.25a	9.37a	10.87a	28.75a	35.37b	36.12b	40.00b	0.68b

[1/] Values within each column followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test.

Figure 1. Naptalam-treated yellow nutsedge plants showing effects on height and on shoot production 20 days after naptalam application. 1 = untreated; 2 = naptalam (100 ppm); 3 = naptalam (200 ppm).

Experiment 2: Rhizome Production and Transformation in Culture Solution

Materials and Methods:

Yellow nutsedge plants were established in 900-ml jars containing one-half strength Hoagland's solution. Continuous aeration in each jar was provided by syringes connected to a main air line. When the plants were at the six to seven leaf stage (38 to 46 cm tall), they were treated with naptalam. The plants were transferred to 900-ml jars containing 800 ml each of 2.05×10^{-5} M, 4.11×10^{-5} M, and 8.23×10^{-5} M solution of naptalam, respectively. Untreated plants were maintained in aerated jars containing 800 ml of distilled water. All plants in the jars were provided with continuous aeration.

The experiment was carried out using a randomized block design with each treatment replicated six times. Continuous supplemental light, with an intensity of approximately 8,600 lux, was provided by fluorescent tubes and incandescent bulbs.

The jars used in this experiment were covered with inverted paper cups that were provided with a circular hole about 3 cm in diameter at the bottom. The paper cups were painted black to exclude light from the solution in the jars. The bases of the plants were carefully wrapped with cotton so that they would fit snugly into the hole in the paper cup. Yellow nutsedge plants were positioned in such a way

that their roots and rhizomes were immersed into the herbicide solution in the jars. A piece of wire about 15 cm long, was attached to the neck of each jar to provide support for the plants. The wire had a circular loop about 9 cm in diameter at the end into which the shoots of the plants were inserted. The loop at the end of the wire helped keep the plants in place.

Twenty-four days after naptalam treatment, the total number of rhizomes produced by each plant and the number of rhizomes transformed to shoots were determined. Data on the number of rhizomes transformed to shoots were expressed as a percentage of the total number of rhizomes. The data were analyzed statistically and differences among treatments were determined using Duncan's multiple range test.

Results and Discussion:

The application of naptalam to yellow nutsedge plants grown in culture solution significantly increased the total number of rhizomes produced per plant and the percentage of rhizomes transformed to shoots (Table 2). There was no significant difference in the total number of rhizomes produced in any of the concentrations of naptalam used. However, the percentage of rhizomes transformed to shoots was significantly greater at the highest concentration of naptalam (Figure 2).

Table 2. Effect of naptalam on rhizome production and transformation in culture solution.

Treatment	Total number of rhizomes/plant	Percent rhizomes Transformed to shoots
Untreated	11.33b[1/]	0c
naptalam (2.05×10^{-5}M)	14.17a	80.06b
naptalam (4.11×10^{-5}M)	14.50a	83.72b
naptalam (8.23×10^{-5}M)	15.83a	96.96a

[1/] Values within each column followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

Figure 2. Yellow nutsedge plants grown in culture solution and treated with naptalam. Note the number of rhizomes transformed to shoots in treated plants. 1 = untreated; 2 = naptalam (2.05×10^{-5}M); 3 = naptalam (4.11×10^{-5}M); 4 = naptalam (8.23×10^{-5}M).

Experiment 3: Rhizome Production and Transformation as Influenced by Length of Exposure to Naptalam

Materials and Methods:

Yellow nutsedge plants were established in one-half strength Hoagland's solution similar to those in Experiment 2. When the plants were at the five to seven leaf stage, they were transferred to 900-ml jars containing 800 ml of 4.11×10^{-5}M solution of naptalam. The plants were exposed to the naptalam solution for 0.5, 2, and 8 days. Untreated plants were maintained for comparison. After each designated time of exposure, the plants were transferred to jars filled with half-strength Hoagland's solution.

The experiment was conducted using a randomized block design with each treatment replicated six times. Supplemental light was provided by fluorescent tubes and incandescent bulbs 24 hours a day. The intensity of the supplemental light was approximately 8,600 lux.

Ten days after the last plants were removed from the naptalam solution, the experiment was terminated. Data on the total number of rhizomes produced per plant and the number of rhizomes transformed to shoots per plant were taken. The number of rhizomes transformed to shoots was expressed as a percentage of the total number of rhizomes produced per plant. The data were subjected to statistical analysis and differences among treatments were determined by Duncan's multiple

range test.

Results and Discussion:

Longer exposure to naptalam resulted in an increased number of rhizomes per plant and a greater percentage of rhizomes transformed to shoots (Table 3 and Figure 3).

Table 3. Effect of length of exposure to naptalam on rhizome production and transformation.

Days of treatment with 4.11×10^{-5}M naptalam solution	Total number of rhizomes/plant	Percent rhizomes Transformed to shoots
0	13.67c[1/]	10.64c
0.5	18.83b	27.28b
2.0	20.67ab	52.18a
8.0	23.67a	57.68a

[1/] Values within each column followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

Figure 3. The effect of length of exposure of yellow nutsedge plants grown in culture solution to naptalam. 1 = untreated; 2 = 0.5 days; 3 = 2 days; 4 = 8 days.

Experiment 4: Split and Single Topical Applications of Naptalam

Materials and Methods:

Yellow nutsedge plants were transplanted into plastic pots with three plants per pot. Thirty days after transplanting, the different treatments were applied. The treatments used were single applications of naptalam at 1.12, 2.24, 4.48, and 8.97 kg/ha and split applications of naptalam at the total rate of 1.12, 2.24, 4.48, and 8.97 kg/ha. Split applications consisted of 4 weekly treatments at 25 percent of the total rate starting from 30 days after transplanting. Untreated plants were maintained for comparison. All the herbicide treatments were applied over the top of yellow nutsedge plants in 374 liters of water per hectare. The experiment was conducted using a randomized block design with each treatment replicated four times. Experimental plants were watered regularly by sub-irrigation.

The number of new shoots per pot were taken 15 days after the last split application of naptalam. The data were statistically analyzed and differences among treatments were determined using Duncan's multiple range test.

Results and Discussion:

The treatments that produced the greatest number of new shoots

were split applications of 2.24, 4.48, and 8.97 kg/ha and a single application of 8.97 kg/ha (Table 4).

The results indicate that split applications of naptalam were better than single applications in enhancing the production of new shoots. Split applications increased the number of new shoots significantly more than single applications at all rates except the highest rate.

Table 4. Effect of single and split foliar applications of naptalam on new shoot production in yellow nutsedge.

Treatment		Number of new shoots
Total naptalam applied (kg/ha)	single or split	per 3 plants
1.12	single	7.75b[1/]
	split	11.25a
2.24	single	8.50b
	split	14.25a
4.48	single	8.50b
	split	14.50a
8.97	single	13.75a
	split	16.25a
0	---	0.25c

[1/] Values followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test.

Experiment 5: Split and Single Soil Applications of Naptalam

Materials and Methods:

In a greenhouse experiment, three yellow nutsedge plants were transplanted into plastic pots filled with sandy loam soil.

Thirty days after transplanting, the different treatments were applied. The treatments are outlined in Table 5. Single treatments of naptalam were applied 30 days after transplanting. This was accomplished by applying directly to the soil of each pot, 50 ml each of 200, 400, 800, or 1600 parts per million of naptalam solution. Untreated plants were maintained for comparison. The split applications of naptalam were divided into 4 weekly applications starting 30 days after transplanting. Therefore, the amount of naptalam applied each week at each rate was 25 percent of the total rate.

The experiment was conducted using a randomized block design with each treatment replicated four times. The plants were watered regularly by sub-irrigation and fertilized as needed. Data on number of new shoots per three plants were taken 15 days after the last split application of naptalam was made. The data obtained were subjected to statistical analysis and differences among treatments were determined using Duncan's multiple range test.

Results and Discussion:

All naptalam treatments caused a significant increase in production of new shoots (Table 5). There were no significant differences in the number of new shoots per three plants at each concentration of naptalam between single and split applications except at the highest concentration, where the split application resulted in significantly more new shoots than the single application.

Table 5. Effect of single and split soil applications of naptalam on new shoot production in yellow nutsedge.

Treatment		Number of new shoots per 3 plants
Total naptalam applied (ppm)	single or split	
200	single	22.50d[1/]
	split	21.50d
400	single	26.25bcd
	split	30.50abc
800	single	36.00a
	split	29.00abcd
1600	single	25.75cd
	split	33.50ab
0	---	0e

[1/] Values followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test.

Experiment 6: Effect of Naptalam, Nitrogen, and Photoperiod on Yellow Nutsedge

Materials and Methods:

Single yellow nutsedge plants were transplanted into plastic pots containing white sand on July 29, 1973. Seventy-two plants were established in the greenhouse. Twenty days after establishment in the greenhouse, the plants were transferred into two growth chambers with 36 plants in each growth chamber. Experimental treatments included naptalam at 0, 200, and 400 parts per million, photoperiods of 10 and 20 hours, and complete Hoagland's solution of 1/32, 1/8, and 1/2 strength N.

The temperature in both growth chambers was maintained at 30 C and light intensity provided by fluorescent tubes and incandescent bulbs was approximately 16,500 lux. Naptalam treatments were made in two applications. The first naptalam treatment was made by applying 50 ml each of 100 or 200 parts per million of naptalam solution directly to the soil in each pot. These treatments were applied to the same plants 12 days later.

The application of different amounts of nitrogen was accomplished by using a slightly modified Hoagland and Arnon solution (18). Calcium nitrate was the main source of nitrogen and potassium chloride was the main source of potassium in the modified nutrient solution. One liter

of the modified nutrient solution of full N strength was made up of 1.0 ml of 1 M KH_2PO_4, 10.0 ml of 1 M $Ca(NO_3)_2$, 2.0 ml of 1 M $MgSO_4$, 5.0 ml of 1 M KCl, 1.0 ml of 10,000 parts per million solution of iron chelate, and 1.0 ml of micronutrients. Application of different amounts of nitrogen was made by varying only the volume of calcium nitrate in the nutrient solution. For example, 1/2, 1/8, and 1/32 strength N would be equivalent to the use of 5.0, 1.25, and 0.31 ml of 1 M $Ca(NO_3)_2$ per liter of solution, respectively. We assumed that the varying amounts of nitrogen would have the primary influence on nutsedge growth but the varying amounts of calcium should not be completely ignored. The plants received 100 ml of the modified nutrient solution containing varying amounts of nitrogen each week. The plants were also watered with tap water by sprinkle irrigation regularly.

At each given photoperiod, there were nine treatments which consisted of three naptalam and three nitrogen levels, in all combinations. Each treatment was replicated four times.

The experiment was terminated on October 4, 1973. The sand was separated from the underground parts of the plants by washing with running water. New shoots and tubers were carefully separated from the main shoots and their dry weights were determined. The data were analyzed as a factorial, with naptalam, photoperiod, and

nitrogen as the factors. Differences among treatments were determined using Duncan's multiple range test.

Results and Discussion:

The application of naptalam to yellow nutsedge plants grown under a 20-hour photoperiod significantly increased the dry weight of new shoots (Figures 4 and 8). The dry weight of new shoots was increased about five times with the application of 200 parts per million naptalam and by about seven times at the higher concentration of the herbicide. There was no significant effect on plants grown under 10-hour photoperiod.

There was a significant increase in the dry weight of new shoots when nitrogen was increased from 1/32 to 1/8 N strength of Hoagland's solution (Figure 5). Further increase in the amount of nitrogen did not result in a corresponding increase in dry weight of new shoots.

Untreated plants grown under 10-hour photoperiod induced production of numerous tubers, but treatment with naptalam inhibited tuber production (Figures 6 and 9).

The application of nitrogen to untreated plants grown under 10-hour photoperiod resulted in increased dry weight of tubers. Yellow nutsedge plants treated with naptalam did not respond to nitrogen application (Figure 7).

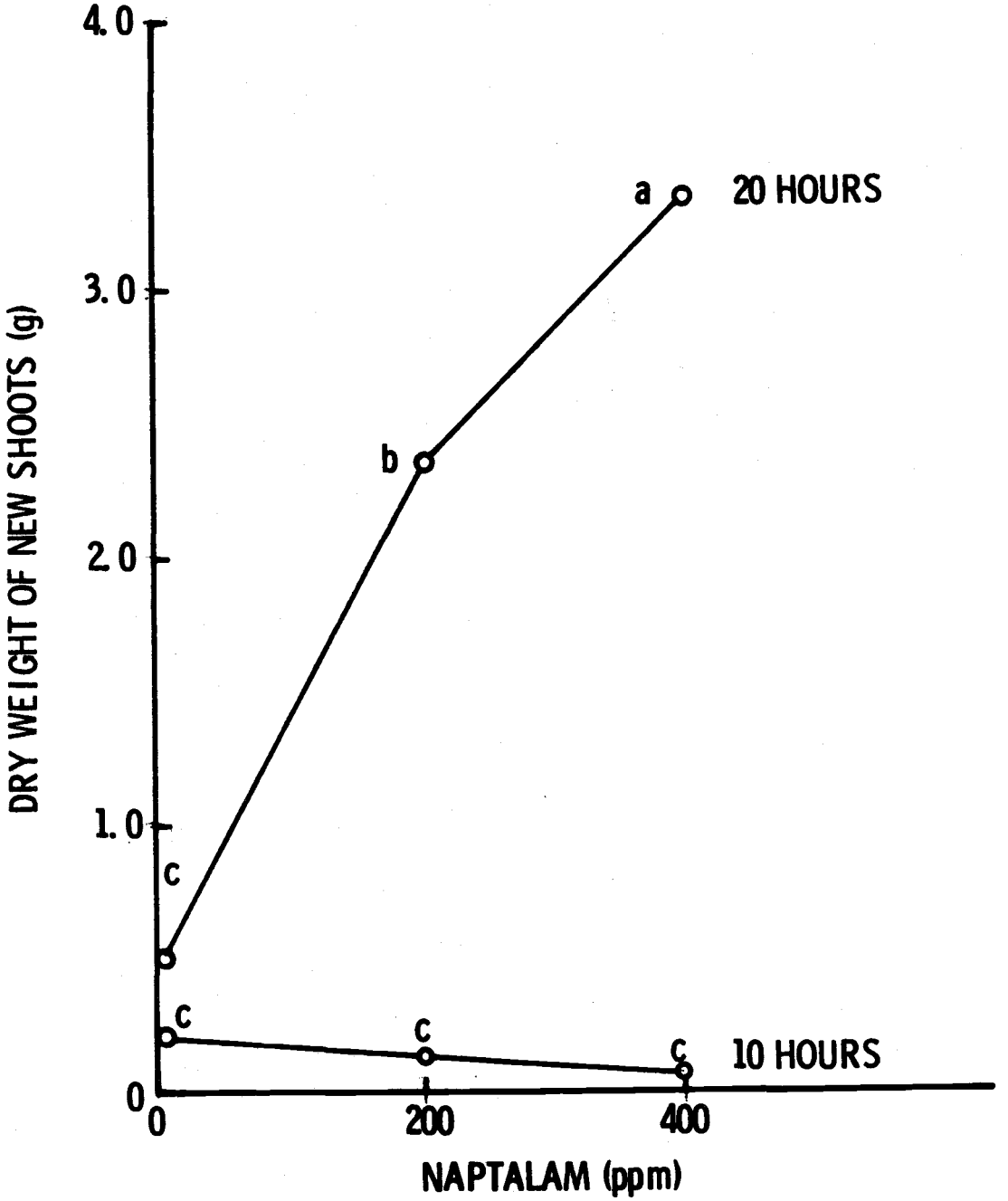

Figure 4 Effect of photoperiod and naptalam on dry weight of new shoots of yellow nutsedge. Values with the same letter are not significantly different at the 5% level based on Duncan's multiple range test.

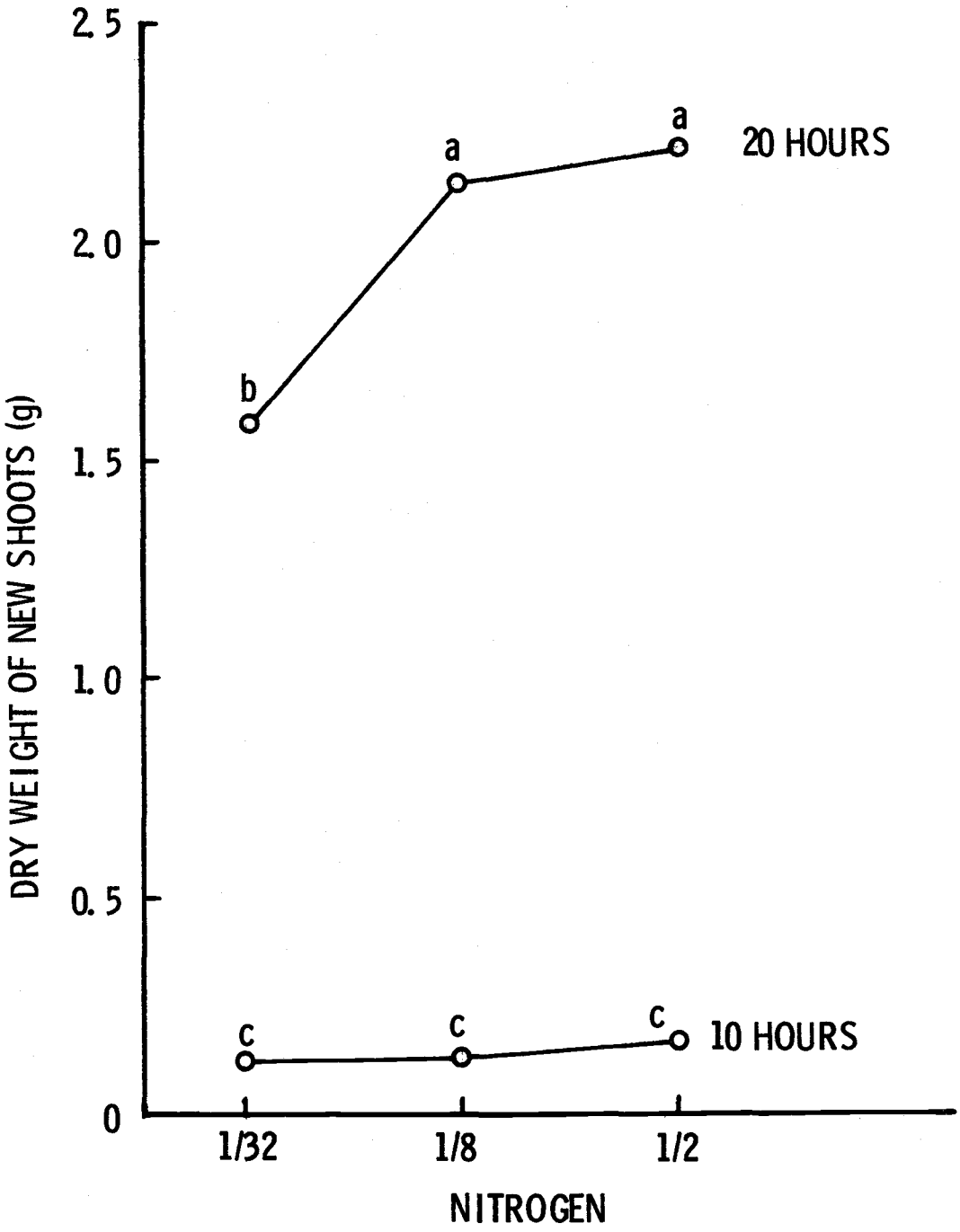

Figure 5 Effect of photoperiod and nitrogen on dry weight of new shoots of yellow nutsedge. Values with the same letter are not significantly different at the 5 % level based on Duncan's multiple range test.

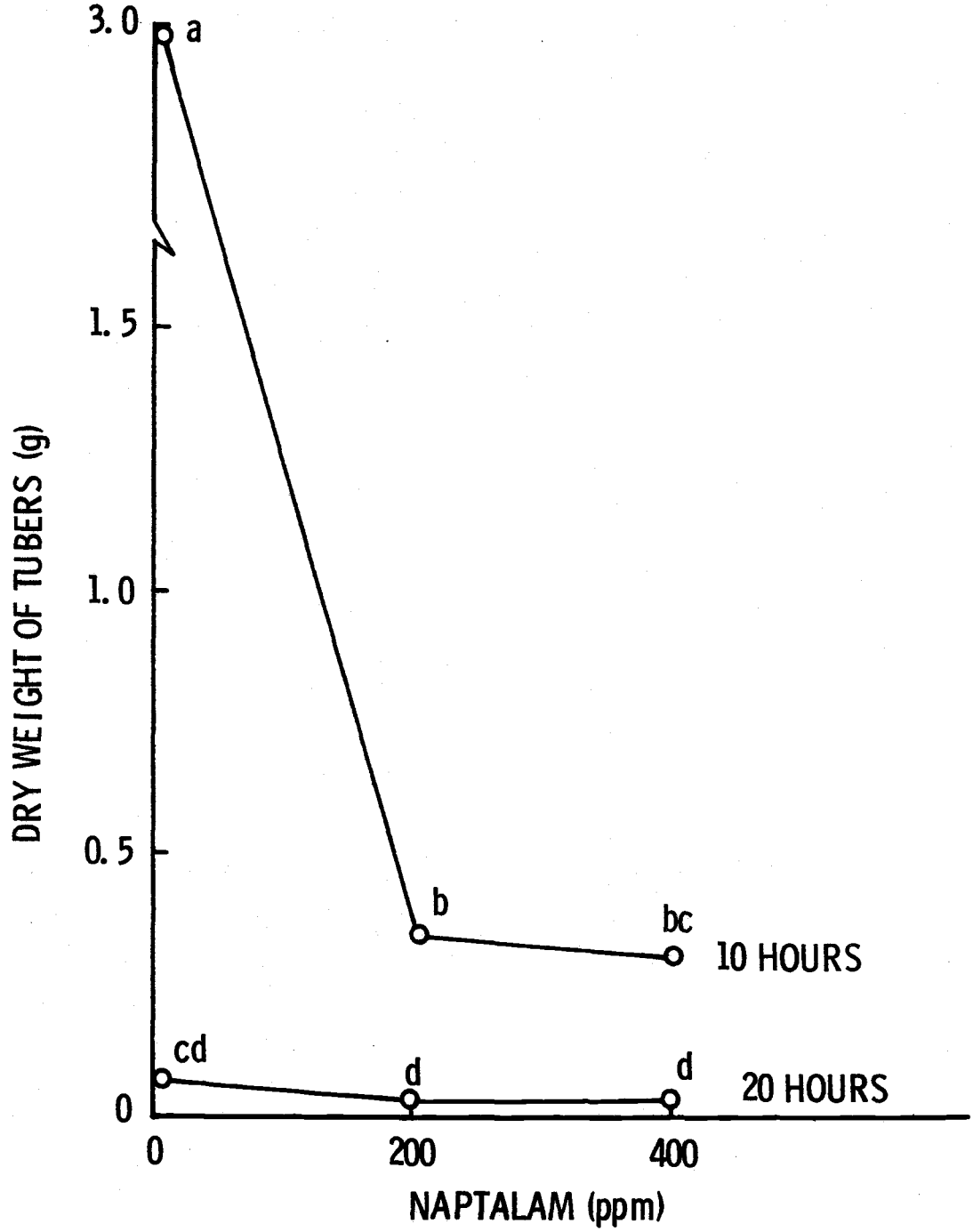

Figure 6 Effect of photoperiod and naptalam on dry weight of yellow nutsedge tubers. Values with the same letter are not significantly different at the 5 % level based on Duncan's multiple range test.

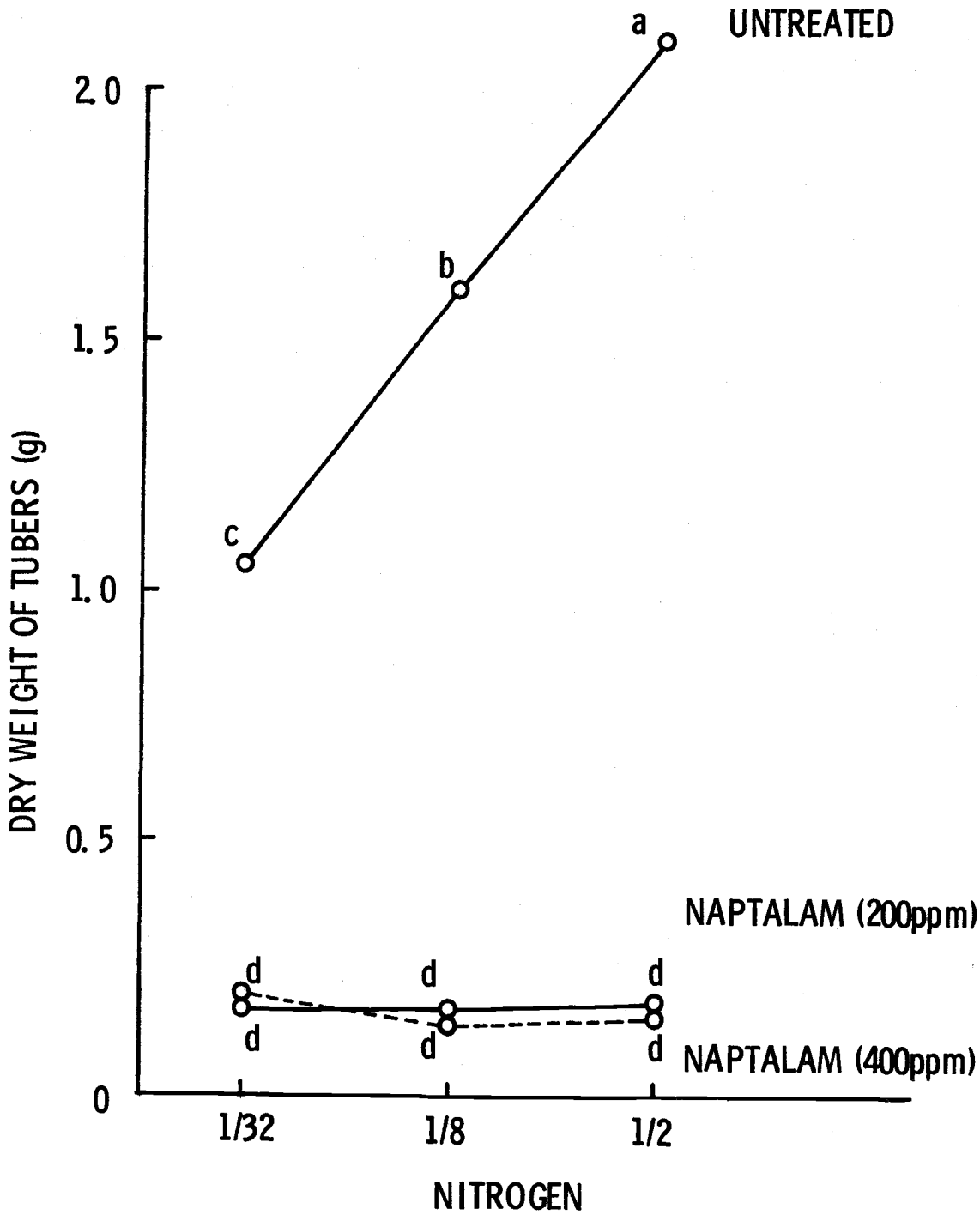

Figure 7 Effect of naptalam and nitrogen on dry weight of yellow nutsedge tubers. Values with the same letter are not significantly different at the 5 % level based on Duncan's multiple range test.

Figure 8. Effect of long photoperiod and naptalam on shoot production in yellow nutsedge. A_1LD = Untreated; C_1LD = naptalam (400 ppm).

Figure 9. Effect of short photoperiod and naptalam on tuber production in yellow nutsedge. A_1SD = Untreated; C_1SD = Naptalam (400 ppm).

Experiment 7: Effect of Photoperiod and Naptalam on Shoot and Tuber Production of Yellow Nutsedge

This experiment was conducted to determine if growing yellow nutsedge plants under long day conditions and treating them with naptalam would encourage shoot production and if further exposure to short day conditions would induce the newly-formed shoots to produce tubers. The effect of this kind of treatment was compared with those of plants grown under continuous short day conditions.

Materials and Methods:

Single yellow nutsedge plants were transplanted into plastic pots filled with a mixture of one-third sand and two-thirds soil on December 9, 1973. After 15 days of establishment in the greenhouse, 36 plants were selected and 18 were placed into each of two growth chambers. One growth chamber had a 20-hour photoperiod and the other a 12-hour photoperiod. The temperature in both growth chambers was maintained at 30 C and light intensity was approximately 16,500 lux. Six plants in each growth chamber were treated with 50 ml of 200 or 800 ppm naptalam solution immediately after they were transferred to the growth chambers. The naptalam solution was carefully applied directly to the soil in each pot. Untreated plants were maintained for comparison. At the time of naptalam treatment, the plants had five to

seven leaves and were 35 to 46 cm tall. Twenty days after naptalam treatment, the length of photoperiod in the growth chamber which was previously maintained at 20 hours was reduced to 12 hours.

The plants were watered regularly by sprinkle irrigation. Forty days after naptalam treatment, the experiment was terminated. The underground parts of the plants were carefully separated from the main plants with the use of running water. Rhizomes that were transformed to shoots, rhizomes that were transformed to tubers, and untransformed rhizomes per pot were counted and expressed as percentage of the total number of rhizomes per pot. These data were analyzed as a factorial, with naptalam and photoperiod as the factors. Since there were no differences due to replications, the mean square value for replications was pooled with the mean square value for error. Differences among treatments were determined by Duncan's multiple range test.

Results and Discussion:

Results are presented in Table 6. The percentage of rhizomes transformed to shoots in untreated plants grown in the continuous 12-hour photoperiod regime was not significantly different from those grown in the 20 + 12-hour photoperiod although 12 percent were transformed in the latter and none in the former. The percentages of rhi-

zomes transformed to shoots in plants grown in the 20 + 12-hour photoperiod and treated with either 200 or 800 ppm naptalam were significantly greater than that of the untreated plants. Figure 10 shows that the plant treated with 200 ppm naptalam and grown in the 20 + 12-hour photoperiod (B1) had more new shoots than the untreated plant grown under the same photoperiod regime (A1). There were no significant differences in the number of rhizomes transformed to tubers in plants grown under the 20 + 12-hour photoperiod with the application of 200 ppm naptalam, 800 ppm naptalam, and when no naptalam was applied, indicating that the 20 days of short-day treatment was not sufficient to induce newly-formed shoots to produce tubers. There was a tendency for the percentage of rhizomes transformed to shoots to increase in plants grown under the continuous 12-hour photoperiod when treated with naptalam but a significant difference, compared to that of the untreated, was demonstrated only at the higher rate of application (800 ppm).

The number of rhizomes transformed to tubers was greatest in the untreated plants grown under the continuous 12-hour photoperiod. Application of 200 ppm naptalam to the plants grown under the continuous 12-hour photoperiod resulted in a significantly lower percentage of rhizomes transformed to tubers compared to that of the untreated plants grown under the same photoperiod regime. However,

the percentage of rhizomes transformed to tubers in plants treated with naptalam at the higher rate (800 ppm) did not differ from that of the untreated plants grown under the continuous 12-hour photoperiod. This discrepancy may be due to the adverse effect of the high rate of naptalam and the short photoperiod treatment on the sum of all the rhizomes produced per pot which was only 10 in plants treated with 800 ppm naptalam but was 33 in the untreated plants grown under the same photoperiod regime. This corresponds to a reduction of about 69 percent. The actual numbers of rhizomes transformed to tubers in plants treated with 800 ppm naptalam and grown under the continuous 12-hour photoperiod were low, but since the sum of all the rhizomes in this treatment was markedly reduced, the corresponding figure representing the number of rhizomes transformed to tubers became inflated when expressed as percentage of the sum of all rhizomes. Thus, the true effect of the treatment may have been masked by the severe inhibition of growth of yellow nutsedge.

Table 6. Effect of photoperiod and naptalam on shoot and tuber production in yellow nutsedge.

Treatment		Percent rhizomes transformed to shoots	Percent rhizomes transformed to tubers	Total number of rhizomes transformed to shoots, to tubers, and untransformed rhizomes/pot
Naptalam (ppm)	Length of photoperiod			
0	20 days 20-hour photoperiod followed by 20 days 12-hour photoperiod	12.61c[1/]	17.22cd	29.83a
	40 days 12-hour photoperiod	0c	50.83a	33.50a
200	20 days 20-hour photoperiod followed by 20 days 12-hour photoperiod	47.49ab	7.72d	20.83ab
	40 days 12-hour photoperiod	11.14c	28.73bc	24.83a
800	20 days 20-hour photoperiod followed by 20 days 12-hour photoperiod	60.99a	10.93d	28.16a
	40 days 12-hour photoperiod	33.69b	36.29ab	10.33b
		(p=0.01)	(p=0.05)	(p=0.01)

[1/] Values within each column followed by the same letter are not significantly different at the levels indicated using Duncan's multiple range test.

Figure 10. Yellow nutsedge plants showing effects of photoperiod and naptalam on tuber and shoot production. A = Untreated; B = Naptalam (200 ppm); 1 = 20 days 20-hour photoperiod followed by 20 days 12-hour photoperiod; 2 = 40 days 12-hour photoperiod.

Experiment 8: The Effect of Sequence of Naptalam Application and Photoperiod on Shoot and Tuber Production of Yellow Nutsedge

This experiment was conducted to study the effect of applying naptalam to yellow nutsedge plants grown under short day conditions and subsequent application of naptalam to the same plants under long day conditions to induce new shoot production. The objective of this approach was to continually inhibit tuber formation and encourage shoot production to impair the regenerative capacity of the weed.

Materials and Methods:

Single plants were transplanted into plastic pots on January 12, 1974. The pots contained a mixture of one-third sand and two-thirds soil to facilitate examination of the underground parts of the plants. After 20 days in the greenhouse, 36 plants were transferred to a growth chamber with a temperature of 30 C and a 12-hour photoperiod to encourage tuber production. Twelve plants were treated with 50 ml of 200 or 800 ppm naptalam, and 12 plants were left untreated for comparison. The naptalam solution was carefully applied directly on the soil of each pot. The first naptalam treatments were applied when the plants were at the six to eight leaf stage (36 to 53 cm in height).

Light intensity in the growth chamber was approximately 16,500 lux. The plants were watered regularly with tap water by sprinkle ir-

rigation. Each plant received 100 ml of full strength Hoagland's solution once a week. Fifty days after the first naptalam treatment, six plants each from the untreated, and those previously treated with 200 or 800 ppm naptalam solution were treated with 50 ml of 200 ppm naptalam solution, and the length of photoperiod in the growth chamber was increased from 12 to 20 hours. The plants were kept in the growth chamber for another 50 days. After 120 days, the new shoots and the tubers produced by each plant were carefully separated from the main shoot of the plants. The shoots and tubers produced by each plant were counted and dry weights of new shoots were determined. The dry weight of each new shoot was calculated by dividing the dry weights of new shoots produced by each plant by the number of new shoots that the plant produced. Data on the number of new shoots per plant, number of tubers per plant, and average dry weight of each new shoot were subjected to statistical analysis and differences among treatments were determined using Duncan's multiple range test.

Results and Discussion:

The number of new shoots produced by yellow nutsedge plants treated only with 200 ppm naptalam 70 days after transplanting were comparable to those produced by plants treated only with 200 ppm naptalam 20 days after transplanting, and the untreated control. The

additional treatment of 200 ppm naptalam 70 days after transplanting resulted in significant increases in the number of new shoots per plant when applied to the plants previously treated with 200 or 800 ppm naptalam 20 days after transplanting (Table 7 and Figure 11).

Untreated plants produced the greatest number of tubers. The application of naptalam significantly reduced the number of tubers produced per plant. Application of naptalam 70 days after transplanting reduced the number of tubers per plant by 60 percent.

Table 7. Effect of sequence of naptalam application and photoperiod on shoot and tuber production.

Treatment				
Naptalam 20 days after transplanting (ppm)	Naptalam 70 days after transplanting (ppm)	Number of new shoots per plant 120 days after transplanting[1/]	Number of tubers per plant 120 days after transplanting	Dry weight of each new shoot 120 days after transplanting (g)
0	0	6.83d	24.50a	1.1110a
0	200	8.50cd	9.00b	0.7343ab
200	0	9.50cd	4.50c	1.0251a
200	200	13.83ab	3.67c	0.6792ab
800	0	12.17bc	2.83c	0.6555ab
800	200	17.83a	2.67c	0.4362b

[1/] Values within the same column followed by the same letter are not significantly different at the 1% level as determined by Duncan's multiple range test.

Figure 11. Naptalam-induced shoot production in yellow nutsedge plants. A_1 = Untreated; B_2 = Naptalam (200 ppm) at 20 days after transplanting followed by naptalam (200 ppm) at 70 days after transplanting.

Experiment 9: The Effect of Time of Application of Naptalam on Number and Size of New Shoots of Yellow Nutsedge Grown Under Long Photoperiod

The results of Experiments 6 to 8 established that applications of naptalam induced new shoot production under long day conditions. This experiment was conducted to determine the stage of growth of yellow nutsedge and the rate of naptalam that would produce the greatest number and the largest size of new shoots. It was thought that a yellow nutsedge plant with numerous large new shoots would provide more leaf area and allow greater absorption of translocated herbicides.

Materials and Methods:

On November 30, 1973, single plants were transplanted into plastic pots containing one-third sand and two-thirds soil. The sand-soil mixture was used so that the underground parts of the plants could be easily separated from the growth medium at the termination of the experiment. Forty-eight plants were transferred to a growth chamber with a temperature of 30 C and a 12-hour photoperiod. Four plants were treated with 50 ml of 100, 200, 400, 800, or 1600 ppm of naptalam solution 2 or 4 weeks after transplanting. The naptalam solution was carefully applied directly to the soil in each pot. Untreated plants were maintained for comparison.

Two weeks after transplanting, the plants had five to seven

leaves and were 30 to 41 cm in height, and four weeks after transplanting they had eight to twelve leaves and were 43 to 51 cm tall. The plants were watered regularly by sprinkle irrigation. They were harvested 40 days after naptalam application by separating the underground parts of the plants from the growth medium with the aid of running water. New shoots were carefully separated from their respective main shoots and counted. The dry weight of new shoots produced by each plant was determined. Average dry weight for each new shoot was calculated by dividing the total dry weight of new shoots per plant by the number of new shoots produced by each plant. The data on the number of new shoots produced per plant and the average dry weight of new shoots were analyzed as a factorial, with rates of naptalam and time of application as the factors. Differences among treatments were determined using Duncan's multiple range test.

Results and Discussion:

Results are presented in Table 8. The number of new shoots produced by plants treated with 100, 200, or 400 ppm naptalam 2 weeks after transplanting was significantly greater than the number produced by untreated plants. Increases in the number of new shoots by treated plants compared with the untreated plants were 95, 124, and 171 percent for 100, 200, and 400 ppm naptalam, respectively. The number of new shoots produced by plants treated with 400 ppm naptalam was signif-

icantly greater than the number produced by plants treated with 100 ppm naptalam. Applications of 800 or 1600 ppm naptalam resulted in a marked reduction in the number of new shoots produced compared to plants treated with lower rates of naptalam. This was due to severe inhibition of growth of yellow nutsedge plants at these rates.

When naptalam was applied 4 weeks after transplanting, the number of new shoots produced per plant was significantly greater than that of the untreated plants only in those treated with from 400 to 1600 ppm naptalam. At the highest rate of naptalam (1600 ppm), the number of new shoots produced by the plants was significantly greater than at 400 ppm naptalam but was not significantly different from plants treated with 800 ppm naptalam.

The average dry weight of each new shoot from plants treated with 100, 200 or 400 ppm naptalam 2 weeks after transplanting did not differ from that of the untreated plants. However, the average dry weights of each new shoot in plants treated with 800 and 1600 ppm naptalam 2 weeks after transplanting were significantly lower than that of the untreated plants. When naptalam was applied 4 weeks after transplanting, the dry weight of each new shoot did not differ significantly from that of the untreated plants at all rates of naptalam used although a trend toward reduced growth at the higher rates was noted.

In summary, the application of 100 to 400 ppm naptalam to yel-

low nutsedge plants grown at the 20-hour photoperiod 2 weeks after transplanting produced more new shoots which were comparable in size to the untreated plants (Figure 12). Higher rates of naptalam were required to stimulate the production of new shoots in older plants than in younger plants, and the new shoots produced at these high rates were smaller.

Table 8. The effect of naptalam on number and size of new shoots at two stages of growth of yellow nutsedge.

Treatment		Number of new shoots per plant	Average Dry weight of each new shoot (mg)
Time of naptalam application (weeks after transplanting)	Naptalam (ppm)		
2	0	5.25d[1/]	223.20a
	100	10.25bc	242.85a
	200	11.75ab	314.02a
	400	14.25a	179.02ab
	800	5.50d	68.55b
	1600	6.00d	75.25b
4	0	7.75d	193.42ab
	100	8.00cd	242.87a
	200	8.00cd	288.90a
	400	8.25c	216.35a
	800	10.75bc	119.60b
	1600	13.00ab	96.65b

[1/] Values within the same column followed by the same letter are not significantly different at the 1% level based on Duncan's multiple range test.

Figure 12. Increased number of new shoots of yellow nutsedge plants grown under 20-hour photoperiod and treated with naptalam at two weeks after transplanting. A = Untreated; C = naptalam (200 ppm).

SECTION II

SOME EFFECTS OF GLYPHOSATE ON YELLOW NUTSEDGE

Experiment 10: The Effect of Glyphosate at Different Stages of Growth of Yellow Nutsedge

Materials and Methods:

In a greenhouse experiment, single yellow nutsedge plants were transplanted into plastic pots containing sandy loam soil. A randomized block design with a factorial arrangement of treatments was used. The factors studied and the levels at which they were used are as follows:

A. Rates of glyphosate applied: 0, 0.56, 1.12, 2.24, and 4.48 kg/ha.

B. Stages of growth of yellow nutsedge: 2, 4, and 6 weeks after transplanting.

Each treatment was replicated six times. The plants had six to seven leaves and were 28 to 46 cm in height 2 weeks after transplanting. After 4 weeks, they had eight to nine leaves and were 61 to 71 cm in height and after 6 weeks, they had 10 to 12 leaves and were 71 to 84 cm tall. Glyphosate was applied at the times and rates indicated above as a spray over the top of the plants in 374 liters of herbicide solution per hectare. The plants were watered regularly by sprinkle irrigation.

Thirty days after glyphosate application, the shoots of the plants were harvested and the fresh and dry weight of the shoots produced per pot was determined. Since the plants were not harvested at the same time, the fresh and dry weight of shoots were expressed as a percentage of the untreated plants. The data were subjected to statistical analysis and differences among treatments were determined using Duncan's multiple range test.

Results and Discussion:

The results are presented in Table 9. Fresh weights of shoots of yellow nutsedge plants sprayed with 0.56 kg/ha were 16, 20, and 34 percent of the untreated plants when glyphosate was applied at 2, 4, and 6 weeks after transplanting, respectively. These data showed that 0.56 kg/ha glyphosate reduced fresh weight of shoots of the plants to a greater extent when applied 2 or 4 weeks after transplanting than 6 weeks after transplanting. There were no significant differences in fresh weight of shoots when glyphosate was applied at rates of from 1.12 to 4.48 kg/ha at any of the three stages of growth of yellow nutsedge. When glyphosate was applied 4 weeks after transplanting, the fresh weight of shoots, as a percentage of the untreated plants, at 4.48 kg/ha was significantly lower than that at 0.56 kg/ha. Application of 1.12 kg/ha glyphosate 6 weeks after transplanting resulted in sig-

nificantly lower fresh weight of shoots than that of plants treated with 0.56 kg/ha. Increasing the rate of glyphosate beyond 1.12 kg/ha did not result in further significant decrease in fresh weight of shoots.

The dry weight of shoots produced by treated plants expressed as a percentage of the untreated plants showed the same trend observed with the data on fresh weight of shoots. The dry weight of shoots produced by treated plants were 32, 54, and 74 percent at 2, 4, and 6 weeks after transplanting, respectively. These values were all significantly different from each other, indicating that glyphosate was more effective in reducing shoot growth of younger plants than of older ones.

Table 9. The effect of glyphosate on fresh and dry weight of shoots at three stages of growth of yellow nutsedge.

Treatment		Fresh weight of shoots as percent of untreated	Dry weight of shoots as percent of untreated
Time of glyphosate application (weeks after transplanting)	Glyphosate (kg/ha)		
2	0	100.00a[1]	100.00a
	0.56	15.95cd	32.31d
	1.12	6.36cd	23.79d
	2.24	3.13d	17.90d
	4.48	3.30d	20.33d
4	0	100.00a	100.00a
	0.56	19.56c	53.96c
	1.12	10.00cd	43.99c
	2.24	7.84cd	37.02cd
	4.48	5.62d	25.94d
6	0	100.00a	100.00a
	0.56	33.80b	74.30b
	1.12	11.10cd	45.49c
	2.24	11.78cd	49.73c
	4.48	9.42cd	41.34c

[1] Values within the same column followed by the same letter are not significantly different at the 1% level based on Duncan's multiple range test.

Experiment 11: Effect of Single and Split Applications of Glyphosate on Yellow Nutsedge

Materials and Methods:

A greenhouse experiment was conducted to compare the effect of single and split applications of glyphosate on yellow nutsedge. On March 7, 1974, single yellow nutsedge plants were transplanted into plastic pots containing sandy loam soil. A randomized block design with a factorial arrangement of treatments was used. The factors studied were:

A. Method of application: Single and split.

B. Rates of glyphosate used: 0, 0.07, 0.14, 0.28, 0.56, and 1.12 kg/ha.

Each of the above treatments were replicated six times. The choice of rates of glyphosate used in this experiment was based on results of preliminary experiments which indicated that the application of glyphosate at rates higher than 1.12 kg/ha completely killed the shoots of the plants. Therefore, the highest rate of glyphosate used in this experiment was 1.12 kg/ha. Glyphosate was applied at each of the rates indicated above as a spray over the top of the plants in 374 liters of herbicide solution per hectare. Single applications and the first application of the split application were applied 30 days after transplanting. In the case of split applications, one-half of the total amount

of the herbicide was sprayed during the first application and the other half was sprayed 10 days later. The plants had 9 to 12 leaves and were 63 to 81 cm in height when the single and the first split application were made. The plants that were sprayed with the single application of glyphosate were harvested 75 days after the first application. Plants that were sprayed with split applications of glyphosate were harvested 75 days after the second application. The shoots were cut and their dry weight was determined. Since the plants were not harvested at the same time, the dry weight of shoots was expressed as a percentage of the shoots produced by the untreated plants. The data were subjected to statistical analysis and differences among treatments were determined using Duncan's multiple range test.

Results and Discussion:

The results are presented in Table 10. There was no significant difference due to the method of application of glyphosate. The dry weight of shoots of treated plants expressed as a percentage of the untreated plants was comparable in both single and split applications at each rate of glyphosate.

The single application of glyphosate at 0.56 kg/ha significantly reduced the dry weight of shoots compared to the lower rates of glyphosate and the untreated plants. Both single and split applications of

glyphosate at the highest rate (1.12 kg/ha) significantly reduced the dry weight of shoots compared to all other treatments.

Table 10. Effect of single and split application of glyphosate on dry weight of yellow nutsedge shoot.

Treatment		Dry weight of shoot as percent of untreated
Method of application	Total Glyphosate applied	
single	0.07	107.33a[1/]
	0.14	104.87a
	0.28	110.65a
	0.56	77.08b
	1.12	40.72c
	0	100.00ab
split	0.07	102.83ab
	0.14	102.22ab
	0.28	106.37a
	0.56	85.88ab
	1.12	36.36c
	0	100.00ab

[1/] Values within the same column followed by the same letter are not significantly different at the 1% level based on Duncan's multiple range test.

Experiment 12: Viability of Yellow Nutsedge Tubers Produced by Glyphosate-treated Yellow Nutsedge Plants

Materials and Methods:

Single yellow nutsedge plants were transplanted into plastic pots containing sandy loam soil on January 12, 1974. Plants were grown in the greenhouse for 70 days to allow sufficient rhizomes to be produced. On March 23, 1974, the plants were transferred to a growth chamber. At this time, they had 10 to 12 leaves and were 76 to 96 cm in height. The plants were grown at 30 C and 10-hour photoperiod to induce tuber production. They were watered regularly by sprinkle irrigation. Many tubers were already formed after 45 days of exposure in the 10-hour photoperiod. The plants were taken to the greenhouse and sprayed with 0.28, 0.56, 1.12, and 2.24 kg/ha glyphosate in 374 liters of herbicide solution per hectare. Untreated plants were maintained for comparison. Four plants were used for each rate of application. The plants were tall and drooping so bamboo stakes were installed 2 days after glyphosate application to keep the plants in an upright position. Injury ratings on the plants were taken 25 days after glyphosate application. Then the underground parts of the plants were carefully washed with running water and the tubers were separated from the parent plants. The tubers produced by plants treated with each rate of glyphosate were collected and placed in plastic bags.

Early attempts to grow the newly harvested tubers failed because they were dormant. To break dormancy, the tubers were subjected to cold treatment (51). The tubers were placed in plastic bags and stored in the refrigerator at 5 C for 3 weeks. After exposure to cold treatment, 60 uniform tubers were selected from each rate of application and 30 were placed into each of two petri dishes lined with filter paper. Twenty ml of distilled water were poured into each petri dish. The petri dishes were then placed in a growth chamber at 30 C and 12-hour photoperiod. After 3 weeks, the number of tubers that sprouted and those that were soft were counted. Tubers that were hard but did not sprout were also counted and classified as dormant. The number of sprouted tubers, dormant tubers, and non-viable tubers were expressed as a percentage of the total number of tubers in each petri dish. The data were analyzed as a completely randomized design and differences among treatments were determined using Duncan's multiple range test.

Results and Discussion:

The results are presented in Table 11. Injury ratings 25 days after glyphosate application showed significantly higher ratings with higher rates of glyphosate. The shoots of plants that received a spray of 1.12 kg/ha glyphosate were nearly dead while those that received

2.24 kg/ha of glyphosate were completely killed.

Untreated plants produced the highest percentage of sprouted tubers (67%). The percentage of tubers which sprouted was significantly reduced by all treatments as compared to untreated plants. As glyphosate rates increased, significant reductions in the percentage of tubers which sprouted occurred up to 1.12 kg/ha. Differences between the two higher rates were not significant. A similar observation was reported by Zandstra, et al. (62) with repeated field application of glyphosate at 2 kg/ha on purple nutsedge.

Glyphosate appeared to induce tuber dormancy at the lower rates and kill many tubers at the higher rates. For example, the application of 0.28 and 0.56 kg/ha glyphosate resulted in 57 and 68 percent dormant tubers, respectively, while application of 1.12 and 2.24 kg/ha glyphosate resulted in 47 and 52 percent dormant tubers, respectively. Furthermore, the application of 1.12 and 2.24 kg/ha glyphosate resulted in 42 and 38 percent dead tubers, respectively.

In summary, the application of glyphosate to yellow nutsedge plants significantly reduced the percentage of sprouted tubers. At lower rates of application (0.28 and 0.56 kg/ha), the low percentage of sprouted tubers was due to an increase in percentage of dormant tubers. At the higher rates of application (1.12 and 2.24 kg/ha), the low percentage of sprouted tubers was due to both dormant and dead tubers.

Glyphosate at 1.12 and 2.24 kg/ha which essentially killed the top-growth of yellow nutsedge was apparently translocated into the tubers, killing 42 and 38 percent of the tubers, respectively. Nevertheless, the remaining tubers which were not killed by the treatments still accounted for over 50 percent of the tubers and are still capable of regeneration.

Table 11. Effect of glyphosate on topgrowth of yellow nutsedge and viability of yellow nutsedge tuber.

Rate of glyphosate applied (kg/ha)	Injury ratings at 25 days after glyphosate application[1]	Percent sprouted tubers	Percent dormant tubers	Percent non-viable tubers
0	0d[2]	66.67a	26.67d	6.66b
0.28	27.00c	43.33b	56.66ab	0b
0.56	52.00b	26.66c	68.33a	5.00b
1.12	97.00a	11.66d	46.66c	41.67a
2.24	100.00a	10.00d	51.67bc	38.33a

[1] Rating scale: 0 = no injury 100 = completely killed

[2] Values within the same column followed by the same letter are not significantly different at the 1% level based on Duncan's multiple range test.

SECTION III

INFLUENCE OF NAPTALAM ON GLYPHOSATE TOXICITY TO YELLOW NUTSEDGE

Experiment 13: Effect of Simultaneous Application of Naptalam and Glyphosate on Naptalam-induced Shoot Production and Growth of Yellow Nutsedge

Materials and Methods:

In a greenhouse experiment, single yellow nutsedge plants were transplanted into plastic pots containing a mixture of one-third sand and two-thirds soil. The different treatments used in this experiment were naptalam (400 ppm), glyphosate (0.56 kg/ha), and naptalam (400 ppm) plus glyphosate (0.56 kg/ha). An untreated check was included for comparison. These treatments were applied one month after the plants were transplanted. At this time, the plants had five to six leaves and were 22 to 29 cm in height. The experiment was conducted using a randomized block design with each treatment replicated five times. Fifty ml of 400 ppm naptalam solution was applied directly to the soil in each pot. Plants that were treated with glyphosate received a foliar application of the herbicide at 0.56 kg/ha in 374 liters of herbicide solution per hectare. The plants that were treated with both naptalam and glyphosate received soil application of naptalam followed immediately by a foliar spray of glyphosate.

The plants were watered regularly by sprinkle irrigation. Data on the number of new shoots produced by each plant were taken at 10, 20, and 40 days after treatment. Forty days after herbicide treatment, the experiment was terminated and new shoots were carefully separated from the main plants and counted. The fresh weight of new shoots produced by each plant was determined. Data on average fresh weight of each new shoot was calculated by dividing the fresh weight of all new shoots produced per plant by the number of new shoots produced by each plant. In addition, data on fresh weight, and height of main shoots of the plants were taken at the end of the experiment. The data were statistically analyzed and differences among treatments were determined by Duncan's multiple range test.

Results and Discussion:

Results are presented in Table 12. The number of new shoots produced per plant 10 and 20 days after herbicide treatment indicated that the application of glyphosate simultaneously with naptalam temporarily inhibited naptalam-induced shoot production in yellow nutsedge plants. For example, 10 days after herbicide treatment, plants that were treated with naptalam alone had five new shoots per plant. Simultaneous application of glyphosate with naptalam reduced the number of new shoots per plant from five to one. Twenty days after herb-

icide application, simultaneous application of both herbicides reduced the number of new shoots per plant compared to those treated with naptalam alone by about 62 percent.

Forty days after herbicide application, the number of new shoots produced by plants treated with both naptalam and glyphosate did not differ from those in plants treated with naptalam alone. However, data on fresh weight of each new shoot showed that the new shoots produced by plants treated with naptalam plus glyphosate were much smaller than those produced by plants treated with naptalam alone. The fresh weight and average height of the main shoot of plants showed that treatment with naptalam inhibited growth of the main shoots.

In plants treated with naptalam plus glyphosate, glyphosate appeared to be preferentially translocated to the underground rhizomes that were being transformed to shoots and inhibited their growth. This is in agreement with the delayed appearance (for about 5 days) of glyphosate symptoms on main shoots of plants treated with naptalam and glyphosate compared to plants treated with glyphosate alone (Figures 13 and 14). This is further supported by the delay in production of new shoots in plants treated with naptalam plus glyphosate compared to that in plants treated with naptalam alone, and the lower fresh weight of each new shoot produced in plants treated with the combination.

The results of this experiment showed that the simultaneous application of naptalam and glyphosate delayed naptalam-induced shoot production in yellow nutsedge. This effect is undesirable because interference with naptalam-induced shoot production would eventually result in fewer rhizomes transformed to shoots and consequently, fewer shoots exposed to the glyphosate spray. The beneficial effects from the use of naptalam and glyphosate in a yellow nutsedge control program cannot be achieved by applying both herbicides simultaneously but by applying glyphosate to the plants after most of the new shoots have been formed.

Table 12. Effect of simultaneous application of naptalam and glyphosate on shoot production and growth of yellow nutsedge.

Treatment	Number of new shoots per plant at 10 DAT[1]	20 DAT	40 DAT	Fresh weight of each new shoot (g)	Fresh weight of main shoot (g)	Average height of main shoot (cm)
Untreated	1.60b[2]	2.20b	2.80b	0.2551a	5.1282a	57.60a
Naptalam (400 ppm)	5.20a	9.60a	12.20a	0.1337b	1.6633b	32.60b
Glyphosate (0.56 kg/ha)	1.00b	2.00b	2.00b	0.1299b	4.3223a	53.20a
Naptalam (400 ppm) + Glyphosate (0.56 kg/ha)	1.20b	3.60b	11.00a	0.0640c	1.2221b	29.60b
	(p=0.01)	(p=0.01	(p=0.01)	(p=0.05)	(p=0.01)	(p=0.01)

[1] DAT = Days After Treatment

[2] Values within each column followed by the same letter are not significantly different at the levels indicated based on Duncan's multiple range test.

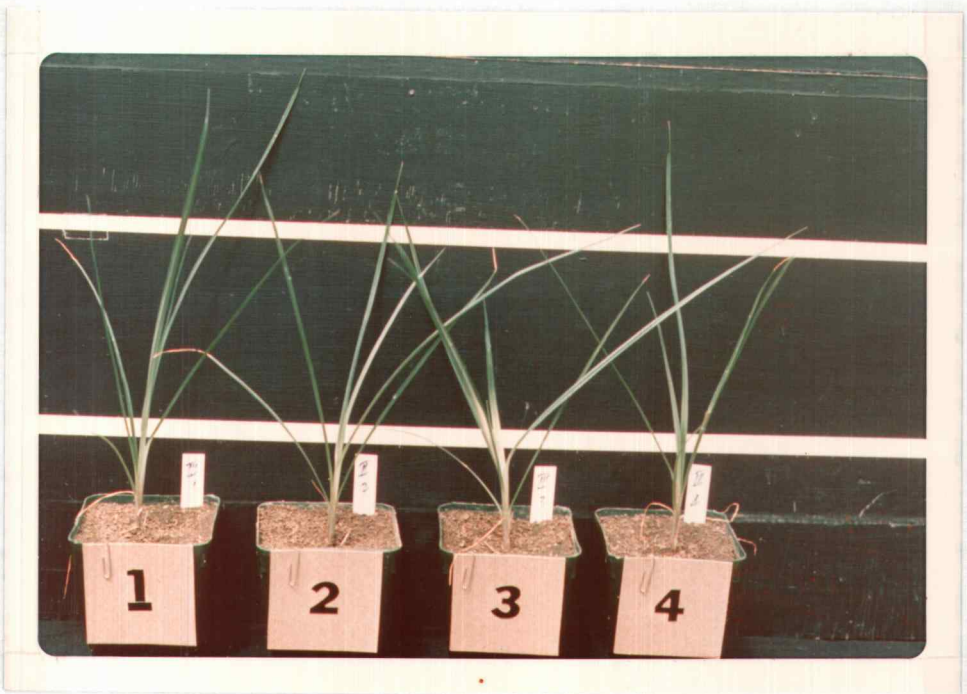

Figure 13. Delayed appearance of glyphosate symptoms on yellow nutsedge plants treated simultaneously with naptalam and glyphosate. 1 = Untreated; 2 = Naptalam (400 ppm); 3 = Glyphosate (0.56 kg/ha); 4 = Naptalam (400 ppm) + Glyphosate (0.56 kg/ha).

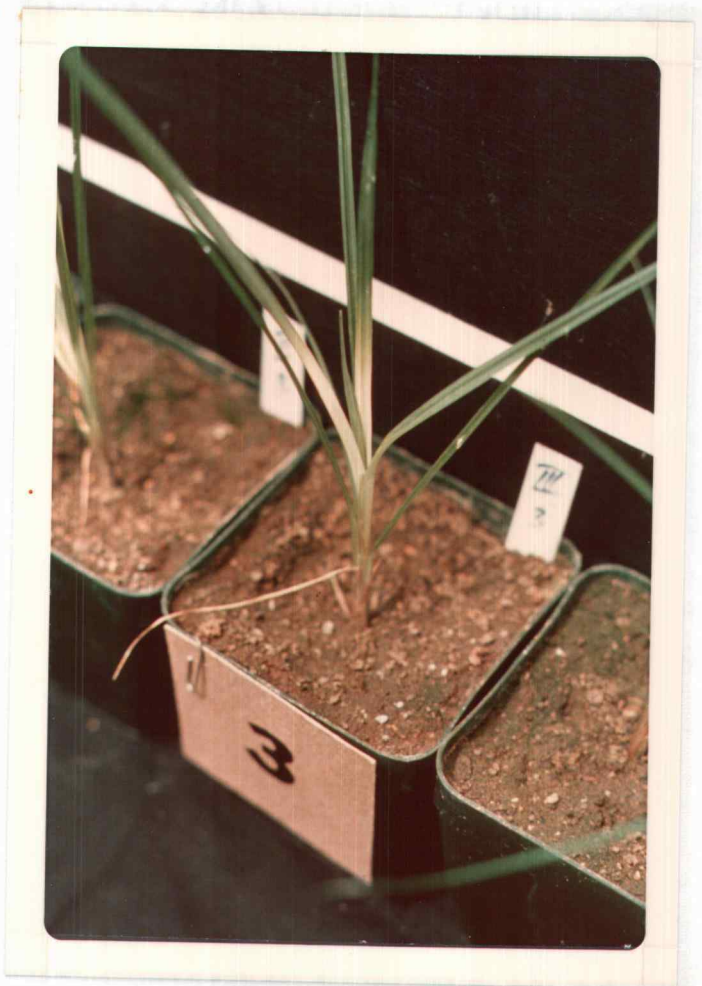

Figure 14. Close-up of yellow nutsedge plant treated with glyphosate (0.56 kg/ha) showing the effect of the herbicide.

Experiment 14: Application of Glyphosate to Naptalam-treated Yellow Nutsedge Plants

Materials and Methods:

Yellow nutsedge plants were transplanted into plastic pots filled with sandy loam soil with two plants per pot on July 18, 1974 and established in the greenhouse. The different treatments used in this experiment were naptalam (800 ppm), glyphosate (0.56 and 1.12 kg/ha), naptalam (800 ppm) followed by glyphosate (0.56 kg/ha), and naptalam (800 ppm) followed by glyphosate (1.12 kg/ha). An untreated check was included for comparison. The experiment was conducted using a randomized block design with each treatment replicated four times. Naptalam treatments were made 15 days after the plants were transplanted. Fifty ml of 800 ppm naptalam solution were applied carefully to the soil in each pot. At this time, the plants had six to eight leaves. Glyphosate treatments were made 2 weeks after naptalam application when the plants had 8 to 10 leaves and the naptalam-induced new shoots were 4 to 5 cm in height. Glyphosate, at the rates indicated above, was applied in 374 liters of herbicide solution per hectare. The plants were watered regularly by sub-irrigation. Thirty days after glyphosate application, the experiment was terminated. The shoots of the plants were harvested and the dry weight of shoots per pot was determined. The data were statistically analyzed and differences among

treatments were determined using Duncan's multiple range test.

Results and Discussion:

The results are presented in Table 13. Growth of yellow nutsedge plants treated with naptalam alone and with all rates of glyphosate was inhibited. Treatments of naptalam followed by glyphosate inhibited growth of plants much more than the application of naptalam or glyphosate alone.

Table 13. Effect of treatments of naptalam followed by glyphosate on dry weight of yellow nutsedge plants.

Treatment	Average dry weight of shoots per two plants (g)
Untreated	13.87a[1/]
Naptalam (800 ppm)	7.92c
Glyphosate (0.56 kg/ha)	10.89b
Glyphosate (1.12 kg/ha)	6.97d
Naptalam (800 ppm) followed by glyphosate (0.56 kg/ha)	4.42e
Naptalam (800 ppm) followed by glyphosate (1.12 kg/ha)	4.39e

[1/] Values followed by the same letter are not significantly different at the 1% level based on Duncan's multiple range test.

Experiment 15: Effect of Glyphosate Application at Different Times After Naptalam Treatment

Materials and Methods:

On April 6, 1974, single yellow nutsedge plants were transplanted into plastic pots filled with sandy loam soil. The experiment was conducted in the greenhouse. A 3 x 2 x 2 factorial experiment was established with six replications. The different factors and the levels at which they were used are as follows:

A. Time of glyphosate application: 1, 2, and 4 weeks after naptalam treatment.

B. Concentrations of naptalam used: 0 and 400 ppm.

C. Rates of glyphosate applied: 0 and 0.56 kg/ha.

Naptalam treatments were made 2 weeks after the plants were transplanted. Fifty ml of 400 ppm naptalam solution was applied directly to the soil in each pot. At this time, the plants had six to seven leaves and were 23 to 28 cm in height. The plants were watered regularly by sprinkle irrigation. The first glyphosate treatment was made 1 week after naptalam application to plants with seven to eight leaves and 25 to 33 cm tall. Naptalam-induced new shoots were not evident at this time. Glyphosate at 0.56 kg/ha was applied as a foliar spray in 374 liters of herbicide solution per hectare. The second glyphosate application was made 2 weeks after naptalam treatment when the plants

had seven to nine leaves. Untreated plants were 33 to 41 cm in height while those treated with naptalam were 25 to 36 cm tall. New shoots in the naptalam-treated plants were 0.60 to 2.54 cm in height. The third glyphosate application was made 4 weeks after naptalam treatment. Untreated plants had 7 to 11 leaves and were 81 to 132 cm tall. Naptalam-treated plants were 74 to 89 cm in height. The new shoots produced by naptalam-treated plants were 3 to 25 cm tall.

Plants were harvested forty days after each glyphosate application. The shoots produced in each pot were cut and fresh and dry weights were determined. Data on fresh and dry weights of shoots were expressed as a percentage of the untreated plants because the plants were not harvested at the same time.

The method suggested by Colby (11) was used to determine if phytotoxicity from the application of 400 ppm naptalam followed by 0.56 kg/ha glyphosate was synergistic in yellow nutsedge plants. The method involved the calculation of the expected response of the weed to the application of the two herbicides based on the observed response of the weed to each herbicide applied alone. The calculated value for the expected response was compared with the observed response of the weed to the application of the two herbicides. The result is considered synergistic when the observed response is greater than the expected, and antagonistic when the observed response is less than the expected.

The expected response of yellow nutsedge plants to the application of glyphosate following naptalam treatment was calculated using Colby's equation (11):

$$E_1 = \frac{X_1 \quad Y_1}{100}$$

Where: E_1 = Expected fresh or dry weight of shoots, as percent of the untreated, of plants treated with 400 ppm naptalam followed by 0.56 kg/ha glyphosate.

X_1 = Fresh or dry weight of shoots, as percent of the untreated, of plants treated with 400 ppm naptalam.

Y_1 = Fresh or dry weight of shoots, as percent of the untreated, of plants treated with 0.56 kg/ha glyphosate.

The differences between the calculated expected value and the observed response were determined for each replication at each time of glyphosate application. The differences between the observed and the expected values were then subjected to the chi-square test (32). Chi-square (X^2) is obtained by the formula:

$$X^2 = \frac{(\text{Observed} - \text{Expected})^2}{\text{Expected}}$$

The chi-square values across replications at each time of glyphosate application were added and the total value was compared with the val-

ues in an accumulative chi-square distribution table to determine if differences between the expected and the observed effects were significant.

The differences between the average expected fresh or dry weight of shoots as percent of the untreated and the average observed fresh or dry weight of shoots as percent of the untreated at each time of glyphosate application were determined.

Results and Discussion:

The combination of naptalam followed by glyphosate reduced yellow nutsedge growth significantly more than the expected at all times of glyphosate treatment, regardless of whether fresh or dry weights were used (Table 14). This provides strong evidence for synergisim between these two herbicides on yellow nutsedge and supports the possibility of using such a combination in a control program. The degree of synergism tended to be greater when glyphosate was applied 2 weeks after naptalam treatment than at 1 or 4 weeks (Figure 15).

Table 14. Synergistic effect of treatments of naptalam followed by glyphosate on yellow nutsedge.

Treatment		Fresh weight of shoots as percent of untreated			Dry weight of shoots as percent of untreated		
Time of Glyphosate application (weeks after naptalam treatment)	Herbicide(s)	Observed[1]	Expected[2]	Expected – Observed[2]	Observed[1]	Expected[2]	Expected – Observed[2]
1	Untreated	100.00			100.00		
	Naptalam (400 ppm)	64.20			54.70		
	Glyphosate (0.56 kg/ha)	88.82			105.57		
	Naptalam (400 ppm) followed by Glyphosate (0.56 kg/ha)	27.48	57.27	+29.79*S	38.13	61.67	+23.54*S
2	Untreated	100.00			100.00		
	Naptalam (400 ppm)	78.99			70.54		
	Glyphosate (0.56 kg/ha)	93.25			95.06		
	Naptalam (400 ppm) followed by Glyphosate (0.56 kg/ha)	30.96	79.99	+49.03*S	36.93	70.04	+33.11*S
4	Untreated	100.00			100.00		
	Naptalam (400 ppm)	78.06			64.91		
	Glyphosate (0.56 kg/ha)	84.25			86.59		
	Naptalam (400 ppm) followed by Glyphosate (0.56 kg/ha)	37.28	66.22	+28.94*S	40.09	55.90	+15.81*S

[1] Average of six replications

[2] Values determined according to Colby's method. The * indicates a significant difference between the expected and the observed values at the 0.05% probability level using the chi-square test. The + sign indicates that the expected value is greater than the observed value and S stands for synergism.

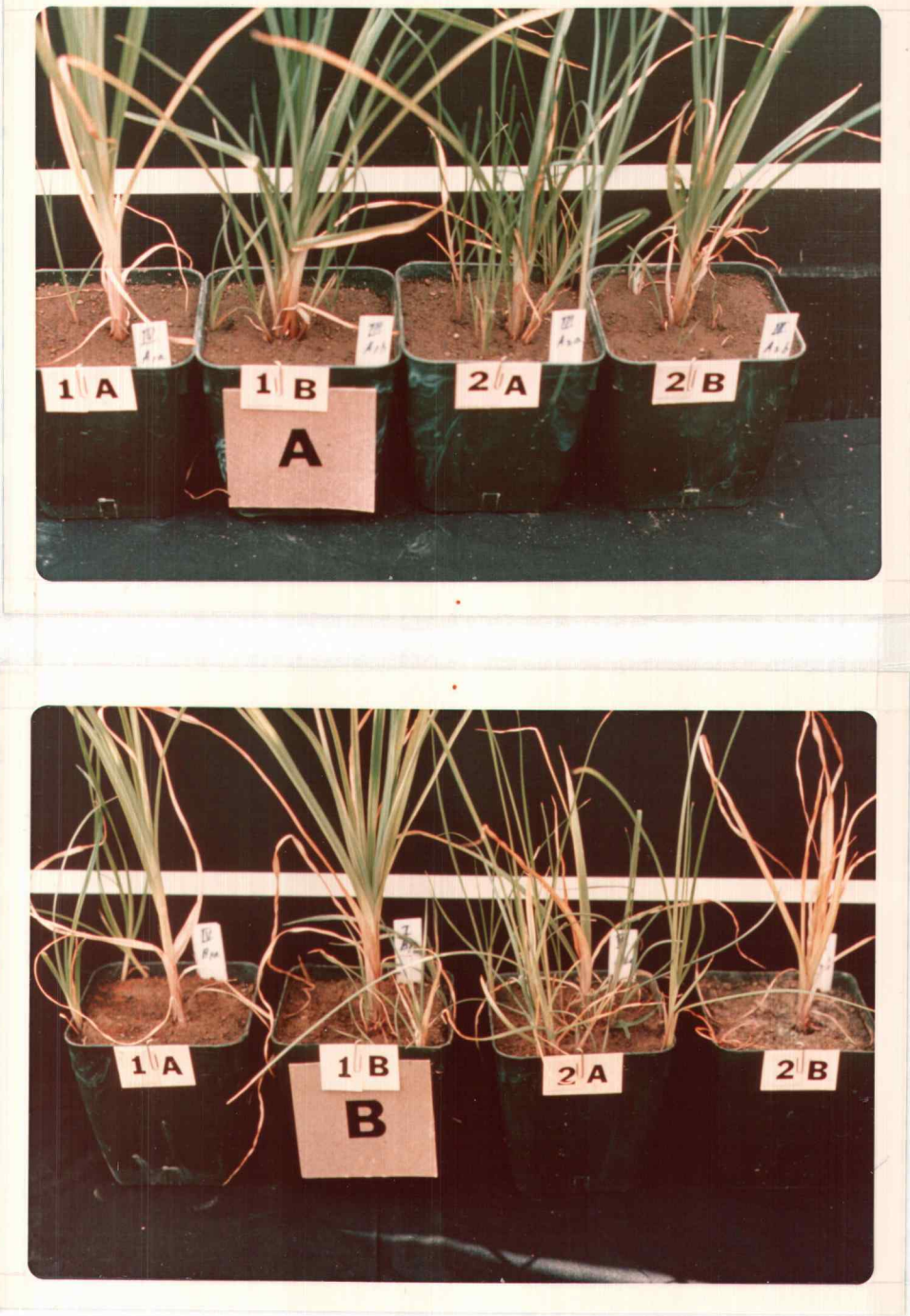

Figure 15. Effect of treatments of Naptalam followed by Glyphosate on yellow nutsedge. 1A = Untreated; 1B = Glyphosate (0.56 kg/ha); 2A = Naptalam (400 ppm); 2B = Naptalam (400 ppm) followed by Glyphosate (0.56 kg/ha); A = Glyphosate applied one week after naptalam treatment; B = Glyphosate applied two weeks after naptalam treatment; C = Glyphosate applied four weeks after naptalam treatment.

Figure 15. Effect of treatments of Naptalam followed by Glyphosate on yellow nutsedge. 1A = Untreated; 1B = Glyphosate (0.56 kg/ha); 2A = Naptalam (400 ppm); 2B = Naptalam (400 ppm) followed by Glyphosate (0.56 kg/ha); A = Glyphosate applied one week after naptalam treatment; B = Glyphosate applied two weeks after naptalam treatment; C = Glyphosate applied four weeks after naptalam treatment.

Experiment 16: Effect of Glyphosate Application Following Naptalam Treatment on Subsequent Tuber and Rhizome Production, and Regrowth of Yellow Nutsedge Plants

Materials and Methods:

Plants from Experiment 15 that had been sprayed with 0.56 kg/ha glyphosate 4 weeks after they were treated with 400 ppm naptalam were allowed to regrow after topgrowth was cut. The plants were regularly watered by sprinkle irrigation. One hundred days after the topgrowth was cut, the underground parts of the plant regrowth were carefully separated from the soil medium by washing with running water. Untransformed rhizomes as well as those that were transformed to tubers in each pot were carefully separated from the main plant and counted. The sum of the number of rhizomes transformed to tubers and the number of untransformed rhizomes in each pot was determined and designated as total number of tubers and rhizomes per pot. The topregrowth from each pot was cut and their dry weight was determined. All the above data were analyzed as a randomized block design and differences among treatments were determined by Duncan's multiple range test.

Results and Discussion:

The results are presented in Table 15. Data on number of rhi-

zomes transformed to tubers per pot showed that the untreated plants and the plants treated with 400 ppm naptalam produced the highest number of tubers. The change in length of photoperiod from the start of this experiment in June, 1974 to the time it was terminated in October, 1974, was from 15 to 11 hours (60). This change in photoperiod is conducive to tuber production in yellow nutsedge. The number of tubers produced by the plants treated with 0.56 kg/ha glyphosate was significantly lower than the number of tubers produced by untreated or naptalam-treated plants. Application of glyphosate at 0.56 kg/ha reduced the number of tubers per pot from 165 to 132, a reduction of about 20 percent. This observation is in agreement with those reported by Zandstra, et al. (62) in Hawaii and Terry (42) in Tanzania on their studies involving glyphosate on purple nutsedge. Terry (42) reported a reduction in the number of tubers present in the top 10 cm of soil after treating purple nutsedge with 4 kg/ha glyphosate. Zandstra, et al. (62) reported a reduction of about 92 percent in the number of tubers in the upper 13 cm of soil after repeated applications of 2 kg/ha glyphosate on purple nutsedge. The lowest number of tubers were produced by plants treated with naptalam (400 ppm) followed by glyphosate (0.56 kg/ha). Only 56 tubers were produced in this treatment, which is 66 percent less tubers produced than by the untreated plants. These data indicate that the application of glyphosate after treatment with

naptalam had a more drastic effect on tuber production than the application of glyphosate alone.

The untreated plants produced the greatest number of untransformed rhizomes. The number of untransformed rhizomes produced in all the other treatments were significantly lower than those of the untreated plants but there were no significant differences among the remaining treatments.

The untreated plants and the plants treated with 400 ppm naptalam produced the greatest total number of tubers and rhizomes. Glyphosate application significantly reduced the total number of tubers and rhizomes (approximately 69 percent of that of the untreated plants). Plants treated with naptalam followed by glyphosate produced a significantly lower total of tubers and rhizomes than all the other treatments (Figure 16). The total number of tubers and rhizomes produced in this treatment was reduced by 62 percent in comparison with the untreated plants.

The dry weight of regrowth of plants treated with naptalam followed by glyphosate was significantly lower than that of the untreated plants and plants treated with naptalam alone but was comparable to plants treated with glyphosate alone.

The application of naptalam followed by glyphosate was superior to either glyphosate alone or naptalam alone in reducing the number of

tubers produced by yellow nutsedge plants. The naptalam treatment transformed most of the rhizomes, which were also potential tubers, into new shoots. Glyphosate application following naptalam treatment killed the new shoots that were formed and resulted in a marked reduction in the total number of tubers and rhizomes produced by yellow nutsedge plants. This has demonstrated a possible way of reducing the regenerative capacity of yellow nutsedge, which would lead to improved control.

Table 15. Effect of treatment of naptalam followed by glyphosate on subsequent tuber and rhizome production and regrowth of yellow nutsedge plants.

Treatment	Number of rhizomes transformed to tubers per pot	Number of untransformed rhizomes per pot	Total number of tubers and rhizomes per pot	Dry weight of regrowth per pot (g)
Untreated	165.50a[1/]	58.33a	223.83a	3.6356a
Naptalam (400 ppm)	168.33a	23.50b	191.83a	3.8882a
Glyphosate (0.56 kg/ha)	132.33b	22.17b	154.50b	3.1728ab
Naptalam (400 ppm) followed by glyphosate (0.56 kg/ha)	56.00c	29.83b	85.83c	2.8003b
	(p=0.01)	(p=0.01)	(p=0.01)	(p=0.05)

[1/] Values within each column followed by the same letter are not significantly different at the levels indicated based on Duncan's multiple range test.

Figure 16. Effect of treatment of Naptalam followed by Glyphosate on subsequent tuber and rhizome production of yellow nutsedge. 1 = Untreated; 3 = Glyphosate (0.56 kg/ha); 4 = Naptalam (400 ppm) followed by glyphosate (0.56 kg/ha) 4 weeks after Naptalam treatment.

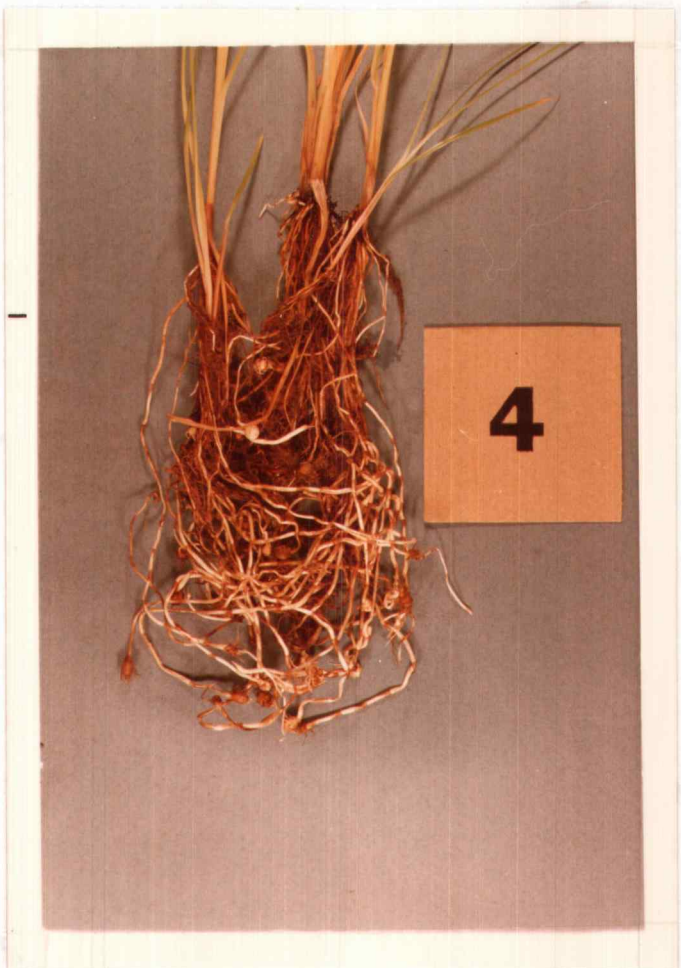

Figure 16. Effect of treatment of Naptalam followed by Glyphosate on subsequent tuber and rhizome production of yellow nutsedge. 1 = Untreated; 3 = Glyphosate (0.56 kg/ha); 4 = Naptalam (400 ppm) followed by glyphosate (0.56 kg/ha) 4 weeks after Naptalam treatment.

SUMMARY AND CONCLUSIONS

Effects of Naptalam on Shoot and Tuber Production, Rhizome Transformation, and Growth of Yellow Nutsedge Plants

The application of naptalam to yellow nutsedge plants resulted in a significantly greater number of new shoots compared to the untreated plants whether it was applied to the soil, through a liquid growth medium, or as a topical spray. Naptalam-treated plants were inhibited in growth and were stubby in appearance.

Soil applications of naptalam at 100 and 200 ppm to yellow nutsedge plants (six to eight leaf stage) resulted in the production of three and four times as many new shoots, respectively, as those of the untreated plants 45 days after treatment.

The percentages of rhizomes transformed to shoots and the number of rhizomes produced per plant in yellow nutsedge plants treated with naptalam through the liquid growth medium were significantly greater than those of the untreated plants. These observations indicated that the increase in the number of new shoots in naptalam-treated plants was due to the transformation of rhizomes to shoots and also to an increase in the number of rhizomes produced. Longer exposure of plants to naptalam solution resulted in more rhizomes transformed to shoots.

When naptalam was applied as a spray over the top of the plants, split applications proved to be more effective in producing new shoots than single applications. When naptalam was applied to the soil, there was no significant difference in the number of new shoots produced per plant between the single and split applications except at the highest concentration (1600 ppm), where the split application resulted in significantly more new shoots than the single application.

Experiments conducted in growth chambers showed that the application of naptalam to yellow nutsedge plants grown under long day conditions resulted in significantly higher dry weights of new shoots compared to the untreated plants. Furthermore, the application of nitrogen (from 1/32 to 1/8 N Hoagland's solution) significantly increased the dry weight of new shoots. Growing the plants under short day conditions induced tuber production but this was inhibited by naptalam application.

Yellow nutsedge plants grown for 50 days under a 12-hour photoperiod and for another 50 days at a 20-hour photoperiod produced numerous tubers. Application of naptalam significantly increased the number of new shoots at the higher rate of application and inhibited tuber production. The late application of naptalam (70 days after transplanting) reduced the number of tubers produced per plant by approximately 60 percent.

The application of naptalam (100 to 400 ppm) to yellow nutsedge plants with five to seven leaves, grown under a 20-hour photoperiod resulted in the production of more new shoots which were comparable in size to the new shoots in the untreated plants. Higher rates of naptalam were needed to stimulate the production of new shoots in older plants than in younger plants.

Photoperiod studies involving yellow nutsedge have shown that exposure to long day conditions (14 to 24-hour photoperiods) induced rhizome proliferation and transformation of rhizomes into shoots while exposure to short day conditions (8 to 12.5-hour photoperiods) induced tuber production (6, 14, 20). The results of Experiments 6 to 8 showed that naptalam-treated plants produced significantly more new shoots than the untreated plants when grown under a 20-hour photoperiod, and applications of naptalam to plants grown under short day conditions (10 to 12-hour photoperiods) inhibited tuber production. Although the length of the long day treatment used in these experiments was greater than the actual length of photoperiod during the summer months in latitudes where yellow nutsedge abounds, the results obtained still indicated the ability of long photoperiod to increase the number of new shoots produced by naptalam-treated plants. Thus, the information obtained from these experiments points out a possible way of effectively using naptalam in a yellow nutsedge control program.

Naptalam may be applied to the plants just before tubers are formed to inhibit tuber production, and may be applied again after the new plants have emerged to induce transformation of rhizomes to shoots. The number of new shoots produced by naptalam-treated plants may be increased by applying the herbicide to younger plants, and in plants supplied with high amounts of nitrogen.

Some Effects of Glyphosate on Yellow Nutsedge

Yellow nutsedge plants were treated with different rates of glyphosate at different stages of growth. Data on fresh and dry weights of shoots indicated that glyphosate was more effective in controlling shoots of younger plants than of older ones.

There were no significant differences in dry weights of shoots of yellow nutsedge plants when split and single applications were compared.

Tubers produced by glyphosate-treated plants had a significantly lower percentage sprouting than tubers produced by the untreated plants. Glyphosate appeared to make the tubers dormant at the lower rates (0.28 and 0.56 kg/ha) and kill many of them at the higher rates (1.12 and 2.24 kg/ha). When applied at the higher rates, glyphosate apparently translocated to the tubers and killed some of them but over 50 percent of the tubers were not killed and were still capable of re-

generation. A more lasting control of yellow nutsedge with glyphosate may be achieved by applying higher rates or by repeated applications. However, more studies are needed to determine if high rates of the herbicide would result in rapid kill of the plants and thus hinder effective translocation, and if the herbicide can reach tubers that are located deeper in the soil. Information on time of application of the herbicide that would allow it to be translocated to most, if not all of the tubers, also is needed. The most effective destruction of some deep rooted perennial weeds with glyphosate appears to be at the early bud or bloom stage for broadleaved species or at the late boot stage or early head stage for grasses and certain sedges (36).

Influence of Naptalam on Glyphosate Toxicity

The data obtained from Experiments 13 to 15 showed that it is more advantageous to apply glyphosate to yellow nutsedge plants after naptalam treatment than to apply the two herbicides simultaneously. Simultaneous application of naptalam and glyphosate delayed naptalam-induced production of new shoots. Glyphosate appeared to be preferentially translocated to the underground rhizomes that were being transformed to shoots and inhibited their growth. On the other hand, application of glyphosate 1 to 4 weeks after naptalam treatment resulted in a synergistic effect on yellow nutsedge plants. Fresh and dry weights

of shoots of plants treated with naptalam followed by glyphosate were significantly lower than the calculated expected fresh and dry weights of shoots according to Colby's method (11) indicating that the reduction in yellow nutsedge growth resulting from the application of naptalam followed by glyphosate was greater than the expected reduction in growth due to the application of both herbicides.

The application of naptalam followed by glyphosate was superior to either glyphosate or naptalam alone in reducing the number of tubers produced by regrowth of yellow nutsedge plants. There was no significant reduction in the number of tubers produced by regrowth of plants treated with naptalam alone compared to the untreated plants. The application of glyphosate alone reduced the number of tubers produced per plant by 20 percent but the application of naptalam followed by glyphosate reduced the number of tubers produced per plant by 66 percent. The marked reduction in the total number of rhizomes and tubers produced by plants treated with the combination of naptalam followed by glyphosate indicated that most of the rhizomes that were transformed to shoots by the naptalam treatment were killed by the glyphosate spray.

The results obtained in this study show a possible way of formulating a desirable spray program for yellow nutsedge control using naptalam and glyphosate in areas located in the temperate regions.

Maximum tuber production occurs during the fall months when the photoperiod is from 9 to 12 hours while emergence of new plants occurs in the spring (20, 39, 41, 60). In such a case, application of naptalam to the plants near the end of summer when tubers are starting to be formed, would inhibit tuber production. A second application of naptalam in the spring after the new plants have emerged, would induce rhizome transformation into shoots. Subsequent application of glyphosate to the naptalam-treated plants in mid summer may kill the plants including the newly-formed shoots, leading to a more lasting control of yellow nutsedge. This spray program needs to be tested under field conditions to verify or disprove the concepts proposed by the results of this thesis.

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APPENDIX

Appendix Table 1. Number of new shoots per plant at 15 days after treatment.

Treatment	Blocks								Average
	A	B	C	D	E	F	G	H	
Untreated	0	3	0	0	1	0	0	1	0.62
Naptalam (100 ppm)	4	4	5	4	4	2	2	3	3.50
Naptalam (200 ppm)	3	3	2	4	2	3	3	6	3.25

Appendix Table 2. Number of new shoots per plant at 30 days after treatment.

Treatment	Blocks								Average
	A	B	C	D	E	F	G	H	
Untreated	0	5	1	0	2	4	2	3	2.12
Naptalam (100 ppm)	7	9	5	11	10	7	8	6	7.87
Naptalam (200 ppm)	9	7	11	5	10	11	9	13	9.37

Appendix Table 3. Number of new shoots per plant at 45 days after treatment.

Treatment	Blocks								Average
	A	B	C	D	E	F	G	H	
Untreated	0	5	1	0	2	4	2	3	2.12
Naptalam (100 ppm)	8	10	8	11	10	8	8	6	8.62
Naptalam (200 ppm)	10	12	11	10	10	12	9	13	10.87

Analysis of Variance for Data in Appendix Table 1.

Source	SS	df	MS	F
Blocks	17.2917	7	2.4702	0.4415 N.S.
Treatments	234.3334	2	117.1667	20.9406 **
Error	78.3333	14	5.5952	
Total	329.9584	23		

C. V. = 36.6%

Analysis of Variance for Data in Appendix Table 2.

Source	SS	df	MS	F
Blocks	19.2917	7	2.7560	1.1238 N.S.
Treatments	330.3334	2	165.1667	67.3490 **
Error	34.3333	14	2.4524	
Total	383.9584	23		

C. V. = 21.7%

Analysis of Variance for Data in Appendix Table 3.

Source	SS	df	MS	F
Blocks	228.6670	7	32.6667	3.4300 *
Treatments	1009.3340	2	504.6670	52.9901 **
Error	133.3330	14	9.5238	
Total	1371.3340	23		

C. V. = 6.9%

Appendix Table 4. Average height of plants at treatment time (cm).

Treatment	Blocks								Average
	A	B	C	D	E	F	G	H	
Untreated	34	29	30	23	34	33	26	23	29.00
Naptalam (100 ppm)	31	28	29	29	34	28	27	23	28.62
Naptalam (200 ppm)	33	28	29	25	36	29	27	23	28.75

Appendix Table 5. Average height of plants at 15 days after treatment (cm).

Treatment	Blocks								Average
	A	B	C	D	E	F	G	H	
Untreated	39	35	42	44	53	51	46	45	44.37
Naptalam (100 ppm)	34	32	35	39	44	40	40	35	37.37
Naptalam (200 ppm)	36	35	34	31	45	35	33	34	35.37

Appendix Table 6. Average height of plants at 30 days after treatment (cm).

Treatment	Blocks								Average
	A	B	C	D	E	F	G	H	
Untreated	44	36	49	52	54	53	49	47	48.00
Naptalam (100 ppm)	34	33	35	38	45	40	41	36	37.75
Naptalam (200 ppm)	37	36	35	32	45	36	33	35	36.12

Analysis of Variance for Data in Appendix Table 4.

Source	SS	df	MS	F
Blocks	297.9600	7	42.5700	14.3800 **
Treatments	0.5800	2	0.2900	0.0900 N.S.
Error	41.4200	14	2.9600	
Total	339.9600	23		

C. V. = 6.0%

Analysis of Variance for Data in Appendix Table 5.

Source	SS	df	MS	F
Blocks	350.9590	7	50.1370	5.5418 **
Treatments	357.3340	2	178.6670	19.7488 **
Error	126.6660	14	9.0470	
Total	834.9590	23		

C. V. = 7.7%

Analysis of Variance for Data in Appendix Table 6.

Source	SS	df	MS	F
Blocks	298.9580	7	42.7083	3.6146 *
Treatments	663.2500	2	331.6250	28.0667 **
Error	165.4170	14	11.8155	
Total	1127.6250	23		

C. V. = 8.5%

Appendix Table 7. Average height of plants at 45 days after treatment (g).

Treatment	Blocks								Average
	A	B	C	D	E	F	G	H	
Untreated	55	47	59	56	55	55	55	50	54.00
Naptalam (100 ppm)	34	36	40	43	43	44	44	40	40.50
Naptalam (200 ppm)	38	37	42	37	48	45	40	33	40.00

Appendix Table 8. Dry weight of main shoots at 45 days after treatment (g).

Treatment	Blocks								Average
	A	B	C	D	E	F	G	H	
Untreated	1.8000	1.0975	1.8835	1.5385	1.6508	1.6247	1.5651	1.6242	1.5980
Naptalam (100 ppm)	0.5691	0.7574	0.8100	0.6274	0.8736	0.8598	1.0202	0.8642	0.7977
Naptalam (200 ppm)	0.7532	0.5692	0.4777	0.6177	1.0980	0.7713	0.6263	0.5281	0.6802

Analysis of Variance for Data in Appendix Table 7.

Source	SS	df	MS	F
Blocks	228.6667	7	32.6666	3.4299 *
Treatments	1009.3334	2	504.6667	52.9900 **
Error	133.3333	14	9.5238	
Total	1371.3334	23		

C. V. = 7.0%

Analysis of Variance for Data in Appendix Table 8.

Source	SS	df	MS	F
Blocks	0.2915	7	0.0416	1.1460 N.S.
Treatments	3.9914	2	1.9957	54.9780 **
Error	0.5081	14	0.0363	
Total	4.7910	23		

C. V. = 18.6%

Appendix Table 9. Total number of rhizomes per plant.

Treatment	Blocks A	B	C	D	E	F	Average
Untreated	9	10	12	11	15	11	11.3333
Naptalam (2.05×10^{-5}M)	15	15	14	13	14	14	14.1667
Naptalam (4.11×10^{-5}M)	13	14	18	16	11	15	14.5000
Naptalam (8.23×10^{-5}M)	14	18	18	15	17	13	15.8333

Appendix Table 10. Percentage rhizomes transformed to shoots.

Treatment	Blocks A	B	C	D	E	F	Average
Untreated	0	0	0	0	0	0	0
Naptalam (2.05×10^{-5}M)	86.67	73.33	64.29	84.62	92.86	78.57	80.0567
Naptalam (4.11×10^{-5}M)	76.92	71.43	88.89	87.50	90.91	86.67	83.7200
Naptalam (8.23×10^{-5}M)	92.86	88.89	100.00	100.00	100.00	100.00	96.9583

Analysis of Variance for Data in Appendix Table 9

Source	SS	df	MS	F
Blocks	18.2084	5	3.6417	0.9371 N.S.
Treatments	64.4584	3	21.4861	5.5290 **
Error	58.2916	15	3.8861	
Total	140.9584	23		

C.V. = 14.1%

Analysis of Variance for Data in Appendix Table 10.

Source	SS	df	MS	F
Blocks	372.3900	5	74.4780	1.9608 N.S.
Treatments	34940.0500	3	11646.6830	306.6312 **
Error	569.7400	15	37.9820	
Total	35882.1800	23		

C.V. = 9.4%

Appendix Table 11. Total number of rhizomes per plant.

Days of treatment with 4.11 x 10^{-5}M naptalam solution	Blocks						Average
	A	B	C	D	E	F	
0	22	19	13	4	13	11	13.6666
0.5	31	25	16	9	19	13	18.8333
2.0	32	25	25	8	20	14	20.6666
8.0	35	23	24	16	23	21	23.6666

Appendix Table 12. Percentage rhizomes transformed to shoots.

Days of treatment with 4.11 x 10^{-5}M naptalam solution	Blocks						Average
	A	B	C	D	E	F	
0	9.09	5.26	7.69	25.00	7.69	9.09	10.6366
0.5	29.03	28.00	18.75	33.33	31.58	23.08	27.2817
2.0	56.25	48.00	56.00	50.00	60.00	42.86	52.1850
8.0	45.71	43.75	58.33	62.50	73.91	61.90	57.6833

Analysis of Variance for Data in Appendix Table 11.

Source	SS	df	MS	F
Blocks	1000.7084	5	200.1417	33.3103 **
Treatments	317.1250	3	105.7083	17.5934 **
Error	90.1256	15	6.0084	
Total	1407.9590	23		

C.V. = 12.7%

Analysis of Variance for Data in Appendix Table 12.

Source	SS	df	MS	F
Blocks	480.2670	5	96.0534	1.8717 N.S.
Treatments	8685.5200	3	2895.1733	56.4165 **
Error	769.7670	15	51.3178	
Total	9935.5540	23		

C.V. = 14.0%

Appendix Table 13. Number of new shoots per 3 plants.

Treatment		Blocks				
Total naptalam applied (kg/ha)	single or split	A	B	C	D	Average
1.12	single	12	6	5	8	7.75
	split	9	13	14	9	11.25
2.24	single	10	6	9	9	8.50
	split	12	18	14	13	14.25
4.48	single	6	8	8	12	8.50
	split	9	13	22	14	14.50
8.97	single	16	12	9	18	13.75
	split	15	14	19	17	16.25
0	---	0	1	0	0	0.25

Analysis of Variance for Data in Appendix Table 13.

Source	SS	df	MS	F
Blocks	11.3300	3	3.7700	0.3785 N.S.
Treatments	779.390	8	97.4200	9.7811 **
Error	239.1700	24	9.9600	
Total	1029.8900	35		

C.V. = 29.9%

Appendix Table 14. Number of new shoots per 3 plants.

Treatment		Blocks				
Total naptalam applied (ppm)	single or split	A	B	C	D	Average
200	single	18	28	22	22	22.50
	split	22	18	15	31	21.50
400	single	22	36	23	24	26.25
	split	34	33	29	26	30.50
800	single	36	42	28	38	36.00
	split	29	31	35	21	29.00
1600	single	32	27	23	21	25.75
	split	33	37	35	29	33.50
0	---	0	0	0	0	0

Analysis of Variance for Data in Appendix Table 14.

Source				
Blocks	124.8900	3	41.6300	1.8014 N.S.
Treatments	3540.5000	8	442.5625	19.1513 **
Error	554.6100	24	23.1087	
Total	4220.0000	35		

C.V. = 19.2%

Appendix Table 15. Effect of naptalam, photoperiod, and nitrogen on dry weight of new shoots (g).

Treatment			Replications				
Naptalam (ppm)	Hours of photoperiod	Nitrogen	I	II	III	IV	Average
0	20	1/32	0.6722	0.6352	0	0	0.3268
		1/8	0.8521	0.1941	0.9452	0.3940	0.5963
		1/2	0.4653	0.4610	0.5955	0.6365	0.5396
	10	1/32	0.2276	0	0.1906	0.0862	0.1261
		1/8	0.0582	0.1354	0.3563	0.0862	0.1590
		1/2	0.8509	0	0.4251	0	0.3190
200	20	1/32	1.5063	1.4583	1.3324	1.9558	1.5632
		1/8	2.2682	2.7240	2.3547	3.6820	2.7572
		1/2	3.3361	2.3212	2.3961	3.1347	2.7970
	10	1/32	0.0992	0.1620	0.3787	0.0496	0.1724
		1/8	0.2362	0.0362	0.1939	0.0496	0.1290
		1/2	0.0678	0	0.1289	0.0285	0.0563
400	20	1/32	2.7630	2.5799	3.4618	3.5491	3.0884
		1/8	2.5839	3.5992	3.8000	3.8160	3.4498
		1/2	2.9667	3.4671	4.3117	4.1209	3.7166
	10	1/32	0.2115	0	0	0.0583	0.0674
		1/8	0.1586	0.0177	0.0134	0.1592	0.0872
		1/2	0.2192	0.0317	0.1423	0.0379	0.1078

Analysis of Variance for Data in Appendix Table 15.

Source	SS	df	MS	F
Replications	0.5216	3	0.1739	1.4208 N.S.
Treatments	126.9500	17	7.4676	61.0098 **
Naptalam	24.4249	2	12.2124	99.7745 **
Nitrogen	1.8436	2	0.9218	7.5310 **
Photoperiod	68.9202	1	68.9202	563.0735 **
Naptalam x Nitrogen	0.5002	4	0.1250	1.0212 N.S.
Naptalam x Photoperiod	28.5996	2	14.2998	116.8284 **
Photoperiod x Nitrogen	1.5885	2	0.7942	6.4886 **
Naptalam x Photoperiod x Nitrogen	1.0731	4	0.2683	2.1920 N.S.
Error	6.4207	51	0.1224	
Total	133.7123	71		

C.V. = 31.4%

Appendix Table 16. Effect of naptalam, photoperiod, and nitrogen on dry weight of tubers (g).

Treatment			Replications				
Naptalam (ppm)	Hours of photoperiod	Nitrogen	I	II	III	IV	Average
0	20	1/32	0.2091	0.0642	0.0915	0.2151	0.1450
		1/8	0.0363	0	0.0321	0	0.0171
		1/2	0.1041	0	0	0	0.0260
	10	1/32	2.0211	1.2899	2.1821	2.4891	1.9955
		1/8	3.7043	2.6784	3.2319	3.3517	3.2416
		1/2	4.2355	3.9114	5.1663	3.8118	4.2812
200	20	1/32	0.0225	0.0094	0.0096	0.0169	0.0146
		1/8	0.0062	0.0362	0.0259	0	0.0171
		1/2	0	0	0	0.0157	0.0039
	10	1/32	0.3482	0.2849	0.5068	0.1825	0.3306
		1/8	0.4897	0.1724	0.4954	0.1526	0.3275
		1/2	0.3522	0.1882	0.5996	0.3067	0.3617
400	20	1/32	0	0	0.0108	0.1424	0.0383
		1/8	0.0173	0.0286	0.0188	0.0277	0.0231
		1/2	0	0.0401	0.0666	0	0.0267
	10	1/32	0.4846	0.2119	0.3861	0.3000	0.3456
		1/8	0.2415	0.2612	0.1973	0.4580	0.2895
		1/2	0.3502	0.5457	0.1929	0.0980	0.2967

Analysis of Variance for Data in Appendix Table 16.

Source	SS	df	MS	F	
Replications	0.3914	3	0.1305	2.2461	N.S.
Treatments	103.0853	17	6.0638	104.3683	**
Naptalam	33.3997	2	16.6999	287.4337	**
Nitrogen	1.4555	2	0.7277	12.5250	**
Photoperiod	27.6682	1	27.6682	476.2169	**
Naptalam x Nitrogen	2.5917	4	0.6479	11.1515	**
Naptalam x Photoperiod	31.4882	2	15.7441	270.9828	**
Photoperiod x Nitrogen	2.0766	2	1.0383	17.8709	**
Naptalam x Photoperiod x Nitrogen	4.4054	4	1.1013	18.9553	**
Error	2.9619	51	0.0581		
Total	106.4386				

C. V. = 36.8%

Appendix Table 17. Percent rhizomes transformed to shoots.

Treatment		Replications						
Naptalam (ppm)	Photoperiod	I	II	III	IV	V	VI	Average
0	20 + 12-hour photoperiod	12.50	21.74	8.57	3.33	10.00	19.51	12.61
	Continuous 12-hour photoperiod	0	0	0	0	0	0	0
200	20 + 12-hour photoperiod	40.91	69.23	42.86	34.48	39.13	58.33	47.49
	Continuous 12-hour photoperiod	8.00	10.00	11.43	0	6.67	30.77	11.14
800	20 + 12-hour photoperiod	56.00	46.34	80.95	71.43	64.00	47.22	60.99
	Continuous 12-hour photoperiod	42.86	33.33	16.67	54.54	33.33	21.43	33.69

Analysis of Variance for Data in Appendix Table 17.

Source	SS	df	MS	F
Replications	95.8113	5	19.1622	0.1373 N.S.
Treatments	16824.5913	5	3364.9182	24.1152 **
Photoperiod	5814.0613	1	5814.0613	41.6674 **
Naptalam	10154.2413	2	5077.1206	36.3860 **
Naptalam x Photoperiod	856.2887	2	428.1443	3.0683 N.S.
Error	3488.3687	25	139.5347	
Total	20408.7713	35		

C.V. = 35.4%

Appendix Table 18. Percent rhizomes transformed to tubers.

Treatment		Replications						
Naptalam (ppm)	Photoperiod	I	II	III	IV	V	VI	Average
0	20 + 12-hour photoperiod	12.50	13.04	14.29	26.67	10.00	26.83	17.22
	Continuous 12-hour photoperiod	39.53	39.13	74.42	72.22	66.67	13.04	50.83
200	20 + 12-hour photoperiod	9.09	0	7.14	17.24	8.70	4.17	7.72
	Continuous 12-hour photoperiod	40.00	22.50	34.29	23.81	13.33	38.46	28.73
800	20 + 12-hour photoperiod	8.00	17.07	4.76	9.52	4.00	22.22	10.93
	Continuous 12-hour photoperiod	14.29	33.33	66.67	27.27	33.33	42.86	36.29

Analysis of Variance for Data in Appendix Table 18.

Source	SS	df	MS	F
Replications	814.2414	5	162.8482	0.8216 N.S.
Treatments	8192.2214	5	1638.4442	8.2667 **
Photoperiod	6397.5914	1	6397.5914	32.2790 **
Naptalam	1548.7114	2	774.3557	3.9070 *
Naptalam x Photoperiod	245.9186	2	122.9593	0.6203 N.S.
Error	4954.9086	25	198.1963	
Total	13961.3714	35		

C. V. = 45.7%

Appendix Table 19. Total Number of rhizomes transformed to shoots, tubers, and untransformed rhizomes per pot.

Treatment		Replications						
Naptalam (ppm)	Photoperiod	I	II	III	IV	V	VI	Average
0	20 + 12-hour photoperiod	40	23	35	30	10	41	29.83
	Continuous 12-hour photoperiod	43	23	43	36	33	23	33.50
200	20 + 12-hour photoperiod	22	13	14	29	23	24	20.83
	Continuous 12-hour photoperiod	25	40	35	21	15	13	24.83
800	20 + 12-hour photoperiod	25	41	21	21	25	36	28.16
	Continuous 12-hour photoperiod	7	6	12	11	12	14	10.33

Analysis of Variance for Data in Table 19.

Source	SS	df	MS	F
Replications	208.5800	5	41.7160	0.5044 N.S.
Treatments	2022.5800	5	404.5160	4.8911 **
Photoperiod	103.3600	1	103.3600	1.2497 N.S.
Naptalam	980.1600	2	490.0800	5.9257 **
Naptalam x Photoperiod	939.0600	2	469.5300	5.6772 **
Error	2067.5900	25	82.7036	
Total	4298.7500	35		

C.V. = 30.0%

Appendix Table 20. Number of new shoots per plant 120 days after transplanting.

Treatment		Replications						
Naptalam (ppm) 20 days after transplanting	Naptalam (ppm) 70 days after transplanting	I	II	III	IV	V	VI	Average
0	0	4	8	9	7	5	8	6.83
0	200	6	8	8	9	9	11	8.50
200	0	7	12	10	10	8	10	9.50
200	200	12	15	14	14	17	11	13.83
800	0	14	10	11	12	10	16	12.17
800	200	15	25	18	15	15	19	17.83

Appendix Table 21. Number of tubers per plant 120 days after transplanting.

Treatment		Replications						
Naptalam (ppm) 120 days after transplanting	Naptalam (ppm) 70 days after transplanting	I	II	III	IV	V	VI	Average
0	0	23	24	15	31	19	35	24.50
0	200	8	7	9	14	8	8	9.00
200	0	0	5	1	6	4	11	4.50
200	200	7	4	2	6	0	3	3.67
800	0	0	5	1	5	2	4	2.83
800	200	5	1	5	0	0	5	2.67

Analysis of Variance for Data in Appendix Table 20.

Source	SS	df	MS	F
Replications	44.5555	5	8.9111	1.6906 N.S.
Treatments	484.5555	5	96.9111	18.3854 **
Rate of naptalam	323.5555	2	161.7777	30.6914 **
Nature of treatment	136.1111	1	136.1111	25.8221 **
Rate x nature of treatment	24.8889	2	12.4444	2.3594 N.S.
Error	131.7779	25	5.2711	
Total	660.8889	35		

C. V. = 20.0%

Analysis of Variance for Data in Appendix Table 21

Source	SS	df	MS	F
Replications	165.8056	5	33.1611	2.6855 *
Treatments	2155.8056	5	431.1611	34.9180 **
Rate of Naptalam	1432.8889	2	716.4444	58.0220 **
Nature of treatment	272.2500	1	272.2500	22.0484 **
Rate x nature of treatment	450.6667	2	225.3333	18.2488 **
Error	308.6944	25	12.3478	
Total	2630.3056	35		

C. V. = 44.7%

Appendix Table 22. Dry weight of each new shoot 120 days after transplanting (g).

Treatment		Replications						
Naptalam (ppm) 20 days after transplanting	Naptalam (ppm) 70 days after transplanting	I	II	III	IV	V	VI	Average
0	0	1.6076	0.9905	0.4926	1.3513	0.9789	1.2453	1.1110
0	200	0.8667	0.7566	1.0757	0.6349	0.6206	0.4511	0.7343
200	0	1.0166	0.5012	0.7972	1.1237	1.4429	1.2692	1.0251
200	200	0.4904	0.4393	1.0258	0.5586	0.7794	0.7816	0.6792
800	0	0.1629	0.6608	0.8238	0.7751	0.8002	0.7101	0.6555
800	200	0.5302	0.4241	0.3167	0.4040	0.5396	0.4024	0.4362

Analysis of Variance for Data in Appendix Table 22.

Source	SS	df	MS	F
Replications	0.1881	5	0.0376	0.4820 N.S.
Treatments	1.8924	5	0.3784	4.8512 **
Rate of naptalam	0.9631	2	0.4815	6.1730 **
Nature of treatment	0.8874	1	0.8874	11.3769 **
Rate x nature of treatment	0.0419	2	0.0209	0.2679 N.S.
Error	1.9504	25	0.0780	
Total	4.0309	35		

C. V. = 36.1%

Appendix Table 23. Number of new shoots per plant.

Treatment		Replications				
Time of naptalam application (weeks after transplanting)	Naptalam (ppm)	I	II	III	IV	Average
2	0	6	4	6	5	5.25
	100	12	9	10	10	10.25
	200	15	10	12	10	11.75
	400	13	12	19	13	14.25
	800	5	5	6	6	5.50
	1600	6	5	7	6	6.00
4	0	8	6	8	9	7.75
	100	8	9	7	8	8.00
	200	8	9	8	7	8.00
	400	8	7	10	8	8.25
	800	12	9	12	10	10.75
	1600	12	12	15	13	13.00

Analysis of Variance for Data in Appendix Table 23.

Source	SS	df	MS	F
Replications	24.7325	3	8.2441	4.5709 *
Treatments	380.5600	11	34.5963	19.1818 **
Time of Application	2.5225	1	2.5225	1.3985 N.S.
Naptalam	104.6825	5	20.9365	11.6081 **
Time of Application x Naptalam	273.3550	5	54.6710	30.3121 **
Error	59.5200	33	1.8036	
Total	464.8125	47		

C.V. = 14.8%

Appendix Table 24. Average dry weight of each new shoot (mg).

Treatment		Replications				
Time of naptalam application (weeks after transplanting)	Naptalam (ppm)	I	II	III	IV	Average
2	0	181.70	172.40	245.40	293.30	223.20
	100	244.80	123.00	338.80	264.80	242.85
	200	485.10	194.30	295.30	281.40	314.02
	400	223.40	115.40	218.80	158.50	179.02
	800	90.20	38.80	81.80	63.40	68.55
	1600	78.30	37.30	86.70	102.70	75.25
4	0	254.70	109.30	210.80	198.90	193.42
	100	226.60	271.30	252.10	221.50	242.87
	200	270.60	367.70	183.40	333.90	288.90
	400	217.50	195.70	132.60	319.60	216.35
	800	126.80	104.10	144.90	102.60	119.60
	1600	81.60	89.80	105.20	110.00	96.65

Analysis of Variance for Data in Appendix Table 24.

Source	SS	df	MS	F
Replications	23709.8100	3	7903.2700	2.1801 N.S.
Treatments	296952.2000	11	26995.6545	7.4468 **
Time of Application	1004.6700	1	1004.6700	0.2771 N.S.
Naptalam	285002.1300	5	57000.4260	15.7238 **
Time of Application x Naptalam	10945.4000	5	2189.0800	0.6038 N.S.
Error	119628.1300	33	3625.0948	
Total	440290.1400	47		

C. V. = 31.9%

Appendix Table 25. Fresh weight of shoots as percent of untreated.

Treatment								
Time of glyphosate application (weeks after transplanting)	Glyphosate (kg/ha)	Blocks						Average
		A	B	C	D	E	F	
2	0	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	0.56	20.71	15.62	9.73	29.62	4.18	15.87	15.95
	1.12	16.41	7.91	2.42	5.52	3.94	1.95	6.36
	2.24	5.45	2.31	2.75	2.99	3.35	1.94	3.13
	4.48	4.60	4.93	2.34	3.36	2.50	2.07	3.30
4	0	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	0.56	23.20	33.51	13.16	17.05	12.05	18.39	19.56
	1.12	13.42	7.22	8.74	8.33	8.31	13.98	10.00
	2.24	15.43	5.83	5.32	7.75	4.55	8.17	7.84
	4.48	8.79	5.91	5.01	4.00	3.35	6.69	5.62
6	0	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	0.56	63.44	72.46	18.30	9.83	25.81	12.99	33.80
	1.12	16.79	7.85	9.21	11.50	11.32	9.93	11.10
	2.24	12.13	11.33	10.75	10.32	17.68	8.46	11.78
	4.48	5.82	14.55	8.99	8.66	11.19	7.32	9.42

Analysis of Variance for Data in Appendix Table 25.

Source	SS	df	MS	F
Blocks	744.2199	5	148.8439	2.5495 *
Treatments	117614.6799	14	8401.0485	143.9026 **
Glyphosate	116132.0699	4	29033.0174	497.3101 **
Time of Application	850.3599	2	425.1799	7.2829 **
Glyphosate x Time of Application	632.2501	8	79.0312	1.3537 **
Error	4086.6101	70	58.3801	
Total	122445.5099	89		

C. V. = 26.1%

Appendix Table 26. Dry weight of shoots as percent of untreated.

Treatment		Blocks						
Time of glyphosate application (weeks after transplanting)	Glyphosate (kg/ha)	A	B	C	D	E	F	Average
2	0	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	0.56	27.49	31.42	19.35	58.91	29.35	27.32	32.31
	1.12	34.21	24.36	13.55	30.40	28.97	11.27	23.79
	2.24	17.01	17.43	17.21	23.56	18.83	13.35	17.90
	4.48	20.58	28.50	15.52	24.62	18.78	13.97	20.33
4	0	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	0.56	64.48	49.16	53.03	44.69	43.01	69.37	53.96
	1.12	42.92	26.92	37.26	40.23	38.67	77.92	43.99
	2.24	44.18	26.76	34.43	41.37	27.42	47.96	37.02
	4.48	25.33	29.74	26.20	20.93	19.27	34.16	25.94
6	0	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	0.56	99.57	112.72	74.83	40.95	62.99	54.75	74.30
	1.12	59.87	32.51	40.69	50.30	48.86	40.72	45.49
	2.24	45.93	46.64	47.80	41.77	80.85	35.40	49.73
	4.48	20.83	60.45	40.30	32.60	63.51	30.38	41.34

Analysis of Variance for Data in Appendix Table 26.

Source	SS	df	MS	F
Blocks	293.0546	5	58.6109	0.3772 N.S.
Treatments	71270.5346	14	5090.7524	32.7653 **
Glyphosate	59714.4946	4	14928.6236	96.0842 **
Time of Application	8204.0746	2	4102.0373	26.4016 **
Glyphosate x Time of Application	3351.9654	8	418.9956	2.6967 *
Error	10875.9154	70	155.3702	
Total	82439.5046	89		

C. V. = 24.4%

Appendix Table 27. Dry weight of shoots as percent of untreated.

Treatment		Blocks						
Method of application	Total glyphosate applied (kg/ha)	A	B	C	D	E	F	Average
Single	0.07	113.27	121.53	101.14	78.10	111.02	118.93	107.33
	0.14	116.24	122.29	90.23	95.29	106.71	98.44	104.87
	0.28	134.78	125.44	94.55	103.83	90.89	114.42	110.65
	0.56	45.92	109.09	91.04	43.68	73.68	99.07	77.08
	1.12	50.02	38.58	59.91	41.50	30.23	24.09	40.72
	0	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Split	0.07	107.77	99.99	107.41	109.29	113.27	79.28	102.83
	0.14	96.10	107.04	91.14	105.61	132.65	80.77	102.22
	0.28	112.05	108.43	105.83	107.22	132.31	72.36	106.37
	0.56	69.44	69.55	76.64	99.71	115.62	84.30	85.88
	1.12	35.37	32.00	31.93	39.27	35.13	44.46	36.36
	0	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Analysis of Variance for Data in Appendix Table 27.

Source	SS	df	MS	F
Blocks	1223.6025	5	244.7205	1.0338 N.S.
Treatments	43299.7225	11	3936.3384	16.6288 **
Method of Application	24.4625	1	24.4625	0.1033 N.S.
Glyphosate	42873.7225	5	8574.7445	36.2235 **
Method of Application x Glyphosate	401.5375	5	80.3075	0.3392 N.S.
Error	13019.4675	55	236.7175	
Total	57542.7925	71		

C. V. = 17.2%

Appendix Table 28. Injury ratings 25 days after glyphosate application.

Rate of glyphosate applied (kg/ha)	Replications				Average
	I	II	III	IV	
0	0	0	0	0	0
0.28	40	20	30	20	27.00
0.56	60	30	50	70	52.00
1.12	95	100	100	95	97.00
2.24	100	100	100	100	100.00

Appendix Table 29. Percentage sprouted tubers.

Rate of glyphosate applied (kg/ha)	Replications		Average
	I	II	
0	63.33	70.00	66.67
0.28	40.00	46.67	43.33
0.56	23.33	30.00	26.66
1.12	13.33	10.00	11.66
2.24	10.00	10.00	10.00

Appendix Table 30. Percentage dormant tubers.

Rate of glyphosate applied (kg/ha)	Replications		Average
	I	II	
0	26.67	26.67	26.67
0.28	60.00	53.33	56.66
0.56	66.67	70.00	68.33
1.12	50.00	43.33	46.66
2.24	46.67	56.67	51.67

Appendix Table 31. Percentage non-viable tubers.

Rate of glyphosate applied (kg/ha)	Replications		Average
	I	II	
0	10.00	3.33	6.66
0.28	0	0	0
0.56	6.67	3.33	5.00
1.12	36.67	46.67	41.67
2.24	43.33	33.33	38.33

Analysis of Variance for Data in Appendix Table 28.

Source	SS	df	MS	F
Treatments	30420	4	7605.0000	93.1225 **
Error	1225	15	81.6666	
Total	31645	19		

C. V. = 16.3%

Analysis of Variance for Data in Appendix Table 29.

Source	SS	df	MS	F
Treatments	4538.9444	4	1134.7361	382.9299 **
Error	44.4500	15	2.9633	
Total	4583.3944	19		

C. V. = 5.4%

Analysis of Variance for Data in Appendix Table 30.

Source	SS	df	MS	F
Treatments	1877.5889	4	469.3972	70.3860 **
Error	100.0333	15	6.6689	
Total	1977.6222	19		

C. V. = 5.2%

Analysis of Variance for Data in Appendix Table 31.

Source	SS	df	MS	F
Treatments	3199.0311	4	799.7578	101.8346 **
Error	117.8033	15	7.8535	
Total	3316.8344	19		

C. V. = 15.3%

Appendix Table 32. Number of new shoots per plant 10 days after treatment.

Treatment	Blocks					Average
	A	B	C	D	E	
Untreated	1	2	3	0	2	1.60
Naptalam (400 ppm)	7	4	5	4	6	5.20
Glyphosate (0.56 kg/ha)	1	1	3	0	0	1.00
Naptalam (400 ppm) + Glyphosate (0.56 kg/ha)	0	2	3	0	1	1.20

Appendix Table 33. Number of new shoots per plant 20 days after treatment.

Treatment	Blocks					Average
	A	B	C	D	E	
Untreated	2	4	3	0	2	2.20
Naptalam (400 ppm)	12	8	11	6	11	9.60
Glyphosate (0.56 kg/ha)	2	2	4	1	1	2.00
Naptalam (400 ppm) + Glyphosate (0.56 kg/ha)	1	4	7	0	6	3.60

Appendix Table 34. Number of new shoots per plant 40 days after treatment.

Treatment	Blocks					Average
	A	B	C	D	E	
Untreated	2	5	4	1	2	2.80
Naptalam (400 ppm)	16	8	15	9	13	12.20
Glyphosate (0.56 kg/ha)	2	2	4	1	1	2.00
Naptalam (400 ppm) + Glyphosate (0.56 kg/ha)	8	12	15	8	12	11.00

Analysis of Variance for Data in Appendix Table 32.

Source	SS	df	MS	F
Blocks	12.5000	4	3.1250	3.0488 N.S.
Treatments	58.9500	3	19.6500	19.1707 **
Error	12.3000	12	1.0250	
Total	83.7500	19		

C. V. = 45.0%

Analysis of Variance for Data in Appendix Table 33.

Source	SS	df	MS	F
Blocks	43.3000	4	10.8250	2.5029 N.S.
Treatments	173.3500	3	57.7833	13.3603 **
Error	51.9000	12	4.3250	
Total	268.5500	19		

C. V. = 47.8%

Analysis of Variance for Data in Appendix Table 34.

Source	SS	df	MS	F
Blocks	45.5000	4	11.3750	2.3494 N.S.
Treatments	428.4000	3	142.8000	29.4978 **
Error	58.1000	12	4.8417	
Total	532.0000	19		

C. V. = 31.4%

Appendix Table 35. Fresh weight of each new shoot (g).

Treatment	Blocks					Average
	A	B	C	D	E	
Untreated	0.1483	0.6157	0.3975	0.1846	0.3793	0.2551
Naptalam (400 ppm)	0.1002	0.2205	0.1065	0.1390	0.1025	0.1337
Glyphosate (0.56 kg/ha)	0.2199	0.1799	0.0776	0.0631	0.1110	0.1299
Naptalam (400 ppm) + Glyphosate (0.56 kg/ha)	0.0587	0.0749	0.0568	0.0433	0.0865	0.0640

Appendix Table 36. Fresh weight of main shoot (g).

Treatment	Blocks					Average
	A	B	C	D	E	
Untreated	5.1353	4.9310	4.1030	6.6478	4.8238	5.1282
Naptalam (400 ppm)	1.4564	1.4432	1.4969	1.8974	2.0228	1.6633
Glyphosate (0.56 kg/ha)	4.0765	3.8736	5.0133	5.7751	2.8732	4.3223
Naptalam (400 ppm) + Glyphosate (0.56 kg/ha)	1.1109	2.0724	1.2927	0.6154	1.0192	1.2221

Appendix Table 37. Average height of main shoot (cm).

Treatment	Blocks					Average
	A	B	C	D	E	
Untreated	52	56	56	62	62	57.60
Naptalam (400 ppm)	31	34	30	33	35	32.60
Glyphosate (0.56 kg/ha)	49	54	55	61	47	53.20
Naptalam (400 ppm) + Glyphosate (0.56 kg/ha)	30	35	32	27	24	29.60

Analysis of Variance for Data in Appendix Table 35.

Source	SS	df	MS	F
Blocks	0.0105	4	0.0026	0.3939 N.S.
Treatments	0.0951	3	0.0317	4.8030 *
Error	0.0789	12	0.0066	
Total	0.1845	19		

C.V. = 35.7%

Analysis of Variance for Data in Appendix Table 36.

Source	SS	df	MS	F
Blocks	2.4510	4	0.6127	0.9877 N.S.
Treatments	55.9851	3	18.6617	30.0850 **
Error	7.4432	12	0.6203	
Total	65.8793	19		

C.V. = 25.5%

Analysis of Variance for Data in Appendix Table 37.

Source	SS	df	MS	F
Blocks	70.5000	4	17.6250	0.9796 N.S.
Treatments	3023.3500	3	1007.7833	56.0138 **
Error	215.9000	12	17.9917	
Total	3309.7500	19		

C.V. = 9.8%

Appendix Table 38. Average dry weight of shoots per 2 plants (g).

Treatment	Blocks				Average
	A	B	C	D	
Untreated	13.9287	13.2880	14.2071	14.0619	13.8714
Naptalam (800 ppm)	8.4052	8.0017	7.8870	7.3895	7.9208
Glyphosate (0.56 kg/ha)	10.9618	10.7144	11.2588	10.6181	10.8883
Glyphosate (1.12 kg/ha)	7.8108	7.0955	6.7495	6.2426	6.9746
Naptalam (800 ppm) followed by glyphosate (0.56 kg/ha)	4.4657	4.4901	3.7372	4.9801	4.4183
Naptalam (800 ppm) followed by glyphosate (1.12 kg/ha)	3.6797	4.7267	4.0004	5.1593	4.3915

Analysis of Variance for Data in Appendix Table 38.

Source	SS	df	MS	F
Blocks	0.1728	3	0.0576	0.1903 N.S.
Treatments	278.7500	5	55.7500	184.2366 **
Error	4.5391	15	0.3026	
Total	283.4619	23		

C.V. = 6.8%

Appendix Table 39. Fresh weight of shoots as percent of untreated.

Time of Glyphosate application (weeks after Naptalam treatment)	Expected or Observed	Blocks						Average
		A	B	C	D	E	F	
1	Expected	76.39	47.93	50.24	74.85	40.18	54.07	57.27
	Observed	36.48	13.05	30.92	41.11	28.14	15.20	27.48
2	Expected	117.99	79.21	105.02	128.98	22.73	26.04	79.99
	Observed	37.39	28.33	37.13	32.77	22.67	27.50	30.96
4	Expected	77.38	85.45	64.14	76.74	61.56	32.09	66.22
	Observed	41.70	60.04	32.11	34.12	44.48	11.28	37.28

Appendix Table 40. Dry weight of shoots as percent of untreated.

Time of Glyphosate application (weeks after Naptalam treatment)	Expected or Observed	Blocks						Average
		A	B	C	D	E	F	
1	Expected	29.32	40.64	32.86	52.22	26.29	188.69	61.67
	Observed	32.91	20.05	38.34	37.46	30.29	69.76	38.13
2	Expected	105.00	55.80	53.28	100.17	24.58	81.43	70.04
	Observed	43.60	39.30	40.97	36.05	32.13	29.54	36.93
3	Expected	49.31	75.69	50.89	45.37	48.67	65.49	55.90
	Observed	42.27	67.11	37.74	32.77	36.68	23.99	40.09

Appendix Table 41. Chi-square values for fresh and dry weights of shoots.

Time of Glyphosate application (weeks after Naptalam treatment)	Fresh or Dry weight	Blocks						Total
		A	B	C	D	E	F	
1	Fresh weight	20.85	25.38	7.42	15.20	3.60	27.94	100.39
	Dry weight	0.43	10.43	0.91	4.17	0.60	74.96	91.50
2	Fresh weight	55.05	32.68	43.88	71.76	0	0.08	203.45
	Dry weight	35.90	4.87	2.84	41.04	2.16	14.26	101.07
4	Fresh weight	16.45	7.55	15.99	23.67	4.73	13.49	81.88
	Dry weight	1.00	40.24	3.39	3.49	2.95	26.29	77.36

Appendix Table 42. Number of rhizomes transformed to tubers per pot.

Treatment	Blocks						Average
	A	B	C	D	E	F	
Untreated	143	158	170	189	172	161	165.50
Naptalam (400 ppm)	152	175	137	188	168	190	168.33
Glyphosate (0.56 kg/ha)	146	153	118	122	132	123	132.33
Naptalam (400 ppm) followed by Glyphosate (0.56 kg/ha)	52	53	60	63	57	51	56.00

Appendix Table 43. Number of untransformed rhizomes per pot.

Treatment	Blocks						Average
	A	B	C	D	E	F	
Untreated	56	71	91	33	47	52	58.33
Naptalam (400 ppm)	18	20	19	24	28	32	23.50
Glyphosate (0.56 kg/ha)	34	12	28	15	19	25	22.17
Naptalam (400 ppm) followed by Glyphosate (0.56 kg/ha)	20	44	25	25	34	31	29.83

Appendix Table 44. Total number of tubers and rhizomes per pot.

Treatment	Blocks						Average
	A	B	C	D	E	F	
Untreated	199	229	261	222	219	213	223.83
Naptalam (400 ppm)	170	195	156	212	196	222	191.83
Glyphosate (0.56 kg/ha)	180	165	146	137	151	148	154.50
Naptalam (400 ppm) followed by Glyphosate (0.56 kg/ha)	72	97	85	88	91	82	85.83

Analysis of Variance for Data in Appendix Table 42.

Source	SS	df	MS	F
Blocks	1039.2084	5	207.8416	0.9070 N.S.
Treatments	49259.7917	3	16419.9305	71.6619 **
Error	3436.9583	15	229.1305	
Total	53735.9584	23		

C. V. = 11.6%

Analysis of Variance for Data in Appendix Table 43.

Source	SS	df	MS	F
Blocks	621.7084	5	124.3416	0.8156 N.S.
Treatments	5151.4584	3	1717.1528	11.2635 **
Error	2286.7916	15	152.4527	
Total	8059.9584	23		

C. V. = 36.9%

Analysis of Variance for Data in Appendix Table 44.

Source	SS	df	MS	F
Blocks	570.0000	5	114.0000	0.2731 N.S.
Treatments	63330.0000	3	21110.0000	50.5830 **
Error	6260.0000	15	417.3333	
Total	70160.0000	23		

C. V. = 12.5%

Appendix Table 45. Dry weight of regrowth per pot (g).

Treatment	Blocks						Average
	A	B	C	D	E	F	
Untreated	3.0393	3.5568	3.0155	3.4011	3.4122	5.3890	3.6356
Naptalam (400 ppm)	3.9595	3.9764	4.3029	3.2196	3.6620	4.2091	3.8882
Glyphosate (0.56 kg/ha)	2.4932	2.5220	3.2780	3.2381	3.8225	3.6729	3.1728
Naptalam (400 ppm) followed by Glyphosate (0.56 kg/ha)	2.2435	3.7388	2.7548	3.3683	2.3129	2.3834	2.8003

Analysis of Variance for Data in Appendix Table 45.

Source	SS	df	MS	F
Blocks	2.0042	5	0.4008	0.9685 N.S.
Treatments	4.2153	3	1.4051	3.3956 *
Error	6.2076	15	0.4138	
Total	12.4271	23		

C.V. = 19.0%