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Biology and Life Cycle of Purple and Yellow Nutsedges (*Cyperus rotundus* and *C. esculentus*)¹

E. W. STOLLER and R. D. SWEET²

INTRODUCTION

Yellow and purple nutsedges (*Cyperus esculentus* L. #³ CYPES and *C. rotundus* L. # CYPRO) are herbaceous perennial weeds that are among the worst pests known. Holm et al. (20) list purple nutsedge as the world's worst weed and yellow nutsedge as the sixteenth worst weed. Both weeds infest crop production areas in tropical and temperate climates, causing large losses in crop yields (20, 61). While both species proliferate in the warm regions of the world (20), yellow nutsedge inhabits a wider range than purple nutsedge in the temperate areas, primarily because yellow nutsedge can tolerate colder temperatures (43). With such an extended range of habitation, many ecotypic variations of these species would be expected since they likely have adjusted to a multitude of local environments.

The biological characteristics and life cycles reveal many similarities and also some differences between species. We propose to summarize the research on the biology and life cycle as it relates to the weediness of both yellow and purple nutsedge. As a basis for discussion of the biology of these weeds, we first review some salient features of the morphology and growth habit. Wills et al. (66, 67), present a detailed morphological and anatomical description.

Yellow and purple nutsedge both exhibit prolific vegetative activity which produces a complex underground system of basal bulbs, rhizomes, and tubers. Shoots arise from the basal bulbs as a fascicle. Basal bulbs are a primary site for prolific vegetative growth because they contain the meristems for leaves, rhizomes, roots, and flower stalks. The tubers

contain quiescent buds and function like the seeds of annuals, acting as the primary dispersal units. Tubers are produced on rhizomes and lie dormant in the soil for extended periods. They germinate under the appropriate environmental conditions to produce plants that perpetuate the infestations. While both yellow and purple nutsedge produce viable seeds, they are insignificant for propagating these species in most cultivated areas, primarily due to inadequate seedling vigor.

TUBER BIOLOGY

Tubers are recognized as the primary dispersal unit for both species, so the literature abounds with reports on tuber biology. Tubers are produced on rhizomes and consist of rhizomatous tissue with numerous buds, a characteristic of many stem tissues (45, 66, 67). These buds sprout and initiate rhizomatous growth which develop into seedlings typical of most monocotyledonous plants and eventually grow into mature plants.

In purple nutsedge, basal bulbs are similar to tubers in appearance and sprouting characteristics (14, 18, 29, 33, 38, 41). Basal bulbs, sometimes called corms (66), also are reported to fuse with tubers to form propagules with large amounts of starch (14). Hauser (18) reported that basal bulbs sprout and differentiate into plants quickly, whereas tubers often remain dormant. Morphological differences between tubers and basal bulbs have not been described adequately, making the interpretation of some tuber biology literature tentative. However, the biology of these structures may be similar enough to make exact identification superfluous.

Tuberization. Tuber formation begins from 4 to 6 weeks after seedling emergence. Many authors report that more than 95% of purple and yellow nutsedge tubers usually are formed in the upper 45 cm of soil (1, 3, 10, 29, 42, 57, 58). In most soils, more than 80% of tubers occur in the upper 15 cm. Rhizomes do not penetrate deeply in heavy

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³ Letters following this symbol are the WSSA-approved computer-code from Composite List of Weeds, Weed Sci. 32, Suppl. 2. Available from WSSA, 309 West Clark Street, Champaign, IL 61820.

textured soils, so tubers are distributed deepest in light-textured soils.

Daylength is the principal factor that stimulates tuber production in yellow nutsedge; short photoperiods stimulate reproductive growth, and long photoperiods stimulate vegetative growth (3, 25, 63). In plants grown with photoperiods of 9 to 12 h, rhizomes differentiate into tubers rather than basal bulbs (25, 63); with photoperiods longer than 12 h most rhizomes differentiate into basal bulbs (25). Nitrogen enhances basal bulb (and consequently shoot) production over tuber production, indicating how nutrients can stimulate vegetative rather than reproductive growth (13).

Daylength does not affect tuberization dramatically in purple nutsedge as it does in yellow nutsedge (16, 22, 62, 63). Horowitz (23) found natural daylength had no effect on tuberization in purple nutsedge and suggested that a minimum temperature of 20 C was necessary to stimulate the process. In other studies of continuous plantings throughout the year in a tropical climate, high mean temperature stimulated the plant to distribute more dry matter into tubers than did low temperatures (16).

Considering the wide latitudinal spread of both species, photoperiod responses may reflect local ecotypic adaptation to several environmental conditions including photoperiod, temperature, and moisture conditions.

When purple and yellow nutsedge are cultured in fields without interference from other plants, they produce 10 to 30 million tubers per ha in a season (18, 23). After tuber population attains this high level, it seems to stabilize or to decrease slightly (47). Crop interference reduces tuber number and size (47). Shading these weeds without interference also greatly reduces the number and size of tubers produced (26, 37, 64). Thus when crops compete for light, they exert an interfering effect. Even though yellow and purple nutsedge, as C_4 plants, are sensitive to shading, they efficiently divert dry matter into tubers. Purple nutsedge converted 44 to 50% of its dry weight into tubers, while yellow nutsedge stored 28 to 33% in tubers when both species were grown side by side (26, 63). Tubers are produced even under heavy shade (90%) in these species (37, 64).

Tuber sprouting. When a tuber sprouts, one or

more of the numerous buds on the tuber begin growth (5, 25, 45). Yellow nutsedge buds cluster at the apical end of tubers (5), while purple nutsedge buds cluster at the nodes along the entire length (29, 38). Several buds can sprout at one time, with some remaining dormant for subsequent sprouting on other occasions (45, 55). Purple nutsedge tubers exhibit apical dominance since the most apical buds sprout and inhibit sprouting of the more basipetal buds (29, 42). Buds in yellow nutsedge tubers break dormancy in acropetal order, starting with the oldest (basipetal) bud (5). Yellow nutsedge tubers can sprout at least three separate times, expending more than 60% of the tuber dry weight, carbohydrate, oil, starch, and protein on the first sprouting but consuming less than 10% of these constituents during each of the next two sproutings (45). Organic acids apparently are consumed when purple nutsedge tubers sprout (36).

When tubers were exposed to constant temperatures, the minimum temperature required to stimulate tuber germination was 12 C for yellow nutsedge (45) and 20 C for purple nutsedge (21, 23, 34). This may explain partly why yellow nutsedge inhabits colder climates than purple nutsedge. These minima should not be considered as cardinal temperatures because tubers in soil are exposed to diurnal temperature fluctuations and sprout better under alternating than constant temperatures. In field studies, shoots emerge from tubers situated as far as 45 cm below the soil surface (10, 21). However, germination percentage is highest and shoot emergence is fastest from tubers placed closest to the soil surface and decreases as tuber depth increases (46). Even if emergence is delayed, tuber production at the end of a season is similar in both the early and late emerging purple nutsedge plants (21). Low oxygen concentration inhibits sprouting of purple nutsedge tubers (35).

Tuber longevity. Due to apical dominance and bud dormancy, tubers remain in the soil for extended periods before sprouting. Control would be facilitated if tuber longevity were short enough so that all buds could sprout at the same time so the resultant plants could be killed.

Both purple and yellow nutsedge tuber longevity is a function of tuber depth in the soil; tuber survival time increases as its depth in the soil increases (44). Yellow nutsedge tubers had a half-life of 4 and

6 months at 10 and 20 cm, respectively, in a non-crop environment in Illinois (46). In continuous corn that was moderately infested with yellow nutsedge, at least 2 yr of season-long control were required to reduce tuber populations to 20% of the original density while 3 yr of treatment reduced tubers by another 5% (47). The time required for 100% of the tubers to die in cropping situations is not known but is of interest if eradication is desired.

The impact of cold and desiccation on tuber longevity is a significant factor in tuber ecology. Desiccation and temperature extremes can kill both yellow and purple nutsedge tubers (1, 10, 11, 53, 54). Reports concerning desiccation of purple nutsedge tubers consistently show that drying tubers from their natural state ($\approx 85\%$ water) to about 15% water will kill them, and intermediate moisture contents result in reduced viability (39, 42). The time required to reach this critical moisture level apparently is not significant, but it may take 7 to 14 days of field drying under full sunlight to kill purple nutsedge tubers (1, 42, 57).

In yellow nutsedge, conflicting reports exist concerning tuber desiccation, probably a result of ecotypic variation (11, 44, 52, 53, 60). Desiccation easily killed Illinois tubers (44) but did not affect greatly the California, Florida, or South Africa ecotypes (11, 53, 60).

Yellow nutsedge tubers can withstand colder temperatures than purple nutsedge tubers, a factor which allows yellow nutsedge to inhabit colder ranges than purple nutsedge (43). In a laboratory study, 50% of the purple and yellow nutsedge tubers were killed at -2 and -7 C, respectively (43). In the field, however, some yellow nutsedge tubers tolerated -20 C during the winter (46). There is variability between ecotypes in tuber cold hardiness, with the most northern U.S. ecotypes displaying the most cold hardiness⁴. Differences within and among the species may be related to component fatty acids, lipids, or sugars in tubers (48).

Desiccation may interact with temperature in affecting tuber longevity, especially at intermediate temperatures. A combination of both low temperature and low humidity is more effective in killing yellow nutsedge tubers than either treatment alone (53). These factors are important in the northern latitudes of the plants' range because the tubers can be exposed to cold or drying conditions to kill tubers. Tubers furthest from the soil surface are least susceptible to winterkill due to the insulating effect of the frozen surface soil (46). Tillage operations which bring tubers to the soil surface can reduce tuber populations in arid environments, particularly with purple nutsedge which is sensitive to desiccation (1, 10, 42). To kill purple nutsedge tubers, the tillage operation must cut the tuber roots that supply moisture to the tubers (1).

Dormancy and germination. Yellow nutsedge tubers are most dormant at the end of the season they were produced and least dormant in the spring and early summer, which partly accounts for the emergence pattern in the field (50). Often, dormant tubers in the field can be sprouted by washing soil from them and placing them in a suitable environment (3, 44).

It is likely that a deep-dormancy characteristic contributes to perpetuating field infestations. A high percentage of fresh yellow nutsedge tubers sprouted in the greenhouse or field the first spring following formation⁵. However, similar tubers remaining in the field did not sprout the first or subsequent years but retained their viability.

Certain chemical or physical means can break tuber dormancy in both species. Ethylene chlorohydrin, thiourea, gibberellic acid, ethyl ether, ethephon, benzyladenine, KSCN, H_2O_2 , and O_2 at appropriate concentrations can break dormancy of yellow nutsedge tubers (3, 44). Physical actions such as storage at 2 to 5 C (stratification), scarification, desiccation, and leaching with water also break dormancy in yellow nutsedge tubers (44, 52, 58, 59).

Tillage operations also can break tuber dormancy (50). In temperate climates, cool winter temperatures and leaching with water are natural actions that promote tuber germination. Drought can cause tuber dormancy in purple nutsedge (23). The selective herbicides used for yellow and purple nutsedge control do not appear to kill the tubers; rather,

⁴Mathiesen, R. 1976. Plant development and tuber composition of six biotypes of yellow nutsedge. Ph.D. thesis, Univ. Illinois, Urbana-Champaign.

⁵McCue, A.E.S. 1982. The influence of environment and management of yellow nutsedge (*Cyperus esculentus* L.) tubers. Ph.D. thesis, Cornell Univ., Ithaca, NY.

they act on the seedlings and shoots. Tubers removed from seedlings killed by soil-applied herbicides will sprout when placed in fresh media (44). Also, tubers sprout when exposed to herbicides in nutrient culture (44).

SEED BIOLOGY

Interest in nutsedge seed (botanically, an achene) biology is subsiding because evidence is lacking that seeds play a significant role in propagation, especially in cultivated fields (31, 44). Seedlings from seeds lack the vigor required to survive field conditions. An early research report on purple nutsedge related the lack of importance of seeds and seedlings in propagation (30). Many research workers who have investigated nutsedge propagation still feel seeds are unimportant in propagation even though plants have reached maturity from seedlings derived from seeds (2, 17, 19, 27, 31, 42, 56). For example, yellow nutsedge seeds sown in soil and watered adequately produced both seeds and tubers in one season in Massachusetts (19).

Often seeds are absent since many populations do not generate inflorescences (21, 44). Even when inflorescences are produced, seeds are sometimes absent (3, 19). Seed yields may be high, with viability less than 5% (27). There are reports of plentiful seed propagation with viability above 40% (19, 27). Seed production may occur most readily in young, vigorously growing populations (19).

Germination percentage has been increased by aging, heat treatments, and chemicals (2, 3, 27). Light does not stimulate germination (3).

WHOLE PLANT BIOLOGY

Extensive literature exists on plant biology concerning interference of yellow and purple nutsedges in crops. While interference is reported in a subsequent section of this series, several aspects are discussed here.

These weeds do not compete vigorously with tall-statured crops. Both purple and yellow nutsedges possess C_4 photosynthetic characteristics which render the nutsedges sensitive to the shade produced by tall crops (26, 28, 37, 44). Their relatively short growth habit usually relegates them to the shade. Both yellow and purple nutsedge

grow best under high soil moisture, high fertility (6, 33), and high temperatures (9, 22, 65); those are conditions enhanced by growers to produce crops.

Clipping shoots to be an effective control measure must be repeated often to be effective. Monthly clippings only slightly reduced tuber numbers in purple nutsedge, while clipping at 2-week intervals reduced tubers 60% (21). Weekly clippings effectively controlled purple nutsedge (33, 38).

An approach to nutsedge control is to pretreat plants with growth regulators to predispose the tissues (principally tubers) to subsequent herbicide applications. Many chemicals that affect differentiation of rhizomes into tubers rather than shoots have been tested, but none have effectively enhanced control (4, 15, 21, 51).

Another important biological characteristic is the allelopathic potential of tissues, especially tubers (12, 24, 40). Ground yellow nutsedge tubers at 0.3% dry weight in sand (w/w) significantly reduced growth of soybean [*Glycine max* (L.) Merr.] and corn (*Zea mays* L.) seedlings (12). Analysis of tuber constituents in both yellow and purple nutsedge revealed many phenolic compounds known to have allelopathic properties (24, 40). High concentrations of both eugenol and salicylic acid inhibited sprouting of yellow and purple nutsedge tubers (24). Extracts from yellow nutsedge tubers inhibited seed germination of several crop plants (40, 59). However, these weeds have not demonstrated inhibition of crop growth in the field by allelopathy.

LIFE CYCLE

The life cycle of yellow nutsedge in the Corn Belt of the United States has been described (26, 44), but no scheme has been proposed for purple nutsedge and yellow nutsedge growing in different agricultural areas. Obviously, the timing of major physiological processes in the Corn Belt does not transcend the entire range of both yellow and purple nutsedges, but the cycle will adapt to many cropping environments because the weeds grow with crops. Therefore, where the following discussion from Stoller (44) is not adaptable universally, other pertinent reports will be mentioned.

Tuber sprouting and seedling development. Tubers lie dormant in the soil until stimulated to sprout.

Soil warming is considered the major sprouting stimulus in temperate climates (44), while soil moistening is a sprouting stimulus in arid climates (23). When a tuber sprouts, one or more rhizomes elongate vertically from tuber buds. These rhizomes, expressing negative geotropism, are a continuation of the rhizome that formed the tuber. Roots radiate horizontally from the rhizome as it grows toward the soil surface. The rhizome tip at the soil surface is exposed to sunlight and diurnal temperature fluctuations which are the principal factors that stimulate the basal bulb to form on the rhizome under the soil surface (49). These rhizome tips are strong and sharp and can penetrate hard substrates, so mulching is an ineffective control. The rhizome extends mostly by internode elongation until the basal bulb is initiated.

Basal bulbs consist of a section of stem (rhizome) with compacted internodes containing meristems for roots, secondary rhizomes, leaves, and the flower stalk. Leaves originate at the bulb from a plicate, triangular fascicle, beginning with the outermost leaf and the fascicle terminates, under appropriate conditions, in a seed-bearing rachis (25, 67). The leaves which comprise the shoot extend below the soil surface to the basal bulb. Each successive, photosynthetically active leaf tends to be longer than the previous leaf in early shoot development (25). Parent tubers remain attached to the plant throughout the season, and the plant may derive food from tubers in times of stress (14, 45).

Vegetative development. Several weeks after the primary shoot emerges, secondary rhizomes radiate horizontally from the basal bulb. In the early growth stages, the rhizome tips turn upward, differentiating into secondary basal bulbs similar to the primary basal bulb. Secondary bulbs produce shoots, rhizomes, and flower stalks as described for primary bulbs; and subsequent development of tertiary and higher order bulbs forms the complex system of subterranean, vegetative growth. In an open field without crop interference, a single tuber can proliferate into a dense stand of shoots covering several square meters in a single season (17, 18, 58). Rapid vegetative proliferation occurs as conditions permit until tuberization predominates.

Photoperiod is a major factor controlling rhizome differentiation in yellow nutsedge (3, 25, 26), but temperature fluctuations, chemicals, and nutrition

also influence rhizome differentiation (13). Under long days, rhizomes of yellow nutsedge differentiate into basal bulbs while they differentiate into tubers under short days (25, 44).

The effect of photoperiod on rhizome differentiation in purple nutsedge is not defined clearly (16, 62). Horowitz (23) found no apparent effect of natural photoperiods (10 to 14 h) on tuberization in purple nutsedge, while Hammerton (16) showed that daylength was the major factor that influenced purple nutsedge growth and development in Jamaica. Williams (63) found tuber production accelerated as daylength decreased in purple nutsedge.

Tuberization. As growth progresses and daylength shortens in temperate climates, yellow nutsedge rhizomes differentiate into tubers. In purple nutsedge, tuberization can begin within 17 days after shoot emergence (14), but dormant tubers are not found until 8 weeks after emergence (18). Purple nutsedge tuberization apparently can occur all year in tropical climates (16, 22). By the time tuberization occurs, the plant complex usually includes many aerial shoots interconnected by rhizomes that are capable of diverting resources into tubers. Tuberization in purple nutsedge may be a response to excess carbohydrate, regulated by growth substances, photoperiod and temperature (13, 16).

One yellow nutsedge plant, growing unrestricted, can produce 7000 tubers with tuber populations of 1000/m² in a single season (1, 6, 18, 23, 42, 57, 58). When nutsedges grow with crops, however, shading reduces tuber production (26, 28). In an Illinois study of continuous corn without adequate nutsedge control (47), tuber densities increased rapidly in the first season; then remained at about 1000 tubers/m² for the next 3 yr. Apparently, the rate of tuber decay paralleled tuber production in this situation.

Flowering. Flowering is erratic among yellow and purple nutsedge populations. Many populations of yellow and purple nutsedge do not flower after growth for a cropping season, but tubers always are produced when these weeds grow for that length of time.

Photoperiod may be the principal factor that influences flowering in yellow nutsedge (3, 25), but the stimulant for purple nutsedge is not clearly

identified. Andrews (2) considered high humidity a stimulant in the Gezira. Ecotypic variation for flower production surely exists in yellow nutsedge. Flowering occurred only between 12 and 14 h photoperiods in Maryland (25), with longer than 14 h photoperiods in Illinois (26), and with less than 14 h daylength in Mississippi (63).

Superficially, the first evidence of flowering is when the foliar tube elongates from the fascicle center (25). The foliar tube is a hollow tube formed by the two most recently differentiated leaves growing as a single unit. The flowering structure arises from meristems in the basal bulb and elongates inside the foliar tube. The inflorescence bursts from the foliar tubes as it protrudes from the fascicle. The inflorescence sometimes develops mature, viable seeds.

ECOTYPIC VARIATION

There are reports on ecotypic variation in both yellow and purple nutsedge (7, 8, 32, 65, 68, 69). Variability appears in almost every morphological and biological characteristic measured, particularly when locations were involved. In-depth studies on ecotypic variability both within and among sites are lacking. Some ecotype differences in yellow nutsedge appear to be correlated with differences between the two established botanical varieties, *esculentus* and *leptostachyus*. Some authors specify that they worked with these varieties, while others call variants ecotypes. Apparently there are ecotypes within the named varieties. Unfortunately, there is no systemized taxonomic description to report variability in these species. The yellow nutsedge var. *sativas*, commonly known as chufas, is cultivated for the edible tubers and is not an aggressive weed like the other varieties (44).

There are reports of ecotypic variation in several important biological characteristics such as tuber dormancy and longevity, rhizome and tuber development, flowering, and responses to herbicides. In New York, tuber longevity and dormancy dif-

ferences were responsible for time differences required to eliminate established infestations of varieties *esculentus* or *leptostachyus* after preventing tuber formation⁶. Significantly, there were time differences required to eliminate the populations within varieties when they were grown at two locations, revealing an important variety-by-location interaction which has not been researched adequately. In Illinois, tubers originating from southern ecotypes were easier to winter-kill than tubers originating from northern ecotypes⁴. The superior cold hardiness of northern ecotype tubers may be due partly to their having the highest percentage of unsaturated fatty acid in the tuber lipids (48).

There also are differences among yellow nutsedge ecotypes in the physiology of rhizome development (7). When yellow nutsedge rhizomes penetrated potato (*Solanum tuberosum* L.) tubers in New York, ecotypic differences in rhizome number, diameter, and depth in the soil resulted in differential damage to potato⁶. Damage occurred if the potato tubers were present prior to or at the depth of rhizome growth. Potato tuber damage was limited when ecotypes developed rhizomes after the potato tubers were formed or when the rhizomes developed deeper than the potato tubers.

In the United States, var. *esculentus* apparently prevails in cooler climates than var. *leptostachyus*⁷. In 35 experiments involving 20 ecotypes of varieties *esculentus* and *leptostachyus*, population density, temperature, rainfall, fertility level, and other factors influenced the flowering and tuberization characteristics so that variety classification was difficult⁷. Research on both taxonomic classification and environmental variability in purple and yellow nutsedges is needed.

Some variation in yellow nutsedge response to herbicides may be due to intraspecific differences (8, 32), although research to clarify this aspect is limited. Var. *leptostachyus* was more susceptible to atrazine [6-chloro-*N*-ethyl-*N'*-(1-methylethyl)-1,3,5-triazine-2,4-diamine] and metribuzin [4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4*H*)-one] than var. *esculentus*, but the reverse was true for 2,4-D [(2,4-dichlorophenoxy)acetic acid] (8). Boldt⁶ studied the responses of four *esculentus* and one *leptostachyus* ecotypes to several soil-applied herbicides and concluded

⁶Boldt, P. F. 1976. Factors influencing the selectivity of U-compounds on yellow nutsedge. M.S. thesis, Cornell Univ., Ithaca, NY.

⁷Yip, C. P. 1978. Yellow nutsedge (*Cyperus esculentus* L.) ecotypes, their characteristics and responses to environment and herbicides. Ph.D. thesis, Cornell Univ., Ithaca, NY.

that varietal differences were minimal but ecotype differences were significant. The ecotypes with tubers that sprouted quickly and grew rapidly were damaged most, probably because the early growth enhanced herbicide absorption. Differential response to atrazine within var. *esculentus* was ascribed to differences in root exposure (32). Yip⁷ investigated five *leptostachyus* and three *esculentus* ecotypes for their response to alachlor [2-chloro-*N*-(2,6-diethylphenyl)-*N*-(methoxymethyl)-acetamide] and atrazine. There was no correlation between varieties and response to alachlor, but var. *esculentus* was more susceptible to atrazine than var. *leptostachyus*. Costa and Appleby (8) reported an opposite response. Perhaps, the opposite responses to atrazine which both investigators reported are due to differences in the botanical classification used or the ecotypes studied. For example, Costa and Appleby observed the fewest rhizomes and largest tubers on var. *esculentus*, while Yip⁷ reported that var. *leptostachyus* had these characteristics.

FUTURE RESEARCH

Considerable literature exists on the biology and life cycle of yellow and purple nutsedge, but each report usually covers an aspect of only one ecotype or variety from the extremely wide range of environments these species inhabit. While the total literature offers enough information to synthesize the general physiological characteristics of nutsedge biology and life, the ecotypic and environmental variability reported herein suggests that additional research on ecotypic variation would be appropriate. Variability has been reported in every morphological, biochemical, and physiological parameter studied, suggesting that variability would play a significant role in infestation severity and longevity as well as in its responses to control practices. Clarifying ecotype by environmental interactions also needs additional evaluation. Different environments have diverse effects on the physiological responses of an ecotype, making environmental variability as important as ecotypic variability.

A suitable classification scheme to catalog the ecotypes of yellow and purple nutsedge should be devised so researchers can report and can compare the exact ecotypes evaluated. In addition, research is needed to determine the geographical distribution of ecotypes in relation to national,

regional, local, and specific site situations and to determine the physiological reasons for differences in distribution.

Additional studies of tuber dormancy and longevity, and responses of tubers or whole plants to herbicides are desirable to enhance control and possible eradication methods for these weeds. Differential responses of ecotypes to herbicides also will need additional research efforts in regard to control strategy.

LITERATURE CITED

1. Andrews, F. W. 1940. A study of nut grass (*Cyperus rotundus* L.) in the cotton soil of the Gezira. I. The maintenance of life in the tuber. *Ann. Bot. (Lond.)* 4:177-193.
2. Andrews, F. W. 1946. A study of nut grass (*Cyperus rotundus* L.) in the cotton soil of the Gezira. *Ann. Bot. (Lond.)* 10:15-30.
3. Bell, R. S., W. H. Lachman, E. M. Rahn, and R. D. Sweet. 1962. Life history studies as related to weed control in the Northeast. I. Nutgrass. *Rhode Island Agric. Exp. Stn. Bull.* 364.
4. Bendixen, L. E. 1970. Altering growth form to precondition yellow nutsedge for control. *Weed Sci.* 18:599-603.
5. Bendixen, L. E. 1973. Anatomy and sprouting of yellow nutsedge tubers. *Weed Sci.* 21:501-503.
6. Bhardwaj, R. B. L., and R. D. Verma. 1968. Seasonal development of nutgrass (*Cyperus rotundus* L.) under Delhi conditions. *Indian J. Agric. Sci.* 38:950-957.
7. Boldt, P. F., C. P. Yip, and R. D. Sweet. 1976. Phenotypic studies of five New York yellow nutsedge selections. *Abstr. Weed Sci. Soc. Am.* 155.
8. Costa, J., and A. P. Appleby. 1976. Response of two yellow nutsedge varieties to three herbicides. *Weed Sci.* 24:54-58.
9. Davis, C. H. 1942. Response of *Cyperus rotundus* L. to five moisture levels. *Plant Physiol.* 17:311-316.
10. Davis, C. H., and R. S. Hawkins. 1943. Eradication and control of nutgrass. *Ariz. Agric. Exp. Stn. Bull.* 189.
11. Day, B. E., and R. C. Russell. 1955. The effect of drying on survival of nutgrass tubers. *Calif. Agric. Exp. Stn. Bull.* 751.
12. Drost, D. C., and J. D. Doll. 1980. The allelopathic effect of yellow nutsedge (*Cyperus esculentus*) on corn (*Zea mays*) and soybeans (*Glycine max*). *Weed Sci.* 28:229-333.
13. Garg, D. K., L. E. Bendixen, and S. R. Anderson. 1967. Rhizome differentiation in yellow nutsedge. *Weeds* 15:124-128.
14. Hammerton, J. L. 1974. Experiments with *Cyperus rotundus* L. I. Growth and development and effects of 2,4-D and paraquat. *Weed Res.* 14:365-369.
15. Hammerton, J. L. 1975. Experiments with *Cyperus rotundus* L. II. Effects of some herbicides and growth regulators. *Weed Res.* 15:177-183.
16. Hammerton, J. L. 1975. Experiments with *Cyperus rotundus* L. III. Season variations in growth. *Weed Res.* 15:339-348.
17. Hauser, E. W. 1962. Establishment of nutsedge from space-planted tubers. *Weeds* 10:209-212.
18. Hauser, E. W. 1962. Development of purple nutsedge under field conditions. *Weeds* 10:315-321.
19. Hill, E. R., W. H. Lachman, and D. N. Maynard. 1963. Reproductive potential of yellow nutsedge by seed. *Weeds* 11:160-161.
20. Holm, L. G., D. L. Plucknett, J. V. Pancho, and J. P. Herberger. 1977. *The World's Worst Weeds. Distribution and Biology.* Univ. Press Hawaii, Honolulu. p. 125-133.
21. Horowitz, M. 1965. Data on the biology and chemical control of the nutsedge (*Cyperus rotundus*) in Israel. *PANS (Pest Artic. News Summ.)* 11(4):389-416.

22. Horowitz, M. 1972. Effect of growth regulators on *Cynodon dactylon* (L.) Pers., *Sorghum halepense* (L.) Pers., and *Cyperus rotundus* L. *Weed Res.* 12:11–20.
23. Horowitz, M. 1972. Growth, tuber formation and spread of *Cyperus rotundus* from single tubers. *Weed Res.* 12:348–363.
24. Jangaard, N. O., M. M. Sckerl, and R. H. Schieferstein. 1971. The role of phenolics and abscisic acid in nutsedge tuber dormancy. *Weed Sci.* 19:17–20.
25. Jansen, L. L. 1971. Morphology and photoperiodic responses of yellow nutsedge. *Weed Sci.* 19:210–219.
26. Jordan-Molero, J. E., and E. W. Stoller. 1978. Seasonal development of yellow and purple nutsedges (*Cyperus esculentus* and *C. rotundus*) in Illinois. *Weed Sci.* 26:614–618.
27. Justice, O. L., and M. D. Whitehead. 1946. Seed production, viability, and dormancy in the nutgrasses *Cyperus rotundus* and *C. esculentus*. *J. Agric. Res.* 73:303–318.
28. Keeley, P. E., and R. J. Thullen. 1978. Light requirements of yellow nutsedge (*Cyperus esculentus*) and light interception by crops. *Weed Sci.* 26:10–16.
29. Loustalot, A. J., T. J. Muzik, and H. J. Crazado. 1954. Studies on nutgrass (*Cyperus rotundus* L.) and its control. Puerto Rico Fed. Bull. No. 52. Mayaguez, Puerto Rico.
30. MacMahon, P. 1899. Nut-grass (*Cyperus rotundus*). *Queensl. Agric. J.* 5:460–465.
31. Mulligan, G. A., and B. E. Junkins. 1976. The biology of Canadian weeds. 17. *Cyperus esculentus* L. *Can. J. Plant Sci.* 56:339–350.
32. Nishimoto, R. K., C. P. Yip, and R. D. Sweet. 1978. Some factors influencing atrazine activity on yellow nutsedge. *Weed Sci.* 26:421–424.
33. Nyahoza, F. 1973. Studies of the biology of *Cyperus rotundus* L. early growth and vegetative reproduction strategy. *E. Afr. Agric. For. J.* 17:120–130.
34. Palmer, R. D. 1964. Sprouting and growth of purple nutsedge tubers. *Miss. Agric. Exp. Stn. Inf. Sheet* 872.
35. Palmer, R. D., and W. K. Porter, Jr. 1959. The metabolism of nut grass (*Cyperus rotundus* L.). I. The influence of various oxygen and carbon dioxide levels upon germination and respiration. *Weeds* 7:481–489.
36. Palmer, R. D., and W. K. Porter, Jr. 1959. The metabolism of nut grass (*Cyperus rotundus* L.). II. The respiratory quotient and its relation to storage materials and some terminal enzymes. *Weeds* 7:490–503.
37. Patterson, D. T. 1982. Shading responses of purple and yellow nutsedges (*Cyperus rotundus* and *C. esculentus*). *Weed Sci.* 30:25–30.
38. Ranade, S. B., and W. Burns. 1925. The eradication of *Cyperus rotundus* L. (A study in pure and applied botany.) *Mem. Dep. Agric. India Bot. Ser.* 13:99–192.
39. Rao, J. S., and M. Nagarajan. 1962. Relationship between moisture levels and viability of nutgrass tubers. *Madras Agric. J.* 49:120–123.
40. Sanchez-Tames, R., M. D. V. Gesto, and E. Vieitez. 1973. Growth substances isolated from tubers of *Cyperus esculentus* var. *aureus*. *Physiol. Plant.* 28:195–200.
41. Sierra, J. N. 1974. Some observations on the sprouting capacity of *Cyperus rotundus* tubers. *Philipp. Weed Sci. Bull.* 1:30–34.
42. Smith, E. V., and G. L. Fick. 1937. Nutgrass eradication studies: I. Relation of the life history of nutgrass, *Cyperus rotundus* L., to possible methods of control. *J. Am. Soc. Agron.* 29:1007–1013.
43. Stoller, E. W. 1973. Effect of minimum soil temperature on differential distribution of *Cyperus rotundus* and *C. esculentus* in the United States. *Weed Res.* 13:209–217.
44. Stoller, E. W. 1981. Yellow nutsedge: A menace in the Corn Belt. *U.S. Dep. Agric. Tech. Bull.* 1642.
45. Stoller, E. W., D. P. Nema, and V. M. Bhan. 1972. Yellow nutsedge tuber germination and seedling development. *Weed Sci.* 20:93–97.
46. Stoller, E. W., and L. M. Wax. 1973. Yellow nutsedge shoot emergence and tuber longevity. *Weed Sci.* 21:76–81.
47. Stoller, E. W., L. M. Wax, and F. W. Slife. 1979. Yellow nutsedge (*Cyperus esculentus*) competition and control in corn (*Zea mays*). *Weed Sci.* 27:32–37.
48. Stoller, E. W., and E. J. Weber. 1975. Differential cold tolerance, starch, sugar, protein, and lipid of yellow and purple nutsedge tubers. *Plant Physiol.* 55:859–863.
49. Stoller, E. W., and J. T. Woolley. 1983. The effects of light and temperature on yellow nutsedge (*Cyperus esculentus*) basal-bulb formation. *Weed Sci.* 31:148–152.
50. Taylorson, R. B. 1967. Seasonal variation in sprouting and available carbohydrate in yellow nutsedge tubers. *Weeds* 15:22–24.
51. Teo, C. K. H., L. E. Bendixen, and R. K. Nishimoto. 1973. Bud sprouting and growth of purple nutsedge altered by benzyladenine. *Weed Sci.* 21:19–23.
52. Thomas, P. E. L. 1967. A preliminary study on the dormancy of *Cyperus esculentus* tubers. *PANS (Pest Artic. News Summ.)* 13:329–333.
53. Thomas, P. E. L. 1969. Effects of desiccation and temperature on survival of *Cyperus esculentus* tubers and *Cynodon dactylon* rhizomes. *Weed Res.* 9:1–8.
54. Thomas, P. E. L., and I. E. Henson. 1968. Influence of climate and soil moisture on tuber dormancy of *Cyperus esculentus*. *PANS (Pest Artic. News Summ.)* 14:271–276.
55. Thullen, R. J., and P. E. Keeley. 1975. Yellow nutsedge sprouting and resprouting potential. *Weed Sci.* 23:333–337.
56. Thullen, R. J., and P. E. Keeley. 1979. Seed germination and germination in *Cyperus esculentus* and *C. rotundus*. *Weed Sci.* 27:502–505.
57. Tripathi, R. S. 1969. Ecology of *Cyperus rotundus* L. III. Population of tubers at different depths of the soil and their sprouting response to air drying. *Proc. Nat. Acad. Sci., India* 39:140–142.
58. Tumbleson, M. E., and T. Kommedahl. 1961. Reproductive potential of *Cyperus esculentus* by tubers. *Weeds* 9:646–653.
59. Tumbleson, M. E., and T. Kommedahl. 1962. Factors affecting dormancy in tubers of *Cyperus esculentus*. *Bot. Gaz.* 123:186–190.
60. Waters, W. E. 1965. Influence of hot-water on viability of *Cyperus esculentus* and *Cyperus rotundus* tubers. *Proc. Fla. State Hort. Soc.* 78:437–440.
61. William, R. D. 1976. Purple nutsedge: Tropical scourage. *Hort. Science* 11:357–364.
62. Williams, R. D. 1978. Photoperiod effects on the reproductive biology of purple nutsedge (*Cyperus rotundus*). *Weed Sci.* 26:539–542.
63. Williams, R. D. 1982. Growth and reproduction of *Cyperus esculentus* L. and *Cyperus rotundus* L. *Weed Res.* 22:149–154.
64. Wills, G. D. 1975. Effect of light and temperature on growth of purple nutsedge. *Weeds Sci.* 23:93–96.
65. Wills, G. D. 1978. Initial evaluations of purple nutsedge (*Cyperus rotundus* L.) ecotypes. *Abstr. Weed Sci. Soc. Am.* 40.
66. Wills, G. D., and G. A. Briscoe. 1970. Anatomy of purple nutsedge. *Weed Sci.* 18:631–635.
67. Wills, G. D., R. E. Hoagland, and R. N. Paul. 1980. Anatomy of yellow nutsedge (*Cyperus esculentus*). *Weed Sci.* 28:432–437.
68. Yip, C. P., and R. D. Sweet. 1978. Biotypes of yellow nutsedge (*Cyperus esculentus* L.): I. Morphological characteristics. *Abstr. Weed Sci. Soc. Am.* 127.
69. Yip, C. P., and R. D. Sweet. 1978. Biotypes of yellow nutsedge (*Cyperus esculentus* L.): II. Tuber dormancy and responses to photoperiod and herbicides. *Abstr. Weed Sci. Soc. Am.* 128.