BIOLOGY AND CONTROL OF WEEDY CYPERACEAE SPECIES OF THE KENYAN HIGHLANDS

A Thesis

Submitted to the Faculty

of

Graduate Studies

by

Lyle Frank Friesen

In Partial Fulfillment of the

Requirements for the Degree

of

Master of Science

Department of Plant Science

ISBN Ø-315-33841-5

BIOLOGY AND CONTROL OF WEEDY CYPERACEAE SPECIES OF THE KENYAN HIGHLANDS

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A thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

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ABSTRACT

Friesen, Lyle Frank. M.Sc., The University of Manitoba, October, 1986. The Biology and Control of Weedy Cyperaceae Species of the Kenyan Highlands. Major Professor; Dr. E.H. Stobbe.

Cyperus rigidifolius Steud., Cyperus esculentus L., Cyperus teneristolon Mattf. & Kuk., and Cyperus usitatus Burch. var. usitatus were identified as important sedge weeds found in cultivated fields and pastures in the highland areas of Kenya. Identification of sedge weeds, particularly in early stages of growth, is difficult because they often grow in mixed stands in the field and a mature inflorescence must be present to use taxonomic keys. A description of each of these species was prepared to assist non-taxonomists in correctly identifying these weeds.

Getting sedges to grow when and where desired is a major obstacle to conducting controlled environment or greenhouse studies investigating the biology and control of these weeds. Satisfactory sprouting percentages were obtained by desiccating C. rigidifolius basal bulbs, and by cutting C. esculentus tubers into longitudinal halves. Cutting C. usitatus var. usitatus bulbs into longitudinal or cross-sectional halves stimulated sprouting somewhat, and was the most effective pretreatment method used with this species. C. teneristolon rhizome pieces possessing a swollen area sprouted readily, and slender rhizome pieces did not sprout.

In-crop control of sedge weeds is not always feasible because only a limited number of effective herbicides are available. EPTC, butylate, alachlor, and metolachlor delayed the emergence for several months of C. teneristolon plants in sunflowers, although these herbicides had little effect on established C. rigidifolius plants and patches. In experiments involving plants growing in pots, bentazon and bentazon + dichlorprop gave acceptable control only of young C. esculentus plants, and erratic control of C. rigidifolius plants.

Three non-selective herbicides were also tested. A single postemergence application of 0.75 kg/ha of AC 252.925 killed sedge weeds in field and pot experiments. AC 252.925 is soil active and persisted for approximately four months in the field.

A minimum of 2.0 kg/ha of glyphosate was required to achieve satisfactory, consistent control of sedge weeds. C. teneristolon plants from Njoro were not controlled even at this relatively high rate.

Glufosinate was not particularly active against sedge weeds as 2.0 kg/ha gave marginally acceptable control of C. usitatus var. usitatus plants in the field, and was ineffective when applied to C. teneristolon plants growing in pots.

ACKNOWLEDGMENTS

The author wishes to thank the following people who were directly or indirectly involved in this study.

Dr. E.H. Stobbe for offering the opportunity to do research in Kenya as part of a CIDA project, and for his guidance in the research and preparation of this thesis.

Dr. G. Robinson and Dr. M. Pritchard for reviewing this manuscript.

Miss C.H.S. Kabuye of the Herbarium, National Museum of Kenya, Nairobi, for identifying various specimens.

P.J. Terry and A.S. McCue for advice and reference materials.

The staff at National Plant Breeding Station, Njoro, for helping with the research work.

Doug for being a friend, a helpful and knowledgeable fellow graduate student, and a first-rate cook and baker.

The Behr's for being my home away from home.

The Stobbes', Toews', and Wiebes' for hospitality and friendship.

John for friendship, providing a place to stay in Winnipeg, and use of his PC-AT.

My sister, Kimberley, and brother-in-law, Peter, for the letters, letter-tapes, and many parcels that they sent to Kenya.

My parents for their unfailing love and encouragement, and for visiting me in Kenya when I was feeling homesick - I love you.

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I INTRODUCTION

The Cyperaceae (sedge) family is a large family consisting of about 75 genera and 4,000 species, most of them inhabiting the tropics and subtropics (Stoller, 1982). Napper (1963, 1964, 1965, 1966, 1971) produced a flora of the Cyperaceae of East Africa with keys and notes on the identification of 357 sedges found in these countries. Of 57 East African sedges recorded as weeds, 19 were considered by Terry (1976) to be sufficiently widespread to be included in his key of "Important Sedge Weeds Of East Africa".

Most of the scientific literature available on the biology and control of sedge weeds is devoted to two species, Cyperus rotundus L. (purple nutsedge) and Cyperus esculentus L. (yellow nutsedge). Cyperus rotundus has been listed as the worst weed in the world (Holm et al., 1977), as it has been reported to be a weed in 52 crops in 92 countries.

Members of the Cyperaceae family can be readily distinguished from the Gramineae (grass) family on the basis of a triangular stem, and three-ranked leaves with one-third phyllotaxy (a triangular leaf arrangement when viewed from above) possessing a closed leaf sheath. Other than these common characteristics, sedges display a great deal of interspecific and intraspecific variation with regards to plant size and plant form. It is the existence of this large amount of

intraspecific variation that makes the identification of a sedge difficult for even experienced taxonomists.

Due to climatic factors, most of the land in Kenya devoted to small grains, oilseed crops, and improved or tame pastures is between 1,600 to 3,000 m above sea level. Sedge weeds also thrive in these agro-climatic zones. Farmers in Kenya are aware of and concerned about sedge weeds because control, especially selective control, is difficult, and eradication, once the sedge infestation is established, is almost impossible.

Objectives of this study were to:

1) identify the sedge weeds present in the wheat growing areas of Kenya,
2) develop procedures that when followed would result in the germination of a high percentage of the propagative structures of specific species, and
3) evaluate selective and non-selective herbicides for the control of sedge weeds.

II LITERATURE REVIEW

Taxonomy And Identification Of Sedge Species

Sedges are members of the Cyperaceae family. The Cyperaceae is a large and diverse family consisting of some 75 genera (Stoller, 1982). Sedges are classified in the class Monocotyledoneae, and the subdivision Angiospermae (Looman and Best, 1979).

Detailed keys of the Cyperaceae of East Africa have been published (Napper, 1963, 1964, 1965, 1966, 1971; Haines and Lye, 1983). The Haines and Lye (1983) publication has merged the genera Kyllinga, Mariscus, and Pycreus with Cyperus.

Taxonomically, species identification usually requires a plant with a mature inflorescent seed head and mature achenes (seeds), but obtaining positive identification often is desirable or necessary at an early stage of growth. Parker (1972) and Terry (1976) simplified the existing complex Cyperaceae keys and provided descriptions of the major weedy sedge species found in East Africa, so that sedge species identification could be performed in the field by non-taxonomists. Terry's (1978) report concerning the distribution of the major sedge weeds of East Africa is helpful in identifying sedges growing in this region.

The existence of intraspecific variability complicates identification. Stoller (1982) lists five varieties of Cyperus esculentus and states that additional varieties exist, but that no

systematic classification of them is currently available. C. esculentus varieties differ in the size of various spikelet components (the taxonomic characteristic used as the basis for naming varieties), and in leaf size, tuber weight, and response to herbicides (Stoller, 1982; Costa and Appleby, 1976).

Germination Of Propagative Structures

Morphology And Physiology Of C. esculentus And C. rotundus Propagules

Achene. Holm et al. (1977) stated that in the Cyeraceae the ovary contains a solitary anatropous ovule, erect from the base. The trigonous achene is about one-half as long as the glume in C. rotundus. Botanically, the achene is a fruit. In most of the Cyperaceae, the seed is erect from the base of the fruit, free from the pericarp, and has a thin testa. The pericarp is thick and hard. The endosperm is made up of a peripheral oily layer with starchy tissue beneath. The small embryo is lenticular, globose, or ovoid, and it is situated within the base of this fleshy endosperm. The lower end of the embryo is occupied by a radicle that is without any marked root-sheath development, and the upper portion of the embryo is filled by the cotyledon. There is a distinct cotyledonary sheath that encloses the first leaf.

Only the cotyledon grows during the initial stages of germination. The cotyledonary sheath elongates to break its coverings and bends geotropically upward. The middle portion of the cotyledon then grows

rapidly to pull the main root out of the seed (Holm et al., 1977).

Tuber. Wills and Briscoe (1970) and Wills et al. (1980) reported that a tuber is an enlarged section of rhizome with terminal buds. The apical meristem of an actively growing rhizome is sheathed within a succession of sharply pointed scale leaves. Each successive scale-leaf grows through the apex of the previously matured leaf, resulting in a series of nodes and scale leaves along the rhizome. Progressive shortening of internodes, an increase in rhizome diameter, and starch accumulation in cells are early concurrent events in tuber formation at the tips of C. esculentus and C. rotundus rhizomes.

In C. esculentus, the internodes at the tip become increasingly shorter, resulting in a group of appressed leaves to form a cone. Buds are present in the axils of the terminal leaves under the canopy of this cone, one bud per node. Occasionally a bud forms at the next older node, just outside of the cone. Buds have never been observed at older nodes on the tubers nor along the rhizomes (Bendixen, 1973).

C. esculentus tubers lie dormant in the soil at various depths during the off-season. In most soils in the U.S.A., more than 75% of the tubers are produced in the upper 15 cm (Stoller, 1982). Those tubers very near the soil surface (2 to 5 cm deep) can be killed by desiccation or extreme cold (in countries that experience winter). In the U.S.A., the cold and wet conditions of overwintering are thought to contribute to the dissipation of dormancy (Stoller, 1982).

When the favourable conditions of the growing season return, some tubers are stimulated to germinate. Shoots readily arise from tubers 30 cm deep, and a tuber planted 80 cm deep in a sandy silt loam soil

was observed to successfully produce a shoot (Tumbleson and Kommedahl, 1961). When a tuber germinates, one or more slender rhizomes elongate vertically towards the soil surface from the buds at the terminal end of the tuber. Because of the presence of numerous buds, a tuber can germinate several times, as well as produce several shoots almost simultaneously (Bendixen, 1973).

Stoller et al. (1972), using C. esculentus tubers collected from fields near Urbana, Illinois, reported that multiple sprouts were produced only during the first germination (an average of 1.29 sprouts per tuber). The proportion of tubers that regenerated new growth, after removal of the original sprout(s), decreased with each germination. Eighty percent of the tubers germinated once, 52.2% twice, and 26.5% germinated three times. The magnitude of the weight loss by the tubers decreased with each germination. Over 60% of the dry weight, carbohydrate, starch, protein, and oil present in the original tubers was consumed during the first germination; from 6 to 18% of the remaining constituents was used during the second germination, and 2 to 10% during the third germination. They also reported that the energy loss from the tubers during each successive germination was accompanied by a proportional loss in vigour of the newly sprouted shoots.

Lorougnon (1969 - as cited by McCue, 1982) found only three buds per C. esculentus tuber, the apical bud being the largest, and sprouting followed a basipetal pattern.

In contrast to Lorougnon (1969), Bendixen (1973), working with C. esculentus tubers collected from fields near Columbus, Ohio, reported that five to seven buds are usually formed in tubers, and that the oldest bud is the largest and most basipetal. He found that two buds

usually broke dormancy and developed almost simultaneously if the tubers and sprouts had not been disturbed. However, if these sprouts were then removed from the tuber, additional buds soon broke dormancy. In one tuber, six buds sprouted in four days. The maximum number of buds per tuber breaking dormancy was seven. The oldest bud broke dormancy first, followed shortly by the second oldest bud. Sprouting was always in a stepwise acropetal sequence regardless of the number of buds breaking dormancy.

Bendixen (1973) concluded that it was expected that bud initiation and development would proceed acropetally at the terminal six nodes in developing C. esculentus tubers. The fact that buds broke dormancy in this same acropetal sequence is contrary to the widespread and well-known pattern of apical dominance.

During the latter one-third of the growing season, the C. esculentus plant uses its complex system of shoots and rhizomes to efficiently fix dry matter in tubers. In the Corn Belt (U.S.A.), about one-third of the total plant dry weight is commonly in tubers by the end of the season (Stoller, 1982). Mature C. esculentus tubers tend to be spherical in shape, although distorted shapes are also common. Mature tubers vary greatly in size both within a local population as well as among various populations; e.g. 3 to 12 mm in diameter, and from 70 to 710 mg in weight (Stoller, 1982).

Buds on C. rotundus tubers are located at nodes throughout the length of the tuber, in contrast with apical clustering of buds on C. esculentus tubers. The apical bud of a single C. rotundus tuber exerts a strong dominance over sprouting of the lateral buds, as the apical bud sprouts first (Holm et al., 1977). This apical bud dominance does

not preclude the production of near-simultaneous multiple sprouts by a germinating tuber. Nyahoza (1974) reported that C. rotundus tubers immersed in still water for 16 days prior to being placed in a favourable environment for germination, sprouted 100% and produced an average of 3.6 sprouts per tuber within five days. Tubers in his control treatment also sprouted 100%, but produced only an average of 1.6 sprouts per tuber.

Axillary bud formation in actively growing rhizomes of C. esculentus and C. rotundus apparently does not occur, and plants established from rhizome pieces have not been observed (Holm et al., 1977).

Mature C. rotundus tubers are 1 to 1.5 cm long and 0.5 to 1 cm in diameter (Holm et al., 1977).

Basal Bulb. In both C. rotundus and C. esculentus the basal bulb is the focus of the leafy shoot and the beginning of subterranean growth (Wills and Briscoe, 1970; Wills et al., 1980; Holm et al., 1977). Basal bulbs have always been found at the base of green or senescent C. rotundus and C. esculentus shoots, and basal bulbs have always been associated with shoots (i.e. basal bulbs are never dormant). Basal bulbs are subterranean and contain meristems for roots, rhizomes, leaves, and flower structures. A basal bulb (sometimes called a tuberous bulb, or a corm) forms at the tip of the upward growing rhizome that originates from a germinating tuber. Shoots never sprout directly out of a tuber, instead, when the tip of the upward growing rhizome encounters sunlight and diurnal temperature fluctuations it differentiates to form a basal bulb. In a uniform seedbed, all basal bulbs are at a comparable

distance from the soil surface, regardless of depth of the tubers. During formation of a basal bulb, a short stem extends acropetally with leaves developing from compact nodes. One leaf grows at each node, and the flower stalk arises from the center of the triangular cluster formed by the basal portions of the leaves. In C. rotundus, the parenchymatous cells of the basal bulb enlarge and accumulate starch; in C. esculentus, the laterally growing parenchyma cells do not accumulate starch.

Several weeks after emergence, after the primary basal bulb and its shoot are well established, rhizomes develop from the basal bulb (Holm et al., 1977; Stoller, 1982). These early season rhizomes elongate nearly horizontally from the basal bulb. The tips turn upward, differentiating into secondary basal bulbs with their associated shoots. These secondary basal bulbs also produce rhizomes, and a repetition of these events creates a series of tertiary and higher order basal bulbs each with a shoot. This process forms a complex system of vegetative growth with the original tuber giving rise to a patch of basal bulbs, their shoots, and eventually, tubers, with rhizomes connecting all the basal bulbs of one "patch". The vascular system is continuous from the aerial shoot throughout the entire plant unit for at least one season. In C. esculentus plants, the shoots, basal bulbs, and rhizomes die and disintegrate during the off-season.

A description of the size, shape, and general appearance of C. rotundus or C. esculentus basal bulbs was not found in the literature reviewed; it appears that this organ of vegetative propagation has been mostly ignored by researchers. Holm et al. (1977) points out that it is difficult to study the formation and growth of tubers and basal

bulbs in C. rotundus because initially it is so hard to distinguish between them. In some soils, basal bulbs may be produced as deep as 20 cm, so these two structures cannot be sorted on the basis of distance from the soil surface (Hauser, 1962b). A newly formed C. rotundus basal bulb located at the terminus of a rhizome may look very much like a newly formed tuber that is in a similar position. It is their activity that distinguishes them: the tuber remains temporarily dormant while the basal bulb produces a shoot.

Plant age and photoperiod are thought to be the major factors controlling the differentiation of C. rotundus and C. esculentus rhizome tips, but temperature fluctuations, chemicals, and nutrition also affect the differentiation process. Tuber production may begin once the plant has reached a certain stage of development, usually after three to six weeks of growth. In general, long days promote differentiation into basal bulbs, and short days stimulate differentiation into tubers (Holm et al., 1977; Stoller, 1982). Daylength is maximal early in the growing season in the U.S.A. and other countries not situated near the equator, promoting maximum vegetative growth during the initial part of the season.

Parker (1972) described the basal bulb of C. rotundus as "swollen", and the basal bulb of C. esculentus as "slim".

Nyahoza (1974) used basal bulbs, as well as tubers, in his study of the sprouting potentiality of the vegetative axillary buds of C. rotundus. Williams et al. (1977) used basal bulbs to establish C. rotundus plants for a greenhouse experiment.

Factors Affecting The Germination Of The Propagule

Growth Environment. In Kenya, propagule dormancy may be affected by varying temperature and moisture conditions (photoperiod is constant) during the formation of sedge weed propagules. Dormancy is a result of the plant and propagule's physiological reactions to combinations of external factors present during propagule formation and storage (Vegis, 1969).

Yip (1978 - as cited by McCue, 1982), at Cornell University, New York, found that varying temperature regimes at the time of C. esculentus tuber formation affected the subsequent sprouting ability of the tubers. The majority of the C. esculentus ecotypes he tested produced tubers with a reduced sprouting potential when grown at 29/24 C as compared to 21/16 C.

Thomas and Hensen (1968), using C. esculentus tuber stock from South Africa, studied the influence of controlled climate and soil moisture on tuber sprouting and dormancy. Eighteen percent of the tubers, produced by C. esculentus plants grown under tropical, wet conditions, sprouted shortly after collection. Tuber sprouting was reduced when tubers were produced under hot, dry conditions, due to desiccation of the tubers and subsequent death. Conversely, dry conditions enhanced the sprouting of tubers produced in cool environments, as desiccation was not a factor at the lower temperatures.

Storage Environment. Storage environment affects propagule viability and dormancy. The storage variables include temperature, moisture, duration, and atmosphere. Specific storage conditions are required to

achieve high sprouting percentages with the propagules of some sedge species (Justice, 1957).

Justice and Whitehead (1946) collected large numbers of C. rotundus achenes from southern states (U.S.A.), and found that achenes did not germinate immediately after harvest. Storage conditions they tested included: room temperature, constant 2 C, constant 10 C, in the dark; and 2 C in the dark for 16 hours followed by 20 C in the light for 8 hours, and 10 C in the dark for 16 hours followed by 20 C in the light for 8 hours. Achenes were tested for germination at an alternating temperature of 20 C in the dark for 16 hours and 35 C in the light for 8 hours, on a substrate moistened with a 0.2% solution of potassium nitrate. Achenes stored at room temperature and at 10 C both showed 1% germination after four months. Germination improved with time, with storage conditions using alternating temperatures and dark and light giving the best results (up to 18% germination). An overall average of 4% of the 13,500 C. rotundus achenes used in all of their experiments germinated.

Justice and Whitehead (1946) also collected C. esculentus achenes from a number of states, and found that viability varied from 50 to 95%. Most achenes were dormant immediately after harvest, but four months of storage in dry conditions at room temperature, or in moist conditions at 10 C, effectively broke dormancy.

C. esculentus tubers collected from fields in northeastern United States after overwintering germinated readily (70 to 95%), but fall-harvested tubers were dormant (Tumbleson and Kommedahl, 1962). Bell et al. (1962) reported that dormant tubers were stimulated to germinate by one month's storage on moist blotter paper at 10 C. Storage

of tubers in a moist environment for nine weeks at 4 C enhanced sprouting in most of the C. esculentus ecotypes that Yip (1978) examined.

Terry (1983) suggested that dry storage in a sealed glass jar, held at room temperature in constant darkness, for eight to twelve months would enhance the sprouting of C. usitatus var. usitatus bulbs.

Palmer and Porter (1959a) studied the effect of the storage atmosphere on the sprouting of C. rotundus tubers. Tubers were held for 17 days in flasks with various CO_2 and O_2 concentrations. No sprouting occurred in 100% CO_2, and 95% of the tubers sprouted in 100% O_2. When the flasks were opened and exposed to air for 11 days, 90% of the tubers sprouted regardless of the previous treatment.

Stoller (1982) noted that C. esculentus tuber longevity is dependent upon tuber depth. Deeply buried tubers, where temperatures were low, the soil generally moist, and the overall environment constant, lived longer. Data from the Illinois site indicated that the half-life of C. esculentus tubers was four months when buried 10 cm below the soil surface, and six months when buried 20 cm below the surface (Stoller and Wax, 1973). Three years of season-long control was required to reduce tubers to 15% of original density - the original density of viable tubers was 1,200 per square metre, sampled to a depth of 15 cm (Stoller et al., 1979).

Physiological Factors. C. esculentus tubers are produced in a successional fashion so that at any give time there is a range of maturities present. Taylorson (1967) and McCue (1982) investigated the effects of age on C. esculentus tuber dormancy. They reported that newly formed (white) tubers sprouted readily, and that dormancy increased with the

physiological age of the tubers. Black or brown tubers exhibited the greatest degree of dormancy.

It has been reported that an endogenous promoter-inhibitor complex controls dormancy in seeds and resting buds (Wareing and Saunders, 1971). Promoters may include giberellins and cytokinins; inhibitors may include abscissic acid and phenolic compounds. The overall amounts of these compounds and more importantly, the balance between promoters and inhibitors depends upon the physiological age of the propagule and the influence of the surrounding environment.

Muniz and Tames (1982) recorded the abscisic acid content of C. esculentus tubers throughout the year (in Spain). Abscisic acid levels were highest in November and lowest in April, which corresponded to natural dormancy patterns - i.e. 88% of tubers collected in October or November were dormant, while only 5% of tubers collected in March or April were dormant. Dormant tubers of C. rotundus have been found to be rich in polyphenol oxidase (Palmer and Porter, 1959b), which indicates that phenolic compounds may be involved in the dormancy mechanism.

Leaching has been tested as a method of removing possible water soluble germination inhibitors located in the outer covering of a propagule. Tumbleson and Kommedahl (1961) increased C. esculentus tuber (tubers were collected in October from a field in southern Minnesota) germination from 5 - 9% to 75 - 90% by washing the tubers out of tuber-infested soil with cold (13 C) water. Other researchers, however, have reported no effect of washing on C. esculentus tuber germination (Taylorson, 1967; Yip, 1978).

McCue (1982) reported that unsprouted, dormant C. esculentus tubers were a bright yellow colour inside after being held at 13 C in a germinator for five days. Although the yellow substance was not identified, it may have been an inhibitory substance, as there are naturally occurring carotenoids that can be photo-oxidized to yield growth-inhibitory products that are very similar in structure to abscisic acid (Wareing and Phillips, 1981).

Pretreatments. Many chemical substances have been found to stimulate or enhance the sprouting of sedge propagules. Thiourea (5%), ethylene chlorohydrin (1%), ethylene, and potassium thiocyanate have all been reported as enhancing the sprouting of C. esculentus tubers (Bundy et al., 1960). Thomas (1967) found that seven days of a hydrogen peroxide (3%) treatment increased the sprouting of C. esculentus tubers from 27% to 60%. Hydrogen peroxide was found to be corrosive and probably enhanced sprouting by increasing oxygen supply to the buds (chemical scarification).

Bell et al. (1962) reported increased germination of C. esculentus achenes after treatment with concentrated sulfuric acid for 2, 5, or 10 minutes.

Thomas (1967) scarified C. esculentus tubers using an abrasive surface which exposed about 10% of the interior of a tuber. Sprouting increased from 40% to 85%. Nyahoza (1974) cut C. rotundus basal bulbs (collected only from the base of green C. rotundus shoots) into longitudinal and cross-sectional halves, and into one-internode segments taken from the middle of the basal bulbs. He reported 100% sprouting of both types of basal bulb halves after eight days, with an average of

1.2 sprouts per half. In almost all cases, the vegetative axillary bud(s) that sprouted were those nearest to the apical end of the basal bulb half. Similarly, nearly 100% of the one-internode segments sprouted within eight days of being placed in the germination environment.

Heat, in combination with a moist environment, has been successfully used to break the dormancy of C. rotundus achenes. Justice (1956) found the achenes of C. rotundus to be dormant at maturity, and, in some samples, this dormancy was retained in dry storage at room temperature for seven to eight years. Dormancy was broken by holding the achenes at 40 C on a moist substratum for three to six weeks, and subsequently germinating them using alternating temperatures of 20 C in the dark and 30 C in the light (16 hours darkness, 8 hours light).

Justice (1957) found that the "seeds" of most of the Cyperaceae species that he harvested initially were dormant, but that dormancy was broken in most cases by prechilling for at least ten weeks at temperatures ranging between 2 C and 10 C. Bell et al. (1962) found that cool, moist storage (or prechilling) for one month stimulated dormant C. esculentus tubers to sprout.

Day and Russell (1955) and McCue (1982) studied the effect of desiccation on the germination and overall viability of sedge propagules. Day and Russell (1955) stored air-dried tubers of C. esculentus for six months at room temperature with only a 25% loss in viability. McCue (1982) placed C. esculentus tubers in dry sand in petri dishes and incubated the dishes at 32 - 38 C for varying lengths of time. She found that it took only one day of these conditions for tubers to lose 90% of their moisture. The number of tubers sprouting

decreased and the number dead and dormant increased as tubers became more desiccated. After 14 days of desiccation she reported that tubers had lost 100% of their moisture, with 0% sprouting, 30% dead, and 70% dormant (as determined by a tetrazolium test) after five days in an environment favourable for germination.

Tumbleson and Kommedahl (1961) reported that 90% of the C. esculentus tubers gathered from the soil surface immediately after disking sprouted, while only 10% of the tubers gathered from the same soil surface two days later, sprouted. They did not determine whether unsprouted tubers were dormant or dead, however.

C. rotundus tubers are susceptible to being killed by desiccation. Smith and Fick (1937), in an experiment designed to mimic field conditions, planted C. rotundus tubers 5 cm and 10 cm deep in dry soil that was protected from rain, but was exposed to direct sunlight. At the 5 cm level, 80% of the tubers were killed in eight days and all were dead in 12 days. All of the tubers at 10 cm were killed in 16 days. These researchers found that C. rotundus tubers were killed after four days on a dry soil surface fully exposed to the sun, after 16 days in open air in a laboratory, and after 32 days in open air in a storeroom. In all cases the tuber moisture content was 15% at death, except in the case where tubers were in the sunlight, it was 24%.

Germination Environment. Stoller and Wax (1971) reported that the minimum sprouting temperature of C. esculentus tubers was 12 C. McCue (1982) found that a 13 C incubation temperature decreased and delayed sprouting of C. esculentus tubers and increased dormancy and death, however, 67% of the tubers incubated at 13 C sprouted. Ueki (1969), in

Japan, obtained 95% sprouting of C. rotundus tubers at 30 - 35 C, with no sprouting above 45 C or below 10 C.

Standard germination tests for C. esculentus tubers have been developed by several researchers (Tumbleson and Kommedahl, 1961; Bendixen, 1973; McCue, 1982). Tumbleson and Kommedahl (1961), placed C. esculentus tubers in petri dishes prepared with three sections of filter paper and 10 mL of water, and placed these petri dishes in a Mangelsdorf germinator at 28 C. Bendixen (1973) buried C. esculentus tubers 1 cm deep in sand, cultured in growth chambers maintained at 26 C with 12 hour photoperiods, and irrigated daily with tap water. McCue (1982) placed 20 - 30 tubers into a petri dish containing 50 cc sterile sand and 10 mL distilled water. Prepared petri dishes were placed in plastic bags to maintain moisture levels, and the plastic bags placed in an incubator set to maintain a constant temperature of 35 C.

McCue (1982) investigated the interaction of moisture levels and media on C. esculentus tuber sprouting. Twenty tubers were placed in each prepared petri dish. The high moisture treatment was 25 mL of water added to 50 cc of sand, and 12 mL of water with filter paper (the two water levels created a similar moisture environment for the tuber); the moderate moisture treatment was 10 mL with sand, and 5 mL with filter paper; the low moisture treatment was 2 mL with sand, and 1 mL with fiter paper. She found that there was a significant interaction between media and moisture levels. In sand, there was no effect of moisture levels on the number of tubers that sprouted. With filter paper, there was a decrease in sprouting as moisture levels increased. However, 100% of the tubers sprouted in both media at the low moisture

level. She concluded that sand appeared to be a more stable medium than filter paper because water was uniformly distributed throughout the sand. With filter paper, the tuber resting in water (the moderate and high moisture treatments) caused the petri dish environment to become anaerobic.

Andrews (1940), in Sudan, investigated the effect of soil moisture on the sprouting of C. rotundus tubers. Soil moisture contents of 10, 20, 30, 35, 40, 50, and 60% were established, in near airtight containers, prior to planting of the tubers in the containers. Eight days later there was no sprouting in soils containing 10, 50, and 60% moisture. Very little sprouting was observed in the 20% soil moisture containers, but sprouting activity peaked in the 30, 35, and 40% soil moisture treatments. He later determined that dormancy is induced in C. rotundus tubers held for two to four weeks in soils with moisture levels of 50 to 60%, and that an 8% soil moisture level is adequate to maintain viability for long periods.

McCue (1982) reported a significant interaction between media and tuber density as they affected the sprouting of C. esculentus tubers. Two tubers per dish, 10 tubers per dish, and 50 tubers per dish were placed in petri dishes containing either 50 cc of sand or filter paper. Twelve mL of water was added to the dishes containing sand, and 5 mL to the dishes with filter paper. She found that there was no effect of density in sand on the percentage of tubers sprouting (100%, 100%, and 96% sprouted - low, medium, and high density treatments, respectively), although the low density treatment had a greater percentage of tubers with multiple sprouts as compared to the other densities. With filter paper, tubers in the low density treatment sprouted 100%, medium

density, 85%, and high density, 42%, and the percentage of tubers with multiple sprouts declined as density increased. She concluded that there was no effect of density in sand because it dispersed the moisture. The lack of moisture dispersion, with filter paper, created a semi-anaerobic environment in the petri dish. She postulated the production of a volatile gas in these dishes, that inhibited or prohibited sprouting.

Nyahoza (1974) investigated the effect of C. rotundus tuber density on sprouting. He placed 80, 160, and 320 (low, medium, and high density treatments, respectively) C. rotundus tubers in 8 X 10 cm glass dishes containing pulped filter papers as the germination substratum. There were no significant differences between the sprouting percentages obtained for the three tuber densities. He concluded that it was unlikely that congestion of tubers adversely affects the germination of their axillary buds.

Competitive Ability Of Sedge Weeds

Intraspecific Competition. Competition occurs when plants are so spaced that the reaction of one, to the lack of space and limited supply of nutrients, affects the response of the other by limiting it (Harper, 1977). Competition therefore modifies the growth and reproductive patterns of plants. On a population level, competition results in mortality, or in a plasticity response - a reduction in overall plant size, seed output, or rate of vegetative reproduction. However, where plants are competing for light, an unusually tall,

spindly growth habit may predominate. On the individual level, competition can alter the partitioning of dry weight to reproductive structures.

The effects of density on the growth of C. rotundus were monitored by Williams et al. (1977). Planting densities were one (low), nine (medium), and 25 (high) sprouted basal bulbs per pot, which were equivalent to 32, 288, and 800 plants per square metre, respectively. They found that the number of shoots per pot increased with increasing density and time. Tubers per pot, after nine weeks of growth, were also most numerous in the high density pots. Shoot height increased as density increased; shoots in the high density pots were an average of 12 cm taller than shoots in the low density pots, after nine weeks of growth. As expected, they found that the number of shoots, tubers, and inflorescences produced per planted basal bulb decreased with increased density. The total plant matter dry weight per pot increased with increased density, although the dry weight per plant decreased with increased density.

Williams et al. (1977) also investigated the effect of density on the partitioning of dry weight to the reproductive structures of C. rotundus. Plants in the high density treatment partitioned more dry weight into tubers than did plants at low and medium densities, while partitioning of dry weight into inflorescences was greater at the low and medium densities than at the high density. Increased tuberization by C. rotundus plants, in response to intra- and interspecific competition, has also been reported by Nyahoza (1973). This shift to vegetative reproduction under stress conditions caused by competition helps explain why C. rotundus is difficult to control.

McCue (1982) investigated the effects of density on C. esculentus growth and development. She found that the number of shoots, the dry weight of shoots, and the tuber number produced, per original tuber planted, decreased with increased density. In contrast to Williams et al. (1977) results with C. rotundus, C. esculentus flower number increased with increasing density, although flower production was delayed. Tuber initiation was affected by density; the higher the density the earlier the initiation. However, tuber numbers per pot, at the final harvest, were not affected by density. She concluded that as a growth component tuber number appeared to be less "plastic" than other components such as shoot growth.

Additional experiments conducted by McCue (1982) separated the effects of density on C. esculentus growth into above ground and below ground components. She found that close spacing of plants reduced the number of tubers, flowers, shoots, and shoot dry weight. None of these four parameters of growth were significantly affected by different below ground volumes, although she observed that the small soil volume treatment tended to produce smaller plants. Thus, she concluded, above ground competition is a more effective way of reducing C. esculentus growth than below ground competition.

Interspecific Competition. Normally, in undisturbed upland fields, sedge weeds compete poorly with the indigenous vegetation. Both C. esculentus and C. rotundus are shade-intolerant; both species possess a high photosynthetic efficiency by way of the C_4 dicarboxylic acid-carbon dioxide fixation pathway (Black et al., 1969). In addition to high rates of photosynthesis and efficient growth under high

temperature and high light intensity conditions, C_4 plants are characterized by a lack of shade tolerance, high translocation rates from leaves, low water requirements for dry matter production, and distinct vascular bundles.

Hauser (1962a) found that continuous shading (72% shade, by a porous plastic screen) of C. rotundus plants gave a 10 to 57% reduction in the numbers of tubers and basal bulbs formed during one growing season.

Keeley and Thullen (1978) reported that the average number of C. esculentus shoots and tubers, and total dry matter production increased in direct proportion to increased amounts of light. Correlation coefficients were highly significant - an indication that C. esculentus can fully utilize light intensities approaching those of full sunlight. They determined that as little as 30% shade reduced C. esculentus dry matter and tuber production by 32%. However, heights of plants grown under 30 to 80% shade exceeded that of plants grown under full sunlight or 94% shade.

This observed sensitivity of specific sedge species to shading appears to indicate that rapid shading by early planted and/or tall crops would suppress the growth of these weeds. Various experiments, though, have demonstrated that sedge weed competition can cause severe crop yield losses, even in the tallest crops. Crop loss data are generally reported from experiments that measure the loss in crop yield due to full-season competition from a native population of weeds that germinate and grow during that particular experiment (Williams, 1976). Chapman (1966) reported a 38% reduction in sugar cane yields in Australia, due mainly to C. rotundus competition for moisture at the

stooling time of the crop (i.e. fewer canes are produced under moisture stress). Cruz et al. (1969) reported that C. rotundus caused a 40% reduction in maize (corn) yields in Columbia, in a field where each maize plant competed with 220 C. rotundus plants.

Stoller (1982) stated that crop yield reductions in the Corn Belt (U.S.A.), due to C. esculentus competition, are as high as 30% in soybeans, and 47% in corn. He concluded that significant crop yield losses are possible, especially on light-textured soils or under droughty conditions.

In addition to yield losses, sedge weeds can lower the quality of crops. Rhizomes of C. rotundus and C. esculentus can penetrate and pass completely through the edible root, tuber, or bulb of vegetable root crops such as onion or potato. In some badly C. esculentus infested potato fields in the U.S.A., every potato tuber was found to have a rhizome running through it or into it (Holm et al., 1977).

Sedge weeds affect crops by competing for moisture, nutrients, and sunlight. Recent investigations have also discovered that C. rotundus and C. esculentus residues are allelopathic to other plants under greenhouse conditions. Friedman and Horowitz (1970) demonstrated that an extract of soil incubated with pieces of C. rotundus tubers and rhizomes would inhibit radicle growth of crop plants (barley, mustard, and wheat) at germination. In a subsequent experiment, C. rotundus tubers and rhizomes were allowed to decay in the soil for periods of one to three months before barley was planted. Barley growth was inhibited 15 to 25% by the residues in the soil (Horowitz and Friedman, 1971).

Drost and Doll (1980) reported that C. esculentus residues, incorporated into soil, inhibited the growth of corn and soybeans under greenhouse conditions. At equal concentrations, tuber residues were found to reduce the growth of corn and soybeans more than foliage residues. The highest concentration of tuber residues tested, 0.675% (w/w), reduced the dry weight of soybean shoots and corn shoots an average of 45% and 20%, respectively.

Williams (1976) stated that C. rotundus grows best when competition from other weeds is reduced, as in intensively cultivated row crops. Stoller (1982) noted that C. esculentus becomes an increasingly important weed in the Corn Belt, U.S.A., when annual weeds are controlled with selective herbicides. Ranade and Burns (1925) observed that farmers in India implicitly recognized that standard tillage and cropping practices contributed to the proliferation of sedge weeds by occasionally allowing native vegetation to become re-established in fields heavily infested with C. rotundus, so that after several years relatively few viable tubers would remain and crops could again be planted. Plucknett et al. (1976) reported that research conducted at the International Rice Research Institute (IRRI), Philippines, demonstrated that, in an upland rotation sequence, a serious infestation of C. rotundus was quickly and almost entirely replaced by a population consisting mainly of annual grasses. This rapid shift was accomplished by the use of low rates of the herbicide butachlor and the growing of crops with a high leaf-area index.

However, Tumbleson and Kommedahl (1961) found that four consecutive years of fallow were required to substantially reduce the number and viability of C. esculentus tubers in a Minnesota peat soil (from

9,420 to 75 tubers per square metre, sampled 15 cm deep; viability decreased from 72% to 28%).

Eradication of sedge weeds requires constant vigilance since these weeds produce vast quantities of dry matter and propagative structures in relatively short periods of time. Under ideal conditions, a single propagative structure can rapidly proliferate into a dense stand of shoots covering several square metres. Tumbleson and Kommedahl (1961) reported that a single C. esculentus tuber, planted in June in a silt loam soil in southern Minnesota, produced more than 1,900 shoots and 6,900 tubers after one full year. The 6,900 tubers were produced in the fall of the first season, and the 1,900 shoots the spring of the next. The patch containing the shoots and tubers was approximately 2 m in diameter (3.1 square metres).

Chemical Control Of Sedge Weeds

Selective Herbicides

EPTC and Butylate. Two herbicides in the thiocarbamate family, EPTC (S-ethyl dipropylthiocarbamate) and butylate (S-ethyl diisobutyl-thiocarbamate), have been widely used to gain selective sedge weed control in a number of crops. EPTC and butylate also possess activity against many grasses and some broadleaf weeds. These compounds generally are applied preplant incorporated (ppi) because they are volatile. Volatilization losses of EPTC and butylate are greater from a moist soil surface than from a dry soil surface. Dissipation of

herbicidal activity is attributed to leaching and microbial breakdown. EPTC has a half-life in most soils of approximately one week, and butylate has a half-life of three weeks (WSSA, 1983; Ashton and Crafts, 1973).

Uptake of EPTC and butylate is through both plant roots and shoot parts exposed underground. Translocation of these herbicides in plants is mainly via the apoplast. Thiocarbamates act by primarily inhibiting the growth of emerging shoots of sensitive plants (Ashton and Crafts, 1973).

Holt et al. (1962) reported that EPTC, applied at rates of 4.5, 9.0, 13.5, and 18.0 kg/ha, retarded the germination of C. rotundus tubers during an initial four week period following application and incorporation. However, the herbicidal activity of the 4.5 and 9.0 kg/ha treatments dissipated eight to twelve weeks after application, resulting in a relatively high emergence of C. rotundus shoots. Tuber germination in the 13.5 and 18.0 kg/ha treatments, eight to twelve weeks after application, also was high (69% to 100%), but the majority of the shoots that emerged rapidly died. A subsequent examination of these tubers showed complete necrosis of the interior tissues.

Rincon and Warren (1978) investigated the herbicidal effects of five thiocarbamate herbicides, butylate, EPTC, molinate, pebulate, and vernolate, on C. rotundus growth in pots. Treatments were 0.5, 1.0, 2.0, and 5.0 kg/ha for each herbicide. They found that the thiocarbamates stimulated multiple sprouting of nondormant tubers (no effect was observed on the overall percentage of tubers which sprouted), with tubers in herbicide treated soil producing approximately twice as many sprouts as the controls. However, these sprouts were abnormal and did

not reach the soil surface. None of the treatments killed the tubers, though, as tubers which initially sprouted developed normal new sprouts when repotted into untreated soil, or when herbicidal activity in the original pots had dissipated. They also found that herbicide persistence was directly related to the level of initial activity, with the most effective reduction in shoot numbers, nine weeks after treatment, given by butylate, EPTC, and vernolate followed by pebulate and molinate.

Keeley and Thullen (1974) reported similar results from two greenhouse experiments involving C. esculentus plants. EPTC at 6.72 kg/ha delayed sprouting of C. esculentus tubers, but did not kill them. After 12 weeks in treated soil, 66% of the tubers had sprouted, giving rise to normal shoots. A high percentage of firm tubers (95%) were recovered from treated soil after 12 weeks, and a high percentage of these tubers (64%) sprouted or resprouted when placed in untreated soil. There was no apparent herbicidal effect when these tubers sprouted or resprouted in untreated soil.

Obrigawitch et al. (1980) reported that the activity of EPTC, applied at 4.48 kg/ha to a field in Texas, declined rapidly resulting in approximately 40% control of C. esculentus plants two months after application.

Alachlor and Metolachlor. Alachlor [2-chloro-2',6'-diethyl-N-(methoxymethyl) acetanilide] and metolachlor [2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl) acetamide] are members of the chloroacetamide family of compounds. They are applied preplant incorporated, preemergence, or postemergence for the control of annual

grasses, sedge weeds, and certain broadleaf weeds in crops such as corn, soybeans, peanuts, potatoes, and vegetable crops. Volatility of both compounds is low, and they are readily adsorbed on soil colloids. Microbial breakdown of the herbicides is the primary cause of dissipation of activity (WSSA, 1983).

Alachlor and metolachlor are primarily absorbed by shoots of germinating seedlings, although some uptake by roots also occurs. Shoot and root growth is inhibited, and if seedlings do emerge, they are usually stunted or deformed. Translocation of chloroacetamides is mostly upward in plants, primarily via the apoplast (WSSA, 1983; Ashton and Crafts, 1973).

Similar to the effect of EPTC, 4.48 kg/ha of alachlor delayed the sprouting of C. esculentus tubers, but did not kill them (Keeley and Thullen, 1974). After 12 weeks in soil treated with 4.48 kg/ha of alachlor, 54% of the tubers had sprouted, giving rise to normal shoots. When these tubers were removed from the treated soil and planted in untreated soil, 69% of the tubers sprouted or resprouted. Keeley and Thullen (1974) concluded that tubers appeared to escape injury by failing to sprout until the herbicides had adequately dissipated.

McCue (1982) stated that the point of growth inhibition, as caused by EPTC or alachlor, was in the basal bulb region of emerging C. esculentus plants. Two treatments, 3.3 kg/ha of EPTC and 2.2 kg/ha of alachlor, were used in a pot experiment comparing the action of these herbicides. She reported that some basal bulbs gave rise to numerous shoots, where normally there would be one shoot per basal bulb. These shoots were stunted and usually died. Other basal bulbs produced rudimentary shoots which did not emerge above the soil surface.

Germination of several buds on tubers planted in the herbicide treatments also was observed, with each nondormant tuber usually producing three to four sprouts (rhizomes). In all cases, root development appeared to be normal. She found (in this pot experiment) that after the rhizomes and roots decayed, which took eight to twelve weeks, the tubers appeared as if they had never sprouted. She concluded that past researchers may have overlooked this sequence of events and made incorrect statements about how thiocarbamate and acetanilide herbicides affect the sprouting of C. esculentus tubers.

McCue (1982) evaluated the efficacy and persistence of EPTC (4.4 kg/ha), butylate (4.4 kg/ha), alachlor (4.4 kg/ha), and metolachlor (2.2 kg/ha) for C. esculentus control in a field near Ithaca, New York. She reported that the herbicidal action of all the herbicides weakened with time, with the degree of control becoming unacceptable five to eleven weeks after application. Butylate was more persistent than EPTC, and metolachlor gave better control and was more persistent than alachlor. Only the metolachlor treatment significantly reduced production of new tubers and total tuber number as compared to the check. New tubers exhibited increased dormancy and/or death when removed from the butylate, alachlor, and metolachlor treatments. The number, viability, and dormancy of old tubers was not affected by any of the herbicide treatments.

Armstrong et al. (1973) compared the effectiveness of three methods of applying alachlor, preplant incorporated, preemergence, and postemergence, for the control of C. esculentus in a field near East Lansing, Michigan. The plots were evaluated four weeks after herbicide application. They reported that with inadequate rainfall preplant

incorporated treatments of alachlor were more effective than preemergence treatments, but with adequate rainfall (12.7 to 25.4 mm within ten days after herbicide application) both preemergence and preplant incorporated treatments effectively controlled C. esculentus. Postemergence applications of alachlor were not effective.

Stoller (1982), referring to thiocarbamate and chloroacetamide herbicides used for the control of sedge weeds, stated that when soil applied herbicides are applied preemergence at planting time, adequate rainfall within several days is necessary to achieve the same degree of control as with equivalent treatments applied by preplant incorporation. To be effective, the herbicides have to be placed where they can readily be absorbed by the emerging shoot and roots. He concluded that since roots are present on the rhizome extending from the newly-germinated tuber to the basal bulb in emerging C. esculentus plants, herbicides need to be incorporated into the soil to facilitate uptake.

Bentazon. Bentazon [3-isopropyl-1H-2,1,3-benzothiadiazin-4(3H)one 2,2-dioxide] is a selective, postemergence herbicide primarily used for the control of broadleaf weeds in crops such as small grains, pulses, and rice. Bentazon also exhibits activity against some sedge weeds. The herbicide displays contact activity with foliar applications, as it is absorbed by the green parts of plants and translocated only to a small extent - mostly acropetally. Application of bentazon results in the irreversible blockage of the photosynthetic electron transport chain in susceptible plants, and after a short period of growth stagnation death occurs (Anonymous, 1982; WSSA, 1983).

Stoller et al. (1975) applied bentazon at 1.7 and 3.4 kg/ha to C. esculentus plants two (4 - 5 leaf stage), three (5 - 7 leaves), or four (7 - 9 leaves) weeks old. In the greenhouse, the younger plants were more susceptible to bentazon than the older plants. However, at the time of the final assessment of the greenhouse experiment, six weeks after bentazon application, the 3.4 kg/ha rate gave complete kill of all treated plants. In contrast, in the field the response of different-aged plants to bentazon did not differ greatly, and the youngest plants were affected the least. This poorer control of young plants in the field was thought to be the result of inadequate spray coverage of the erect leaves possessed by young C. esculentus plants. Overall control of C. esculentus plants in the field approached 90%, 15 days after application of 3.4 kg/ha of bentazon, and then declined as plants began to recover from the herbicide application. The leaves contacted by spray were killed, on plants which displayed considerable initial damage, but young leaves did not exhibit any injury symptoms and therefore were thought to have been inadequately contacted by the spray.

McCue (1982) reported that bentazon gave erratic control of C. esculentus plants. Some plants escaped control regardless of the timing of the bentazon application, whether the experiment was in the greenhouse or field. Bentazon was applied only at a relatively low rate of 1.1 kg/ha (with 1.6% oil), and this amount of bentazon may have been insufficient to achieve satisfactory, consistent control. Split applications of bentazon were found to be more effective than a single one, because of the recovery of sprayed plants and the emergence, in field experiments, of new plants after herbicide application.

Dichlorprop. Dichlorprop [2-(2,4-dichlorophenoxy) propionic acid] is a selective, postemergence herbicide mainly used in small grains. Dichlorprop displays systemic activity against a number of broadleaf weeds, similar to other phenoxy herbicides. Dichlorprop is often used in combination with other herbicides to achieve control of a broad spectrum of weeds in small grain cereal crops (WSSA, 1983).

Parker et al. (1969) reported that a postemergence application of 2.2 kg/ha of dichlorprop severely injured three to four week-old C. rotundus plants growing in a greenhouse. They defined severe injury as a greater than 60% reduction in plant vigour for a period of at least two weeks. Additional references with regards to the herbicidal effect of dichlorprop on sedge weeds were not found.

Non-selective Herbicides

AC 252.925. AC 252.925 [the isopropylamine salt of 2-(4-isopropyl-4-methyl-5-oxo-2-imidazolin-2-yl) nicotinic acid] is a residual, highly translocated herbicide that possesses activity against a broad spectrum of herbaceous and woody plants when applied either pre- or postemergence. Postemergent applications of the herbicide have been found to be more effective than preemergent applications, particularly for control of perennial weed species. AC 252.925 is readily absorbed by the foliage and roots of plants and is translocated rapidly throughout the plant, with accumulation in the meristematic regions. Treated plants stop growing soon after application, although kill usually is slow, as chlorosis and tissue necrosis may not be apparent in some plant species until two weeks after application. Chlorosis

appears first in the youngest leaves, and necrosis spreads from this point. In perennials, the herbicide is translocated into and kills underground storage organs (Anonymous, 1983a).

Field studies have indicated that the biological activity of AC 252.925 persists in soil for three months to one year under temperate conditions and for three to five months under tropical conditions, depending on dosage and soil moisture content. Aerobic microbial activity was found to slowly decompose the free acid of AC 252.925 in soil, under laboratory conditions. Laboratory and field studies have shown that once AC 252.925 is adsorbed to soil particles, lateral and vertical movement is limited (Anonymous, 1983a; Anonymous, 1983b).

AC 252.925 has given effective control of C. rotundus under field conditions when applied at 0.75 kg/ha postemergence or 1.0 kg/ha preemergence (Anonymous, 1983a).

Glyphosate. Glyphosate [the isopropylamine salt of N-(phosphonomethyl) glycine] is a broad spectrum, highly translocated herbicide that displays little or no soil activity because of its affinity for soil and organic matter particles. It is applied postemergence, enters the plant through aerial, chlorophyll containing parts, and translocates to areas of high metabolic activity where the aromatic amino acid biosynthetic pathway is inhibited. The herbicidal effects in perennials usually are not visible until seven to ten days after application (WSSA, 1983; Jaworski, 1972).

Environmental factors have been shown to affect the activity of glyphosate on sedge weeds. Chase and Appleby (1979) reported that glyphosate effectiveness against C. rotundus was reduced under

conditions of high moisture stress and low humidity. Tharawanich and Linscott (1975) reported that activity of glyphosate against C. esculentus was reduced by increased temperature and length of photoperiod. Moosavi-Nia and Dore (1979) found that C. rotundus plants grown under reduced light intensity regimes were more susceptible to glyphosate than plants grown in the check or unshaded treatment. It is not clear what the implications of these findings are with regards to the control of sedge weeds in the field using glyphosate, in fact, published results are conflicting in some instances (Terry, 1985).

Zandstra et al. (1974) reported that glyphosate, applied as single treatments in the field at 2.0 and 4.0 kg/ha, reduced the stand of C. rotundus to 74% and 33% of the control, respectively. Terry (1974) obtained up to 85% control of C. rotundus for 88 weeks in a Tanzanian coffee estate using two applications of 2.0 kg/ha (a total dose of 4.0 kg/ha). Terry (1974) also reported that glyphosate appeared to suppress sprouting or promote dormancy in C. rotundus tubers.

Zandstra and Nishimoto (1977), in a greenhouse experiment involving C. rotundus, studied the effects of plant age on glyphosate translocation and activity. Following the foliar application of 4.0 kg/ha of glyphosate to 6, 12, and 24 week-old C. rotundus plants they obtained 0%, 5%, and 32% sprouting, respectively, of tubers on intact tuber chains, as compared to 74%, 53%, and 54% from untreated plants. Separation of tubers from the connecting rhizomes of the tuber chains did not increase sprouting in the glyphosate treatments, but did in the check as up to 90% of isolated tubers from 24 week-old untreated plants sprouted. They concluded that glyphosate prevented most tubers from germinating, and appeared to kill them.

Zandstra and Nishimoto (1977) also showed that C. rotundus plants accumulate glyphosate in meristems, using ^{14}C-methyl labeled glyphosate. Older tubers (four to five weeks old at the time of application) did not accumulate nearly as much of the herbicide as did younger tubers, probably because their meristematic activity was low and translocation to these tubers was reduced. These researchers concluded that the best time to apply glyphosate is when most tubers in the soil have germinated, and new tubers produced are connected to healthy foliage - usually within eight to twelve weeks of commencement of the growing season.

Researchers investigating the effect of timing of glyphosate application on the control of C. esculentus have reported conflicting results. Stoller et al. (1975) found C. esculentus to be more susceptible to glyphosate at the 4 - 6 leaf stage than at 6 - 8 leaves. Boldt and Sweet (1974) found that application of glyphosate to young plants, less than 20 cm tall, was not as effective as when older plants were treated, primarily because of regrowth after application. Sprouting of tubers was affected only in plants treated at 25 cm, as these plants were just initiating tubers at this growth stage. Tubers harvested from these glyphosate treated plants exhibited a decrease in sprouting compared to tubers harvested from untreated plants.

Stoller et al. (1975) found that rates of glyphosate near 2.0 kg/ha were required to obtain satisfactory control of C. esculentus in the field. Terry (1985) stated that the lowest dose of glyphosate required for reliable control in most situations is about 2.0 kg/ha. However, McCue (1982) did not obtain satisfactory control of C. esculentus in either the greenhouse or the field with 3.3 kg/ha of

glyphosate. The greenhouse experiment involved treating plants at various growth stages with 3.3 kg/ha of glyphosate. Young plants (2 - 5 cm tall at the time of application) had, within three weeks of herbicide application, regrowth in the form of small, numerous shoots. Older plants (30 - 36 cm tall, just prior to tuber formation) exhibited the least amount of shoot regrowth, but kill of the sprayed shoots was much slower than in young plants.

Glufosinate. Glufosinate-ammonium [ammonium-(3-amino-3-carboxypropyl)-methyl-phosphinate], also called glufosinate, is a broad spectrum, postemergence herbicide. It is primarily a contact herbicide, although some translocation from treated leaves to other plant parts does occur. Glufosinate displays little or no soil activity (Anonymous, 1983c; Langeluddeke et al., 1983).

Glufosinate, or an active metabolite of glufosinate, inhibits the action of glutamine synthetase, an enzyme which catalyzes the combination of glutamic acid and ammonia in the plant cell. The result of this inhibition is an accumulation of ammonia in plant cells and disruption of photosynthesis. Leaves of glufosinate treated plants usually become chlorotic two to five days after application. Young plants having a large proportion of foliage with a high metabolic activity are particularly susceptible, and optimum herbicidal action of glufosinate is obtained under environmental conditions which are favourable for active plant growth (Anonymous, 1983c).

Control of C. rotundus in Spain, for a period of 75 days, was obtained with a single application of 2.0 kg/ha of glufosinate. However, C. esculentus in South Africa was not controlled with either single or

split applications of up to 4.5 kg/ha of glufosinate (Anonymous, 1983c).

III DESCRIPTION OF SEDGE WEEDS OF THE WHEAT GROWING AREAS OF KENYA

Introduction

Positive identification of sedge weeds, especially young, non-flowering sedges, in the field is difficult. For example, in one wheat field near Menengai five different species of sedge weeds were observed: Cyperus rigidifolius Steud., Cyperus esculentus L. (yellow nutsedge), Cyperus teneristolon Mattf. & Kuk., Cyperus usitatus Burch. var. usitatus, and Bulbostylis schimperiana (A. Rich.) C.B.Cl.

Keys for the identification of sedge weeds are primarily concerned with floral morphology. Sedge weeds may also be differentiated on the basis of their below-ground parts. Examining the below-ground plant parts to confirm sedge species identification can be difficult, though, because sedge weeds often grow in mixed stands. For example, C. usitatus var. usitatus bulbs (5 to 20 cm underground) were collected from the central portion of a dense, monoculture patch of C. rigidifolius.

A number of detailed taxonomic descriptions (which emphasize floral characteristics) of sedge weeds have been prepared (Napper, 1963, 1964, 1965, 1966, 1971; Hafliger and Kuhn, 1982; Haines and Lye, 1983). This thesis follows the classification system outlined in Haines and Lye (1983). The following descriptions were prepared to al-

low the reader to easily identify sedge weeds, in the wheat growing areas of Kenya, on the basis of their vegetative characteristics.

Description Of Sedge Weeds

Cyperus rigidifolius Steud. (Figure 3.1). C. rigidifolius is a perennial weed up to 1.2 m tall (more commonly 35 to 50 cm tall in cultivated fields, 20 to 30 cm in pastures and lawns) with stout, dark, woody rhizomes connecting shoots via very swollen, woody "basal bulbs" (swellings at the base of each shoot - for a glossary of terms see Appendix 1). This sedge species does not produce tubers or dormant bulbs underground, but propagates vegetatively from these basal bulbs. This description of the underground portion of C. rigidifolius is in disagreement with Terry (1976), who stated that this sedge possesses irregular-shaped tubers. C. rigidifolius does not have a tuber system like mature C. esculentus plants where tubers possessing varying degrees of dormancy are produced at the terminal ends of stolons. The term "basal bulb" best describes the organ of vegetative propagation of C. rigidifolius, because formation of a basal bulb at the tip of a rhizome is immediately followed by shoot development. Parker (1972) recognized the fact that basal bulbs are always associated with shoots, whether green or senescent, when he wrote, "this species [C. rigidifolius] apparently does not form many dormant tubers". Based upon personal observations, this species does not form any dormant tubers.

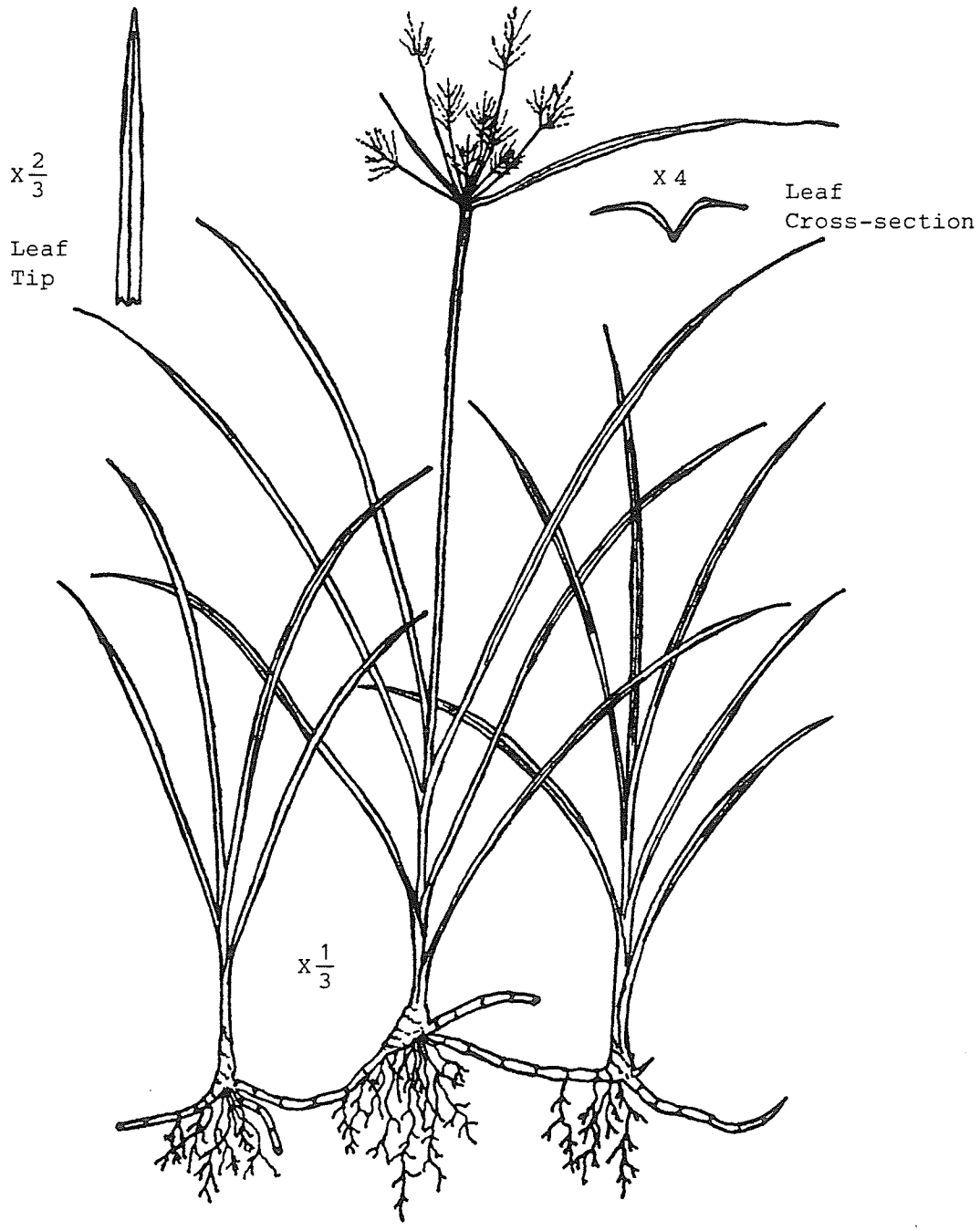


Figure 3.1. Cyperus rigidifolius
(redrawn from Terry, 1976)

C. rigidifolius basal bulbs are extremely variable in size and shape. Average dimensions of a basal bulb are approximately 3.5 cm long by 1.5 to 2.0 cm in diameter. Basal bulb size appeared to be dependent upon age and the number of rhizomes, which interconnect the basal bulbs, produced. Three rhizomes per basal bulb was the maximum number observed. The basal bulbs have a dark brown exterior.

As the name suggests, the leaves, stem, and rhizomes are unusually tough. The leaves have a conspicuous silvery colour on their undersides and are difficult to break when pulled, as compared to other sedge species. In cultivated fields, a shoot would usually flower within six weeks of emergence, after the production of seven to nine leaves. The inflorescence is composed of numerous black spikelets crowded into dense spikes of variable size and number. Densities of up to 800 shoots per square metre were observed.

C. rigidifolius is widely distributed throughout the highlands of East Africa and is found in many crops, but tends to be a problem only in areas that are not intensively cultivated such as lawns, pastures, and minimum tilled fields (Terry, 1976). In minimum tilled fields, it was observed to establish dense monoculture patches where no other plants can grow.

Cyperus esculentus L. - Yellow Nutsedge (Figure 3.2). C. esculentus is a perennial weed, up to 60 cm tall (more commonly 30 to 40 cm), producing many slender, occasionally branching underground stolons (referred to as rhizomes in much of the literature) with terminal rounded tubers. Mature (brown in exterior colour) C. esculentus tubers tend to be spherical to oval in shape, although distorted shapes, due to obstruc-

Figure 3.2. Cyperus esculentus

(redrawn from Hafliger and Kuhn, 1982)

tions during development, are common. Tubers collected ranged from 3 to 9 mm in diameter, with an average size of approximately 6 to 7 mm.

In early stages of plant growth, stolons give rise to daughter shoots rather than tubers. C. esculentus leaves have characteristic narrow, pinched leaf tips, even when young. The leaf has a shoulder 1 to 2 cm from the tip, which tapers to an attenuated, needlelike point. C. esculentus has a spreading inflorescence with spikes of yellow-gold spikelets. There is one three-sided achene (seed) per flower. However, seedlings established from achenes were not observed. Viable achenes often are produced in the U.S.A. (Justice and Whitehead, 1946; Thullen and Keeley, 1979), but they apparently do not play a role in propagating the species in cultivated fields because the small and non-vigourous seedlings do not survive (Stoller, 1982). C. esculentus seedlings, arising from achenes, have never been observed in fields in the U.S.A. (Thullen and Keeley, 1979).

The germination of the underground tubers, which possess varying degrees of dormancy, re-establishes the weed at the beginning of each growing season (Parker, 1972; Stoller, 1982). Although C. esculentus is a perennial, it exhibits a seasonal pattern of growth in the field, normally dying back in the dry season and then regenerating from isolated tubers when the rains return. Plant growth and development early in the growing season, in cultivated fields, was very rapid. A shoot would usually flower within one month of emergence, after the production of nine to eleven leaves.

Densities of over 700 shoots per square metre have been recorded (Terry, 1976) and each shoot can have 10 to 20 stolons which terminate in a daughter shoot, or in a tuber.

Cyperus teneristolon Mattf. & Kuk.(Basionym: Kyllinga pulchella Kunth.) (Figure 3.3). C. teneristolon is a perennial weed with erect stems up to 50 cm (more commonly 20 to 30 cm) tall emerging at short intervals from a tough, reddish brown rhizome situated just beneath the soil surface. In addition to this relatively short rhizome, which links the basal portions of individual shoots, C. teneristolon also produces a profusion of long and slender stolons. It does not produce bulbs or tubers, but regenerates from pieces of rhizome containing a swollen area (approximately 10 to 12 mm long, 4 to 7 mm in diameter) - usually a site where branching of the rhizome had occurred. It has very slender leaves, usually lighter in colour than C. rigidifolius or C. esculentus.

C. teneristolon only occasionally flowers in the field and thus, is often incorrectly identified. The inflorescence, when present, is an oval to oblong, dark brown to black, terminal head usually with one to three much smaller, sessile heads at its base.

C. teneristolon can be a serious problem - densities of over 800 shoots per square metre were observed. This sedge weed can grow very densely underneath the crop canopy, whereas other sedge weeds such as C. rotundus and C. esculentus are not shade-tolerant (Holm et al., 1977).

Cyperus usitatus Burch. var. usitatus (Figure 3.4). C. usitatus var. usitatus is a perennial weed up to 30 cm tall, with shoots that develop on the soil surface away from the brown to black parent bulbs to which they are connected by a stolon up to 15 cm long. Its leaves are generally slender, although shoots with fleshy twisted leaves also

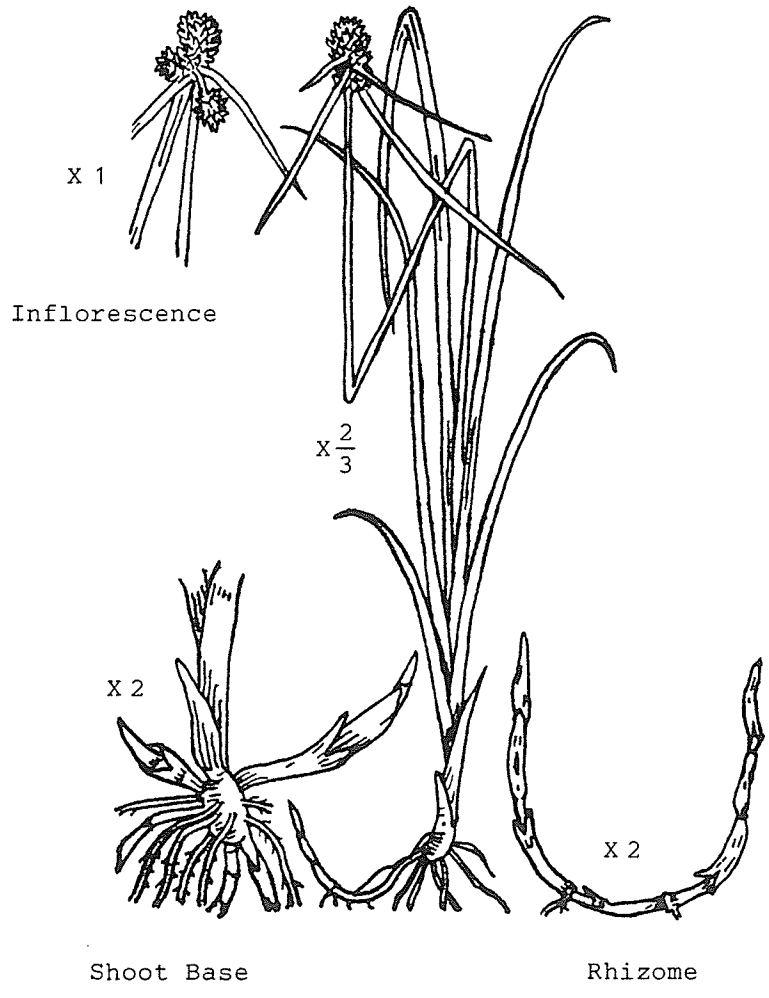
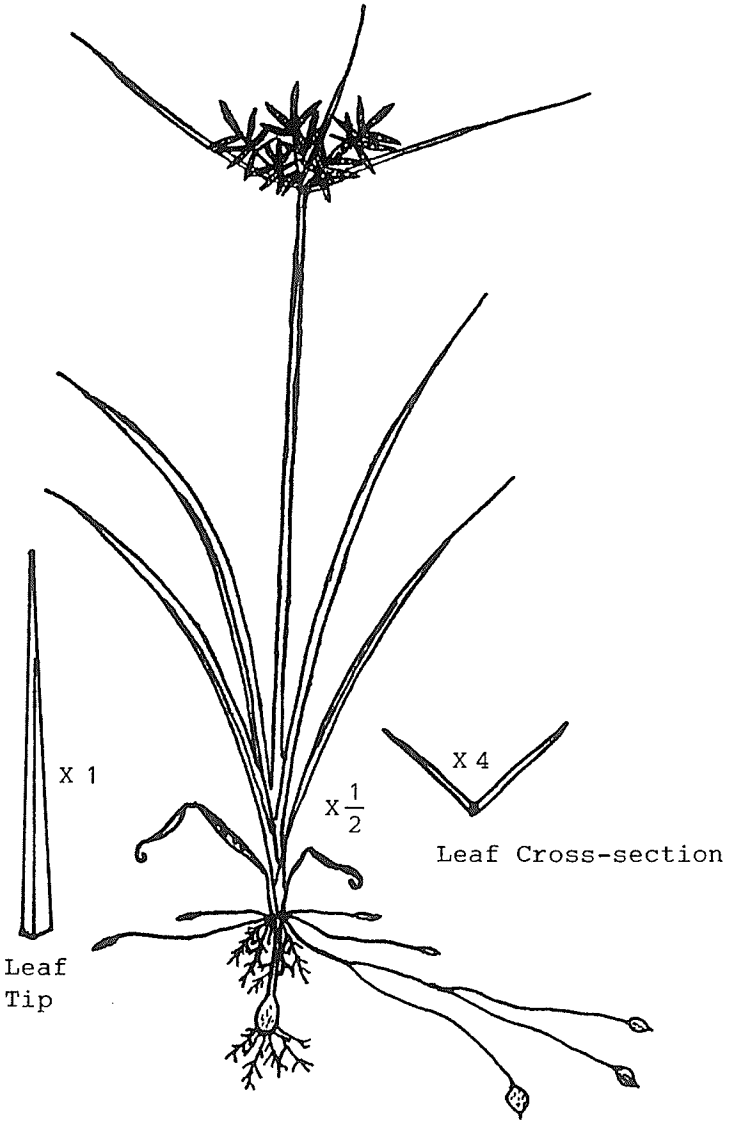
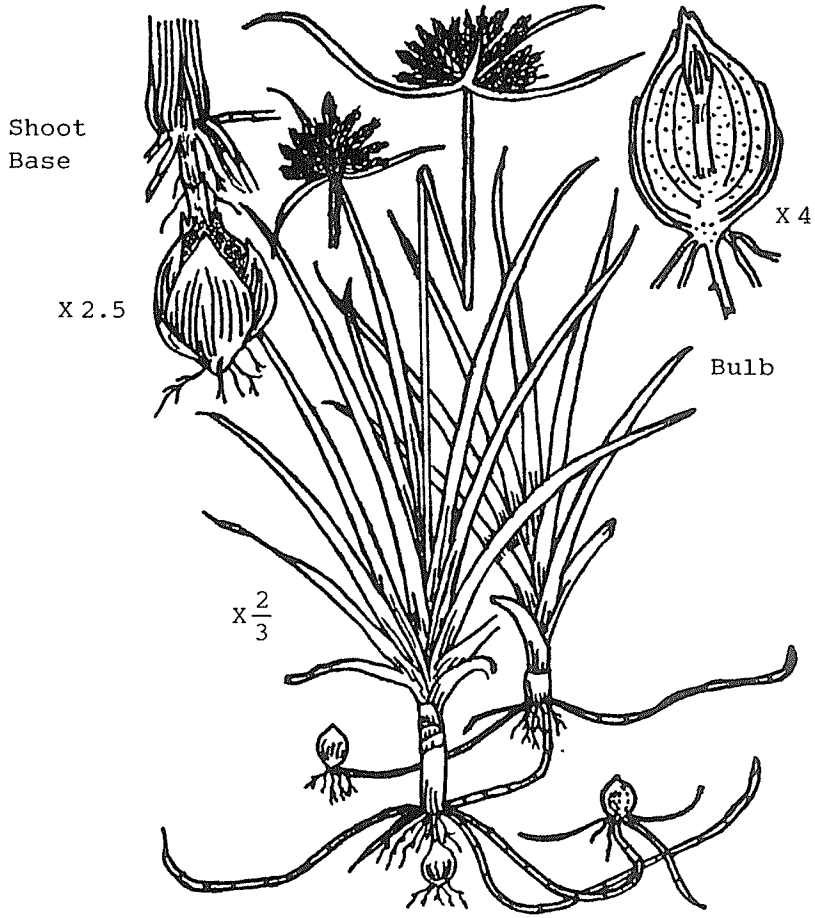


Figure 3.3. Cyperus teneristolon
(redrawn from Haines and Lye, 1983)



Specimen A (redrawn from Terry, 1976)



Specimen B (redrawn from Haines and Lye, 1983)

Figure 3.4. Cyperus usitatus var. usitatus

occur. Shoots growing in cultivated fields usually flowered within three months of emergence. C. usitatus var. usitatus has a dense inflorescence of red-brown spikelets.

Densities of up to 500 shoots per square metre were observed and each shoot can produce as many as 20 slender, branched stolons which terminate in either daughter shoots or underground bulbs. These bulbs are more or less spherical in shape with a pointed tip at one end, and are about the size of a pea seed (approximately 5 to 7 mm in diameter). Immature bulbs are white in colour and vary greatly in size, as size is dependent upon relative maturity.

C. usitatus var. usitatus exhibits much intraspecific variation in plant size, plant form, and pattern of growth. These differences are apparent to researchers familiar with sedge weeds, and non-taxonomists may incorrectly assume the presence of distinct sedge species. Plants similar to both specimens (Figure 3.4) were collected from a field near Njoro, and were positively identified at the Royal Botanic Gardens, Kew, Richmond, Surrey, U.K. to be of the same species and variety.

C. usitatus Burch. var. stuhlmannii (C.B.Cl.) (basionym: C. stuhlmannii C.B.Cl.) is very similar in appearance and in distribution to C. usitatus var. usitatus. This variety differs from the variety usitatus mainly in its more ample inflorescence with more involucral bracts (Haines and Lye, 1983). Both varieties have been identified as weeds found in National Plant Breeding Station (N.P.B.S., Njoro) fields, but the variety stuhlmannii is not common.

Bulbostylis schimperiana (A. Rich.) C.B.Cl.. B. schimperiana is a small, tufted annual sedge 5 to 15 cm tall, with filiform leaves 3 to 10 cm tall. The inflorescence is a hemispherical head, 5 to 10 mm wide, with sessile, dark brown to black spikelets. It is commonly found in cultivated fields in the Njoro - Menengai and surrounding areas, but because of its small size, it does not threaten nor visibly affect crop production.

Three of the above species, C. usitatus var. usitatus, C. usitatus var. stuhlmannii, and B. schimperiana are not very competitive, and are easily shaded by most crops.

Cyperus rotundus L. (Purple Nutsedge), although a common tropical sedge weed, was not identified in the wheat growing areas of Kenya (1,600 to 3,000 m). It is doubtful whether C. rotundus occurs as a weed above 1,800 m, as it prefers warmer environments (Terry, 1978).

IV PROPAGATIVE STRUCTURES - VIABILITY AND DORMANCY

Introduction

Andersen (1968) wrote, "Weed scientists often are hampered in their research by difficulties in growing weeds when and where they are wanted". The most difficult step in growing a specific weed is to stimulate germination or sprouting of the structure(s) involved in propagation of the plant. Procedures that consistently stimulate a majority of the propagules (of the weed of interest) to sprout must be developed if controlled environment growth studies or pot experiments are contemplated.

Dormancy is one of the major problems in getting weeds to grow when and where desired. Propagules of some species may be capable of germination when collected but may become dormant during storage, while for the propagules of other species, vice versa. The viability of the propagule and the degree of dormancy it possesses are greatly influenced by environmental factors experienced during formation and subsequent storage, and by the duration of the storage period (Stoller, 1982; Andersen, 1968). These pregermination external factors interact with inherent internal factors such as germination inhibitors and hormones, to determine propagule viability and dormancy. The germination environment also plays a major role in determining overall germinability of plant propagules.

The following experiments were conducted to develop a set of procedures that when followed would result in the germination of a high percentage of the propagative structures of specific sedge weed species.

Materials And Methods

General Materials And Methods

Experiments involving four sedge species' propagative structures, namely, achenes (seeds), basal bulbs, tubers, bulbs, and rhizomes were conducted using petri dishes to provide a suitable environment for germination. A propagative structure was considered sprouted when a white rhizome or stolon tip was visible. This sprout was then monitored for growth and development for two to three days before the structure was removed from the petri dish and recorded as "sprouted".

All petri dishes used were 9.0 cm in diameter, and, unless otherwise noted, were prepared by placing two Whatman No. 2 filter paper disks in each dish bottom, saturating these disks with distilled water, placing the propagative structures on top of the moist filter paper, and then covering with the lid. Distilled water was added as required to the petri dishes to maintain the filter papers in the saturated condition for the duration of an experiment.

Unless otherwise noted, the petri dishes were placed in a Cleland International Inc. Model 500L germination chamber (or "germinator"), and checked every three to five days at which time the sprouted structures were removed. Each germination study was conducted for 60 days.

The germination chamber was set at a constant 20 C, in constant darkness, and the humidity maintained at 100%. Prior to the arrival of the germination chamber at N.P.B.S., the petri dishes were placed in an office desk drawer and covered by several layers of cloth bags.

The viability of unsprouted C. esculentus tubers and C. usitatus var. usitatus bulbs was determined at the end of a germination study. The tuber or bulb was judged to be viable and dormant if, when cut in half, the tissue was firm and white. This is similar to the procedure used by Banks (1983) to determine the viability of C. esculentus tubers that he collected from herbicide treated plots. Dead tubers and bulbs were rotted, usually contained a watery fluid, and were not structurally sound after 60 days in a moist petri dish, and could not be cut cleanly by a razor blade.

Samples of whole C. esculentus tubers or C. usitatus var. usitatus bulbs were also cut in half immediately after collection, prior to use in sprouting experiments, to determine percentage viability of the population. Tubers or bulbs were judged to be dead if their cut surfaces were a brownish colour.

Viability of C. rigidifolius basal bulbs could not be determined by cutting them in half, as these basal bulbs were woody. Hence, at the end of a germination study, nonsprouted C. rigidifolius basal bulbs were discarded.

Achenes of the various sedge species were collected by snipping off the mature inflorescences, rubbing out the achenes by hand, and then carefully blowing away the chaff.

Unless otherwise noted, all propagative structures used in the germination experiments were mature in external appearance.

Specific Collection And Experimental Procedures

C. rigidifolius. *C. rigidifolius* basal bulbs were collected by digging a hole (approximately 25 cm by 25 cm by 25 cm) in the midst of an infestation. The individual basal bulbs were then teased free from the sides of the hole, and connecting rhizomes and the shoot were cut off very close to the basal bulb with clippers. The basal bulb was immediately placed in water and washed. Basal bulbs occurring at the base of green, vigourous shoots, and basal bulbs with senesced shoots were collected without distinction.

The basal bulbs, depending upon the experiment, were either immediately placed in prepared petri dishes, or were spread out on a shaded shelf to dry (desiccate) for varying lengths of time. In one experiment, nonsprouted basal bulbs were removed from the germination chamber after 60 days, removed from the petri dishes and allowed to desiccate for 24 hours, and then arranged in new petri dishes and replaced in the germination chamber. In order to avoid overcrowding, a maximum of eight basal bulbs per petri dish was observed in all experiments.

In addition to evaluating the germination potential of basal bulbs, two experiments were conducted using 2 - 3 cm long pieces of rhizome.

The inflorescences of 15 mature *C. rigidifolius* plants were collected on October 28, 1982 from three different fields at N.P.B.S., Njoro. The achenes (several thousand) were rubbed out of the heads by hand. Two hundred achenes were placed in four petri dishes, 50 per dish, and these dishes placed in a desk drawer. The rest of the

achenes were stored in a paper bag on a shelf for five months. At the beginning of April, 1983, 200 of these stored achenes were placed in four petri dishes. Prior to being placed in a desk drawer, these petri dishes were placed in a refrigerator (2 - 4 C) for 14 days.

C. esculentus. C. esculentus tubers and achenes were collected from plants that were grown in 4 L pots. The tubers were collected by screening soil through a wire mesh (5 mm by 5 mm). Water was used to facilitate separation of the tubers from the soil. A few small tubers passed through the mesh, but most of these were immature.

Germination studies were conducted using whole tubers and tubers cut in half longitudinally. The tuber halves were placed in petri dishes with the uncut side resting on the moist filter paper. Whole tubers which did not sprout after 60 days in the germination chamber were cut in half, and the halves were placed in freshly prepared petri dishes. Viability of nonsprouting tuber halves could not be visually assessed because the cut surface turned brown and moldy during the germination period.

An additional germination study was conducted to determine the effect of desiccation as a pretreatment. The desiccation pretreatment procedure was identical to that used with C. rigidifolius basal bulbs.

To avoid overcrowding, the maximum number of whole C. esculentus tubers per petri dish was 25, and tuber halves, 40.

C. esculentus achenes were collected on September 14, 1983, and 50 of these were immediately placed in prepared petri dishes in the germination chamber. Other achenes were stored at room temperature for two months. One hundred of these achenes were then placed in a freezer

for 14 days, and an additional 100 were placed in prepared petri dishes in a refrigerator for 14 days, prior to placing both lots of these 2.5 month-old achenes in the germination chamber.

C. usitatus var. usitatus. C. usitatus var. usitatus bulbs were collected using the same procedure that was used for C. esculentus tubers. Bulbs for the following experiments were collected from fields at N.P.B.S or from plants grown in pots. Mature bulbs were gently squeezed between the forefinger and thumb during the collection procedure, to ensure that only firm, structurally sound bulbs were collected.

In a sprouting study, freshly collected, mature C. usitatus var. usitatus bulbs were planted in 4 L, polyethylene pots filled with soil. One hundred sixty bulbs, collected from a field, were planted 3 cm deep in 80 pots (two bulbs per pot). These pots were placed outdoors in a wire mesh enclosed area (Cage) and were watered as required. The duration of this experiment was 6 months.

Germination studies were conducted using petri dishes prepared with either moist filter paper or sand. The sand was poured into the petri dish bottom until it was approximately three-quarters full, and then saturated with distilled water. These studies evaluated the sprouting of both immature and mature bulbs. The immature bulbs used were white in exterior colour, while the mature bulbs were dark brown to black.

Sprouting studies were conducted using mature bulbs which were pretreated by various methods including soaking in water for 48 hours, storage in moist petri dishes placed in a refrigerator for 14 days, and

desiccation for varying lengths of time. The desiccation procedure followed was the same as was outlined for C. rigidifolius.

Heat was also used in an attempt to stimulate sprouting of bulbs. Four lots of 20 bulbs each were exposed to 2.5, 5, 7.5, and 10 minutes, respectively, at 100 C in an oven.

Sprouting studies were conducted on bulbs cut longitudinally through the center, cross-sectionally through the center, and longitudinally off-center. These halves were placed into petri dishes with the uncut side resting on the moist filter paper. The viability of nonsprouting bulb halves, at the end of a germination trial, could not be determined visually, because the cut surface would turn brown and moldy during the germination period.

To avoid overcrowding, each petri dish contained a maximum of 25 whole bulbs or 30 bulb halves.

The sprouting potential of C. usitatus var. usitatus stolon pieces was also investigated. Stolons were collected from plants growing in pots, and cut into 2 cm long pieces with each piece containing at least one node. Twenty stolon pieces were placed in petri dishes in the germination chamber, and an additional twenty stolon pieces were planted 2 - 3 cm deep in pots filled with soil.

C. teneristolon. C. teneristolon rhizomes were collected from plants growing in a field at N.P.B.S. and cut into 2 cm long pieces. Twenty of the rhizome pieces contained a swollen area, and another twenty rhizome pieces did not have a swollen area, although each piece contained at least one node. Ten rhizome pieces of each type were planted 3 cm deep in pots filled with soil, and the remaining pieces were

placed in petri dishes in the germination chamber.

On September 8, 1983, 100 C. teneristolon achenes were collected from a mature plant grown in a pot and placed in a petri dish in the germination chamber. The collection procedure was the same as described for C. rigidifolius.

Results And Discussion

C. rigidifolius. The majority of the basal bulbs collected on 20/09/83 sprouted within five days of being placed in the germination chamber. At the termination of the trial, 86% of the basal bulbs had sprouted (Table 4.1). The basal bulbs used in this trial were collected from the edges of an actively growing and spreading patch, and all of these basal bulbs had green shoots. In contrast, few of the basal bulbs collected on 10/11/83 sprouted - only 17% had sprouted after 60 days in the germinator. Basal bulbs of the second collection date had mature, senesced shoots, and it would appear that basal bulb dormancy was established during the senescence period.

TABLE 4.1. Sprouting of freshly collected C. rigidifolius basal bulbs.

Experiment commenced	No. of basal bulbs used	Cumulative total sprouted (days in germinator) 5	10	15	20	30	60	Sprouted (%)
20/09/83	7	4	5	5	5	5	6	86
10/11/83	35	0	2	2	2	6	6	17

Studies were then initiated to examine the effect of pretreatment on the sprouting of C. rigidifolius basal bulbs. The desiccation for 24 hours of 29 nonsprouted basal bulbs, that had been placed in the germinator 60 days previous without pretreatment, effectively increased the percent sprouting from 17% (10/11/83 experiment, Table 4.1) to 41% (10/01/84 experiment, Table 4.2). However, this pretreatment at the end of a sprouting experiment was only half as effective as when basal bulbs were subjected to 24 hours of desiccation immediately after collection. Desiccation, for 24 hours, of freshly collected C. rigidifolius basal bulbs was an effective procedure for increasing sprouting, yielding overall sprouting percentages of 80% and 85%.

Approximately 25% of the basal bulbs that sprouted in the various experiments gave rise to more than one sprout, prior to removal from the petri dishes, with a maximum of three sprouts per basal bulb observed. The variation in the collection and pretreatment procedures employed did not appear to affect this percentage of basal bulbs producing near-simultaneous multiple sprouts.

Sprouting percentages fell when the desiccation period was prolonged. Desiccation for 168 hours (seven days) killed basal bulbs, and rotting of the basal bulbs was extensive by the time they were discarded after 36 days in the germinator (Table 4.2). Desiccation of basal bulbs for 24 hours, followed by storage in a dry, sealed glass jar for 96 hours resulted in 33% of the basal bulbs sprouting.

Rotting of unsprouted basal bulbs was not common, except where desiccation was prolonged, although a small amount of mold growth was present in almost all petri dishes after 60 days in the germinator.

TABLE 4.2. Sprouting of pretreated C. rigidifolius basal bulbs.

Experiment commenced	No. of basal bulbs used	Pretreatment	Cumulative total sprouted (days in germinator) 5	10	15	20	30	60	Sprouted (%)
11/11/83	5	desiccated for 24 hours (immediately after collection)	4	4	4	4	4	4	80
30/12/83	72	desiccated for 24 hours (immediately after collection)	50	57	58	59	61	61	85
10/01/84	29	desiccated for 24 hours (after being in the germinator for 60 days)	8	11	11	11	11	12	41
17/11/83	10	desiccated for 168 hours (immediately after collection)	0	0	0	0	0	-[1.]	0
03/01/84	24	desiccated for 24 hours, and then stored in a dry, sealed glass jar for 96 hours	2	2	6	6	8	8	33

1. These basal bulbs were discarded after 36 days in the germinator because they were rotting.

In experiments where a high percentage (80% plus) of basal bulbs sprouted, most sprouted within the first five days. In experiments where the overall sprouting percentage was low, the majority of basal bulbs that sprouted, sprouted after at least 15 days in the germination chamber. This slower germination response suggests that some dormancy mechanism was at least partially operative.

Most researchers (e.g. Stoller et al., 1972; Nyahoza, 1974; McCue, 1982) who have investigated the sprouting of C. rotundus and/or C. esculentus tubers have used short germination periods of five to eight days. Their percentage sprouted results probably do not include tubers that possessed even shallow dormancy at the beginning of the germination test, as these tubers would not have broken dormancy and sprouted during the short germination period utilized.

Rhizome pieces did not produce any sprouts (Table 4.3). These results are consistent with observations of C. rigidifolius in the field, where shoots arising from rhizome pieces were not observed. Holm et al. (1977) stated that other Cyperaceae species such as C. rotundus or C. esculentus do not arise from rhizome pieces.

C. rigidifolius achenes did not germinate (Table 4.4). Consistent with these results, plants arising from achenes were never observed.

C. esculentus. The majority of recently produced, freshly collected, whole C. esculentus tubers appeared to be dormant (Table 4.5). Only 3% of the tubers had sprouted, and 8% were dead when the experiment was terminated. Some of these dead tubers may have been nonviable before the experiment began, because in most samples of tubers that were cut in half the percentage dead ranged between 0% and 5%.

TABLE 4.3. Sprouting of C. rigidifolius rhizome pieces.

Experiment commenced	No. of rhizome pieces used	Cumulative total sprouted (days in germinator) 5	10	15	20	30	60	Sprouted (%)
14/09/83	20	0	0	0	0	0	0	0
10/11/83	20	0	0	0	0	0	0	0

TABLE 4.4. Germination of C. rigidifolius achenes.

Experiment commenced	No. of achenes used	Pretreatment	Cumulative total sprouted (days in desk drawer) 5	10	15	20	30	60	Sprouted (%)
28/10/82	200	-	0	0	0	0	0	0	0
01/04/83	200	prechilling[1].	0	0	0	0	0	0	0

1. 14 days in a refrigerator (2 - 4 C) in moist petri dishes.

TABLE 4.5. Sprouting of freshly collected, whole C. esculentus tubers.

Experiment commenced	No. of tubers used	Cumulative total sprouted (days in germinator) 5	10	15	20	30	60	Sprouted (%)	No. of dead tubers after 60 days
23/09/83	60	0	0	0	0	1	2	3	5

McCue (1982) reported that recently produced, freshly collected, mature (brown) C. esculentus tubers were mostly dormant. She conducted an experiment examining the effects of the interaction of photoperiod and plant age on tuber production and viability and discovered that freshly collected, immature (white or gold) tubers had a greater propensity to sprout (17% to 38% sprouted) than more mature tubers (4% to 8% sprouted).

Cutting recently produced, freshly collected C. esculentus tubers into halves stimulated sprouting, but method of placement of tuber halves in the petri dishes was found to be critical for rapid and optimal sprouting. In one trial, only tuber halves with the cut side up had sprouted during the first five days in the germination chamber. The cut side on these tuber halves was exposed to air trapped in the petri dish, and this cut side turned a brownish colour during the five days. In contrast, the cut side of tuber halves that were placed cut side down remained white in colour (due to lack of aeration). This trial was then terminated by rearranging the tuber halves so that all were cut side up. Thomas (1967) obtained a marked increase in sprouting, from 40% to 85%, due to exposing the interior of C. esculentus tubers to air. He exposed about 10% of the interior of tubers to air by rubbing the tubers on an abrasive surface.

Almost without exception, in all experiments involving C. esculentus tuber halves, sprouts from germinating tuber halves arose from buds located near the cut surface, at the distal end of the tuber (the part of the tuber farthest from the stolon attachment point). These observations of the location of sprouts on tuber halves are in agreement with the literature reviewed (Stoller et al., 1972; Bendixen, 1973).

Fresh or recently collected tubers (stored in moist, warm conditions for 15 days) cut into halves, exhibited the highest sprouting percentages, 69% and 63% (Table 4.6). Sprouting of tuber halves decreased dramatically as the time interval between collection of the whole tubers and subsequent use increased. Tuber halves, derived from unsprouted, whole tubers that had been in the germination chamber for 60 days had a sprouting percentage of 23%. Tubers that were stored in moist, cool conditions (refrigerator, 2 - 4 C) for 96 days, prior to being cut in half, had sprouting percentages of the halves of 43% and 39% (Table 4.7). Tuber halves, derived from unsprouted, whole tubers subjected to both the cool, moist 96-day storage period and 60 days in the germination chamber, had a sprouting percentage of 36%.

Thullen and Keeley (1975) tested the germinability of C. esculentus tubers that had been air-dried (overnight) and then stored in a refrigerator (5 C) for six months. They found that refrigerated storage altered the sprouting pattern of C. esculentus tubers, and that readiness to sprout (94% of these tubers sprouted within two weeks of being planted in soil), and a relatively large number of multiple sprouts (three or four) per tuber characterized these tubers. They concluded that artificially keeping tuber buds from sprouting allowed more buds to reach a physiological condition where they could sprout. In the experiments presented in Table 4.7, the moist conditions present during refrigerated storage may have enhanced tuber dormancy; in contrast, the cool, dry storage conditions utilized by Thullen and Keeley (1975) encouraged maximum sprouting.

The majority, an average of 84%, of the tuber halves that sprouted, sprouted during the first five days of an experiment, except

TABLE 4.6. Sprouting of tuber halves derived from pretreated *C. esculentus* tubers.

Experiment commenced	No. of tubers used	Pretreatment	Tuber halves - cumulative total sprouted (days in germinator) 5	10	15	20	30	60	Sprouted (%)
29/09/83	13[1.] or 26 halves	-	17	17	18	18	18	18	69
10/10/83	16[2.] or 30 halves	storage in moist conditions at room temperature for 15 days	17[3.]	17	19	19	19	19	63
23/11/83	20[4.] or 40 halves	in the germinator for 60 days	0	4	5	6	9	9	23

1. All 13 tubers were judged to be viable when cut into halves.

2. One tuber, of 16, was dead (6% dead).

3. Four of these 17 sprouted tuber halves had two sprouts.

4. After 60 days in the germinator none of these whole tubers had sprouted, and all were judged to be viable when cut into halves.

TABLE 4.7. Sprouting of tuber halves derived from C. esculentus tubers stored 96 days in cool, moist conditions.

Experiment commenced	No. of tubers used	Pretreatment	Tuber halves - cumulative total sprouted (days in germinator) 5	10	15	20	30	60	Sprouted (%)
29/12/83	32[1] or 60 halves	-	20[2]	24	26	26	26	26	43
04/01/84	20[3] or 38 halves	in the germinator for 6 days (no sprouting of the whole tubers)	13	14	15	15	15	15	39
29/02/84	39[4] or 64 halves	in the germinator for 60 days	0	18[5]	20	20	23	23	36

1. Two tubers, of 32, were dead (6% dead).

2. Five of these 20 sprouted tuber halves had two sprouts.

3. One tuber, of 20, was dead (5% dead).

4. One whole tuber sprouted five days after the petri dishes were placed in the germinator; the other 39 whole tubers did not sprout during the 60 day period. Seven of these tubers were dead (18% dead).

5. Four of these 18 sprouted tuber halves had two sprouts.

for those tuber halves derived from whole, unsprouted tubers that had been in the germination chamber for 60 days. Tuber halves derived from unsprouted, whole tubers that had been in the germination chamber for 60 days took longer to sprout and had lower overall sprouting percentages than other tuber halves. The reduced rate of sprouting and reduced final sprouting percentage would indicate that the dormancy of tubers placed in warm, moist conditions was enhanced. In contrast, the Canada Weed Committee - Eastern Section (1974 - as cited by McCue, 1982) reported that drying, or dry storage, of C. esculentus tubers encouraged dormancy; McCue (1982) stated that tubers used in research should be stored under moist conditions in order to promote maximum sprouting.

In this study, storing tubers under moist, cool conditions reduced the final sprouting percentage of tuber halves as compared to halves derived from freshly harvested tubers, but moist, refrigerated storage did not affect the rate of sprouting. In all experiments, no additional sprouting of tuber halves occurred after 30 days.

Sprouting of freshly collected, whole tubers, which were desiccated for 48 hours prior to being placed in the germinator, did not occur. In fact, this desiccation pretreatment killed all of these whole tubers as they became very moldy and rotten within 30 days of being placed in the germinator. However, other researchers have found that C. esculentus tubers tolerate long periods of dryness (two weeks to six months) with only a moderate loss in viability (Day and Russell, 1955; McCue, 1982).

Germination of C. esculentus achenes did not occur regardless of the pretreatment procedure used (Table 4.8). The viability of these

achenes was not determined, but the dry storage period and the pretreatments may not have been of sufficient duration to break dormancy. Justice and Whitehead (1946) dry stored C. esculentus achenes for four months prior to obtaining 80% germination; Justice (1957) generally used prechilling periods varying from 10 to 35 weeks at 10 C, to stimulate germination of the achenes of a number of different Cyperaceae species. Other reasons for the lack of germination include a possibly unsuitable germination environment, as alternating temperatures and light may be required for germination, or, perhaps, C. esculentus plants in the wheat growing areas of Kenya may produce mostly nonviable achenes. C. esculentus seedlings, growing from germinated achenes, were never observed.

C. usitatus var. usitatus. Sprouting of C. usitatus var. usitatus bulbs planted in soil proceeded slowly. Less than 10% of the total emerged during the six months duration of this experiment (Table 4.9). Emergence occurred over a long period of time indicating variability in the level of dormancy possessed by this population of bulbs. Somewhat similarly, Thullen and Keeley (1975) reported that a C. esculentus tuber sprouted for the first time 64 weeks after being planted in soil.

Trials using immature bulbs were also conducted (Table 4.10). Immature bulbs did not germinate on moist filter paper or in moist sand, but 40% of the bulbs in the moist sand retained their structural integrity. This retention of structural integrity throughout the 60 day time period of a germination experiment is probably indicative of dormant, viable propagative structures.

TABLE 4.8. Germination of C. esculentus achenes.

Experiment commenced	No. of achenes	Pretreatment	Cumulative total sprouted (days in germinator) 5	10	15	20	30	60	Sprouted (%)
14/09/83	50	-	0	0	0	0	0	0	0
24/11/83	100	dry achenes were placed in a freezer for 14 days	0	0	0	0	0	0	0
24/11/83	100	14 days in cool, moist conditions (refrigerator)	0	0	0	0	0	0	0

TABLE 4.9. Emergence of shoots from C. usitatus var. usitatus bulbs planted in pots filled with soil.

Experiment commenced	No. of bulbs used	Cumulative total of emerged shoots (months in pots) 1	2	3	4	6	Emerged (%)
09/11/82	160[1.]	1	5	8	12	14	9

1. Bulbs were collected from a field.

TABLE 4.10. Sprouting of freshly collected, immature C. usitatus var. usitatus bulbs.

Experiment commenced	No. of bulbs used[1.]	Germination medium	Cumulative total sprouted (days in desk drawer) 5	10	15	20	30	60	Sprouted (%)	No. dead after 60 days
04/07/83	20	filter paper	0	0	0	0	0	0	0	-[2.]
12/07/83	20	sand	0	0	0	0	0	0	0	12

1. Bulbs were collected from a field.

2. Not determined.

Sprouting of freshly collected, mature C. usitatus var. usitatus bulbs did not occur (Table 4.11). Origin of the bulbs and the type of germination medium used were varied, but these factors did not appear to influence the results. The percentage of dead bulbs at the end of the germination period also remained fairly constant, at 45% and 50%.

Sprouting of pretreated bulbs was also minimal (Table 4.11). No sprouting of bulbs pretreated by soaking in water for 48 hours occurred, in both germination mediums. Bulbs placed in the moist sand medium had a slightly higher percentage dead after 60 days than bulbs placed on moist filter paper. Ten percent of the bulbs pretreated in a cool, moist environment (in petri dishes in a refrigerator) for 14 days, sprouted. Since some sprouting actually took place, this pretreatment method seemed to be more effective than some of the other methods, although the percentage of dead bulbs was 50%.

Desiccation pretreatments resulted in the sprouting of only three bulbs, out of a total of 105 (Table 4.12). However, fewer than 50% of the bulbs that were desiccated were dead after 60 days in petri dishes. Although desiccation did not break bulb dormancy, neither did it decrease bulb viability as compared to the germination trials involving freshly harvested bulbs.

Sprouting of bulbs pretreated by heat shock did not occur (Table 4.13). However, the number of dead bulbs after 60 days in petri dishes was variable. Pretreating the bulbs for up to 5 minutes at 100 C did not kill them as the percentage dead at the end of the germination test remained a normal 45%. The next increment, 7.5 minutes, resulted in increased death of the bulbs (85% dead). Ten minutes killed virtually all, as 95% of these bulbs were dead at the end of the experiment.

TABLE 4.11. Sprouting of mature C. usitatus var. usitatus bulbs.

Experiment commenced	No. of bulbs used	Pretreatment	Origin of bulbs	Germination medium	Cumulative total sprouted (days in desk drawer) 5	10	15	20	30	60	Sprouted (%)	No. dead after 60 days
04/07/83	10	-	field	filter paper	0	0	0	0	0	0	0	-[1]
12/07/83	10	-	field	sand	0	0	0	0	0	0	0	5
26/08/83	20	-	pot	filter paper	0	0	0	0	0	0	0	9
14/07/83	20	soaked in water for 48 hours	field	sand	0	0	0	0	0	0	0	11
14/07/83	20	soaked in water for 48 hours	field	filter paper	0	0	0	0	0	0	0	9
18/07/83	20	14 days in cool, moist conditions (refrigerator)	field	filter paper	0	2	2	2	2	2	10	10

1. Not determined.

TABLE 4.12. Sprouting of mature C. usitatus var. usitatus bulbs pretreated by desiccation.

Experiment commenced	No. of bulbs used	Pretreatment	Origin of bulbs	Cumulative total sprouted (days in desk drawer) 5	10	15	20	30	60	Sprouted (%)	No. dead after 60 days
07/07/83	20	desiccated for 72 hours (immediately after collection)	field	0	0	2	2	2	2	10	8
01/09/83	25	desiccated for 72 hours (immediately after collection)	pot	0	0	0	0	0	0	0	10
05/09/83	25	desiccated for 168 hours (immediately after collection)	pot	0	0	1	1	1	1	4	12
12/09/83	25	desiccated for 336 hours, or 14 days, (immediately after collection)	pot	0	0	0	0	0	0	0	10
05/02/84	20	stored in a dry, sealed glass jar for 40 days	field	0[1.]	0	0	0	0	0	0	4

1. Days in germinator for this 05/02/84 trial only.

TABLE 4.13. Sprouting of mature C. usitatus var. usitatus bulbs pretreated by heat shock.

Experiment commenced	No. of bulbs used[1.]	Pretreatment (minutes in 100 C oven)	Cumulative total sprouted (days in desk drawer) 5	10	15	20	30	60	Spr. (%)	No. dead after 60 days
28/08/83	20	2.5	0	0	0	0	0	0	0	9
28/08/83	20	5.0	0	0	0	0	0	0	0	9
28/08/83	20	7.5	0	0	0	0	0	0	0	17
28/08/83	20	10.0	0	0	0	0	0	0	0	19

Spr. = sprouted

1. Bulbs used were collected from plants grown in pots.

Cutting bulbs in half resulted in the highest sprouting percentages obtained, 25% and 11%, of all the germination experiments conducted involving C. usitatus var. usitatus bulbs (Table 4.14). Perhaps even higher sprouting percentages could have been realized if bulb halves from freshly collected bulbs had been used (as observed in the experiments involving C. esculentus tuber halves, where tuber halves derived from freshly collected tubers sprouted best).

In the 09/09/83 experiment, some bulbs were cut cross-sectionally and some bulbs were cut longitudinally through the center. The sprouts of the six bulb halves derived from whole bulbs cut cross-sectionally through the center did not appear to be as vigourous as the sprout from the longitudinal bulb half, although 25% of the cross-sectional bulb halves sprouted as compared to 4.5% of the longitudinal bulb halves. The one longitudinal bulb half that sprouted was derived from a bulb actually cut about 1 mm off center, and the sprout was growing out of the thicker "half". All bulbs in the 04/09/83 experiment were cut longitudinally off center as a result of the above observations, and the portion that sprouted was, in all cases, the thicker "half".

Sprouted bulb halves were planted separately in pots filled with soil, and only three of the six sprouted, cross-sectional bulb halves eventually emerged - 39, 43, and 49 days after being planted. Sprouted, asymmetric longitudinal bulb halves emerged within an average of 18 days after being planted in pots, and only two of these 11 sprouted bulb halves failed to emerge.

The percentage of dead bulbs, as determined at the end of individual germination experiments, decreased when the petri dishes were placed in the germination chamber, rather than in an office drawer.

TABLE 4.14. Sprouting of C. usitatus var. usitatus bulb halves derived from whole, unsprouted bulbs that had been in the germinator for 40 days and 80 days.

Whole bulbs					Bulb halves							
						Cumulative total sprouted (days in germinator)						
Experiment commenced	No. of bulbs used [1.]	No. of days in germinator	Spr. (%)	No. of dead bulbs	No. of viable halves	5	10	15	20	30	60	Spr. (%)
09/09/83	25	40	0	2	46 (total)							
					22 symmetric, longitudinal halves (cut through the center)	0	0	1	1	1	-[2.]	5
					24 symmetric, cross-sectional halves (cut through the center)	0	0	6	6	6	-[2.]	25
04/09/83	50	80	0	3	94 asymmetric, longitudinal halves (cut off center)	0	1	3	7	10	-[2.]	11

Spr. = sprouted

1. Bulbs used were collected from plants grown in pots.

2. Terminated after 30 days because the bulb halves were beginning to rot.

Petri dishes placed in the germination chamber had 8%, 6% (Table 4.14), and 20% (Table 4.12) dead bulbs after 40, 80, and 60 days, respectively. In comparison, after 60 days in a petri dish in a desk drawer, the percentage of dead bulbs was never less than 40%, and usually between 40% and 50%. The greater incidence of bulb death occurring in the desk drawer environment, as compared to the germination chamber, is probably a result of the combination of fluctuating temperature and the presence of greater amounts of inoculum.

Sprouting of C. usitatus var. usitatus stolon pieces in petri dishes did not occur, nor did any shoots emerge from the pieces planted in pots. After 60 days this experiment was terminated. Sprouting of stolon pieces in the field was never observed; C. usitatus var. usitatus plants always originated from bulbs.

C. teneristolon. All C. teneristolon plants examined in the field at the beginning of a growing season originated from irregularly shaped, swollen rhizome pieces. These swollen rhizome pieces often closely resembled C. esculentus tubers in exterior appearance. In the germination experiment conducted, the only C. teneristolon rhizome pieces to sprout, in both media (petri dishes, and pots filled with soil), were those containing a swollen area (Table 4.15). Furthermore, the sprouts grew only from these swellings, not from the slender part of the rhizome.

Rhizome pieces containing a swollen area appeared to take longer to sprout when planted in soil as compared to when placed in petri dishes in the germination chamber. At least some of this delay can be explained by the fact that what appears as "days to sprouting" is, for

TABLE 4.15. Sprouting of *C. teneristolon* rhizome pieces.

Experiment commenced	No. of rhizome pieces	Germination medium	Cumulative total sprouted (days) 5	10	15	20	30	60	Spr. (%)
06/09/83	10 with a swollen area	soil	0	0	0	2[1.]	4	4	40
	10 - slender (no swellings)	soil	0	0	0	0	0	0	0
	10 with a swollen area	filter paper	0	6	6	6	6	6	60
	10 - slender (no swellings)	filter paper	0	0	0	0	0	0	0

Spr. = sprouted

1. Each sprouting rhizome piece in soil was unearthed and examined upon shoot emergence.

those rhizome pieces planted 3 cm deep in soil, actually "days to emergence".

No sprouting of C. teneristolon achenes occurred during the 60 days the petri dish was in the germination chamber. C. teneristolon plants were not observed to originate from germinating achenes.

Conclusions

In general, sedge propagative structures appear to require a pretreatment prior to being placed in a favourable environment, if their full sprouting potential is to be realized. Pretreatment of these structures resulted in large gains in overall sprouting percentages of up to seven times that of non-pretreated structures.

Allowing C. rigidifolius basal bulbs to desiccate for 24 hours, immediately after collection, was the most effective pretreatment method for this species with approximately 80% of these pretreated basal bulbs subsequently sprouting. C. rigidifolius basal bulbs appear to be quite sensitive to desiccation, as lengthening the drying period beyond 24 hours decreased the percentage that eventually sprouted.

The most effective pretreatment for C. esculentus tubers was the cutting longitudinally of freshly collected tubers into halves, and placing these halves cut side up in the petri dish. Using this technique, the sprouting of tuber halves approached 70%. Placement of tuber halves cut side up in petri dishes was critical to ensure rapid sprouting.

Moist storage of whole C. esculentus tubers, under both cool (2 - 4 C) and warm (20 C) conditions, appeared to induce dormancy. Tuber halves derived from freshly collected tubers sprouted best.

Cutting C. usitatus var. usitatus bulbs in half, the bulb halves being placed cut side up in petri dishes, was the only pretreatment method that consistently resulted in sprouting. A maximum of 25% sprouting of bulb halves was achieved. Cutting bulbs longitudinally off center appeared to be best. The lack of aeration of the interior tissues of whole C. esculentus tubers and whole C. usitatus var. usitatus bulbs, apparently prevents prompt germination of these structures.

C. usitatus var. usitatus bulbs were more resistant to desiccation than C. rigidifolius basal bulbs or C. esculentus tubers, since allowing bulbs to dry for two weeks on a shelf did not result in an abnormal percentage of dead bulbs at the end of a germination experiment.

Petri dishes placed in an office drawer had approximately four times the number of dead C. usitatus var. usitatus bulbs after the 60 day germination period, as compared to petri dishes placed in the germination chamber. The constant germination chamber environment positively influenced the viability of dormant bulbs (sprouting was not affected), possibly because there was less chance of contamination of the petri dishes.

C. teneristolon rhizome pieces containing swellings, usually sites where branching of the rhizome had occurred, sprouted without a pretreatment, while slender rhizome pieces did not sprout. Uprooting young C. teneristolon plants in the field confirmed this observation.

Sprouting of C. rigidifolius rhizome pieces or C. usitatus var. usitatus stolon pieces did not occur. Pieces of C. esculentus stolons were not tested.

Sprouting of C. rigidifolius, C. esculentus, or C. teneristolon achenes did not occur. Achenes of C. usitatus var. usitatus were not tested.

V CHEMICAL CONTROL OF SEDGE WEEDS

Introduction

Terry (1985) stated that the term "weed control" is a common, but ambiguous expression. Control has been used to describe the suppression, inhibition, or eradication of weed growth, often based only upon observations of aerial components. Perennial weeds, though, possess subterranean organs important to their survival, growth, and dispersal. Certain herbicides, such as glyphosate, possess activity against these perennating organs, but this activity has not always been assessed. Terry (1985) concluded that citations of "good control" or "poor control" are difficult to avoid or quantify, and that their relevance must be interpreted according to the situation in which they are used.

Cunningham-van Someren (1974) discussed the definition and use of the word "control" with regards to sedge weeds. His strict definition of control meant that a compound must inhibit growth in the year applied, and prevent regrowth during the following season (with second year assessments conducted after normal tillage operations). He emphasized that assessments of sedge weed control should include an extensive examination of both above-ground and below-ground plant parts, as a herbicide may inhibit shoot growth somewhat, while having little or no effect on the production of tubers or bulbs. He stated that most of the existing literature regarding the control of sedge weeds uses

the term "control" to mean the suppression of shoot growth over a single growing season. Unless otherwise noted, this commonly used, less strict definition of control will apply in the following text.

Numerous chemicals have been screened for activity against sedge weeds (mainly C. rotundus and C. esculentus) over the years. Parker et al. (1969) investigated the effectiveness of 98 compounds in controlling C. rotundus and C. esculentus. Their work consisted entirely of greenhouse experiments, and they advised caution in extrapolating their results to the field for the following reasons: 1) control of well established stands in the field may be much less successful, 2) the doses of herbicide required are tolerated in only a limited range of crop situations, and 3) the cost of the herbicides may render the treatment uneconomic. They reported that the only chemicals which eradicate C. rotundus in a single treatment are the soil fumigants and the highly persistent soil sterilant herbicides. Eradication is possible with methyl bromide (at a very high cost). However, they found that a different soil fumigant, metham-sodium, was not as likely to give a complete kill. They stated that at sufficiently high doses some of the triazines, ureas, or uracils might be capable of eradicating C. rotundus, but cost would again be high and the soil unusable for a long period.

The following experiments were conducted to evaluate certain herbicides for the control of sedge weeds. Factors examined included the degree and duration of herbicidal control, and the timing and method of application.

Materials And Methods

Field Experiments

Selective Sedge Weed Control In Sunflowers, 1982 and 1983. An experiment, to investigate the control of sedge weeds in sunflowers, was conducted for two successive growing seasons at N.P.B.S., Njoro. In both years, the trials were conducted in the same field, but at different locations in the field. The experimental design was a randomized complete block using four replications. The plot size was 6 m by 15 m in 1982, and 7 m by 15 m in 1983.

Herbicides were applied using a boom-type, bicycle sprayer equipped with flat fan nozzles (Teejet[1.]). Compressed air, regulated at 275 kPa, was the propellant. Untreated strips were not left between plots or replicates, with all assessments and measurements taken from a central 3 m by 10 m portion of each plot.

Incorporation of the preplant incorporated (ppi) herbicides, EPTC[2.] and butylate[3.], occurred within 30 minutes of application. All ppi herbicide treatments in an individual replicate were applied and then the replicate was disk harrowed to a depth of about 10 cm. A second incorporation with the disk harrow, at right angles to the first pass, was done after ppi treatments in all four replicates had been applied.

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1. Teejet nozzles are manufactured by Spraying Systems Co., Illinois.

2. EPTC was applied as the commercial formulation, Eptam (770 g a.i./litre) - Stauffer Chemical Co.

3. Butylate was applied as the commercial formulation, Sutan (850 g a.i./litre) - Stauffer Chemical Co.

A shallow cultivation was performed prior to planting the sunflowers, to prepare a smooth seedbed. Sunflower seeds were planted using a 3-row corn planter, with a row spacing of 90 cm. The seeds were planted 4 to 6 cm deep. The final plant stand was three to four sunflower plants per metre of row. One hundred-twenty kg/ha of di-ammonium phosphate (18-46-0) was applied with the treated seed (copper and insecticide) at planting time.

Plots were visually assessed to determine the degree of sedge control provided by the various herbicide treatments, and to assess crop tolerance to these treatments. The European Weed Research Council (EWRC) visual rating system was used in these assessments (Table 5.1). The rating scores are presented as the average of the four replicates.

Counts were made of the number of sedge shoots occurring in a 0.25 m^2 area on each of the dates when the plots were visually assessed. Counts were made on three random, 0.25 m^2 quadrats per plot.

Approximately 80% of the sedge weeds present in the field were C. teneristolon with the remainder being C. rigidifolius. Some of the C. rigidifolius plants were present in clusters of ten shoots or less, but most were growing in larger patches.

In-crop control of broadleaf weeds was performed using a knapsack sprayer equipped with a shielded, floodjet nozzle, applying a total spray volume of 170 L/ha. At the time of application the sunflowers were approximately 1.5 m tall and just beginning to flower. The broadleaf weeds ranged in size from seedlings to 75 cm tall (Appendix 3 - a complete list of all the weeds identified in the plots).

At harvest the sunflower plants were 80% brown or black in appearance with only a few green stalks and green leaves present. The

TABLE 5.1. EWRC visual scoring for herbicide efficacy and crop tolerance.

	Efficacy (weed kill)		
Score	Description	Approximate % control	Crop tolerance
1	complete kill	100	no effect.
2	excellent	99.9 - 98	very slight effects; some stunting and yellowing just visible.
3	very good	97.9 - 95	slight effects; stunting and yellowing obvious; effects reversible.
4	good - acceptable	94.9 - 90	substantial chlorosis and (or) stunting; probably no effect on yield; most effects probably reversible.
5	moderate - but not generally acceptable	89.9 - 82	strong chlorosis/stunting; thinning of stand; some yield loss expected.
6	fair	81.9 - 70	increasing severity of damage.
7	poor	69.9 - 55	
8	very poor	54.9 - 30	
9	none (control)	29.9 - 0	total loss of plant and yield.

adapted from Australian Weeds Committee (1979).

plants were cut at ground level, and the fresh weight was determined from two rows, each 3 m long, per plot. The fresh weights are presented as tonnes/hectare.

1982. Preplant incorporated herbicides were applied and incorporated on May 28 into moist soil. An open pollinated, oilseed cultivar of sunflower, Kensun (Kenya Seed Co.), was planted on June 4, 1982. One day after planting, alachlor[4.] was applied to a dry soil surface. The top 3 to 5 cm of soil remained dry during the three weeks following application of alachlor, as only 20.5 mm of rainfall was received during this period (Appendix 2). Herbicides were applied using 6503 nozzles (Teejet) delivering a total spray volume of 317 L/ha.

Visual assessment of sedge weed control and sedge shoot counts were performed on June 29 and August 16.

To control broadleaf weeds, 1.4 L/ha of Buctril M[5.] was applied between the rows of sunflowers on July 29, using the knapsack sprayer.

The plots were harvested on November 10, 159 days after planting. The previously described harvest method was used because of the widespread and serious head deformities caused by the systemic action of the MCPA component of Buctril M. The shielded nozzle of the knapsack sprayer did not adequately protect the lower leaves and stems of the sunflower plants from the spray droplets. Birds caused severe damage to the sunflower heads that set seeds.

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4. Alachlor was applied as the commercial formulation, Lasso (480 g a.i./litre) - Monsanto Co.

5. Buctril M contains 225 g/L bromoxynil octanoate + 225 g/L MCPA ester - May and Baker Ltd.

1983. Preplant incorporated herbicides were applied on May 20 and incorporated into dry soil. The oilseed sunflower hybrid, 301 A (Kenya Seed Co.), was planted on May 24. The pre-emergence herbicides, alachlor and metolachlor[6.], were applied two days after planting to a very dry soil surface. Herbicides were applied using 80015 nozzles (Teejet) delivering a total spray volume of 170 L/ha.

Visual assessment of sedge weed control and sedge shoot counts were performed on June 28. The visual assessment did not include crop tolerance ratings because the lack of adequate rainfall during June resulted in very poor emergence of the crop. Only 37.9 mm of rain was received during the entire month.

The unsatisfactory emergence of the sunflowers necessitated the replanting of the trial on July 1. Eight days prior to replanting, 1.4 L/ha of Buctril M was applied to the trial area to kill the few sunflower plants and broadleaf weeds present. To conserve moisture, tillage was not done prior to replanting. The replanting operation was identical to the original planting procedure, except that fertilizer was not used. Herbicide treatments were not re-applied. Emergence of the sunflowers was poor until mid-July, when regular rains were received.

Sedge shoot counts were performed on September 19. Quadrats 25 cm by 25 cm were used in the plots that were very densely infested with sedge weeds.

Pardner[7.], at 2 L/ha, was applied inter-row with the knapsack

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6. Metolachlor was applied as the commercial formulation, Dual (960 g a.i./litre) - Ciba-Geigy Inc.

7. Pardner contains 225 g/litre of bromoxynil - May and Baker Ltd.

sprayer on August 23. The sunflowers were not adversely affected by the application of Pardner.

The plots were harvested on December 7, 160 days after planting. At this time, seed losses due to birds and vandalism were apparent. The harvesting procedure used was the same as in 1982.

AC 252.925 (Arsenal). An experiment using AC 252.925[8] was established to determine the optimum rate and method of application for vegetation control, particularly sedge weeds. A second experiment was established to investigate the effects of differing spray solution volumes on AC 252.925 efficacy. These experiments were conducted from May 16 to November 28, 1983 in a fallow field at N.P.B.S., Njoro.

The design of both experiments was a randomized complete block, with four replications. Plots were 2.5 m by 10 m. Unless otherwise noted, the treatments were applied using a boom-type, bicycle sprayer equipped with flat fan nozzles (Teejet), and with a spray width of 2.0 m. The spray solution volumes and nozzles used in these experiments are presented in Table 5.2.

The preemergence (pre), non-incorporated treatments of AC 252.925 were applied May 16 to a dry soil surface. The entire experimental area was worked several times, using a disk harrow, three days prior to the herbicide application. It was very dry from mid-May to mid-July, and moist during August and September, 1983 (Appendix 2).

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8. Active ingredient of AC 252.925 is the isopropylamine salt of 2-(4-isopropyl-4-methyl-5-oxo-2-imidazolin-2-yl) nicotinic acid - American Cyanamid Co. The formulation used was an aqueous solution containing 250 g a.e./litre.

TABLE 5.2. Spray solution volumes and nozzles used to apply AC 252.925.

Spray solution volume (L/ha)	Nozzle used
11.5	controlled droplet applicator[1]. (spinning disc)
79	Teejet 650067
231	Teejet 6502
317	Teejet 6503
634	Teejet 6503 (double application)

1. Herbi, product of Micron Sprayers Ltd., Three Mills, Bromyard, Herefordshire, U.K.

The postemergence (poe) AC 252.925 treatments were applied June 20. A small amount of rain (2.3 mm) fell in the late afternoon, about eight hours after application. Sedge weeds in the plots were mainly C. rigidifolius, with a few scattered C. usitatus var. usitatus plants also present. At the time of application most of the sedges were 20 to 30 cm tall, and some of the C. rigidifolius plants were flowering. Broadleaf weeds had two to six leaves and were 5 to 15 cm tall.

The broadleaf weeds, treated by a postemergence application of AC 252.925, became chlorotic and necrotic more rapidly than the sedge plants. The plots were assessed for broadleaf weed control on July 19 (29 days after the postemergence application of AC 252.925), and for sedge control on October 5 (107 days after application). The EWRC

visual rating system was used to describe the herbicidal activity. The rating scores presented are the average of the four replicates. Assessments of general weed control are presented in Appendix 4.

Counts were made of the number of sedge shoots occurring in two random, 0.25 m^2 quadrats per plot, on October 5. Sedge shoots with at least 50% green leaves were considered to be living.

Buctril M (1.4 L/ha) was applied on July 20 to control broadleaf weeds in the check plots and in the unsprayed strips between plots. On September 2, the herbicide was applied to check plots, unsprayed strips, and glyphosate[9] treated plots. On October 10, Buctril M was applied over the entire experimental area.

Wheat (c.v. Tembo), rapeseed (c.v. Regent), and sunflowers (Kenya Seed Co., hybrid 301) were planted October 18 in 2 metre long rows in the AC 252.925 treated plots of the first replicate, of the rate and application method experiment. The check plots were too densely infested with sedges, and the glyphosate treated plots too densely infested with annual grasses to allow planting of the crop species.

Fifteen C. rigidifolius basal bulbs were collected November 10 from plots treated with AC 252.925 applied postemergence at 0.75 kg/ha. These basal bulbs were collected from the central portion of plots in three replicates, and each was attached to a dead shoot. All of the collected basal bulbs were firm and appeared to be structurally sound. The basal bulbs were washed and placed in petri dishes in the germination chamber (the same procedure as outlined in Section IV).

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9. Glyphosate was applied as the commercial formulation, Roundup (360 g a.i./litre) - Monsanto Co.

Glufosinate. An experiment to determine the optimum rate of glufosinate[10.] to control young C. usitatus var. usitatus plants was conducted from May 16 to June 7, 1983 in a fallow field at N.P.B.S., Njoro. Plots were laid out in a randomized complete block design, with five replications. Plots were 7 m by 10 m. All herbicide treatments were applied on May 16, using a boom-type, bicycle sprayer equipped with flat fan nozzles (Teejet 80015) delivering a total spray volume of 170 L/ha. No rain fell in the 24-hour period immediately following herbicide application.

The sedge weeds present in the plots were C. usitatus var. usitatus. At the time of herbicide application most of the sedge plants were in an early growth stage, 5 to 10 cm tall with few daughter shoots present, and were growing vigourously. Other weeds, mainly broadleaf weeds, were in the two to four leaf stage.

All plots were visually assessed on June 7 to determine the degree of sedge control provided by the various treatments. The EWRC visual rating system was used to describe the herbicidal activity. The rating scores are the average of the five replicates.

Counts were made of the number of sedge shoots occurring in two random, 0.25 m^2 quadrats per plot, on June 7. Sedge shoots with at least 50% green leaves were considered to be living. Shoots that had emerged after the herbicide application were not counted.

Statistical Procedures. Statistical methods were used to analyze data in all field experiments. Prior to the analysis of variance, each data

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10. Glufosinate is manufactured by Hoechst AG. The formulation used was a solution containing 200 g a.i./litre.

set was subjected to the Burr-Foster Q-test to determine the degree of homogeneity of the variances. Data was transformed ($\sqrt{y}$ transformation) when required by this test, and then subjected to analysis of variance. Treatment means are all presented as non-transformed data, and where transformation was necessary it was noted. Multiple comparisons to rank treatment means were made using Duncan's Multiple Range Test. All statistical tests were conducted at the 5% level of significance. Only those differences significant at the 5% level were considered meaningful.

Pot Experiments

Pot experiments were conducted to investigate the activity of herbicides against the sedge weeds of the Njoro area. The pots used were 4 L plastic pails, and, unless otherwise noted, were filled with soil from a field at N.P.B.S., Njoro. The pots were located in the cage at N.P.B.S. - a wire mesh enclosed area. Pots were watered as required, based upon a visual inspection.

The *C. rigidifolius* plants used in these experiments were established from sprouted basal bulbs planted approximately 4 cm deep, one basal bulb per pot. These basal bulbs were collected from a field at N.P.B.S. and sprouted in petri dishes.

Unless otherwise noted, the *C. esculentus* plants were established from sprouted tubers or tuber halves planted 2.5 cm deep, two per pot, and upon shoot emergence, thinned to one per pot.

C. teneristolon and *C. usitatus* var. *usitatus* plants were established from transplants. These transplants usually had two to four leaves and were 2 to 3 cm tall. The transplants were planted two per pot, and after one week thinned to one plant per pot.

C. teneristolon and C. usitatus var. usitatus plants often grow in mixed stands in fields near Njoro. These sedges are very similar in appearance when young. Unintentional mixing of these sedge species occurred during transplanting. Positive identification of the plants was made at the time of herbicide application.

Unless otherwise noted, the herbicides were applied using the bicycle sprayer equipped with flat fan nozzles (Teejet 80015), delivering a total spray volume of 170 L/ha.

Assessments of herbicidal activity included percentage control ratings and descriptions of the plants that survived. Percentage control is the percentage of plants in each treatment that exhibited complete shoot necrosis with no regrowth at the time of assessment. For each surviving plant, the number of shoots were counted, and the height of the tallest shoot with its leaves or inflorescence held vertical was measured. The interval between application and assessment was variable and related to the rate at which shoots become necrotic.

Herbicides used in the pot experiments were:

AC 252.925. Isopropylamine salt of 2-(4-isopropyl-4-methyl-5-oxo-2-imidazolin-2-yl) nicotinic acid - manufactured by American Cyanamid Co. The formulation used was an aqueous solution containing 250 g a.e./litre.

Glyphosate. Glyphosate was applied as the commercial formulation, Roundup (360 g a.i./litre). Roundup is a trade name, Monsanto Co. An adjuvant, DSK 158 at a rate of 0.5% (v/v) (trade name Frigate, Diamond Shamrock Co.) was added to the spray solution when glyphosate was applied at 0.72 kg/ha.

Glufosinate. Manufactured by Hoechst AG. The formulation used was a solution containing 200 g a.i./litre.

Bentazon. Bentazon was applied as the commercial formulation, Basagran (480 g a.i./litre). Basagran is a trade name, BASF AG.

Bentazon + Dichlorprop. Bentazon + dichlorprop was applied as the commercial formulation, Basagran DP (260 g bentazon + 340 g dichlorprop/litre). Basagran DP is a trade name, BASF AG.

Results And Discussion

Field Experiments

Sunflowers. The thiocarbamate herbicides, EPTC and butylate, and the chloroacetamide herbicides, alachlor and metolachlor, exhibited herbicidal activity against C. rigidifolius and C. teneristolon (Tables 5.3 and 5.4). However, the herbicidal activity of these two different types of compounds differed in speed of expression and persistence.

The preplant incorporated thiocarbamate herbicides, EPTC and butylate, initially gave good control of sedge weeds at all the rates used, in both 1982 and 1983, but this level of control did not persist for an entire growing season. In 1982, many new sedge shoots were emerging by the August 16 assessment (80 days after herbicide application), although the treated plots still had fewer sedge shoots than the check plots. In 1983, by the September 19 assessment (122 days after application), all of the EPTC and butylate treated plots had dense sedge

TABLE 5.3. Selective control of sedge weeds in sunflowers, 1982.

Herbicide	Rate (kg/ha)	Visual assessments[1.] Sedge control June 29	Sedge control Aug. 16	Crop tolerance June 29	Crop tolerance Aug. 16	Sedge shoot count means (m^2)[2.] June 29	Sedge shoot count means (m^2)[2.] Aug. 16	Sunflower fresh weight[2.] (tonnes/ha)
none	-	9	9	1	1	196 c[3.]	229 b	11.6 a
EPTC	3.08	2	3	3	2	3 a	32 a	15.6 a
EPTC	3.85	2	3	3	2	2 a	34 a	16.5 a
EPTC	4.62	2	3	3	2	3 a	32 a	16.1 a
butylate	3.40	2	3	2	2	2 a	23 a	11.8 a
butylate	4.25	2	3	2	2	1 a	16 a	14.1 a
butylate	5.10	2	3	2	2	2 a	25 a	17.5 a
alachlor	3.36	7	5	2	2	98 b	71 a	13.2 a
alachlor	4.32	7	4	2	2	86 b	47 a	12.0 a
alachlor	5.28	7	4	3	2	87 b	53 a	17.3 a

1. EWRC visual rating system.
2. Treatment means followed by the same letter do not differ at the 5% level (Duncan's MRT).
3. Data was transformed ($\sqrt{y}$) prior to analysis.

TABLE 5.4. Selective control of sedge weeds in sunflowers, 1983.

Herbicide	Rate (kg/ha)	Sedge control[1.] (visual) June 28	Sedge shoot count means (m^2)[2.] June 28	Sept. 19	Sunflower fresh weight[2.] (tonnes/ha)
none	-	9	109 b[3.]	725 d	9.5 b
EPTC	2.31	2	5 a	623 cd	8.9 b
EPTC	3.08	2	3 a	445 c	14.8 ab
EPTC	3.85	2	2 a	643 cd	11.9 ab
EPTC	4.62	2	1 a	428 bc	14.1 ab
butylate	3.40	2	4 a	627 cd	14.7 ab
butylate	5.10	2	2 a	459 c	11.7 ab
alachlor	4.32	8	99 b	208 ab	19.2 a
alachlor	5.28	8	94 b	121 a	18.1 a
metolachlor	5.00	8	96 b	57 a	18.7 a

1. EWRC visual rating system.

2. Treatment means followed by the same letter do not differ at the 5% level (Duncan's Multiple Range Test).

3. Data was transformed ($\sqrt{y}$) prior to analysis.

infestations, with some of these plots not different than the check. These results are comparable to what researchers in the U.S.A. have reported - activity of thiocarbamate herbicides dissipates between five to twelve weeks after application (Obrigawitch et al., 1980; McCue, 1982).

The degree of sedge control in the alachlor and metolachlor treatments initially was not acceptable in both 1982 and 1983. In fact, in 1983 - the dryer of the two growing seasons, these treatments initially were not different than the check treatment (Table 5.4). However, as time progressed, the change in sedge weed numbers in alachlor and metolachlor treated plots was minimal as compared to the increase in infestation levels in the thiocarbamate treatments and the check.

In 1982, all three alachlor treatments exhibited a decrease in the number of sedge shoots between the June 29 and August 16 assessment dates (Table 5.3). Plots treated with 3.36 kg/ha of alachlor had an average of 28% fewer shoots per square metre on the second as compared to the first assessment. Similarly, the 4.32 kg/ha treatment had 45% fewer shoots, and the 5.28 kg/ha treatment had 40% fewer sedge shoots. During this same time period, the number of sedge shoots in the check plots increased by 14%, and in the thiocarbamate plots the average increase (for all treatments) was approximately 1,200%.

In 1983, both alachlor treatments exhibited an increase in the numbers of sedge shoots between the June 28 and September 19 assessment dates, but this increase was modest compared to the thiocarbamate treatments (Table 5.4). The number of sedge shoots approximately doubled (a two-fold, or 200% increase) in the 4.32 kg/ha treatment, and increased by 29% in the 5.28 kg/ha treatment. During this time the

number of sedge shoots in the thiocarbamate treatments increased a minimum of 125-fold, with an increase of up to 400-fold in some treatments. There was a corresponding 7-fold increase in sedge shoots in the check.

The metolachlor treatment, in 1983, had 40% fewer sedge shoots per square metre on September 19 as compared to June 28. McCue (1982), working in the U.S.A., reported that metolachlor gave better and more persistent control of C. esculentus than EPTC, butylate, or alachlor.

The delayed activation of alachlor and metolachlor can be attributed, in both years, to a lack of adequate rainfall in the three to four weeks immediately following application. Armstrong et al. (1973), working in Michigan, reported that between 12.7 to 25.4 mm of rainfall was required within ten days of a preemergence application of alachlor to achieve acceptable control. In 1982, 30.3 mm of rainfall was received in the ten days following the preemergence application of alachlor. In 1983, 7.5 mm was received in the ten days following preemergence application of alachlor and metolachlor. Due to differences in temperature and rates of evaporation, it would seem likely that preemergence applications in Kenya would require more rainfall to move the herbicides into the soil than was required in a northern U.S. state in the spring season.

The thiocarbamate herbicides, EPTC and butylate, appeared to delay the germination of individual C. rigidifolius basal bulbs and C. teneristolon rhizome pieces for a period of approximately two months after application and incorporation. These herbicides also appeared to inhibit the spread (by laterally growing rhizomes) of established C. rigidifolius patches during this time. Researchers in the U.S.A. have

reported that these thiocarbamate herbicides do not kill the propagative structures (tubers) of C. rotundus and C. esculentus. Keeley and Thullen (1974) reported that C. esculentus tubers in EPTC or alachlor treated soil escaped injury by failing to sprout until the herbicides had adequately dissipated. However, McCue (1982) found that multiple (three to four) sprouts were produced per tuber by tubers planted in EPTC or alachlor treated soil. These sprouts were abnormal and most did not reach the soil surface. Later, after the rhizomes and roots decayed, a tuber appeared as if it had never sprouted. Keeley and Thullen (1974) reported that tubers retained the capacity to resprout and produce normal shoots when replanted in untreated soil, or, if left in treated soil, when the herbicides had dissipated. Rincon and Warren (1978) found that C. rotundus tubers in EPTC or butylate treated soil were stimulated to produce multiple sprouts. These sprouts were abnormal and did not reach the soil surface. Tubers which initially sprouted developed normal new sprouts when repotted into untreated soil, or when herbicidal activity had dissipated.

The observed herbicidal activity of alachlor and metolachlor was difficult to characterize, due partly to the delay in activation of these herbicides. The herbicidal effect of alachlor and metolachlor on established C. rigidifolius plants and patches was minimal. However, alachlor and metolachlor, in combination with competition from the crop and other weeds, killed some of the young C. teneristolon plants in those treatments that exhibited a reduction in sedge shoots between the first and second assessment dates. In those treatments that showed a moderate increase in sedge shoot numbers (the two alachlor treatments in 1983), alachlor severely inhibited germination of C. teneristolon

rhizome pieces and the subsequent formation of daughter shoots, in comparison to the check.

Crop injury, due to the soil applied herbicides used, was slight. Initially, in both years, some wrinkling of the leaves was evident in a small percentage of sunflower seedlings in the EPTC and butylate treatments, but these symptoms of herbicide injury disappeared after approximately two weeks of growth. Specific crop injury symptoms were not apparent in the alachlor and metolachlor plots, although sunflowers growing in the alachlor treated plots in 1982 appeared to be slightly shorter than those in the check plots.

The application of selective herbicides with activity against sedges, as well as some other weeds, generally resulted in greater fresh weight of the above ground portion of mature sunflower plants compared to plants harvested from untreated plots. In 1982, the fresh weight of sunflowers harvested from the highest rate butylate and alachlor treatments was 51% and 49%, respectively, greater than the check.

Significant differences in sunflower fresh weight existed between treatments in 1983. Sunflower plants from the alachlor and metolachlor treatments had greater fresh weights than those from the check. All of the thiocarbamate treatments were not different from the check. The fresh weight of sunflowers in the chloroacetamide herbicide treatments was an average of 96% greater than in the check.

AC 252.925. AC 252.925 effectively controlled the sedge weeds (mainly C. rigidifolius) present in a fallow field at N.P.B.S., Njoro. Postemergence applications were more effective than preemergence

applications (Table 5.5). Approximately equivalent sedge control was obtained with 1.0 kg/ha applied preemergence, or 0.25 kg/ha postemergence, although the degree of control achieved was unsatisfactory in both treatments. The weather may have negatively affected the performance of AC 252.925 applied preemergence, as only 27.1 mm of rain fell between May 16 and June 20, 1983. This minimal amount of rainfall probably was not enough to adequately incorporate the herbicide into the soil.

Sedge shoots took a long time to turn necrotic after a postemergence application of AC 252.925. At the time of the October 5 assessment, 107 days after application, some of the sprayed shoots were still a yellowish-green colour with only the top 5 to 7 cm of each leaf desiccated. Growth and development of the herbicide treated sedge shoots ceased two to three weeks after application, even though the shoots stayed green for six to eight weeks. This cessation of growth and subsequent desiccation of the shoots was rate dependent, with these events requiring more time in sedges treated with 0.25 kg/ha of AC 252.925 than in those sedges treated with the higher rates.

The plots were assessed October 5, instead of waiting for 100% desiccation of the treated shoots, because new shoots or shoot regrowth from the basal bulbs of treated C. rigidifolius plants were beginning to emerge in all the preemergence treatments, and in the 0.25 kg/ha postemergence AC 252.925 treatment. Some of these new shoots, particularly those in the preemergence 1.25 kg/ha treatment, exhibited injury symptoms such as a stunted growth habit and the profuse production of short, slender leaves.

TABLE 5.5. Control of sedge weeds using AC 252.925 at several rates and two application methods.

Herbicide[1.]	Rate (kg/ha)	Method of application	Sedge control[2.] (visual)	Sedge shoot count means (m^2)[3.]
none	-	-	9	566 e
AC 252.925	0.75	pre	6	109 d
	1.00	pre	5	57 cd
	1.25	pre	4	31 bc
	0.25	poe	6	60 cd
	0.50	poe	3	18 ab
	0.75	poe	2	3 a
	1.00	poe	2	4 a
glyphosate	1.44	poe	5	55 cd

1. All herbicide treatments were applied using flat fan nozzles (Teejet 6503) delivering a total spray volume of 317 l/ha.

2. EWRC visual rating system.

3. Treatment means followed by the same letter do not differ at the 5% level (Duncan's Multiple Range Test). Shoot count data was transformed ($\sqrt{y}$) prior to analysis.

Excellent control of sedge weeds was obtained in the postemergence 0.75 and 1.00 kg/ha AC 252.925 treatments (Table 5.5). In comparison to the 0.75 kg/ha postemergence treatment, the highest rate (1.25 kg/ha) of the preemergence treatments gave only just adequate control, with the plots having ten-fold more sedge shoots present. Glyphosate, at 1.44 kg/ha, gave unacceptable sedge control as there were 18-fold more sedge shoots in the glyphosate plots 107 days after application, as compared to the AC 252.925 0.75 kg/ha postemergence plots. The check, as compared to the 0.75 kg/ha postemergence treatment, had 189 times as many sedge shoots. The technical information report on AC 252.925 (Anonymous, 1983a) stated that 0.75 kg/ha postemergence, or 1.0 kg/ha preemergence, has given effective control of C. rotundus under field conditions.

The spray volume experiment provided additional data to confirm results observed in the rate and application method experiment. It also provided information about the effects of type of applicator and spray solution volume on AC 252.925 efficacy (Table 5.6). Significantly poorer control resulted in the AC 252.925 treatments applied by the spinning disc applicator as compared to equivalent treatments applied by flat fan nozzles. Two of the conventionally applied (the two highest spray volumes - 317 and 634 L/ha) 0.25 kg/ha treatments gave better control of sedges than the 0.75 kg/ha treatment applied by the spinning disc applicator. The 0.25 kg/ha treatment applied by the spinning disc applicator gave very poor control - it had an average of 107 sedge shoots per square metre.

The effect of carrier volume on AC 252.925 efficacy, for the various conventionally applied treatments, was minimal. There were no

TABLE 5.6. Control of sedge weeds using AC 252.925 at two rates and several spray solution volumes.

Herbicide[1.]	Rate (kg/ha)	Total spray volume (L/ha)	Sedge control[2.] (visual)	Sedge shoot count means (m^2)[3.]
none	-	-	9	514 g
AC 252.925	0.25	11.5	7	107 f
		79	4	24 cd
		231	4	32 cd
		317	3	14 bc
		634	4	21 c
	0.75	11.5	5	44 d
		79	2	4 a
		231	2	3 a
		317	2	5 ab
		634	2	4 a
glyphosate	1.08	79	6	72 e

1. All herbicide treatments were applied postemergence.

2. EWRC visual rating system.

3. Treatment means followed by the same letter do not differ at the 5% level (Duncan's Multiple Range Test). Shoot count data was transformed ($\sqrt{y}$) prior to analysis.

differences between the numbers of sedge shoots present in each of the conventionally applied 0.25 kg/ha treatments, nor were there differences between any of the conventionally applied 0.75 kg/ha treatments. The 0.25 kg/ha of AC 252.925, 79 L/ha total spray volume treatment gave marginally poorer general vegetation control than did the other higher solution volume, conventionally applied 0.25 kg/ha treatments. This effect was not apparent in the conventionally applied 0.75 kg/ha treatments, all of which gave excellent vegetation control. The effect of differing droplet size distributions, as produced by the three different flat fan nozzles used, may also have influenced the results. The effects of droplet size on AC 252.925 efficacy were not investigated.

A rate response to AC 252.925 existed, as the conventionally applied 0.25 kg/ha treatments had an average of six times as many sedge shoots as the conventionally applied 0.75 kg/ha treatments (Table 5.6). These two experiments also showed that AC 252.925 possesses much greater activity against sedges than does glyphosate, as a postemergence application of 0.25 kg/ha of AC 252.925 gave control approximately equivalent to 1.44 kg/ha of glyphosate, when assessed 107 days after application (Table 5.5).

Injury symptoms were not apparent in any of the crop species in any of the plots, as of November 28, 1983. At this time, the wheat was in the late tillering stage, the rapeseed had several large leaves (the plants were approximately 15 cm tall), and the sunflowers were about 40 cm tall. Unfortunately, a herd of goats wandered into the area and destroyed the plots during the first week of December. The germination and growth of both grassy and broadleaf weeds in all of the treated

plots, and the reinfestation of the plots by C. rigidifolius daughter shoots from sedges bordering the treated areas was further evidence that the residual herbicidal activity of AC 252.925 was mostly dissipated by this time.

Sprouting of the C. rigidifolius basal bulbs collected from plots treated postemergence with 0.75 kg/ha of AC 252.925 did not occur. After 60 days in the germination chamber the basal bulbs were discarded because some were beginning to rot. It appears likely that this rate killed the entire C. rigidifolius plant, based upon the results of this sprouting trial, and the observed reinfestation of treated plots from the edges inward. Published results of experiments involving several perennial weeds treated with AC 252.925, including C. rotundus, stated that the underground storage organs were killed by translocation of AC 252.925 (Anonymous, 1983a).

Glufosinate. Glufosinate was not very effective in controlling C. usitatus var. usitatus. At least 2.0 kg/ha of glufosinate was required to obtain acceptable control of young C. usitatus var. usitatus plants (Table 5.7). Glyphosate, applied at 1.08 kg/ha, gave a degree of control equivalent to 1.5 to 2.0 kg/ha of glufosinate.

The degree of sedge control obtained with glufosinate was highly rate dependent - it ranged from negative control, an actual increase in sedge shoots in plots treated with 0.5 kg/ha of glufosinate, to a 90% reduction in sedge shoots, compared to the check, in the 2.5 kg/ha glufosinate treatment. Sedges growing in the plots treated with 0.5 kg/ha of glufosinate did not have to compete with other plants for sunlight, moisture, and nutrients because most of the broadleaf weeds

TABLE 5.7. Control of C. usitatus var. usitatus plants in the field with postemergent applications of glufosinate.

Herbicide	Rate (kg/ha)	Sedge control[1.] (visual)	Sedge shoot count means (m^2)[2.]
none	-	9	50 c
glufosinate	0.5	9	70 d
	1.0	6	23 b
	1.5	5	11 ab
	2.0	4	8 ab
	2.5	3	5 a
glyphosate	1.08	4	10 ab

1. EWRC visual rating system.

2. Treatment means followed by the same letter do not differ at the 5% level (Duncan's Multiple Range Test).

originally present in these plots were killed by the glufosinate treatment (whereas most of the sedges were only slightly injured by this suboptimal rate of herbicide). It was quite dry by the end of May, 1983, and competition for moisture may have been a limiting factor in sedge growth and development in the check plots.

Pot Experiments

AC 252.925

C. esculentus. AC 252.925, even at the 0.25 kg/ha rate, effectively halted growth and development of *C. esculentus* shoots, including flowering shoots, within two weeks of application (Table 5.8). No new daughter shoots were produced following AC 252.925 application, although the basal one-third of the leaves of most shoots remained green. The scape and inflorescence of any flowering shoots (flowering at the time of application) did turn completely necrotic.

The inadvertent activation of the irrigation system in the Cage, one hour after AC 252.925 application, may partially be to blame for the observed slow kill of *C. esculentus*. The herbicidal control obtained in this experiment was a result of fast foliar uptake and lingering soil activity. The technical information report on AC 252.925 (Anonymous, 1983b) stated that in field trials conducted in Brazil, weed control in plots receiving heavy rainfall two hours after treatment was comparable to plots not receiving rain after application.

TABLE 5.8. Control of C. esculentus plants in pots with postemergent applications of AC 252.925.

Treatment[1.]	Plants[2.] per treatment	Assessment - 106 days after application: Control (%)	Shoots/ plant (no.)[3.]	Height[3.] (cm)
check	3	-	36	43
0.25 kg/ha	3	100	-	-
0.50 kg/ha	3	100	-	-

1. One hour after herbicide application approximately 20 to 30 mm of water was applied, over a two hour period, by the irrigation system.

2. The sedges were established from sprouted tubers or tuber halves. AC 252.925 was applied Jan. 17, 1984, and there were 15 shoots/plant, 2 flowering shoots/plant, 27 cm tall at this time (an advanced growth stage).

3. Surviving plants only. Data presented are averages.

C. teneristolon. The response of C. teneristolon to AC 252.925 was rate dependent (Table 5.9). The first shoot regrowth of plants treated with 0.25 kg/ha emerged mid-May, 1983, approximately 60 days after application, while the first regrowth of plants treated with 0.50 kg/ha emerged at the beginning of July, 1983. Regrowth of plants treated with 0.75 kg/ha did not occur.

The second 0.25 kg/ha AC 252.925 application, applied July 11, 1983 to shoot regrowth, resulted in greatly reduced control as compared to the original 0.25 kg/ha treatment. There was a short period of time after the original 0.25 kg/ha treatment when green shoots were not present. This total above ground kill was never attained following the 0.25 kg/ha re-application, because as the treated green shoots were dying and desiccating (the first regrowth), new shoots (re-regrowth) were emerging. AC 252.925 affected the regrowth of C. teneristolon as shoot regrowth was not as robust nor as tall as the shoot growth of the check plants.

Wheat was planted in the 0.50 and 0.75 kg/ha treatments on July 28, 1983 (132 days after AC 252.925 application). Extensive herbicidal injury was evident by the time the wheat reached the two to three leaf stage. Injury symptoms included severe stunting, chlorosis of the leaves, and splitting or branching of the culm. Growth and development of the wheat past the three leaf stage did not occur, instead, wheat plants became chlorotic and then necrotic.

Shoot regrowth of all three C. teneristolon plants treated with 0.50 kg/ha of AC 252.925 was present by mid-August, 1983. Other plants growing in these pots at this time included Gallant Soldier (Galinsoga parviflora), Green Cudweed (Gnaphalium purpureum), and a Digitaria spp.

TABLE 5.9. Control of C. teneristolon plants (from Njoro) in pots with postemergent applications of AC 252.925.

Treatment	Plants[1.] per treatment	Date of herbicide application[2.]	Assessments: July 11/83 Control (%)	July 11/83 Shoots/plant (no.)[3.]	July 11/83 Height[3.] (cm)	Feb. 15/84 Control (%)	Feb. 15/84 Shoots/plant (no.)	Feb. 15/84 Height (cm)
check	4	-	-	90	35	-	senesced after flowering	
0.25 kg/ha + 0.25 kg/ha[4.]	4	March 18/83 July 11/83	0	65	8	0	107	11
0.50 kg/ha	3	March 18/83	33	15	4	0	52	15
0.75 kg/ha	3	March 18/83	100	-	-	100	-	-

1. The sedges were established from transplants on Dec. 28, 1982.
2. On March 18, 1983 there were 45 shoots per plant, 18 cm tall (none flowering).
3. Surviving plants only. Data presented are averages.
4. The second 0.25 kg/ha application was applied after assessments were performed on July 11/83.

Vegetation was not present in the 0.75 kg/ha treatment until the end of September, 1983, when several seedlings of Green Cudweed emerged.

Wheat was planted in the 0.75 kg/ha treatment on January 6, 1984. Again, in all pots, the wheat exhibited severe injury symptoms and did not develop past the three leaf stage. All pots used in this experiment had watertight bottoms which prevented AC 252.925 residues from leaching, although only limited vertical and lateral movement in soil apparently occurs (Anonymous, 1983a).

Glyphosate

C. rigidifolius. Glyphosate gave complete control of young C. rigidifolius plants even at the low 0.72 kg/ha rate (Table 5.10). Shoot regrowth did not occur where plants were in an early growth stage at the time of application.

The two older C. rigidifolius plants involved in this experiment appeared to be more resistant to glyphosate's herbicidal properties than the younger plants. Postapplication shoot chlorosis of the older plants occurred more slowly than in younger plants. Complete shoot necrosis of the older plant in the 1.44 kg/ha glyphosate treatment did not occur, and vigorous shoot regrowth emerged approximately two months after application. The original herbicide application appeared to have no effect on the subsequent growth and development of these shoots. Approximately 70 days after application, all shoots of the older plant in the 2.16 kg/ha glyphosate treatment finally were 100% necrotic and shoot regrowth did not occur.

TABLE 5.10. Control of C. rigidifolius plants in pots with postemergent applications of glyphosate.

Treatment	Plants per treatment[1.]	Assessment - 104 days after application: Control (%)	Shoots/ plant (no.)[2.]	Height[2.] (cm)
check	4	-	15	35
0.72 kg/ha	4	100	-	-
1.44 kg/ha	4	75[3.]	14	28
2.16 kg/ha	4	100	-	-

1. The sedges were established from sprouted basal bulbs. Glyphosate was applied January 3, 1984. At time of application, the majority of the plants were in an early growth stage - three shoots/plant, 22 cm tall. Two plants (one in each of the 1.44 and 2.16 kg/ha treatments) were older - seven shoots/plant, 25 cm tall.

2. Surviving plants only. Data presented are averages.

3. The one older plant survived this treatment.

Researchers investigating the effect of timing of glyphosate application on the control of C. esculentus have reported conflicting results. Stoller et al. (1975) found C. esculentus to be more susceptible to glyphosate at the 4 - 6 leaf stage than at the 6 - 8 leaf stage. Boldt and Sweet (1974) reported that applications of glyphosate to young C. esculentus plants, less than 20 cm tall, were not as effective as applications to older plants.

The slow kill of the older C. rigidifolius plants, after glyphosate application in this experiment, was similar to results reported by McCue (1982) for C. esculentus. She applied 3.3 kg/ha of glyphosate, in a greenhouse experiment, to C. esculentus plants at different growth stages. Within three weeks of herbicide application, 30% of the young plants (2 - 5 cm tall at the time of application) had regrowth in the form of small, numerous shoots. Injury symptoms such as abnormal pigmentation of the leaves and stunting initially were present, but eventually the shoots grew normally. C. esculentus plants treated at the old growth stage (30 - 36 cm tall, just prior to tuber formation) had the least amount of shoot regrowth, although kill of the sprayed shoots was much slower than in young plants. Plants treated at the optimum growth stage (15 - 20 cm tall) became necrotic at a rate approximately midway between that exhibited by the other growth stages, and these plants also had some shoot regrowth.

C. esculentus. Only the highest rate of glyphosate, 2.16 kg/ha, gave complete control of four week-old (just beginning to flower) C. esculentus plants, with no shoot regrowth 115 days after application (Table 5.11). Each of the other two glyphosate treatments, 0.72 and

TABLE 5.11. Control of C. esculentus plants (from Menengai) in pots with postemergent applications of glyphosate.

Treatment	Plants per treatment[1.]	Assessment - 115 days after application: Control (%)	Shoots/ plant (no.)[2.]	Height[2.] (cm)
check	4	-	21	60
0.72 kg/ha	4	50	15	12
1.44 kg/ha	4	50	4	26
2.16 kg/ha	4	100	-	-

1. The sedges were established from transplants on May 4, 1983. The pots into which they were planted were filled with soil from Menengai. Glyphosate was applied May 23, and there were five shoots per plant, 20 cm tall (the primary shoot was just beginning to flower) at this time.

2. Surviving plants only. Data presented are averages.

1.44 kg/ha, gave 50% control with shoot regrowth present in two of the four plants 115 days after application. The shoot regrowth present was stunted and not as dense as the shoot growth of the check plants.

Other researchers have reported similar results. Stoller et al. (1975) found that rates of glyphosate near 2 kg/ha were required to obtain satisfactory control of C. esculentus in the field. Terry (1985) stated, in a review article, that based on the reports of many researchers the lowest dose of glyphosate required for reliable control is about 2.0 kg/ha. However, McCue (1982) did not obtain satisfactory control of C. esculentus in either the greenhouse or the field with 3.3 kg/ha of glyphosate.

At the termination of the experiment, the soil from each pot was individually washed through the wire screen (as outlined in Section IV) to collect the tubers that had been produced. An average of 134 mature tubers (brown exterior) per pot were collected from the check. There were approximately the same number of white, immature tubers in the check which were discarded.

Tubers were not found in any of the pots containing plants with complete shoot kill. Eight mature tubers were recovered from one pot, and two immature tubers from the other pot, of the two pots in the 1.44 kg/ha glyphosate treatment containing shoot regrowth. The eight mature tubers were cut into halves, and placed in petri dishes in the germination chamber. Ultimately, three of the sixteen tuber halves sprouted and were planted in pots, and further growth and development proceeded normally.

One pot did not contain any tubers, and 26 tubers of varying maturities were recovered from the other pot, of the two pots in the

0.72 kg/ha treatment containing shoot regrowth. The 26 tubers were cut into halves, and placed in petri dishes in the germination chamber. Ultimately, 21 of the 52 tuber halves sprouted and some were planted in pots. Again, further growth and development of sedge plants originating from these tuber halves was normal.

These results indicate that glyphosate apparently does not affect the growth of C. esculentus plants originating from tubers produced by postapplication shoot regrowth. However, it appears to be unlikely that tubers produced by postapplication regrowth, particularly when glyphosate was applied at rates above 0.72 kg/ha, are as viable as tubers produced by untreated plants (Section IV). McCue (1982) reported that of three different herbicides tested in the field, tubers collected from the glyphosate treatment (3.3 kg/ha) had the lowest percent sprout and the highest percent dormant. Surprisingly, she found that the percentage of dead tubers in the glyphosate treatment (18%) was not significantly different from the percentage of dead tubers in the other herbicide treatments, or in the cultivated treatment, but that the check had a significantly higher percentage of dead tubers (31%). She did not explain this result.

C. teneristolon. Satisfactory control of C. teneristolon plants from Njoro was not achieved, even at the highest rate of glyphosate applied, 2.16 kg/ha. However, split applications appeared to be more effective than single applications, and young plants were more susceptible to glyphosate than older plants (Tables 5.12 and 5.13).

The initial application of 0.72 kg/ha of glyphosate, using the spinning disc applicator, caused only temporary, slight chlorosis of

TABLE 5.12. Control of C. teneristolon plants (from Njoro), in pots with postemergent applications of glyphosate, at two growth stages.

Treatment	Plants[1] per treatment	Date of herbicide application[2]	June 10 assessment: Control (%)	Shoots/plant (no.)[3]	Height[3] (cm)
check	6	-	-	76	35
		EARLY			
0.72 kg/ha[4] + 0.72 kg/ha	4	Feb. 7 March 24	50	19	12
0.72 kg/ha + 0.72 kg/ha	6	Feb. 7 April 5	50	16	10
1.44 kg/ha	6	Feb. 7	67	63	20
2.16 kg/ha	6	Feb. 7	50	42	20
		ADVANCED			
0.72 kg/ha	4	April 5	0	52	15
1.44 kg/ha	4	April 5	0	23	10
2.16 kg/ha	4	April 5	0	20	10

1. The sedges were established from transplants on Dec. 28, 1982.

2. On Feb. 7 there were 23 shoots per plant, 12 cm tall. On April 5 there were 55 shoots per plant, 23 cm tall (a few shoots were just beginning to flower).

3. Surviving plants only. Data presented are averages.

4. This treatment was applied using the spinning disc applicator (Herbi). All other herbicide treatments were applied using the bicycle sprayer. The second treatment of the 0.72 + 0.72 kg/ha split application was applied when active shoot regrowth was observed.

TABLE 5.13. Control of C. teneristolon plants from two locations (Njoro and Menengai) in pots with postemergent applications of glyphosate.

		Assessments - 115 days after application					
		Njoro			Menengai		
Treatment	Plants[1.] per treatment	Control (%)	Shoots/ plant (no.)[2.]	Height[2.] (cm)	Control (%)	Shoots/ plant (no.)	Height (cm)
check	4	-	55	20	-	53	25
0.72 kg/ha	4	25	26	20	100	-	-
1.44 kg/ha	4	75	12	14	100	-	-
2.16 kg/ha	4	75	13	25	100	-	-

1. The sedges were established from transplants on May 4, 1983. The transplants were planted in pots filled with soil from the area where they were collected. Glyphosate was applied May 23, and sedges from both locations had 3 shoots/plant, 12 cm tall at this time.

2. Surviving plants only. Data presented are averages.

the leaves of treated plants (Table 5.12). Prior to the second application, treated plants closely resembled the untreated plants of the check.

In contrast, the initial application of 0.72 kg/ha of glyphosate using the bicycle sprayer equipped with flat fan nozzles, resulted in the death of 75% of the shoots of the treated plants. At the time of the second application (April 5), these plants had 90% fewer shoots, and these shoots were half as tall, as compared to the check plants.

The second application of 0.72 kg/ha of glyphosate to the previously treated plants resulted in greatly increased control - the death of 50% of the treated plants. The plants in the treatment applied with the spinning disc applicator changed from resembling the check (45 days after the first application of 0.72 kg/ha of glyphosate) to resembling the early growth stage plants treated with a single application of 2.16 kg/ha of glyphosate (78 days after the second application of 0.72 kg/ha). Overall control of plants in the split application treatments was somewhat superior to that obtained in the treatment involving a single application, to plants in an early stage of growth, of 2.16 kg/ha of glyphosate.

The single application treatments of 1.44 and 2.16 kg/ha of glyphosate, to plants in an early growth stage, resulted in the death of 67% and 50% of the plants, respectively. Although the higher rate resulted in a lower percentage control rating, plants that survived the 2.16 kg/ha treatment had 30% fewer shoots than plants that survived the 1.44 kg/ha treatment, at the termination of the experiment. Also, shoots sprayed with the 2.16 kg/ha rate of glyphosate generally became chlorotic and necrotic more quickly than shoots sprayed with 1.44 kg/ha.

Glyphosate did not give effective control of C. teneristolon plants in an advanced stage of growth, at any of the rates used (Table 5.12). The highest rate applied, 2.16 kg/ha, killed approximately 50% of the shoots, but did not cause the death of any of the treated plants. Shoots that survived the herbicide application exhibited temporary chlorosis and moderate stunting. However, differences between treated plants, related to the rate of glyphosate applied, were apparent at the termination of the experiment. The plants treated with 0.72 kg/ha had approximately twice as many shoots, and these shoots were taller, than plants treated with 1.44 or 2.16 kg/ha of glyphosate. The 1.44 and 2.16 kg/ha treatments were similar in appearance.

Young (three week-old) C. teneristolon plants from Njoro were more susceptible to glyphosate than older plants, as single applications of 1.44 and 2.16 kg/ha resulted in the death of 75% of these plants (Table 5.13). Glyphosate gave complete control of young C. teneristolon plants from Menengai, at all three rates used, in contrast to the partial control of C. teneristolon plants from Njoro. In appearance and growth habit C. teneristolon plants from the two sites were identical, but plants from Njoro displayed greater resistance to the herbicidal activity of glyphosate.

C. usitatus var. usitatus. The response of young C. usitatus var. usitatus plants to glyphosate application was dependent upon the rate used. The lowest rate, 0.72 kg/ha of glyphosate, resulted only in temporary, slight chlorosis of the shoots. Glyphosate at 1.44 kg/ha killed 75% of the treated plants, and 2.16 kg/ha gave complete control (Table 5.14). Where complete control was not obtained, sublethal rates

TABLE 5.14. Control of C. usitatus var. usitatus plants in pots with postemergent applications of glyphosate.

Treatment	Plants[1.] per treatment	Assessment - 115 days after application: Control (%)	Shoots/ plant (no.)[2.]	Height[2.] (cm)
check	4	-	4	20
0.72 kg/ha	4	0	8	20
1.44 kg/ha	4	75	10	14
2.16 kg/ha	4	100	-	-

1. The sedges were established from transplants on May 4, 1983. Glyphosate was applied May 23, and there were two shoots/plant, 7 cm tall at this time.

2. Surviving plants only. Data presented are averages.

TABLE 5.15. Control of C. teneristolon plants (from Njoro) in pots with a postemergent application of glufosinate.

Treatment	Plants[1.] per treatment	Assessment - 60 days after application: Control (%)	Shoots/ plant (no.)[2.]	Height[2.] (cm)
check	4	-	70	30
2.0 kg/ha	4	0	50	20

1. The sedges were established from transplants on Dec. 28, 1982. Glufosinate was applied March 18, 1983, and there were 45 shoots/plant, 18 cm tall (an advanced growth stage) at this time.

2. Data presented are averages.

of glyphosate appeared to stimulate C. usitatus var. usitatus shoot regrowth. Plants treated with 0.72 kg/ha of glyphosate had twice as many shoots as the check plants, 115 days after application.

Glufosinate

C. teneristolon. Temporary chlorosis of the shoots and subsequent slight stunting were the only visible effects resulting from the application of 2.0 kg/ha of glufosinate to C. teneristolon plants in an advanced stage of growth (Table 5.15). Sixty days after treatment, the treated plants closely resembled the untreated check plants, although the treated plants had 30% fewer shoots, and these shoots were shorter than the check plants. Glufosinate, like glyphosate, may be more effective against young C. teneristolon plants.

Bentazon and Bentazon + Dichlorprop

C. rigidifolius. Satisfactory control of young C. rigidifolius plants was not obtained with bentazon or bentazon + dichlorprop (Table 5.16). The treatments involving only bentazon resulted in better control than the bentazon + dichlorprop treatments, though. Due to formulation differences, the amounts of bentazon applied in the bentazon only treatments were greater than the amounts of bentazon applied in the bentazon + dichlorprop treatments. It is probable, therefore, that dichlorprop possesses little, if any, herbicidal activity against C. rigidifolius, and that the injury symptoms observed were caused by bentazon.

TABLE 5.16. Control of C. rigidifolius plants in pots with postemergent applications of bentazon and bentazon + dichlorprop.

Treatment	Plants per treatment[1.]	Assessment - 52 days after application: Control (%)	Shoots/plant (no.)[2.]	Height (cm)[2.]
check	4	-	12	32
bentazon 2.40 kg/ha	4	50	9	26
bentazon 3.36 kg/ha	4	50	10	27
bentazon 1.30 kg/ha + dichlorprop 1.70 kg/ha	4	25	6	25
bentazon 1.82 kg/ha + dichlorprop 2.38 kg/ha	4	0	8	27

1. The sedges were established from sprouted basal bulbs. The herbicides were applied Feb. 23, 1984, and there were three shoots/plant, 13 cm tall at this time.

2. Surviving plants only. Data presented are averages.

Bentazon, at the 2.40 and 3.36 kg/ha rates, killed the above ground portion of C. rigidifolius shoots, but did not prevent shoot regrowth from the basal bulbs in half of the treated plants. This shoot regrowth was normal and appeared to be unaffected by the herbicide treatment. The lower rates of bentazon, applied in the bentazon + dichlorprop treatments, caused only partial chlorosis of the majority of the treated shoots. The production of new leaves resumed seven to ten days after herbicide application and these plants quickly regained their green colour.

C. esculentus. Experiments investigating the control of C. esculentus using only bentazon were not conducted.

Bentazon + dichlorprop gave complete control of C. esculentus plants in an early stage of growth, when applied at rates of 1.30 + 1.70 kg/ha (respectively) or more (Table 5.17). The lowest rate, 0.78 + 1.02 kg/ha, did not give adequate control. The youngest shoots in the 0.78 + 1.02 kg/ha treatment became completely necrotic within one week of herbicide application, but the older shoots (8 cm tall or taller) did not. Within two weeks of herbicide application, these older shoots resumed the production of new leaves and normal growth.

In contrast, 1.30 + 1.70 kg/ha of bentazon + dichlorprop was ineffective when applied to C. esculentus plants in an advanced growth stage. Only the smallest shoots and the inflorescences present became completely necrotic. The majority of the shoots of the treated plants exhibited only temporary chlorosis and the death of two or three leaves, and then resumed growth.

TABLE 5.17. Control of C. esculentus plants, in pots with postemergent applications of bentazon + dichlorprop, at two growth stages.

Treatment[1]	Plants per treatment[2]	Date of herbicide application[3]	March 30 assessment: Control (%)	Shoots/ plant (no.)[4]	Height (cm)[4]
check	4	-	-	38	40
		EARLY			
0.78 + 1.02 kg/ha	4	Nov. 22/83	25	24	37
1.30 + 1.70 kg/ha	4	Nov. 22/83	100	-	-
1.82 + 2.38 kg/ha	4	Nov. 22/83	100	-	-
		ADVANCED			
1.30 + 1.70 kg/ha	4	Jan. 3/84	0	31	26

1. The rates are bentazon and dichlorprop, respectively.

2. The sedges were established from sprouted tuber halves.

3. On Nov. 22, 1983 there were three shoots per plant, 12 cm tall. On Jan. 3, 1984 there were 20 shoots per plant, two flowering shoots per plant, 28 cm tall.

4. Surviving plants only. Data presented are averages.

These results are similar to what Stoller et al. (1975), working in the U.S.A., reported. They found that young C. esculentus plants were more susceptible to bentazon than older plants. They obtained a maximum of 90% control of C. esculentus plants in the field, with an application of 3.4 kg/ha of bentazon. McCue (1982) reported that 1.1 kg/ha of bentazon gave erratic control of C. esculentus plants regardless of plant age and whether the experiment was conducted in the greenhouse or in the field. It is likely that 1.1 kg/ha of bentazon is too low a rate to obtain satisfactory, consistent control of C. esculentus.

Conclusions

The selective herbicides, EPTC, butylate, alachlor, and metolachlor, gave effective control of C. teneristolon and C. rigidifolius present in sunflowers. The thiocarbamate herbicides (ppi), EPTC and butylate, gave excellent early season control, but their activity began to dissipate approximately two months after application. In contrast, the chloroacetamide herbicides (pre), alachlor and metolachlor, began to have some effect one month after application and were active for approximately four months.

The delay in the activation of the chloroacetamide herbicides was due to the interaction of the application technique, preemergence (not incorporated), and the abnormally dry weather immediately following application in both 1982 and 1983. The thiocarbamate herbicides were incorporated within minutes of application and appeared to be active and effective immediately.

Minimum dosages of 3 kg/ha of EPTC or butylate, and 4 to 5 kg/ha of alachlor or metolachlor were required to obtain acceptable control of C. teneristolon and C. rigidifolius in sunflowers. Differences between the herbicidal activities of EPTC and butylate were not evident, but this was not the case for alachlor and metolachlor. Metolachlor was active against a wider spectrum of both grassy and broadleaf weeds, and also appeared to be somewhat more persistent than alachlor.

A reduction in sedge weed competition due to the use of herbicides generally resulted in an increase in the fresh weight of sunflowers in both 1982 and 1983, although these increases were not significant in most instances. Fresh weights significantly heavier than the check were recorded only in 1983 and only in the alachlor and metolachlor treatments.

The non-selective herbicide, AC 252.925, gave remarkably effective, season long control (approaching 100%) of C. rigidifolius plants of varying maturities when applied as a single postemergence treatment at rates of 0.50 kg/ha or more. It displays greater activity against this sedge weed than glyphosate does, as 0.50 kg/ha of AC 252.925 gave better control than 1.44 kg/ha of glyphosate. AC 252.925 kills very slowly with treated sedge shoots requiring about 100 days after a postemergence application to become completely necrotic. AC 252.925 is soil active and persistent as plants did not emerge in plots treated with a single postemergence application of 0.50 kg/ha (or more) for approximately two months, although treated sedge weeds slowly becoming necrotic were present.

AC 252.925, despite its soil activity, was not very effective when applied preemergence. A preemergence application of 1.0 kg/ha resulted

in a measure of control equivalent to that of 0.25 kg/ha applied postemergence.

The herbicidal activity of AC 252.925 was diminished when a low volume, controlled droplet, spinning disc applicator (Herbi) was used. This loss of herbicidal efficacy, compared to the same rate conventionally applied, was also observed in an experiment where the spinning disc applicator was used to apply 0.72 kg/ha of glyphosate to C. teneristolon plants growing in pots. It is likely that the combination of the narrow, vertically oriented leaves of sedges and the lack of any downward momentum (other than that caused by gravity) of spray droplets from a spinning disc applicator reduces herbicidal efficacy. The increased control resulting from conventional, hydraulic pressure spray applications may be due to the fact that the conventional type of sprayer forces the herbicide droplets down into the axils of sedge leaves.

AC 252.925 activity was not affected by differences in carrier volume, as applied by a conventional, hydraulic pressure sprayer equipped with flat fan nozzles (79, 231, 317, and 634 L/ha total spray volume). It may be possible to reduce conventionally applied carrier volume below 79 L/ha and still obtain excellent herbicidal activity.

C. esculentus plants growing in pots were very susceptible to AC 252.925, as the growth of plants was arrested by a single, postemergence application of 0.25 kg/ha of AC 252.925.

In an experiment involving C. teneristolon plants growing in pots, 0.75 kg/ha postemergence of AC 252.925 gave complete, long term control. The 0.25 + 0.25 kg/ha (split application) and 0.50 kg/ha treatments did not prevent the regrowth of treated sedge plants.

Wheat, planted in the pots in the 0.75 kg/ha treatment 42 weeks after AC 252.925 application, exhibited severe injury symptoms - an indication of the soil activity and persistence of this herbicide.

In the field, the initial six weeks of growth and development of wheat, rapeseed, and sunflowers in plots treated four months previously with a postemergence application of AC 252.925 (up to 1.0 kg/ha) was normal. This bioassay trial unfortunately was terminated approximately 45 days after planting.

Satisfactory control of young C. usitatus var. usitatus plants in the field was obtained by applications of 2.0 kg/ha (or more) of glufosinate. Glufosinate was not as active as glyphosate against C. usitatus var. usitatus plants.

Glufosinate, applied at 2.0 kg/ha to C. teneristolon plants (from Njoro) in an advanced growth stage in pots, was ineffective. Glyphosate also did not control these plants. However, shoot regrowth in the 1.44 and 2.16 kg/ha glyphosate treatments was stunted.

Glyphosate was more effective when applied to young C. teneristolon plants (from Njoro) growing in pots. A single application of 0.72 kg/ha killed 25% of the plants, while single applications of 1.44 and 2.16 kg/ha killed 50% to 75% of the treated plants. Split applications of 1.44 kg/ha (total) killed 50% of the plants. Plants were recorded as killed if shoot regrowth did not occur.

Young C. teneristolon plants from Menengai, growing in pots, were all killed with a single application of 0.72 kg/ha of glyphosate. The 1.44 and 2.16 kg/ha treatments also gave complete kill. C. teneristolon plants from the two locations, Njoro and Menengai, did not differ in appearance or growth habit. The different responses of these plants to glyphosate may be ecotypic.

Young C. rigidifolius plants, growing in pots, were killed by the application of 0.72 kg/ha of glyphosate. The 1.44 and 2.16 kg/ha treatments also gave complete kill of young C. rigidifolius plants. Older C. rigidifolius plants were more resistant to glyphosate, and rates of at least 2.16 kg/ha were required. Chlorosis and necrosis of the treated shoots of older plants occurred more slowly than in younger plants.

At least 2.16 kg/ha of glyphosate was required to give complete kill of relatively young (beginning to flower) C. esculentus plants growing in pots. The 0.72 and 1.44 kg/ha treatments killed 50% of the plants.

Glyphosate at 2.16 kg/ha also was required to give complete kill of young C. usitatus var. usitatus plants growing in pots. The 1.44 kg/ha treatment killed 75% of the plants, and the 0.72 kg/ha treatment was ineffective.

Bentazon, even when applied at 3.36 kg/ha, did not give acceptable control of young C. rigidifolius plants growing in pots. Bentazon + dichlorprop gave poorer control than bentazon only, but this decrease in efficacy probably was the result of the decrease in the actual amount of bentazon applied in these treatments, as compared to the bentazon only treatments.

Bentazon + dichlorprop at 1.30 + 1.70 kg/ha, respectively, or at higher rates, gave complete kill of relatively young (beginning to flower) C. esculentus plants growing in pots. However, this treatment was ineffective when applied to advanced growth stage C. esculentus plants. Bentazon only treatments were not applied to C. esculentus plants.

VI SUMMARY AND CONCLUSIONS

Five sedge species, Cyperus rigidifolius Steud., Cyperus esculentus L., Cyperus teneristolon Mattf. & Kuk., Cyperus usitatus Burch. var. usitatus, and Bulbostylis schimperiana (A. Rich.) C.B.Cl., were identified as weeds commonly occurring in fields in the highland areas of Kenya. C. rigidifolius, C. esculentus, and C. teneristolon are the most competitive of these species and pose the greatest threat to crop yields and production. B. schimperiana is a very small, annual sedge weed that does not appear to affect the growth of crops. Positive identification of nonflowering sedges is difficult, but is possible with the careful examination of below-ground plant parts. It is important to know which sedge species are present early in the growing season (or, preferably, to know which sedges were present in previous years) so that appropriate control measures, including in-crop spot treatments, can be performed.

Achenes (seeds) apparently do not play an important role in the spread of C. rigidifolius, C. esculentus, C. teneristolon, and C. usitatus var. usitatus, as plants originating from achenes were not observed. Achenes of C. rigidifolius, C. esculentus, and C. teneristolon were tested and did not germinate. Each of these four sedge species has a characteristic vegetative propagule. These propagules were mostly dormant after collection, except for C. teneristolon rhizome pieces which readily sprouted. All possible

storage conditions and durations were not investigated using these propagules, although moist storage under cool or room temperature conditions induced or reinforced dormancy in C. esculentus tubers.

A desiccation pretreatment was required to stimulate sprouting of the basal bulbs of C. rigidifolius plants. Basal bulbs were left to dry on a shelf for 24 hours prior to being placed in petri dishes. This desiccation pretreatment which stimulated sprouting may be analogous to field conditions during the dry season in Kenya.

Whole C. esculentus tubers and whole C. usitatus var. usitatus bulbs only occasionally sprouted. Satisfactory sprouting of C. esculentus tuber halves, derived from freshly collected tubers cut longitudinally into halves and placed with the uncut side resting on moist filter paper in petri dishes, occurred. Cutting C. usitatus var. usitatus bulbs into halves was the only treatment that reliably stimulated sprouting, although the percentage of halves that sprouted was still quite low - a maximum of 25% sprouting occurred. C. esculentus tubers and C. usitatus var. usitatus bulbs appear to require aeration of the interior tissues to sprout. It is possible that these propagules do not sprout in the field until sufficient abrasion or decay of the outer coverings has occurred.

C. teneristolon rhizome pieces possessing a swollen area sprouted readily in germination tests. The sprout originated from this swollen area, and both in the field and in germination tests only rhizome pieces with a swollen area sprouted.

The soil active, selective herbicides, EPTC, butylate, alachlor, and metolachlor had a minimal effect on established C. rigidifolius patches, and appeared to only delay the emergence of C. teneristolon

plants for several months. However, the absence of sedge weed competition during the crucial seedling and establishment stages of the sunflowers generally resulted in increased fresh weight of mature sunflower plants. The chloroacetamide herbicides, alachlor and metolachlor, should preferentially be used to selectively control sedge weeds in sunflowers in Kenya due to their wider spectrum of activity, superior persistence, and soil conserving method of application (preemergence, no incorporation).

Bentazon + dichlorprop gave good control of young C. esculentus plants growing in pots, but was ineffective when applied to older plants. Satisfactory control of C. rigidifolius plants growing in pots was not achieved with bentazon or bentazon + dichlorprop applications. Bentazon is a selective, postemergence herbicide with activity against some sedges, that can be used in small grains, and because these properties are unique further investigations are warranted.

AC 252.925 was the most active of the three non-selective herbicides tested - the other non-selective herbicides were glyphosate and glufosinate. Postemergence applications of 0.75 kg/ha of AC 252.925 killed C. rigidifolius plants in the field (a range of growth stages were present), and C. teneristolon plants in an advanced vegetative growth stage in pots. The growth of flowering C. esculentus plants in pots was halted for the duration of the experiment, 15 weeks, by a postemergence application of 0.25 kg/ha of AC 252.925. The activity of AC 252.925 was diminished when it was applied using a low volume, spinning disc applicator.

AC 252.925 is soil active and persistent, but treatments applied preemergence were not as effective as postemergence applications. In

the field, herbicidal activity had mostly dissipated four months after application. AC 252.925 appears to be particularly useful in the control of C. rigidifolius patches in cultivated fields. C. rigidifolius does not produce tubers or bulbs underground, hence, eradication of patches of this sedge weed might be accomplished with two to three applications of AC 252.925 in consecutive growing seasons.

Most of the experiments with glyphosate involved application to sedges growing in pots; established sedge weeds in the field may be more resistant to glyphosate's herbicidal activity. In general, glyphosate was most effective when applied at a high rate (2.16 kg/ha) to sedges in an early stage of growth. Young C. rigidifolius plants growing in pots were killed by an application of 0.72 kg/ha of glyphosate, but satisfactory control of older C. rigidifolius plants in the field was not obtained with 1.44 kg/ha. C. esculentus plants that were beginning to flower were killed by 2.16 kg/ha of glyphosate. This rate, 2.16 kg/ha, also was required to kill young C. usitatus var. usitatus plants. Satisfactory control of C. teneristolon plants from Njoro was not achieved with 2.16 kg/ha, although young plants were more affected than older plants. Young C. teneristolon plants from Menengai were killed by an application of 0.72 kg/ha of glyphosate. The differing susceptibilities of C. teneristolon plants from the two locations to glyphosate may be an inherent characteristic of each population.

Glufosinate was not particularly active against sedge weeds, as 2.0 kg/ha was required to control young C. usitatus var. usitatus plants in the field. C. teneristolon plants in an advanced vegetative growth stage in pots were only slightly affected by the application of 2.0 kg/ha of glufosinate.

VII SUGGESTIONS FOR FURTHER WORK

- Some of the germination experiments involving the propagative structures of sedge weeds should be repeated in order to confirm results obtained in this study, and to generate data that can be statistically analyzed. If possible, the approximate age of the propagative structures used in germination experiments should be determined, and the prevailing environmental conditions during the period of their formation and maturation should be recorded.

- Germination tests involving large numbers of achenes, collected from C. rigidifolius, C. esculentus, C. teneristolon, and C. usitatus var. usitatus plants growing in a number of locations in the Kenyan highlands, could be conducted. The results of these germination tests should give some indication as to the importance or potential importance of achenes in the dissemination of these sedges.

- Experiments to determine the effects of sedge weed competition on the growth and yield of small grain crops (primarily wheat) should be conducted. In conjunction with these studies, selective control of sedge weeds in the field using bentazon could be investigated.

- Cultural practices for the control of sedge weeds, such as mowing or tillage, should be investigated. Intensive cultivation in the dry

season of C. rigidifolius patches might be a very effective control measure.

- Experiments to determine the persistence of AC 252.925 in soil and the effect of residues on following crops should be conducted. A particularly attractive practice, if soil residues are not a problem, would be the application of AC 252.925 to sedge weeds during the "short rains", with the subsequent planting of a crop at the beginning of the next "long rains" (or growing season).

LIST OF REFERENCES

Andersen, R.N. 1968. Germination and Establishment of Weeds for Experimental Purposes. W. F. Humphrey Press Inc., Geneva, New York, pp. 1-7 and 56-58.

Andrews, F.W. 1940. A Study of Nutgrass (Cyperus rotundus L.) in the Cotton Soil of the Gezira. 1. Maintenance of life in the tuber. Ann. Bot. 4:177-193.

Anonymous. 1982. Product information - Basagran. BASF AG.

Anonymous. 1983a. AC 252.925 - Broad-spectrum herbicide for industrial sites and railways. Technical information report, American Cyanamid Co.

Anonymous. 1983b. Arsenal - for use in rubber and oil palm plantations. Technical information report, American Cyanamid Co.

Anonymous. 1983c. Product information - Hoe 39866, glufosinate-ammonium. Hoechst AG.

Armstrong, T.F., W.F. Meggitt, and D. Penner. 1973. Yellow nutsedge control with alachlor. Weed Sci. 21:354-357.

Ashton, F.M., and A.S. Crafts. 1973. Mode of Action of Herbicides. John Wiley and Sons, New York, pp. 91-117 and 303-327.

Australian Weeds Committee. 1979. Guidelines for the Field Evaluation of Herbicides. Australian Govt. Pub. Service, Canberra.

Banks, P.A. 1983. Yellow nutsedge (Cyperus esculentus) control, regrowth, and tuber production as affected by herbicides. Weed Sci. 31:419-422.

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. 1. Nutgrass. Northeast Region. Publ. Rhode Island Agr. Exp. Sta. Bull. 364.

Bendixen, L.E. 1973. Anatomy and sprouting of yellow nutsedge tubers. Weed Sci. 21:501-503.

Black, C.C., Jr., T.M. Chen, and R.H. Brown. 1969. Biochemical basis for plant competition. Weed Sci. 17:338-344.

Boldt, P.F., and R.D. Sweet. 1974. Glyphosate studies on yellow nutsedge. Proc. NEWSS 28:197-203.

Bundy, O.M., W.F. Donnalley, and E.M. Rahn. 1960. Growth and development of northern nutgrass as affected by certain environmental conditions. NEWSS Abstr. 14:44.

Chapman, L.S. 1966. Prolific nutgrass growth. Cane Growers Quarterly Bulletin 30:16.

Chase, R.L., and A.P. Appleby. 1979. Effects of humidity and moisture stress on glyphosate control of Cyperus rotundus L. Weed Res. 19:241-246.

Costa, J., and A.P. Appleby. 1976. Response of two yellow nutsedge varieties to three herbicides. Weed Sci. 24:54-58.

Cruz, R., C. Romeo, and J. Cardenas. 1969. Control of Cyperus rotundus in Sinu Valley. Fiziologia Vegetal (COMALFI) Bogota, pp. 60-61.

Cunningham-van Someren, G.R. 1974. What do workers mean by "control" of Cyperus spp.? A question of interpretation. Proc. 5th East African Herbicide Conf., Nairobi, Kenya.

Day, B.E., and R.C. Russell. 1955. The effect of drying on survival of nutgrass tubers. California Agric. Expt. Sta. Bull. 751.

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. 28:229-233.

Friedman, T., and M. Horowitz. 1970. Phytotoxicity of subterranean residues of three perennial weeds. Weed Res. 10:382-385.

Hafliger, E., and U. Kuhn. 1982. Monocot Weeds 3. Documenta Ciba-Geigy, Ciba-Geigy Ltd., Basel, Switzerland.

Haines, R.W., and K.A. Lye. 1983. The Sedges and Rushes of East Africa. East African Natural History Society, Nairobi, Kenya.

Harper, J.L. 1977. Population Biology of Plants. Academic Press, New York, pp. 151-381.

Hauser, E.W. 1962a. Establishment of nutsedge from space planted tubers. Weeds 10:209-212.

Hauser, E.W. 1962b. Development of purple nutsedge under field conditions. Weeds 10:315-321.

Holm, L.G., D. L. Plucknett, J.V. Pancho, and J.P. Herberger. 1977. The World's Worst Weeds: Distribution and Biology. University Press of Hawaii, pp. 8-24 and 125-133.

Holt, E.C., J.A. Long, and W.W. Allen. 1962. The toxicity of EPTC to nutsedge. Weeds 10:103-105.

Horowitz, M., and T. Friedman. 1971. Biological activity of subterranean residues of Cynodon dactylon L., Sorghum halepense L., and Cyperus rotundus L. Weed Res. 11:88-93.

Jaworski, E.G. 1972. Mode of action of N-phosphonomethyl glycine: inhibition of aromatic amino acid biosynthesis. Agr. and Food Chem. 20:1195-1198.

Justice, O.L. 1956. Germination behavior in seeds of nutgrass (Cyperus rotundus L.). Assoc. Offic. Seed Anal. Proc. 46:67-71.

Justice, O.L. 1957. Germination, dormancy, and viability in seeds of certain weedy species of Cyperus. Assoc. Offic. Seed Anal. Proc. 47:167-174.

Justice, O., and M. Whitehead. 1946. Seed production, viability and dormancy in the nutgrasses, Cyperus rotundus and Cyperus esculentus. J. of Agric. Res. 73:303-318.

Keeley, P.E., and R.J. Thullen. 1974. Yellow nutsedge control with soil-incorporated herbicides. Weed Sci. 22:378-383.

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.

Langeluddeke, P., H.U. Reuss, C. Ceconi, T.H. Manning, and M. Rottele. 1983. Glufosinate (Hoe 39866), a new non-selective contact herbicide: results of several years' experimentation in orchards and vineyards from different European countries. Weed Absts. 32:319.

Looman, J., and K. F. Best. 1979. Budd's Flora of the Canadian Prairie Provinces. Canadian Govt. Pub. Centre, Hull, pp. 21-22.

Lorougnon, G. 1969. Etude morphologique et biologique de deux varietes de Cyperus esculentus Linn. (Cyperacees). Cah. ORSTOM, ser. Biol. 10:35-63.

McCue, A.S. 1982. The influence of environment and management of yellow nutsedge (Cyperus esculentus L.) tubers. Ph.D. Thesis, Cornell University, Ithaca, New York.

Moosavi-Nia, H., and J. Dore. 1979. Factors affecting glyphosate activity in Imperata cylindrica (L.) Beauv. and Cyperus rotundus L. II: effect of shade. Weed Res. 19:321-327.

Muniz, B.F., and R.S. Tames. 1982. Seasonal patterns of growth regulators in tubers of yellow nutsedge (Cyperus esculentus). Weed Sci. 30:83-86.

Napper, D.M. 1963. Cyperaceae of East Africa - I. J. E. Afr. Nat. Hist. Soc. 24(106):1-18.

Napper, D.M. 1964. Cyperaceae of East Africa - II. J. E. Afr. Nat. Hist. Soc. 24(109):23-46.

Napper, D.M. 1965. Cyperaceae of East Africa - III. J. E. Afr. Nat. Hist. Soc. 25(110):1-27.

Napper, D.M. 1966. Cyperaceae of East Africa - IV. J. E. Afr. Nat. Hist. Soc. 26(113):1-17.

Napper, D.M. 1971. Cyperaceae of East Africa - V. J. E. Afr. Nat. Hist. Soc. 28(124):1-24.

Nyahoza, F. 1973. Studies of the biology of Cyperus rotundus L. - early growth and vegetative reproduction strategy. E. Afr. Agric. For. J. 39:120-130.

Nyahoza, F. 1974. Studies of the biology of Cyperus rotundus L. - 2. Sprouting potentiality of the vegetative axillary buds. E. Afr. Agric. For. J. 39:258-264.

Obrigawitch, T., J.R. Abernathy, and J.R. Gipson. 1980. Response of yellow (Cyperus esculentus) and purple (Cyperus rotundus) nutsedge to metolachlor. Weed Sci. 28:708-715.

Palmer, R.D., and W.K. Porter, Jr. 1959a. The metabolism of nutgrass (Cyperus rotundus L.). I. The influence of various oxygen and carbon dioxide levels upon germination and respiration. Weeds 7:481-489.

Palmer, R.D., and W.K. Porter, Jr. 1959b. The metabolism of nutgrass (Cyperus rotundus L.). III. Polyphenoloxidase in the dormant tuber. Weeds 7:504-510.

Parker, C. 1972. Distinguishing Cyperus rotundus from some related species. PANS, Vol. 18, No. 4:477-482.

Parker, C., K. Holly, and S.D. Hocombe. 1969. Herbicides for nutgrass control - conclusions from ten years of testing at Oxford. PANS 15:54-63.

Plucknett, D.L., E.J. Rice, L.C. Burrill, and H.H. Fisher. 1976. Approaches to weed control in cropping systems. 1976 Cropping Systems Symposium, IRRI, Philippines.

Ranade, S.B., and W. Burns. 1925. The eradication of Cyperus rotundus L. India Dept. Agr. Mem. Bot. Series 13:99-192.

Rincon, D.J., and G.F. Warren. 1978. Effect of five thiocarbamate herbicides on purple nutsedge (Cyperus rotundus). Weed Sci. 26: 127-131.

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. of Am. Soc. of Agron. 29: 1007-1013.

Stoller, E.W. 1982. Yellow nutsedge: a menace in the corn belt. USDA Technical Bulletin No. 1642.

Stoller, E.W., and L.M. Wax. 1971. Longevity and seasonal sprouting characteristics of yellow nutsedge tubers. N. Cent. Wd. Control Conf. 26:84-85.

Stoller, E.W., and L.M. Wax. 1973. Yellow nutsedge shoot emergence and tuber longevity. Weed Sci. 21:76-81.

Stoller, E.W., D.P. Nema, and V.M. Bhan. 1972. Yellow nutsedge tuber germination and seedling development. Weed Sci. 20:93-97.

Stoller, E.W., L.M. Wax, and R.L. Matthiesen. 1975. Response of yellow nutsedge and soybeans to bentazon, glyphosate, and perfluidone. Weed Sci. 23:215-221.

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.

Taylorson, R.B. 1967. Seasonal variation in sprouting and available carbohydrate in yellow nutsedge tubers. Weed Sci. 15:22-24.

Terry, P.J. 1974. Long-term control of Cyperus rotundus with glyphosate. Proc. 5th E. Afr. Weed Control Conf., pp. 173-188.

Terry, P.J. 1976. Sedge weeds of East Africa. I - Identification. E. Afr. Agric. For. J. 42(2):231-249.

Terry, P.J. 1978. Sedge weeds of East Africa. II - Distribution. WRO Technical Report No. 50.

Terry, P.J. 1983. Personal communication.

Terry, P.J. 1985. "Efficacy of glyphosate for weed control in the tropics and sub-tropics" in The Herbicide Glyphosate, E. Grossbard and D. Atkinson editors. Butterworths, London, pp. 375-401.

Tharawanich, T., and D.L. Linscott. 1975. Factors influencing the effect of glyphosate on yellow nutsedge. Abstract, Proc. of the Northeastern Weed Sci. Soc., p. 132.

Thomas, P.E.L. 1967. A preliminary study on the dormancy of Cyperus esculentus tubers. PANS 13:329-333.

Thomas, P.E.L., and I.E. Henson. 1968. Influence of climate and soil moisture on tuber dormancy of Cyperus esculentus. PANS 14:271-276.

Thullen, R.J., and P.E. Keeley. 1975. Yellow nutsedge sprouting and resprouting potential. Weed Sci. 23:333-337.

Thullen, R.J., and P.E. Keeley. 1979. Seed production and germination in Cyperus esculentus and Cyperus rotundus. Weed Sci. 27:502-505.

Tumbleson, M.E., and T. Kommedahl. 1961. Reproductive potential of Cyperus esculentus by tubers. Weeds 9:646-653.

Tumbleson, M.E., and T. Kommedahl. 1962. Factors affecting dormancy in tubers of Cyperus esculentus. Bot. Gaz. 123:186-190.

Ueki, K. 1969. Studies on the control of nutsedge (Cyperus rotundus L.) on the germination of a tuber. Proc. 2nd Asian Pacific Weed Control Interchange, University of Philippines, pp. 1-12.

Vegis, A. 1969. Dormancy in higher plants. Ann. Rev. of Plant Phys. 15:185-224.

Wareing, P.F., and I.D.J. Phillips. 1981. Growth and Differentiation in Plants. 3rd Ed. Pergamon Press, Oxford, pp. 70-73.

Wareing, P.F., and P.F. Saunders. 1971. Hormones and dormancy. Ann. Rev. of Plant Phys. 22:261-288.

Williams, R.D. 1976. Purple nutsedge: tropical scourge. Hort. Sci. 11:357-364.

Williams, R.D., P.C. Quimby Jr., and K.E. Frick. 1977. Intraspecific competition of purple nutsedge (Cyperus rotundus) under greenhouse conditions. Weed Sci. 25:477-481.

Wills, G.D., and G.A. Briscoe. 1970. Anatomy of purple nutsedge. Weed Sci. 18:631-635.

Wills, G.D., R.E. Hoagland, and R.N. Paul. 1980. Anatomy of yellow nutsedge (Cyperus esculentus). Weed Sci. 28:432-437.

WSSA (Weed Science Society of America). 1983. Herbicide Handbook. 5th Ed. WSSA, Champaign, Illinois.

Yip, C.P. 1978. Yellow nutsedge (Cyperus esculentus L.) ecotypes, their characteristics and responses to environment and herbicides. Ph.D. Thesis, Cornell University, Ithaca, New York.

Zandstra, B.H., and R.K. Nishimoto. 1977. Movement and activity of glyphosate in purple nutsedge. Weed Sci. 25:268-274.

Zandstra, B.H., C.K.H. Teo, and R.K. Nishimoto. 1974. Response of purple nutsedge to repeated applications of glyphosate. Weed Sci. 22:230-232.

APPENDIX 1

Glossary Of Terms

Achene - a dry, indehiscent fruit.

Acropetal - from the base toward the apex, or from below upward.

Anatropous - having the ovule inverted at an early period in its development, so that the micropyle is bent down to the funicle (the stalk of an ovule), to which the body of the ovule is united.

Annual - plant completing its life-cycle within twelve months from germination.

Appressed - pressed close to, or lying flat against.

Axil - angle between scale leaf and rhizome or stolon.

Basal Bulb - subterranean organ found at the base of each sedge shoot (in some sedge species) that contains meristems for leaves, rhizomes, roots, and floral structures. Basal bulbs essentially consist of a short acropetal stem with compact nodes.

Basipetal - from the apex toward the base, or from above downward.

Bract - leaf-like appendage to the inflorescence.

Bulb - underground organ of storage and vegetative propagation consisting of a short stem bearing fleshy leaves or leaf bases with buds in their axils and scale leaves (e.g. onions have bulbs).

Creeping (of rhizome) - growing beneath the surface of the soil and producing shoots and roots at the nodes.

Filiform - threadlike.

Glume - dry bract partially enclosing a spikelet. There are two glumes per spikelet.

Head - dense inflorescence of small, crowded, usually sessile flowers.

Inflorescence - flowering shoot bearing more than one flower.

Lanceolate - flattened, widest in the middle and tapering to a point (i.e. spear-shaped).

Node - part of rhizome or stolon where shoots or new rhizomes and stolons are formed from buds enclosed in scale leaves.

Nut - an indehiscent, polycarpellary, one-seeded fruit, with a woody pericarp.

Nutlet - any small nutlike fruit or seed.

Perennial - plant living more than two years and flowering in each year when established.

Propagule - primary unit of propagation in plant species (e.g. seed, or tuber, or basal bulb, or bulb, or rhizome fragment).

Rachis - main axis of inflorescence.

Rhizome - elongated underground stem usually bearing buds in the axils of reduced scale leaves. Serves for perennation and propagation (i.e. survives for more than one season).

Scale leaf - membranous tough leaf which is usually smaller than normal leaves and is usually protective.

Sessile - lacking a stalk.

Shoot - above ground part of a plant which develops from a rhizome, stolon, tuber, bulb, seed, or stem base.

Spikelet - unit of inflorescence consisting of a central rachis bearing glumes and flowers.

Stolon - elongated underground stem bearing buds and scale leaves. New plants, tubers, or bulbs, are formed terminally. Unlike rhizomes they do not live for more than one season.

Tuber - swollen underground stem containing stored food and acting as an organ of perennation and vegetative propagation. Tubers possess minute scalelike leaves with buds in the axils (e.g. potatoes have tubers).

Tuberous - thickening and forming tubers.

Underground stem - rhizome or stolon.

Adapted from P.J. Terry (1976).

APPENDIX 2 Precipitation and temperature recorded at the National Plant Breeding Station, Njoro, Kenya, February 1982 to February 1984.

	February, 1982		March, 1982		April, 1982		May, 1982		June, 1982	
Date	Rain mm	Temperature Min. (°C) Max.	Rain mm	Temperature Min. (°C) Max.	Rain mm	Temperature Min. (°C) Max.	Rain mm	Temperature Min. (°C) Max.	Rain mm	Temperature Min. (°C) Max.
1		10.4 - 25.3		8.2 - 27.8		13.0 - 24.0	N.V.*	N.V. - N.V.	14.7	10.0 - 22.8
2		8.0 - 26.5		9.6 - 28.3	18.3	12.0 - 20.9	19.4	10.2 - 25.0		9.3 - 22.0
3		10.4 - 26.5		10.5 - 28.0		12.5 - 19.3	17.0	11.0 - 23.8	4.5	7.9 - 22.4
4		9.6 - 26.8		9.5 - 28.0	1.0	12.5 - 25.0	12.5	9.0 - 23.2		9.1 - 22.8
5		9.6 - 26.5		8.7 - 28.0	0.3	11.0 - 25.0		12.0 - 22.0		8.2 - 22.3
6		8.5 - 26.2	0.4	10.5 - 27.0		10.0 - 24.5	3.0	13.2 - 21.5		8.0 - 23.0
7		8.4 - 27.7		9.0 - 26.3		10.5 - 26.3		8.8 - 22.2		8.2 - 22.5
8		10.3 - 26.8	0.8	8.0 - 27.0	8.3	12.5 - 26.0		10.2 - 22.4		8.9 - 22.5
9		10.1 - 27.3		9.0 - 27.3	3.0	9.2 - 22.8		10.8 - 22.6		8.2 - 22.7
10	0.5	10.6 - 25.5		8.0 - 26.8		10.2 - 24.6		9.2 - 21.6		9.2 - 23.2
11		9.3 - 26.0		8.0 - 26.7	0.5	9.8 - 23.2	13.6	13.4 - 22.8	0.5	7.8 - 23.0
12		9.3 - 26.1		6.5 - 27.6	4.2	10.4 - 25.4	3.0	10.2 - 22.0		7.5 - 23.6
13		8.8 - 27.3		9.0 - 26.5		13.8 - 24.9	6.5	10.9 - 22.2		8.2 - 22.5
14		12.3 - 27.3		7.8 - 27.3		11.9 - 25.2		9.6 - 22.2	0.5	8.8 - 22.6
15	5.0	9.3 - 26.5		8.8 - 27.2	0.6	11.3 - 24.3		10.2 - 22.2	0.3	7.0 - 27.1
16	7.4	9.9 - 24.9		9.3 - 26.2	11.3	13.1 - 23.5		8.3 - 22.3		10.1 - 22.2
17	5.4	9.8 - 25.0		7.5 - 27.0	11.5	13.5 - 22.9	4.7	10.3 - 23.4	4.9	10.2 - 22.5
18	2.7	9.0 - 26.0		8.3 - 27.3	2.3	9.5 - 21.6	22.9	13.0 - 22.2	3.7	11.6 - 22.5
19		8.5 - 25.4		11.0 - 28.4	1.1	11.2 - 24.6	3.7	11.5 - 21.5		10.6 - 21.9
20		8.0 - 26.5		11.3 - 27.8	11.4	10.6 - 24.0	5.8	10.3 - 21.8		8.0 - 22.8
21		8.3 - 25.6		11.4 - 27.6	4.0	9.9 - 23.8	T	10.5 - 21.6	0.5	12.3 - 22.5
22		8.5 - 26.4	2.3	8.0 - 27.0	1.8	11.9 - 23.4	3.2	10.0 - 21.9	0.8	11.7 - 22.4
23		8.6 - 26.3		7.9 - 28.0		10.2 - 24.1	7.0	12.8 - 23.1		11.8 - 21.8
24		8.3 - 25.8		8.5 - 28.0	2.3	10.1 - 24.4	1.1	9.5 - 20.7	8.0	8.9 - 21.4
25		10.0 - 28.3		8.8 - 28.4	2.3	7.5 - 22.8		9.0 - 22.8	1.3	6.6 - 21.7
26		10.3 - 28.3		7.0 - 28.5	8.6	10.8 - 23.4		10.5 - 23.0		6.9 - 22.4
27		10.5 - 29.2		9.0 - 27.8	11.0	12.2 - 23.5	4.9	12.4 - 23.1		5.0 - 22.0
28		7.6 - 27.8		11.0 - 28.7	32.8	9.9 - 23.3	0.4	9.9 - 22.0		6.8 - 21.0
29			1.4	13.8 - 28.4	3.6	13.4 - 23.4		11.5 - 23.6	0.6	5.7 - 21.4
30				13.0 - 24.5	3.9	11.0 - 24.0	3.1	12.5 - 22.0		5.6 - 21.8
31				13.0 - 27.5			8.0	10.9 - 22.0		
Total	21.0		4.9		144.1		139.8		40.3	
Average		9.4 26.6		9.4 27.5		11.1 23.8		10.7 22.4		8.6 22.5

Appendix 2

Date	July, 1982 Rain mm	July, 1982 Temperature Min. (°C) Max.	August, 1982 Rain mm	August, 1982 Temperature Min. (°C) Max.	September, 1982 Rain mm	September, 1982 Temperature Min. (°C) Max.	October, 1982 Rain mm	October, 1982 Temperature Min. (°C) Max.	November, 1982 Rain mm	November, 1982 Temperature Min. (°C) Max.
1		5.5 - 20.1	16.8	7.8 - 24.3		7.9 - 23.4		6.8 - 22.6	0.5	10.6 - 21.5
2		5.5 - 21.8	36.3	12.0 - 22.6	0.6	7.4 - 23.0		6.5 - 23.1	17.0	13.4 - 21.2
3		8.5 - 23.8	1.0	10.8 - 20.0	0.9	8.2 - 24.3		6.6 - 23.2	8.3	13.5 - 21.4
4		11.0 - 23.0	13.1	8.0 - 20.8	4.2	10.2 - 23.5	0.4	5.2 - 22.8	8.5	9.8 - 21.4
5		6.6 - 22.6	22.8	8.0 - 21.4	0.4	8.5 - 23.5		6.4 - 23.7		10.0 - 22.1
6		6.4 - 21.3	8.6	7.4 - 21.6		7.0 - 23.2		7.8 - 24.4		9.9 - 23.9
7		11.6 - 22.6	3.8	6.8 - 22.3	3.2	7.1 - 23.4	0.3	7.5 - 23.5	1.3	10.3 - 23.3
8	1.4	8.0 - 22.2		7.0 - 21.6		6.0 - 23.0	1.3	7.0 - 24.7		11.6 - 23.4
9	8.3	6.4 - 21.8		6.8 - 22.5		7.2 - 23.3	1.3	7.8 - 23.3		11.0 - 21.3
10		8.4 - 21.8		7.0 - 22.0		7.0 - 23.0		7.3 - 23.6	T	11.6 - 22.3
11		7.0 - 22.0	3.4	8.2 - 21.4	0.4	8.2 - 23.4		8.9 - 23.9	T	9.2 - 23.2
12		8.0 - 23.0	11.3	10.1 - 24.9		6.0 - 22.7	1.0	12.5 - 21.7	12.4	9.6 - 22.0
13		6.5 - 22.7	38.5	11.5 - 22.0		7.0 - 23.6	0.2	7.0 - 21.0		9.0 - 22.2
14		7.1 - 23.2	6.5	10.8 - 20.3		8.1 - 24.6	0.1	11.0 - 24.0		10.0 - 21.6
15		11.4 - 22.7	20.6	11.9 - 18.1	1.0	13.3 - 21.8	0.7	10.5 - 24.4	15.0	11.8 - 21.6
16	6.0	6.3 - 22.8	13.7	12.3 - 19.8	0.2	11.6 - 21.2	0.2	7.4 - 23.4	6.3	10.8 - 20.5
17		10.5 - 22.0	0.3	12.2 - 20.3	2.5	9.3 - 22.7	1.9	13.0 - 21.5		9.8 - 20.8
18		8.5 - 22.0		8.9 - 21.0		7.6 - 23.7	8.5	12.5 - 18.8		12.6 - 21.5
19		5.4 - 23.0		8.8 - 21.2		7.6 - 23.0	37.8	10.5 - 21.3		9.2 - 18.2
20		5.1 - 22.7	12.3	7.4 - 21.4		8.7 - 24.0	12.1	7.3 - 19.9	1.0	11.4 - 20.6
21		5.5 - 23.8		8.0 - 23.1		12.3 - 23.6	3.6	11.3 - 21.3		8.3 - 20.3
22		7.0 - 22.9	0.2	8.0 - 21.6	2.3	8.8 - 22.7	9.3	10.8 - 18.8		9.0 - 22.9
23	2.3	7.8 - 22.8	3.7	9.0 - 22.1	9.7	12.0 - 22.8	1.6	9.8 - 21.8	5.0	8.8 - 22.5
24	7.6	10.8 - 22.6	0.5	9.8 - 21.1	1.3	7.4 - 21.3		8.0 - 21.2	0.6	13.7 - 22.8
25	T	8.3 - 19.3	12.5	7.0 - 21.4	1.9	6.8 - 22.0		9.3 - 19.6	0.5	9.5 - 22.0
26		6.9 - 21.1		7.5 - 21.7		11.3 - 22.0	1.3	8.5 - 22.1	9.5	11.8 - 22.0
27		6.5 - 21.9	1.0	9.4 - 22.5		6.3 - 22.6	T	10.5 - 23.3	13.2	10.2 - 20.6
28		6.2 - 22.6	4.0	6.6 - 21.6		7.5 - 23.3		8.5 - 22.8	3.2	12.5 - 21.4
29	0.4	8.2 - 23.8	16.6	7.1 - 21.6		6.5 - 23.4	0.4	11.1 - 24.0	24.8	8.3 - 18.3
30		7.0 - 24.5	0.4	7.3 - 22.4		8.0 - 23.1	12.0	12.5 - 20.5	7.3	12.1 - 20.3
31	T	8.4 - 24.4		6.9 - 22.5			0.4	13.2 - 22.3		
Total	26.0		247.9		28.6		94.0		134.4	10.6 21.6
Average		7.6 22.5		8.7 21.7		8.4 23.1		9.1 22.3		

Appendix 2

Date	December, 1982 Rain mm	December, 1982 Temperature Min. (°C) Max.	January, 1983 Rain mm	January, 1983 Temperature Min. (°C) Max.	February, 1983 Rain mm	February, 1983 Temperature Min. (°C) Max.	March, 1983 Rain mm	March, 1983 Temperature Min. (°C) Max.	April, 1983 Rain mm	April, 1983 Temperature Min. (°C) Max.
1	6.0	13.3 - 21.5	N.V.	8.3 - N.V.		10.5 - 24.3		10.0 - 28.0	0.7	10.6 - 26.6
2	22.1	12.5 - 21.7		9.3 - 23.7	0.8	11.0 - 26.8		8.9 - 28.0	2.4	10.4 - 25.3
3	2.6	12.5 - 21.5		6.0 - 22.8		14.2 - 26.3		8.0 - 27.5		10.5 - 24.0
4	2.8	12.5 - 21.5		6.2 - 23.2		11.7 - 24.0		10.1 - 27.0		10.0 - 28.3
5	1.6	12.8 - 22.3		8.0 - 23.5		11.5 - 25.1	4.7	10.1 - 27.2		11.0 - 27.5
6		8.4 - 21.4	1.7	11.0 - 23.5		8.0 - 25.3		10.0 - 26.4		10.3 - 27.3
7	1.3	11.5 - 20.4	14.0	10.0 - 23.5		7.4 - 25.8		9.0 - 27.0		9.5 - 28.0
8	6.6	11.8 - 20.6		6.8 - 22.3		6.9 - 26.0		9.5 - 28.4	1.6	10.0 - 27.5
9	0.2	8.0 - 21.0		7.6 - 23.1		7.1 - 25.8	0.5	10.0 - 29.0		9.0 - 22.5
10		7.6 - 22.0		7.7 - 22.7		9.5 - 27.0		10.4 - 23.6		9.2 - 25.6
11	1.6	9.5 - 20.9		7.0 - 23.3		11.9 - 27.0		10.1 - 25.8		10.0 - 27.0
12		10.9 - 21.8		5.9 - 22.6	14.6	10.8 - 23.8		10.9 - 29.0	2.7	10.0 - 27.4
13	6.8	12.3 - 22.3		8.3 - 22.3	1.2	10.8 - 19.7		11.5 - 28.6		11.0 - 25.5
14		8.4 - 20.3		7.0 - 23.7		11.6 - 25.3	4.3	11.5 - 28.0	0.9	11.3 - 24.5
15		9.0 - 21.0		8.0 - 23.3		14.0 - 25.1		12.3 - 25.1		10.3 - 26.1
16		8.0 - 22.9		9.0 - 23.3		12.1 - 23.5		10.0 - 27.4	T	12.0 - 27.2
17	2.7	13.5 - 22.3		9.0 - 24.0		12.1 - 25.2		10.5 - 26.5	1.4	10.8 - 27.5
18	8.8	11.2 - 22.1		9.4 - 25.1	4.2	10.5 - 25.8		10.8 - 27.3	7.7	10.4 - 27.0
19		8.2 - 22.0		10.9 - 25.1		12.2 - 26.5		10.3 - 27.3		11.0 - 27.8
20		7.6 - 21.9	0.5	10.7 - 25.8	2.0	11.0 - 25.8		9.5 - 28.0	2.1	10.9 - 27.6
21		11.4 - 23.7		10.5 - 25.6	3.4	8.8 - 24.0		9.8 - 28.4		12.1 - 26.8
22	3.3	13.2 - 23.0		11.4 - 26.4		10.2 - 26.0		10.0 - 28.6	0.8	13.2 - 23.7
23	1.8	9.3 - 22.8		9.7 - 25.5		10.4 - 26.2		11.0 - 29.0	9.2	12.6 - 23.3
24		6.5 - 22.0		11.0 - 25.0		9.4 - 26.3		11.9 - 29.1	15.6	12.4 - 20.7
25		8.3 - 22.6		11.8 - 25.9		9.3 - 26.4		11.4 - 28.8	1.2	13.4 - 21.5
26		9.7 - 22.7		9.9 - 25.5		7.0 - 25.1		11.4 - 29.4	0.1	12.7 - 23.5
27		8.8 - 23.4	8.0	9.5 - 24.2		9.5 - 26.7		11.3 - 29.0	46.2	12.5 - 25.0
28		9.5 - 22.4	T	9.2 - 25.4	1.7	10.5 - 27.0		12.5 - 28.6	1.0	12.9 - 22.0
29		7.0 - 21.9		7.9 - 25.5			0.2	15.4 - 28.3	2.6	12.6 - 25.3
30		7.0 - 22.1		8.8 - 25.3				11.6 - 27.5	8.5	12.0 - 22.8
31		6.8 - 22.2		9.3 - 26.0			4.0	12.5 - 27.5		
Total	68.2		24.2		27.9		13.7		104.7	
Average		9.9 28.4		8.9 24.2		10.4 25.4		10.7 27.7		11.1 25.5

Appendix 2

Date	May, 1983 Rain mm	May, 1983 Temperature Min. (°C) Max.	June, 1983 Rain mm	June, 1983 Temperature Min. (°C) Max.	July, 1983 Rain mm	July, 1983 Temperature Min. (°C) Max.	August, 1983 Rain mm	August, 1983 Temperature Min. (°C) Max.	September, 1983 Rain mm	September, 1983 Temperature Min. (°C) Max.
1	15.1	11.0 - 20.5		7.9 - 24.0	N.V.	9.5 - N.V.	2.6	9.5 - 22.5	5.2	9.8 - 22.3
2	18.1	13.5 - 24.5		8.3 - 24.1		7.0 - 21.2	7.3	8.0 - 22.4	4.2	12.5 - 21.0
3	33.5	10.0 - 24.5		8.2 - 22.8	2.0	6.2 - 21.5	T	7.0 - 22.1		11.0 - 22.5
4		9.9 - 24.0	5.3	8.2 - 24.5		6.0 - 22.0		8.0 - 23.2	13.4	9.3 - 21.4
5		10.3 - 23.5	0.4	13.8 - 22.4		5.5 - 21.0	1.8	9.3 - 24.3	6.2	11.7 - 22.3
6	10.8	11.0 - 24.5		12.8 - 24.0		5.0 - 22.0		6.0 - 23.5	30.1	7.9 - 21.9
7		12.0 - 22.0		7.2 - 23.9		7.5 - 23.3		7.0 - 24.3	1.3	6.8 - 21.8
8		10.0 - 24.0		7.7 - 23.6		6.4 - 22.5		9.0 - 24.6		9.3 - 21.2
9		10.6 - 22.5		8.0 - 23.8		6.8 - 23.0		9.0 - 24.0	10.8	8.6 - 21.7
10	14.5	14.0 - 23.1	1.1	8.6 - 25.2		8.0 - 23.7	3.1	9.5 - 20.3	11.0	9.4 - 21.5
11	1.4	10.0 - 24.0		8.5 - 25.3		7.3 - 24.5	6.5	10.5 - 22.5	1.9	8.7 - 20.5
12		12.7 - 22.9		8.3 - 24.2		6.6 - 24.4	2.1	9.5 - 20.5	7.7	7.6 - 21.9
13		12.7 - 22.5	1.1	9.4 - 24.7		7.3 - 23.2	29.0	11.8 - 20.1		7.8 - 23.5
14		9.2 - 22.8		10.0 - 24.0		7.6 - 24.4	0.4	11.4 - 20.0		7.0 - 23.2
15	4.3	8.9 - 22.8	3.9	8.5 - 25.1		9.0 - 26.0		9.2 - 17.0		8.4 - 24.5
16		10.0 - 24.5		8.5 - 24.5	12.4	10.6 - 25.3	1.0	9.5 - 20.0	3.5	9.6 - 24.0
17		10.2 - 25.5		9.4 - 24.0	3.8	12.8 - 24.3	14.0	12.0 - 22.0		8.8 - 23.6
18		9.6 - 24.0		7.9 - 24.0	0.9	12.8 - 22.1	0.8	11.9 - 20.6	2.6	7.8 - 21.8
19		8.5 - 24.2		12.5 - 25.0	0.9	9.3 - 19.5	22.2	12.6 - 16.5		7.3 - 23.4
20	0.6	8.8 - 24.5	2.3	13.0 - 25.5	21.6	8.0 - 18.9	12.0	9.0 - 21.0	2.5	8.0 - 23.0
21	7.2	10.0 - 24.5		11.8 - 23.5	8.1	10.8 - 20.3	8.7	11.6 - 21.3	7.6	11.4 - 22.5
22		9.9 - 23.9	4.1	11.3 - 23.2	1.0	11.8 - 18.8	0.8	9.7 - 21.7	2.5	8.6 - 21.6
23		10.4 - 24.0	3.8	12.0 - 20.9	0.6	12.2 - 22.5	3.8	10.0 - 21.5	6.7	8.0 - 23.2
24	1.1	12.9 - 24.0	T	12.0 - 23.5	2.1	12.5 - 21.0	6.7	11.0 - 22.1	3.4	8.4 - 22.5
25	2.3	10.7 - 24.3		11.5 - 24.2		12.7 - 19.2		8.0 - 20.3	0.7	9.0 - 23.0
26	4.1	10.0 - 24.0	0.2	10.4 - 25.7	12.0	10.5 - 22.4		9.1 - 21.9		11.5 - 24.1
27		8.7 - 24.1	2.6	12.6 - 23.4	4.5	10.7 - 22.1		12.4 - 22.6	5.2	8.6 - 23.5
28		8.9 - 25.0		10.5 - 23.6		9.2 - 23.5	3.0	9.6 - 23.4		9.5 - 23.0
29		10.5 - 25.6	13.1	11.5 - 22.9	0.5	9.8 - 23.0	32.6	8.3 - 22.3	0.6	9.6 - 23.3
30		10.2 - 24.8		10.5 - 20.2		7.8 - 21.8	9.1	9.5 - 22.5		9.5 - 21.1
31		8.1 - 24.1				9.6 - 22.4	0.5	10.8 - 22.6		
Total	113.0		37.9		70.4		168.0		127.1	
Average		10.4 23.8		10.0 23.9		8.9 22.3		9.7 21.7		9.1 22.5

Appendix 2

Date	October, 1983 Rain mm	October, 1983 Temperature Min. (°C) Max.	November, 1983 Rain mm	November, 1983 Temperature Min. (°C) Max.	December, 1983 Rain mm	December, 1983 Temperature Min. (°C) Max.	January, 1984 Rain mm	January, 1984 Temperature Min. (°C) Max.	February, 1984 Rain mm	February, 1984 Temperature Min. (°C) Max.
1	1.8	9.3 - 23.5	4.3	10.0 - 21.7	2.8	6.5 - 22.8		9.0 - 23.1	0.8	8.1 - 24.5
2		8.7 - 22.6	7.9	10.5 - 21.3		7.8 - 23.0		8.0 - 23.6		8.4 - 24.5
3		11.0 - 24.5	6.2	9.0 - 22.1	5.5	6.3 - 22.9		8.9 - 24.0		8.8 - 24.5
4	11.6	12.6 - 23.5		8.9 - 19.5		6.6 - 23.0		8.4 - 23.5	2.2	8.6 - 25.5
5		12.9 - 23.0	6.0	9.0 - 21.5	1.7	8.4 - 22.3		7.0 - 23.4		7.5 - 24.9
6	0.2	13.3 - 22.9	27.1	10.0 - 23.2	24.2	9.2 - 21.1		5.0 - 23.1		7.6 - 26.0
7	8.0	12.5 - 21.5	9.1	11.0 - 22.5		7.0 - 20.5		5.8 - 22.3		8.6 - 25.5
8	1.3	12.4 - 20.4	6.4	9.0 - 22.4	4.8	9.4 - 17.6		6.6 - 23.0		9.0 - 21.5
9	2.6	12.4 - 21.3		9.0 - 22.1	5.2	7.5 - 21.4	0.3	11.0 - 22.9		9.5 - 26.5
10	3.5	12.0 - 20.8		9.0 - 23.0	4.3	10.0 - 20.4		9.2 - 23.3		6.8 - 26.7
11	6.3	10.9 - 21.5		9.0 - 24.2		10.2 - 19.0		10.3 - 23.2		7.1 - 26.2
12	5.2	10.7 - 21.1		8.7 - 23.7		8.5 - 22.5		9.9 - 24.5		7.8 - 25.7
13	T	9.0 - 21.5		8.5 - 23.7		8.0 - 24.0		8.2 - 23.8		7.2 - 26.2
14	2.9	10.0 - 22.4	1.6	10.1 - 23.6		7.4 - 23.5		7.7 - 23.8		6.6 - 25.7
15	6.9	11.4 - 22.7	1.8	9.0 - 23.5		8.4 - 23.5	0.2	8.0 - 23.7		8.0 - 26.5
16	1.1	13.0 - 22.8	0.1	9.1 - 23.8		7.5 - 23.0		8.7 - 24.1		8.9 - 27.4
17		8.2 - 23.5		9.5 - 23.7		7.5 - 22.4		9.2 - 24.0		9.0 - 27.3
18		8.5 - 23.0		10.5 - 22.7		8.9 - 24.4		8.0 - 24.5		8.1 - 27.0
19		9.3 - 23.6	7.0	10.6 - 21.4	10.1	12.3 - 24.3		7.8 - 24.4		5.0 - 26.3
20	3.0	8.4 - 22.3	3.0	13.0 - 21.4	0.3	13.2 - 22.4		8.2 - 24.2		5.7 - 25.0
21	0.5	10.0 - 23.0		9.5 - 21.6	0.2	11.5 - 22.9		8.2 - 24.0		8.2 - 26.0
22		11.8 - 22.8		8.1 - 22.4		10.5 - 21.9		7.9 - 24.6		8.6 - 27.0
23		10.9 - 22.8		10.1 - 22.6	1.2	13.0 - 23.0		9.1 - 24.5		7.0 - 26.2
24		7.5 - 21.3		8.4 - 23.3	44.5	12.0 - 21.0		8.4 - 24.5		7.0 - 26.2
25	2.1	9.0 - 21.3		8.0 - 23.4	13.4	11.1 - 20.5		9.5 - 24.5		8.3 - 26.9
26		7.3 - 22.3	1.7	9.9 - 22.5	2.7	10.0 - 19.2		8.5 - 24.6		8.8 - 27.2
27		8.3 - 22.5		7.8 - 22.5		11.1 - 20.7		8.3 - 23.8	T	9.1 - 25.9
28	1.1	7.4 - 22.7	1.0	8.8 - 23.3		13.0 - 21.5		8.0 - 25.4		9.5 - 26.6
29		7.3 - 22.0		9.0 - 22.6		8.5 - 21.5		8.1 - 26.4	11.9	9.5 - 26.1
30		9.2 - 22.0	T	7.7 - 21.5		9.5 - 22.5		9.4 - 26.7		
31	1.7	10.4 - 22.7				9.8 - 22.5		10.7 - 25.3		
Total	59.8		83.2		120.9		0.5		14.9	
Average		10.2 22.4		9.4 22.6		9.4 22.0		8.4 24.1		8.0 25.9

* N.V. = No Value, no data available; "T" = Trace

APPENDIX 3

Weeds present in the sunflower experiments, field 8, N.P.B.S., Njoro.

Broadleaf Weeds:

Scientific name	Family	Common name
Amaranthus spp.	Amaranthaceae	Pigweed family
Bidens pilosa	Compositae	Blackjack
Chenopodium spp.	Chenopodiaceae	Goosefoot family
Datura stramonium	Solanaceae	Datura
Emex australis	Polygonaceae	Devil's Thorn
Galinsoga parviflora	Compositae	Gallant Soldier
Malva verticillata	Malvaceae	Mallow
Nicandra physalodes	Solanaceae	Chinese Lantern
Oxalis spp.	Oxalidaceae	Oxalis
Oxygonum sinuatum	Polygonaceae	Double Thorn
Physalis ixocarpa	Solanaceae	Gooseberry
Polygonum convolvulus	Polygonaceae	Black Bindweed
Tagetes minuta	Compositae	Mexican Marigold
Tetragonia tetragonicides	Aizoaceae	New Zealand Spinach

Grassy and Monocot Weeds:

Scientific name	Family	Common name
Chloris pycnothrix	Gramineae	False Stargrass
Commelina benghalensis	Commelinaceae	Wandering Jew
Cyperus rigidifolius	Cyperaceae	-
Cyperus teneristolon	Cyperaceae	-
Digitaria scalarum	Gramineae	African Couchgrass
Eleusine indica	Gramineae	Wild Finger Millet
Eleusine multiflora	Gramineae	Club Goosegrass
Eragrostis tenuifolia	Gramineae	Wiry Lovegrass
Pennisetum clandestinum	Gramineae	Kikuyu Grass
Setaria pumila	Gramineae	Pale Setaria
Sorghum verticilliflorum	Gramineae	Wild Sorghum

APPENDIX 4

TABLE 1. General weed control (excluding sedge weeds) in the AC 252.925 rate and application method experiment, July 19 visual assessment.

		AC 252.925 (pre) (kg/ha)			AC 252.925 (poe) (kg/ha)				glyphosate (poe) (kg/ha)
Weed species	Check	0.75	1.00	1.25	0.25	0.50	0.75	1.00	1.44
Amaranthus spp.	9	1	1	1	1	1	1	1	1
Datura stramonium	9	3	2	1	1	1	1	1	1
Galinsoga parviflora	9	1	1	1	1	1	1	1	1
Leucas martinicensis	9	1	1	1	1	1	1	1	1
Nicandra physalodes	9	1	1	1	1	1	1	1	1
Physalis ixocarpa	9	1	1	1	2	1	2	1	1
Polygonum convolvulus	9	6	6	4	3	2	1	1	6
Tagetes minuta	9	1	1	1	2	1	1	1	1
Commelina benghalensis	9	1	1	1	5	6	4	5	5
Digitaria spp.[1.]	9	8	7	5	6	7	6	5	5
Pennisetum clandestinum	9	7	6	4	5	4	4	5	1
Setaria spp.[2.]	9	1	1	1	1	1	1	1	1

The EWRC visual rating system was used.

1. Digitaria spp. included Digitaria scalarum, and others.

2. Setaria pumila and Setaria verticillata were the Setaria species present.

APPENDIX 4

TABLE 2. General weed control (excluding sedge weeds) in the AC 252.925 spray solution volume experiment, July 19 visual assessment.

	Check	AC 252.925 0.25 kg/ha					AC 252.925 0.75 kg/ha					Glyphosate 1.08 kg/ha
		Total spray volume (L/ha)										
Weed species	-	11.5	79	231	317	634	11.5	79	231	317	634	79
Amaranthus spp.	9	2	1	1	1	1	2	1	1	1	1	1
Datura stramonium	9	1	1	1	1	1	1	1	1	1	1	1
Galinsoga parviflora	9	5	1	1	1	1	4	1	1	1	1	1
Leucas martinicensis	9	5	1	1	1	1	5	1	1	1	1	1
Nicandra physalodes	9	5	1	1	1	2	3	1	1	1	1	1
Physalis ixocarpa	9	5	2	2	2	2	5	2	2	2	2	1
Polygonum convolvulus	9	6	4	2	3	3	6	1	1	1	1	4
Tagetes minuta	9	5	3	2	3	2	5	1	1	1	1	1
Commelina benghalensis	9	6	5	5	5	5	6	5	5	5	5	5
Setaria spp.[1.]	9	6	1	1	1	2	6	1	1	1	1	1

The EWRC visual rating system was used. All herbicide treatments were applied postemergence.

1. Setaria pumila and Setaria verticillata were the Setaria species present.

Note: Eleusine multiflora initially was controlled at all rates of AC 252.925. The glyphosate treatment also gave good control. However, Eleusine multiflora and Gnaphalium purpureum are some of the first weeds to germinate and grow in areas previously sprayed with AC 252.925.

APPENDIX 5

Soil Characteristics of Field 8, N.P.B.S., Njoro

	0 - 15 cm	15 - 30 cm
pH (KCl 1:2)	4.6	4.7
pH (H_2O 1:1½)	5.2	5.5
Na (m.eq.%)	.06	.07
K (m.eq.%)	2.65	2.67
Ca (m.eq.%)	5.2	6.1
Mg (m.eq.%)	1.4	1.8
Mn (m.eq.%)	1.56	1.43
P (p.p.m.)	24.0	22.0
N (%)	0.18	0.17
C (%)	1.76	1.44
Hp (m.eq.%)	0.2	0.3
Cu (p.p.m.)	0.8	0.5
Zn (p.p.m.)	11.5	6.8
Fe (p.p.m.)	42.0	41.0
Sand (%)	34	26
Silt (%)	26	32
Clay (%)	40	42
Texture	C/CL	C
E.C. (mmhos, 1:2½)	0.16	0.16
C.E.C. (m.eq.%)	25.4	26.2

Analysis conducted by Soil Testing Laboratory, National Agricultural Laboratories, Nairobi. Values underlined are considered low to deficient for crop growth.

The soils in the Njoro area were derived from volcanic ash (andosols), are moderately acidic, and considered by National Agricultural Laboratories to be low in C, N, and Ca; and deficient in P and Cu.