INVESTIGATIONS ON ALLELOPATHIC INFLUENCE AND CONTROL OF PURPLE NUTSEDGE *(Cyperus rotundus L.)*

By

AMEENA. M.

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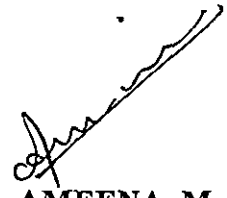
VELLAYANI, THIRUVANANTHAPURAM

1999

DECLARATION

I hereby declare that this thesis entitled "**INVESTIGATIONS ON ALLELOPATHIC INFLUENCE AND CONTROL OF PURPLE NUTSEDGE (*Cyperus rotundus* L.)**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any University or Society.



Vellayani

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CERTIFICATE

Certified that this thesis entitled "**INVESTIGATIONS ON ALLELOPATHIC INFLUENCE AND CONTROL OF PURPLE NUTSEDGE (*Cyperus rotundus* L.)**" is a record of research work done independently by Smt. Ameena. M under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Vellayani

Dr. Sansamma George
(Chairman, Advisory Committee)
Asst. Professor (Sr. Scale)
Dept. of Agronomy
College of Agriculture
Vellayani.

Approved by :

CHAIRMAN :

Dr. Sansamma George

MEMBERS:

Dr. G. Raghavan Pillai

Dr. S. Chandini

Smt. Brigit Joseph

EXTERNAL EXAMINER

1-11-99

Dr. C. S. RAVINDRAN
Senior Scientist
CTCRI, TVM.

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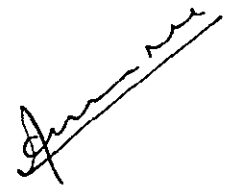

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LIST OF ABBREVIATIONS

@	-	at the rate of
kg	-	Kilogram
ha	-	hectare
ai	-	active ingradient
g	-	gram
mg	-	milligram
cm	-	centimeter
m	-	meter
%	-	per cent
t	-	tonnes
N	-	Nitrogen
P	-	Phosphorus
K	-	Potassium
DAS	-	Days after sowing
DASP	-	Days after spraying
WP	-	Wettable powder
SL	-	Soluble liquid
2, 4-D	-	2, 4 dichloro phenoxy acetic acid

INTRODUCTION

INTRODUCTION

'Weeds' are the most severe and widespread constraint in crop production. Estimates have been made about the annual loss of agricultural production due to various pests and it has been observed that in India, pests damage agricultural produce of the value of Rs.6000 crores, out of which weeds account for the maximum loss (33 per cent) i.e., among all the pests, weeds alone are responsible for one third loss in crop production. (Gautham and Mishra, 1995).

Perhaps there is no other weed species as well known all over the world as *Cyperus rotundus* L. Because of its perennial habit and rapid growth, this sedge has become a serious threat to crop fields of the entire globe. Although usually called nutgrass, it is a perennial sedge belonging to the family Cyperaceae in which the genus *Cyperus* has about 700 species (Lawrence, 1963). Of these *Cyperus rotundus* L., (purple nutsedge) and *C. esculentus* (yellow nutsedge) are by far the most serious weeds. Though nutsedge is a native of Asia, the plant is adaptable to a wide variety of soils and environmental conditions in tropical and subtropical regions. It produces both seeds and tubers, but reproduction is by tubers. The tubers may be thought of as a resting stage that allows the weed to survive adverse conditions.

The weed causes yield reduction not only by competition with the crop for water and nutrients but also with the exudation of allelopathic substances. It asserts allelopathic effects on crop plants through inhibition of germination, growth or metabolism (Del Moral and Cates, 1971). It grows in abundance for a period of 3 to 4 months without allowing any other weeds to come up (Leela, 1994). Under field conditions the deleterious effect may be facilitated by exudates, leachates from decomposing residues and residues incorporated in the growing medium (Garcia and Anderson, 1984). Though the information on the allelopathic effects of many weed species is available, relatively less information is available regarding their effect on the field crops.

The weed becomes problematic due to its resistance to control measures. Understanding nutsedge control begins with the realisation that tubers are the key to the weed survival. The general control measures adopted by farmers are hand weeding and deep digging. But sprouts reappear within 48 hours of hand weeding and deep digging often leads to increased infestation (Hosmani, 1995). Collecting the tubers while ploughing is effective but is labour consuming. Control programmes should be aimed at preventing the formation of tubers through prevention of growth of nutsedge plants. If no new tubers are formed, it will eventually eliminate nutsedge problems.

Chemical weed control through the use of herbicides offers excellent opportunities in controlling this weed. Herbicides which translocate

rapidly into the tubers are reported to give satisfactory and effective control of the weed. Among the systemic herbicides, glyphosate has been reported giving successful control (Tewari, 1995). Effective control of weed by application of 2, 4-D has also been reported. (Singh and Arya, 1995). The wide range in the optimum dose of the herbicides for effective weed control emphasises the need for location specific studies.

The persistence of these herbicides in the soil under the prevailing climatic and edaphic conditions warrants the urgent need to study whether the residues will affect the productivity of successive crops. Since the commonly employed chemical methods for finding out the residual toxicities of herbicides in soil are expensive, laborious and time consuming, bioassay appears to be a suitable alternative.

With this background, an investigation was conducted with the following objectives.

1. To study the allelopathic influence of nutsedge on important field crops.
2. To investigate the effectiveness of systemic herbicides for control of the weed.
3. To monitor the persistence of the herbicides in soil.
4. To study the effect of chemical weed control on growth and yield of subsequent field crops.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Nutgrass or Purple nutsedge (*Cyperus rotundus* L.) is regarded as one of world's worst weeds. It is a persistent and prolific weed occurring in agricultural areas of tropics and subtropics. It is a strong competitor with crops and its interference may result from competition or allelopathy. The typical growth habit and the mode of propagation of this weed pose tremendous problem in its control. Efforts are being made since long to prevent propagation and control of this weed. Various control measures have been advocated from time to time by weed scientists. Of these, chemical control by systemic herbicides has been found most effective in many situations. In this chapter, an attempt has been made to review the available literature on the biology, allelopathy and control measures of this abnoxious weed.

2.1 Biology of Purple nutsedge (*Cyperus rotundus* L.)

A detailed description of the weed was made by Ranade and Burns (1925). The aerial shoot is composed of primary leaves varying in number from 5 to 8 and in length from 5 to 20 cm or more. The tubers are white and succulent when young and turn reddish brown and finally black with age. The tubers have nodes and internodes and scaly leaves and axillary buds. The buds develop into rhizomes and they in turn end in tubers. The rhizomes are thin, dark and have vascular tissue in them. The developed tubers are very hardy and are

capable of withstanding severe unfavourable environmental conditions. The rhizome may grow upwards and form the aerial shoots. At the juncture of the rhizome and the leaves, below the ground level, a tuberous enlargement is formed which is referred to as basal bulb (Smith and Fick, 1937). Thus, a nutsedge plant is composed of aerial shoots, basal bulbs, a chain of tubers and their associated rhizomes and developing tubers (Veerabhadriah, 1977).

Wills (1998) collected purple nutsedge from 21 different locations to compare their reproduction and morphological characteristics. Differences were found with respect to flowering, length of culms supporting the inflorescence and number, the number of shoots produced from single tubers, number of leaves per shoot and the length and width of leaves.

2.1.1 Origin and distribution

The probable origin of nutsedge assumed by De Bach (1964) is Eurasia, but it is very commonly found in the tropical and subtropical areas of Asia, Africa, South and North Americas. The plant is adaptable to a wide variety of soils and environmental conditions in tropical or subtropical regions. Holm *et al.*(1977) observed that *C. rotundus* is distributed throughout the world. According to Thakur (1977), nutgrass is widely distributed as an agricultural weed in almost all parts of the country upto an elevation of 2500 m. The regions where it is not a serious problem are West Africa and parts of the Middle East

(Mercado, 1979). Shelke (1981) opined that nutsedge is native to India and is widely known in the world by the common names nutgrass, nutsedge or purple nutsedge.

2.1.2 Climate

Bharadwaj and Verma (1968) reported that the most favourable period for nutgrass development was the rainy season (July to October) when the mean monthly temperature ranged from 26 to 31°C and the available moisture in the top 15 cm soil layer was 75 per cent. Tuber development was slow during December to February because of low temperature and again during May to June because of restricted water supply. Williams (1976) studied life cycle of nutsedge in Brazil and observed that when irrigated it grows throughout the year, and is especially competitive at the onset of rainy season (November-December). Stoller (1976) reported that tubers remain dormant during the dry season of tropical region, whereas in temperate climate dormancy is during the winter months. Pandey (1984) observed that tuber did not sprout in humid tropical climate for a month in December when minimum and maximum temperature varied between 8.7°C to 23.4°C. Sprouting started towards the third week of January with rise in temperature and plants continued to grow vigorously till October end. Jha (1982) while studying ecophysiology of *C. rotundus* recorded that tuber sprouting in Indian arid zone took place in July after receiving first showers of rain.

Tripathi (1967) noticed that high temperature favour tuber germination. Ueki (1969) obtained 95 per cent germination of tubers at 30 to 35°C, with no sprouting above 45°C or below 10°C. In incubation tests, tubers survived for 10 days, 12 hours and 30 minutes at 45°, 50° and 60°C respectively. Sprouting of more than 50 per cent of the tubers occurred between 13° and 40°C. Ghume (1976) carried out an experiment in glass house and inferred that the optimum temperature for the sprouting of *C. rotundus* was 30 to 35°C. Minimum and maximum temperature limits of sprouting were 15° and 40°C respectively.

2.1.3 Leaves

Shelke (1981) observed that leaves of purple nutsedge were three ranked with closed sheaths and without ligules. Leaves had a distinct midrib and were very dark green and 0.25 to 0.75 cm in width and length of leaf varied from 5 to 20 cm depending upon environmental conditions. The upper leaf surface had a waxy cutin without stomates while the lower leaf surface was thinly cutinized. Wills(1987) noticed that leaves of purple nutsedge were dark green, shiny and corrugated in cross section. They were 6 to 10 mm wide and 10 to 35 cm long. The rachis, which grew through the centre of the leaf bundle, was erect, simple, smooth, triangular in cross section and 10 to 60 cm long .

2.1.4 Stem

C. rotundus is an erect, persistent, glabrous, perennial herb with an unjointed, triangular, solid stem (Shelke, 1981).Pandey (1984) observed that purple nutsedge had slender, smooth, single triangular stems with shiny appearance .

2.1.5 Inflorescence

As per the reports of Wills (1987) in purple nutsedge the rachis supports a terminal inflorescence which is simple or slightly compound, loose umbel. Each inflorescence is subtended by two or more involucral leaves or leaf like bracts that are as long or longer than the flower bearing rays. The rays are formed from three to nine slender, spreading, three sided peduncles of unequal length. Near the ends are clusters of narrow spikelets, 0.8 to 2.5 cm long and 2 mm wide, 10 to 40 flowered, acute and compressed with a red, reddish brown, or purplish brown colour. They possess glumes, 2 to 3.5 mm long, which are ovate and nearly blunt with three to seven nerves. Individual seeds are achenes, 1.5 mm long which are ovate or oblong ovate, three angled, dull olive grey to brown or black in colour covered with a network of grey lines. Each achene is sessile on the spikelet and is subtended and covered by a single scale or glume .

2.1.6 Tubers

The plant is perennial, with fibrous roots clothed with flexuous hairs. It develops a series of shoots connected by underground network of

rhizomes terminating in either basal bulb or tuber. Rhizomes are of two types: wiry and fleshy. These can be distinguished as primary and secondary rhizomes respectively. Scales of the rhizomes soon disintegrate and usually absent on old rhizomes (Kern, 1974).

One characteristic feature of this weed is its rapid and high magnitude of multiplication. Because of the large number of underground tubers produced in a short time, a count of aerial shoots does not give an accurate measure of infestation. Jha (1982) recorded that in 50 × 50 cm space of semiarid region in July the density of tubers and shoots were 220 and 178 respectively, resulting into a total sum of 88,000 tubers and 71,200 plants per hectare.

Parker (1985) conducted experiments on the pattern of rhizomes and tuber development in pot grown *C. rotundus* and showed that the development of tubers with dormant apices was normally delayed until the stage of tertiary or quarternary rhizome growth.

Tuber, an underground vegetative organ of *C. rotundus* is rich in stored food material and is responsible for propagation. It occurs upto a depth of 30 to 40 cm (Bendixen, 1973). Several buds remain present on tubers which sprout repeatedly until the food reserves in the tuber are exhausted or until all buds develop (Bendixen, 1973). Gill *et al.* (1982) studied the viability of

C. rotundus tubers and observed that the tubers brought to surface during hot weather cultivations were rendered non viable within 24 hours. Loss of viability was due to the high temperature injury and to a threshold moisture loss. Ruchburg *et al.* (1993) reported that tubers were killed readily by drying. Isolated tubers were killed by 4 days exposure to direct sunlight. Temperature of 60°C and above killed tubers in 1 hour. Exposure to a temperature of -3.8°C for 8 hours did not kill tubers.

The tuber which does not produce shoot is known as dormant or chain tuber. Terry (1974) has reported that as many as 85 per cent of these tubers remain dormant in land which was not tilled. He observed that this dormancy of nutsedge could be removed if it was broken from the chain and germination could be induced. Apical dominance was found to exist in purple nutsedge on both the tuber and the system as a whole (Ruchburg *et al.*, 1993). Neser *et al.* (1997) conducted field experiments to study the survival and dormancy of purple nutsedge and found that tuber dormancy increased with age. He has reported that tubers were able to enter a state of secondary dormancy after sprouting.

The effect of temperature and water on the sprouting of tubers of *C. rotundus* was studied by several workers. Temperature of 30 to 50°C and water capacity of 40 to 60 per cent was optimum for sprouting. (Wills, 1975).

Tuber sprouting was more rapid and complete with alternating temperature than with constant temperature. Increasing temperature fluctuation from 0 to 60°C for 12 hours daily linearly increased total tuber sprouting (Miles *et al.*, 1996).

Erasmo *et al.* (1994) conducted experiments to evaluate the effect of light quality on sprouting of purple nutsedge and found that red light decreased the number of sprouts per tuber and shoot length compared to other wave length and white light.

Mean day length during growth was a major factor influencing growth and developments, but mean temperature appeared to be important in determining new tuber size and proportion of dry matter as new tubers and shoot number appeared to be a reliable guide to rhizome and tuber production (Hammerton, 1975).

There was a marked reduction in both shoot and tuber dry weights and in the number of new shoots and tubers when light intensity was reduced. (ICRISAT, 1980). This is because *C. rotundus* is highly shade sensitive. Shading significantly reduced dry matter accumulation, leaf area production and total tuber production (Patterson, 1981). Nemoto *et al.*, (1994) reported that shading reduced chlorophyll a and b levels and this was maximum at 50 per cent shading.

Devandra *et al.* (1996) observed that by the 30th day, planted tuber reserves were completely depleted and the bulk of photosynthates was diverted for shoot and root development. Photosynthates were used for tuber development 40 days after sowing.

2.1.7 Seeds

Flowering in *C. rotundus* can occur within 21 days after emergence under field condition (Okafor, 1973). In the tropics flowering occurs almost round the year (Mercado, 1979). Jha and Sen (1981) have recorded two seasons of its flowering that is during September-October and January-April in India.

Ranade and Burns (1925) observed that in moderately infested fields at least 132 million nutsedge seeds per hectare were added to the soil every year. They have reported that purple nutsedge produced 60 inflorescences per meter square in fields in India and that individual flower head produced an average of 220 seeds.

Holm *et al.* (1977) have reported a high degree of sterility in *C. rotundus* and failed to find viable seed. Thullen and Keely (1979) also reported in similar lines while Jha and Sen (1981) got success in germinating seeds in laboratory and some of them established seedlings in the field.

Seeds produced in Sudan would not germinate just after harvest (Andrews, 1946), but in India, fresh seeds of *C. rotundus* could germinate and germinability increased with storage period (Tripathi, 1969). Jha and Sen (1981) obtained 80 per cent and 86 per cent germination after 40 minutes conc. H_2SO_4 pre treatment to seeds and washing in tap water respectively.

Mercado (1979) remarked that production potential of seeds was much lower than that of the tubers, but the seeds could be just as good source of infestation like the tubers. The reasons of seed dormancy have been mainly attributed to the hard and almost impermeable seed coat and some water soluble germination inhibitors (Jha and Sen, 1981).

2.2 Allelopathy of nutsedge (*Cyperus rotundus* L.)

The concept that one plant influences the growth of another is well known in agriculture. Molisch (1937) coined the term allelopathy to refer to the biochemical interaction between all type of plants including micro organism. Rice (1974) has used the term allelopathy to refer to the deleterious effect that one plant has on another through the production of chemical retardants that escape into the environment.

2.2.1 Allelopathic effect of nutsedge shoots

The allelopathic potentiality of nutsedge was reported first by Beiber (1967) who recorded the inhibition of germination and seedling

development of crown vetch by aqueous extract of *Cyperus rotundus* shoots. The growth of cucumber, lettuce and tomato bioassay plants under glass house and sand culture conditions was reduced by leachates from decaying nutsedge leaves (Gilreath, 1981). Velu and Rajagopal (1996) conducted pot experiments to assess the allelopathic effects of aqueous extracts of cuttings of purple nutsedge on soybean and found that extracts of cuttings tended to decrease the crop vigour index, dry matter accumulation, leaf area and yield with leaf cutting extracts exerting the most effect. This is in conformity with the result of Wibowo *et al.* (1996) who reported that shoot extracts of purple nutsedge significantly decreased root nodule formation, growth and yield of soybeans.

2.2.2 Allelopathic effect of nutsedge roots and tubers

Singh (1968) noticed that the aqueous extract of nutsedge tubers inhibited the germination and growth of pearl millet, cowpea, maize and blackgram. The length and vigour of seedlings observed from the very beginning were greatly hampered by the tuber extract. Radicles emerging from groundnut seeds, which received tuber extract, were observed coming upwards, as against their usual downward movement.

Friedman and Horowitz (1971) found that the aqueous and ethanolic extracts of roots and tubers of *C. rotundus* inhibited the germination and radicle elongation of barley. Similarly, inhibition of growth of sorghum and

soybean crop by tuber extract of *C. rotundus* was reported by Lucena and Doll (1976).

Gilreath and Locasio (1980) carried out tests to examine the allelopathic potential of *C. rotundus* tubers and assayed fractions for their specific biological activity. He reported that specific fractions either inhibited germination or reduced the speed of germination and extension of the radicle depending on the concentration. The residues and water extracts of nutsedge significantly reduced the growth of soybean and maize, tubers being more inhibitory than foliage (Dorst and Doll, 1980). Methanol extracts of the dry matter of *C. rotundus* tubers was found to inhibit the germination and seedling growth of lettuce and white clover (Komai and Ueki, 1980).

Lall and Savongdy (1981) studied the allelopathic effect of purple nutsedge on the growth of pearl millet and found that root exudates of growing plants of *C. rotundus* significantly reduced plant height and dry matter production, but it did not affect the germination of pearl millet seeds. Gastal and Casela (1982) noticed the negative influence of dried and ground roots of *C. rotundus* on germination of soybean. They also found that the emergence could be reduced further by increasing the quantities.

Castro *et al.* (1984) studied the allelopathic influence of some weed extracts on germination of rice seeds and reported that aqueous extracts of

nutsedge tubers completely inhibited root development and reduced the growth of aerial parts. Velu *et al.* (1992) reported that root extracts had maximum reduction in the germination percentage. Varshney and Saxena (1994) observed the effect of water extracts of tuber and shoot of purple nutsedge on germination and growth of grain legumes. It was evident that the extracts had reduced the seed germination of faba bean and lentil, but did not affect peas and chick pea. Reduction in coleoptile and radicle elongation of all grain legumes was noticed except in pea where extracts had stimulatory effect. Kawisi *et al.* (1995) conducted laboratory and green house experiments to determine the allelopathic effects of *C. rotundus* on germination and seedling growth of tomato, onion, cabbage and squash. The study revealed that tuber extracts delayed germination in tomato, onion and squash but not in cabbage. Dilutions of 100-2000 times marginally stimulated germination in most crops. Overall shoot and root growth was generally more susceptible than germination for all the crops.

Leela (1995) studied the allelopathic effect of purple nutsedge on growth of field crops and found that aqueous leachates of *C. rotundus* tubers completely inhibited seed germination in finger millet, wheat, sorghum and Indian mustard.

Raju and Reddy (1996) compared the allelopathic effect of cyperaceous weeds on germination and growth of rice and found that

C. rotundus and *C. esculentus* were most inhibitory to rice. In another study carried out in Indonesia root extracts significantly reduced root nodule formation, growth and yield of soybeans (Wibowo *et al.*, 1996).

2.2.3 Allelopathic effect of nutsedge whole plant

Lall and Savongdy (1981) observed that leachates of *C. rotundus* residues significantly reduced plant height and dry matter production of pearl millet. Uppar *et al.*(1993) noticed that seeds of wheat treated with aqueous extracts of nutsedge dry matter recorded 57 per cent reduction in germination.

Porwal and Mundra (1993) reported that aqueous extract of *C. rotundus* did not influence germination of blackgram and paddy but could reduce the coleoptile and radicle growth of blackgram. Radicle growth of paddy was not significantly influenced by the treatment.

Velu and Rajagopal (1996) conducted pot experiments to assess the allelopathic effects of aqueous extract of *C. rotundus* on soybean and found that extracts of nutsedge tended to decrease the crop vigour index, dry matter accumulation leaf area and yield with whole plant cutting exerting the maximum effect.

2.2.4 Chemical nature of allelopathy in *Cyperus rotundus*

According to Lucena (1974) biologically active substances produced by the underground parts of *C. rotundus* acted on the hormonal

processes that regulate plant growth, and the response depended on the concentration in the media where the plants germinate and grow. Komai and Ueki (1975) analysed the polyphenolic substances in purple nutsedge tubers at both dormant and non dormant stage. The polyphenols isolated were primarily catechol, tannin of leucocyanidin and leucocyamidin glucoside. Phenolic acids detected in the hydrolysis of the phenols with HCl or NaOH were p-coumaric acid and proto catechuic acid. These allelopathic substances are released into the soil during decomposition of crop residues (Patterson, 1981).

Einhellig (1987) reported that allelopathic inhibition of germination and plant growth typically occurred from the joint action of several allelochemicals. Additive or synergistic effects have been shown in bioassays with combination of monoterpenes, organic acids and several classes of phenolic compounds. Leela (1995) recorded the presence of phenolic acids viz., p-coumaric acid, p-hydroxy benzoic acid, o-coumaric acid, caffeic acid and ferulic acid from the aqueous extract of tubers of purple nutsedge.

Reviewing the literature, Hosmani (1995) concluded that the inhibitory substances were phenolics identified as cyperone, p-selinine, cypernone and 2-cypernone.

2.3 Chemical control of Purple nutsedge (C. *rotundus* L.)

Holt *et al.* (1962) considered purple nutsedge to be one of the most difficult weeds to control throughout the world. Research workers from time to time have suggested its control measures, yet this weed continued to infest vast productive land. Various control measures such as cultural, mechanical, biological and chemical have been tried from time to time. Bharadwaj and Verma (1968) were of the opinion that during ploughing or interculture operations many connecting rhizomes were broken and internal tubers were made free from dominance of the terminal tubers. Ploughing and interculture, therefore, usually increased nutgrass infestation, if the conditions are favourable for the growth of tubers.

Several herbicides are in use to control this noxious weed in different parts of the world. In earlier days, the introduction of dalapon, paraquat and MSMA were claimed to be effective in nutgrass control. Paraquat, a non selective and contact herbicide showed mortality by its contact action but regeneration took place after sometime, (Tewari, 1995). So the use of systemic herbicides was considered a better option.

2.3.1 Control of nutsedge(*C. rotundus* L.) using glyphosate.

Successful control of nutsedge by the application of glyphosate has been reported in recent years. The advent of glyphosate

(N-phosphonomethyl glycine) - a non selective and highly translocated herbicide has proved a boon to the farmers. Glyphosate is easily translocated to underground organs and appears to inhibit the aromatic amino acid biosynthesis pathway thereby resulting in death of tuber. (Jawarski, 1972)

Bernard (1974) conducted experiments on control of *Cyperus rotundus* and found that application of glyphosate reduced the fresh weight of green leaves, number of sprouts produced from original tubers, new tubers and basal bulbs and indicated that herbicide was translocated and affected original and newly developed tubers (Chawdhery, 1974).

Gossette *et al.* (1975) studied the response of purple nutsedge to glyphosate and found that at high rates (1.5 to 3 lb per acre) 91 per cent control was obtained upto a month. One year later higher rates provided 50 to 70 per cent control in undisturbed plots, but the plots disced 2 months later became rapidly infested. Chase (1979) based on his studies pointed out that glyphosate application 3 days later by cultivation resulted in 90 per cent control of *C. rotundus*. A second application 35 days after cultivation resulted in more than 90 per cent control.

Standifer (1980) reported that by repeated glyphosate application @ 2.24 and 4.48 kg ha^{-1} the active tuber counts declined more rapidly in soil.

Wang (1981) observed that *Cyperus rotundus* at the 9 leaf stage was sensitive to glyphosate and good control was given when applied at 3-7 kg ai ha^{-1}.

Jha and Sen(1982) found that killing of foliage had taken place after 4-5 days but new shoots reemerged after 15 days. When counted, it was found that upto 70 days tuber production was reduced by 76.9 per cent.

Doll and Piedrahita (1982) observed that glyphosate killed *C. rotundus* foliage and the tubers attached to treated plants. Therefore regrowth after glyphosate application under field conditions is due to dormant tubers which sprout after treatment. Beltrao *et al.* (1983) observed that single application of glyphosate at 2 or 3 kg ha^{-1} gave satisfactory control for 30 days and control was no better with the higher rates. Applications should be made when the weed was at the 6 or 7 leaf stage and growing vigorously and before it started to flower.

Liu and Twu (1993) based on their experiments with post emergent herbicides on nutsedge control reported that glyphosate resulted in 100 per cent mortality of *C. rotundus* tubers in the tuber germination experiment. Also, glyphosate @ 2.46 and 1.64 k.g ai ha^{-1} reduced the weed growth by 97 and 88 per cent respectively.

Cosme *et al.* (1993) found that glyphosate @ 0.72 kg ai ha^{-1} reduced the number of *C. rotundus* plants by 60 per cent. Charles (1995) based on experiments conducted in cotton reported that traditional nutgrass control techniques were unsatisfactory, but repeated glyphosate applications gave effective nutgrass control both in cotton and fallow.

Satao *et al.* (1995) reported that post emergent application of glyphosate at 2.76 kg ai ha^{-1} + a second spraying 20 days after sowing + a third spraying 20 DAS resulted in the least population density of this weed. Mc Intyre and Barte (1995) recorded post emergence spray of glyphosate at 1 kg ai ha^{-1} as the best treatment for control of purple nutsedge. The response of purple nutsedge population to glyphosate application was studied by Zaenudin *et al.* (1996) and they observed that post emergence application of 0.72 kg glyphosate ha^{-1} at 4-8 weeks after weed emergence resulted in good control of the weed.

Desai *et al.* (1996) conducted field experiments on red sandy loam soil to evaluate glyphosate (2-4 kg ha^{-1}) as a means of controlling *Cyperus rotundus*. Results revealed that in glyphosate sprayed plots there was drying of the weed after a week of spraying. Rhizome dry weight and sprouting were also reduced by glyphosate application.

Charles (1997) evaluated a range of herbicides for controlling nutgrass and found that multiple applications of glyphosate reduced tuber density

by upto 96 per cent over 2 seasons. This was improved with successive application of glyphosate. Freitas *et al.* (1997) reported that double application of glyphosate resulted in 90.8 per cent reduction in the number of plants. The number of tubers was reduced by 76.3 per cent.

2.3.2 Control of purple nutsedge (*C. rotundus* L.) using glyphosate + ammonium sulphate.

Suwunnacck and Parker (1975) studied the effectiveness of glyphosate on nutsedge and found that application of $NH_4 SO_4$ at 2.25 kg ha^{-1} enhanced the effectiveness of glyphosate. Zemanek and Stabra (1979) conducted laboratory and glass house experiments to investigate the biological effect of glyphosate and reported that adding of some inorganic compounds like $NH_4 SO_4$ to the solution of glyphosate at 0.1-0.8 kg ha^{-1} increased the effect of this herbicide when applied to spring barley leaves.

Ampong - Nyarko (1980) studied the effect of ammonium sulphate on the activity of glyphosate and found that addition of ammonium sulphate increased the activity of glyphosate. Leaf wash off 24 hours after spraying reduced glyphosate activity even when ammonium sulphate and wetters were present.

Sharma *et al.* (1980) reported that addition of ammonium sulphate @ 1.25 kg ha^{-1} to the rates of glyphosate at 0.84 and 1.12 kg ha^{-1} not

only increased the percentage kill, but also resulted in the kill of broader spectrum of species of weeds.

Tuner (1985) suggested that ammonium salts at concentration upto 10 per cent increased the activity of glyphosate against *C. rotundus* with or without surfactant. Increased activity of glyphosate in the presence of ammonium salts resulted from increased membrane permeability. Wills and Mc Whorter (1985) have also noticed that the activity of glyphosate against *C. rotundus* was generally increased by the addition of NH_4^+, K^+ and Na^+.

Thakur *et al.* (1993) conducted pot experiments for the control of *Cyperus rotundus* L. and reported that for getting complete control and check on regeneration of this weed, the foliar application of glyphosate @1.0 kg ha^{-1} + 0.5 per cent NH_4SO_4 fertilizer at 4-6 leaf stage of weed gave an excellent control. Addition of ammonium sulphate increased the effectiveness of glyphosate by 10 per cent.

Inder Dev *et al.* (1996) observed that the efficacy of glyphosate at 1.0 kg ha^{-1} increased substantially when applied in combination with 2 per cent ammonium sulphate. The increase in phytotoxicity was, however, marginal at 2.0 kg ha^{-1} glyphosate. Addition of ammonium sulphate to glyphosate also reduced regeneration substantially.

However, Rambakudzibga (1979) reported that presence or absence of ammonium sulphate did not affect the rate of glyphosate translocation into tubers. According to him the inclusion of ammonium sulphate in spray mixture did not affect glyphosate translocation. Campeglia (1983) has also reported that addition of ammonium sulphate did not enhance control.

2.3.3 Control of *Cyperus rotundus* L. using 2, 4-D sodium salt

Very often 2, 4-D has been applied for control of nutsedge, although the results have not always been consistent. Efficiency of control of *Cyperus rotundus* L. with 2, 4-D also varies greatly with its formulations. Roa *et al.* (1973) reported sodium salt of 2, 4-D more effective as compared to ester formulation.

Bharadwaj (1981) carried out investigations to find out suitable measures to control nutsedge. The study revealed that application of 2, 4-D at 4.4 kg ha^{-1} soon after cultivation on bare soil caused more than 80 per cent reduction in the initial stand of nutsedge in a single season. Complete control of nutsedge was achieved by repeating the treatment for one more season.

Graf *et al.* (1982) based on their study conducted in corn field for control of nutsedge reported that direct sprays of 2, 4-D to tall maize plants gave selective control of purple nutsedge.

Effect of 2, 4-D on sprouting and growth of tubers of *C. rotundus* was studied by Gill *et al.* (1986). They observed that 2, 4-D did not prevent tuber sprouting, but inhibited bud growth and the sprouted buds rotted at higher 2, 4-D concentration.

Pathak *et al.* (1989) studied the effect of herbicide and moisture level on *C. rotundus* in upland rice and found that 2, 4-D applied at post emergence effectively controlled *C. rotundus* when moisture supply was well above pan evaporation.

Liu and Twu (1993) reported that the sodium salt of 2, 4-D at 3.2 kg reduced *C. rotundus* growth by 42 per cent and it did not affect germination of tubers.

2.3.4 Control of nutsedge using 2, 4-D + urea

Addition of urea for increasing the absorption and efficiency of 2, 4-D sodium salt has been reported by many scientists.

Jain *et al.* (1974) studied the effect of various rates of 2, 4-D with and without urea on weeds of dwarf wheat. They reported that 2, 4-D at 0.5 kg when combined with 3 per cent urea produced lowest dry matter accumulation of weeds which showed the synergistic effect of 2, 4-D and urea spray. They

also found that 2, 4-D along with urea increased the income per hectare over application of 2, 4-D alone.

Gautam and Mani (1975) reported that foliar spary of 3 per cent urea + 0.5 kg ai ha^{-1} of 2, 4-D showed higher efficiency than the single foliar application of 2, 4-D herbicide showing that 2, 4-D was not only compatible with urea, but also when mixed with urea the efficiency of 2, 4-D could be increased.

2.3.5 Control of purple nutsedge using glyphosate + 2,4-D

The interaction response of glyphosate + 2, 4-D is synergistic in *Cyperus rotundus*. Many workers have reported that the combination of these herbicides was more effective than separate application.

Mangoensokarjo (1979) recorded higher weed control efficiency in plots that received mixtures of 1.5 kg glyphosate + 0.5 kg 2, 4-D salt.

Manickam and Gnanamoorthy (1994) conducted experiments to find out effectiveness of chemical control of nutsedge. They found that spraying of glyphosate @ 1 per cent + 2, 4-D sodium salt @ 0.05 per cent considerably reduced the weed dry matter and hence higher weed control index was recorded under this treatment. The maximum mortality of nuts upto 66.6 per cent with

minimum nut regeneration upto 23.3 per cent were also noted under this treatment. They suggested that this might be due to the auxinic effect of 2, 4-D on effective translocation to primary and secondary tubers when added at sublethal concentration.

Inder Dev *et al.* (1996) reported that efficacy of glyphosate at 1.0 kg ha^{-1} was increased substantially when applied in combination with 2, 4-D @ 1.0 kg ha^{-1} as compared to application of glyphosate alone. Addition of 2, 4-D to glyphosate reduced regeneration of weeds substantially .

In integrated management study to control *Cyperus rotundus* in maize, application of glyphosate @ 1.25 kg ai ha^{-1} in combination with 2, 4-D sodium salt before sowing maize was effective in reducing population, dry matter and tuber number of *Cyperus rotundus* L. (AICRPWC Project coordinator's Report, 1996).

2.3.6 Herbicide residues and their effect on growth and yield of subsequent field crops.

Singh and Gupta (1978) reported that glyphosate applied @ 12.5 l ha^{-1} for controlling nutsedge was found to be safe even 5 days after spraying for growing crops like bhindi , cotton and brinjal.

Balyan *et al.* (1981) studied the toxicity and residual effect of 2, 4-D and reported that use of 2, 4-D in the previous crop did not cause any phytotoxic effect on the succeeding crop. It was observed that plant height, dry matter production and the number of branches per plant was more or less similar in all the concentration when compared to control. No visible symptom of malformation was observed in any treatment. No phytotoxic symptom of the residual effect of different concentration of 2, 4-D on succeeding cotton crop was observed.

Leveille *et al.* (1993) evaluated the effects of glyphosate residues in soils 15 months after treatment and it was found that 6 of them contained no detectable residues and the average for all samples was 0.1888 $\mu g\ g^{-1}$. Reynolds *et al.* (1993) conducted chemical and biological studies upto 3 years after the treatment in order to study the environmental fate and impacts of the herbicide glyphosate in temperate coastal rain forest. They found that glyphosate residues rapidly dissipated and degraded in the natural environment. After one year, remaining residues were strongly adsorbed to organic matter and soil particles where they appeared to be inactivated and immobilized.

Experiments were conducted to study the contamination of pesticides from agriculture and industrial areas to soil and water. The pesticides

evaluated included glyphosate, MCPA, atrazine, dimethoate etc. and none of the herbicides were found detectable in fish. (Grande *et al.*, 1994).

Hakin *et al.* (1994) suggested that glyphosate and 2, 4-D had limited persistence in soil. Germination and seedling growth of the drilled cereals were very good in plots receiving fertilizers + glyphosate treatments (Vidrih and Kosmil, 1994). Results of bioasssy using green gram confirmed that soil activity of glyphosate and 2,4-D were far below the level to cause any phytotoxicity(Manickam and Gnanamoorthy,1994).

Thompson *et al.* (1994) observed that initial foliar residues of glyphosate were dependent on application rate and increased by a similar factor for each kilogram per hectare applied, irrespective of the formulation type. Mean time to 50 per cent dissipation were 2 days and for 90 per cent dissipation were < 16 days for all herbicide formulations. Glyphosate residue dissipation was independent of the salt formulation applied.

In anaerobic experiments 2, 4-D herbicides were found to be quite persistent. But under aerobic conditions biodegradation was observed after a lag period (Kuhlmann and Kaczmarczyk, 1995). Foy *et al.* (1996) studied the herbicide residue in tree rows after repeated application of glyphosate and 2, 4-D. During the 12^{th} growing season, young trees planted between existing

trees failed to make proper growth. Oat bioassay of soils collected from treated rows revealed that the tree row top soil produced less oat biomass than upper deep row soils.

Jagannathan and Nadanam (1996) conducted field experiments to study the residual effect of glyphosate on germination of succeeding crops finger millet, sorghum, cowpea, green-gram and cassava. It was found that glyphosate at 2.0 kg ha^{-1} had no phytotoxic effect and did not affect the germination of these crops, irrespective of the time of sowing after application.

Wilson *et al.* (1997) studied 2, 4-D dissipation in field soils after applications of 2, 4-D ester and salt forms and it was revealed that ester and amine forms have little effect on the rate of dissipation of 2, 4-D because they were converted rapidly to the same anionic form.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation comprised of four experiments taken up both in the laboratory and in the field. Laboratory experiments were undertaken to examine the allelopathic influence of purple nutsedge (*Cyperus rotundus* L.) on important field crops. Field experiments were carried out to investigate the effectiveness of systemic herbicides for control of nutsedge and to assess the effect of chemical weed control on growth and yield of subsequent field crops. The materials used and the methods adopted in the experiments are detailed hereunder.

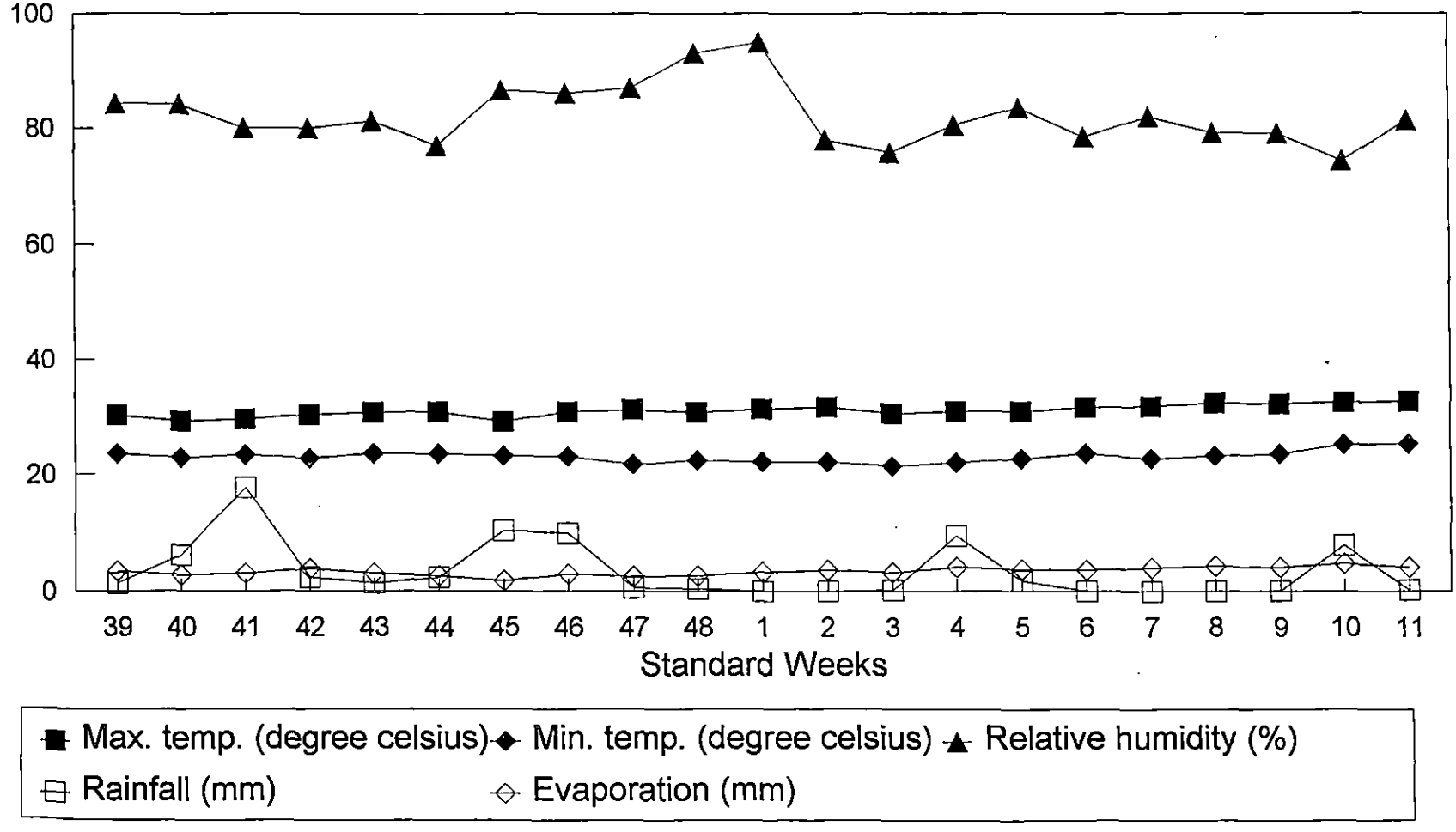
3.1 Site description

The field experiments were conducted in the garden lands of the Instructional Farm attached to the College of Agriculture, Vellayani, Thiruvananthapuram, Kerala. The farm is situated at 8.5° N latitude and 76.9° E longitude at an altitude of 29 m above mean sea level.

3.1.1 Climate and season

Vellayani experiences a humid tropical climate. Field experiments were conducted during October 1998 to March 1999. The data on various weather parameters, viz. weekly rainfall, maximum and minimum temperature and relative humidity during the experimental period are presented in Appendix-I and graphically represented in Fig.1.

Fig. 1 Weather parameters during the cropping period (Oct.1998 - Mar.1999)



3.1.2 Soil

The soil of the experimental area belonged to the textural class of sandy clay loam and of the taxonomical order Oxisol. Soil was medium in available nitrogen, high in available phosphorus and low in available potassium. The pH of the soil was 4.8. (Table 1)

3.1.3 Cropping history of the experimental site

The site of the field experiment was lying fallow for one year prior to the experiment.

Table 1

Soil Characteristics of the Experimental site

A. Physical composition

Sl. No.	Fraction	Content in soil (%)	Method
1	Coarse sand	36.35	Bouyoucos
2	Fine sand	15.00	Hydrometer method
3	Silt	17.50	(Bouyoucos, 1962)
4	Clay	30.00	

B. Chemical composition

Sl. No.	Parameter	Content	Rating	Method
1	Available N (kg ha $^{-1}$)	434.62	Medium	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
2	Available P_2O_5 (kg ha $^{-1}$)	39.21	High	Bray colorimetric method (Jackson, 1973)
3	Available K_2O (kg ha $^{-1}$)	122.35	Low	Ammonium acetate method (Jackson, 1973)
4	P^H	4.80	Acidic	P^H meter with glass electrode (Jackson, 1973)

3.2 Materials and methods

3.2.1 Ex.I Allelopathic studies

Six separate laboratory experiments were undertaken to examine the allelopathic influence of nutsedge on some of the important field crops. The experiment was carried out at room temperature in the laboratory.

3.2.1.1 Test crops

Cereals and millets

Rice - *Oryza sativa* L.

Ragi - *Eleusine coracana* (L). Gaertn

Legumes

Cowpea - *Vigna unguiculata* (L). Walp

Green gram - *Vigna radiata* (L.) Wilczek

Vegetables

Bitter gourd - *Momordica charantia* L.

Bhindi - *Abelmoschus esculentus* (L.) Moench

3.2.1.2 Technical programme

Design	:	Completely Randomised Design (CRD)
No. of treatments	:	10
Replications	:	3
Medium	:	Filter paper circle in petriplate

Treatments

Treatment details are furnished in Table 2.

Table 2

Treatment details of experiment no.I

Sl.No.	Notation	Treatments
1	T_1	Fresh shoot aqueous extract
2	T_2	Fresh tubers aqueous extract
3	T_3	Fresh whole plant aqueous extract
4	T_4	Dry shoot aqueous extract
5	T_5	Dry tubers aqueous extract
6	T_6	Dry whole plant aqueous extract
7	T_7	Fresh shoot blended extract
8	T_8	Fresh tubers blended extract
9	T_9	Fresh whole plant blended extract
10	T_{10}	Control (Distilled water)

3.2.1.3 Preparation of plant extract

Fresh plant samples at active growth stages were collected from the field without damaging the roots and tubers and cleaned off dirt and soil. Aqueous extract was prepared by soaking the respective plant parts in distilled water for 24 hours. Blended extract was prepared by blending the respective plant parts in distilled water. A ratio of 1:10 i.e., ten parts of distilled water on weight/volume (w/v) basis was followed for soaking in all the treatments. Extracts were filtered through filter paper. Fifty seeds each of the test crops were placed in petri dishes lined with one sheet of germination paper. Moisture in the paper was maintained by adding 10 ml of the extract daily. Distilled water served as the control.

3.2.1.4 Observations

3.2.1.4.1 Germination percentage

The number of seeds that germinated were counted from the day of first count till last count and expressed as percentage of the total seeds. (Agrawal, 1995).

3.2.1.4.2 Length of seedling root

On the day of final germination count, the root length of all the sprouted seedlings was measured. The mean root length was arrived at and expressed in cm.

3.2.1.4.3 Length of seedling shoot

On the day of final germination count the shoot length of all sprouted seedlings was measured. The mean shoot length was arrived at and expressed in cm.

3.2.1.4.4 Vigour index (VI)

Seedling vigour index was calculated by adopting the formula suggested by Abdul-Baki and Anderson (1973) and expressed as a number.

VI = Germination percentage × [Root length + shoot length]

3.2.1.4.5 Fresh weight of seedlings

Fresh weight of all the sprouted seedlings was measured in a Sartorius monopan balance and expressed in milligrams per plant.

3.2.1.4.6 Dry weight of seedlings

All sprouted seedlings were oven dried at 70°C to constant weight and weighed in a monopan balance and the dry weight was expressed in milligrams per plant.

3.2.1.4.7 Response Index (RI)

The response index with respect to each parameter was calculated using the following formula suggested by Williamson and Richardson (1988)

If $T > C$, $RI = 1 - (C/T)$

$T = C$, $RI = 0$

$T < C$, $RI = (T/C) - 1$

3.2.2 Ex.II Control of Nutsedge

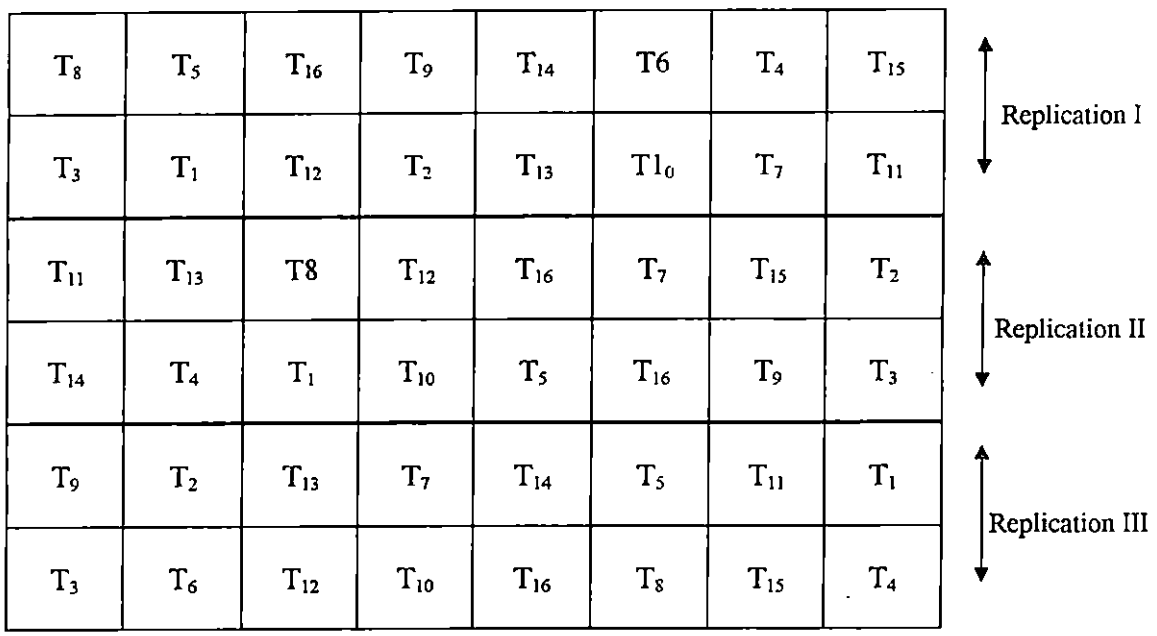
A field experiment was conducted to investigate the effectiveness of two systemic herbicides, viz. Glyphosate and 2,4-D sodium salt, for control of the weed *Cyperus rotundus* L.

3.2.2.1 Establishment of nutsedge

The experimental field was cleared and plots were laid out. Farm Yard Manure @ 5t ha^{-1} was applied as basal followed by chemical fertilizers in the ratio 40:20:30. Planting was done on 21st October, 1998.

For nutsedge propagation, uniformly sized tubers were dug out from the infested fields and planting was done at a spacing of 15 cm in 20 cm rows so that 400 plants were maintained in each plot. This was done to ensure uniformity in plant population. Uniform planting depth was maintained and plots were irrigated.

Fig. 2 Layout plan of Experiment II.



Design - Randomised Block Design (RBD)

Plot size - 4 m × 3 m

Replication - 3

3.2.2.2 Design and Layout

Design	:	Randomised Block Design (RBD)
No. of Treatments	:	(15 + 1 control) = 16
Replications	:	3
Total no: of plots	:	48
Gross plot size	:	$4 \times 3 = 12\ m^2$

Treatments

Treatment details are furnished in Table 3.

Table 3

Treatment details of experiment no: II

Sl. No.	Notations	Treatments
1	T_1	Glyphosate @ 1.5 kg ai ha^{-1}
2	T_2	Glyphosate @ 2.0 kg ai ha^{-1}
3	T_3	Glyphosate @ 2.5 kg ai ha^{-1}
4	T_4	Glyphosate @ 1.5 kg ai ha^{-1} + 0.5 per cent NH_4SO_4
5	T_5	Glyphosate @ 2.0 kg ai ha^{-1} + 0.5 per cent NH_4SO_4
6	T_6	Glyphosate @ 2.5 kg ai ha^{-1} + 0.5 per cent NH_4SO_4
7	T_7	2, 4-D sodium salt @ 1.5 kg ai ha^{-1}
8	T_8	2, 4-D sodium salt @ 1.75 kg ai ha^{-1}
9	T_9	2, 4-D sodium salt @ 2.0 kg ai ha^{-1}
10	T_{10}	2, 4-D sodium salt @1.5kg ai ha^{-1} + 1 per cent Urea
11	T_{11}	2,4-D sodium salt @1.75kg ai ha^{-1} + 1 per cent Urea
12	T_{12}	2, 4-D sodium salt @2.0kg ai ha^{-1} + 1 per cent Urea
13	T_{13}	Glyphosate @ 1.5 kg ai ha^{-1} + 2, 4-D sodium salt @ 0.25 kg ai ha^{-1}
14	T_{14}	Glyphosate @ 2.0 kg ai ha^{-1} + 2, 4-D sodium salt @ 0.25 kg ai ha^{-1}
15	T_{15}	Glyphosate @ 2.5 kg ai ha^{-1} + 2, 4-D sodium salt @ 0.25 kg ai ha^{-1}
16	T_{16}	Weedy check

Plate. 1 A field view of experimental plots

3.2.2.4 Herbicides used in the treatments

a) Glyphosate (N-phosphonomethyl glycine)

Formulation	:	41 per cent SL
Trade name	:	Round up
Produced by	:	Monsanto Chemicals
Price	:	Rs.468 per litre

b) 2,4-D Sodium salt (2,4-Dichloro phenoxy acetic acid)

Formulation	:	80 per cent WP
Trade name	:	Fernoxone
Produced by	:	Imperial Chemical Industries, U.K.
Price	:	Rs. 120 per Kg.

3.2.2.5 Application of herbicides

Herbicidal spray solution in water was prepared as per treatments and sprayed with Pneumatic hand sprayer uniformly over the foliage of nutsedge. Spraying was done one month after planting of tubers when weed population was at 6-8 leaf stage. Care was taken to ensure uniformity in spraying and to avoid drift.

3.2.2.6 Observations

3.2.2.6.1 Nutsedge biology

For studying nutsedge biology, observations were taken from control plot (weedy check).

3.2.2.6.1.1 Plant height

Plant height was measured from the base to the tip of the inflorescence, averaged out and expressed in cm.

3.2.2.6.1.2 Number of aerial shoots per tuber

Number of shoots per tuber was counted and averaged out.

3.2.2.6.1.3 Number of leaves per shoot

Number of leaves per shoot was counted and averaged out.

3.2.2.6.1.4 Length and width of leaf

Length and width of leaves were measured, averaged out and expressed in cm.

3.2.2.6.1.5 Days to flowering

Number of days required for 50 per cent flowering was recorded.

3.2.2.6.1.6 Spikelet length

Nutsedge inflorescence was collected and spikelet length was measured, averaged out and expressed in cm.

3.2.2.6.1.7 Seed viability

Hundred seeds of nutsedge were sown in petri dishes lined with germination paper moistened with distilled water. Germination count was noted and expressed in percentage.

3.2.2.6.1.8 Length of tuber

Nutsedge plants were uprooted, tubers were collected at random and the length of the tubers was measured, averaged out and expressed in cm.

3.2.2.6.1.9 Tuber viability

Tubers were collected at random from uniformly sized plants and were sown in petri dishes both as single tubers and in chains. Number of tubers germinated were counted and expressed in percentage.

3.2.2.6.1.10 Tuber number at maturity

Ten plants were uprooted at random and the total number of tubers were counted and expressed as number of tubers per plant.

3.2.2.6.1.11 Tuber weight at maturity

Ten plants were uprooted at random; tubers were separated and cleaned and total tuber dry weight was recorded.

3.2.2.6.1.12 Days to maturity

Days to maturity was recorded as number of days taken for complete drying up of the aerial shoots that have sprouted out from the tubers sown.

3.2.2.6.2 Observations on Treatment effects

On the respective days of observations, an iron quadrat of 30 cm × 30 cm was placed randomly at three places in the net plot area and

observations on weeds were taken. Observations were recorded till 6 weeks after spraying at weekly intervals.

3.2.2.6.2.1 Shoot fresh weight

After counting the number of aerial shoots, shoots of weed samples from one of the quadrat was taken at random and expressed in per m^2 area basis.

3.2.2.6.2.2 Shoot dry weight

Weed samples collected for recording shoot fresh weight was dried at 70°C to a constant weight and weed dry matter expressed in per m^2 area basis.

3.2.2.6.2.3 Tuber fresh weight

Tubers of nutsedge from above weed samples were separated, cleaned of dirt, weighed and expressed in per m^2 area basis.

3.2.2.6.2.4 Tuber dry weight

The tubers collected were dried and the tuber dry weight was expressed in per m^2 area basis.

3.2.2.6.2.5 *Tuber viability*

30 and 45 days after the application of herbicides, ten tubers were collected at random from each plot, detached and the individual tubers were kept

Plate. 2 Visible symptoms of Glyphosate application.

Plate.3 Visible symptoms of 2, 4-D application

but the older leaves dried up at a faster rate. Complete drying of foliage was observed by the end of 3 weeks.

4.2.2.1.4. Morphological symptoms on tubers

When uprooted one week after spraying of herbicides, the tuber showed no distinct change in morphological features. But, after 2 weeks, tubers were found deep black in colour, malformed, shrunken and stony. Some of the tubers were seen hollow and when pressed it got crumbled. The effect was more or less similar in all the chemical treatments.

4.2.2.2 Shoot fresh weight (Table 11)

The results indicated that the herbicidal treatments did not have significant influence on fresh weight of shoots for the first two weeks.

However, data on the shoot weight at 3 weeks after spraying revealed a drastic reduction when compared to the weedy check. All the herbicide treatments recorded significant reduction in foliage growth. The treatments T_3, T_1 (Glyphosate @ 2.5 & 1.5 kg ai ha^{-1} respectively) T_1 (2, 4-D @ 1.75 kg ai ha^{-1} + 1 per cent urea) and T_{13}, T_{14}, T_{15} (Glyphosate + 2, 4-D combinations) recorded 100 per cent control of foliage.

All the weed control treatments recorded complete control of nutsedge shoots when observed at 4 weeks after herbicide application. There

Table 11

Effect of treatments on Shoot fresh weight of purple nutsedge (g m^{-2})

Treatments	1 week after spraying	2 weeks after spraying	3 weeks after spraying	4 weeks after spraying	6 weeks after spraying
T_1	4.58	2.51	0.0	0.00	0.00
T_2	5.66	2.90	0.85	0.00	0.00
T_3	4.10	2.48	0.00	0.00	0.00
T_4	5.46	2.39	0.35	0.00	0.00
T_5	3.51	2.29	0.21	0.00	0.00
T_6	3.27	2.64	0.15	0.00	0.00
T_7	4.63	2.85	0.32	0.00	0.00
T_8	3.40	2.46	0.21	0.00	0.00
T_9	3.37	2.86	0.20	0.00	0.00
T_{10}	4.29	2.75	0.18	0.00	0.00
T_{11}	4.13	2.43	0.0	0.00	0.00
T_{12}	4.17	2.75	0.07	0.00	0.00
T_{13}	5.72	3.0	0.00	0.00	0.00
T_{14}	5.15	3.23	0.00	0.00	0.00
T_{15}	3.97	2.57	0.00	0.00	0.00
T_{16}	4.44	5.12	18.83	18.04	18.23
F (15, 20)	1.09	1.41	201.30**	--	--
CD (0.05)	--	--	0.95	--	--

** Significant at 0.01 level

* Significant at 0.05 level

Table 12

Effect of treatments on shoot dry weight of purple nutsedge (g m^{-2})

Treatments	1 week after spraying	2 weeks after spraying	3 weeks after spraying	4 weeks after spraying	6 weeks after spraying
T_1	1.43	1.15	0.0	0.00	0.00
T_2	1.66	1.23	0.40	0.00	0.00
T_3	1.35	1.07	0.00	0.00	0.00
T_4	1.30	0.84	0.14	0.00	0.00
T_5	1.15	0.90	0.07	0.00	0.00
T_6	1.31	0.81	0.006	0.00	0.00
T_7	1.45	1.02	0.10	0.00	0.00
T_8	1.16	1.05	0.007	0.00	0.00
T_9	1.25	0.65	0.07	0.00	0.00
T_{10}	1.35	0.98	0.07	0.00	0.00
T_{11}	0.91	1.08	0.0	0.00	0.00
T_{12}	1.87	0.90	0.003	0.00	0.00
T_{13}	1.66	1.04	0.00	0.00	0.00
T_{14}	1.32	1.31	0.00	0.00	0.00
T_{15}	1.43	0.87	0.00	0.00	0.00
T_{16}	1.80	2.11	8.28	8.39	8.21
F (15, 20)	0.57	0.82	69.40**	--	--
CD (0.05)	--	--	0.71	--	--

** Significant at 0.01 level

* Significant at 0.05 level

was complete weed kill in terms of nutsedge shoots for all herbicide treatments, while weedy check recorded 16.04 gm^{-2}. On 6 weeks after spraying also the trend was the same.

4.2.2.3 Shoot dry weight (Table 12)

None of the herbicidal treatments was able to bring about significant reduction in shoot dry weight for the first 2 weeks after application.

But, by three weeks after herbicide application the treatments significantly reduced the shoot dry weight compared to control. No fresh shoot could be collected from T_1, T_3, T_{11}, T_{13}, T_{14} and T_{15} and the shoot dry weight was recorded as zero. The dry weight values recorded by other herbicidal treatments were also significantly lower than that of control.

On 4 and 6 weeks after spraying, the herbicidal treatments recorded cent percent control of nutsedge shoots in terms of dry weight of shoots.

4.2.2.4 Tuber fresh weight (Table 13)

The data revealed that on one week after spraying there was no significant reduction in fresh weight of nutsedge tuber by any of the herbicidal treatments.

Table 13

Effect of treatments on Tuber fresh weight of purple nutsedge (g m^{-2})

Treatments	1 week after spraying	2 weeks after spraying	3 weeks after spraying	4 weeks after spraying	6 weeks after spraying
T_1	6.10	5.56	3.84	3.02	1.62
T_2	7.36	6.29	3.83	3.60	1.54
T_3	6.29	5.64	3.93	3.90	1.51
T_4	7.97	5.37	5.02	4.37	2.94
T_5	7.15	4.99	4.23	3.47	1.85
T_6	7.86	5.84	6.01	4.79	2.23
T_7	8.00	6.02	5.95	5.37	2.32
T_8	6.38	7.05	5.69	4.56	2.58
T_9	7.58	6.97	7.02	4.97	2.38
T_{10}	6.66	5.38	6.41	5.60	3.09
T_{11}	7.21	7.32	6.80	4.99	2.66
T_{12}	7.88	6.23	3.92	4.10	3.36
T_{13}	8.29	5.71	4.45	4.08	2.19
T_{14}	9.08	6.41	5.92	4.39	1.58
T_{15}	7.57	4.92	3.75	3.65	1.85
T_{16}	7.85	11.35	23.88	22.00	28.72
F (15, 20)	0.83	4.77**	4.28**	52.46**	170.60**
CD (0.05)	--	2.00	6.73	1.78	2.07

** Significant at 0.01 level

* Significant at 0.05 level

However, by 2 weeks after spraying, fresh weight of tuber was found to decrease significantly by all herbicide application. When compared to control, there was considerable reduction in tuber fresh weight for all herbicide treated plots and the effect was more or less same for all treatment. Lowest value was recorded by T_{15} (Glyphosate @ 2.5 kg ai ha^{-1} + 2, 4-D @ 0.25 kg ha^{-1}) followed by T_5 (glyphosate @ 2 kg ai ha^{-1} + 0.5 per cent NH_4SO_4) and in other treatments also tuber fresh weight recorded substantial reduction.

After 3 weeks, fresh weight of tubers reduced further and when compared to weedy check the reduction was drastic.

The values recorded on 4 weeks after spraying showed still further reduction in tuber fresh weight. Maximum reduction was recorded for Glyphosate @ 1.5 kg ai ha^{-1} (T_1) followed by glyphosate @ 2.0 kg ai ha^{-1} + 0.5 per cent NH_4SO_4 (T_5). These treatments resulted in 3.02 and 3.47 gm^{-2} tuber fresh matter compared to 22.0 gm^{-2} for the weedy check. Tuber fresh weight was found to decrease to the extent of 75 to 87 per cent in the various herbicide treated plots.

When observed at 6 weeks after spraying the tuber fresh weight in general showed values lower than that of the values recorded on 3 and 4 weeks after spraying and the trend was the same in control plot also. The tuber

fresh weight was the lowest in T_3 (glyphosate @ 2.5 kg ai ha^{-1}) and when compared to the control the reduction was 95 per cent. Other herbicidal treatments also recorded significantly lower values than the control.

4.2.2.5 Tuber dry weight (Table 14)

From the data it was evident that with one week, none of the herbicide treatments were able to reduce the tuber biomass significantly.

But by 2 weeks after spraying all the herbicide treatments recorded significantly lower tuber weight than the weedy check. Among the treatments, Glyphosate at 2.5 and 1.5 kg ha^{-1} (T_3 and T_1) recorded the lowest tuber dry weight values of 2.73 and 2.62 respectively, while that of weedy check was 5.82g m^{-2}.

At 21 days of treatment spraying T_1 and T_2 (glyphosate alone at 1.5 and 2.0 kg ai ha^{-1} respectively) were found to give maximum control of nutsedge tuber dry matter. The other herbicidal treatments also gave good reduction of tuber biomass and tuber dry weight values in general were lower than that recorded on 2 weeks after spraying. The untreated check recorded pronounced increase in tuber dry weight over the previous week.

At the end of 4 weeks, reduction in tuber dry weight by herbicide application ranged from 63-80 per cent. Glyphosate @ 2.0 kg ai ha^{-1} (T_2)

Table 14

Effect of treatments on Tuber dry weight of purple nutsedge (g m^{-2})

Treatments	1 week after spraying	2 weeks after spraying	3 weeks after spraying	4 weeks after spraying	6 weeks after spraying
T_1	2.92	2.62	1.64	1.07	1.11
T_2	3.41	3.55	1.94	1.97	1.13
T_3	3.27	2.73	2.18	2.36	1.15
T_4	4.12	3.13	3.12	2.89	1.94
T_5	3.72	3.12	2.45	2.73	1.38
T_6	4.24	2.90	3.32	3.27	1.64
T_7	3.75	3.39	3.04	2.94	1.79
T_8	2.88	3.60	3.32	3.33	1.89
T_9	3.42	3.31	3.10	3.13	1.65
T_{10}	3.04	2.96	3.17	3.51	2.25
T_{11}	3.68	3.26	3.34	3.54	1.87
T_{12}	3.19	3.08	2.0	2.65	2.49
T_{13}	3.84	3.34	2.22	2.12	1.62
T_{14}	4.21	3.23	3.13	2.14	1.17
T_{15}	4.03	3.02	2.03	1.97	1.34
T_{16}	4.00	5.82	11.85	19.52	26.18
F (15, 20)	0.97	2.38*	3.28**	29.9**	187.8**
CD (0.05)	--	1.34	3.77	3.16	1.83

** Significant at 0.01 level

* Significant at 0.05 level

followed by Glyphosate @ 2.5 kg ai ha^{-1} + 2, 4-D sodium salt @ 0.25 kg ai ha^{-1} (T_{15}) recorded the highest reduction in tuber dry weight but were comparable with the other chemical treatments.

When observed 6 weeks after spraying the tuber dry weight was found to decrease further in all treatments and when compared to weedy check, the herbicide treated plots showed significantly lower tuber dry weight.

4.2.2.6 Tuber viability (Table 15)

There was significant reduction in sprouting of tubers, when collected one month after herbicide application. All the herbicide treatments resulted in significant tuber mortality with T_3, T_4, T_6, T_{13} and T_{15} recording 100 per cent mortality.

Germination percentage of tubers collected after six weeks of herbicide application showed an increase in germinability over the previous record. In all herbicide treated plots except T_{15}, T_{14} and T_{13} there was regeneration which was comparable to that of control. The Glyphosate + 2, 4-D combination treatments recorded significant mortality with T_{15} (Glyphosate @ 2.5 kg ai ha^{-1} + 2, 4-D sodium salt @ 0.25 kg ai ha^{-1}) recording the highest mortality percentage of 100.

Table 15

Effect of treatments on germination percentage of tubers collected 30 & 45 days after herbicides application

Treatments	Tubers collected 30 DASP				Tubers collected 45 DASP			
	2 WAS		3 WAS		2 WAS		3 WAS	
T_1	0.00	(0.00)	2.36	(8.85)	19.40	(26.14)	46.5	(43.04)
T_2	0.00	(0.00)	2.36	(8.85)	13.93	(21.92)	68.9	(56.14)
T_3	0.00	(0.00)	0.00	(0.00)	12.99	(21.13)	24.97	(29.98)
T_4	0.00	(0.00)	0.00	(0.00)	61.96	(51.92)	61.96	(51.92)
T_5	5.11	(13.07)	5.11	(13.07)	5.11	(13.07)	32.8	(34.99)
T_6	0.00	(0.00)	0.00	(0.00)	2.36	(8.85)	13.93	(21.92)
T_7	32.91	(34.99)	45.99	(42.68)	8.55	(17.01)	32.8	(34.99)
T_8	2.36	(8.85)	9.25	(17.70)	5.1	(13.07)	13.93	(21.92)
T_9	18.91	(25.76)	32.29	(34.61)	5.1	(13.07)	13.93	(21.92)
T_{10}	9.25	(17.70)	25.00	(29.98)	19.40	(26.14)	32.8	(34.99)
T_{11}	0.00	(0.00)	2.36	(8.85)	5.11	(13.07)	13.93	(21.92)
T_{12}	9.25	(17.70)	9.25	(17.70)	5.11	(13.07)	19.40	(26.14)
T_{13}	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)	5.11	(13.07)
T_{14}	2.36	(8.85)	2.36	(8.85)	0.00	(0.00)	2.36	(8.85)
T_{15}	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)
T_{16}	86.06	(68.05)	90.75	(72.27)	59.8	(50.7)	73.7	(59.16)
F (15, 20)		6.18**		5.52**		2.02**		2.47**
CD (0.05)		21.40		24.38		13.38		13.23

** Significant at 0.01 level

* Significant at 0.05 level

Figures in paranthesis indicate transformed values

WAS - Weeks after sowing

DASP - Days after spraying

From the data it was also evident that the tubers collected from herbicide treated plot took more time for sprouting.

4.2.2.7 Weed Control Efficiency (Table 16)

Spraying of Glyphosate alone at 1.5 kg ai ha^{-1} considerably reduced the weed dry matter of both shoot and tuber and hence recorded the highest weed control efficiency at 3 weeks after spraying. All herbicides recorded good weed control efficiency compared to control and they were on par.

At 4 weeks after herbicide application all treatments significantly reduced the weed dry matter accumulation when compared to weedy check. Weed control efficiency recorded by all treatments were on par among themselves.

When observed 6 weeks after herbicide application, the lowest dry matter and greatest weed control efficiency was recorded by T_{14} (Glyphosate @2 kg ai ha^{-1} + 2, 4-D sodium salt @ 0.25 kg ai ha^{-1}) which was comparable with all other herbicidal treatments except T_4, T_{10} & T_{12}.

4.2.3 Effect of herbicide application on associated weeds

Other weed species which came up after planting the nutsedge tubers were removed as and when necessary till the time of herbicide application.

Table 16

Weed control efficiency of the herbicide treatments

Treatments	3 weeks after spraying	4 weeks after spraying	6 weeks after spraying
T_1	91.00	88.33	87.66
T_2	88.66	88.66	88.00
T_3	88.66	87.00	88.00
T_4	83.66	84.00	78.66
T_5	85.66	85.00	84.66
T_6	79.66	82.00	81.33
T_7	82.33	83.33	81.00
T_8	80.0	81.33	80.00
T_9	81.0	82.66	83.66
T_{10}	83.0	80.33	76.33
T_{11}	80.33	80.00	82.00
T_{12}	88.0	85.33	73.33
T_{13}	87.0	88.33	82.33
T_{14}	81.66	88.00	88.66
T_{15}	89.0	89.00	86.0
T_{16}	--	--	--
F (15, 20)	51.60**	51.47**	37.45**
CD (0.05)	8.63	8.63	9.98

** Significant at 0.01 level

* Significant at 0.05 level

After that, no further weeding was done and the weeds that came up were noted and the following observation were made.

4.2.3.1 Weed flora

Associated weeds started emerging after the control of nutsedge population. The dominant weed flora of the experimental field are given in Table. 17.

4.2.3.2 Weed count (Table 18)

Data on weed density observed at 3 and 6 weeks after spraying indicated that the application of the post emergent herbicide had no significant influence on density of the associated weeds, which germinated thereafter from the soil.

4.2.3.3 Weed fresh weight (Table 18)

Though significance was observed at 6 weeks after spraying, no consistent pattern was noticed on fresh weight of associated weeds.

4.2.3.4 Weed dry matter (Table 18)

At three weeks after spraying, the dry weight of associated weeds showed no significant variation due to treatment effects. However, the data on 6 weeks after spraying showed considerable variation between treatments.

Table 17

Associated weed flora of the experimental field

Scientific name	Common name / Vernacular name	Family
Dicots		
Vernonia cineria	Poovamkurunnu	Compositae
Oldenlandia aspera	Nonganampullu	Umbelliferae
Euphorbia hirta	Tharavu	Euphorbiaceae
Emelia sonchifolia	Muyal chevian	Compositae
Boerhaavia diffusa	Thazhuthama	Nyctaginaceae
Boerraria hispida	Tharakala	Rubiaceae
Monocots		
Digitaria ciliaris	Crab grass	Graminae
Brachiaria distichophylla		Graminae
Perotis indica	Narivanpullu	Graminae
Alloteropsis cimicina		Graminae
Digitaria sanquinalis	Large Crab grass	Graminae
Eleusine indica	Goose grass	Graminae
Sedges		
Bulbostylis barbata	Sooryan	Cyperaceae

Table 18

Weed count, fresh and dry weight of associated weeds (g m^{-2})

Treatments	Weed Count (m^{-2}) 6 WASP		Weed fresh weight (g m^{-2}) 6 WASP	Weed dry matter (g m^{-2}) 6 WASP
T_1	2.84	(1.68)	18.47	4.22
T_2	1.99	(1.41)	35.22	5.73
T_3	2.48	(1.57)	8.35	4.55
T_4	3.47	(1.86)	17.49	6.11
T_5	2.16	(1.47)	20.22	4.94
T_6	2.16	(1.47)	16.50	4.86
T_7	3.47	(1.86)	23.77	12.19
T_8	7.56	(2.75)	44.71	12.00
T_9	3.65	(1.91)	27.14	11.59
T_{10}	2.16	(1.47)	26.21	9.69
T_{11}	3.82	(1.95)	35.12	8.38
T_{12}	3.32	(1.82)	19.15	18.16
T_{13}	3.25	(1.80)	32.64	4.42
T_{14}	2.94	(1.71)	8.78	5.59
T_{15}	4.0	(2.0)	25.91	3.63
T_{16}	5.17	(2.27)	35.25	9.33
F (15, 20)	–	1.69	2.02*	4.06**
CD (0.05)	–	–	20.50	5.80

** Significant at 0.01 level

* Significant at 0.05 level

WASP - Weeks after spraying

Figures in paranthesis indicate transformed values

Maximum value was recorded by T_{12} (18.16g) and the lowest value was that of T_{15} (3.63g).

4.3 Persistence of Glyphosate and 2, 4-D sodium salt in soil

The persistence of the herbicidal treatments in soil was studied by observing germination and early growth response of a sensitive indicator plant cucumber (*Cucumis sativus* L.) at zero and 10 days after herbicide application. The results obtained are presented hereunder.

4.3.1 Sowing on the day of herbicide application (Table 19)

The data on germination count showed that germination of cucumber seeds sown on the same day of herbicide application was not affected by the treatments.

However, plumule growth of cucumber seedlings was affected when sown on the same day of herbicide application. There was appreciable reduction in shoot length for treatments T_3 (1.37 cm), T_{14} (1.59 cm), T_7 (2.62 cm) and T_8 (4.23 cm) compared to that of control (11.36 cm). The effect of all other treatments was same as that of control

Significant reduction in the growth of radicle was also observed in seedlings grown in the herbicide treated soils. The treatment T_{14} recorded the

Table 19

Residual effect of treatments on germination and early growth of cucumber sown on zero days after herbicide spraying

Treatments	Germination percentage		Root length (cm)	Shoot length (cm)	Fresh weight (mg/pl)	Dry weight (mg/pl)
T_1	76.1	(27.5)	5.52	13.82	683	70
T_2	73.0	(27.0)	3.23	12.09	753	56
T_3	52.7	(22.9)	2.01	12.52	473	50
T_4	63.2	(25.1)	2.56	11.86	576	60
T_5	76.3	(27.6)	3.29	13.64	826	70
T_6	69.2	(26.3)	2.48	13.08	716	83
T_7	69.7	(26.4)	0.34	2.62	173	36
T_8	76.5	(27.6)	0.71	4.23	233	43
T_9	38.4	(19.6)	1.77	9.56	96	20
T_{10}	35.5	(18.8)	0.54	11.97	170	27
T_{11}	72.2	(26.8)	3.33	12.15	370	46
T_{12}	79.1	(28.1)	3.53	12.64	403	36
T_{13}	76.1	(27.5)	0.22	1.37	846	86
T_{14}	63.2	(25.1)	0.14	1.59	580	06
T_{15}	83.2	(28.8)	2.43	11.79	920	80
T_{16}	70.0	(26.4)	3.78	11.36	1086	86
F (15, 20)		1.83	6.88**	29.86**	7.12**	1.95
CD (0.05)		---	1.69	2.37	321	--

** Significant at point 0.01 level

* Significant at 0.05 level

(Figures in paranthesis indicate transformed values)

lowest value (0.14 cm) followed by T_{13} (0.22 cm), T_7 (0.34 cm), T_{10} (0.54 cm), T_8 (0.70 cm), T_9 (1.77 cm) and T_3 (2.01 cm) while the radicle length of the control was 3.78 cm. The other treatments were on par with the untreated control.

The residues of herbicides caused significant reduction in fresh weight of cucumber seedlings. All treatments except T_{15}, T_{13} and T_5 showed significant decrease over control. Drastic reduction in fresh weight was recorded for T_9, T_{10}, T_7, T_8, T_{11} and T_{12} and they were on par among themselves and with the control.

However, the dry weight of the seedlings was not affected even when sown on the same day of herbicide application.

4.3.2 Sowing 10 days after herbicide application (Table 20)

No significant reduction in germination of cucumber seeds was seen when sown 10 days after herbicide application. All the treatments recorded good germination percentage compared to control.

In terms of shoot length and root length, the inhibitory influence was not significant for the treatments.

There was no appreciable reduction in fresh and dry weight of the seedlings compared to control. The residual effect of herbicides 10 days after

Table 20

Effect of treatments on germination and early growth of cucumber sown on 10 days after spraying

Treatments	Germination percentage		Root length (cm)	Shoot length (cm)	Fresh weight (mg/pl)	Dry weight (mg/pl)
T_1	86.6	(29.4)	5.77	14.77	1240	100
T_2	86.4	(29.3)	5.50	14.21	1330	96
T_3	100.0	(31.6)	7.60	14.25	1200	116
T_4	90.0	(30.0)	6.45	14.33	1260	96
T_5	93.2	(30.5)	6.60	14.43	1380	376
T_6	89.8	(29.9)	5.99	14.68	1210	363
T_7	93.2	(30.5)	4.66	14.24	1310	393
T_8	93.2	(30.5)	4.89	14.12	1240	83
T_9	76.5	(27.6)	5.07	14.07	1260	60
T_{10}	93.2	(30.5)	4.93	14.33	1540	140
T_{11}	89.8	(29.9)	4.68	14.77	1340	153
T_{12}	96.8	(31.0)	4.97	14.73	1200	113
T_{13}	93.0	(30.5)	5.51	14.02	1500	136
T_{14}	86.6	(29.4)	4.69	14.44	1500	143
T_{15}	93.2	(30.5)	5.21	14.07	1580	150
T_{16}	93.2	(30.5)	4.78	14.26	1150	116
F (15, 20)		1.71	1.31	0.008	0.28	0.770
CD (0.05)		--	--	--	--	--

(Figures in paranthesis indicate transformed values)

application was not significant enough to cause any reduction in early growth of the indicator plant.

4.4 Effect of chemical weed control on growth and yield of subsequent field crops

The effect of application of different rates of glyphosate, 2, 4-D sodium salt and their combination on growth and yield of subsequent field crops was studied by raising two test crops i.e., Ragi (*Eleusine coracana*) and cucumber (*cucumis sativus* L.) in a portion of the treated plots. The crops were sown 15 days after herbicide application. The results obtained are presented hereunder.

4.4.1 Growth and yield characteristics of Ragi (*Eleusine coracana*) (Table 21)

The data on height of ragi plants indicated that the herbicide treatments had no significant influence on plant height of the crop sown.

The number of tillers produced per plant was observed to follow a similar trend.

In terms of the number of productive tillers per plant, there was no significant reduction by the herbicide treatments also, there was no significant variation in the number of days for 50 per cent flowering of ragi plants. When

Table 21

Effect of weed control treatments on growth and yield of Ragi (*Eleusine coracana* (L.) Gaertn

Treatments	Plant height (cm)	No. of tillers per plant	No. of productive tillers per plant	Days to 50% flowering	Grain yield per plant (g)	Straw yield per plant (g)	Seed viability percentage
T_1	88.66	7.86	3.8	61	32.66	54.66	100
T_2	98.33	6.80	3.53	61	32.0	58.66	100
T_3	92.66	8.20	3.53	63	32.0	53.33	100
T_4	106.66	6.80	4.0	63	28.66	53.33	100
T_5	102.66	6.33	4.40	60	29.33	54.66	100
T_6	97.66	6.86	3.60	63	29.33	56.0	100
T_7	89.66	8.80	3.80	61	28.0	56.0	100
T_8	92.0	7.06	3.60	64	30.0	54.66	100
T_9	91.33	5.13	3.66	61	30.0	53.33	100
T_{10}	83.00	6.46	3.86	64	31.33	46.66	100
T_{11}	84.00	5.26	3.33	63	26.66	53.33	100
T_{12}	96.66	9.59	4.13	62	35.33	57.33	100
T_{13}	87.66	6.66	3.60	60	26.66	59.33	100
T_{14}	101.66	7.06	3.66	61	29.33	57.33	100
T_{15}	82.00	8.66	4.13	63	31.33	54.66	100
T_{16}	92.33	4.46	2.60	61	20.0	41.33	100
F (15, 20)	0.72	1.74	0.32	0.05	0.31	0.008	NA
CD (0.05)	--	--	--	--	--	--	--

compared to control there was no appreciable reduction in grain and straw yield of ragi when sown in herbicide treated plots.

All treatments recorded cent per cent germination of ragi seeds when tested for viability.

None of the treatments recorded any effect on seed viability and all the treatments recorded cent percent germination.

4.4.2 Growth and yield characteristics of Cucumber (*Cucumis sativus*) (Table 22)

It was observed that vine length of cucumber was not significantly influenced by pre emergent herbicide application.

There was no significant reduction in the number of female flowers produced per plant compared to control.

No significant reduction in the number of fruits produced per plant was observed compared to control.

Data on fruit set percentage also showed a similar trend. The effect on fruit set percentage was not significant.

There was no appreciable reduction in fruit yield of cucumber per plant. The effect of herbicides was not significant to cause any reduction.

Table 22

Effect of weed control treatments on growth and yield of Cucumber (*Cucumis sativus* L.)

Treatment	Length of vine (m)	No. of female flowers	No. of fruits per plant	Fruitset percentage	Fruit yield per plant (g)	Seed viability percentage
T_1	1.88	3.54	0.99	34.0	880.0	100
T_2	1.51	2.55	1.10	46.66	826.66	100
T_3	1.48	3.21	0.88	47.66	811.0	100
T_4	1.70	3.55	1.22	46.33	865.33	100
T_5	1.29	3.20	1.11	34.66	853.33	100
T_6	1.54	3.22	1.33	32.33	806.66	100
T_7	1.74	2.33	1.22	44.33	852.66	100
T_8	1.74	3.44	1.44	41.0	874.33	100
T_9	1.28	2.33	0.72	33.66	807.66	100
T_{10}	1.40	2.33	1.00	46.66	889.0	100
T_{11}	1.45	2.65	0.99	35.66	833.33	100
T_{12}	1.91	3.55	1.66	37.66	883.33	100
T_{13}	1.48	2.98	1.38	42.0	796.66	100
T_{14}	1.65	3.22	1.38	35.33	827.66	100
T_{15}	1.86	3.33	1.55	33.66	820.0	100
T_{16}	1.86	2.32	0.66	26.0	688.66	100
F (15, 30)	1.72	0.64	0.66	0.56	0.005	NA
CD (0.05)	--	--	--	--	--	--

Cent per cent germination of cucumber seeds was recorded by all treatments similar to that of control.

All the treatments recorded good seed viability with cent percent germination for all treatments.

4.4.3 Economics (Table 23)

In ragi, the economics was found influenced by the different weed management practices. The highest net income (Rs.15,070/-) was recorded by 2, 4-D @ 2.0 kg ai ha^{-1} + 1% urea closely followed by 2,4-D @ 1.5 kg ai ha^{-1} + 1 % urea. The B:C ratio was found to range from 0.65 to 2.16 with 2,4-D @ 2.0 kg ai ha^{-1} + 1% urea recording the highest B: C ratio and hand weeded check recorded the lowest B:C ratio of 0.65.

For cucumber also, the net income was substantially influenced by different herbicide treatments. Net income obtained for all 2,4-D treatments were higher than that of the other treatments. The highest net income (Rs.12033/-) was recorded by 2,4-D @ 1.50 kg ai ha^{-1} + 1% urea closely followed by 2,4-D @ 1.75 kg ai ha^{-1} (Rs. 11650/-). The B : C ratio was found to be in similar lines. The hand weeded control undoubtedly recorded the lowest B:C ratio.

Table 23

Effect of treatments on economics of Ragi cultivation

Treatments	Normal cost of cultivation excluding weeding (Rs/ha^{-1})	Expense for weeding (Rs ha^{-1})	Total Expenses (Rs ha^{-1})	Gross Income (Rs ha^{-1})	Net Income (*Rs ha^{-1}*)	B:C Ratio
T_1	11,000	6755	17555	25599	7844	1.44
T_2	11,000	8561	19561	25599	6038	1.31
T_3	11,000	10513	21513	25599	4086	1.18
T_4	11,000	6843	17843	22399	4556	1.26
T_5	11,000	8649	19649	23199	3550	1.18
T_6	11,000	10601	21601	23199	1598	1.07
T_7	11,000	1527	12527	22399	9872	1.78
T_8	11,000	1654	12654	23999	9745	1.89
T_9	11,000	1785	12785	23999	11214	1.87
T_{10}	11,000	1671	12671	24799	12128	1.95
T_{11}	11,000	1798	12798	20799	8001	1.62
T_{12}	11,000	1929	12929	27999	15070	2.16
T_{13}	11,000	6868	17868	20799	2931	1.16
T_{14}	11,000	8674	19674	23199	3525	1.17
T_{15}	11,000	10626	21626	24799	3173	1.15
2 HW	11,000	13500	24500	15999.	-8501	0.65

Cost of Glyphosate - Rs. 468 l^{-1}

Cost of 2,4-D Sodium Salt - Rs. 120 kg^{-1}

Wage rate of ordinary labourer - Rs 135 day^{-1}

Wage rate of skilled labourer (for spraying) - Rs. 137 day^{-1}

Rent of sprayer - Rs. 4 per hour

Cost of 1 kg Ragi - Rs. 3 kg^{-1}

Cost of mussoriephos - Rs. 4 kg^{-1}

Cost of M.O.P - Rs. 3.5 kg^{-1}

HW - Hand weeding

Table 24

Effect of treatments on economics of Cucumber cultivation

Treatments	Normal cost of cultivation excluding weeding (Rs/ha^{-1})	Expense for weeding (Rs ha^{-1})	Total Expenses (Rs ha^{-1})	Gross Income (Rs ha^{-1})	Net Income (Rs ha^{-1})	B:C Ratio
T_1	10,000	6755	16755	23464	6709	1.40
T_2	10,000	8561	18561	22024	3463	1.18
T_3	10,000	10513	20513	21624	1111	1.05
T_4	10,000	6843	16843	23064	6221	1.36
T_5	10,000	8649	18649	22744	4095	1.22
T_6	10,000	10601	20601	21488	887	1.04
T_7	10,000	1527	11527	22712	11185	1.97
T_8	10,000	1654	11654	23304	11650	1.99
T_9	10,000	1785	11785	21512	9727	1.82
T_{10}	10,000	1671	11671	23704	12033	2.03
T_{11}	10,000	1798	11748	22208	10410	1.88
T_{12}	10,000	1929	11929	23544	11615	1.97
T_{13}	10,000	6868	16868	21224	4356	1.26
T_{14}	10,000	8674	18674	22048	3374	1.18
T_{15}	10,000	10626	20626	21864	1238	1.06
2 HW	10,000	13500	23500	18344	-5156	0.78

Cost of Glyphosate - Rs. 468 l^{-1}

Cost of 2,4-D Sodium Salt - Rs. 120 kg^{-1}

Wage rate of ordinary labourer - Rs 135 day^{-1}

Wage rate of skilled labourer (for spraying) - Rs. 137 day^{-1}

Rent of sprayer - Rs. 4 per hour

Cost of 1 kg Ragi - Rs. 3 kg^{-1}

Cost of mussoriephos - Rs. 4 kg^{-1}

Cost of M.O.P - Rs. 3.5 kg^{-1}

HW - Hand weeding

DISCUSSION

DISCUSSION

The present investigation was undertaken with the objective of assessing the allelopathic influence of purple nutsedge (*Cyperus rotundus* L.) on germination and early growth of field crops and also to study the effectiveness of some systemic herbicides in controlling this abnoxious weed. The results of the experiments presented in the previous chapter are discussed hereunder with an approach to bring out the impact of the inferences field crop production.

Experiment I Allelopathic studies

Allelopathy has been increasingly recognised as an important ecological mechanism which influences plant dominance, succession, formation of plant communities, climax vegetation and crop productivity . Such influences of plants, both beneficial and harmful have important implications on crop production and have been responsible to a considerable degree for the development of any agricultural practice including crop rotation, cover cropping, fertilizer application, disposition of crop residues etc. (Velu *et al.*, 1992). Production of allelochemicals is regulated by the stage of the plant and is modified by environmental stresses like temperature extremes, nutrient and moisture variables, insects and diseases, radiation and herbicides (Einhellig, 1995). Though many physiological processes are affected by allelochemicals, retardation of growth is indicated to be the frequent response. The effect of

allelochemicals on metabolic changes of receiver plant include effect on cell division, elongation, membrane permeability, mineral uptake, stomatal movement, pigment synthesis, enzyme activity, photosynthesics and plant water relations (Wink and Twardenski, 1992). In the present study, the allelopathic influence of purple nutsedge (*Cyperus rotundus* L.) on 3 different classes of field crops were observed. i.e., cereals and millets (Rice and Ragi), pulses (Cowpea and Green gram) and Vegetables (Bitter gourd and Bhindi).

5.1.1 Allelopathic influence of purple nutsedge on Rice and Ragi

Results of the present investigation showed that the seeds of rice and ragi when treated with aqueous extract of purple nutsedge recorded a lower percentage of germination when compared to the control. The inhibitory influence on the first day of germination count was more and that too the dry plant part extract exerted the maximum influence. In general, the blended extract had no pronounced effect on seed germination. It was also evident that nutsedge extracts had more inhibitory influence on rice than ragi.

The important indication of the above response pattern is that *Cyperus rotundus* did have some negative influence on germination of both rice and ragi. The effect was evident in terms of germination failure as well as delay in germination. Dry whole plant and shoot exerted the maximum effect while blended extract failed to have any effect. These results are in conformity with the

Fig. 3 Allelopathic influence of nutsedge extracts on plumule length, radicle length, fresh weight and dry weight of rice

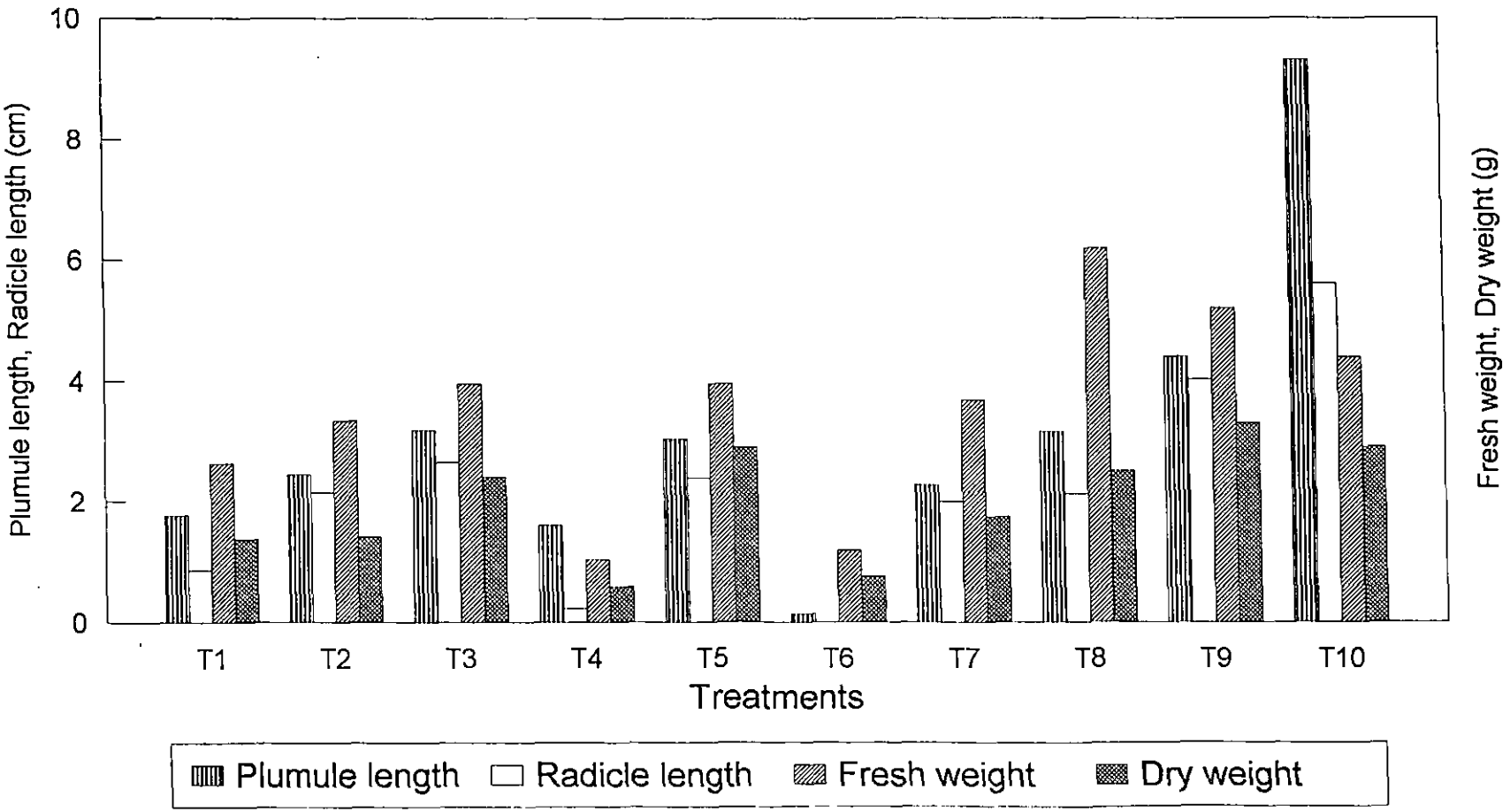
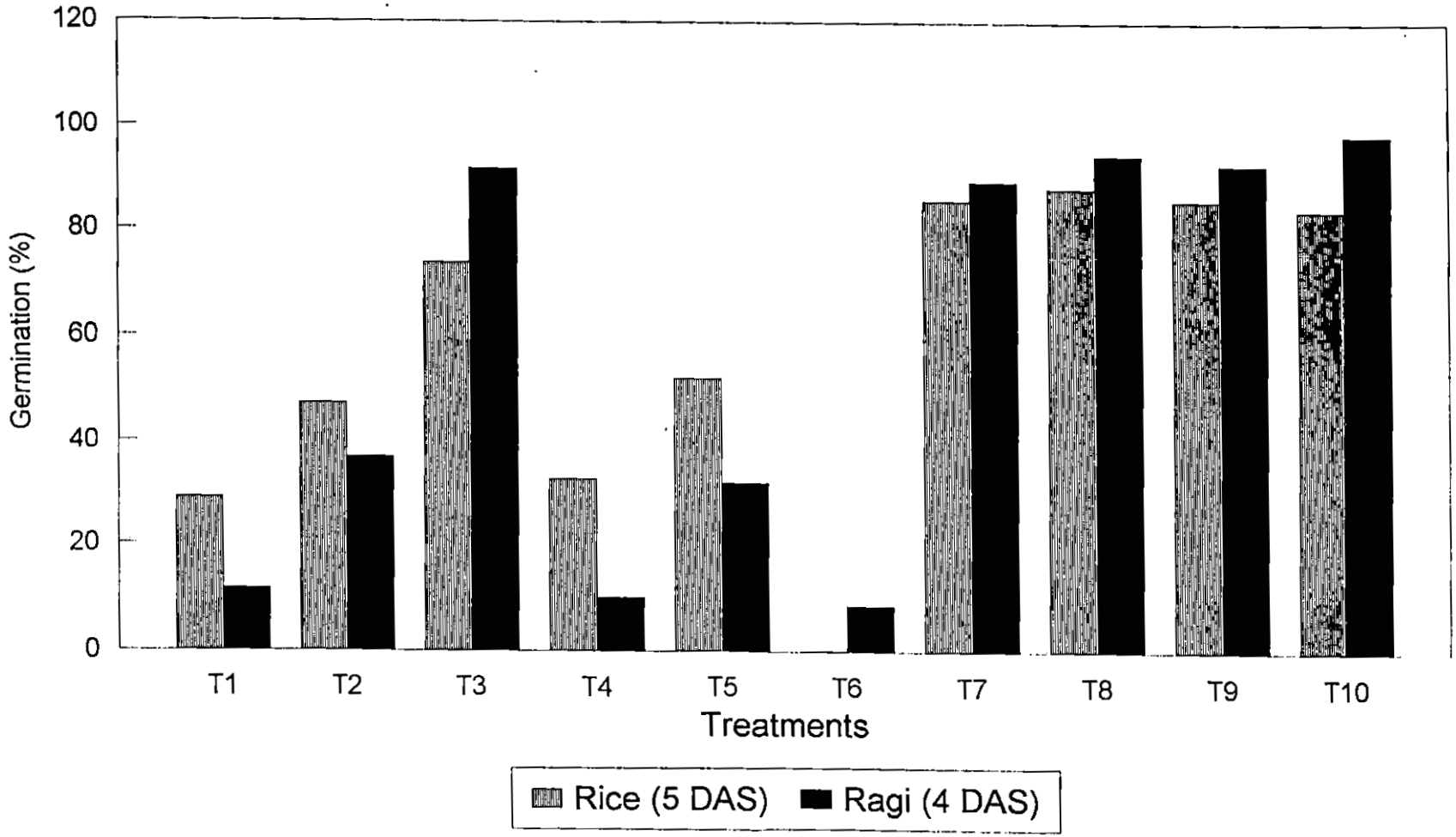


Fig. 4 Allelopathic influence of nutsedge extracts on germination of rice & ragi



findings of Leela (1995) and Raju and Reddy (1996). In an earlier report Singh (1968) observed the inhibition of germination in rice due to aqueous extracts of nutsedge which he attributed to the presence of polyphenols and sesquiterpenes. Leela (1995) reported presence of *p*-hydroxy benzoic acid, caffeic acid, *o*-coumaric acid and ferulic acid in *C. rotundus.* Among the many groups of secondary metabolites that have been encountered in allelopathic interactions are, simple water soluble organic acids, straight chain alcohols, aliphatic aldehydes and ketones, simple phenols, benzoic acid, phenolic acids, cinnamic acid, flavanoids, tannins, terpenoids of many categories, alkaloids, cyanogenic glucosides etc. (Einhellig, 1995; Rizvi *et al.*, 1992).

However, these findings are contrary to the reports of Porwal and Mundra (1993). The possible explanation for such contradictory result is that donor plant generate allelochemicals based on the stress condition under which they are grown (Einhellig , 1996). The response can also vary with the variety of seeds used and concentration of extract .

Plumule and radicle growth of rice was also significantly suppressed by aqueous extract of dry plants and shoot. The growth suppression was much pronounced in terms of radicle length. Significant reduction in radicle growth was recorded by all treatments and the inhibition was found to range from 29 to 100 per cent. Dry whole plant extract recorded the highest inhibition

followed by dry shoot aqueous extract. Among the treatments, dry whole plant recorded complete failure of rice radicle growth. Similar findings of inhibition of root development had been recorded earlier by Castro *et al.* (1984) and Varshney and Saxena (1984). Raju and Reddy (1996) compared the allelopathic effect of cyperaceous weeds on growth of rice and found that *C. rotundus* was most inhibitory to rice. This may be due to the presence of allelochemicals in nutsedge shoots which are inhibitory to rice. Hso-Freng Yuan (1982) observed that the inhibitory compounds in nutsedge extracts suppressed carbohydrate metabolism in rice roots. They also inhibited polysaccharide biosynthesis in cell wall and biosynthesis of pectic substances markedly. But this result is contradictory to the findings of Porwal and Mundra (1993) who reported that aqueous extract of *C. rotundus* did not influence radicle growth of paddy significantly. This indicates that the variety of crop may have a role in deciding the extent of allelopathic response. Unlike in rice, plumule, radicle growth of ragi seedling was not inhibited by nutsedge extracts. This could be explained by the fact that allelochemicals are selective in their action or in their turn, plants are selective in their responses.

Fresh weight of both rice and ragi seedlings were inhibited by aqueous extracts of fresh and dry plant parts. This observation is in close agreement with the results of Lucena and Doll (1976) and Dorst and Doll (1980). This could be due to the presence of growth inhibitors like vanillic

acid, ferulic acid, p-coumaric acid etc. in tubers of nutsedge. Vanillic acid inhibited biosynthesis of hemicellulose while ferulic and vanillic acids suppressed cellulose biosynthesis (Hso-Freng Yuan, 1982).

The dry weight is one of the deciding factors of plant vigour and it is a function of growth of both root and shoot (Velu *et al.*, 1992). Maximum reduction in dry weight was caused by treatments involving dry and fresh shoots. The reduction in dry weight of seedlings obtained for the shoot extract is amply supported by Lall and Savongdy (1981) where they reported a low dry matter accumulation in pearl millet with whole plant of nutsedge exerting the maximum effect.

Vigour index was drastically reduced in rice seedlings for all nutsedge treatments except blended extract of whole plant. The reduction in vigour index was caused by dry whole plant, dry shoot and fresh shoot. This is due to the cumulative effect of reduction in germination percentage, shoot length and root length. However in ragi, seedling vigour was not affected.

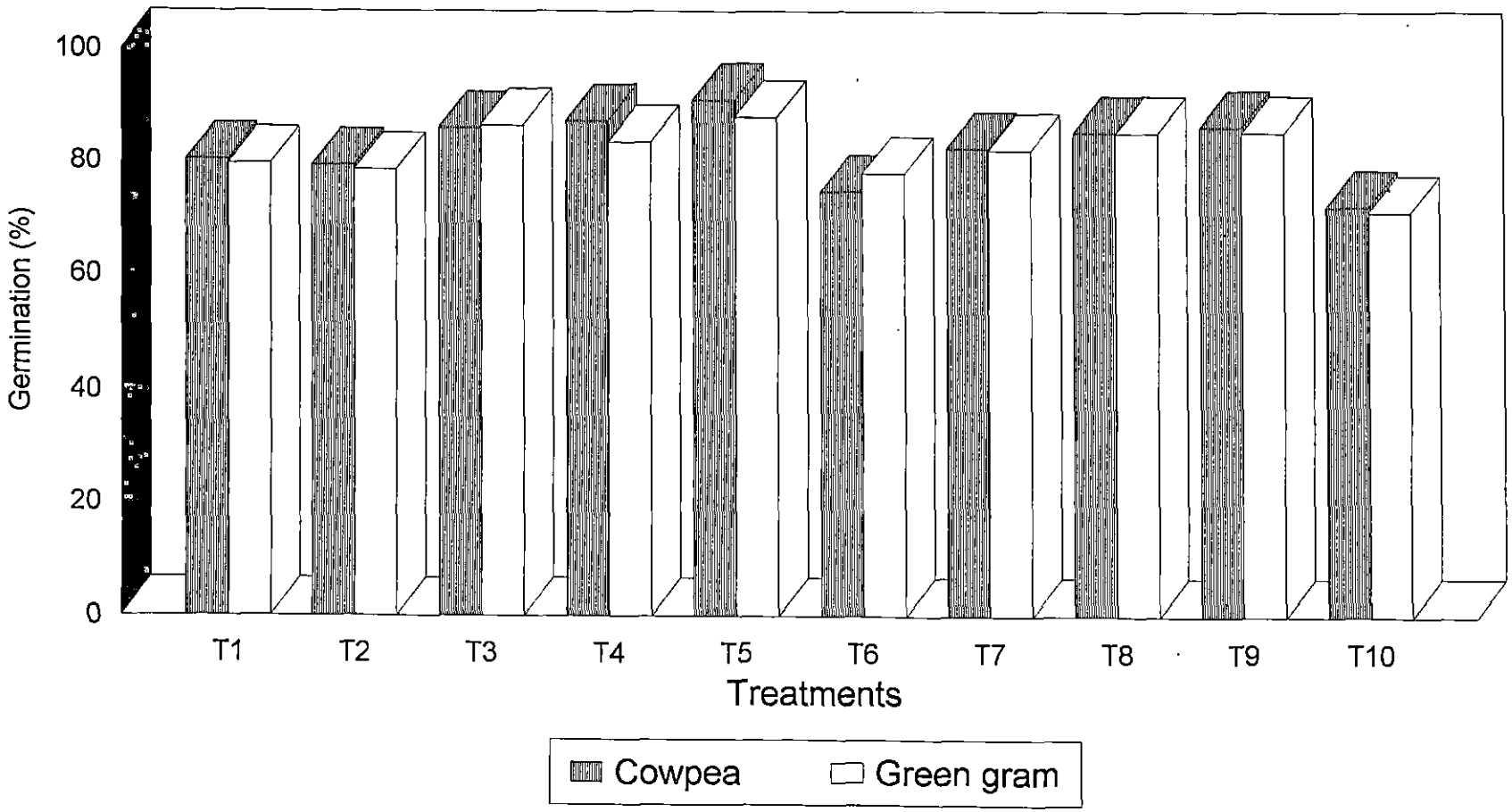
The data on response indices revealed that in rice, inhibitory influence was maximum for plumule and radicle growth. This is in accordance with the findings of Fischer (1980) who opined that retardation of growth was the frequent response to allelochemicals. However, germination inhibition was the most important response to allelochemicals in ragi.

A critical review of the above response pattern revealed that, although germination of both crops are affected by nutsedge extract, ragi plants come up vigorously after an initial inhibition. But in rice, the germination and further growth were likely to be inhibited and purple nutsedge can become a weed to upland rice, due to its competitive effect as well as allelopathic influence.

5.1.2 Allelopathic influence of purple nutsedge on cowpea and green gram

Contrary to the influence on rice and ragi, nutsedge extracts seem to have some positive effect on germination of the legume seeds tested. All treatments involving aqueous extracts of nutsedge stimulated germination of both cowpea and green gram seeds. Though reports of specific stimulation of germination of cowpea and green gram seeds by nutsedge extracts are not available, the general stimulatory effect of nutsedge extracts had been recorded in legumes by earlier workers. Varshney and Saxena (1994) reported that application of tuber and shoot extracts of nutsedge enhanced the germination of lental and pea seeds. This observed stimulatory effect of nutsedge extracts on germination of legume seeds might be because the secondary plant metabolites have multiple functions and some may serve as seed germination stimulants as reported by Saiki and Yoneda (1981).

Fig. 5 Allelopathic influence of nutsedge extracts on germination of cowpea & green gram (5 DAS)



However, plumule growth of cowpea was found suppressed by nutsedge extracts. Significant suppression over control was recorded by fresh and dry plant extracts while blended extracts showed no significant effect. Similar findings of allelopathic growth inhibition of cowpea (Singh, 1968) and other grain legumes (Dorst and Doll, 1980; Velu and Rajagopal, 1996) have been recorded. In green gram, reduction in coleoptile length was brought about only by dry whole plant (T_6) extract treatment. Among the other treatments, T_4, and T_1 were comparable to control and others were stimulatory. Such results confirm that the toxic effects of allelochemicals are species specific (Bhatt and Todaria, 1990) and allelochemicals exuded by different plant parts can have different response in crops.

In cowpea, radicle growth was suppressed significantly by aqueous extract of dry shoot and whole plant parts. This is in conformity with the reports of Wibowo *et al.* (1996). Leela (1995) reported presence of coumarins in *Cyperus* extracts and this could interfere with root cell elongation, water relations and photosynthesis in plants. The radicle growth in green gram was found comparable in all the treatments.

Growth suppression was much pronounced in terms of seedling fresh weight and dry weight of cowpea whereas in green gram fresh weight alone

was affected. Velu and Rajagopal (1996) reported a low dry weight, leaf area and yield in soybean when it was subjected to treatment with nutsedge extracts.

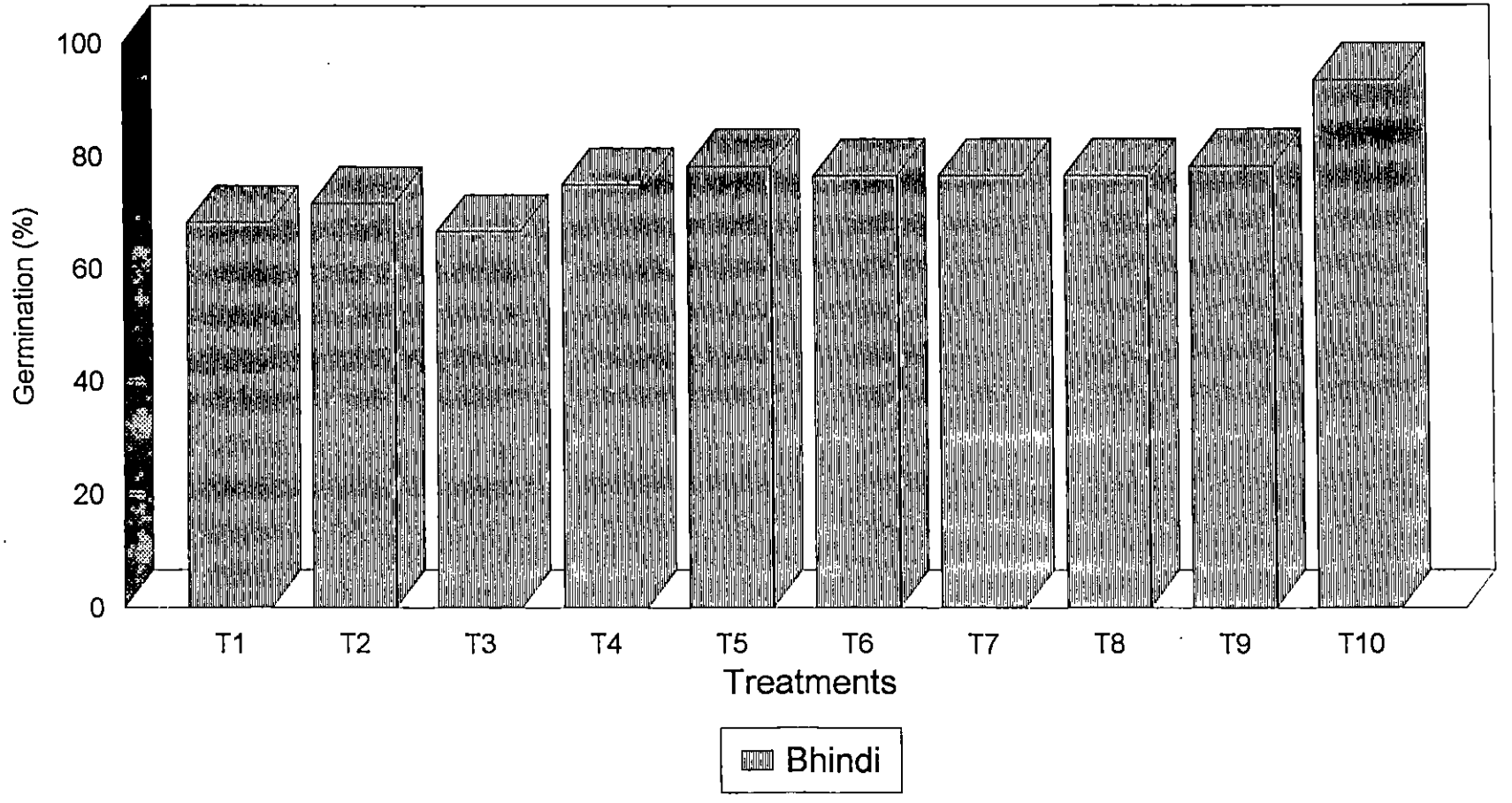
The vigour index is a measure of physiological efficiency of seedlings. Vigour index of cowpea was drastically reduced for treatments with dry plant parts compared to blended extracts and control. Similar inhibition on vigour index was recorded by Singh (1968) in cowpea and black gram and Velu and Rajagopal (1996) in soybean. Inhibition of radicle growth which in turn resulted in poor nutrient absorption and consequent poor biomass accumulation could be the reason for such a drastic reduction in seedling vigour.

A comparison of response indices showed that in both cowpea and green gram plumule growth was more inhibited than all the other growth parameters. In cowpea, seedling vigour was also inhibited to the same degree. The results thus showed that among the two legumes themselves there was differential response to the allelochemicals exuded by nutsedge plants.

5.1.3 Allelopathic influence of Purple nutsedge on Bitter gourd and Bhindi

From the results it was clear that the aqueous extracts of nutsedge could significantly influence germination of both bitter gourd and bhindi. Here again, blended extracts showed no distinct effect on germination. Specific inhibition of vegetable seeds by *C. rotundus* extracts had been reported

Fig. 6 Allelopathic influence of nutsedge extracts on germination of bhindi seeds (4 DAS)

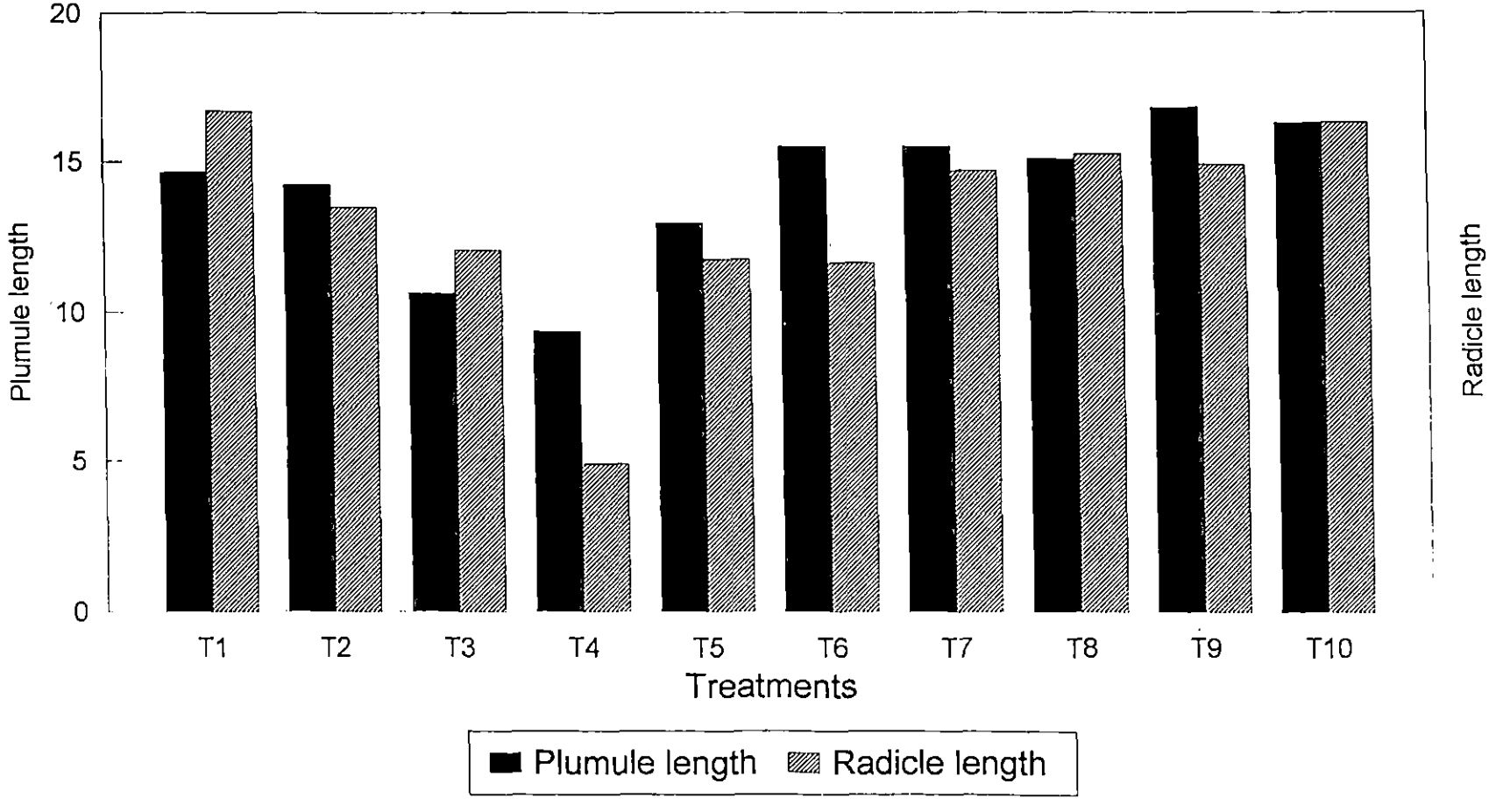


earlier by Komai and Ueki (1980) and Kawisi *et al.* (1995) where they have reported on germination and seedling growth suppression in tomato, onion and cabbage. Leela (1994) recorded the presence of phenolic acids namely p-hydroxy benzoic acid, *p*-coumaric acid, *o*-coumaric acid, caffeic acid and ferulic acid from the aqueous leachates of *C. rotundus*. The lower germination percentage recorded by these crops could be due to the presence of such allelochemicals which inhibit many of the physiological processes including germination.

The length of plumule of both the crops was influenced by aqueous extract of dry shoot and fresh whole plant. Similar response has been recorded by Komai and Ueki (1980). Radicle length of bitter gourd seedlings was found significantly inhibited by the extracts of dry plant parts and the maximum suppression was by dry shoot extract. However, root growth of bhindi seedlings was not affected by any of the treatments. This differential inhibition could be because many plants have the ability to detoxify a range of metabolites (Seigler, 1996).

Dry weight of bhindi and bitter gourd seedlings was not significantly affected by nutsedge extracts while seedling vigour of both the plants were reduced drastically by aqueous extract of dry nutsedge plant parts. Similar reduction in seedling vigour was reported by Velu and Rajagopal (1996)

Fig. 7 Allelopathic influence of nutsedge extracts on plumule length and radicle length of bitter gourd



by whole plant cuttings of nutsedge. In bhindi and bitter gourd, the reduction in vigour can be attributed to the reduction in germination percentage.

The values of response indices also indicated that there was a general and pronounced suppression of seedling vigour in both the vegetables when treated with the nutsedge extract.

Analysing the allelopathic response of the different crops, it could be inferred that the aqueous extract of dry nutsedge plant parts had greater allelopathic effect than the other treatments. So also, the blended extracts failed to elicit any response on these field crops. It might be because in the present study, weed samples for the extract collection were taken on a weight by volume basis and weed biomass in dry plant extract was more. Moossa (1997) has reported that as the concentration of leachate increased, the inhibitory influence of allelochemicals also increased. The insignificant effect of the blended extract might be because during blending process adopted in the present study, the allelochemicals were subjected to some changes rendering them inactive.

A practical implication of these findings is that use of nutsedge residues as mulch would lead to unfavourable growth retardation in crop plants since allelopathic interaction is possible through leaching of inhibitors from these residues. So, also if nutsedge residues are left in the field after hand weeding or

chemical spraying the allelochemicals present in them can reach the crops growing in the field and injure them. There are reports that such toxic substances added to the soil through the residues remain for a long time especially in low rainfall areas and would have inhibitory effect on germination of crop plants (Richardson and Williamson, 1988). This will ultimately play an important role in regulating plant diversity also.

Unlike the experimental condition in the present study in the lab, there is an interplay of factors in the actual field conditions which necessitates field verification of the above findings. Still the results of the present study unmistakably points out the allelopathic influence *C. rotundus* can exert on field crop production.

5.2 Control of nutsedge

5.2.1 Biology of Purple nutsedge

Many works have been carried out throughout the world to understand the biology of purple nutsedge as it is essential for formulating proper control measures.

In the present study, the height of nutsedge plants was found to vary from 22 to 54 cm with an average height of 34 cm. The average number of aerial shoots produced from each tuber was 3 to 4 and the number of leaves

produced per shoot ranged from 7 to 10. Average leaf length was 39.60 cm and leaf width varied from 3 to 4 mm with an average of 3.5 mm. These biometric characters were in conformity with the reports of scientists like Jha and Sen (1980) who have made detailed studies on purple nutsedge biology under conditions in arid zones of Jodhpur and of Wills (1987) in southern region of United States.

However, the leaf width (3 to 4 mm) recorded was less than that recorded by Wills (1987) (6 to 10 mm) which can be attributed to the probable variations in fertility conditions of the soil in which the plants were growing.

Inflorescence emergence was noticed from 21 days after planting while a few plants took 28 days for flowering. This is in consonance with the observations of Okafor (1973) who suggested that flowering of *C. rotundus* can occur within 21 days after emergence under field conditions. But this is in variance with the observations of Hauser (1962) who reported 7 weeks for purple nutsedge to come to flowering. The variations in climatic conditions between the places where the biological studies were undertaken could explain the moderate deviations in the data.

As reported by several earlier workers (Ray, 1975; Pandey, 1984; Wills, 1987) colour of spikelet was found purplish brown to light brown. Spikelet length varied from 0.8 to 11.5 cm with an average of 1.17 cm.

Although a large quantity of seeds are produced by nutsedge, reports on their viability and germinability are not consistent. In the current study germinability of nutsedge seeds was found zero. The findings of Holm *et al.* (1977) and Thullen and Keeley (1979) are also in similar lines. But contrary to that Tripathi (1969) and Jha and Sen (1981) observed a low germination percentage and not zero. Such contradictions could be attributed to the variation in environmental conditions under which the authors have conducted their studies. Sen (1977) has reported that a high correlation exist between the environmental conditions of a particular habitat and the successful germination of a particular weed seed.

Tuber forms the principal source of propagation in this noxious weed. There is wide variation in the reports on number of tubers produced by the plant at maturity. Present study recorded an average tuber number of 12 tubers per plant. A single tuber produced 4 more tubers within a period of 30 days. Smith and Fick (1937) found that a single nutsedge tuber produced a system of 46 tubers and basal bulbs in 3 to 5 months in the green house, while tuber production by single tuber had been as low as 6 tubers within 45 days period in a study reported by Hammerton (1974). These variations in tuber population could be attributed to the fact that tuber production is determined photoperiodically (Berger and Day, 1969).

Nutsedge tubers are stem tubers, irregular in shape and dark brown in colour. Tuber length was observed to vary from 1.6 to 2.4 cm. The tuber length recorded by other workers varied as 1.25 cm (Pandey, 1984) 2.54 cm (Ray, 1975) and 3.5 cm (Wills, 1987).

Tuber, an underground vegetative organ of *Cyperus rotundus* is rich in stored food material and is responsible for propagation. Dry matter accumulation in tubers for each plant was found to have an average weight of 13.75 g. Jha (1982) recorded dry tuber weight of 15.3 g under moist tropical conditions.

Numerous workers have reported presence of apical dominance of nutsedge tubers in chains. When germination percentage of detached tubers were observed, it was found to vary from 70 to 100 per cent with a mean germination percentage of 85 for all tubers. But when sown in chains, sprouting of tubers was limited to tubers at the ends of each chain. This could be well explained by the fact that apical dominance exists in chains and tubers in the middle of the chain will not germinate unless the chain is broken. (Ray, 1975; Pandey, 1984). Smith and Fick (1937) observed that in nutsedge, if the chain was broken into pairs, both would germinate and if broken into three, the centre tuber would remain dormant. The dormancy of single tubers separated from chain was broken. This is the reason why cultivation enhanced rather than limiting the infestation of this weed.

5.2.2 Visual Symptoms

Visual symptoms of glyphosate application appeared only after 3 days and it started with the appearance of uniform chlorosis followed by leaf apex necrosis. Similar data have been reported previously by Villanueva *et al.* (1985) who observed that in sedges chlorophyll content has been greatly decreased by glyphosate treatments. Their inference was that chlorophyll content might have been affected by glyphosate either indirectly through photo bleaching or peroxidation of chlorophyll molecule or directly through inhibition of synthesis. In contrast, Abu Irmaileh and Jordan (1978) found that although chlorosis was an earlier symptom of glyphosate injury, carotenoids were more strongly affected than chlorophyll in purple nutsedge. The plants treated with glyphosate were found to dry up and complete drying was observed by the third week in most of the glyphosate treated plots irrespective of the dose and mixing with adjuvant (0.5 per cent NH_4SO_4). No fresh material could be collected from any of the plots by the fourth week and no fresh shoots germinated when observed on sixth week.

Another morphological symptom of glyphosate application was that the tubers from treated plots were deeper black in colour, malformed, shrunken, stony and some of them were hollow. Keeley *et al.* (1985) observed ability of glyphosate to translocate to tubers of nutsedge and tubers were found stony, severely weakened and killed by glyphosate. Morphological symptoms on

tuber development did not show any marked variation between doses tried or with presence of ammonium sulphate.

The treatment effects of 2, 4-D were also discernible by third day only. Here yellowing started from tip downwards in younger leaves and then spread to older leaves. By the second week, whole plants turned yellow and drying was complete within 3 weeks. However, the severe epinastic symptoms attributed to the susceptible broad leaved weeds (Chrispeeles and Hanson, 1962) was not noted in this case irrespective of the rate of 2,4-D and presence of adjuvants (0.25 kg ai ha^{-1}). Here again, the tubers were deep black and malformed.

5.2.3 Effect on shoot growth

During the first 2 weeks, the herbicide treatments did not show any significant influence on foliage growth of purple nutsedge. When observed after 3 weeks of spraying there was drastic reduction in shoot fresh weight compared to control in all herbicide treated plots. Cent per cent control of foliage was recorded by glyphosate @ 1.5 and 2.5 kg ai ha^{-1}, 2, 4-D @ 1.75 kg ai ha^{-1} + 1% urea and the glyphosate + 2, 4-D combination treatments (T_{13}, T_{14} and T_{15}). By the fourth week, all herbicide treatments recorded complete weed kill in terms of nutsedge shoot growth while weedy check recorded shoot fresh and dry weights of 18.04 g m^{-2} and 8.39 g m^{-2} respectively. The effectiveness of

Fig. 8 Effect of treatments on tuber dry weight of purple nutsedge

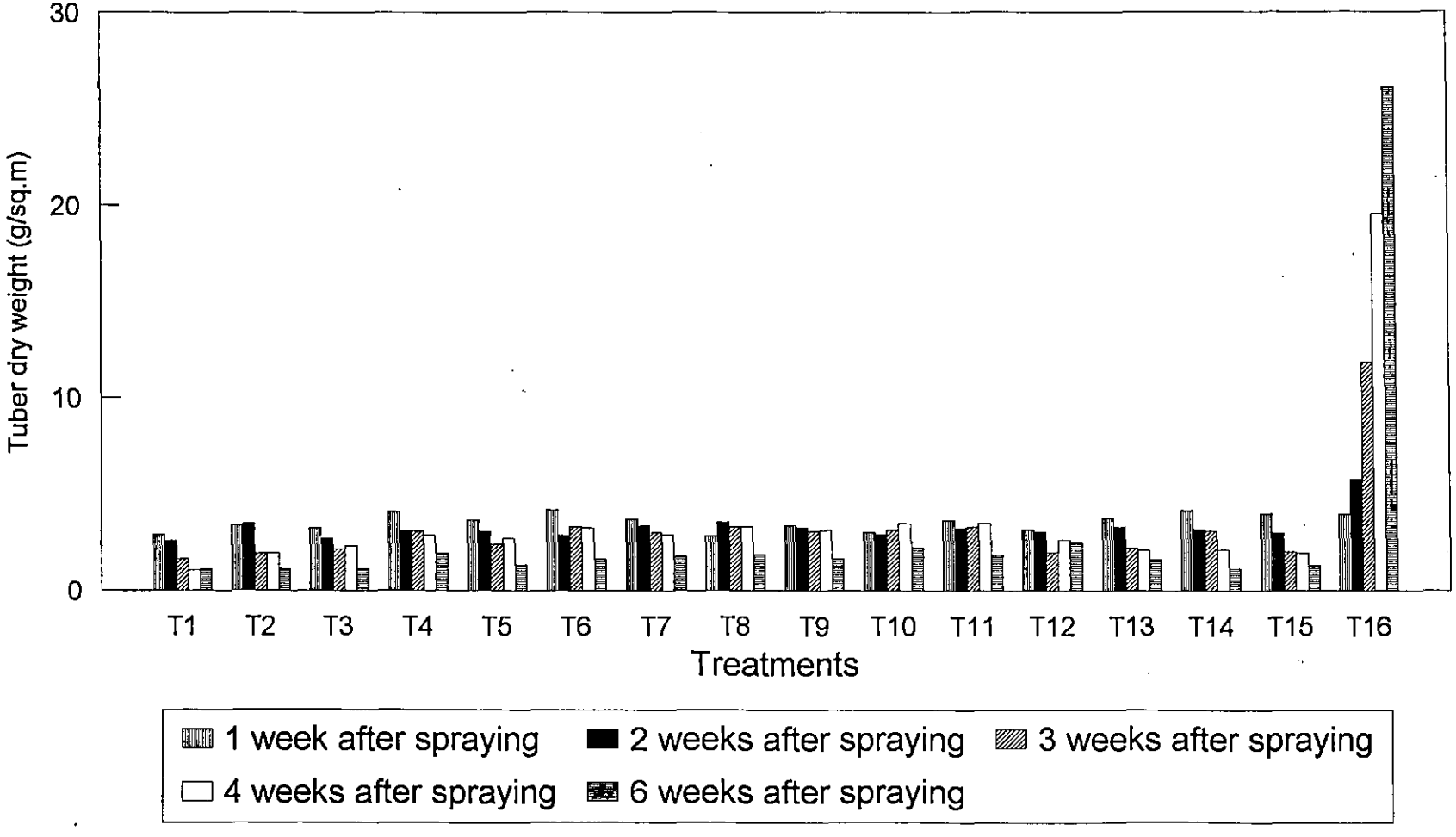


Plate. 4 Nutsedge plants showing the effect of glyphosate application one week after spraying

Plate.5 Nutsedge plants showing the effect of glyphosate application two weeks after spraying


1 Week after Spraying
T13


T14
2WA Spraying


Tc
3 WASH


T14


CONTROL


T10
3WASp

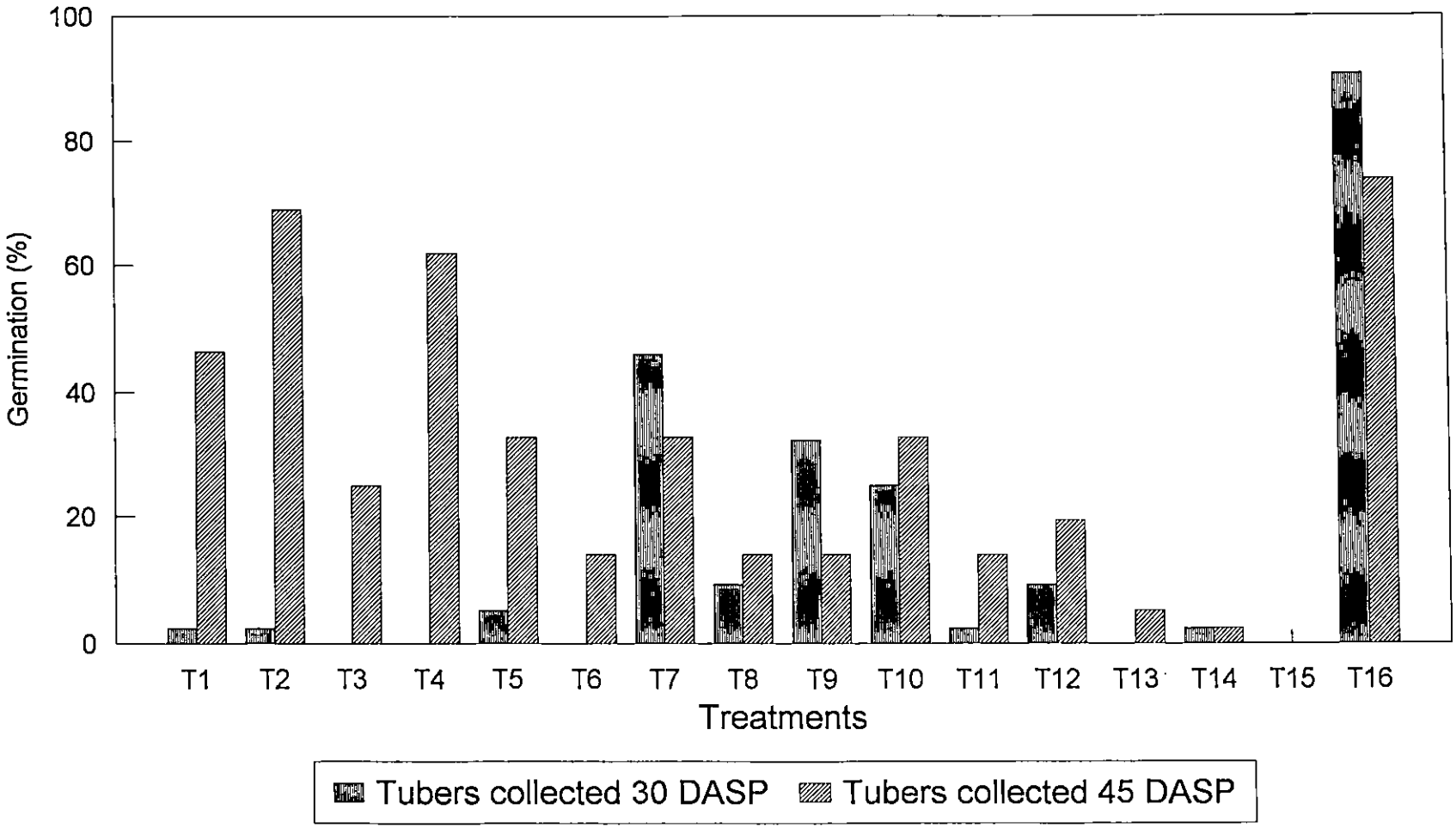

T9
4WA
Sp

glyphosate and 2, 4-D for control of purple nutsedge has been recorded by Thakur *et al.* (1993). They observed that glyphosate and 2, 4-D (@ 1.0 and 1.5 kg ai ha^{-1} respectively) killed the foliage and checked regeneration even upto 360 days of spraying. In the present study, it was evident that the lowest doses tried was sufficient for complete kill of the plant foliage. This is in conformity with some of the earlier reports (Doll and Piedrahita, 1982; Thakur *et al.*, 1993; Liu and Twu, 1993).

5.2.4 Effect on tuber growth and viability

The results showed that herbicide treatments in general inhibited tuberisation and tuber development in nutsedge. However, during the first week of spraying the tuber weight from the treated plots was comparable to that of weedy check. When observed 2 weeks after spraying dry and fresh weight of tubers recorded drastic reduction and on further observation at weekly intervals, the data showed progressive decrease in tuber biomass on all herbicide treated plots. From the data it could be inferred that when treated with the herbicides there was no further tuberisation and the tubers must have rotted and crumbled, making it impossible to collect them. This is in conformity with the reports of Doll and Piedrahita (1982) who reported that glyphosate killed *C. rotundus* foliage and tubers attached to the treated plants. Beltrao *et al.* (1983) observed that single application of glyphosate at 2 or 3 kg ai ha^{-1} is sufficient for 30 days and control was no better with higher rates.

Fig. 9 Effect of treatments on tuber viability of tubers after herbicide application



From the results, it was evident that the lowest dose of herbicides tried (glyphosate and 2, 4-D @ 1.5 kg ai ha^{-1}) were sufficient for complete kill of purple nutsedge plants in the experimental area. This was probably the reason why there was no marked variation between the herbicide treatments. Such complete kill of nutgrass with glyphosate has been reported by Zaenudin *et al.* (1996). In the case of 2, 4-D also its effectiveness for nutsedge control has been recorded by earlier workers (Pathak *et al.*, 1989). The wide range in the optimum dose recommended in various studies is indicative of the extent of variability in the susceptibility of this weed to glyphosate and 2, 4-D. Bhan (1964) reported that the effect of 2, 4-D is better in tropics than in temperate regions possibly because of more vegetative growth of this weed in tropics. In the present study, the nutsedge population was established by planting of uniform sized tubers and application of herbicides was done 35 days after sowing. So it is likely that the tubers that had developed were in active stage and affected by the herbicides checking further tuberisation. However, in a naturally infested area the likely presence of dormant tubers might necessitate repeated spraying for complete weed kill as opined by Bharadwaj (1981) who worked with 2, 4-D and Charles (1995) with glyphosate.

There was significant reduction in viability of tubers collected one month after herbicide application but when tested after 6 weeks there was an increase in germinability over the previous record. This indicated that the

herbicides were able to have only a temporary check on weed infestation as reported earlier by Beltrao *et al.* (1983) and Liu and Twu (1993). The results also showed that tubers collected from herbicide treated plots took more time for sprouting (3 weeks). This must have been the reason why there was no shoot growth during the period of study.

Tubers from glyphosate and 2, 4-D combinations recorded the lowest sprouting percentage indicating weed control for a longer period. This is in line with the results of Manickam and Gnanamoorthy (1994) where they attributed the auxinic effect of 2, 4-D on effective translocation of glyphosate to primary and secondary tubers, when added at sublethal concentration.

However, the data on tuber viability in general is indicative of the chance for reinfestation of the weed and the increase in viability on all the treatments by the sixth week gave added emphasis to this inference.

5.2.5 Effect on Associated weeds

The data on weed count was comparable in all treatments including weedy check. In terms of fresh and dry weight of the weeds, there was considerable variation between treatments, but no specific pattern could be derived. The data is indicative of the potential weed seed inoculum in the soil

and herbicides tried for control of nutsedge showed no influence on their emergence and growth.

5.3 Persistence of glyphosate and 2, 4-D sodium salt in soil

Though germination of cucumber seed was not affected when sown on the same day of herbicide application its further growth was found weakened. However, cucumber seeds sown on soils collected 10 days after spraying recorded germination percentage and growth characters comparable to that of control. This is in line with Thompson *et al.* (1994) and Kuhlmann and Koezmarezyk (1995). In contrast, Manickam and Gnanamoorthy (1994) and Jagannathan and Nadanam (1996) observed that indicator plant could be sown on the same day of herbicide application without any phytotoxicity. Such variation in herbicide persistence could be attributed to the variation in soil type used for the study as reported by Obenshain *et al.* (1997) who observed that there was correlation between soil type and herbicide persistence.

5.4 Effect of chemical weed control on growth and yield of subsequent field crops

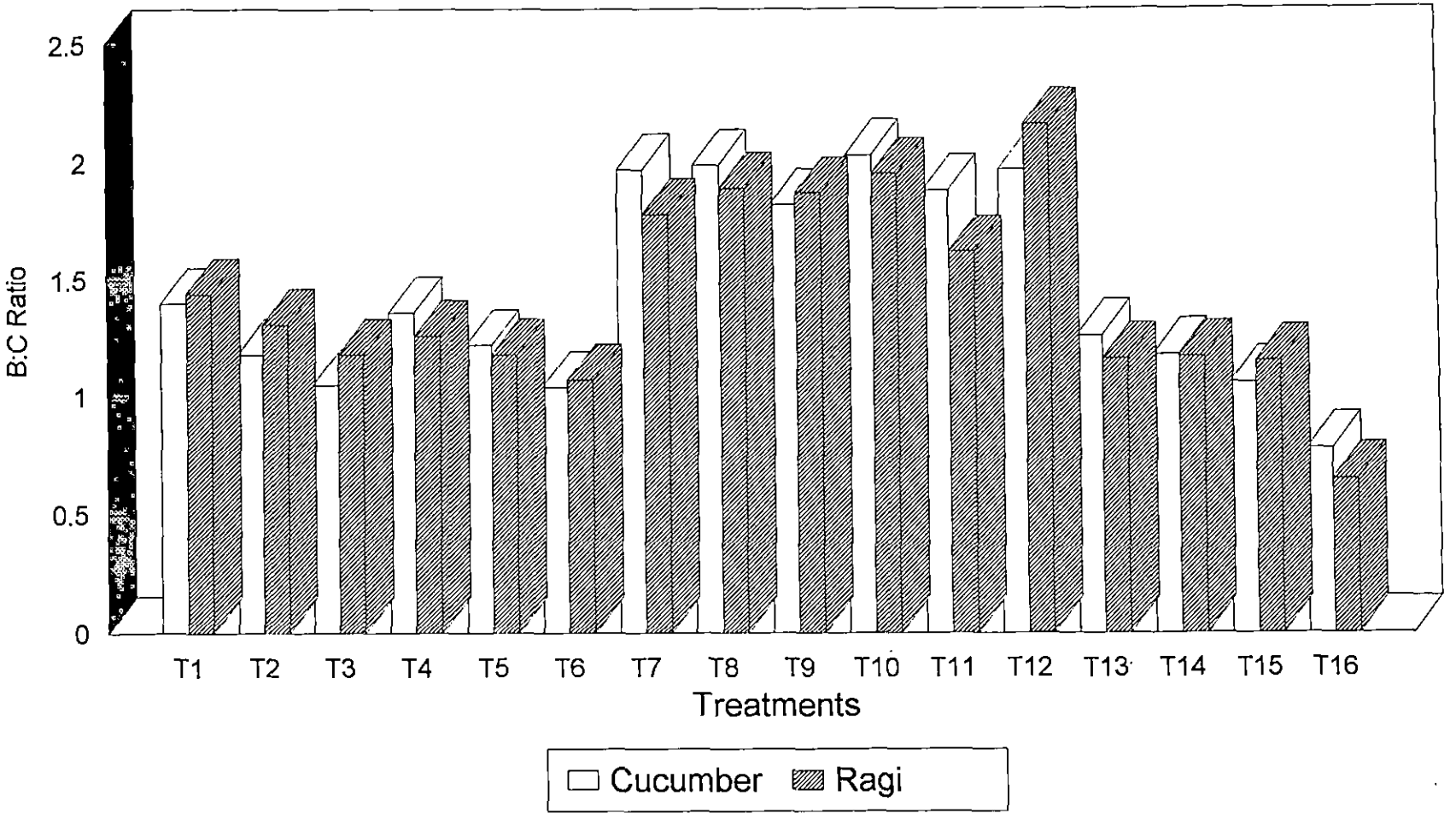
The results indicated that none of the herbicide treatments had any residual effect on growth and yield characteristics of either ragi or cucumber when sown on 15 days after application. No phytotoxic symptoms was noticed on any of the crops tested. Absence of residual effect of glyphosate irrespective

of time of sowing has been recorded by several workers (Jagannathan and Nadanam, 1996; Manickam and Gnanamoorthy, 1994). This indicated that both these herbicides can be used for clearing nutsedge infestation, and crops safely sown after two weeks of spraying.

5.4.1 Economics

In both cucumber and ragi, the economics of crop production showed marked variation between treatments. The 2, 4-D treatments were superior in terms of net income and B:C ratio and highest value was recorded by 2, 4-D @ 1.5 kg ai ha^{-1} + 1% urea in cucumber and 2,4-D @ 2.0 kg ai ha^{-1} + 1% urea in ragi. The treatment receiving hand weeding twice was found least economic. Since the yields recorded by different treatments were comparable, the lower unit cost of 2, 4-D was precisely the reason for its superiority over the other treatments.

Fig. 10 Effect of treatments on benefit cost ratio of cucumber and ragi



SUMMARY

SUMMARY

The present study entitled "Investigations on allelopathic influence and control of Purple nutsedge (*Cyperus rotundus* L.)" was undertaken in the Instructional Farm of College of Agriculture, Vellayani during the period from October 1998 to March 1999. The main objectives were to study the allelopathic influence of purple nutsedge on germination and growth of important field crops; to investigate the effectiveness of systemic herbicides for control of nutsedge and also to assess the effect of chemical weed control on growth and yield of subsequent field crops.

Lab experiments were carried out to examine the allelopathic influence of purple nutsedge on important field crops like rice and ragi (cereals and millets), cowpea and green gram (legumes) and bitter gourd and bhindi (vegetables). The treatments consisted of aqueous extracts of different plant parts of nutsedge. Field experiments were conducted in the garden lands of Instructional Farm to investigate the effectiveness of systemic herbicides like Glyphosate and 2,4-D for control of nutsedge. The treatments consisted of different doses of the herbicides with and without adjuvants and also their combinations. To estimate the residual effect of herbicides on growth and yield of subsequent crops, two test crops viz. cucumber and ragi were raised in the

treated plots and observed for their yield characters. The salient results obtained from the experiments are summarised below.

1. Aqueous extracts of nutsedge inhibited germination and growth of rice and ragi.
2. Aqueous extract of dry plant parts exerted the maximum inhibitory influence while blended extracts showed no influence on the crops tested.
3. Inhibitory effect was more on rice than ragi.
4. Nutsedge extract had some stimulatory effect on germination of cowpea and green gram seeds.
5. Further growth of the legume seedlings were found inhibited with higher degree of inhibition on plumule growth.
6. Aqueous extracts of nutsedge significantly inhibited germination of both bitter gourd and bhindi.
7. Differential inhibition was observed with respect to growth characters of bhindi and bitter gourd.
8. In both the vegetables, the most important growth character inhibited was seedling vigour.
9. In the study on biology of nutsedge, inflorescence emergence was noticed from 21 days after planting.
10. An average number of tubers produced per tuber sown was found 12.

11. Germinability of nutsedge seed was found zero while apical dominance was observed in tubers in chains.
12. Morphological symptoms on application of herbicides started with chlorosis in Glyphosate treated plots, while 2,4-D application resulted in yellowing from tip downwards.
13. During the first 2 weeks after herbicide application, the treatments did not show any significant effect on shoot and tuber weight of nutsedge.
14. All herbicide treatments recorded complete weed kill in terms of shoot growth by the end of 4 weeks.
15. The herbicide treatments in general inhibited tuberisation and tuber weight showed a progressive decrease in herbicide treated plots while weedy check recorded increase in tuber biomass in consecutive observations.
16. Lowest dose of herbicide tried was found sufficient for complete kill of purple nutsedge in the experimental area and there was no regrowth upto 6 weeks after spraying.
17. There was significant reduction in viability of tubers collected one month after herbicide application but the tubers tested 45 days after spraying showed an increase in germinability over the record on 30^{th} day.
18. Tubers from Glyphosate and 2,4-D combinations recorded the lowest sprouting percentage indicating the possibility for weed control for a longer period.

19. Data on tuber viability indicated the chances for reinfestation of the weed.
20. Associated weed population which came up after herbicide application was not affected by the herbicide treatments.
21. Early growth of cucumber seedlings sown on the same day of herbicide application was found affected by the herbicide treatments while cucumber seeds sown on soils collected 10 days after spraying recorded germination percentage and growth characters comparable to that of control.
22. Chemical weed control did not show any deleterious effect on growth and yield characteristics of ragi and cucumber sown on 15 days after application.
23. Application of 2,4-D for nutsedge control was found superior to other treatments in terms of net income and B:C ratio and the lower unit cost of the chemical was precisely the reason for its superiority.

Future lines of work

Since there is an interplay of factors in the actual field conditions, the allelopathic influence of nutsedge as evidenced in the present study needs to be verified under field conditions. Efforts may be done to study the effect on other weeds and to isolate the allelochemicals so as to develop natural herbicides for weed management. An integrated approach for long term management of nutsedge may be investigated and analysis of the herbicide residues may be done quantitatively.

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* Originals not seen

APPENDIX - I

Climatic parameters during the cropping period

(October 1998 to March 1999)

Standard weeks	Temperate (°C)		Relavite humidity (%)	Rainfall (mm)	Evaporation (mm)
	Maximum	Minimum			
39	30.30	23.6	84.3	1.34	3.4
40	29.30	22.9	84.2	6.12	2.76
41	29.60	23.4	80.0	17.65	3.01
42	30.4	22.8	80.07	2.37	3.81
43	30.75	23.5	81.20	1.37	3.06
44	30.90	23.5	77.1	2.37	2.58
45	29.10	23.2	86.6	10.25	1.8
46	30.87	23.1	86.1	9.92	2.97
47	31.24	21.72	86.95	0.6	2.51
48	30.8	22.37	93.1	0.46	2.61
1	31.41	22.08	94.9	0.00	3.25
2	31.77	22.1	78.0	0.00	3.63
3	30.6	21.42	75.8	0.22	3.2
4	31.0	22.02	80.5	9.42	4.1
5	31.0	22.72	83.5	1.8	3.67
6	31.68	23.5	78.5	0.00	3.6
7	31.8	22.67	82.0	0.00	4.02
8	32.4	23.2	79.2	0.00	4.32
9	32.3	23.6	79.2	0.14	4.11
10	32.65	25.2	74.5	7.85	4.72
11	32.71	25.3	81.35	0.22	4.08

INVESTIGATIONS ON ALLELOPATHIC INFLUENCE AND CONTROL OF PURPLE NUTSEDGE *(Cyperus rotundus L.)*

By

AMEENA. M.

ABSTRACT OF THESIS

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VELLAYANI, THIRUVANANTHAPURAM

1999

ABSTRACT

Lab and field experiments were conducted at the Instructional farm, College of Agriculture, Vellayani to study the allelopathic influence of Purple nutsedge (*Cyperus rotundus* L) on important field crops; to investigate the effectiveness of systemic herbicides for control of nutsedge and also to assess the effect of chemical weed control on growth and yield of subsequent field crops.

In Ex. no. I, allelopathic influence of purple nutsedge on important field crops like rice, ragi, cowpea, green gram, bitter gourd and bhindi were studied. The treatments comprised of aqueous extracts and blended extracts of fresh and dry plant parts of nutsedge. The results revealed that aqueous extracts of nutsedge inhibited germination of rice, ragi, bitter gourd and bhindi while it had some stimulatory effect on germination of cowpea and green gram. The early growth characters of the field crops were found suppressed by the aqueous extract treatment while the blended extract showed no effect. In general, the dry plant parts showed greater effect than the fresh material.

Under Ex.no.II, field studies were made to investigate the effectiveness of systemic herbicides viz. Glyphosate and 2,4-D for control of nutsedge. The treatments included different doses of the herbicides with and

without adjuvants and Glyphosate combined with sublethal dose of 2,4-D. The results revealed that lowest dose of the herbicides were sufficient for complete kill of the purple nutsedge plants in the experimental area and there was no regrowth upto 6 weeks. There was significant reduction in viability of tubers collected one month after herbicide application, but the tubers tested 45 days after spraying showed an increase in germinability over the record on 30th day. Tubers from treatments involving Glyphosate with sublethal dose of 2,4-D recorded the lowest sprouting percentage indicating the possibility for weed control for a longer period.

In Ex. no. III, the persistence of the herbicides in soil were monitored and it was observed that early growth of cucumber sown on the same day of herbicide application was affected while that sown on soils collected 10 days after spraying recorded growth characters comparable to that of control.

From Ex.no.IV, it could be inferred that chemical weed control did not show any deleterious effect on growth and yield characteristics of ragi and cucumber sown 15 days after the treatments. Application of 2,4-D for nutsedge control was found superior to other treatments in terms of net income and B:C ratio and the lower unit cost of the chemical was precisely the reason for its superiority.