INTEGRATED MANAGEMENT OF PERENNIAL WILD RICES IN LOWLAND IRRIGATED RICE

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ABSTRACT

Two field experiments were conducted during the season 1997/98 at Kapunga Rice Irrigation Project (KRIP) in Mbeya region to determine the influence of perennial wild rices on rice yields and to evaluate effectiveness of ploughing depths, hand weeding, herbicides and seeding rates in the control of the wild rices and other weeds.

Experiment 1 was a split plot in a randomized complete block design with three replications. Ploughing depths (10, 15, 20, and 25 cm) constituted the main plots while the seeding rates (110, 130, 150, 170 kg ha^{-1}) were the subplots. Pregerminated IR 54 paddy seeds were sown on 13 February 1998. Data collected included wild rice fresh and dry biomass before and after treatments, plant height at booting and at maturity, number of tillers, and panicles per plant and per square metre, number of grains per panicle, percentage ripened grains and grain yield per hectare. Combinations of 15 cm x 170 kg ha^{-1} (ploughing depth x seeding rates) recorded the highest grain yield of 4852.0 kg ha^{-1} which was significantly ($P \leq 0.05$) different from other treatment combinations. Lowest rhizome fresh and dry biomass of 17.0 and 4.9 g m^{-2} respectively, were recorded in the same treatment combinations signifying better effectiveness in reducing wild rice biomass than other treatments. The high grain yields were attributed to high number of panicles per square metre, high percentage ripened grains, number of grains per panicle and larger grain size than other treatments as a result of reduced wild rice biomass per square metre.

Experiment 2 was laid out in a randomized complete block design replicated three times.

There were ten treatments comprising of hand weeding treatments and combinations of herbicides (glyphosate or whip super) with hand weedings and an unweeded check. The different weed control practices applied had significant ($P \leq 0.05$) effects on the reduction of rhizomatous wild rices and other weeds' density. Two hand weedings reduced the density of wild rices by 73% and other weeds by 72% while glyphosate applied at the rate of 5.4 kg a.i ha^{-1} reduced wild rices density by 91%, other weeds by 65% compared to the unweeded check.

Plots hand weeded twice recorded the highest grain yield of 1648.4 kg ha^{-1} which differed significantly ($P \leq 0.05$) from all other treatments. Plots treated with glyphosate at 5.4 kg a.i ha^{-1} which had the highest reduction in wild rice density, recorded a grain yield of 1456.1 kg ha^{-1}. The lowest grain yield was recorded in plots treated with whip super at the rate of 20 g a.i ha^{-1}, this low grain yields in whip super treatments may be due to its being less effective in reducing wild rice density than to two hand weedings or glyphosate and its toxic effects on rice plants. Grain yield was significantly and positively correlated with percentage effective tillers, number of grains per panicle, percentage ripened grains, number of panicles per square metre, and 1000 grain weight. Negative correlations were obtained between grain yield per hectare and wild rice shoot fresh biomass and weed densities per square metre showing that the weeds had significant negative effects on grain yield.

Economic analyses revealed that all weed control practices were significantly beneficial, the highest net benefits being Tanzanian shillings (Tshs.) 307 859.27 ha^{-1} for the plots

hand weeded twice. It is therefore evident that hand labour is beneficial but since labour availability is not guaranteed, this may limit large scale rice production reliance on it. Manual labour can therefore be utilized by small scale producers while large scale producers can use glyphosate for wild rice control.

DECLARATION

I, **MAGDALENE NELSON ENOCK MKOCHA**, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is the result of my original work, and that it has not, and is neither being concurrently submitted for a degree award in any other University.

Signed: .....

Date: 25/5/99

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DEDICATION

To my parents **Lilian Mkocha** and the late **Nelson Enock Mkocha** for sending me to school.

To my children **Tina Noela** and **Kelvin Martin** for their love, and endurance.

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ABBREVIATIONS AND SYMBOLS

a.i	active ingredient
ANOVA	analysis of variance
°C	degrees Celsius
CGA	chlorazifop-propynyl
CIDA	Canadian International Development Agency
cm	centimetre
CIMMYT	International Maize and Wheat Improvement Center
CV	coefficient of variation
DAT	days after transplanting
DMRT	Duncan's Multiple Range Test
E	east
e.g.	for example
FAO	Food and Agriculture Organization of the United Nations
ha	hectare
ha^{-1}	per hectare
ht	height
i.e.	that is
IITA	International Institute of Tropical Agriculture
IRAT	Institute de Recherche Agronomiques Tropicales
IR/IRRI	International Rice Research Institute
kg	kilogram

KRIP	Kapunga Rice Irrigation Project
l	litres
m	metre
m^2	square metre
m^{-2}	per square metre
mc	moisture content
MCPA	Methyl Chloro Phenoxy Acetic Acid
mm	millilitre
ms	mean square
N	Nitrogen
NA	Naphthalic Anhydride
NAFCO	National Agricultural and Food Corporation
no.	number
n.s.d.	no significant difference
ODNRI	Overseas Development Natural Resources Institute
pH	hydrogen ion concentration
pp	pages
S	South
SA	Sulphate of Ammonia
SE	Standard Error
spp	species
ssp	subspecies

TFTW	Training Fund for Tanzanian Women
Tsh	Tanzanian shillings
TSP	Triple superphosphate
US$	United States Dollars
var	variety
WARDA	West African Rice Development Association
wt	weight
%	percentage

CHAPTER ONE

1.0 INTRODUCTION

Rice (*Oryza sativa* (L.)) is the staple food for approximately 50% of the world's population. In terms of calories, rice accounts for about 20% of the worlds' total caloric consumption. In the year 1994, rice production was 27.4% of the world's cereal production, making rice the second most important cereal after maize (FAO, 1995). About 44% of rice produced in tropical Africa is produced in East Africa on an area of 1.3 million hectares. In Tanzania, rice is the third most important cereal after maize and sorghum (Monyo and Mwaruka, 1975; FAO, 1995). Tanzania's total annual rice production is still below its demand e.g. in 1975 its production was 412 000 tons while demand was 414 000 tons (Ministry of Agriculture, 1995).

In Tanzania the crop is mainly produced by small scale farmers and by large state farms run by the National Agricultural and Food Corporation (NAFCO). The national rice yields in Tanzania are very low averaging 1.7 tons ha^{-1} compared to Kenya whose average production is 7.0 tons ha^{-1} hectare (FAO, 1995). Factors which have contributed to the low rice yields in NAFCO farms include use of low yielding cultivars which are preferred by the consumers, ageing agricultural machinery, salinity problems, insects, birds, and weeds. Of the world's rice growing

area, about 53% is grown under irrigated conditions and accounts for 73% of the total production (Schnier *et al.*, 1990).

Rice grown under irrigation also referred to as paddy can either be directly seeded or transplanted. In NAFCO farms, direct seeding has been adopted as the most efficient method as it eliminates labour demand for seedling bed preparation, seedling care, puddling, pulling and transportation of seedlings. It also shortens the cropping cycle as the plants do not suffer transplanting shock. One major shortcoming of direct seeding is that weed competition is greater than in transplanted paddy because the rice plants and weeds germinate together (De Datta and Bernasor, 1971; Schnier *et al.*, 1990). Heavy weed infestation in the NAFCO farms is one of the major problems limiting rice production. At the Kapunga Rice Irrigation Project (KRIP) major weeds include *Cyperus* spp., southern cutgrass (*Leersia* spp.), *Fimbrystilis* spp., barnyardgrass *(Echinochloa* spp.), *Sacciolepis* spp., *Panicum* spp., wild rices (*Oryza* spp.) and broad leaved weeds like *Sesbania* spp., *Nymphea* spp., morning glory (*Ipomea* spp.), water primrose (*Jussiaea* spp.), and wandering jew (*Commelina* spp.). The wild rices are the most difficult to control as they belong to the same genus as the cultivated rice and hence cannot be selectively controlled by herbicides.

Wild rices have spread on over 2000 ha i.e. over 80% of the total area at KRIP (KRIP, 1996). Grain yields in the infested areas are utmost 0.5 t ha $^{-1}$ or nil in

any of the fields heavily infested by wild rices.The other effects of wild rices, based on observations at KRIP is that their seeds which are black in colour mix and contaminate the rice crop as they cannot be separated after milling. As a result the market value of milled rice is reduced. Wild rices also serve as alternative hosts of insects like stem borers (*Chilo* spp.), and gall-midges (*Orseolia oryzae*) which are on the rise at KRIP. The other pests harboured by wild rices and other weeds include disease pathogens such as causative agents for rice blast (*Pyricularia oryzae*) which have been observed at KRIP. It is the fact that the negative effects of wild rices listed above outweigh the positive aspects which has necessitated embarking on their control.

Principles of weed control can either be chemical, cultural, biological, preventive, or integrated (Akobundu, 1987).

On the basis of the literature, it is evident that the wild rice problem has increased at KRIP due to continuous cultivation of the same crop over years, use of selective herbicides in controlling annual weeds which has led to the build up of wild rices. A number of weed control practices are employed already in NAFCO farms however, it is necessary to determine the most effective, practical and economical practices which can be integrated to curb the wild rice problem at KRIP, in other NAFCO farms and in Tanzania at large. Therefore studies were conducted at KRIP with the following objectives:-

a. to evaluate the influence of wild rices on rice yields.

b. to determine the effectiveness of ploughing depth and seeding rate in the control of wild rices

c. to assess economic benefits of different wild rice control methods.

d. to evaluate effects of different weed control methods

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Importance of rice

Rice is the staple food of about half of the worlds' population and accounts for 20% of the worlds' calorie consumption. In terms of production, rice is the second most important cereal after maize (FAO, 1995). In Tanzania, it ranks third after maize and sorghum in terms of production (Ministry of Agriculture, 1995).

The chemical composition of rice grains vary depending on the genetic make up of a given plant variety, and also upon environmental influences such as location, season in which it is grown, fertilizer treatments, degree of milling and conditions of storage. However, an average sample of milled rice grains will contain 80% starch, 7.5% protein, 0.5% ash and 12% water (Chandler, 1976).

2.2. Environmental requirements for rice growth

2.2.1 Moisture requirements

Rice is a semi aquatic plant, and is less tolerant to soils with low moisture content than most cereals. Various studies have indicated that the rice plant can easily tap water available in the upper 20 - 25 cm of the soil profile. The water availability

varies with water supply and the moisture retention capacity of the soil in which the rice is growing. Rice requires at least 600 mm of rain to complete its growth cycle but a monthly rainfall of 200 mm during the growth cycle is reported to be a minimum requirement (Moormann and Veldkamp, 1978).

2.2.2 Rice soils

Rice soil reaction types range from pH 4.5 to 8.0 but, good paddy soils are almost invariably acid with pH values varying from 5.5 - 6.5. The pH of the paddy soil influences the availability and uptake of mineral elements by the rice plant. Soils like clay, clay loam and loamy soils are most suitable for rice cultivation (Chatterjee and Maiti, 1985; Grist, 1986).

2.2.3 Temperature requirements

Different varieties of rice are adapted to a wide range of environmental conditions but, varieties adapted to produce well in the tropics require a temperature in the range of 25 - 37°C. In most of these varieties optimal temperature for vegetative growth and tillering is about 30°C (Williams *et al.*, 1980). Low temperatures at early vegetative stages retard the growth of shoots and roots since temperatures below 30°C retard the uptake of nitrogen, potassium, phosphorus and silica (Chatterjee and Maiti, 1985; Grist, 1986). Chatterjee and Maiti (1985) reported that a temperature of 15°C delayed panicle initiation by 17 days and extended the time

required for complete heading. The highest grain yields which resulted from larger number of tillers, panicles, spikelets, lower spikelet sterility, and greater 100 grain weight were obtained at 32 / 20°C (maxima / minima) temperature cycles. Low temperatures after heading cause a decrease in number and weight of fertilized spikelets. Flower opening, pollen ripening and fertilization largely depend on day maximum temperature, the critical day maximum temperature being estimated at about 20 - 25°C (Nishiyama, 1984; Grist, 1986; Matsuo and Hoshikawa, 1993).

2.2.4 Light intensity

Light intensity is an important factor in growth of rice plants. The number of tillers is larger under strong light than under weak light irrespective of temperature conditions. Shading of leaf sheaths inhibit development of tillers through decreased dry matter production owing to inhibition of photosynthesis and reduced distribution of photosynthates to the tillers (Matsuo and Hoshikawa, 1993).

2.3.0 Kinds of rice cultures

Rice can be produced under lowland and upland conditions, as well as in water depths of up to several metres.

2.3.1 Irrigated lowland rice

In this kind of rice culture, rice is grown in bunded fields in which irrigation regimes fed from wells or rivers control the depth of water (Chandler, 1976).

2.3.2 Rain - fed lowland paddy

The paddies in this case are bunded and after the rains come the water accumulates on the soil surface. The land is ploughed and harrowed prior to the rains. If rainfall is adequate and evenly distributed, yields can be as high on rain-fed paddies as on irrigated fields (Chandler, 1976; Matsuo and Hoshikawa, 1993).

2.3.3 Upland rice

In this case rice is grown in fields like any other cereal. The land is tilled before the rain season and the rice is normally seeded by broadcasting. Because of the erratic rainfall patterns, poor weed control, low fertilizer use, and high disease incidence, yields are normally low in upland rice. Singh *et al.* (1992) reported 40 - 70% yield reduction of upland rice attributed to abundant rainfall which provided favourable conditions for luxurious growth of weeds.

2.3.4 Deep water or floating rice

Rice grown in areas where water depths reach 1 - 5 m is called deep water or floating rice. This type of culture is common in Bangladesh, Thailand, India,

Vietnam, Indonesia and W. Africa (Chandler, 1976).

2.4.0 Weed competition in rice production

Weeds are defined as plants growing out of place; plants with a negative value or as plants not sown whose undesirable features outweigh their desirable features (Muzik, 1970; Anderson, 1983; Kassasian, 1985; Akobundu, 1987; IITA, 1984; Hurle, 1997). Sources of weeds according to Lockhart and Wiseman (1983) include; seeds sown with the crop seed; seeds sown in the previous years; seeds carried into the fields by birds, animals, wind, and weed seeds in farmyard manure. The second source is the vegetative parts like rhizomes, stolons, deep creeping roots, taproots, bulbs, bulbils and bulbous shoot bases brought into fields with agricultural implements and irrigation water. According to Grist (1986), there are about 30 000 species of weeds worldwide of which 200 cause significant damage to major food crops and 10 of which cause 90% crop losses. Weeds of lowland rice include wild rices (*Oryza* spp.), *Cyperus* spp., *Fimbrystilis* spp, and *Eleochoris* spp. (Akobundu and Fagade, 1978). Wild rices are among the most troublesome weeds in many parts of the world (Deuse, 1982). Weeds interfere with the crop in terms of space, water, nutrients, and light (Muzik, 1970; Hill, 1977; Hurle, 1997). Weeds also crowd out and shade the crop interfering with air circulation, encouraging high humidity thereby creating favourable conditions for growth and multiplication of disease pathogens. Shading decreases light on crop plants affecting photosynthesis

thus reducing their food production (Mukundan, 1974). Weeds utilize moisture, nutrients that would otherwise be used by the crop, and sometimes act as hosts for other pests. For instance *Leersia oryzoides* is an alternate host of bacterial blight, barnyardgrass and *Panicum* spp., are alternative hosts of stem borers, while wild rices are alternative hosts of gall- midges and stem borers (Chatterjee and Maiti, 1985). Other types of weed damage include less effective use of land, added production costs in protection of the crop from pests, added harvesting costs, poor quality products, problems in water management and less human efficiency (Klingman, 1961; Chisaka, 1977). Sometimes beneficial interactions occur between weeds and crop plants as in the case of *Tagetes* spp. and *Polygonum* spp. which secrete substances that control nematodes. Some weeds also act as hosts to predators of crop pests (Kassasian, 1985). Other benefits of weeds according to Hurle, (1997) is that they directly contribute to biodiversity, they act as 'break crops' in crop monoculture systems. Hurle (1997) further hypothesized that weed competition at early stages of crop development may promote growth of crop plants. During early stages depletion of nutrients at the crop plants root zone by the weeds may induce the plant roots to elongate further in order to obtain nutrients in the lower soil layers, in the process crop growth is enhanced. However the negative aspects of weeds outweigh their benefits and hence the need for weed control.

The kind of weeds and the degree of weed infestation vary with the rice culture, stand establishment, moisture regime, land preparation, and cultural practices. Direct seeded rice is more susceptible to weed infestation than transplanted rice and upland rice is more prone to weed damage than lowland and deep water rice (De Datta and Bernasor, 1971; Akobundu, 1979; Ahmed and Moody 1980; Pons and Kruijf, 1985; De Datta, 1986).

2.4.1 Types of rices

Rice and its relatives in the genus *Oryza* evolved as a plant taxon adapted to moist and marshy sites of the tropics as a member of the Bambusoidea or the Oryzoideae according to Tsunoda and Takahashi, (1984). Although there are about 20 species of the genus *Oryza*, most of the cultivated rice is *Oryza sativa* L. and the only other species of rice grown for food is *O. glaberrima* Steud (Purseglove, 1975). Chandler, (1976) reported that the African species *O. glaberrima* was selected and established from an annual wild rice named *O. breviligulata* Chev. and Roer. or *O. barthii* A. Chev. He further explains that the nomenclature of wild rices in Africa has been very confused such that the names *O. stapfii* Roz., *O. breviligulata* A. Chev. and *O. barthii* are used interchangeably.

2.4.2 Distribution and occurrence of wild rices

A number of wild rice species are problem plants in dry seeded or irrigated rice.

The most common species in Africa are *Oryza barthii*, an annual type previously known as *O. breviligulata*, the rhizomatous perennial *O. longistaminata* Chev. and Rochr. and a small seeded annual *O. punctata* Kotchy ex Steud. *Oryza perennis* Moench. and *O. rufipogon* Griff. which are non rhizomatous forms occur in Asia and S. America. These are closely related to rice and are sometimes classified as subspecies or varieties e.g *Oryza sativa* ssp. *fatua* or var. *spontanea*. The annual forms closely related to rice are usually referred to as red rices. In Africa annual wild rices occur from Senegal in the west, to Tanzania mainland in the east and are widely spread in Zanzibar as well. In Tanzania mainland, wild rices are found in abundance in the NAFCO farms because of the direct seeding method practised (ODNRI, 1976; Parker and Dean, 1976; Carpenter, 1978; IITA, 1984).

Wild rice species including *Oryza barthii*, *O. longistaminata*, *O. punctata* Kotschy. *O. rufipogon* and *O. perennis* differ greatly from the temperate 'wild rice' *Zizania aquatica* L. or *Z. palustris* which does not occur as a weed and is used as a culinary delicacy in North America (Martin and Leonard, 1967; ODNRI, 1976; Parker and Dean, 1976;). Annual wild rices are propagated by seeds while perennial wild rices are propagated by both seeds and rhizomes. Both types of wild rices share the characteristic of shattering soon after each individual seed matures, usually before the crop is harvested. Wild rices also have awns, a red pericarp and prolonged dormancy periods (Rai, 1973; Purseglove, 1975; ODNRI, 1976; De Datta

and Hoque, 1982). Where herbicides that control only annual weeds have been applied, perennial weeds soon develop into large plants because of lack of competition from other weeds. For example the more difficult perennial sedge, *Scirpus maritimus* L., has become an extensive problem weed in the Philippines and Italy (ODNRI, 1976; Boyall, 1983). Both perennial and annual wild rices occur at KRIP and in other NAFCO rice farms.

2.4.2.1 *Oryza rufipogon* Griff. "red rice"

Oyza rufipogon is a perennial wild rice which has long anthers, slender grain and long rhizomes from which tillers sprout. Unhusked grain is awned and is purple coloured at maturity. These red rices occur in Brazil, Guyana, and USA and includes the wild red and black rices (Rai, 1973; Parker and Dean, 1976; Matsuo and Hoshikawa, 1993).

2.4.2.2 *Oryza longistaminata* Chev. and Rochr.

This is the rhizomatous perennial wild rice which is a major problem weed in Mali, Guinea, Senegal, Sierra Leone, Nigeria, Ivory Coast, Upper Volta, Dahomey, Cameroon, Congo, Sri lanka, Uganda and Tanzania. This species was previously and is still occasionally referred to as *O. barthii* A.Chev. and sometimes as *O. perennis* Moench.

Oryza longistaminata differs from *O. sativa* since it is a perennial and forms

extensive rhizome systems, but its seeds are comparable to those of *O. rufipogon*. *Oryza longistaminata* is tall and is an outcrossing rice which usually grows in creeks and drains and often sets only a few seeds. (Parker and Dean, 1976; Carpenter, 1978; Akobundu, 1979; Ibrahim and Kabuye, 1987).

2.4.2.3 *Oryza barthii* Chev.

Oryza barthii Chev. is an annual wild rice occurring in Africa and was formerly called *O. breviligulata* and is closely related to the traditional cultivated rice species of West Africa *O. glaberrima*, just as *O. rufipogon* is related to shorter *O. sativa*. In Tanzania, *O. barthii* occurs in Dodoma, Manyoni and Singida districts, Mbeya and Rukwa. Grains of *O. barthii* are longer, more hispid, and awned than *O. glaberrima*. Another species *O. stapfii* Roschev. is a form intermediate between *O. barthii* and *O. glaberrima*. *Oryza barthii* occurs mainly in West Africa in Sierra Leone and Mali (Redhead and Polhill, 1970; Purseglove, 1975; Parker and Dean, 1976; Akobundu, 1979).

2.4.2.4 *Oryza punctata* Kotschy ex Steud.

This wild rice species has small seeds, long awns and occurs in East and West Africa, and has grown to be a serious problem in Swaziland as well. In Tanzania, *Oryza punctata* has been reported in Mbeya, Kwimba, Shinyanga and Pemba. The small seeds usually shatter before the crop is harvested, but those which remain on

the panicles contaminate the milled rice and hence reduce its quality (Redhead and Polhill, 1970; ODNRI, 1976; De Datta and Hoque, 1982).

2.4.3 Extent of yield losses

Estimates on rice yield losses due to weeds have been reported to be 70 - 100% in upland rice, 33 - 75% in lowland rice and 46 - 84% in direct seeded rice (Singh and Battacharyya, 1989). A number of other factors are known to have influence on the effect of weeds on crop growth and yield. These include fertility level, rice culture, frequency of land use, water management and weed control technology (Akobundu, 1987; Perera *et al.*, 1992). Ishiy and Lovato (1976) found that rice is sensitive to weed competition for the first 75 days and the most critical period was 15 - 30 days after germination. Weeds generally affect yields during tillering and heading stages and yield losses of up to 80% or more have been reported. Weed competition can affect the uptake of nutrients, reduce the tillering ability of the plants, reduce panicle weight and increase the number of unfilled grains and hence reduce grain yields (Kusanagi, 1981; Akobundu, 1987). Saikia and Pathak (1983) reported levels of nitrogen uptake by rice plants to be 16% and 99% in weed infested and weed free plots, respectively. According to Diarra *et al.* (1985), red rice densities of 5, 108, and 215 plants m^{-2} reduced grain yields of commercial rice by 22, 77, and 82%, respectively at cultivated plant density of 195 plants m^{-2}.

Deuse (1982) reported that wild rices are the most dangerous weed pests in cultivated rice. Perennial wild rices cause serious problems and often cause total crop failure in Mali (Diarra, (1981). In Mali the most troublesome weeds are the rhizomatous wild rices, *Oryza longistaminata* Chev. and Rochr. Competition due to *O. longistaminata* caused severe yield reductions of up to 33% when weed control was delayed until 60 days after seeding (De Datta and Hoque, 1982).

2.5.0 Weed control

Weed control refers to the manipulation of weed densities to levels at or below economic threshold. The objectives of weed control evolve around minimization of competition for resources between weeds and crop plants, minimization of introduction of new weeds in a given area and reduction of their spread.

Components of weed control include cultural weed management, chemical, biological and preventive weed control measures. Integrated weed management is a concept used to describe approaches to weed control through sequential combination of two or more of the above methods (Noda, 1977; Akobundu, 1987).

2.5.1 Preventive weed control

Preventive weed control aims at prevention of weeds from being introduced into new areas and prevention of the spread of weeds. In order to prevent the spread or

introduction of weeds, clean seed should be used, bunds and irrigation channels should be kept clear of weeds, tools and machinery used in crop production should be kept clean. Livestock should be kept away from rice fields as much as possible and also the rice crop must be sown or transplanted on weed free ground (ODNRI, 1976; Roberts, 1982).

2.5.2 Cultural control

Cultural weed control refers to all types of soil disturbances and physical manipulation of the vegetation to provide weed free conditions for crop growth. These include hand weeding, mechanical tillage, burning, flooding, mulching, and crop rotation. Hand weeding could be by hoeing or by pulling weeds or by using machines pushed by humans, animal or tractor drawn implements or self propelled and require steering by an operator (Akobundu and Poku, 1986). Poor weed control measures is among the important factors for the low rice yields in most parts of the world (Ramaiah and Muthukrishnan, 1992).

2.5.2.1 Choice of cultural practices

Annual types of wild rices are not serious weeds in transplanted rice unless they are present in the crop seed or in the nursery bed. Red rices in a direct sown crop can be reduced by sowing pre-germinated seed on puddled fields or on standing water. Sowing in rows simplifies weeding. A study of weed control under poor

water control conditions revealed that uncontrolled weeds caused up to 61% yield reductions while a good water management of 10 - 20 cm depth helped to control even troublesome weeds such as barnyardgrass. (Akobundu, 1981).

2.5.2.2 Choice of cultivars

In most parts of the world, the weed problem has been worsened by replacement of traditional late maturing varieties with improved early maturing short rice varieties which are less competitive to weeds (Perera *et al.*, 1992). In appropriate environments sowing of purple leaved rice cultivars like IR 1552 has also been advocated so that weeds can be easily distinguished by colour. However, this has a limitation since in the long run some crossing occurs and the wild rices also acquire the purple colour (Parker and Dean, 1976).

2.5.2.3 Tillage practices

Deep ploughing, with adequate soil inversion leads to reduction of wild rices especially the annual types. Incase of the rhizomatous wild rices, deep ploughing has to be done soon after harvest to allow the rhizomes to dry. In some cases deep ploughing is followed by irrigation to germinate the weeds and this is followed by another ploughing. Mechanical cultivation may be repeated several times to control all the wild rices. Results of ploughing depth experiments as a wild rice control measure in Mali showed that ploughing to a depth of 15 cm on a sandy soil was

effective (Koli and Diarra, 1983; IITA, 1984).

2.5.2.4 Crop rotation

Most crops have associated weeds, growing the same crop continuously on the same land tends to enhance build up of such weeds. In order to reduce or prevent build up of such weeds crop rotation is practised. Rotation of lowland rice with an upland crop such as a legume led to reduced infestation of water tolerant weeds in USA and in the Philippines (Akobundu and Fagade, 1978). In Japan, double cropping of winter wheat and rape prevented serious infestation of perennial weeds like *Cyperus serotinus* C.B. Clarke, and *Sagittaria pygmea* Miq in lowland rice fields while in Egypt three year rotation of rice with cotton and wheat controlled infestation of all noxious weeds except barnyardgrass (Noda, 1977)

2.5.3 Chemical control

Herbicides offer the most practical, effective and in most cases most economical means of reducing crop losses and production costs. In areas where rice is direct seeded, chemical weed control is the only alternative to hand or hoe weeding (Akobundu and Fagade, 1978; Akobundu and Poku, 1986; Singh and Singh, 1994).

Herbicides commonly used for weed control in rice include 2,4-D, [(2,4-dichlorophenoxy) acetic acid], propanil, [3', 4'- dichloropropioanilide], MCPA,

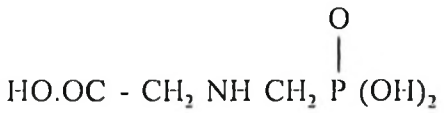
[[(4-chloro-o-tolyl)oxy] butyric acid], bentazon, [3-isopropyl-1-H-2,1,3-benzothiadiazin-(4)3H- one 2,2-dioxide], bifenox, [methyl 5-(2,4-dichlorophenoxy)-2-nitrobenzoate], butachlor, [N-(butoxymethyl)-2-chloro-2'6'- diethyacetanilide] and molinate, [S-ethylhexahydro-1H-azepine-1-carbothioate] (Singh and Singh, 1994). Non selective herbicides such as glyphosate [N- (phosphonomethyl) glycine], and paraquat, [1,1'-dimethyl-4,4'- bipyridinium ion] can be effectively used to control wild rices before the crop is sown or planted. *Oryza longistaminata*, the highly dormant and most difficult wild rice to control was reduced in population by 94, 95, and 99% when glyphosate was applied at 3, 4 and 5 kg a.i. ha^{-1} respectively, in Mali (De Datta and Hoque, 1982). Lower rates at the level of 2 kg ha^{-1} of glyphosate have also been reported to be as effective as two hand weedings in the control of *O. longistaminata* (Gill, 1981). Some control of the rhizomes has also been reported following the use of dalapon [2,2-dichloropropionic acid] 10 - 15 kg ha^{-1} and diuron, [3- (3,4- dichlorophenyl)-1, 1- dimethyl urea] at 5 kg ha^{-1}. However, these herbicides have residual toxicity and hence necessitate long fallow periods. Glyphosate has no soil activity and is therefore more useful than dalapon and diuron (Parker and Dean, 1976). Higher rates of the selective herbicides have been used with antidotes to control wild rices. Antidotes, also referred to as protectants, or safeners are chemicals which are used to modify the selective action of herbicides in crops (Hoffman, 1962; ODNRI, 1976; Akobundu, 1987). Naphthalic anhydride (NA) when used as a seed dressing at 0.5 - 1% by weight has

been found to protect rice against molinate, [S-ethyl hexahydro-1*H*-azepine-1-carbonate], alachlor, [2-chlor-2', 6'-diethyl-N- (methoxymethyl) acetanilide] and benthiocarb, [S-(4-chlorobenzyl)-N-diethylthiolcarbamate] (ODNRI, 1976). Parker and Dean (1976), reported protection of rice against butachlor, [N- (butoxymethyl)-2-chloro-2'6'-diethylacetanilide] and metolachlor by the antidotes CGA 24705 and NA. Better protection has been observed when herbicides with antidotes are applied pre-emergence than at post emergence (Wirjahardja and Parker, 1977).

2.5.3.1 **Glyphosate**

Glyphosate is an organophosphorus compound, it is a phosphonate derivative of the amino acid glycine. It is foliar acting, and with no activity through the soil. It is active on most annual and perennial weeds and actually most green plants. Glyphosate is readily absorbed by the leaves and is highly mobile in the plant via the symplastic system and in the apoplastic system. Absorption and transport are affected by plant growth habit, differences in spray coverage, cuticular and plasmalema permeability and environmental conditions. Degradation within the plant is slow. In the soil it is so strongly adsorbed to clay and organic matter that it becomes unavailable to plants. Foliar chlorosis is a common symptom following glyphosate application. Leaves of regrowing perennial plants are often malformed, or striated and multiple shoot formation is common usually from a single node giving a 'witches' broom effect (Roberts, 1982).

Chemical structure:



2.5.3.2 Fenoxaprop-P-ethyl (whip super)

Whip super, [(D+)- ethyl-2-(4-(6- chloro-2- benzoxazolyl- oxy)- phenoxy-propanoate] is a post emergence herbicide of grass weeds in rice, some turf species and broad leaved crops. The herbicide is taken up rapidly by susceptible plants via the leaves and stems and transported to sites of action. Within the plant the active ingredient is degraded to the free acid which has the herbicidal effect. The herbicide acts by inhibiting fatty acid synthesis, thereby preventing further formation of cell membranes leading to death of the plant. Whip super confers good control of water foxtail (*Alopecrus aequalis*, black grass (*A.myosuroides*), *Aspera spica-vent*, oats (*Avena* spp.), crabgrass, barnyard grass, goose grass (*Eleusine* spp.), canary grass (*Phalaris* spp.), foxtail (*Setaria* spp.), johnson grass (*Sorghum halepense*) and maize (*Zea mays* (L.) (AgrEvo, 1996).

2.5.4 Biological control

According to DeBatch and Schlinger (1964), biological control in ecological terms is the action of predators, or pathogens in maintaining another organism's population density at a lower average than would occur in their absence. In broader

terms, however, Akobundu (1987) defined biological control of weeds as the control or suppression of weeds by action of one or more organisms, through natural means or by manipulation of weed, organism or environment.

A number of factors have widened the opportunities for biological control of weeds and these are:-

a) widespread development of resistance by pests to pesticides

b) increased global awareness of the quality of the environment because of the negative impact of pesticides on this quality, on terrestrial and estuarine wild life and man

c) realization of man's exhaustion of fossil fuel reserves

d) the chemical industry cannot produce and the consumers, especially in developing countries, cannot afford to buy pesticides (Huffaker, 1976).

Based on the broader definition, biological control can be effected by using bioagents which may be microbial or macrobial, use of live mulches, exploitation of crop canopies and plant densities or using allelopathic effects of plants.

2.5.4.1 Biological control by plant canopy

Manipulation of plant densities through higher seeding rates, narrow inter-row spacing and use of cultivars with high tillering abilities are some of the useful biological control measures (Akobundu, 1987; Ramakrishnan *et al.*, 1992).

The effect of the plant canopy is to shade the lower storey plants and limit their ability to synthesize carbohydrates. This can be achieved by providing favourable conditions for the crop seedling establishment, breeding for high competitive crops i.e. those able to establish complete ground cover rapidly like sweet potatoes and spreading type cassava (Akobundu, 1987).

Moody (1977) cited by Akobundu, (1987) reported significant reductions in weed densities in lowland rice when seeding rates were increased from 80 to 200 kg ha^{-1}. Kim and Moody (1980) recorded that transplanting rice at a 10 x 10 cm spacing led to a significant reduction in weed weight compared to a 20 x 20 cm plant spacing in herbicide treated and untreated plots. In a study to determine the effect of seed rate on the weed weight per hectare and grain yield of wet seeded rice, yield was highest at the 200 kg ha^{-1} but was not significantly different between the different seed rates (Akobundu, 1987).

2.5.4.2 Biological control by allelopathy

According to Altieri (1987), allelopathy is any direct or indirect harmful effect by one living plant on another through the production of chemical compounds released to the environment. Allelopathy must occur when non of the environmental factors on which plants compete for is limiting. The negative effects include inhibition of smooth germination, effect on growth and development of the other species sharing

the same habitat (Akobundu, 1987). In an experiment with wheat, an exudate identified as ferulic acid was found to inhibit germination and root growth of *Ipomea lacunosa*, *I.purpurea*, *Ambrosia artemisifolia* L., crabgrass *(Digitaria* spp.) and *Sida spinosa* L. (Burgos and Talbert, 1996).

2.5.4.3 Biological control with live mulch

Live mulch is a crop production technique in which a crop is directly planted in a living cover of an established cover crop without tillage or destruction of the fallow vegetation (Akobundu, 1980 (b); Akobundu, 1987; Altieri, 1987). Legume cover crops used as live mulches include *white clover (Trifolia repens)* , *hairy vetch (Vicia villosa)*, and *red clover (Trifolia pretense)*. Other crops like *melons(Cucumis* spp), pumpkins, *cowpeas (Vigna unguicullata)* and *sweet potatoes (Ipomea* spp). in perennial crops of coffee *(Caffea* spp), coconut *(Cocos nucifera)*, or orchards have also be used as live mulches. Based on field experiments, Akobundu (1987) reported that live mulches of wild groundnut (*Arachis repens*), and wild winged beans *Psophocarpus palustris* and centro (*Centrosema pubescens* Benth) reduced weed weight such that in the unweeded conventionally tilled plots it was eight times more than in unweeded plots of either centro, wild winged beans or wild groundnuts.

The effect of live mulch in weed control is to suppress weeds and reduce weed

seed population. A useful live mulch plant must be of low or medium plant height, aggressive, able to provide rapid complete ground cover, deep rooted, drought, pest and shade tolerant and easy to establish from seed (Akobundu, 1987).

2.5.4.4 Use of bioagents in weed control

Prospective bioagents of weed control can largely be categorized into invertebrates such as insects, disease pathogens, parasitic higher plants, and more competitive crop plants. Others include vertebrates like geese, ducks, sheep, goats, cattle and fish (Kassasian, 1971; Akobundu, 1987). The effect of the bioagent is either to directly eat and kill the weed, stress it, lower the hosts' resistance to diseases and other herbivores or impair the reproductive potential by eating the flowers, fruits, or seeds (Stiling, 1985).

2.5.5 Integrated weed management

Williams (1984), defined integrated weed control as a management system that on the basis of the knowledge of the ecology and population dynamics of a weed population, uses all appropriate techniques including cultural, chemical and biological in as compatible a manner as possible. Integrated weed management pays due consideration on environmental quality while attempting to maintain populations of the weeds at levels below those causing economic damage in current and future years.

Although chemical weed control measures are fairly effective in controlling weeds in direct seeded rice, the use of herbicides has several limitations which in developing countries include high cost, unavailability on time in addition to the differential effect under different conditions of soil moisture, temperature and application method. For these reasons integrated weed management is gaining ground for minimizing the effect of weeds on rice yields (Linda, 1980; Dahama *et al.*, 1992). An efficient weed management system should integrate preventive measures such as use of weed free seeds, keeping bunds and irrigation canals clear of weeds, appropriate tillage practices, use of competitive cultivars and use of herbicides where deemed necessary (ODNRI, 1976; Bernasor and De Datta, 1986). No single weed control method can, in isolation, effectively control weeds which have variable growth habits and life cycles (Akobundu and Poku, 1986).

A trial conducted in Mali showed that integration of chemical control by glyphosate, with hand mowing significantly reduced *O. longistaminata* (Diarra, 1981). In another experiment, Goiogoi and Kalita (1992) found that integrating butachlor and one hand weeding plus thiobencarb plus 2,4-D were equally effective and gave higher yields than the weedy check. Saikia and Pathak (1993) cited of repeated hand weeding following pre-emergence herbicide application to have effectively reduced weed competition in upland rice.

Vongsaroj (1985) reported of integrated control of *O. sativa* F. *spontanea* by seed

cleaning, land preparation, use of purple leaf coloured varieties which can be easily distinguished from the green wild rices during weeding, row seeding, transplanting and the use of herbicides with an antidote. Integrated weed control can be achieved by combining any two or more compatible weed control measures such as cultural e.g. good water management plus use of herbicides to control weeds in lowland rice fields, or a combination of chemical weed control and use of higher seeding rates (Bhattacharjee, 1978; Akobundu, 1980 (a); Diarra *et al.*, 1985; De Datta 1986; Akobundu, 1987).

From the literature above, it is evident that there is a wide range of wild rice control methods which can be combined for effective weed control. The methods vary from preventive measures e.g. use of clean seed and clean implements, weed free irrigation channels and bunds, plus cultural methods such as off-season deep cultivation, choice of more competitive varieties and crop rotation. Other methods include use of non selective herbicides such as glyphosate at rates ranging from 2 to 6 kg a.i ha^{-1}. Higher seeding rates of up to 200 kg ha^{-1} also are useful. It is up to the farmer to chose the most appropriate control measure combinations which can effectively control wild rices as well as other weeds but with due considerations to availability of inputs, technology, economical factors, type of rice culture and environmental safety.

Most of the farmers normally practice weed control whereby fields are no not attended offseason or when under fallow, weeds being controlled only during the cropping season. It is advisable for weed management i.e manipulation of weeds to prevent their spread, and introduction to new areas be undertaken continuously for effective weed control.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experiment site

Two field experiments were conducted during the cropping season 1997/98 at KRIP situated in the Usangu plains in Mbeya region 1040 m above sea level. The KRIP lies at Latitude 008° 50' 30''S and Longitude 034° 10' 30'' E, and experiences a unimodal rainfall pattern received between the months of November and May. The mean monthly rainfall and mean temperatures during experimentation were as summarized (Appendix 1). The experiment area had not been planted with any crop in the previous season although it was under continuous paddy rice cultivation beforehand.

3.2 Experiment 1: The effect of ploughing depth and seeding rate on wild rice control

3.2.1 Experimental design

The experiment was set as a split plot in a randomized complete block design with three replications. Ploughing depths constituted the mainplots while the seeding rates were the subplots. Individual sub plots had a dimension of 5 x 5 m. A one

metre path was maintained around the main plots. Treatments were randomly allocated both on the main plots and in the subplots. The descriptions for the main and subplots treatments are presented in Tables 1 and 2.

Table 1: Description of main plot treatments

Main plot treatment no.	Code	Ploughing depth (cm)
1	M1	10
2	M2	15
3	M3	20
4	M4	25

Table 2. Description of subplot treatments

Subplot treatment number	Code	Seeding rate (kg ha^{-1})
1	S1	110
2	S2	130
3	S3	150
4	S4	170

3.2.2 Land preparation, seeding and cultural practices

3.2.2.1 Land preparation

The experimental area was ploughed in September by using hand hoes set at the different depths as per main plot treatments. The depths were set by welding a metal piece parallel to the cutting edge of the hoe at the desirable depths. The metal pieces prevented the hoe from digging deeper into the soil than the required ploughing depth.

3.2.2.2 Seeding

The initial plan was to dry seed the experiment but because of the continuous rains as a result of environmental changes reffered to as *El Nino*, the seed was pre-germinated by soaking for 24 hours, covered with a wet sack and left for 3 days to allow radicles to grow. Due to standing rain water, it was impossible to seed in lines and therefore the pre-germinated seeds were broadcast in water. The rice variety IR 54 was used in the trial and seeding rates were varied according to the subplot treatment descriptions.

3.2.2.3 Weed control

Wild rices were not controlled by any method other than the main and subplot treatments. Other weeds were controlled through two hand weedings done 30 days and 50 days after establishment.

3.2.2.4 Fertilizer application

Triple super phosphate (TSP) (TSP: P_2O_5 = 46%) fertilizer was broadcasted and incorporated prior to seeding at the rate of 75 kg ha^{-1}. Sulphate of ammonia (SA : N = 21%) was used as the source of Nitrogen at the tillering stage. A total of 297.6 g SA was hand broadcasted per plot to obtain a rate of 50 kg N ha^{-1}. Urea fertiliser (N = 46%) was applied at the panicle initiation stage (60 days after establishment) at the rate of 50 kg N ha^{-1}. A total of 135.87 g of urea was applied per plot to achieve the above rate.

3.2.2.5 Water management

Initially it was impossible to control water depths, but later when the rains subsided i.e. from mid April, the water depth was controlled at a 10 cm depth. From maximum tillering stage the water level was raised to 15 cm and this level was maintained until harvesting time.

3.2.2.6 Pest control

Insect pests which infested the trials to a minor extent included *Orseolia oryzae*, and grass hoppers (*Catantops* spp). These were controlled by spraying Dimecron 50 SCW at the rate of 1 l ha^{-1} using a spray volume of 250 l ha^{-1}. Other pests included rats, preventive control of these pests was done through controlled water level until harvesting time. *Quellea quellea* birds were a menace as well and they were scared away by hanging reflecting tapes around the plots and by vocal means.

3.3 Experiment 2: Comparative performance of glyphosate, whip super and hand weeding for the control of perennial wild rices.

3.3.1 Experimental design

Experiment 2 was laid out as a randomized complete block replicated three times. The plot size in this case was increased to 7 x 7 m so as to have wider guard rows. Wider guard rows were necessary in this case in order to prevent border effects of herbicide drifts to neighbouring plots during postemergence herbicide application.

3.3.2 Treatments

There were 10 treatments (Table 3) which were randomly assigned to each plot in the three replications.

Table 3. Treatments

Treatment code	Treatment description	Time of application
T1	Two hand weedings 30 + 50 DAT	
T2	glyphosate 1.8 kg a.i ha^{-1} + 1 hand weeding 30 DAT	pre planting
T3	glyphosate 1.8 kg a.i ha^{-1}	,,
T4	glyphosate 3.6 ,,	,,
T5	glyphosate 5.4	,,
T6	whip super 20 g a.i ha^{-1}	at tillering
T7	whip super ,, + 1 hand weeding 50 DAT	"
T8	whip super 40 g a.i ha^{-1}	,,
T9	whip super 60 ,,	,,
T10	unweeded control	

DAT = days after transplanting

3.4.1 Land preparation, seeding and cultural practices

3.4.1.1 Land preparation

The experimental area was ploughed during the dry season at a 15 cm depth, harrowed. Wild rice was allowed to grow in plots to be treated with glyphosate.

3.4.1.2 Seeding

Due to the excessive rainfall, it was not possible to dry seed by drilling, instead rice seedlings were raised in a nursery and transplanted when they were 30 days old. By that time they were about 13 cm high. Transplanting was done in March at 17 cm inter-row spacing, and a seeding rate of 65 kg ha^{-1} was used. In order to maintain the seeding rate, 318.5 g of seed were sown in a row for each plot and seedlings were uniformly transplanted into each plot at the mentioned inter-row spacing.

3.4.1.3 Cultural practices

Fertilizer application, pest control, water management and timing of hand weeding were performed as in experiment 1.

3.5 Data collection

3.5.1 Basic data

Meteorological data collected included rainfall, minimum and maximum temperatures (Appendix 1). The soil reaction of the experiment area was acidic and had a pH of 5.71. The soil was brownish grey in colour when dry and had a clay loam texture (26% sand, 35.2% clay and 44.8% silt). The two experiments were conducted in one field B 60, and the basic data is therefore applicable to both.

3.5.2 Weed data

The weed data was collected from a 1 x 1 m quadrat using a 1 m^2 frame placed randomly in each subplot.

3.5.2.1 Experiment 1

In experiment 1 only the fresh and dry weights of the rhizomes were obtained before ploughing. The rhizomes were dug out from a 1.0 m^2 before ploughing. The dug out rhizomes were washed, then shaken to remove excess water and weighed to determine fresh weights. After weighing rhizomes were sun dried to constant dry weights for 5 days and weights recorded. The second wild rice data after treatments was taken when the rice was in the flowering stage. Whole wild rice plants from a 1 x 1 m quadrat were again dug out at the 10 cm depth. Then they were separated into shoot, rhizome and adventitious roots by cutting using a pair

of scissors and weighed to determine fresh weights. The fresh and dry weights of the shoots, and roots were recorded separately following a similar procedure. Based on visual observations weeds in the trial plots were identified and ranked in order of abundance as wild rices (*Oryza longistaminata* and *O.punctata*), *Sacciolepis africana*, barnyard grass, *Sporobolus pyramidalis* Beauv., southern cutgrass, sedges, water chestnut (*Eleocharis* sp.), *Fuirena umbellata* Rottb., wandering jew (*Commelina benghalensis* (L.)), *Fimbristylis miliacea (L.) Vahl*, ivy leaved morning glory (*Ipomea aquatica* Forssk.), *Carex cyrtosaccus*, *Burnatia* sp., water primrose (*Jussiaea repens* (L.)), water plantain (*Alisma* sp.), *Ottelia ulvifolia* (Planch) Walp and monochoria.

3.5.2.2 Weed data in experiment 2

Shoot, rhizome and adventitious root fresh weight data before treatments were obtained from a 1 x 1 m quadrat randomly placed in the plot for each treatment. Data on wild rice and other weeds was collected as described in section 3.5.2.1.

3.5.3 Grain yield and yield components for experiment 1 and 2

The central part of each subplot or plot in experiment 1 and 2, respectively, which had a dimension of 3 x 3 m was reserved as the net harvestable area. The external area was used as the sampling area. A random sample of 10 plants per plot was obtained from the sampling area and marked using labelled pegs which were stuck

adjacent to each sample plant. Except for the grain yield ha^{-1}, yield and number of panicles m^{-2}, all the individual plant data were taken from the same sample plants of each subplot or plot for experiment 1 or 2, respectively.

3.5.3.1 Plant height

Plant height of each of the 10 sample plants $plot^{-1}$ (Experiment 2) or subplot (Experiment 1) was measured from ground level to the flag leaf tip (which was longer than the panicle even at maturity) of each plant using a 1 m long ruler. The computed mean plant height was recorded for each plot or subplot.

3.5.3.2 Number of tillers

The number of tillers of each sample plant were counted and the mean obtained from the 10 plants for each plot or subplot was recorded as the treatment number of tillers plant per plant.

3.5.3.3 Number of panicles

The panicles from each sample plant were harvested, counted and the mean number of panicles per plant computed for each plot or subplot to get the number of panicles per plant.

3.5.3.4 Percentage effective tillers

The percentage effective tillers was computed from the number of tillers and number of panicles per plant of the 10 sample plants per plot or subplot.

3.5.3.5 Number of spikelets

All the spikelets from the 10 sample plants were threshed counted and divided by the total number of panicles of the sample plants per subplot or plot to obtain the number of spikelets per panicle.

3.5.3.6 Number of panicles per square metre

A one square metre quadrat was placed on the sampling area, then all panicles from the area were harvested, counted and recorded as the number of panicles per square metre.

3.5.3.7 Grain yield per square metre

Grain yield per square metre was obtained by weighing the grain obtained after threshing and drying to 14% moisture content (mc) all panicles harvested from the one square metre of each plot or subplot.

3.5.3.8 Grain yield per hectare

All panicles were harvested from the 3 x 3 m net harvestable area of each subplot or plot, threshed, sun dried to 14% mc and weighed. The grain yield per hectare was obtained by converting the grain yield obtained from the harvestable area of each subplot or plot.

3.5.3.9 Percentage ripened grains

The percentage ripened grains was obtained by weighing all the spikelets from the 1 square metre, and then separating into filled and unfilled grains using a 1.06 specific gravity salt solution. The solution was obtained by dissolving 150 g of sodium chloride in a litre of water. The grains were stirred in the salt solution for 1 minute, in the process grains were divided into floating and sunken groups. All the sunken grains were considered as fully ripened ones, and were separated and then sundried following the procedure described by Matsushima (1980). After sun drying to 14% mc, the fully filled grains were reweighed, and the percentage of the ripened grains obtained by computation.

3.5.3.10 One thousand grain weight

The weight (g) of 1000 grains was obtained by weighing five dried samples of 1000 fully filled grains each from each subplot or plot and calculating the mean for each treatment.

3.5.4 Total variable costs of treatments

The costs of the different inputs used in the treatments and prices of the products were determined for use in the economic analyses as follows:-

Costs: Herbicides- glyphosate		Tshs	10 000.00 l^{-1}
	whipsuper	Tshs	34 000.00 "
Labour			1 000.00 $manday^{-1}$
Hiring of sprayer		Tshs	5 000.00 ha^{-1}
Prices:	rice "	Tshs	315.00 kg^{-1}
	broken rice	Tshs	180.00 kg^{-1}
	rice polish	"	1 200.00 60 kg bag^{-1}
	rice straws	"	200.00 13.5 kg $bale^{-1}$

Percentage recoveries of rice, and by-products after milling paddy (IR 54):-

rice - 64.03% (grain size greater than half)

broken rice - 6.91% (grain size half or less than half)

rice bran - 6.34%

husks - 20.72%

dockage - 2%

3.6 Data analysis

Data was analyzed using the MSTATC computer package utilizing the following statistical models:-

3.6.1 Experiment 1: $\mu + \beta_i + \alpha_j + W_{ij} + \tau_k + \alpha\tau_{jk} + \hat{E}_{ijk}$

Response = General effect + Block effect + Main factor effect + Main plot effect + Sub plot effect + Interac. effect + Sub plot random error effect.

3.6.2 Experiment 2: $\mu + \tau_i + \beta_j + \Sigma_{ij}$

Response = General effect + Block effect + Treatment effect + Random error effect

3.6.3 Net benefit analysis of the different treatments in experiment 2.

Added costs were compared with added returns. Costs of herbicides, labour for hand weeding and herbicide application were compiled for each treatment. The total revenue per treatment were calculated from total rice, broken rice, rice polish and straws sales. Prices used for each component are as shown in section 3.6.4. The net benefit was the difference between total revenue and the total costs that vary per treatment (CIMMYT, 1988). The total revenue and total costs that vary were utilized to determine the benefit cost ratio of each treatment and then subjected to an ANOVA (Gittinger 1982).

CHAPTER FOUR

4.0 RESULTS

4.1 Climatic conditions

Rainfall received during the 1997/98 cropping season for the months of January, April and May was much higher than the normal five years' average at KRIP (Figure 1). The heavy rains compelled wet seeding of pre-germinated seeds in experiment 1. This led to poorer seedlings than is usually obtained from dry seeded and rain germinated paddy. At the end of the rain season in mid April, irrigation water was used until harvesting time i.e. in July. The season's mean maximum and minimum temperatures were higher than normal during the months of January to April (Fig.2). On the other hand, the minimum temperatures in May, June and July were much lower than the average in normal years (Figure 2). For both experiments, the cool months of June and July coincided with the critical stages of panicle initiation, anthesis, pollen formation and fertilization of paddy. Hence these phenolic stages which are sensitive to low temperature were adversely affected.

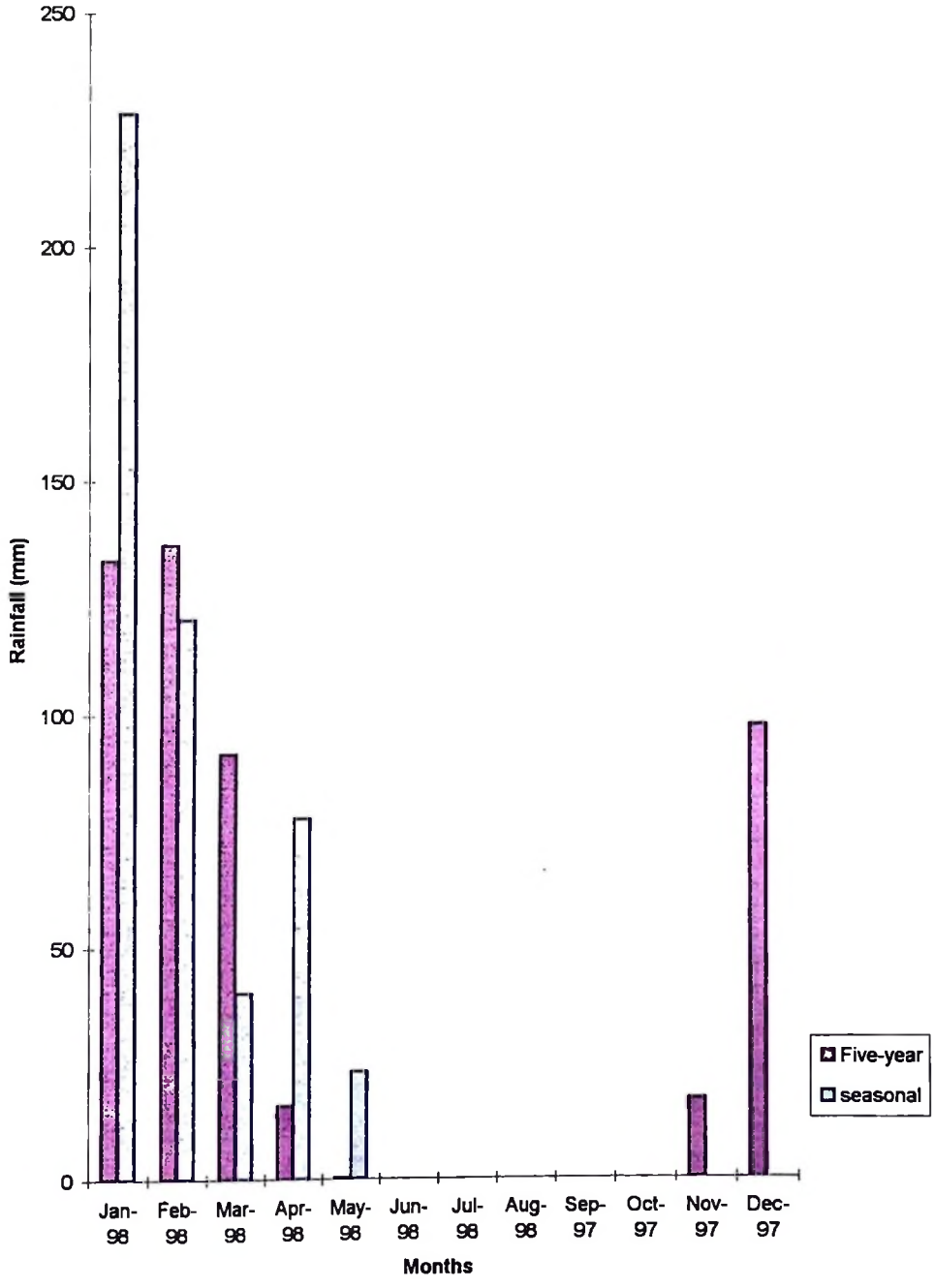


Fig. 1. Five - year mean monthly rainfall (mm) and monthly totals during cropping season at KRIP.

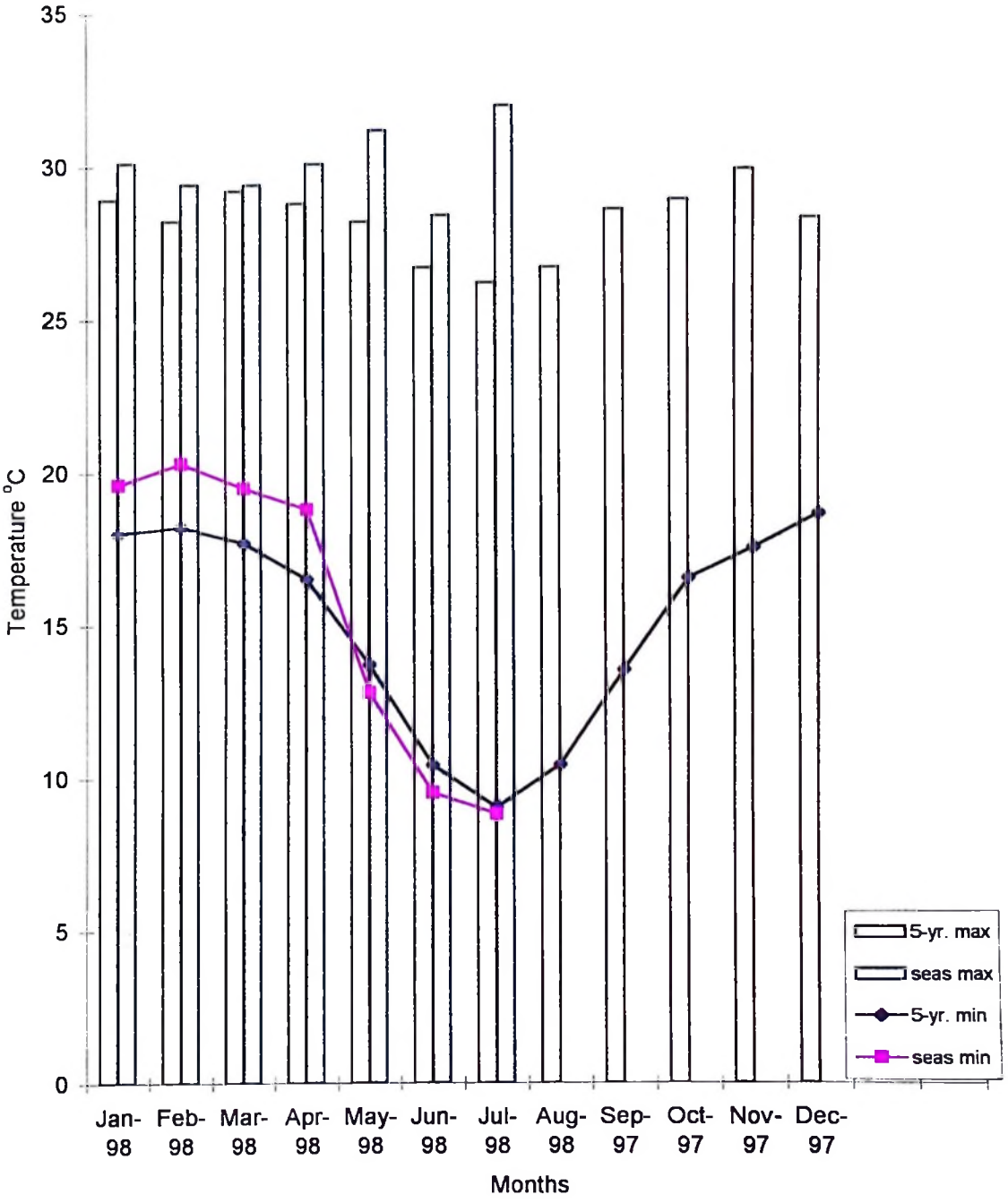


Fig. 2. Five - year mean and seasonal monthly minimum and maximum temperature °C.

4.1.1 Experiment 1. The effect of ploughing depth and seeding rate on wild rice control

4.1.2 Wild rice data

4.1.2.1 Wild rice root biomass

There were no significant ($P \leq 0.05$) differences in fresh and dry wild rice root biomass of rhizomes and adventitious roots in trial plots before treatment application. However, the interactions of ploughing depth and seeding rate had significant ($P \leq 0.05$) effects on the fresh and dry rhizome biomass (Table 4 & 5). Fresh rhizome biomass was significantly highest (72.8 g m^{-2}) for the combination of 25 cm ploughing depth and the seeding rate of 130 kg ha^{-1} but not significantly different ($P \leq 0.05$) from the 63.3 g m^{-2} recorded for 10 the cm ploughing depth in combination with 110 kg ha^{-1} seeding rate. The seeding rate of 150 kg ha^{-1} resulted in the lowest average rhizome fresh biomass over the range of ploughing depths (Table 4). However, fresh rhizome biomass was significantly ($P \leq 0.05$) lowest (17.0 g m^{-2}) for 15 cm and 170 kg ha^{-1}, respective ploughing depth and seeding rate combinations. This fresh rhizome biomass value was similar to that recorded at the 10 x 130, 25 x 130, 10 x 150, 20 x 150, 25 x 150, and 25 x 170 ploughing depth (cm) x seeding rate (kg ha^{-1}), respective combinations. A similar trend of results was registered for the rhizome dry biomass (Table 5).

Adventitious root fresh and dry biomass m^{-2} on the other hand were not

significantly affected by combinations of ploughing depths and seeding rates (Tables 6 and 7).

Table 4. Mean wild rice rhizome fresh biomass (g m^{-2}) for combinations of ploughing depths and seeding rates.

Seeding rates (kg ha^{-1})	Ploughing depths (cm)				
	10	**15**	**20**	**25**	**Mean**
110	63.3ab[1]	55.8bc	42.5cde	32.0efg	**48.4a**[2]
130	19.1g	45.2cde	54.2bcd	72.8a	47.8a
150	32.8efg	42.8cde	23.5fg	30.5efg	**32.4**b
170	56.4bc	17.0g	38.3def	29.0efg	**35.2**b
Mean	**42.9**	**40.2**	**39.6**	**41.1**	

SE: Ploughing depth (PD) = 2.02

SE: Seeding rate (S) = 2.57

SE: PD X S = 5.14

CV: = 21.74%

[1], [2] Values in the main body of the table, and marginal means, respectively, followed by the same letter(s) are not significantly ($P \leq 0.05$) different by DMRT.

Table 5. Mean wild rice rhizome dry biomass (g m^{-2}) for combinations of ploughing depths and seeding rates.

Seeding rates (kg ha^{-1})	Ploughing depths (cm)				
	10	**15**	**20**	**25**	**Mean**
110	18.7ab[1]	17.1abc	12.8cdef	9.4efgh	14.5a[2]
130	6.1gh	14.1bcde	15.5bcd	21.6a	14.3a
150	10.5defgh	12.8cdef	7.3fgh	9.8efgh	10.1b
170	16.6abc	4.9h	11.0defg	8.6efgh	10.3b
Mean	13.0	12.2	11.6	12.3	

SE: Ploughing depth (PD) = 0.58

SE: Seeding rate (S) = 0.67

SE: PD X S = 0.85

CV: = 24.00%

[1],[2] Values in the main body of the table, and marginal means respectively, followed by the same letter(s) are not significantly ($P \leq 0.05$) different by DMRT.

Table 6. Mean adventitious root fresh biomass (g m^{-2}) as affected by combinations of ploughing depths and seeding rates.

Seeding rates (kg ha^{-1})	Ploughing depths (cm)				
	10	**15**	**20**	**25**	**Mean**
110	11.0	12.5	16.0	12.5	**13.0b**[1]
130	12.6	25.1	27.7	12.4	**19.4ab**
150	12.1	12.3	15.9	17.4	**14.4b**
170	16.0	27.8	28.5	14.2	**21.6a**
Mean	**12.9**	**19.4**	**22.0**	**14.1**	

SE: Ploughing Depth (PD) = 5.15

SE: Seeding rate (S) = 2.28

SE: PD X S = 4.57

CV: = 46.25%

[1] Marginal means followed by the same letter(s) are not significantly ($P \leq 0.05$) different by DMRT.

Table 7. Mean adventitious root dry biomass (g m^{-2}) for combinations of ploughing depths and seeding rates.

Seeding rates (kg ha^{-1})	Ploughing depths (cm)				
	10	**15**	**20**	**25**	**Mean**
110	1.9	5.0	3.0	2.4	**3.1**
130	2.5	4.6	4.8	2.4	**3.6**
150	2.1	2.4	2.9	3.4	**2.7**
170	2.9	5.2	4.9	2.5	**3.9**
Mean	**2.4**	**4.3**	**3.9**	**2.7**	**3.3**

SE: Ploughing depth (PD) = 1.21

SE: Seeding rate (S) = 0.44

SE: PD X S = 0.89

CV: = 46.56%

4.1.2.2 Wild rice shoot biomass

Wild rice fresh and dry shoot biomass was not affected significantly ($P \leq 0.05$) by ploughing depth, seeding rate or their interaction. No significant ($P \leq 0.05$) differences in fresh and dry shoot biomass per square metre were observed among ploughing depth and seeding rate combinations. The two parametres had no definite trend among the treatment combinations (Table 8 & 9).

Table 8. Mean wild rice shoot fresh biomass (g m^{-2}) for combinations of ploughing depths and seeding rates

Seeding rates (kg ha^{-1})	Ploughing depths (cm)				
	10	**15**	**20**	**25**	**Mean**
110	124.0	141.6	165.7	205.9	**159.3**
130	153.3	136.0	177.6	134.7	**150.4**
150	160.6	102.1	134.5	149.9	**136.8**
170	174.5	204.6	228.6	159.3	**191.7**
Mean	**153.1**	**146.1**	**176.6**	**162.4**	**159.5**

SE: Ploughing depth (PD) = 36.82

SE: Seeding rate (S) = 18.89

SE: PD X S = 37.75

CV: = 40.99%

Table 9. Mean wild rice shoot dry biomass (g m^{-2}) for combinations of ploughing depths and seeding rates.

Seeding rate (kg ha^{-1})	Ploughing depths (cm)				
	10	**15**	**20**	**25**	**Mean**
110	31.0	35.7	41.4	51.7	**40.0**
130	38.8	34.5	44.7	34.3	**38.0**
150	39.0	25.7	33.2	38.0	**33.9**
170	43.3	50.8	24.3	39.8	**39.5**
Mean	**38.0**	**36.7**	**35.91**	**41.0**	**37.9**

SE: Ploughing depth (PD) = 7.68

SE: Seeding rate (S) = 3.99

SE: PD X S = 7.82

CV: = 35.74%

4.1.3 Grain yield and yield components

4.1.3.1 Number of tillers per plant

The number of tillers per plant was significantly ($P \leq 0.05$) affected by combinations of seeding rates and ploughing depths (Fig.3). The highest number of tillers of 6.33 occurred at 170 kg ha^{-1} seeding rate x 15 cm ploughing depth combination. The highest value was similar to values observed at 10 cm x 130 kg ha^{-1}, 25 x 110, 20 x 150 and 25 x 170 ploughing depth (cm) and seeding rate (kg ha^{-1}) interactions. Tillering was significantly ($P \leq 0.05$) reduced to 3.33 at 25 cm ploughing depth x 130 kg ha^{-1} seeding rate combination, this value was not significantly ($P \leq 0.05$) different from those recorded at 10 cm x 110 kg ha^{-1}, 15 x 110, 20 x 130 and 10 x 170 ploughing depth (cm) and seeding rate (kg ha^{-1}) combinations (Fig.3).

4.1.3.2 Number of panicles per plant

The number of panicles per plant was significantly ($P \leq 0.05$) affected by seeding rates and the interactions between seeding rates and ploughing depths (Appendix VI & VII). The highest mean number of panicles which differed significantly ($P \leq 0.05$) from all other plots was 5.6 at 15 cm ploughing depth x 170 kg ha^{-1} seeding rate interaction. The lowest number was 3.1 at the 25 cm ploughing depth x 130 kg ha^{-1} seeding rate interaction and this was similar to the 3.4 and 3.5 panicles $plant^{-1}$ recorded at 10 cm x 130 kg ha^{-1} and 10 cm x 170 kg ha^{-1} ploughing depth and seeding rate combinations, respectively (Table 10).

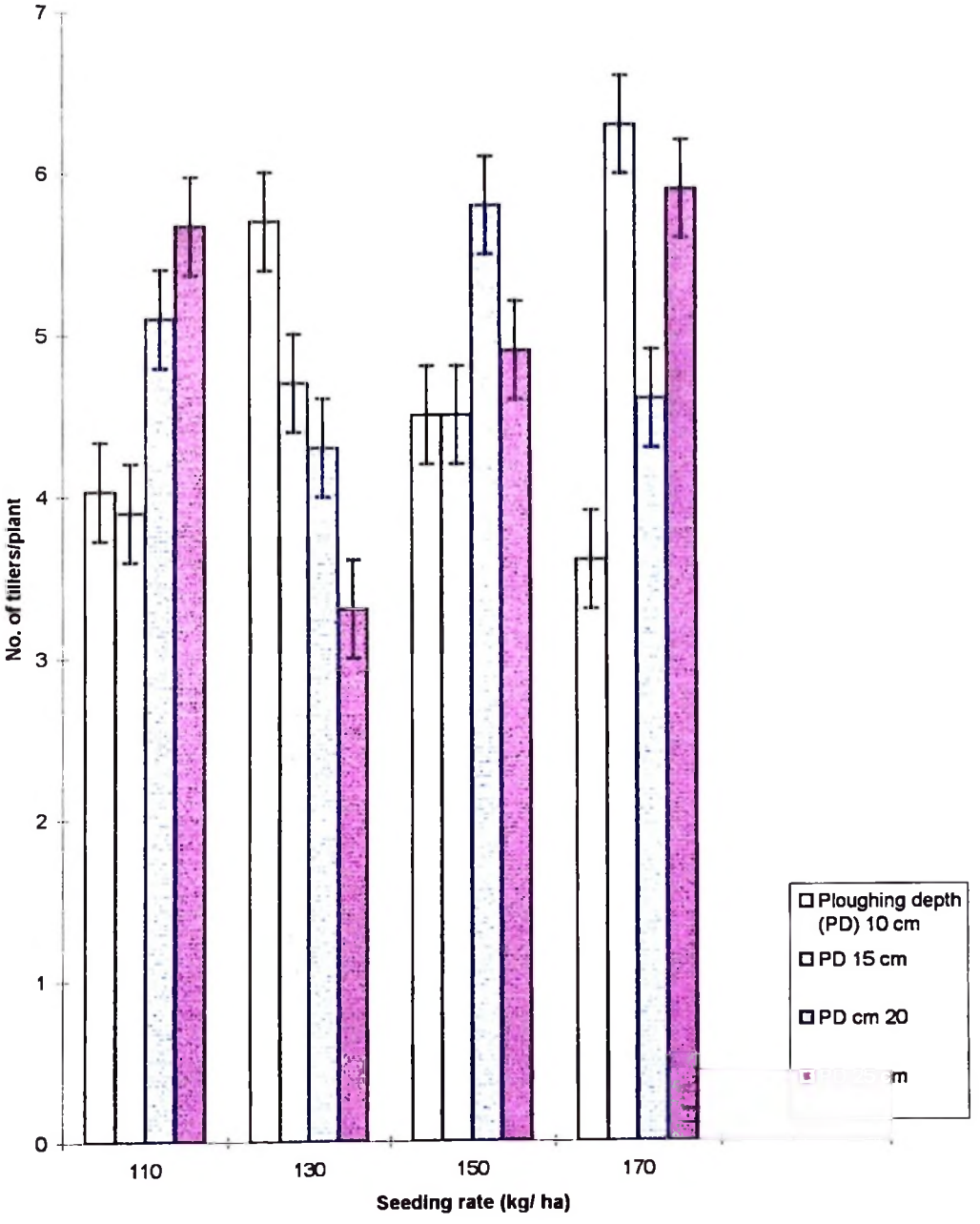


Fig.3. Number of tillers per plant as affected by ploughing depths (PD) (cm) and seeding rates. Bars denote standard errors

Table 10. Number of panicles per plant as affected by ploughing depths and seeding rates.

Seeding rates (kg ha^{-1})	Ploughing depths (cm)				
	10	**15**	**20**	**25**	**Mean**
110	3.4hi[1]	3.8fgh	4.3def	4.5cd	**4.0b[2]**
130	5.1b	4.0defg	3.9efgh	3.1i	**4.0b**
150	4.3def	4.2def	5.1b	4.4de	**4.5a**
170	3.5ghi	5.6a	4.1def	5.0bc	**4.5a**
Mean	**4.1**	**4.4**	**4.34**	**4.3**	

SE: Seeding rate (S) = 0.08

SE: Ploughing depth (PD) = 0.08

SE: PD X S = 0.17

CV: = 6.93%

[1],[2] Values in the main body of the table and marginal means respectively, followed by the same letter(s) are not significantly ($P \leq 0.05$) different by DMRT.

4.1.3.3 Percentage ripened grains

Seeding rates in combination with ploughing depths had significant ($P \leq 0.05$) effects on percentage ripened grains (Appendix VII). The highest mean percentage ripened grains was 77.03 recorded at 15 cm and 170 kg ha^{-1} ploughing depth and seeding rate interactions which differed significantly ($P \leq 0.05$) from the other treatment combinations.the plots. The percentage ripened grains value was similar to those recorded at 10 cm x 130 kg ha^{-1}, 20 x 150, 25 x 170, 25 x 150 and 25 x 110 ploughing depth and seeding rate combinations. The lowest percentage ripened grains was 48.03 at 25 cm x 130 kg ha^{-1} seeding rate combinations, and this was not significantly ($P \leq 0.05$) different from the percentage ripened grains at 10 cm x 110 kg ha^{-1}, 10 x 170, and 20 x 130 ploughing depth and seeding rate interactions (Table 11).

4.1.3.4 Number of spikelets per panicle

The number of spikelets per panicle was not significantly ($P \leq 0.05$) affected by ploughing depth and seeding rate interactions (Appendix VII). The number of spikelets per panicle had no defined trend over the range of ploughing depths and seeding rates (Table 12).

Table 11. Percentage ripened grains as affected by ploughing depths and seeding rates.

Seeding rates (kg ha^{-1})	Ploughing depths (cm)				
	10	**15**	**20**	**25**	**Mean**
110	53.3gh[1]	58.6efg	59.5defg	68.4abc	59.9c[2]
130	71.2ab	61.6cdef	55.2fgh	48.0h	59.0c
150	64.9bcde	64.0bcde	71.0ab	66.7abcd	66.6a
170	54.8fgh	74.0a	55.4fg	68.8abc	63.2b
Mean	**61.0**	**64.5**	**60.3**	**63.0**	**62.2**

SE: Ploughing depth (PD) = 1.04

SE: Seeding rate (S) = 1.13

SE: PD X S = 2.70

CV: = 6.32%. [1],[2] Values in the main table and marginal means, respectively, followed by the same letter(s) are not significantly ($P \leq 0.05$) different by DMRT.

Table 12. Number of spikelets per panicle as affected by ploughing depths and seeding rates.

Seeding rates (kg ha^{-1})	Ploughing depths (cm)				
	10	**15**	**20**	**25**	**Mean**
110	69.6	70.4	74.8	73.5	**72.1**
130	73.5	67.6	76.3	61.2	**69.6**
150	67.1	64.4	68.1	61.2	**65.2**
170	68.0	67.7	86.7	63.7	**71.5**
Mean	**69.5**	**67.5**	**76.5**	**64.9**	

SE: Ploughing depth (PD) = 4.67

SE: Seeding rate (S) = 2.56

SE: PD X S = 5.12

CV: = 12.75%

4.1.3.5 Number of panicles per square metre

The number of panicles per square metre was significantly ($P \leq 0.05$) affected by seeding rates and the interactions of seeding rates x ploughing depths (Appendix VI & VII). Panicle production was highest (773.33 panicles m^{-2}) at 15 cm x 170 kg ha^{-1} interactions of ploughing depth and seeding rate. However, this was similar to the 724.7 panicles m^{-2} recorded for 10 cm x 130 kg ha^{-1} ploughing depth and seeding rate combinations. The lowest number of panicles per square was 423.3 recorded at 25 cm ploughing depth x 130 kg ha^{-1} seeding rate interactions and was significantly different from all the other plots. Generally more panicles were produced at seeding rates of 150 and 170 kg ha^{-1} than at lower seeding rates (Fig.4).

4.1.3.6 One thousand grain weight

The 1000 grain weight was significantly affected ($P \leq 0.05$) by the interactions of ploughing depths and seeding rates (Appendix VII). The highest 1000 grain weight (24.6 g) was recorded at 15 cm x 170 kg ha^{-1} ploughing depth x seed rates interactions and differed significantly ($P \leq 0.05$) from the other plots. This value was similar to those recorded at 10 cm x 110 and 150 kg ha^{-1}, 20 x 150, and 25 x 110, 150 and 170 ploughing depth and seeding rate combinations. The lowest mean 1000 grain weight (23.33 g) was recorded at 25 cm x 130 kg ha^{-1} ploughing depth and seeding rate interactions. The lowest value was similar to that recorded at 10 cm x 110 kg ha^{-1} ploughing depth and seeding rate interactions (Table 13).

4.1.3.7 Grain yield per hectare

The paddy grain yield per hectare was significantly ($P \leq 0.05$) affected by ploughing depths, seeding rates plus the ploughing depth and seeding rates interactions (Appendix V, VI & VII). The highest grain yield (4852 kg ha^{-1}) was recorded at 15 cm x 170 kg ha^{-1} ploughing depth and seeding rate interactions. The lowest mean grain yield ha^{-1} was 2852.0 kg ha^{-1} recorded at 25 x 130 kg ha^{-1} ploughing depth and seeding rate interactions. Both the highest and lowest grain yields per hectare were significantly different from all the other plots (Fig.5).

4.2.0 Correlation coefficients

The grain yield was positively correlated to the number of panicles and tillers plant per plant, percentage ripened grains, grains per panicle, plant height at booting and maturity, grain yield per square metre, thousand grain weight, and panicles per square metre (Table 14). Panicles per plant were positively correlated to tillers per plant, percentage ripened grains, grains per panicle, plant height, thousand grain weight, and grain yield. Panicles per plant were negatively correlated to adventitious roots plus rhizome fresh and dry weights. Tillers per plant were positively correlated to percentage ripened grains, grains per panicle, 1000 grain weight, yield per square metre but were negatively correlated to wild rice shoot dry and fresh weights, roots plus rhizome fresh and dry weights after treatments. There was a negative correlation between grain yield and wild rice rhizome fresh and dry

biomass. Correlation coefficient (r) values recorded were -0.824 and -0.804 for fresh and dry rhizome biomass, respectively. Coefficients of determination (r^2) derived therefrom were 0.68 and 0.65, respectively.

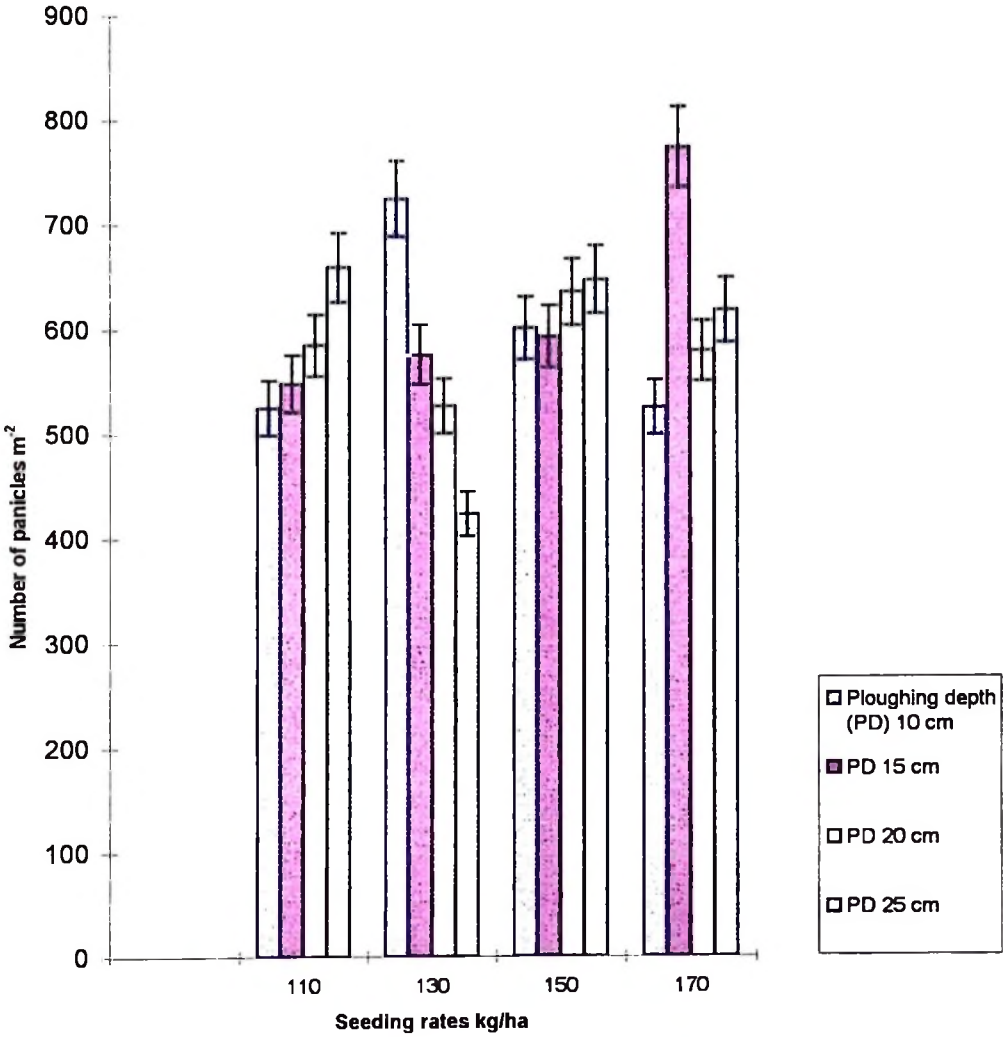


Fig.4 Number of panicles /m^2 as affected by ploughing depths (cm) and seeding rates. Bars denote standard errors.

Table 13. One thousand grain weight as affected by ploughing depths and seeding rates.

Seeding rates (kg ha^{-1})	Ploughing depths (cm)				
	10	**15**	**20**	**25**	**Mean**
110	23.4d[1]	23.8c	24.0bc	24.2abc	**23.8b**[2]
130	24.5a	24.0bc	23.8c	23.3d	**23.9b**
150	24.3ab	24.0bc	24.4ab	24.3ab	**24.2a**
170	23.8c	24.6a	24.0bc	24.3ab	**24.1a**
Mean	**24.0**	**24.1**	**24.0**	**24.0**	

SE: Ploughing depth (PD) = 0.05

SE: Seeding rate (S) = 0.06

SE: PD X S = 0.13

CV: = 0.92%

[1,2] Values in the main body of the table and marginal means, respectively, followed by the same letter(s) are not significantly ($P \leq 0.05$) different by DMRT.

Table 14. Partial correlation coefficients of grain yield and its components.

	1	2	3	4	5	6	7
1.Yield per hectare	1	+0.873*	+0.819*	+0.824*	+0.041*	+0.842nsd	+0.798*
2. Panicles per plant		1	+0.912*	+0.687*	+0.070nsd	+0.657*	+0.804*
3. Tillers per plant			1	+0.662*	+0.064nsd	-0.604*	+0.773*
4. Percentage ripened grains				1	-0.167nsd	+0.868*	+0.637*
5. Grains per panicle					1	-0.070nsd	+0.558nsd
6. Panicles per square metre						1	+.681*
7. Thousand grain wt.							1

* = significant nsd = no significant difference

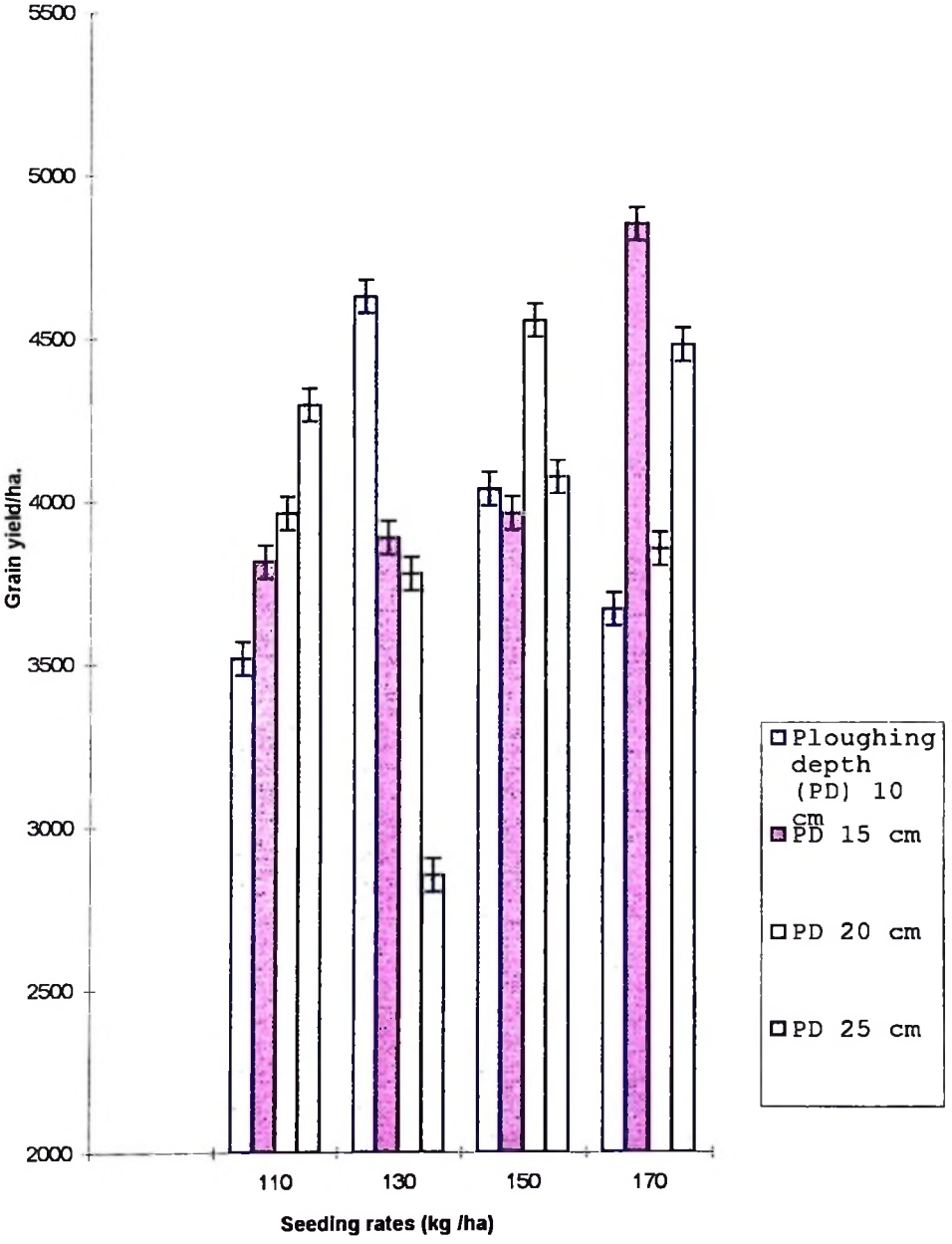


Fig.5. Grain yield per hectare (kg) as affected by ploughing depths (PD) (cm) and seeding rates. Bars denote standard error.

Plate No. 1. Wild rices growing above the rice plants in experiment 1, showing the shading effect. M2S4 are plots ploughed at 15 cm depth and 170 kg ha^{-1} seeding rate.

Plate No. 2. A contrast of the extensive wild rice rhizome and root system on the right and rice plant roots on the left.

4.3 Experiment 2. Comparative performance of hand weeding, glyphosate and whip super for wild rice control

4.3.1 Weed counts

Weed counts were significantly ($P \leq 0.05$) affected by weed control practices (Appendix XIII). The density of other weeds was lower than that of wild rices in all control practices applied. The highest mean number of other weeds was 54.0 plants m^{-2} recorded in the unweeded check, and this was similar to the values recorded in plots sprayed with whip super at 20 g a.i ha^{-1}, and glyphosate at 1.8 g a.i ha^{-1}. The lowest number was 15.3 plants m^{-2} in plots hand weeded twice. However, this lowest value did not differ significantly from all other treatments except the unweeded plots, those treated with glyphosate at the rate of 1.8 kg a.i, and whip super at 20 g a.i ha^{-1} (Table 16).

Wild rice counts per square metre varied significantly from the lowest mean of 24 for plots treated with glyphosate at the rate of 5.4 kg a.i ha^{-1} to the significantly ($P \leq 0.05$) highest number of 252 plants m^{-2} in non weeded plots. The highest mean number of wild rices for the non weeded plots was significantly ($P \leq 0.05$) different from all treatments. The lowest mean number on the other hand, was similar to values recorded in all other treatments, except the unweeded check and plots treated with glyphosate at the rate of 1.8 kg a.i ha^{-1} (Table 15).

4.3.2 Weed biomass

No significant differences in shoot, rhizome and adventitious roots fresh and dry biomass were recorded among all the weed control measures applied in the experiment (Tables 15 & 16).

Table 15. Wild rice adventitious roots fresh and dry biomass (g m^{-2}), wild rice and other weed counts per square metre for different weed control practices

Treatment	Rate (kg a.i ha^{-1})	Adventitious root biomass (g m^{-2})		Weed counts (m^{-2})	
		Fresh	Dry	wild rices	other weeds
Two hw 30 & 50 DAT		9.6	1.5	68.7c[1]	15.3c[1]
Glyph. pre plant + hw 30 DAT	1.8	13.7	2.4	73.3c	20.0c
Glyphosate pre plant	1.8	13.3	2.5	169.7b	43.3ab
Glyphosate "	3.6	21.3	3.9	43.3c	29.3bc
Glyphosate "	5.4	12.6	2.7	24.0c	18.7c
Whip super at tiller	0.02	16.5	2.8	101.0bc	47.0ab
Whip at tiller + hw 50 DAT	0.02	18.7	3.5	82.0bc	21.3c
Whip super at tiller	0.04	19.3	3.0	92.0bc	20.7c
Whip super "	0.06	10.9	2.0	96.3bc	21.7c
Unweeded		15.9	2.7	252.0a	54.0a
Mean		**15.2**	**2.7**	**100.2**	**29.1**
SE		**4.1**	**0.7**	**6.42**	**27.4**
CV %		**38.9**	**46.4**	**47.3**	**37.9**

hw = hand weeding, glyph. = glyphosate, DAT = days after transplanting, tiller = tillering stage, whip = whip super. [1] Values in the same column followed by the same letter(s) are not significantly ($P \leq 0.05$) different by DMRT.

Table 15. Wild rice adventitious roots fresh and dry biomass (g m^{-2}), wild rice and other weed counts per square metre for different weed control practices

Treatment	Rate (kg a.i ha^{-1})	Adventitious root biomass (g m^{-2})		Weed counts (m^{-2})	
		Fresh	Dry	wild rices	other weeds
Two hw 30 & 50 DAT		9.6	1.5	68.7c[1]	15.3c[1]
Glyph. pre plant + hw 30 DAT	1.8	13.7	2.4	73.3c	20.0c
Glyphosate pre plant	1.8	13.3	2.5	169.7b	43.3ab
Glyphosate "	3.6	21.3	3.9	43.3c	29.3bc
Glyphosate "	5.4	12.6	2.7	24.0c	18.7c
Whip super at tiller	0.02	16.5	2.8	101.0bc	47.0ab
Whip at tiller + hw 50 DAT	0.02	18.7	3.5	82.0bc	21.3c
Whip super at tiller	0.04	19.3	3.0	92.0bc	20.7c
Whip super "	0.06	10.9	2.0	96.3bc	21.7c
Unweeded		15.9	2.7	252.0a	54.0a
Mean		**15.2**	**2.7**	**100.2**	**29.1**
SE		**4.1**	**0.7**	**6.42**	**27.4**
CV %		**38.9**	**46.4**	**47.3**	**37.9**

hw = hand weeding, glyph. = glyphosate, DAT = days after transplanting, tiller = tillering stage, whip = whip super. [1] Values in the same column followed by the same letter(s) are not significantly ($P \leq 0.05$) different by DMRT.

Table 16. Wild rice shoot, rhizome fresh and dry biomass (g m^{-2}) for different weed control practices

Treatment	Rate (kg ha^{-1})	Fresh biomass (g m^{-2})		Dry biomass (g m^{-2})	
		Shoot	Rhizome	Shoot	Rhizome
Two hw 30 & 50 DAT		79.7	62.1	20.2	19.9
Glyph. pre plant + hw 30 DAT	1.8	114.1	52.1	29.5	17.0
Glyph. pre plant	1.8	117.9	73.6	32.7	26.6
Glyph. "	3.6	90.0	84.7	24.6	26.9
Glyph. "	5.4	85.8	68.1	22.4	23.1
Whip at tiller	0.02	103.5	75.7	26.7	21.8
Whip at tiller + hw 50 DAT	0.02	97.6	55.4	27.0	20.0
Whip at tiller	0.04	101.9	69.1	27.8	21.0
Whip "	0.06	122.5	53.6	32.0	17.6
Unweeded		134.7	54.2	34.1	17.4
Mean		**104.8**	**64.8**	**27.7**	**21.1**
SE		**23.54**	**14.00**	**5.92**	**4.89**
CV %		**38.92**	**49.30**	**37.05**	**40.10**

hw = hand weeding, glyph. = glyphosate, whip = whip super, tiller = tillering stage, DAT = days after transplanting.

4.3.3 Effect of weed control practices on rice plant height, yields and yield components.

4.3.3.1 Plant height

Crop plants in experiment 2 were generally stunted compared to experiment 1 and the normal plant height of variety IR 54. At booting, rice plants treated with glyphosate 5.4 kg a.i ha^{-1} were significantly ($P \leq 0.05$) tallest (57.8 cm) compared to the shortest plants (48.5 cm) in plots treated with whip super at 60 g a.i ha^{-1}. At maturity the significantly tallest plants recorded mean heights of 61.4 while the shortest plants were 51.1 cm in glyphosate treated plots at 5.4 kg a.i ha^{-1} and whip super at the rate of 60 g a.i ha^{-1} respectively (Table 17).

4.3.3.2 Number of tillers and panicles

Weed control treatments applied had significant ($P \leq 0.05$) effects on the number of tillers and panicles per plant (Appendix XII). Plots hand weeded twice had the highest respective mean number of tillers and panicles per plant of 16.5, and 13.03, which differed significantly from all the other plots. The lowest values were 6.4, and 1.53 tillers and panicles per plant, respectively, in the unweeded check (Table 18).

4.3.3.3 Number of tillers per square metre

The number of tillers per square metre was significantly ($P \leq 0.05$) influenced by the different weed control practices applied in the trial. The highest and lowest number of tillers 748 and 366.3 were recorded in plots treated with whip super at 40 g a.i ha^{-1} and whip super 20 g a.i ha^{-1} respectively. The lowest number of tillers did not differ significantly from those recorded in plots of glyphosate at 1.8 kg a.i ha^{-1} followed by

one hand weeding, whip super at 20 g a.i ha^{-1}, and whip super at 20 g a.i ha^{-1} followed by hand weeding (Table 19).

4.3.3.4 Number of panicles per square metre

The number of panicles per square metre was significantly ($P \leq 0.05$ affected by weed control practices applied (Appendix XII). The highest mean number of 374 panicles m^{-2} in plots hand weeded twice, was significantly reduced to the lowest value of 147.7 panicles in plots sprayed with whip super at the rate of 20 g a.i ha^{-1} (Table 19).

Table 17. Effects of hand weeding, whip super and glyphosate on rice plant height.

Treatment	Rate (kg a.i ha^{-1})	Plant height (cm)	
		Booting	Maturity
Two hand weedings 30 & 50 DAT		53.7c	57.1g
Glyphosate pre plant + hw 30 DAT	1.8	56.4b	59.1b
Glyphosate pre plant	1.8	51.7d	55.3d
Glyphosate "	3.6	53.7c	57.0c
Glyphosate "	5.4	57.8a	61.4a
Whip super at tiller	0.02	51.0d	54.2e
Whip super at tiller + hw 50 DAT	0.02	49.7e	54.1e
Whip super at tiller	0.04	49.0ef	52.1f
Whip super "	0.06	48.5f	51.1f
Unweeded		49.8e	55.3d
Mean		52.14	55.7
CV%		1.19	1.13
SE		0.36	0.36

w = hand weeding, DAT = Days after transplanting, tiller = tillering stage of rice plants

[1] Values in the same column followed by the same letter(s) are not significantly ($P \leq 0.05$) different by DMRT.

Table 18. Effects of hand weeding, whip super and glyphosate on number of tillers, and panicles per plant.

Treatment	Rate (kg ha^{-1})	Number per plant	
		Tillers	Panicles
Two hand weedings 30 & 50 DAT		16.4a[1]	13.0a[1]
Glyph pre plant + hw 30 DAT	1.8	13.2b	9.9b
Glyphosate "	1.8	11.2d	5.6f
Glyphosate "	3.6	13.2b	8.5d
Glyphosate "	5.4	13.5b	9.3c
Whip super at tiller	0.02	10.4e	4.2g
Whip super at tiller + hw 50 DAT	0.02	12.0c	7.3e
Whip super at tiller	0.04	10.7e	3.2h
Whip super "	0.06	9.1f	2.6i
Unweeded		6.4g	1.5j
Mean		**11.62**	**6.51**
SE		**0.15**	**0.08**
CV%		**2.25**	**2.19**

hw = hand weeding, DAT = days after transplanting, glyph. = glyphosate, tiller = tillering stage

[1] Values in the same column followed by the same letter are not significantly ($P \leq 0.05$) different by DMRT.

Table 19. Effects of hand weeding, glyphosate and whip super on number of tillers, panicles and grain yield per square metre.

Treatment	Rate (kg ha^{-1})	Tillers ($^{m-2}$)	Panicles (m^{-2})	Yield (m^{-2}) (g)
Two hw 30 & 50 DAT		471.0f[1]	374.0a[1]	164.6a
Glyphosate pre plant + hw 30 DAT	1.8	371.3g	279.0c	94.6c
Glyphosate pre plant	1.8	544.0d	272.0d	70.2f
Glyphosate "	3.6	553.0d	356.0b	145.9b
Glyphosate "	5.4	519.0e	358.0b	146.0b
Whip at tiller	0.02	366.3g	147.7i	70.0f
Whip at tiller + hw 50 DAT	0.02	377.0g	229.3e	94.3c
Whip at tiller	0.04	748.3a	224.7f	74.4d
Whip "	0.06	732.77b	212.0g	72.2e
Unweeded		641.0c	152.0h	70.3f
Mean		532.37	260.47	100.25
SE		3.51	0.71	0.15
CV%		1.14	0.47	0.26

[1] Values in the same column followed by the same letter(s) are non significantly different by DMRT.

4.3.3.5 Percentage effective tillers

The percentage effective tillers were significantly ($P \leq 0.05$) affected by weed control treatments (Appendix XII). The highest percentage effective tillers of 79.4 was recorded in plots hand weeded twice and this differed significantly from all the other plots. The significantly lowest value was 23.7% recorded in the non weeded treatment (Fig.6).

4.3.3.6 Percentage ripened grains

The percentage ripened grains was significantly ($P \leq 0.05$) affected by weed control measures applied (Appendix XII). Hand weeded plots recorded a significantly higher mean percentage of 60.67 while plots sprayed with 20 g a.i ha^{-1} whip super recorded the lowest percentage of 36.4 (Fig.6).

4.3.3.7 Number of grains per panicle

The number of grains per panicle was significantly ($P \leq 0.05$) affected by weed control treatments applied (Appendix XII). The significantly ($P \leq 0.05$) highest mean number of grains per panicle was 81.5 recorded in the plots hand weeded twice. The lowest value was 55.17 grains $panicle^{-1}$ in unweeded check (Fig.7).

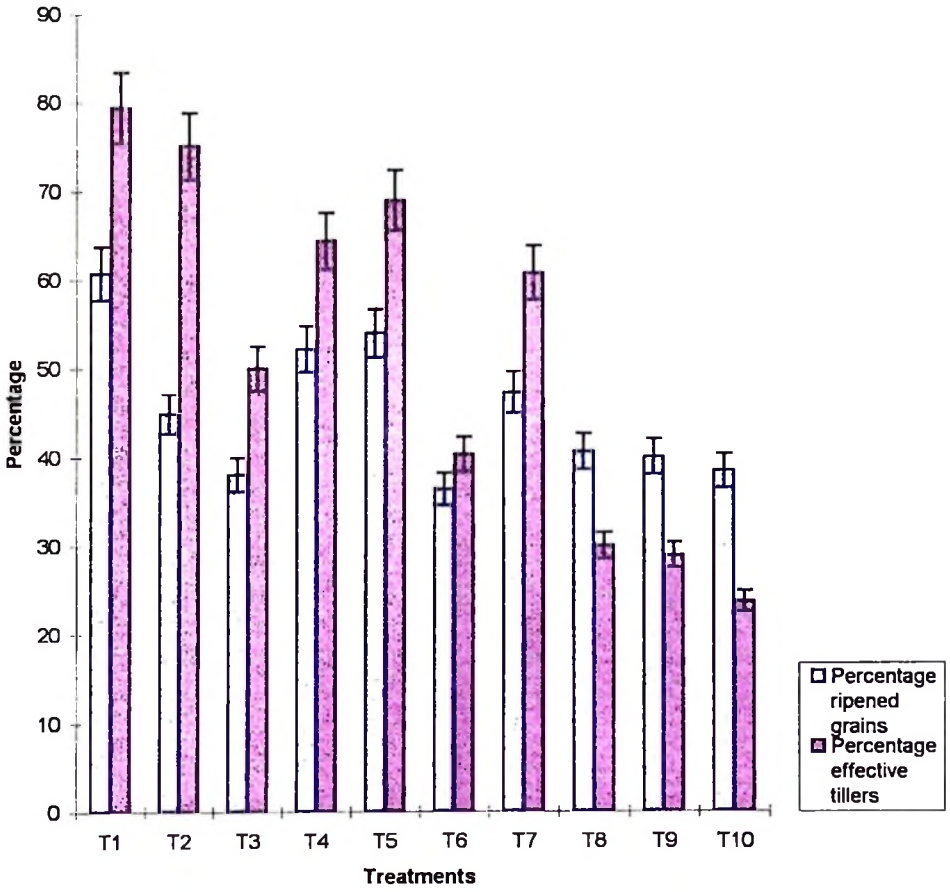


Fig.6. Effects of hand weeding, glyphosate and whip super on percentage ripened grains and percentage effective tillers. Bars denote standard errors.

T1 = two hand weedings 30 and 50 days after transplanting (DAT),
T2 = glyphosate at 1.8 kg a.i ha^{-1} + hand weeding 30 DAT, T3, T4 and
T5 = glyphosate at 1.8, 3.6 and 5.4 kg a.i ha^{-1}, respectively,
T6 = whip super at 0.02 kg a.i ha^{-1},
T7 = whip super at 0.02 kg a.i ha^{-1} + hand weeding 50 DAT, T8 and
T9 = whip super at 0.04 and 0.06 kg a.i ha^{-1},
T10 = unweeded check.

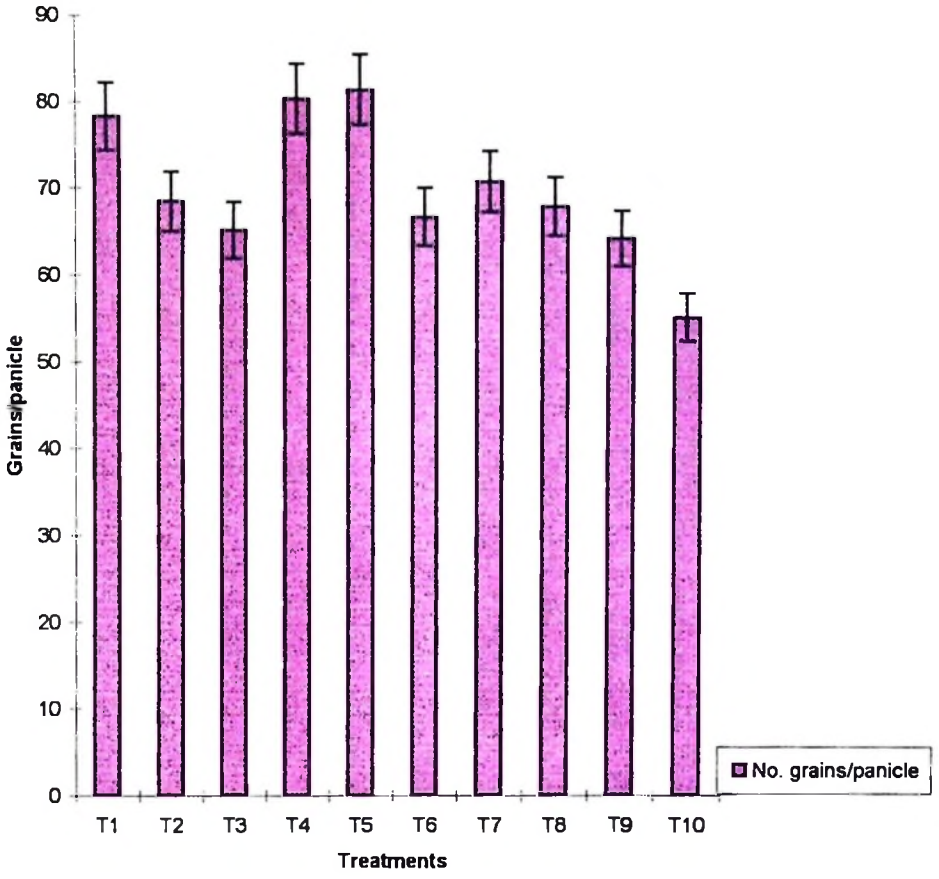


Fig.7 Effects of hand weeding, glyphosate and whip super on the number of grains per panicle. Bars denote standard errors.

T1 = Two hand weedings 30 and 50 days after transplanting (DAT),
T2 = glyphosate at 1.8 kg a.i ha^{-1} + hand weeding 30 DAT, T3, T4 and
T5 = glyphosate at 1.8, 3.6 and 5.4 kg a.i ha^{-1}, respectively,
T6 = whip super at 0.02 kg a.i ha^{-1},
T7 = whip super at 0.02 kg a.i ha^{-1} + hand weeding 50 DAT, T8 and
T9 = whip super at 0.04 and 0.06 kg a.i ha^{-1},
T10 = unweeded check.

4.3.3.8 Thousand grain weight

The 1000 thousand grain weight was significantly ($P \leq 0.05$) affected by the weed control practices (Appendix XII). The highest and lowest values which differed significantly were 23.9 and 23.1 g recorded for glyphosate at 5.4 kg a.i ha^{-1} and in the unweeded plots, respectively. The highest recorded 1000 grain weight was similar to that in glyphosate at 3.6 kg a.i ha^{-1} and two hand weedings ones. The minimum values on the other hand, were not significantly different from those in whip super at 20 and 40 g a.i ha^{-1}, whip super 20 g a.i ha^{-1} followed by hand weeding, glyphosate at 1.8 kg a.i ha^{-1}, glyphosate at 1.8 kg a.i ha^{-1} followed by hand weeding plots (Fig.8).

4.3.3.9 Grain yield

The differences in grain yield ha^{-1} between treatments were significant ($P \leq 0.05$) (Appendix XII). The highest grain yield was 1648.4 kg ha^{-1} recorded in plots hand weeded twice, followed by the plots sprayed with glyphosate at 5.4 kg a.i ha^{-1} which recorded 1460.9 kg ha^{-1}. The lowest grain yield was 700.8 kg ha^{-1} in plots treated with whip super at the rate of 20 g a.i ha^{-1} which was similar ($P \leq 0.05$) to glyphosate at 1.8 kg a.i ha^{-1} and the unweeded plots (Fig.9).

4.3.3.10 Correlation coefficients

Grain yield was significantly ($P \leq 0.05$) and positively correlated to percentage effective tillers, number of grains per panicle, percentage ripened grains, number of panicles, 1000 grain weight plus plant height at and at maturity (Table 20). The number of tillers, wild rice shoot fresh and dry biomass after treatments had a negative correlation to grain yield. Significant negative correlations coefficients (-0.550 and -0.438) were obtained between grain yield, wild rice and other weeds' counts.

4.3.3.11 Herbicide phytotoxicity

Herbicide phytotoxicity symptoms were observed on crop plants in plots treated with whip super. The symptoms included stunting of rice plants, death of some leaves and partial leaf scorching (Plates no. 3 & 4). The number of dead, and scorched leaves were counted from a sample of 10 plants $plot^{-1}$. These symptoms were most severe in plots treated with whip super at 60 g a.i ha^{-1} where up to 14.5% of the leaves were dead. The symptoms were less pronounced in plots of whip super at the rate of 20 g a.i ha^{-1}. Some of the plants recovered about a month after treatment, but other after-effects such as non uniform heading and delayed maturity were observed in these treatments.

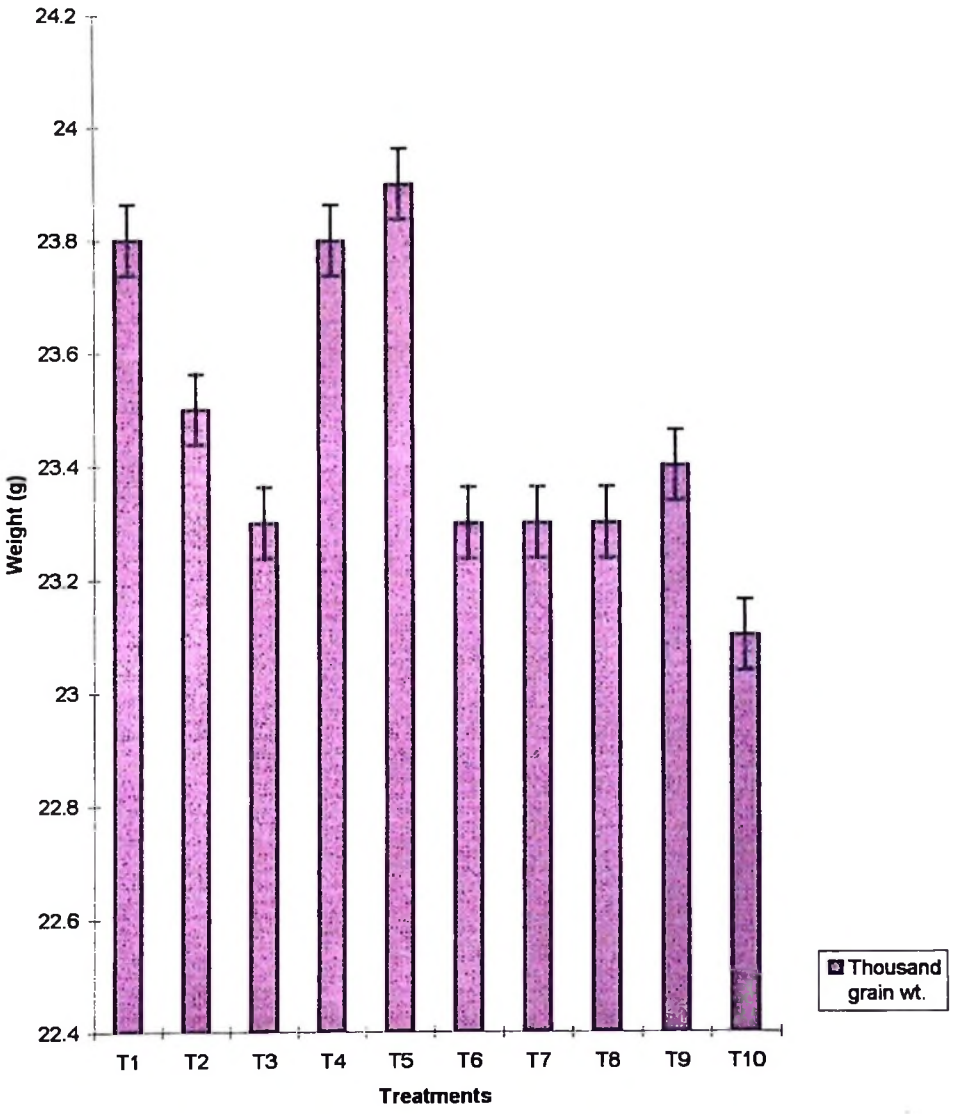


Fig.8. One thousand grain weight (g). Bars denote standard errors.

T1 = Two hand weedings 30 and 50 days after transplanting (DAT),
T2 = glyphosate at 1.8 kg a.i ha^{-1} + hand weeding 30 DAT, T3, T4 and
T5 = glyphosate at 1.8, 3.6 and 5.4 kg a.i ha^{-1}, respectively,
T6 = whip super at 0.02 kg a.i ha^{-1},
T7 = whip super at 0.02 kg a.i ha^{-1} + hand weeding 50 DAT, T8 and
T9 = whip super at 0.04 and 0.06 kg a.i ha^{-1},
T10 = unweeded check.

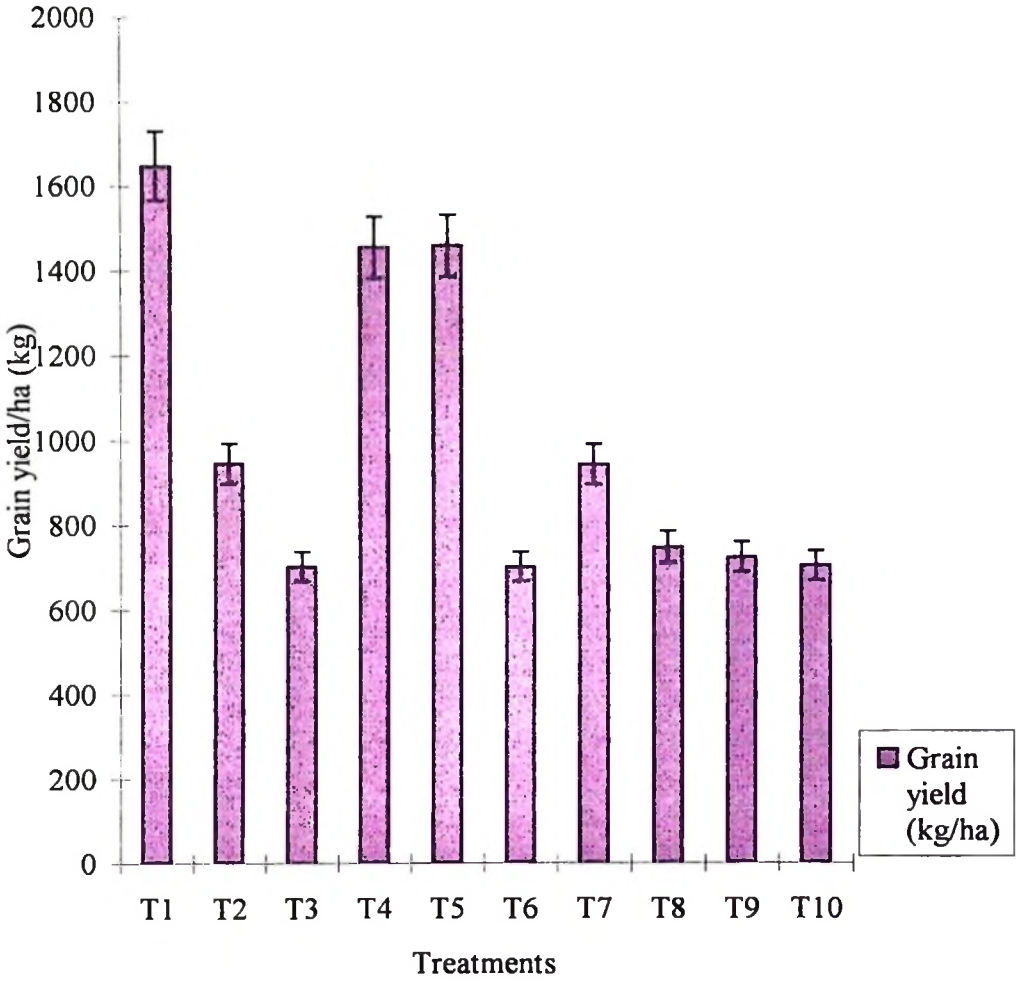


Fig.9.Effects of hand weeding, glyphosate and whip super on grain yield. Bars denote standard errors.

T1 = Two hand weedings 30 and 50 days after transplanting (DAT),
T2 = glyphosate at 1.8 kg a.i ha^{-1} + hand weeding 30 DAT, T3,
T4 and T5 = glyphosate at 1.8, 3.6, and 5.4 kg a.i ha^{-1}respectively,
T6 = whip super at 0.02 kg a.i ha^{-1},
T7 = whip super at 0.02 kg a.i ha^{-1} + hand weeding 50 DAT,
T8 and T9 = whip super at 0.04 and 0.06 kg a.i ha^{-1},
T10 = unweeded check.

Table 20. Experiment 2. Partial correlation coefficients of plant growth parameters, yield and yield components.

Parameter	1	2	3	4	5	6	7
1. Grain yield per hectare	1	0.784*	0.883*	0.973*	0.895*	0.651*	0.874*
2. Percentage effective tillers		1	0.772*	0.804*	0.816*	0.739*	0.745*
3. Grains per panicle			1	0.845*	0.865*	0.565*	0.865*
4. Percentage ripened grains				1	0.875*	0.590*	0.818*
5. Panicles per square metre					1	0.645*	0.871*
6. Height at maturity						1	0.658*
7. Thousand grain wt.							1

* = significant

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4. Percentage ripened grains				1	0.875*	0.590*	0.818*
5. Panicles per square metre					1	0.645*	0.871*
6. Height at maturity						1	0.658*
7. Thousand grain wt.							1

* = significant

Plate No. 3. Experiment 2 (T10) rice growing relative more luxuriously in plots untreated with herbicides than in whip super treated plots below.

Plate No. 4. Rice plants in plots treated with whip super at the rate of 40 g.a.i ha^{-1} (T8). Phytotoxic effects of stunted and dead plants are shown. Compare with Plate No. 3 above.

Table 21. Costs that vary per hectare

Treatment	Rate (kg ha^{-1})	Cost ha^{-1} (T shs.)		
		Herbicide	Herbicide application	Hand weeding
Two hand weedings 30 & 50 DAT				50 000
Glyphosate pre plant + hw 30 DAT	1.8	50 000	5 000	25 000
Glyphosate pre plant	1.8	50 000	5 000	-
Glyphosate "	3.6	100 000	5 000	-
Glyphosate "	5.4	150 000	5 000	-
Whip super at tiller	0.02	17 000	5 000	-
Whip super at tiller + hw 50 DAT	0.02	17 000	5 000	25 000
Whip super at tiller	0.04	34 000	5 000	-
Whip super "	0.06	51 000	5 000	
Unweeded	-	-	-	-

Tshs. 673.26 = 1 US $

hw = hand weeding, DAT = days after transplanting, tiller = tillering stage.

Table 22. Total costs that vary, total revenue, net benefits and benefit cost ratio per hectare

Treatment	Rate (kg ha^{-1})	Total cost (shs)	Total revenue (shs)	Net benefit (shs)	Benefit cost ratio
Two hw 30 & 50 DAT		50 000.00	357 994.75	307859.27a[1]	7.16a[1]
Glyph. pre plant + hw 30 DAT	1.8	80 000.00	206 352.40	126203.17g	2.58g
Glyphosate preplant	1.8	55 000.00	154 011.35	98766.58j	2.80f
Glyphosate "	3.6	105 000.00	316 336.50	211452.45b	3.01e
Whip at tiller	5.4	155 000.00	317 520.50	162470.58c	2.05h
Whip at tiller + hw 50 DAT	0.02	22 000.00	153 580.35	131760.21f	6.98b
Whip at tiller	0.02	47 000.00	206 073.15	159008.32d	4.38c
Whip "	0.04	39 000.00	163 705.30	124639.07h	4.20d
Whip "	0.06	56 000.00	158 383.95	102027.83i	2.82f
Unweeded			154 657.75	154168.91e	
SE				307.7	
CV (%)				96.19	

Tshs. 673.26 = 1 US$

hw = hand weeding, glyph. = glyphosate, whip = whip super, DAT = days after transplanting, tiller = tillering stage.

[1] values in the same column followed by the same letter are not significantly ($P \leq 0.05$) different by DMRT.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Experiment 1: The effect of ploughing depth and seeding rate on wild rice control

5.1.1 Wild rice control

Ploughing is a useful cultivation method with various functions, one of which is weed control. Through ploughing, some weeds are turned over and consequently they die, some parts become severed from the roots or rhizomes occurring below the ground level, while in others e.g. rhizomatous wild rices, rhizomes or roots are brought to the soil surface where they become exposed to a dry atmosphere and desiccate (IITA, 1976; ODNRI, 1976; Roberts, 1982; Radosevich *et al.*, 1997).

The objective of ploughing during the dry season was to expose the extensive root system of the wild rices and other weeds so that the sun desiccates them. Wild rice rhizome and shoot biomass per hectare assessment before treatments and after imposing ploughing depths and seeding rates was used to determine reduction of wild rices. Data for wild rice before treatments involved only the rhizomes since it was collected during the dry season and hence there were no shoots. The results obtained from varying ploughing depths and seeding rates showed that both treatments had significant effects on wild rice control. These effects had an ultimate influence on paddy grain yield. Table 5 shows that the lowest rhizome dry biomass were recorded at the 15 cm ploughing depth in combination with 170 kg ha^{-1} seeding rate. This lowest value, was similar to those recorded at 25 cm x 110, 130, 170 and 20 cm x 150 kg ha^{-1} seeding rates combinations. These results are similar

to those reported by Kolli and Diarra (1983) that in Mali, a 15 cm ploughing depth on a sandy soil was effective in controlling wild rices.

The objective of increasing the seeding rates of paddy was to increase crop plant density and thereby enhance the competitive ability of rice plants over that of weeds. In any crop - weed ecosystem there is competition among the crop plants themselves, among the weed plants, as well as between the crop and the weeds. In this experiment, the low seeding rates of 110 and 130 kg ha^{-1} recorded the highest rhizome fresh and dry biomass. Better wild rice control was observed at 150 and 170 kg ha^{-1} seeding rates. Results of this study demonstrate that high crop plant densities lead to better competitive ability of the crop for space light and nutrients than the weeds. These results support reports by Muzik, (1970); Hill, (1977); Roberts, (1982); and Hurle, (1997). Ploughing depth and seeding rate combinations had no significant effects on wild rice shoot biomass implying that not all the rhizomes were able to sprout and emerge, probably due to the high seeding rates used which gave the crop plants a competitive advantage over space above the ground and suppressed the wild rice shoot emergence. Similar reductions have been reported by Moody (1977) cited by Akobundu, (1987) who obtained significant reductions in weed densities at the highest seeding rate of 200 kg ha^{-1} compared to the lowest seeding rate of 80 kg ha^{-1} in lowland rice. Similar reductions in weed weights at higher crop plant densities, were reported by Kim and Moody (1980) when rice was transplanted at a closer spacing of 10 x 10 cm compared to 20 x 20 cm; Bhattacharjee (1978), as seeding rates of direct sown rice were increased from 40 to 100 kg ha^{-1}, and by Ahmed and Hoque (1981) at IRRI with closer row spacing. In this study, the higher seeding rates of 150 and 170 kg ha^{-1} had similarly controlled wild rices as evidenced by the reductions in wild rice fresh and dry rhizome biomass. Interactions of ploughing depth and seeding rate had significant effects on the rhizome fresh and dry weights. Table 4 & 5 indicate that ploughing

depth (cm) x seeding rate (kg ha^{-1}) combinations of 10 x 130 and 15 x 170 recorded the lowest rhizome fresh and dry weights of 19.1 & 17.0 and 6.1 & 4.9 g m^{-2}, respectively. However, the lack of significant differences in fresh and dry weights of rhizomes over a wide range of ploughing depths, implies that off season ploughing *per se* is a useful tool for rhizomatous wild rice control. Ploughing as a cultivation method has the advantage of exposing the underground vegetative weed parts to the dry surface for desiccation while the other weed parts which survive are suppressed from emerging above the ground by the higher seeding rates of the crop. This emphasizes the need for combining the two treatments for better control of the rhizomatous weeds.

5.1.2 Rice yield and yield components

The highest number of panicles (773.3 m^{-2}) was obtained at the 15 cm ploughing depth x 170 kg ha^{-1} seeding rate interactions. In this experiment the lowest fresh and dry rhizome biomass were also recorded for the same treatment combinations. The results conform with earlier findings by Chisaka (1977), Kusanagi (1981), Akobundu (1987), and Perera *et al.* (1992) who similarly recorded reduced number of tillers due to weed competition and further noted that number of panicles per unit area is one of the yield components severely reduced by weeds. Dense weed growth inhibits root growth and confers reduced ability to obtain resources from the soil leading to a decline in growth of the crop plants. Competition for nutrients between rice plants and weeds at the tillering stage affects the number of tillers which eventually affects the number of panicles per unit area and hence the grain yield.

Results summarized in Table 12 show that the number of grains or spikelets per panicle was not significantly affected by ploughing depths and seeding rates

although it was highest (86.70) at 20 cm ploughing depth and 170 kg ha^{-1} seeding rate combinations. The number of spikelets per panicle were found to have a non significant positive correlation with the grain yield per hectare. Non significant negative correlations observed between the percentage ripened grains and both fresh and dry rhizome biomasses after treatments show that better wild rice control had no significant effect of increasing the number of filled spikelets. The number of spikelets per panicle is determined from about 30 days before heading to about 5 days before heading. Degeneration of spikelets after the differentiation stage determines the number of spikelets per panicle which is not always positively correlated to grain yield (Matsushima, 1980).

Values for percentage ripened grains were highest at ploughing depth of 15 cm x seeding rate of 170 kg ha^{-1} combinations. Similar percentage ripened grains were recorded at 10 x 130, 20 x 150, 25 x 110 and 25 x 170 (cm ploughing depth x kg ha^{-1} seeding rate) (Table 11). The proportion of grains that eventually ripen is determined from the young panicle initiation stage to full heading stage (Matsushima, 1980). Consequently unfavourable conditions on rice plants during this period, such as competition for nutrients, space or limited availability of moisture have adverse effects on grain ripening. In this experiment there was no moisture deficiency during the entire growing period of the crop, therefore the differences in percentage ripened grains may be attributed to competition for space, nutrients and shading effect of the weeds on rice plants. Wild rice plants were taller than the semi-dwarf variety IR 54 used in this study (Plate no.3). Consequently the wild rice canopy shaded rice plants and reduced the amount and quality of light reaching the rice plants underneath. It has been reported that shading of crop plants can result in reduced dry matter production due to impaired photosynthesis and distribution of photosynthates thereby affecting grain filling and hence the low percentage ripened grains (Matsuo and Hoshikawa, 1993). Since no significant

differences in shoot fresh and dry biomass were recorded among the ploughing depth and seeding rate combinations, the shading effect was presumably common for all plots, this factor therefore cannot be the sole cause of the observed differences in percentage ripened grains in the experiment. The other causes being competition between rice and wild rices for nutrients and space. Significant negative correlations were obtained between percentage ripened grains and the respective rhizome fresh and dry biomass. The correlations show that wild rices reduced the percentage ripened grains in the poorly yielding plots of 25 cm x 130 kg ha^{-1} ploughing depth and seeding rate combinations by about 40% due to the weeds' better competitive ability for nutrients. With extensive wild rice rhizome system the weeds are able to extract nutrients over a wider area thereby depriving the crop plants of the nutrients. With good availability of nutrients to the crop, more grains are filled thus incresing the percentage ripened grains. The higher the percentage filled grains ultimately lead to a higher grain yields.

Values for 1000 grain weight were similar ($P \leq 0.05$) over ploughing depths (cm) x seeding rates (kg ha^{-1}) combinations of 10 x 130, 10 x 150, 15 x 150, 15 x 170, 20 x 110, 20 x 150, and 25 x 170 respectively. A high 1000 grain weight which implies large seed size can be obtained when crop plants are not stressed by limited nutrient availability from panicle initiation stage to near heading stages i.e the period when the hull size is determined (Matsushima, 1980). At heading the endosperm starts to develop and therefore the rice plants must reach this stage in good health and vigour. A good nitrogen supply at heading plus good pest control at this stage are very useful to achieve good grain filling and thence a good 1000 grain weight. Other determinants of the 1000 grain weight include sunshine, its efficient utilization by the crop plants, and the respiration rate and translocation of the assimilates. Although wild rices were observed to grow taller than the crop, no significant differences in shoot biomass was recorded for all ploughing depth and

seeding rate combinations. The higher seeding rates of 150 and 170 kg ha^{-1} over the range of ploughing depths recorded the lowest fresh and dry rhizome biomass (32.4, 35.2 & 10.1, 10.3 g m^{-2}, respectively) and highest 1000 grain weight. It is therefore implied that weeds which survived desiccation after ploughing affected nutrient availability to the crop plants through the extensive rhizome system recorded as fresh and dry biomass, thereby leading to reduction in grain size (Plate no.2).

Figure 5 shows that paddy grain yield was significantly highest ($P \leq 0.05$) at 15 cm x 170 kg ha^{-1} ploughing depth and seeding rate combinations. Since it is the same treatment combinations which recorded the lowest rhizome fresh and dry biomass of 17.0 and 4.9 g ha^{-1} respectively, this high yield may be attributed to better wild rice control. In this study the higher grain yields were associated to yield components such as the number of spikelets per panicle, percentage ripened grains, the number of panicles per unit area and the 1000 grain weight as supported by the significantly positive correlations obtained. Correlation coefficients of grain yield per hectare with percentage ripened grains, number of spikelets per panicle, panicles per square metre and 1000 grain weight were 0.824, 0.041, 0.842 and 0.798, respectively. The trend of these results concur with those obtained by other workers (Bhattacharjee, 1978, Kim and Moody 1980; Ahmed and Hoque 1981, De Datta, 1986, and Moody 1977 cited by Akobundu, 1987), where lower weed weights due to lower weed densities resulted in higher grain yields.

5.2 Experiment 2. Comparative performance of hand weeding, glyphosate and whip super for the control of wild rice

5.2.1 Weed control

. The results obtained in this study, are similar to those reported by De Datta and Hoque (1982) in Mali whereby a glyphosate application at the rate of 5 kg a.i ha^{-1} produced a 99% reduction in *O. longistaminata*. Deuse (1982) reported of effective perennial wild rice control at a higher glyphosate rate of 6 kg a.i ha^{-1}. Gill (1981), in contrast found that a lower rate of glyphosate 2 kg a.i ha^{-1} was as effective as two hand weedings in controlling wild rices. Diarra (1981), also, recorded effective perennial wild rice control by glyphosate at 2 kg a.i ha^{-1} in combination with one mowing under deep water culture. Although weed control practices applied reduced weed densities, the weed counts per square metre recorded at heading of the crop were high (84, 72.6, and 42.7 weeds m^{-2}) in plots hand weeded twice and in plots treated with glyphosate at rates of 3.6 and 5.4 kg a.i ha^{-1}, respectively. This shows that these weeds had a significant effect of reducing rice yields in this experiment. Since the three weed control practices i.e two hand weedings, glyphosate at the rates of 3.6 and 5.4 kg a.i provided similar weed control effects, choice of practice will be determined by availability of labour and the relative economic benefits of the methods.

5.2.2 Rice yield and yield components

Paddy grain yields in this experiment were generally lower than the average of 5 tons ha^{-1} for IR 54 variety at KRIP. Significant improvements in paddy yield were obtained as a result of hand weeding, glyphosate and whip super treatments implying that weeds affected grain yields. Besides the effects of weeds, the generally low grain yields in the whole experiment may also be attributed to unfavourable weather conditions encountered due to late planting. The continued *El Nino* rains delayed applications of the glyphosate treatments and as a result planting of the experiment had to be delayed from January to late in March. This

season's maximum temperatures were higher than the past years by up to 3°C in May while the minimum temperatures decreased to 8.8°C in July much lower than the five-year monthly mean temperature. As a result the crop plants were adversely affected by the low temperatures from vegetative to reproductive stages. Rice plants respond differently to varying temperatures at different growth stages depending on the variety. Reproductive stages in the life cycle of the rice plant, which are very sensitive to low temperatures include panicle initiation, booting and anthesis. The panicle being the most sensitive part.

The number of tillers per plant and the number of panicles per plant which determine the percentage effective tillers were significantly affected by the weed control practices in this trial. Table 18 shows that plots hand weeded twice recorded the highest respective number of tillers and panicles per plant of 16.4 and 13.0. Since plots hand weeded twice recorded the lowest density of other weeds and a significant reduction (73%) of wild rices, it is implied that both wild rices and the other weeds had significant negative effects on production of tillers and panicles by the crop. The relatively low number of panicles recorded in unweeded plots and those treated with glyphosate at 1.8 kg a.i and whip super at 0.02 kg a.i ha^{-1} which had inadequate weed control can be attributed to competition between the crop and weeds for nutrients and space. Williams *et al.* (1980) and De Datta (1981), indicate that the optimum temperature range for vegetative growth and tillering of tropical varieties like IR 54 is 25 - 31°C. Minimum temperatures in March and April when the crop was in vegetative stages were as low as 18.8 and 19.5°C. It is therefore anticipated that these low temperatures adversely affected the number of tillers and leaf elongation of the crop. This is evidenced by general stunting of rice plants in all plots, the tallest plants at maturity being only 61.4 cm compared to maximum of 80 cm which is characteristic of the variety (IR 54) used.

The number of grains per panicle was significantly highest (81.5) in plots treated with glyphosate at the rate of 5.4 kg a.i ha^{-1}. The number of grains or spikelets per panicle is one of the yield components most sensitive to weed damage. Dense weed populations, especially of rhizomatous types, inhibit root growth of crop plants and therefore weeds are able to extract nutrients more easily than the crop. The wild rices and other weed densities were significantly high even after application of the weed control practices. Better wild rice control recorded in the plots of glyphosate treatment at the rate of 5.4 and 3.6 kg a.i ha^{-1} led to a higher number of grains per panicle by 47.6% and 45.8% followed by plots hand weeded twice where a 41.8% increase was recorded compared to the unweeded check. The negative correlations obtained with rhizome, shoot, fresh and dry biomass as a result of hand weeding and the herbicide treatments demonstrate that competition of wild rices and the crop below and above ground had significant negative effects on the number of grains per panicle. In this case it is implied that both wild rices and other weeds significantly affected the number of grains per panicle. Kusanagi (1981) similarly reported that weeds reduce panicle weight since they compete better than rice for nutrients and light.

According to Matsushima (1980) percentage ripened grains below 75% is regarded as being unfavourably low. In this experiment the highest recorded percentage ripened grains was only 60.7 in plots hand weeded twice and was lowest (38.4) in the unweeded check. Differences in percentage ripened grains were recorded for the different weed control practices applied in this trial. Better control of wild rices and other weeds (72 and 73%, respectively) in plots hand weeded twice led to a higher percentage ripened grain by 22.3% compared to the non weeded plots.

Rhizomatous wild rices and even the other weeds like southern cutgrass, barnyard

grass, observed in the experimental area are better competitors than rice plants because of their extensive root systems. Competition affects the uptake of nutrients, reduces panicle weight and increases the number of unfilled grains. Reduction of number of unfilled grains result to low percentage ripened grains and hence decreases in grain yields. The differences in percentage ripened grains recorded can therefore be partly associated to weed competition since plots hand weeded twice and glyphosate treated ones at 5.4 and 3.6 kg a.i ha^{-1} rates which had lower weed densities recorded higher values. An additional factor with influence on grain ripening is temperature. Critical low temperatures for inducing sterility for varieties like IR 54 which are cold sensitive is 17 - 19°C. Translocation of photosynthates is also disturbed at temperatures less than 20°C (Matsushima, 1980). High grain sterility increases the percentage of unfilled grains which eventually reduces the percentage ripened grains. The crop in this experiment was subjected to unfavourably low temperature. Symptoms of low temperature effects observed included delayed heading, irregular maturity of the crop and abnormal grains which led to low percentage ripened grains in all plots.

The 1000 grain weight which has a direct relationship with seed or kennel size was generally low in this trial. Significant differences in grain size were recorded among treatments. The largest grain size was recorded in the glyphosate treatment at 5.4 kg a.i ha^{-1}, followed by plots hand weeded twice and glyphosate at 3.6 kg a.i ha^{-1} treatments. These three weed control practices recorded similar grain size. The lowest grain size was recorded in the unweeded plots which was similar to that in glyphosate at 1.8 kg a.i ha^{-1}, whip super 20 & 40 g a.i ha^{-1}, and whip super 20 g a.i.ha^{-1} followed by one hand weeding ones. Grain size according to Matsushima (1980) is determined by the hull size and the development of the caryopsis. The two factors are determined from around 28 days before heading, to about 30 days after heading time. Favourable conditions during this period lead to larger grains.

In this trial plots which recorded relatively higher wild rice and other weed densities also recorded the lowest 1000 grain weight. The reduction in grain size can be attributed to competition conferred by weeds on the crop and the influence of weather. Low fertilization, low spikelet weights and low flower opening are factors which might have reduced the 1000 grain weight because of the cool temperatures in June and July (minimum 9.5, 8.8 °C, respectively) when the crop was in the booting, heading and anthesis stages.

Two hand weedings recorded the highest yield of 1648 kg ha^{-1}. This was followed by 1460.9, 1456.1, and 943.4 kg ha^{-1} in glyphosate sprayed at the rates of 5.4, 3.6 kg a.i ha^{-1}, and 1.8 kg a.i ha^{-1} glyphosate followed by one hand weeding treatments, respectively. Hand weeding recorded the highest yields presumably because it was more effective (72%) in reducing density of other weeds, and also had 73% reduction in wild rice counts per square metre. Glyphosate treatments at 5.4 and 3.6 kg a.i ha^{-1} rates on the other hand, had an advantage of better (91% and 83%, respectively) reduction in wild density. Hand weeding which recorded a 72 and 73% decrease in other weeds and wild rice densities compared to the unweeded check, recorded a 134.6% increase in grain yield. The glyphosate treatment at the rate of 5.4 kg a.i ha^{-1} recorded a 107.9% yield increase relative to the unweeded plots. Whip super treatments recorded significantly low grain yields due to its being relatively ineffective in reducing density of wild rices (the dominant weeds). An additional factor was the phytotoxic effects observed on the rice plants which enhanced the negative weather effects. Rice plants had already been affected by the cool temperatures, whip super killed some of the leaves which later recovered. Based on visual observations, the recovery prolonged the vegetative phase of rice plants thereby delaying heading, flowering and ripening thus predisposing rice plants to the low temperatures later in the season.

Wild rices which are more competitive than rice plants therefore were able to utilize the available nutrients better than the crop resulting to the low grain yield in the unweeded plots. The relatively high grain yields in plots hand weeded twice, and those treated with glyphosate at rates of 5.4 and 3.6 kg a.i ha^{-1} were ascribed to higher percentage effective tillers, grains per panicle, percentage ripened grains, panicles and 1000 grain weight. The generally low grain yields in the whole experiment may also be attributed to unfavourable low minimum temperatures which were as low as 8.8°C thus affecting general plant growth, tiller production, flower opening, fertilization and grain ripening. These results are similar to temperature cycle studies reported by Chatterjee and Maiti (1985) in which highest grain yields attributed to larger number of tillers, panicles and spikelets, lower sterility and higher 100 grain weight were obtained at maximum and minimum temperature ranges of 32 and 20°C than at lower limits.

5.2.3 Implications of results from experiment 1 and 2

The two studies have shown that combinations of off season ploughing and seeding rates plus two hand weedings 30 and 50 DAT, glyphosate at the rates of 3.6 and 5.4 kg a.i ha^{-1} are effective in reducing wild rice rhizome biomass and wild rice densities. Although the lowest fresh and dry rhizome biomass per square metre in experiment 1 were recorded at 15 cm x 170 kg ha^{-1} ploughing depth and seeding rate combinations, comparable results were noted at 25 cm x 110, 150, 170 kg ha^{-1}; 10 x 150 and 20 x 150 interactions. There seems to be no relationship between ploughing depth and dry wild rice rhizome biomass reduction although the highest ploughing depth (25 cm) interactions with all seeding rates except 130 kg ha^{-1} registered similar results. This undefined trend may be attributed to wild rice rhizomes occurrence at variable depths and therefore ploughing having a variable effect of exposing the vegetative parts for desiccation. On the other hand, two hand weedings 30 and 50 DAT, glyphosate applied pre-plant when wild rices were in the

tillering stage at rates of 3.6 and 5.4 kg a.i ha^{-1} had similar significant effects in reducing the weed densities.

Ploughing is a key operation during seedbed preparation and therefore emphasis on the timeliness and controlled ploughing depth are essential for better wild rice control. Off season ploughing of rice fields immediately after harvesting i.e in the months of May, June and July may lead to better results in desiccation of not only wild rice rhizomes but also of underground vegetative parts of other weeds such as southern cutgrass, *Carex* spp. and sedges which are also in abundance at KRIP. Use of glyphosate also requires an off season ploughing followed by irrigation to enhance sprouting of the weeds prior to application of the herbicide. These three weed management practices i.e off season ploughing, chemical control and the higher seeding rates can be used in an integrated manner in combination with other preventive measures such as the use of weed free seeds, clean implements and irrigation channels for better control of wild rices and other weeds in general.

5.2.4 Economic analysis

From the economic analysis of the different wild rice control methods, net benefits for two hand weedings were highest and were followed by glyphosate at the rate of 3.6, and 5.4 kg a.i ha^{-1} in that order. The highest benefit cost ratio of 7.6 was obtained for the two hand weedings as well (Table 22). By implication therefore hand weeding is more beneficial in weed control followed by glyphosate treatments at rates of 3.6 and 5.4 kg a.i ha^{-1}. The results of the two experiments are useful to both small and large scale producers. Two hand weedings could be more practical to small scale rice producers than to large scale ones like NAFCO farms where labour demand becomes so high at critical stages that it becomes inadequate. Availability of herbicides to small scale producers is also more limited than to large

scale farmers. It is therefore implied that hand weeding is more useful to small scale producers while large scale farmers can opt for glyphosate application at rates of 3.6 and 5.4 kg a.i ha^{-1}.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

From the results of the two trials the following conclusions were drawn:-

1. Wild rices can reduce rice grain yields significantly as a result of the weeds' ability to reduce the number of panicles per unit area, number of grains per panicle, percentage ripened grains and one thousand grain weight.

2. Ploughing of paddy fields during the dry season followed by high seeding rates is effective in reducing wild rice density. Combinations of 10 cm (ploughing depth) x 130 kg ha^{-1} (seeding rate) or 15 cm x 170 kg ha^{-1} were effective in reducing wild rice densities.

3. Two hand weedings 30 and 50 DAT, glyphosate at the rates of 5.4 and 3.6 kg a.i ha^{-1} applied before planting when wild rices are in the tillering stage were the most effective wild rice management practices.

4. Hand weeding twice i.e. 30 days after transplanting followed by a second weeding 20 days later was the most economical weed management practice followed by a pre plant application of glyphosate at the rate of 3.6 kg a.i ha^{-1}.

6.2 Recommendations

1. Offseason ploughing of paddy fields immediately after harvesting i.e from May to August should be done to allow longer periods for desiccation of weeds with underground vegetative parts. This should be integrated with higher seeding rates of 170 kg ha^{-1}.

2. Deliberate measures should be undertaken to eradicate wild rices in irrigation channels through excavation while those on bunds should be controlled by herbicides e.g glyphosate at 5.4 kg a.i ha^{-1}. This is an essential step since controlling weeds in the fields alone will be useless as weeds, weed seeds and other weed propagules will still be carried into the fields by irrigation water.

3. The findings reported here were obtained from a single season experiment. It is recommended that the trials be repeated for several more seasons in order to obtain more conclusive data. Sowing pregerminated seed is practical for small scale producers where broadcasting by hand is feasible. Under large scale production, pregerminated seed drilling may lead to cutting of radicles thereby spoiling the seed. As far as possible therefore, the planting methods to be employed in such trials should conform with those being currently employed at KRIP since the abnormal weather conditions forced the changes to wet seeding of pre-germinated seeds and transplanting.

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APPENDICES

Appendix I. Five year mean monthly rainfall (mm), minimum and maximum temperature (°C) (data during cropping season) at KRIP

Month	Rainfall (mm)	Maximum temperature (°C)	Minimum temperature (°C)
January 1998	133.0 (228.5)	28.9 (30.1)	18.0 (19.6)
February 1998	136.3 (120.2)	28.2 (29.4)	18.2 (20.3)
March 1998	91.4 (39.9)	29.2 (29.4)	17.7 (19.5)
April 1998	15.8 (77.4)	28.8 (30.1)	16.5 (18.8)
May 1998	0.3 (23.0)	28.2 (31.2)	13.7 (12.8)
June 1998	0 (0)	26.7 (28.4)	10.4 (9.5)
July 1998	0 (-)	26.2 (32)	9.0 (8.8)
August 1998	0 (-)	26.7 (-)	10.4 (-)
September 1997	0 (-)	28.6 (-)	13.5 (-)
October 1997	0 (-)	28.9 (-)	16.5 (-)
November 1997	16.9 (-)	29.9 (-)	17.5 (-)
December 1997	96.9 (-)	28.3 (-)	18.6 (-)

(-) = data not available

Appendix II. Number of tillers per plant as affected by ploughing depths and seeding rates

Seeding rates (kg ha^{-1})	Ploughing depths (cm)				
	10	15	20	25	Mean
110	4.0	3.9	5.1	5.6	**4.6**
130	5.7	4.7	4.3	3.3	**4.5**
150	4.5	4.5	5.8	4.9	**4.9**
170	3.6	6.3	4.6	5.9	**5.1**
Mean	4.5	4.9	4.9	4.9	

Appendix III. Number of panicles per square metre as affected by ploughing depths and seeding rates

Seeding rates (kg ha^{-1})	**Ploughing depths (cm)**				
	10	**15**	**20**	**25**	**Mean**
110	524.7	548.3	584.7	659.0	**579.2**
130	724.7	575.7	526.7	423.3	**562.6**
150	600.7	592.7	635.3	647.0	**618.9**
170	525.0	773.3	578.7	617.7	**623.7**
Mean	**593.7**	**622.5**	**581.3**	**586.7**	

Appendix IV. Grain yield per hectare as affected by ploughing depths and seeding rates

Seeding rates (kg ha^{-1})	Ploughing depths (cm)				
	10	**15**	**20**	**25**	**Mean**
110	3518.7	3815.0	3963.0	4296.0	**3898.2**
130	4630.0	3889.0	3778.0	2852.0	**3787.2**
150	4037.0	3963.0	4555.7	4074.0	**4157.4**
170	3667.0	4852.0	3852.0	4481.0	**4213.1**
Mean	**3963.2**	**4129.7**	**4037.2**	**3925.8**	

Appendix V. Summary of analysis of variance for plant height, yield and yield components for ploughing depths.

Parameter	Treatment ms	Error ms	Calculated F value
Percentage effective tillers	53.81	56.60	0.95nsd
Panicles plant^{-1}	0.29	0.08	3.60*
Tillers plant^{-1}	0.63	0.46	1.36nsd
Grains panicle^{-1}	294.03	262.01	1.12nsd
Percentage ripened grains	44.73	12.93	3.46*
Panicles m^{-2}	4 031.83	1 630.10	2.47*
Grain yield m^{-2}	616.74	190.45	3.24*
Thousand grain wt.	0.03	0.04	0.81nsd
Grain yield ha^{-1}	97 168.576	4 464.701	21.76*
Plant height (booting)	18.901	305.539	0.07nsd
Plant height (maturity)	18.653	90.897	0.20nsd

Tabulated F value = 2.30 ms = mean square

nsd = no significant difference.

* = significant ($P \leq 0.05$) by DMRT.

Appendix VI. Summary of analysis of variance for plant height, yield and yield components for seeding rates.

Parameter	Treatment ms	Error ms	Calculated F value
Plant height (booting)	4.76	10.71	0.44nsd
Plant height (maturity)	5.83	10.14	0.57nsd
Tillers plant^{-1}	0.85	0.28	3.06*
Panicles plant^{-1}	1.00	0.09	11.45*
Percentage effective tillers	51.72	38.10	1.36nsd
No. of grains panicle^{-1}	117.03	78.75	1.49ns
Percentage ripened grains	144.38	15.46	9.34*
Panicles m^{-2}	10 762.50	2 204.54	4.88*
Grain yield m^{-2}	6 281.41	294.67	21.32*
Thousand grain weight	0.42	0.05	8.44*
Grain yield ha^{-1}	500 141.74	7 887.23	63.41*

Tabulated F value = 2.30 ms = mean square nsd = no significant difference * = significant ($P \leq 0.05$) by DMRT.

Appendix VII. Summary of analysis of variance for plant height, yield and yield components for ploughing depth and seeding rate interactions

Parameter	Treatment ms	Error ms	Calculated F value
Plant height (booting)	22.23	10.71	0.07nsd
Plant height (maturity)	14.56	10.14	1.43nsd
No. of tillers plant^{-1}	3.43	0.28	12.33*
No.of panicles plant^{-1}	1.85	0.09	21.11*
Percentage effective tillers	71.83	38.10	1.881nsd
No. of grains panicle^{-1}	68.54	78.75	0.87nsd
Percentage ripened grains	224.23	15.46	14.50*
No.panicles m^{-2}	29 897.33	2 204.54	13.56*
Grain yield m^{-2}	9 800.61	294.67	33.26*
Thousand grain weight	0.49	0.05	9.96*
Grain yield ha^{-1}	979 407.33	7 887.23	124.17*

Tabulated F value = 2.30

ms = mean square

nsd = no significant difference

* = significant ($P \leq 0.05$) by DMRT

Appendix VIII. Analysis of variance summary of wild rice data after (A) main plot (ploughing depth) treatments.

Parameter	Treatment ms	Error ms	Calculated F value
Shoot fresh wt. (A)	2 090.54	16 271.58	0.13nsd
Shoot dry wt. (A)	59.23	708.01	0.08nsd
Rhizome fresh wt.(A)	24.58	48.86	0.50nsd
Rhizome dry wt.(A)	3.59	5.37	0.67nsd
Adventitious roots fresh wt. (A)	224.29	318.79	0.70nsd
Adventitious roots dry wt. (A)	10.55	17.47	0.60nsd

Tabulated F value = 2.30

ms = mean square

nsd = no significant difference

Appendix IX. Summary of analysis of variance for wild rice data before (B) and after (A) subplot (seeding rates) treatments.

Parameter	Treatment ms	Error ms	Calculated F value
Root fresh wt.(B)	2 617.42	1 941.22	1.35nsd
Root dry wt. (B)	76.74	148.58	0.52nsd
Shoot fresh wt.(A)	6 555.23	4 276.43	1.53nsd
Shoot dry wt.(A)	90.63	183.29	0.49nsd
Rhizome fresh wt.(A)	833.49	79.29	10.51*
Rhizome dry wt.(A)	71.41	8.69	8.21*
Adventitious roots fresh wt. (A)	198.36	62.67	3.16*
Adventitious roots dry wt. (A)	3.20	2.38	1.34nsd

Tabulated F value = 2.30

ms = mean square

ns = no significant difference

* = significant ($P \leq 0.05$) by DMRT.

Appendix X. Analysis of variance summary for wild rice data before (B) and after (A) subplot x main plot (ploughing depths and seeding rates) interaction.

Parameter	Treatment ms	Error ms	Calculated F value
Roots fresh wt. (B)	3 980.04	1 941.22	2.05nsd
Roots dry wt. (B)	229.51	148.58	1.54nsd
Shoot fresh wt.(A)	2 567.27	4 276.43	0.60nsd
Shoot dry wt.(A)	245.21	13.29	1.34nsd
Rhizome fresh wt. (A)	1 026.10	79.29	12.94*
Rhizome dry wt.(A)	86.62	8.69	9.96*
Adventitious root fresh wt. (A)	59.79	62.67	0.95nsd
Adventitious roots dry wt. (A)	2.24	2.38	0.94nsd

* = significant nsd = no significant difference Tabulated F value = 2.30

Appendix XI. Percentage effective tillers and ripened grains, thousand grain weight and grain yield per hectare for experiment 2.

Treatment	Rate (kg ha^{-1})	Percentage Effective tillers	Percentage ripened grains	No. of grains $panicle^{-1}$	Thousand grain wt (g)	Grain yield ha^{-1} (kg)
Two hw 30 & 50 DAT		79.4	60.7	78.3	23.8	1 648.4
Glyphosate + hw 30 DAT	1.8	75.1	44.9	68.5	23.5	944.4
Glyphosate preplant	1.8	50.0	38	65.2	23.3	700.9
Glyphosate "	3.6	64.4	52.2	80.5	23.8	1 456.1
Glyphosate "	5.4	69.0	54.0	81.5	23.9	1 460.9
Whip super-tiller	0.02	40.3	36.4	66.8	23.3	700.8
Whip super + hw 50 DAT	0.02	60.8	47.3	70.9	23.3	943.4
Whip super tiller	0.04	30.0	40.6	68.0	23.3	746.8
Whip super "	0.06	28.9	40.0	64.3	23.4	722.6
Unweeded		23.7	38.4	55.2	23.1	702.7
Mean		52.2	45.3	69.9	23.47	1 002.7
SE		0.29	0.16	0.317	0.0628	0.5338
CV%		0.98	0.63	0.79	0.46	0.09

hw = hand weeding DAT = days after transplanting,

tiller = tillering stage.

Appendix XII. Analysis of variance summary for yield and yield components after treatments in experiment 2.

Parameter	Treatment ms	Error ms	Calculated F value
Grain yield ha^{-1}	418 495.97	0.85	489 515.7*
Percentage effective tillers	1 253.60	0.26	4 841.54*
Tillers $plant^{-1}$	22.58	0.07	331.21*
Panicles $plant^{-1}$	41.19	0.02	2 025.73*
Grains $panicle^{-1}$	201.39	0.30	665.13*
Percentage ripened grains	197.86	0.08	2 418.36*
Tillers m^{-2}	60 235.37	37.08	1 624.57*
Panicles m-2	20 364.83	1.51	13 509.84*
Yield m^{-2}	4 185.25	0.07	61 783.54*
Thousand grain weight	0.23	0.01	19.61*
Plant ht. booting	30.11	0.38	78.10*
Plant ht. maturity	28.94	0.34	72.53*

Tabulated F value = 2.46

ms = mean square

* = significant ($P \leq 0.5$) by DMRT

Appendix XIII. Experiment 2. Analysis of variance summary of wild rice data.

Parameter	Treatment ms	Error ms	Calculated F value
Shoot fresh wt (before)	61.32	105.30	0.58nsd
Shoot dry wt.(before)	12 612.51	10 221.29	1.23nsd
Shoot fresh wt. (after)	911.62	1 662.97	0.55nsd
Shoot dry wt. (after)	61.32	105.30	0.58nsd
Rhizome fresh wt. (after)	372.00	588.47	0.63nsd
Rhizome dry wt. (after)	37.83	71.91	0.53nsd
Rhizome fresh wt (before)	9 404.04	7 031.74	1.34nsd
Rhizome dry wt. (before)	865.94	611.00	1.42nsd
Wild rice counts (after)	13 013.11	2 251.58	5.78*
Other weeds counts (after)	570.31	122.12	4.67*

Tabulated F value = 2.46 nsd = no significant difference.

ms = mean square, * = significant (P ≤ 0.05) by DMRT.