BIOLOGY AND MANAGEMENT OF GOOSE WEED (*Sphenoclea zeylanica* Gaertner) IN WETLAND RICE

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by

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(2018-11-134)

THESIS

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2020

DECLARATION

I, hereby declare that this thesis entitled **“BIOLOGY AND MANAGEMENT OF GOOSE WEED (*Sphenoclea zeylanica* Gaertner) IN WETLAND RICE”** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"BIOLOGY AND MANAGEMENT OF GOOSE WEED (*Sphenoclea zeylanica* Gaertner) IN WETLAND RICE"** is a record of research work done independently by Mr. Mallu Sai Sarath Kumar Reddy (2018-11-134) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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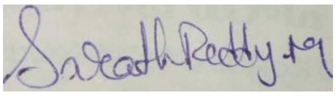

MALLU SAI SARATH KUMAR REDDY

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LIST OF ABBREVIATION

a.i.	-	Active ingredient
ALS	-	Acetolactate synthase
B: C	-	Benefit: Cost ratio
BLW	-	Broad leaved weeds
CD(0.05)	-	Critical difference at 5 per cent level
Cm	-	Centimeter
CRD	-	Completely randomized design
CV	-	Coefficient of variation
DAS	-	Days after sowing
DAT	-	Days after transplanting
DSR	-	Direct seeded rice
ds m^{-1}	-	Deci seimens per meter
EC	-	Electrical conductivity
et al.	-	Co-workers/ Co-authors
etc.	-	Excetra
F	-	Forma
Fb	-	Followed by
Fig	-	Figure
FIRBS	-	Furrow irrigated raised bed system
FYM	-	Farm yard manure
G	-	Grams
g m^{-2}	-	Gram per square meter
g plant $^{-1}$	-	Gram per plant
g mol^{-1}	-	Gram per mole
GR	-	Granules
ha^{-1}	-	Per hectare
$hill^{-1}$	-	Per hill
HI	-	Harvest index

HW	-	Hand weeding
i.e.	-	That is
K	-	Potassium
K_2O	-	Potash
kg ha-^{1}	-	Kilogram per hectare
Kg	-	Kilogram
KAU	-	Kerala Agricultural University
L ha^{-1}	-	Litre per hectare
L	-	Litre
M	-	Meter
m^{-2}	-	Per square meter
Mm	-	Milli meter
Ml	-	Milli litre
mg kg^{-1}	-	Milligram per kilogram
mt ha^{-1}	-	Million tons per hectare
m t	-	Million tons
Min	-	Minimum
Max	-	Maximum
N	-	Nitrogen
No.	-	Number
NS	-	Non-significant
OD	-	Oil dispersion
P	-	Phosphorus
P_2O_5	-	Phosphoric acid
plant $^{-1}$	-	Per plant
pH	-	Potential hydrogen
q ha^{-1}	-	Quintal per hectare
Rs ha^{-1}	-	Rupees per hectare
SEm	-	Standard error mean
SC	-	Soluble concentrate

Sl No.	-	Serial number
SP	-	Soluble powder
Sp.	-	Species
S	-	Significant
$Spike^{-1}$	-	Per spike
$t\ ha^{-1}$	-	Tonnes per hectare
viz.	-	Namely
vs.	-	Versus
VI	-	Vigour index
WCE	-	Weed control efficiency
WDG	-	Water dispersible granules
WI	-	Weed index
WP	-	Wettable powder

LIST OF SYMBOLS

@	-	At the rate of
%	-	Per cent
₹	-	Rupees
±	-	Plus or minus
^{o}C	-	Degree centigrade
^{o}E	-	Degree east
^{o}N	-	Degree north
/	-	Or
>	-	Greater than

INTRODUCTION

1. INTRODUCTION

Rice (*Oryza sativa* (L.) is one of the most important cereal crops of the world and the primary source of food for more than half of the world population (FAO, 2016). More than two-third of the Indian population depends on rice as a major food and it holds a vital role in Indian economy as well as a major asset for food security (Mahajan *et al*., 2017).The total milled rice consumption was about 490 million tonnes in 2018 and projected to reach 550 million tonnes by 2030 and 590 million tonnes by 2040 (Bhandari, 2019). The productivity of paddy in India is low due to disease and pest incidence, low input usage, faulty cropping systems, and a low utility rate of improved technologies by the farmers. As there is no choice to increase the land area under rice cultivation, the only option to meet the required production is by increasing the productivity by optimizing resource utilization.

Rice is cultivated over widely varying environments, such as rainfed upland, rainfed lowlands and irrigated uplands ecosystems. Due to shortage of labour during peak periods of agricultural operations and high labour wages, farmers are shifting from transplanted to direct seeded rice which include wet seeded rice and dry seeded rice. Direct seeding of rice excludes nursery and transplanting that in turn decreases labour requirement and cost of cultivation apart from minimizing crop growth period by 8-10 days (Prasad *et al*., 2016).

The factors affecting the crop yield depends upon the environment in which the crop is grown. Weeds are considered as important pest which reduces the rice yields up to 62.6, 70.6 and 75.8 per cent in transplanted, wet seeded and dry seeded rice, respectively (Singh *et al*., 2005). Competition due to weeds is more severe in direct-sown rice due to age similarity of rice and weed seedlings whereas in transplanted rice aged seedlings are able to compete better (Saha, 2008). Various grasses, sedges and broadleaved weeds compete with crop and cause significant loss to direct seeded rice.

Sphenoclea zeylanica Gaertner commonly known as goose weed or *Pongankala* in Malayalam is a common broadleaved annual weed of wetland rice. It is one among the world’s worst weeds listed by Holm *et al*. (1977). It is widely spread over West Africa, Caribbean area, South east Asia, United States, Pakistan and India (Holm *et al*., 1977). From warm temperate to tropical areas across the world, its main habitats are rice fields, shallow margins of lakes and ponds, ditches, stream banks, wet disturbed soils, sandbars etc. (Carter *et al.,* 2014).The weed directly emerges from seeds in puddled rice fields and has been spreading fast due to its prolific seed production capacity. Its ability to withstand waterlogged conditions as well as drained and moist conditions and ability to germinate under submerged situations makes it a problem weed in rice. Recently, it has emerged as one of the problematic weeds and heavy infestation of this weed has been reported from major rice tracts of Kerala *viz.*, Kuttanad and *Pokkali*. The yield reduction due to *Sphenoclea zeylanica* was 32-50 per cent in wet seeded rice (Moorthy and Manna, 1985). Goose weed incorporated in submerged soil has allelopathic potential to rice and other weeds (Premasthira and Zungsontiporn, 1996).

In wet direct-seeded rice, initial 15-60 days is considered as critical period of crop weed competition during which the field should be weed free to reduce losses. Among different weed management practices hand weeding and herbicide application are possible in wet direct seeded rice. Due to shortage of labour during critical period of crop weed competition and high wage rates, hand weeding is not feasible and the alternate option is the spraying of herbicides.

For controlling diverse flora of weeds that come up during initial and later stages various pre emergence, post emergence and broad-spectrum herbicides are required. Many of the low dose high efficiency herbicides recently available are reported to be more effective than conventional herbicides. Bensulfuron methyl + pretilachlor and pyrazosulfuron ethyl are effective as pre and early post emergence herbicides to kill the initial weed flora. Bispyribac sodium and penoxsulam + cyhalofop-butyl are post emergence herbicides with broad spectrum activity. Metsulfuron methyl + chlorimuron ethyl and ethoxysulfuron are effective in controlling broad leaved weeds and sedges in rice. Testing the efficacy of these herbicides in wet seeded rice with special reference to goose weed is essential for formulating cost effective integrated weed management strategy in wet seeded rice.

In this background, the present study was undertaken with the following objectives

- To study the biology of the weed *Sphenoclea zeylanica* Gaertner in wet seeded rice.
- To develop an effective and economic management strategy using herbicides.
- To study the allelopathic effect of *Sphenoclea zeylanica* Gaertner on rice seeds.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Being the primary source of food, the art of paddy production has been extensively studied by several research workers including weed management and various agro techniques. Goose weed (*Sphenoclea zeylanica* Gaertner), a common annual broad leaved weed (BLW) is becoming a serious weed in direct seeded and transplanted rice fields. This calls for formulating an integrated management strategy after studying its biology, allelopathy and efficacy of herbicides. In the following chapter an effort has been made to review the research works on these aspects as presented.

2.1 BIOLOGY OF GOOSE WEED

Weeds are part of a dynamic ecosystem. Weed biology is the study of the establishment, growth, reproduction and life cycles of weed species and weed societies / vegetation. It is an integrated science with the aim of minimizing the negative effects, as well as using and developing the positive effects of weeds. To manage the weed effectively knowledge about biology is essential. The information about biology *of Sphenoclea zeylanica* Gaertner is discussed as follows.

2.1.1. Classification

Sphenoclea zeylanica Gaertner is a BLW belonging to Sphenocleaceae family included in class dicotyledonae and order campanulales. The taxonomic position of *Sphenoclea* had been challenging for many years. Earlier *Sphenoclea* with its two species was placed under Campanulaceae (Ward, 1978; Godfrey and Wooten, 1981). Rosatti (1986) found many variations between *Sphenoclea* and Campanulaceae in several characteristics and opted for Sphenocleaceae and placed in its own family, Sphenocleaceae.

2.1.2 Origin and Distribution

Sphenoclea zeylanica was reported to be originated in tropical Africa and distributed widely across the world like Africa, Caribbean area, South-East Asia, Pakistan and India (Holm *et al*., 1977). It has multiple names like goose weed in

English, Sfenoclea in Spanish, Phak pot in Thailand, wedge wort etc. Carter *et al.* (2014) reported its distribution across the world in tropical, subtropical and warm temperate regions in Asia, Africa, America, West Indies, and Mexico.

Holm *et al*. (1977) included *S. zeylanica* in the list of world's worst weeds. IRRI (2020b) also included goose weed amongst the dirty dozen weeds and also reported its distribution in south and south east Asia (India, Bangladesh, Malaysia, Thailand, Srilanka and Philippines etc.).

Vidya *et al*. (2004) noticed the presence of *Sphenoclea zeylanica* in Pokkali tracts of Kerala and Raj and Syriac (2016) reported its occurrence in Thiruvananthapuram.

2.1.3 Habit and Habitat

Sphenoclea zeylanica is a stout broad leaved herb which can reach upto a height of 3 feet and was found in moist districts, in swampy places, especially near the coast (Kausik and Subramanyam, 1946). *Sphenoclea zeylanica* is an annual herbaceous weed that can grow in damp grounds and mainly prefers stagnant waters (CABI, 2020).

Sphenoclea zeylanica is a regular BLW in the rice crop globally (Raju and Reddy, 1986). Carter *et al*. (2014) reported growth of *Sphenoclea zeylanica* in rice fields, shallow margins of lakes and ponds, ditches, stream banks, wet disturbed soils, sandbars etc. In lowland plains of eastern India, rainfed rice was severly infested by *Sphenoclea zeylanica* (Malik *et al*., 2014).

2.1.4* Morphology of *Sphenoclea zeylanica

Holm *et al*. (1977) explained Sphenoclea as a annual fleshy erect herb that grows upto a height of 7-150 cm. Carter *et al.* (2014) described stem as erect, hollow with cylindrical shape, often spongy proximally and under submerged condition roots were noticed from the lower nodes. Leaves of *Sphenoclea* are simple with oblong to lanceolate shape and are arranged spirally (IRRI, 2020a).

Inflorescence of *Spenocle*a is a terminal spike, that develops acropetally, ovoid to cylindrical in shape with a length of 0.4-10.3 cm. The flowers are sessile, bisexual and white in colour (Carter *et al.,* 2014). The fruit of *sphenoclea* is a globose capsule with yellowish brown seeds (IRRI, 2020a).

2.1.5 Germination and Dormancy

The main method of propagation is through seeds. Each plant produces numerous seeds and mostly the seeds are germinating from June to December (Carter *et al.*, 2014). *S. zeylanica* seeds are able to germinate even under submerged conditions. Pons (1982) reported that the germination percentage was greater than 25 per cent under submerged condition. Germination was noticed only after 2-3 months of storage that indicates dormancy (Migo *et al.,* 1986) and it germinated only in the presence of light (Mercado *et al.*, 1990). Germination percentage registered was 12 and 14 per cent under green house and laboratory conditions, respectively in the study.

Mercado *et al.* (1990) documented that even after 2 years of storage under favourable conditions, percentage of germination at 17 and 48 DAS was 6 and 34 per cent, respectively which indicates that seeds are viable even after long time.

2.2 DIRECT SEEDED RICE

Among different rice establishment methods followed, manual transplanting is highly accepted and traditional system (Rao and Chauhan, 2015). It requires huge amount of water for growing of nursery and more number of labour for uprooting and transplanting. Thorough puddling and continuous standing water makes field situations adverse for the growth of weeds (Kabdal *et al.,* 2018).

As scarcity of water is an utmost concern in several countries in the world as rivalry exist among agricultural and industrial sectors over excessive water resources and erratic climatic conditions (Hanjar and Quereshi, 2010). Therefore, water shortage endangers the rice production sustainability under irrigated environments (Chauhan *et al.,* 2012). In many parts of Asia at the peak period of transplanting, shortage of rural labour becomes acute (Mahajan *et al.,* 2013). Above conditions led to delay in transplanting, lesser grain yields and prolongs the next planting season (Chauhan *et al.,* 2012).

Dry-seeded rice (DSR) is a potential replacement that can helps to reduce water utilization by nearly 30 per cent excluding the nursery raising process, uprooting of seedling, Puddling, transplanting and saving 10–12 cm of water near the crop base for the initial 15 days after seedling transplanting. Farmers can save around US$100 ha^{-1} in cultivation cost by reducing labour charges at the time of transplanting (Khaliq *et al.*, 2011; Mahajan *et al.*, 2013). Above conditions led to global acceptance of DSR comprising both wet DSR (30 per cent) and dry DSR (40 per cent) among total rice cultivating area of about 30.2 m ha in China (*Luo et al.*,2016).

Under DSR cultivation, exclusion of the habit of retaining 5 cm standing water depth led to germination of weed seedlings earlier or along with crop seedlings and heavy growth of weeds escalated the threat of severe crop-weed competition reporting heavy yield losses (Chauhan and Johnson, 2010a).

The most dangerous weeds seen under DSR condition are *Echinochloa colona, Echinochloa crusgalli, Cyperus iria, Cyperus rotundus* and *Cyperus difformis* (Chauhan and Johnson, 2010b). They may suppress the grain yield of DSR from 57- 76 per cent (Mercado and Talatala, 1977; Maun and Barrett, 1986).

Oerke and Dehne (2004) opined that globally under DSR, nearly 35 per cent losses in rice yield occurred due to severe weed competition. Yield reduction observed under transplanted rice, DSR and upland rice were 30 - 65 per cent, 15 - 35 per cent and 45 - 90 per cent, respectively as stated by DRR (2011). Umkhulzum and Ameena (2019) reported that uncontrolled weed growth in wet seeded rice could cause a grain yield reduction of 49.4 per cent in comparison with the hand weeding treatment.

Efficient, inexpensive, appropriate and timely weed controlling options plays a crucial role in making DSR worthwhile with high acceptance. Such an approach should aid in yield improvement by decreasing cultivation costs along with decreasing the undesirable consequences of weeds on the produce quality (Khaliq *et al.,* 2014).

2.2.1 Critical period of crop weed competition

At early phase of development all the crop plants are almost vulnerable to weed competition, especially during first one-third to one-half of the crop life span (Mercado, 1979). The critical period of weed competition comprises two separate constituents: (i) weed free phase needed for crop species to grow vigorously and able to suppress the upcoming weed crisis and (ii) phase until the simultaneously emerged weeds with the crop plants remain before they start to hamper the crop growth (Ghosheh *et al.,* 1996).

To evade significant decrease in rice yield and efficient exploitation of existing resources for superior rice crop productivity, weed control at the time of critical weed competition is utmost important (Weaver, 1984). It is achieved by eliminating weed plants at the initial stage of the critical period or maintaining weed-free situation in field till the finish of critical period (Woolley *et al.*, 1993).

Moorthy and Saha (2005) opined that the time period of 30-60 DAS in rainfed lowland rice was counted as critical stage for crop weed competition to lower the grain and straw yield losses. Under wet seeded situation initial 15 to 60 DAS and under transplanted condition initial 20-40 DAT were observed as critical periods of crop weed competition (Mukherjee *et al.,* 2008). Cropped area should be kept weed free in transplanted and direct-seeded rice for a period of 30-60 DAT and 40-60 DAS, respectively to take advantage of inputs to obtain better growth rates and yield (Das *et al*., 2012).

Johnson *et al.* (2004) stated that under lowland conditions in wet season 29 - 32 days after sowing (DAS) and 4 - 83 DAS in the dry season were critical intervals for weed management to attain 95 per cent yields of the weed-free plots in the Sahel (West Africa).

To avoid losses occurred due to weeds and to attain utmost grain yield (2.93 t ha^{-1}), weed-free condition for the initial 25-45 DAS is essential in dry direct-seeded rice (Singh *et al.,* 2012). Prolonged weed competition throughout crop season reported 69.71 per cent yield loss in wet seeded rice during *kharif* season and 67.40 per cent during *Rabi* season under direct seeded rice.

2.2.2 Weed flora in wetland rice

Weed flora related with an ecosystem be influenced by environmental characters, crop sown, cultivation practices followed and several biotic and abiotic factors (Yaduraju *et al.,* 2015). In rice ecosystem, rice field is infested by several forms of weeds such as terrestrial, semi-aquatic and aquatic weeds as it is grown under varied environments such as upland and lowland condition. Among the flora, grasses pose serious threat followed by sedges and dicot weeds causing substantial yield reduction across the globe (Ali *et al.,* 2018).

Changes in crop cultivation and establishment techniques lead to shift in weed flora and its size associated with the crop (Johnson and Mortimer, 2005). For example, converting the field from transplanted condition to direct seeded situation could change tillage practices, method of establishment, weed and water management which may lead to development of more competitive grasses and sedges that are difficult-to manage (Malik and Kumar, 2014).Our inability to predict and manage weeds due to weed shift pose serious risk for DSR sustainability.

Change in method of crop establishment from transplanted rice to DSR lead to alteration in the weed flora with *Dactyloctenium aegyptium, Commelina benghalensis, Digitaria ciliaris, Cyperus rotundus, Amaranthus viridis, Digeria arvensis* and *Trianthema portulacastrum* are also seen along with *Echinochloa colona, Echinochloa crusgalli, Leptochloa chinensis, Cyperus difformis, Cyperus iria, Eclipta alba, Sphenoclea zeylanica etc*.(Kaur and Singh, 2015).

Saha and Rao (2010) reported highest relative densities of *Sphenoclea zeylanica* (27.5 per cent) together with *Cyperus difformis* (26.1 per cent), *Marsilea quadrifolia* (23.2 per cent), *Fimbristylis miliacea* (14.5 per cent), *Echinochloa colona* (8.7 per cent) resulting in grasses, sedges and broad leaf weeds density as 8.7, 40.6 and 50.7 per cent, respectively at 30 DAS in wet seeded rice. In lowland plains of Eastern India, rainfed rice was severly infested by *Sphenoclea zeylanica* along with *Paspalum scrobiculatum, Echinochloa crusgalli, Cyperus difformis, C. iria, Fimbristylis miliacea* and *Monochoria vaginalis* (Malik *et al,.* 2014).

Jacob *et al.* (2014) observed that in Kole lands of Kerala under direct seeded rice grassy weeds were seen predominantly accounting 45 per cent of weed population followed by sedges (36 per cent) and BLWs (19 per cent). Raj and Syriac (2016) stated that wet seeded rice is dominated by sedges such as *Schoenoplectus juncoides, Cyperus iria, Cyperus difformis* and *Fimbristylis miliacea* along with grasses like *Ischne miliacea* and BLWs like *Ludwigia perennis*, *Limnocharis flava*, *Sphenoclea zeylanica, Bergia capensis, Commelina diffussa* and *Monochoria vaginalis.*

The mixed weed composition of grasses (48.60 per cent), sedges (30.4per cent) and BLWs (20.9 per cent) reduced grain yield of rice by 40.6 per cent when compared with weed free condition (6.33 t ha^{-1}). Major weed flora included *Echinochloa crusgalli, Digitaria sanguinalis, Echinochloa colonum*, *Leptochloa chinensis, Cyperus iria, Cyperus difformis, Fimbristylis miliacea*, *Ammania baccifera*, *Eclipta prostrata, Ludwigia paraviflora*, *Lippa nodiflora*, *Sphenoclea zeylanica and Marsilea quadrifolium* (Mohapatra, *et al.*, 2017).

Umkhulzum *et al*. (2018) observed a multitude of weeds in wet seeded rice with a clear dominance of sedges such as *S. juncoides, Fimbristylis miliacea, Cyperus difformis, C. iria, C. exaltataus, C. cyperoides;* grasses such as *Ischne miliacea, Digitaria sanguinalis;* BLWs like *Limnocharis flava*, *Lindernia rotundifolia* and *Ludwigia perennis* all throughout the crop life cycle.

IRRI(2020b) recognized 5 grasses *viz*., *Leptochloa chinensis, Echinochloa colona*, *Echinochloa crusgalli, Ischaemum rugosum, Oryza sativa,* 4 *sedges viz., Fimbristylis miliacea*, *Cyperus difformis*, *Cyperus iria*, *Schoenoplectus juncoides*, 3 BLWs *viz., Eclipta prostata*, *Sphenoclea zeylanica*, *Ludwigia hyssipifolia* as problematic in rice fields of Asia.

2.2.3 Yield losses due to weeds

Weeds are the key biotic constraint in rice. Globally, yield decrease due to pests in rice have been estimated to be 40 per cent, among which weeds pose greater threat to yield reduction (32 per cent) (Rao *et al.*,2007).The seriousness of weed competition varies with the competing species, diversity of the weed flora, its intensity, life span and soil fertility status (Hasanuzzaman *et al*., 2009). However, when compared to transplanted rice weeds pose greater threat in DSR due to lack of crop seedling size advantage, simultaneous emergence of crop and weed seeds and absence of standing water at the period of crop emergence (Chauhan and Johnson, 2009;Singh and Singh, 2010).

In direct seeded situation, 50-90 per cent yield losses were noticed in rice while in transplanted environments losses were just 13 per cent due to severe crop- weed competition in DSR (Azmi, 1992). Hazarika *et al.*,(2001) found that weed invasion is less serious in wetland (29 per cent) condition compared to upland condition (71 per cent). In direct seeded situations, yield losses by weeds in dry seeded rice were 96 per cent and wet seeded rice were 61 per cent (Maity and Mukherjee, 2008). Umkhulzum and Ameena (2019) documented the need for maintaining the field weed-free at critical stages of crop growth as uncontrolled weed growth caused a grain yield reduction of 52.2 per cent in wet seeded rice.

Moorthy and Saha (2005) analysed crop weed competition in rainfed lowland rice at 50, 60 and 90 days and reported yield loss of 17.7, 11.8 and 5 per cent, respectively. Yield loss under wet direct seeded paddy due to weed species with density of grasses (8.7 per cent), sedges (40.6 per cent) and broad leaf weeds (50.7 per cent) (*Sphenoclea* was 27.5 per cent) was 49 per cent (Saha and Rao, 2010).

During rainy and winter season, reduction in crop yields were 36.5 and 22.7 per cent while complete crop failure is seen in some cases (Das *et al.,* 2012). Manhas *et al.* (2012) found that unrestricted weed growth caused 33-38 per cent decline in rice yield due to decrease in yield parameters (less number of panicles m^{-2}, grains per panicle, 1000 grain weight). Prolonged weed competition throughout crop season reported 69.71 per cent yield loss in wet seeded rice during *kharif* season and 67.40 per cent *Rabi* season (Raj *et al*., 2013).

Besides yield reduction, weed flora also pose health menaces for humans and animals, reduced quality of farm produce, animal products. They also remove 20-40 kg N, 0.8-15 kg P and 20-40 kg K_2O ha^{-1} compared to weed free plot (Das *et al.,* 2012).

2.3 MANAGEMENT OF GOOSE WEED

2.3.1 Cultural methods of weed control

Continuous waterlogged condition is maintained in rice fields to suppress weed germination and growth. *Sphenoclea* is able to emerge or germinate under submerged conditions and hence there is no effect on *Sphenoclea.* However, delaying the flooding or draining the field have shown adverse effect on the weed growth (Civico and Moody, 1979). Mercado *et al*., 1990 stated that utilizing robust and healthy seedlings along with close spacing will be an efficient way to suppress the incidence of *Sphenoclea* by favouring faster crop growth.

Sphenoclea can be controlled effectively by altering the planting dates of rice. Vongsaroj (1994) reported that puddling done between June to August resulted in higher incidence of *Sphenoclea* when compared to puddling in remaining periods which suggest to avoid puddling in this period. Some farmers in Thailand were growing azolla in the rice fields as it forms a layer on water surface to control *Sphenoclea* (Vongsaroj, 1995).

2.3.2 Hand weeding

2.3.2.1 Effect on weed parameters

Under wet seeded condition manual weeding at 20 and 40 DAS suppressed weed biomass and weed density with 94.4 per cent WCE and yield of 6.46 t ha^{-1} and gave excellent control over *Sphenoclea zeylanica* (27.5 per cent) compared to unweeded control (Saha and Rao,2010 ; Jacob *et al.,* 2014). Kaur and Singh(2015) noticed that lesser weed biomass (117g m^{-2}) was seen in treatment with two HW over sequential application of pendimethalin, butachlor, thiobencarb and oxadiargyl with bispyribac and unweeded control (1077 g m^{-2}) with weed control efficiency of 89.4 per cent in direct seeded rice.

2.3.2.2 Effect on growth and yield parameters

Two hand weeding at 25 and 45 DAT lead to better weed control over herbicidal treatments at all the stages and recorded 19.88 per cent superior grain yield over unweeded plot (Banerjee *et al.,* 2005). Plant height (cm), tillers per hill, effective tillers per hill, dry matter per hill(g), no. of panicles per hill, no. of grains per panicle, grain and straw yield (q ha^{-1}) were superior with two hoeing's or manual weeding twice at 20 and 40 in transplanted rice (Survase *et al.,* 2013). Manual weeding thrice at 30,60,90 days under transplanted condition lead to better growth and yield attributes which ultimately contributed to greater grain yield, straw yield and HI on par with weed free condition (Parvin *et al.,* 2013).

Menon *et al*., (2014) and Sudeshna *et al*., (2014) observed that two manual weeding's at 20 and 40 DAS under wet direct sown rice suppressed weed density and weed biomass with lowest N(0.61 kg ha^{-1}), P(0.11kg ha^{-1}) and K(0.68 kg ha^{-1}) removal by the weeds. Highest N(97.34kg $ha^{-1)}$, P(56.64kg ha^{-1}) and K (85.92kg $ha^{-1)}$ removal by the rice crop was obtained with HW at 20 and 40 days after transplanting with greater control over weeds(Dash *et al*,. 2016).

2.3.2.3 Effect on economic parameters

Hand weeding twice at 20 and 40 DAT gave the best level of weed control, maximum grain yield, straw yield, gross return and net profit with B:C ratio of 0.75 (Bhattacharya *et al.,* 2000 ; Bera *et al.,* 2016). Suryakala *et al.,* (2019) confirmed that HW at 20 and 40 DAT resulted in greater net returns (Rs. 45802 ha^{-1}) and B:C ratio (2.33) over unweeded control (1.71).

2.3.3 Biological control

Ponnappa, (1967) identified a leaf disease of sphenoclea in rice fields of Kerala which is caused by *Cercosporidium helleri*. Mabbayad and Watson (1995) reported that *Alternanthera sp*. when sprayed at a concentration of 10^5-10^6 conidia ml^{-1}@ 50 ml per 0.25 m^{-2} provided an effective control of goose weed by reducing its density and the biomass by 80-99 and 90 per cent, respectively at all growth stages of the weed without any detrimental effect on rice.

2.3.4 Chemical weed management

Even though manual weeding is effective, it was tedious, laborious and uneconomical because of high labour wages due to industrialization and urbanization.

It may not guarantee removal of weeds at bad weather conditions and critical stages of crop-weed competition (Beltran, 2012).

Among different weed control methods, chemical weed management plays an important role in the era of modern agriculture (Singh *et al.,* 2017). Thus, to get effective and timely weed control it has given utmost importance for development and utilization of herbicides (Dnyaneshwar *et al.,* 2018).

Continuous application of same herbicides such as butachlor and anilofos in rice, resulted in shift in weed flora to sedges such as *Scirpus* sp., *Cyperus* sp., *Eleocaris* sp. and *Fimbristylis* sp. and BLW's like *Caesulia auxillaris* (Chauhan *et al*., 2014). Herbicide rotation and herbicide mixtures are two key approaches to suppress the weed floral shift and herbicide resistance in weeds. In recent time's use of herbicide mixtures either ready or tank mix is enhanced as they are able to manage complex weed flora.

2.3.4.1 Bensulfuron methyl + pretilachlor

Bensulfuron-methyl is a sulfonylurea herbicide that effectively kills sedges and BLWs which on mixing with graminicides like butachlor, pretilachlor, mefenacet effectively controls grassy weeds also. A novel herbicide combination of bensulfuron methyl 0.6 per cent+ pretilachlor 6 per cent @ 60+600 g ha^{-1} at 3DAT is suggested for broad spectrum weed control in rice (Mishra, 2019).

According to Sanjay *et al*.,(2013), bensulfuron methyl + pretilachlor @ 0.06+ 0.60 kg a.i. ha^{-1} was effective for controlling weeds in aerobic rice. Bensulfuron methyl + pretilachlor @ 60 + 600 g ha^{-1} and pyrazosulfuron ethyl @ 25 g a.i. ha^{-1} were found to be promising broad spectrum herbicides for early season weed control in semi dry system of rice cultivation(Arya and Ameena, 2016)

2.3.4.1.1 Effect on weed parameters

Tank-mix spraying of bensulfuron-methyl + pretilachlor @ 50+500 g ha^{-1} was found to be highly efficient herbicide for managing *Echinochloa crusgalli*, *Cyperus iria*, *Fimbristylis miliacea*, *Sphenoclea zeylanica*, *Ludwigia parviflora* and *Commelina benghalensis* with 95 per cent WCE (Saha, 2009). Pre-emergent spraying of bensulfuron methyl @ 60g +pretilachlor @ 600 g ha^{-1} at 3 DAS resulted in lesser weed count m^{-2}, lesser weed biomass with superior WCE that is at par with two HW at 20 and 40 DAS (Madhukumar *et al.*, 2013; Teja *et al.*, 2015). Arya and Ameena (2016) stated that pre-emergent application of bensulfuron methyl + pretilachlor at 660 g ha^{-1} followed by either hand weeding at 40 DAS recorded higher weed control efficiency and lower nutrient removal in comparison with hand weeding twice (20 and 40 DAS) in semi dry rice.

Pre-emergence spraying of bensulfuron methyl + pretilachlor at 660 g ha^{-1} along with manual weeding on 35 DAT resulted in weed density of 31.33 m^{-2} and weed biomass of 37.80 kg ha^{-1} lower than manual weeding twice at 20 and 40 DAT (Sureshkumar , 2016). Umkhulzum and Ameena (2019) reported that density of *Schoenoplectus juncoides* was the lowest (0.67 m^{-2}) in bensulfuron methyl +pretilachlor @ 60+ 600 g ha^{-1} treated plots (at 4-7 DAS) with 98.35 per cent decline in weed count in relation to weedy check in wet seeded rice.

2.3.4.1.2 Effect on yield parameters

Spraying of bensulfuron methyl + pretilachlor (6.6 GR) @ 0.06 + 0.60 kg a.i ha^{-1} at 3 DAS along with intercultivation at 40 DAS obtained greater NPK uptake by the crop. It also resulted in more number of productive tillers $hill^{-1}$, spikelets $panicle^{-1}$, lower sterility per cent and test weight due to broad spectrum weed control (Sunil *et al.*, 2011). Arya and Ameena (2016) stated that pre-emergent spraying of bensulfuron methyl + pretilachlor followed by manual weeding at 40 DAS resulted in maximum grain and straw yields of 4817.67 kg $ha^{-1}$and 7969.33 kg ha^{-1}, respectively without any phytotoxic effect on rice.

2.3.4.1.3 Effect on economics

The weed control economics revealed that maximum mean net returns(₹57624 ha^{-1})was registered under pre-emergent spraying of bensulfuron methyl + pretilachlor @ 75+750 g ha^{-1} with higher B:C ratio of 3.48 (Reddy *et al.*, 2012). Application of bensulfuron-methyl + pretilachlor @ 5 DAT registered higher net returns of ₹ 61,729 ha^{-1} with B:C ratio of 1.78 by effective control of BLW's and sedges in transplanted rice (Ramachandra *et al.,* 2014). The best weed management practice for semi dry rice in terms of weed control, yield attributes, yield and economics was the preemergence application of bensulfuron methyl +pretilachlor @ 60 + 600 g ha^{-1}on the day after sowing followed by azimsulfuron @ 30 g ha^{-1} as post emergence application at 25 DAS (Arya and Ameena, 2016).

2.3.4.2 Pyrazosulfuron ethyl

Pyrazosulfuron-ethyl belonging to sulfonylurea's group is one of the promising and commonly used pre-emergence herbicide in rice crop. It can be used as both soil as well as foliar spray (Rajkhowa *et al*., 2006). In DSR spraying of pyrazosulfuron 10 % WP @ 25g ha^{-1} 3-7 DAS successfully controlled sedges, grasses and dicot weeds giving best and promising yield (Upasani and Barla, 2014).

2.3.4.2.1 Effect on weed parameters

Pre-emergent spraying of pyrazosulfuron ethyl 10 % WP @ 20 g ha^{-1} along with cono weeder at 30 DAS resulted in lower weed density and biomass with WCE of 95.9 per cent (Mandal *et al.*, 2013). Pre-emergent spraying of pyrazosulfuron @ 20 g ha^{-1} followed by manual weeding at 45 days reported lesser weed count m^{-2} and weed biomass that are statistically at par with manual weeding at 25 and 45 DAS (Yakadri *et al.,* 2016). Early pre-emergent spray (3 DAT) of pyrazosulfuron ethyl 10 % WP @ 20 g ha^{-1} efficiently controlled sedges, grasses and BLW's in transplanted rice with WCE of 91.33 per cent Ramesha *et al.,*(2017) and with minimum weed index of -10.3(Rana *et al.,* 2018).

2.3.4.2.2 Effect on yield parameters

The grain yield, HI and WI obtained by spraying of pyrazosulfuron-ethyl @ 42 g ha^{-1} was on par with HW twice at 15 and 30 DAT (Pal *et al.*, 2012). Acharya and Bhattacharya (2013) witnessed more number of effective tillers m^{-2}(337), filled grains per panicle (74.67) and grain yield (5.49 t ha^{-1}) in pyrazosulfuron-ethyl treated plots after two HW at 20 and 40 DAT. According to Arya and Ameena, 2016 the number of spikelets per panicle and filled grains per panicle were the highest for pyrazosulfuron ethyl fb hand weeding and was statistically on par with pyrazosulfuron ethyl fb azimsulfuron on semidry rice. Spraying of pyrazosulfuron-ethyl @ 35g ha^{-1}at 3-6 DAT resulted in maximum tillers m^{-2}, filled grains per panicle, 1000 grain weight, grain yield(36.86 q ha^{-1}) and straw yield (55.37 q ha^{-1}) compared to 15 and 25 g ha^{-1} dosage (Malemnganbi and Lhungdim, 2019).

2.3.4.2.3 Effect on economics

Pre-emergent spraying of pyrazosulfuron ethyl @ 25 g ha^{-1}followed by continuous submergence bring about higher B: C ratio of 1.94 (Banerjee *et al.*, 2008). Kaur *et al.* (2016) stated that sand mix application of pyrazosulfuron ethyl @ 20 g ha^{-1}at 0-5 DAT along with hand weeding at 25 DAT registered higher rice grain yield of 5.89 t ha^{-1}, higher net returns and better B:C ratio (2.13) compared to manual weeding twice at 25 and 45 DAT. Under DSR, combination of pyrazosulfuron ethyl @30 g ha^{-1} at 3DAS along with one HW at 30 DAS resulted in superior grain yield (34.07 q ha^{-1}), net returns and B: C ratio that are statistically at par with HW twice (Lhungdim *et al.*, 2019).

2.3.4.3 Bispyribac sodium

Bispyribac sodium is a selective herbicide that is effective for the control of grasses, sedges and BLW's in rice. It belongs to chemical family of pyridiminyloxybenzoic (Lycan and Hart, 2006) that inhibits the enzyme acetolactate synthase (ALS), in susceptible plants. It is effective as a soil as well as foliar treatment (Rawat *et al.*, 2012).

2.3.4.3.1 Effect on weed parameters

Bispyribac-sodium@ 25 g ha^{-1} as post emergent spray lowered total weed density of grasses, sedges and BLW's (2.2 m^{-2}) and weed biomass (1.9 g m^{-2}) with weed control efficiency of 89.8 per cent (Jabran *et al.*, 2012). Prameela *et al.*, (2014) stated that spraying of bispyribac sodium 10per cent SC @ 30 g ha^{-1} suppressed *Sphenoclea zeylanica* and other weeds efficiently with WCE of 97.18 per cent. In transplanted rice, spraying of bispyribac-sodium @20 g ha^{-1} at 21 DAT along with manual weeding at 45 DAT managed weeds efficiently with higher weed control efficiency of 87.74 per cent and lower weed index of 2.83 (Kashid,2019).

2.3.4.3.2 Effect on yield parameters

Bispyribac-sodium @ 30 g ha^{-1} at 15 DAS along with manual weeding at 30 DAS registered more productive tillers m^{-2}, grains per panicle, 1000-grain weight, grain yield(t ha^{-1}) and HI that are at par with hand weeding twice at 20 and 40 DAS (Ihsan *et al.,* 2014).Post emergent spraying of bispyribac sodium @ 25 g ha $^{-1}$ at 20 DAT resulted in higher number of panicles (38 m^{-2}), 1000 grain weight (32.2g), filled grain percentage (67.03 per cent) and higher yield that is at par with HW twice at 20 and 45 DAT (Antralina *et al.,* 2015). Ghosh *et al.,* (2018) observed that spraying of bispyribac sodium @ 25g ha^{-1}at 15 DAT along with hand weeding at 40 DAT resulted in superior growth and yield parameters with B:C ratio of 1.58 that is superior than HW (1.41) treatment.

2.3.4.3.3 Effect on economics

Veeraputhiyan and Balasubramanian (2013) opined that a net profit of Rs.42, 452 ha^{-1} with B: C ratio of 2.89 that is higher than HW twice (2.54) was obtained with post-emergence spraying of bispyribac sodium@ 25g ha^{-1}.Under transplanted conditions, treating the field with bispyribac sodium @ 25 g ha^{-1} at 20 DAT noticed higher B: C ratio and net profits that are at par with HW twice at 20 and 40 DAT (Dash *et al.,* 2016). Bispyribac-sodium sprayed @ 35 g ha^{-1} at 15 DAT registered lower NPK removal by weed when judged against two HW at 20 and 40 DAT (Prashanth *et al.,* 2016).

2.3.4.4 Penoxsulam + cyhalofop-butyl

2.3.4.4.1 Effect on weed parameters

Singh *et al.,*(2016) witnessed lower weed count and weed biomass with post emergent spraying of penoxsulam+cyhalofop-butyl 6 per cent OD @ 150 g ha^{-1} by the efficient suppression of grassy and non-grassy weeds with utmost weed control efficiency followed by penoxsulam+cyhalofop-butyl 6 per cent OD @ 135 g ha^{-1}.

Application of penoxsulam + cyhalofop-butyl @135 g ha^{-1} to the soil lessened the emergence of grasses, sedges, BLW's and reported lesser weed seed bank at the end of first crop season. When compared to manual weeding 46.36 per cent reduction in weed emergence was observed when treated with penoxsulam + cyhalofop-butyl @135 g ha^{-1} (Raj and Syriac, 2018).

2.3.4.4.2 Effect on yield parameters

Pre-mix treatment of penoxsulam + cyhalofop-butyl 6 per cent OD @ 135g ha^{-1} recorded lower weed biomass of 2.7g by means of broad spectrum weed control. It also resulted in higher grain yields of 6.32 t ha^{-1} which is statistically at par with HW twice at 20 and 40 DAS (Kailkhura *et al.*, 2015).Yadav *et al.*, (2018) stated that ready mix application of penoxsulam + cyhalofop @135 gha^{-1} or 150 g ha^{-1} resulted in more tillers m^{-2}, panicle weight, straw yield and grain yield (5.58 t ha^{-1}) that is similar to weed free treatment (5.60 t ha^{-1}). Pendimethalin @ 1 kg ha^{-1} as pre-emergence spray followed by post-emergence spraying of penoxsulam + cyhalofop butyl (130 g ha^{-1}) suppressed the weed removal of N, P and K by 89.5, 83 and 87.9 per cent, respectively when compared with weedy check (Sen, 2018).

2.3.4.4.3 Effect on economics

Penoxsulam + cyhalofop butyl 6 per cent OD @ 135 g ha^{-1} showed excellent weed control when sprayed at 2-4 leaf stage with superior grain yield of 4167 kg ha^{-1}, net returns of Rs. 40,150 ha^{-1} and higher B: C ratio of 2.36 compared to HW treatment in direct seeded rice (Patil, 2014). Post emergent spraying of penoxsulam + cyhalofop – butyl 6 per cent OD @ 135 g ha^{-1} resulted in higher net returns in transplanted rice with B: C ratio of 1.91 superior to weed free condition (1.66) (Yadav *et al.*, 2018).

2.3.4.5 Metsulfuron methyl+chlorimuron ethyl

Metsulfuron methyl + chlorimuron ethyl is a combination sulfonyl urea herbicide, effective against grasses and BLW at lower rates of application (Banerjee, 2000). Almix, is ready mix combination of metsulfuron-methyl 10 per cent WP and chlorimuron-ethyl 10 per cent WP which shows an excellent control against sedges and

BLW's with minimal effect on grasses (Singh *et al*., 2004). This ALS inhibitor is very good in managing BLW and sedges when applied @ 4 g a.i. ha^{-1} at 15 to 25 DAS (Kumar and Ladha, 2011). It is found to be a sulfonyl urea herbicide with post-emergence action (Ali *et al*., 2018).

2.3.4.5.1 Effect on weed parameters

Almix @ 8 g ha^{-1}provided an excellent control over weeds with higher weed control efficiency for BLW's (97.2 per cent), for sedges (60.0 per cent) and for grasses (21.6 per cent) (Singh *et al.,* 2007). Post- emergence spraying of almix 20 WP @ 4 g ha $^{-1}$ at 15 DAT controlled all classes of weeds with minimal weed dry weight (4.45 g m^{-2}), minimal weed index (1.37) and greater weed control efficiency (90.44 per cent) (Pal *et al.*, 2008). Spraying of chloromuron ethyl + metsulfuron methyl at 20 DAT along with handweeding at 40DAT provided an outstanding curb of *Cyperus sp.* and efficiently controlled dicot weeds (Naik *et al.,* 2019).

2.3.4.5.2 Effect on yield parameters

Application of Almix as post emergence at 20 g ha^{-1} along with 4 times cono weeding from 10 DAT at 10 days interval reduced weed biomass and limited nutrient removal by weeds and increased nutrient uptake by the crop (Babar and Velayutham, 2012). Heisnam *et al.,* (2015) stated that early post emergent spraying of metsulfuron methyl 10 per cent + chlorimum ethyl 10 per cent @ 4 g ha^{-1} led to higher number of tillers $hill^{-1}$, no of spikelets , filled grains , test weight, grain yield , straw yield and HI . Spraying of metsulfuron methyl 10 per cent + chlorimuron ethyl 2 per cent @ 20 g ha^{-1} at 1-2 leaf stage of weed plants resulted in higher grain yield(5.10 t ha^{-1}) and straw yield that is statistically at par with HW (5.18 t ha^{-1}) (Mahbub *et al.,* 2017).

2.3.4.5.3 Effect on economics

Pre-emergent spraying of butachlor at 2DAS along with post-emergent spraying of metsulfuron methyl 10 per cent + chlorimuron ethyl 10 per cent@ 4 g ha^{-1}at 21 DAS noticed higher net returns of ₹10,123 ha^{-1} with B:C ratio of 1.96 (Gopinath and Kundu, 2008). Singh *et al.,* (2018) suggested that spraying of pendimethalin @ 1.0 kg ha^{-1} +

almix @ 4 g ha^{-1} resulted in higher yields and economic benefit to the Indian farmers.

2.3.4.6 Ethoxysulfuron

Ethoxysulfuron is a very effective sulfonylurea herbicide that inhibits acetolactate synthetase. It is highly selective with very low mammalian toxicity which suppresses BLW's and sedges in paddy and turf (Son and Rutto, 2002).

2.3.4.6.12 *Effect on weed parameters*

Shyam and Singh (2015) observed that ethoxysulfuron at 60 g ha^{-1} delivered excellent control of *Cyperus rotundus* and BLW's whereas it was not effective against grass weeds. Tripathy *et al.* (2016) stated that sole application of ethoxysulfuron @18 g ha^{-1} effectively suppressed dicot weeds.

In direct seeded rice, lower weed count, weed biomass and highest weed control efficiency were reported when treated with ethoxysulfuron @ 15 g ha^{-1}at 15 DAS along with HW at 40 DAS (Umkhulzum *et al.,* 2018).

2.3.4.6.2 Effect on yield parameters

Higher grain yield of dry seeded rice could be attained by sequential application of ethoxysulfuron @18 g $ha^{–1}$ at 35 DAS with HW at 45 DAS with highest plant height, panicle length, panicles m^{-2}, grains per panicle ,grain yield which is statistically on par with two HW (Mann *et al.,* 2007).Treating weed plants with ethoxysulfuron @ 15 to 20 g ha^{-1} at 4-6 leaf stage significantly improved the grain yield by suppressing sedges and BLW population in transplanted rice (Sondhia and Dixit, 2012).The N, P and K removal by weeds (8.61, 3.13 and 10.95 kg ha^{-1}, respectively) were lesser with ethoxysulfuron 15 g ha^{-1} at 15 DAS followed by HW at 40 DAS (Umkhulzum *et al.*,2018).

2.3.4.6.3 Effect on economics

Singh *et al.,* (2006) observed that higher net returns and B:C ratio(1.36) were obtained with sequential spraying of ethoxysulfuron at 18 g $ha^{–1}$ compared to weed free treatment. It was proved that ethoxysulfuron is one of the options for efficient and economic control of BLW’s in dry seeded rice in the FIRBS.

2.5 ALLELOPATHIC EFFECT OF GOOSE WEED

The beneficial or harmful impact of one plant species on another either directly or by means of chemical substances that released into the environment is referred to as allelopathy (Rice, 1984). Allelochemicals are phytotoxic substances present in plant tissues and soil that are supposed to cause inhibition of germination and growth retardation. Allelochemicals are basically waste products or secondary plant products that are formed in plant metabolic pathways. These might be water-soluble and are liberated into the environment by means of volatilization, leaching, plant residue decomposition and root exudation.

Many reports states that crops and weeds are able to produce some substances that inhibit the development of the associated crops and weeds (Sanchez *et al.*, 1973). Phytotoxic substances produced by the plants shows varied degree of inhibition on different plant species (Drost and Doll, 1980). Earlier research studies of Premasthira and Zungsontiporn (1985) stated that *Sphenoclea zeylanica* produce substances which strongly inhibited the growth of rice seedling. Premasthira and Zungsontiporn (1996b) stated that when goose weed is incorporated in the soil it is able to inhibit the growth of rice seedlings and also reduced the tiller count when compared to untreated soil.

Premasthira and Zungsontiporn (1996a) reported that the efficacy of the inhibiting compounds differed with the age of plants and plant at matured stage contained higher inhibiting substances followed by flowering, vegetative and seedling stages, respectively. He also stated that the efficacy of allelopathic compounds varied with the plant parts in the decreasing sequence in the order of inflorescences (seed), leaves, stem and roots.

Goose weed was also noticed to suppress the growth and flowering of weed seedlings such as *Eclipta thermalis*, *Leptochloa cheinensis* and *Echinochloa crusgalli* due to its allelopathic effect when submerged in soil by means of decomposed plant residues (Premasthira and Zungsonthiporn, 1995).

Hirai (2000) isolated nine plant inhibitors from *Sphenoclea zeylanica* and identified that it belongs to cyclic thiosulfonates, secologanic acid, secologanosides, and secoiridoidglucosides. The cyclic thiosulfonates and secoiridoidglucosides completely inhibited the root growth of rice seedlings.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

An investigation entitled 'Biology and management of goose weed (*Sphenoclea zeylanica* Gaertner) in wetland rice' was undertaken during *kharif* season of 2019 with the main aim of understanding the biology of *Sphenoclea zeylanica*; to develop an efficient management strategy using low dose high efficiency herbicides and to study its allelopathic effect on rice seeds. The details regarding the materials used and the methods implemented for undertaking the experiment are presented in this chapter.

3.1. EXPERIMENTAL SITE

3.1.1 Location

The field trial was conducted in the rice fields of Integrated Farming System Research Station (IFSRS), Karamana, Thiruvananthapuram. The field is situated geographically at 8^0 47' N latitude and 76^0 96' E longitude.

3.1.2 Climate and season

Crop was grown during *kharif* season extending from June to October 2019.The mean rainfall during the crop growing season was 99.05mm at IFSRS, Karamana. Data pertaining to maximum temperature, minimum temperature, rainfall, RH I, RH II and evaporation obtained from Agromet observatory of IFSRS, Karamana, are given in Appendix 1 and graphically represented in Fig 1.

3.1.3 Soil

To work out the inherent fertility status of the soil, the samples were collected from a depth of 15cm from different places in the field and a composite sample was made for analysis. Estimation of physio-chemical traits of soil was done using standard procedures. The physiochemical properties of the soil before the experiment are furnished in Table 1.

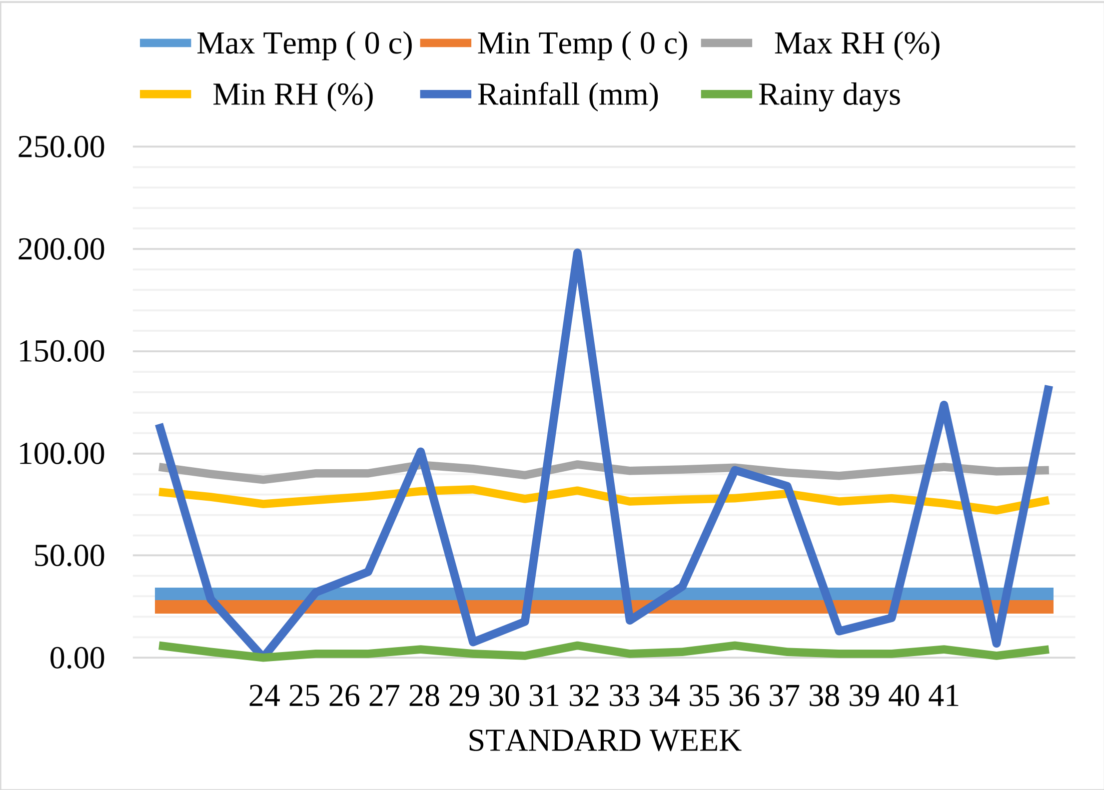


Fig 1. Weather parameters during the experiment (June to October 2019)

Table 1. Physio-chemical properties of the soil in experimental site before experiment

Particulars	content	Status	Method adopted	Reference
a) Physical composition				
Soil separates (%)		Sandy clay loam	Bouycous Hydrometer Method	Bouycous, 1962
(i) Coarse sand	47.48			
(ii) Fine sand	12.11			
(iii) Silt	7.97			
(iv) Clay	32.44			
(v)Textural class				
b)Chemical composition				
(i)soil reaction (pH)	5.39	Strongly acidic	1:2.5 soil : water ratio using pH meter	Jackson, 1958
(ii) EC (dSm^{-1} at 25^0C)	0.46	Normal	1:2.5 soil : water ratio using EC meter	Jackson, 1958
(iii) Available N ($kg\ ha^{-1}$)	273.97	Low	Alkaline permanganate method	Subbiah and Asija 1956
(iv) Available P ($kg\ ha^{-1}$)	38.80	High	Bray colorimetric method	Jackson, 1958
(v) Available K ($kg\ ha^{-1}$)	238.00	Medium	Ammonium acetate method	Jackson, 1958

3.1.4 Cropping history of the field

For the past several years rice was being cultivated in the experimental site. As wet seeding is practiced, there was infestation from all categories of weed plants *viz*., grasses, sedges and broad-leaved weeds (BLWs). Recently, infestation of *Sphenoclea zeylanica* was observed in the field.

3.2 MATERIALS

3.2.1 Crop and Variety

The rice variety *Uma* (MO-16) extensively grown in Kerala was used in this experiment. It is a red kernelled, high yielding (8-10 t ha^{-1}) , medium duration (115-120 days) variety with medium bold grains released from Rice Research Station, Monocompu of Kerala Agricultural University in 1998. It is a dwarf statured, medium tillering, non-lodging variety which has moderate resistance to brown plant hopper.

3.2.2 Manures and fertilizers

Well decomposed powdered farmyard manure (FYM) @ 5 t ha^{-1} was provided as basal dose of organic manure. Fertilizer schedule of 90:45:45 kg N: P_2O_5: K_2O ha^{-1} was followed as per KAU package of practices which is supplied using Urea (46 per cent N), Rajphos (20 per cent P_2O_5) and Muriate of potash (60 per cent K_2O).

3.2.3 Herbicides

Herbicides used in the experiment were bensulfuron methyl+ pretilachlor, pyrazosulfuron ethyl, bispyribac sodium, penoxsulam + cyhalofop-p butyl, metsulfuron methyl + chlorimuron ethyl and ethoxysulfuron. Details regarding technical and toxicity information of above herbicides are mentioned in Table 2.

Table 2. General information of the herbicides

Common name	Bensulfuron methyl + pretilachlor	Pyrazosulfuron ethyl
Trade name	Londax power	Saathi
Chemical name	Methyl α- (4,6 –di methoxy pyrimidin-2yl carbamoyl sulfamoyl)-o-toluate +2-chloro-N-(2,6-diethylphenyl)-N-(2 pro poxyethyl) acetamide	ethyl5-[(4,6-dimethoxypyrimidin-2-yl) carbamoylsulfamoyl]-1-methylpyrazole-4-carboxylate
Molecular formula	$C_6H_{18}N_4O_7S$ + $C_{17}H_{26}ClNO_2$	$C_{14}H_{18}N_6O_7S$
Molecular weight	410.4 + 311.9 $gmol^{-1}$	414.4 $gmol^{-1}$
Group	Sulfonyl urea	Sulfonyl urea
Mode of action	ALS inhibitor	ALS inhibitor
Formulation	0.6%+6% GR	10% WP
Colour, state, odour	Light brown, dry free flowing granule without appreciable odour	White powder with no odour
Toxicity class	Green	Blue
Acute oral toxicity LD_{50} (Rats)	>5000 mg kg^{-1}	>5000 mg kg^{-1}
Acute dermal toxicity LD_{50} (Rats)	>2000 mg kg^{-1}	>2000 mg kg^{-1}
Manufacturer	DuPont	UPL
Cost(Rs)	982 per 4 kg	232 per 80 g

Table 2. General information of the herbicide (continued)

Common name	Bispyribac sodium	Penoxsulam+cyhalofop butyl
Trade name	Nominee gold	Vivaya
Chemical name	Sodium 2,6-bis((4,6-dimethoxypyrimidin-2-yl)oxy)benzoate	2-(2,2-difluoroethoxy)-N-(5,8-dimethoxy-(1,2,4)triazolo(1,5-c)pyrimidin-2-yl)-6 (trifluoromethyl)benzenesulfonamide + (R)-Butyl 2-(4-(4-cyano-2-fluorophenoxy) phenoxy) propanoate
Molecular formula	$C_{19}H_{17}N_4NaO_8$	$C_{16}H_{14}F_5N_5O_5S$ $+C_{20}H_{20}FNO_4$
Molecular weight	452.3 $gmol^{-1}$	483.4 + 357..4 g mol^{-1}
Group	Pyrimidinyloxybenzoic acid	Sulfonyl urea’s
Mode of action	ALS inhibitor	ALS and ACCase inhibitor
Formulation	10% SC	6 % OD
Colour, state, odour	Off-white, viscous suspension liquid concentrate, almost odourless	Yellow, liquid, sweet
Toxicity class	Blue	Green
Acute oral toxicity LD_{50}(Rats)	2635 mg kg^{-1}	>5000 mg kg^{-1}
Acute dermal toxicity LD_{50} (Rats)	2000 mg kg^{-1}	>5000 mg kg^{-1}
Manufacturer	PI industries	Dow agro sciences
Cost (Rs)	470 per 50 ml	1400 per 1 L

Table 2. General information of the herbicide (continued)

Common name	Metsulfuron methyl + chlorimuron ethyl	Ethoxysulfuron
Trade name	Almix	Sunrice
Chemical name	(methyl 2-(4-methoxy-6-methyl-1, 3, 5-triazin-2-ylcarbamoyl-sulfamoyl) benzoate) + (ethyl 2-(4-chloro -6-methoxypyrimidin 2 ylcarbamoyl-sulfamoyl) benzoate)	(2-ethoxyphenyl) N-((4,6-dimethoxypyrimidin-2-yl) carbamoyl)sulfamate
Molecular formula	$C_{14}H_{15}N_5O_6S$+ $C_{15}H_{15}ClN_4O_6S$	$C_{15}H_{18}N_4O_7S$
Molecular weight	398.39 gmol^{-1}	398.4 g mol^{-1}
Group	Sulfonyl urea	Pyrimidinyl sulfonyl urea
Mode of action	ALS inhibitor	ALS inhibitor
Formulation	20% WP	15% WDG
Colour, state, odour	Grey or beige colour powder with a slight odour	White, crystalline solid with no odour
Toxicity class	Blue	Blue
Acute oral toxicity LD_{50} (Rats)	>5000 mg kg^{-1}	>5000 mg kg^{-1}
Acute dermal toxicity LD_{50} (Rats)	>2000 mg kg^{-1}	>2000 mg kg $^{-1}$
Manufacturer	DuPont	Bayer crop science
Cost (Rs)	207 per 8 g	302 per 50 g

3.3 METHODS

Experiment 1- Biology of goose weed (*Sphenoclea zeylanica* Gaertner)

The biology of the weed was studied through keen observation of randomly selected sample plants from weedy check plot (20 m^2 area) starting from emergence of the weed. For the purpose of destructive sampling, a separate set of weed plants. Range and mean values of each of character were worked out.

Experiment II – Management of *Sphenoclea zeylanica* Gaertner using new generation herbicides

Design : RBD

No of treatments 8

No of replications 3

Location : IFSRS, Karamana

Plot size : 5 m x 4 m

Season : *Kharif*, 2019

Variety : Uma

Method of establishment : wet seeding

3.3.1. Treatments:

T_1: bensulfuron methyl + pretilachlor @ 60 + 600 g ha^{-1} at 5 DAS followed by (fb) hand weeding (HW) at 35-40 DAS

T_2: pyrazosulfuron ethyl @ 25g ha^{-1} at 5 DAS followed by hand weeding at 35-40 DAS

T_3: bispyribac sodium @ 25 g ha^{-1} at 20 DAS followed by hand weeding at 35-40 DAS

T_4: penoxsulam + cyhalofop p butyl @ 150 g ha^{-1} at 20 DAS followed by hand weeding at 35- 40 DAS

T_5: metsulfuron methyl+chlorimuron ethyl @ 4gha^{-1}at 20 DAS followed by hand weeding at 35-40 DAS

T_6: ethoxysulfuron@15 g ha^{-1} at 15 DAS followed by hand weeding at 35-40 DAS

T_7: hand weeding at 20 and 40 DAS

T_8: weedy check (un-weeded control)

3.3.2. Cultivation practices

The crop was grown and managed in line with the cultivation practices as per the recommendations of Package of Practices (KAU, 2016).The weed management techniques were followed according to the treatments.

3.3.2.1. Land preparation

The method of crop establishment was by wet seeding. The field was done by thoroughly ploughed, puddled and levelled. The experimental area was partitioned into three blocks with 24 plots each of size 5m x 4m.The width of the bunds between the plots was 30cm and irrigation channel of width 60cm was provided between the blocks. Brief layout of experimental field is shown in Fig. 2

3.3.2.2. Manure and fertilizer application

At final ploughing, well decomposed FYM was incorporated in the soil. The nutrient requirement of rice crop (90:45:45 kg N: P_2O_5: K_2O ha^{-1}) as urea, rajphos, and muriate of potash was done in three splits. At 10 DAS, basal application of one third dose of N, full P and half K was done. One -third of N was applied at active tillering, and the final split of one third N+ half K were top dressed at panicle initiation.

3.3.2.3. Seeds and Sowing

To initiate sprouting, good quality paddy seeds were soaked in water for 12 hours, and subjected to dark conditions. The sprouted paddy seeds were broadcasted in the field at a rate of 100 kg ha^{-1}.

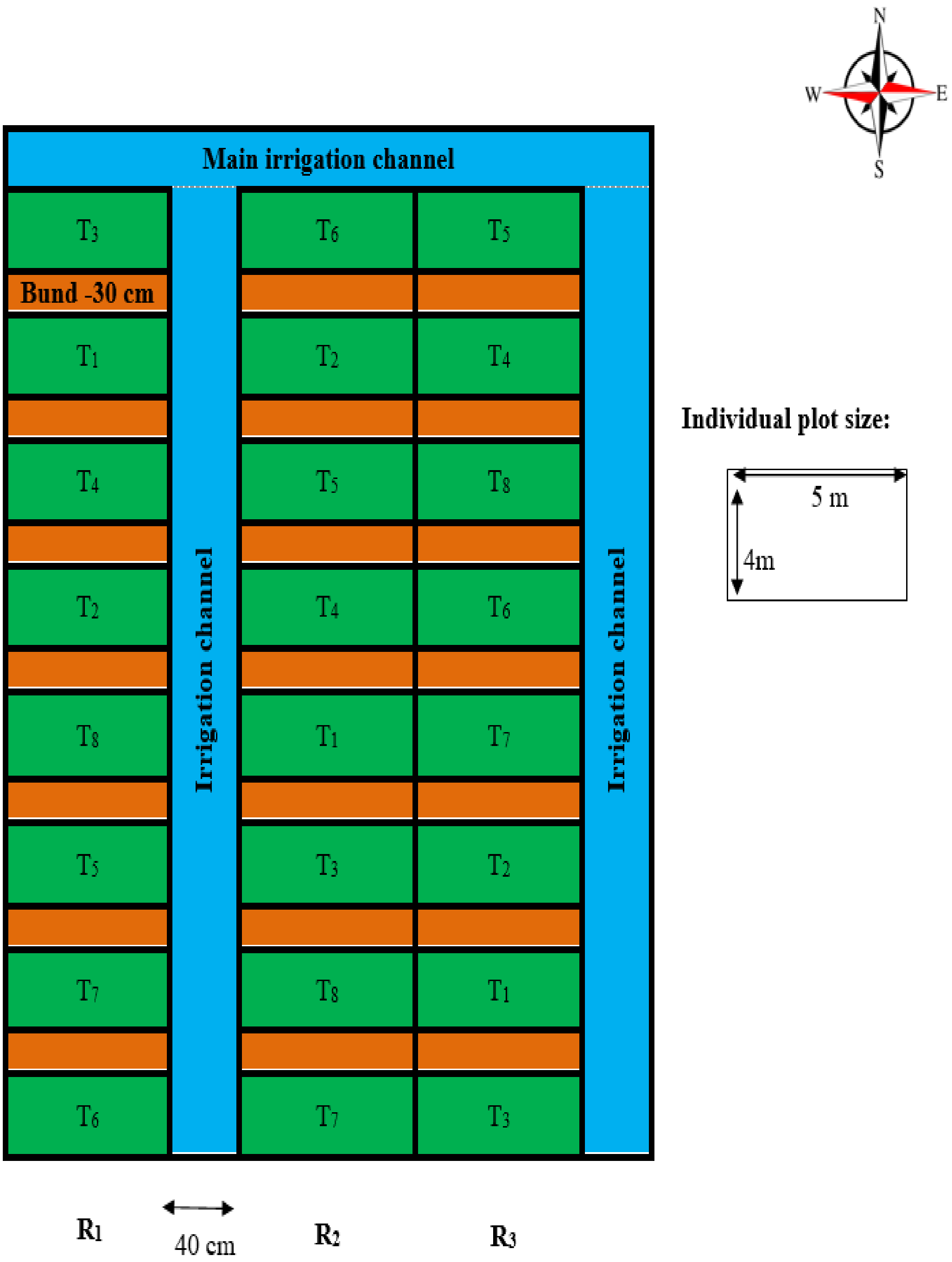


Fig 2. Layout of the experiment.

3.3.2.4. Weed management

Weed management practices were followed according to the treatments framed for the field experiment. The amount of spray volume utilized was 500 L ha^{-1}.Manually operated knapsack sprayer was used for herbicide spraying. Pre-emergence, early post emergence and post emergence herbicide application were done at 5, 15 and 20 DAS, respectively followed by hand weeding at 40 DAS. In weed free check hand weeding was done at 20 and 40 DAS and weedy check plot maintained devoid of weed control practices.

3.3.2.5. Plant protection

The incidence of sheath blight disease was seen at early stages and it was controlled by applying hexaconazole (Contaf 5 EC) at the rate of 1000 mL ha^{-1}.Stem borer was seen at tillering stage and also at grain filling stage that controlled by spraying flubendiamide (Fame 480 SC) at the rate of 50 mL ha^{-1}. Fenvalerate (Tatafen 10 EC) was applied against rice bug (*Leptocorisa acuta*) attack at milk stage.

3.3.2.6. Harvesting and Threshing

Rice crop was harvested manually when the grains are at hard dough stage and dry. Each net plot was threshed separately followed by winnowing. The grain yield and straw yield of individual plots were calculated separately on dry weight basis and expressed in kg ha^{-1}.

Experiment III- Allelopathic effect of goose weed on germination and growth of crops

Design	: CRD
No of treatments	9
No of replications	3
Medium	: Filter paper in petri plate
Test crop	: Rice

3.3.3. Treatments:

T_1: Fresh leaves aqueous extract 10%

T_2: Dry leaves aqueous extract 10%

T_3: Fresh stem aqueous extract 10%

T_4: Dry stem aqueous extract 10%

T_5: Fresh inflorescence aqueous extract 10%

T_6: Dry inflorescence aqueous extract 10%

T_7: Fresh whole plant aqueous extract before flowering 10%

T_8: Fresh whole plant aqueous extract after flowering 10%

T_9: Distilled water (control)

3.3.4. Preparation of plant extract

At active growth stage of *S. zeylanica*, samples for preparation of plant extract were collected from the experimental field. The plant parts such as stem, inflorescence and leaves were separated. Fifty grams each of leaves, stem, inflorescence and whole plant were separately immersed in 500 ml water for 24 hours so as to get10 per cent concentration of fresh aqueous extract. For preparation of dry aqueous extract, the plant sample was shade dried and 50 grams each of leaves, stem, inflorescence and whole plant dried samples were immersed in 500 ml of water for 24 hours. The filtrate obtained was stirred and filtered by using whatman No. 1filter paper. The extract was stored at room temperature.

3.3.5 Methodology

Glass petriplates of 9cm diameter were kept in autoclave at 15 $lbinch^{-1}$ atmosphere pressure for one hour to undergo sterilization and further dried at 120^0C in hot air oven. At the bottom of each petri plate two germination papers were arranged. Fifty healthy seeds of paddy were placed on top of germination paper in circle separately. To each petri plate 5 ml of weed extract or distilled water was applied initially according to the treatments. Afterwards 2 ml extract or distilled water was applied evenly as and when needed until the trial came to an end. The observations on germination and seedling growth were noted and examined.

3.4 OBSERVATIONS

3.4.1. Experiment I- Biology of goose weed *Sphenoclea zeylanica* Gaertner

3.4.1.1. Phenology of Sphenoclea zeylanica

3.4.1.1.1. Days to germination

In weedy check plot the number of days required for emergence of weed sprouts was noticed and expressed in days.

3.4.1.1.2. Days to flowering

Appearance of small spike head on the tip of weed plant was taken as flowering. Sample weed plants were closely observed and days required for spike appearance was counted and expressed in days.

3.4.1.1.3. Days to maturity

Days to maturity was determined by adding total number of days from weed emergence to yellowing of leaves and drying of aerial parts expressed in days.

3.4.1.2. Vegetative characters of goose weed

3.4.1.2.1. Plant height

The height of tagged plants was measured from base to tip of the spike and the mean value expressed in cm.

3.4.1.2.2. Number of leaves per plant

At maximum growth stage, no of leaves for each plant sample were counted and expressed in per plant basis.

3.4.1.2.3. Dry matter per plant

After attaining maturity, ten sample plants were uprooted, cleared off dirt and oven dried to a constant weight at 70 ± 5^{0}C temperature. The dry weight of each plant was determined and mean value expressed in g per plant

3.4.1.2.4. Rooting depth

The sample plants were uprooted at maturity, cleaned to remove soil and length of the root was measured and presented in cm.

3.4.1.2.5. Root dry weight

Ten sample plants were uprooted at maturity, cleared off dirt and oven dried to a constant weight at 70 ± 5^0C temperature. The plant roots were separated carefully and the dry weight was noted and presented in g per plant.

3.4.1.3. Seed characteristics

3.4.1.4 Nutrient removal by weed

At maturity ten sample plants were uprooted, cleared off dirt and oven dried to constant weight at 70 ± 5^0C temperature. The dried weed samples were powdered and sieved using 0.5 mm sieve. With the help of an electronic balance samples were weighed accurately and utilized for NPK analysis after acid digestion. The standard procedures used for plant analysis are listed in (Table 3).

3.4.1.4.1. N uptake

It was estimated by multiplying the weed dry weight ha^{-1} and the N content and expressed in kg ha^{-1}.

3.4.1.4.2. P uptake

It was estimated by multiplying the weed dry weight ha^{-1} and the P content and expressed in kg ha^{-1}.

3.4.1.4.3. K uptake

It was estimated by multiplying the weed dry weight ha^{-1} and the K content and expressed in kg ha^{-1}.

Table 3. Standard procedures followed for plant nutrient analysis

Sl No.	Component	Method	Reference
1.	Nitrogen	Micro kjeldahl method	(Jackson, 1958).
2.	Phosphorus	Vanadomolydo phosphoric yellow colorimetric method.	(Jackson, 1958).
3.	Potassium	Flame photometric method	(Jackson, 1958).

3.4.2. Experiment II Management of *Sphenoclea zeylanica* Gaertner using herbicides

3.4.2.1. Observations on weeds

Weeds within 50cm x50 cm sized quadrat that was positioned at random in three different places in each plot were utilized for subsequent observations.

3.4.2.1.1. Weed flora

Weed flora present in association with *Sphenoclea zeylanica* comprised of grasses, sedges, and broad-leaved weeds (BLW).Periodical observations on weed flora were recorded at 15, 30, 45, 60 DAS.

3.4.2.1.2. Weed density

Weeds present in the quadrat were totalled and grouped into *S. zeylanica* and other weeds. At 15, 30, 45 and 60 DAS observations were noted and expressed as number m^{-2}.

3.4.2.1.3. Weed dry weight

Weed samples were uprooted, cleaned and oven dried till constant weight obtained at 70 ± 5^0c temperature, weighed and expressed in g m^{-2}.

3.4.2.1.4. Weed control efficiency

Weed control efficiency was estimated as per formulae given by Upadhyay and Sivanand (1985).

$$WCE = \frac{(X - Y)}{X} \text{ x } 100$$

WCE = Weed control efficiency.

X = Weed dry matter production in control plot (weedy check)

Y = Weed dry matter production in selected treatment plot whose WCE has to be computed.

3.4.2.1.5. Relative weed density

Weeds present in the quadrat were totalled and the count of a particular weed with reference to other weed was noted at 15, 30, 45and 60 DAS and expressed in percentage.

3.4.2.1.6. Relative weed biomass

The oven dry weight of specific weed species to that of total weed flora dry weight was analysed and expressed in percentage

3.4.2.1.7. Herbicide phytotoxicity

Seven days after spraying, the phytotoxic effect of herbicide on weeds was examined and represented in a 0 to 10 scale as per Rao (2000).

3.4.2.2. **Growth and yield attributes of crop**

At random, three rice plants were tagged from the net plot area of each experimental plot and subsequent observations were taken

3.4.2.2.1. Plant height

Height of the tagged paddy plants were measured from ground level to the longest leaf or panicle at 30, 60 DAS and at harvest. The results were expressed in cm.

3.4.2.2.2. Number of productive tillers per m²

The number of panicles in one square metre were counted from each experimental plot using a quadrat of 0.5m x 0.5m (0.25 m^{-2}) at 60 DAS and denoted as number of productive tillers per m^2.

3.4.2.2.3. Number of grains per panicle

The filled and unfilled grains were collected and counted from ten panicles selected at random, and mean value was represented as number of grains per panicle.

3.4.2.2.4. Sterility percentage

From ten panicles selected at random, the filled and unfilled grains were separated and counted to find out the sterility percentage as per the below formula:

$$\text{Sterility percentage} = \frac{\text{No. of unfilled grains per panicle}}{\text{Total number of grains per panicle}} \times 100$$

3.4.2.2.5. Thousand grain weight

One thousand fully filled, bold grains were collected from the produce and weighed. The result was denoted in g.

3.4.2.2.6. Grain yield

The rice plants were harvested, threshed and winnowed from each net plot separately. Grains were dried to13 per cent moisture content and weighed. The grain yield was denoted in kg ha^{-1}

3.4.2.2.7. Straw yield

After threshing the straw obtained from each plot, it was sundried separately to a constant weight and the weight recorded and denoted in kg ha $^{-1}$

3.4.2.2.8. Harvest Index

Harvest index was figured out with the help of formula derived by Donald and Hanohlin (1976).

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

3.4.2.2.9. Weed index

Weed index was computed by using formula proposed by Gill and Vijayakumar (1969).

$$WI = \frac{(x-y)}{x} \text{X} 100$$

WI = Weed index

X = Grain yield obtained from the treatment that contains lesser number of weeds.

Y = Grain yield obtained from the treated experimental plot to which WI has to be worked out

3.4.2.2.10. Pest and disease incidence

Scoring regarding the pests and diseases observed in the field (stem borer, rice bug, and sheath blight) was done using the evaluation system introduced by the International Rice Research Institute (IRRI, 2013).

3.4.2.3 Chemical analysis

3.4.2.3.1. Nutrient uptake by the crop

Nutrient uptake by the crop was computed by multiplying dry matter produced with its nutrient content and expressed in kg ha^{-1}.

3.4.2.3.2. Nutrient removal by weed

Nutrient removal by *S. zeylanica* was analyzed by multiplying the oven dry weight of weeds with its NPK content.

3.4.2.3.3. Available N, P and K status of soil after the experiment

After the field experiment, the soil samples from each plot were collected, shade dried, powdered and examined for evaluating the N, P and K content of the soil expressed in kg ha^{-1}.

3.4.2.4. Economic analysis

3.4.2.4.1. Net income

Net income was estimated after assessing the gross income obtained and cost of cultivation involved by using the below formula:

$$\text{Net income } (₹\ \text{ha}^{-1}) = \text{Gross income} - \text{Cost of cultivation}$$

3.4.2.4.2. B: C ratio

Benefit cost ratio (BCR) of each and every treatment was calculated by the below specified formula:

$$\text{BCR} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.4.3 Experiment III Allelopathic effect of goose weed on germination and growth of crops

3.4.3.1 Observation on crop

3.4.3.1.1. Germination percentage

The number of seeds germinated were counted from the day of first count to last count (4th and 14th) and germination percentage worked out using the formula

$$\text{Germination percentage} = \frac{\text{Number of seeds germinated}}{\text{Number of seeds kept for germination}} \times 100$$

3.4.3.1.2. Shoot length

On the day of final count, plumule length of all emerged rice seedlings were measured and mean value represented in cm.

3.4.3.1.3. Root length

On the final day, root length of all germinated seedlings were measured and mean value expressed in cm.

3.4.3.1.4. Fresh weight

At the time of final count (14th day), the weight of the germinated rice seedlings in each treatment was recorded and represented in mg per plant.

3.4.3.1.5. Dry weight

At the time of final count (14th day), all the germinated rice seedlings were oven dried to a constant weight at 70 ± 5^{0}c, weighed and expressed in mg per plant

3.4.3.1.6. Vigour index

Seedling vigour index of germinated rice seedlings was calculated using the formula derived by Abdul-Baki and Anderson (1973) and expressed in number.

Vigour index = Germination percentage x (shoot length + root length)

3.5. STATISTICAL ANALYSIS

Recorded data were tabulated and subjected to Analysis of Variance (ANOVA) applicable to Randomized Block Design and Completely Randomized Design formulated by Cochran and Cox (1965). Data requiring transformation were appropriately transformed and analyzed. The treatment *vs* control comparison has been denoted as 'S' when significant and 'NS' when not significant.

RESULTS

4. RESULTS

Field experiments were conducted in the wetlands of IFSRS, Karamana to understand the biology and allelopathic influence of *Sphenoclea zeylanica* and to develop an efficient management strategy using low dose high efficiency herbicides. The observations recorded were analysed statistically and the results are represented in this chapter.

4.1. EXPERIMENT I: WEED BIOLOGY

Goose weed (*Sphenoclea zeylanica* Gartner) belonging to the family Sphenocleaceae is an emerging broad-leaved weed in rice fields of Kerala. The present investigation to study the weed biology was commenced by observing ten sample plants earmarked in the unweeded plots of experimental field. Observations related to biology were recorded at definite growth stages of the weed.

4.1.1 Phenology of goose weed

To understand phenology of goose weed, observations were made during May to October 2019 and the results are represented in Table 4.

In wet seeded paddy fields, concurrent emergence of rice and *Sphenoclea zeylanica* was observed. Under field conditions, seed germination of *Sphenoclea zeylanica* initiated from second day and continued up to 7th day after wet seeding of paddy with an average of 4 days for initiation of germination.

Inflorescence (spike) emergence at the tip of the plant represents the stage of flowering. Inflorescence emergence was noticed from 10th day after emergence and extended up to 24th day. The average number of days for flower initiation was found to be 15 days.

Change in colour of lower fruits from green to brown and dehiscence of fruits from lower portion of spike and shedding of seeds indicate spike maturity. Symptoms of spike maturation were noticed from 29th day onwards extending up to 45th day with a mean period of 36 days for first set of spikes to attain maturity.

Yellowing and browning of leaves followed by drying up of stem represents the stage of final maturity and end of life cycle of the plant. Under field conditions, final plant maturity or completion of life cycle was observed from 60th day extending upto to 81st day with mean duration of 69 days.

4.1.2 Shoot and root characteristics of goose weed

Observations made to study the shoot and root characteristics of goose weed, *Sphenoclea zeylanica* Gaertner are furnished in Table 5.

4.1.2.1 Shoot characteristics

Sphenoclea zeylanica was noticed to be an erect plant with branching habit. Shoots of *Sphenoclea zeylanica* were hollow with circular cross section. At seedling stage, plant height ranged from 1.9 to 4.9 cm with an average height of 3.24 cm. At first flowering, plant height ranged from 15.3 to 24.2cm with mean height of 19.68cm. At maximum flowering, plant height ranged from 24 to 43.5 cm with a mean of 36.2 cm. Maximum plant height was noticed at the stage of maturity and that ranged in between 91.4 to 113.9 cm with a mean of 104.1cm. Number of leaves per plant was maximum at plant maturity and its count varied from 280-384 with a mean of 333 leaves per plant. Dry weight of shoot varied at maturity and ranged from 17.81 to 21.48 g per plant with a mean of 19.69 g per plant. Mean dry matter produced by single plant was found to be 26.24 g per plant.

4.1.2.2 Root characteristics of goose weed

Goose weed had a tap root system with long roots. Rooting depth of goose weed ranged from 26.33 to 33.5 cm with a mean depth of 29.84 cm. Root dry weight was noticed to be in a range of 5.25 to 8.54 g per plant with a mean of 6.55 g per plant.

Table 4: Phenology of gooseweed *Sphenoclea zeylanica* Gartner in wet seeded rice

Characteristics	**Minimum**	**Maximum**	**Mean**	**CV (%)**	**SEm(±)**
Days to germination	2.00	7.00	4.20	1.39	0.86
Days to flowering	10.00	24.00	15.20	2.31	2.39
Days to spike maturity	29.00	45.00	36.40	2.68	3.22
Days to maturity	60.00	81.00	69.40	2.81	3.53

Table 5: Shoot and root characteristics of goose weed (*Sphenoclea zeylanica* Gaertner)

Characteristics	**Minimum**	**Maximum**	**Mean**	**CV (%)**	**SEm(±)**
Plant height at seedling stage(cm)	1.90	4.90	3.24	1.10	0.54
Plant height at first flowering (cm)	15.30	24.20	19.68	1.92	1.66
Plant height at maximum flowering (cm)	24.00	43.50	36.20	2.76	3.42
Plant height at maturity (cm)	91.40	113.90	104.10	2.95	3.89
No. of leaves per plant	280.00	384.00	333.40	6.56	19.24
Dry matter per plant (g)	23.06	30.12	26.24	1.75	1.37
Rooting depth (cm)	26.33	33.50	29.84	1.62	1.17
Root dry weight (g)	5.25	8.54	6.55	1.18	0.62

4.1.3 Floral characteristics of goose weed

Floral characteristics of *Sphenoclea zeylanica* were documented and presented in Table 6.

Inflorescence of goose weed was noted to be a spike that appeared terminally. Flowers were sessile, bisexual, white in colour initially appeared and matured from bottom of spike. The dehiscence and dispersal of seeds were found to occur from base to tip. A single plant was capable of producing 44 to 48 spikes with an average of 55 spikes. Number of fruits in each spike varied from 56 to 69 with a mean of 63 fruits per spike. The length of each spike varied from 3.7 to 4.8 cm with a mean length of 4.26 cm. Numerous tiny brown seeds were observed within each fruit.

4.1.4. Nutrient composition of goose weed

Nutrient content and uptake of goose weed were analyzed and furnished in Table 7.

The nutrient composition of goose weed was analyzed and found to contain 1.306, 0.087 and 1.695 per cent NPK, respectively. Average biomass production as observed from unweeded control was estimated to be 3.75 t ha^{-1}. Consequently, goose weed recorded a nutrient removal of 49, 3.26 and 63.59 kg N, P_2O_5 and K_2O ha^{-1} respectively.

Table 6: Floral characteristics of goose weed *Sphenoclea zeylanica* Gaertner

Characteristics	Minimum	Maximum	Mean	CV (%)	SEm(±)
Number of spikes per plant	44.00	48.00	55.20	4.39	2.57
Number of fruits per spike	56.00	69.00	63.00	4.71	2.47
Length of spike (cm)	3.70	4.80	4.26	1.22	2.50

Table 7. Nutrient composition and uptake of goose weed (*Sphenoclea zeylanica* Gaertner)

Nutrient	Content (%)	Nutrient uptake (kg ha^{-1})
Nitrogen	1.306	49.0
Phosphorus	0.087	3.26
Potassium	1.695	63.59

4.2. EXPERIMENT II: WEED MANAGEMENT

4.2.1. Observations on weeds

4.2.1.1. Weed flora

Weed flora associated with wet seeded rice at various developmental stages *viz.* 15, 30, 45 and 60 DAS are documented in Table 8.

The experimental field was seen occupied with a diverse flora of weeds from all the 3 categories *viz.* grasses, sedges and broad-leaved weeds (BLWs) all through the growing season. Among these, *Sphenoclea zeylanica* was found to be the most dominant weed till the end of critical period of crop weed competition. During later stages, the field was dominated by *Ludwigia perennis, Cyperus difformis, Cyperus iria, Ischaemum rugosum, Bergia capensis, Ludwigia parviflora and Lindernia rotundifolia* were also seen to infest the experimental field all the way through its life cycle.

4.2.1.1.1. Weed flora at 15 DAS

At 15 DAS, BLWs and sedges were the dominating groups of weed flora observed in the experimental field. Among BLWs, *Sphenoclea zeylanica* was the most dominating along with *Ludwigia parviflora, Bergia capensis, Lindernia rotundifolia, Alternanthera sessilis* and *Monochoria vaginalis.* Sedges noticed in the field were *Cyperus iria, Cyperus difformis* and *Fimbristylis miliacea. Marsilea quadrifolia* was the only fern species observed at 15 DAS.

4.2.1.1.2. Weed flora at 30 DAS

At 30 DAS, the field was mainly dominated by BLWs along with sedges and grasses. *Sphenoclea zeylanica, Ludwigia parviflora, Bergia capensis* and *Lindernia rotundifolia* were more in number along with *Monochoria vaginalis.* Sedges associated with the crop were *Fimbristylis miliacea, Cyperus difformis and Cyperus iria.* Among grass weeds *Echinochloa colona, Leptochloa chinensis* and *Ischaemum rugosum* were seen in crop field.

Table 8. Weed flora composition at 15, 30, 45 and 60 DAS in wet seeded rice

Weed flora composition			
15 DAS	30 DAS	45 DAS	60 DAS
Sphenoclea zeylanica	*Sphenoclea zeylanica*	*Sphenoclea zeylanica*	*Sphenoclea zeylanica*
Bergia capensis	*Ludwigia parviflora,*	*Ludwigia parviflora*	*Oryza sativa f spontanea*
Lindernia rotundifolia	*Bergia capensis*	*Lindernia rotundifolia*	*Ludwigia parviflora*
Alternanthera sessilis	*Lindernia rotundifolia*	*Bergia capensis,*	*Bergia capensis*
Monochoria vaginalis	*Monochoria vaginalis*	*Alternanthera sessilis*	*Lindernia rotundifolia*
Ludwigia parviflora	*Fimbristylis miliacea,*	*Cyperus difformis*	*Echinochloa colonum*
Fimbristylis miliacea	*Cyperus difformis,*	*Cyperus iria*	*Leptochloa chinensis*
Marsilea quadrifolia	*Cyperus iria.*	*Fimbristylis miliacea*	*Fimbristylis miliacea*
Cyperus iria	*Echinochloa colonum,*	*Monochoria vaginalis*	*Ischaemum rugosum*
Cyperus difformis	*Leptochloa chinensis*	*Leptochloa chinensis*	*Monochoria vaginalis*
	Ischaemum rugosum	*Ischaemum rugosum*	*Alternanthera sessilis*
			Cyperus iria
			Cyperus difformis

Table 9. Details of weed flora associated with rice crop in experimental field

Sl. No	Common name	Scientific name	Malayalam name	Family
Grasses				
1.	Chinese sprangle top	*Leptochloa chinensis*	*Kuthiravaali*	Poaceae
2.	Blood grass	*Ischne miliaceae*	*Naringa/changalipullu*	Poaceae
3.	Weedy rice	*Oryza sativa f sp spontanea*	*Varinellu*	Poaceae
4.	Jungle rice	*Echinocloa colona*	*Kavada*	Poaceae
Sedges				
5.	Globe finger rush	*Fimbristylis miliacea*	*Mung*	Cyperaceae
6.	Rice flat sedge	*Cyperus iria*	*Manjakora/chengoal*	Cyperaceae
7.	Umbrella sedge	*Cyperus difformis*	*Thalekkettan*	Cyperaceae
Broad leaved weeds				
8.	Goose weed	*Sphenoclea zeylanica*	*Pongankala*	Sphenocleaceae
9.	Bergia	*Bergia capensis*	-	Elatinaceae
10.	Baby tears	*Lindernia rotundifolia*	-	Linderniaceae
11.	Sessile joyweed	*Alternanthera sessilis*	*Vayalcheera/kozhua*	Amaranthaceae
12.	Pondweed	*Monochoria vaginalis*	*Neelolpalam*	Pontederiaceae
13.	Water primrose	*Ludwigia parviflora*	*Neergrampu*	Onagraceae
14.	Water cabbage	*Limnocharis flava*	*Nagappola*	Limnocharitaceae
Ferns				
15.	Airy pepper wort	*Marsilea quadrifolia*	*Nalilakodian*	Marsiliaceae

4.2.1.1.3. Weed flora at 45 DAS

At 45 DAS, dominant weed flora were *Sphenoclea zeylanica, Lindernia rotundifolia, Ludwigia parviflora* along with other BLWs such as *Bergia capensis, Alternanthera sessilis* and *Monochoria vaginalis*. *Fimbristylis miliacea, Cyperus difformis* and *Cyperus iria* were noticed among sedges. The grasses observed in the field were *Leptochloa chinensis* and *Ischaemum rugosum.*

4.2.1.1.4. Weed flora at 60 DAS

At 60 DAS, occurrence of *Oryza sativa f spontanea* was noticed in the field along with *Sphenoclea zeylanica*, *Ludwigia parviflora, Alternanthera sessilis, Bergia capensis, Lindernia rotundifolia, Monochoria vaginalis, Echinochloa colona*, *Leptochloa chinensis*, *Ischaemum rugosum, Fimbristylis miliacea, Cyperus difformis* and *Cyperus iria.*

4.2.1.2 Weed density

The influence of weed management practices on weed density in wet seeded rice at various developmental stages *viz.* 15, 30, 45 and 60 DAS are presented in Table 10.

Weed density refers to the number of weed plants present in unit area which differed with growth stages of crop and weed management treatments tested.

4.2.1.2.1 Weed density at 15 DAS

At 15 DAS, pre-emergent application of bensulfuron methyl + pretilachlor @ 60+600g ha^{-1} at 5 DAS followed by (fb) hand weeding (HW) at 35-40 days after sowing (DAS) (T_1) resulted in lower weed density of 18.67 which is at par with T_2 (pyrazosulfuron ethyl @ 25g ha^{-1} at 5 DAS fb HW at 35-40 DAS) having 36 weeds per square meter. The un-weeded control recorded the highest weed density of 345.33 no. m^{-2} which was on par with T_3 (272), T_4 (291.33), T_5 (281) and T_6(279.33).

Table 10. Effect of weed management practices on weed density at 15, 30, 45 and 60 DAS, no. m^{-2}

Treatments	15 DAS	30 DAS	45 DAS	60 DAS
T_1	18.67 (4.43)	24.00 (4.99)	60.33 (7.82)	60.00 (7.80)
T_2	36.00 (6.08)	36.67 (6.13)	77.67 (8.86)	62.67 (7.97)
T_3	272.00 (16.52)	13.33 (3.78)	45.33 (6.80)	44.00 (6.68)
T_4	291.33 (17.09)	4.00 (2.24)	14.67 (3.95)	10.00 (3.31)
T_5	281.00 (16.78)	8.00 (2.95)	18.67 (4.41)	23.00 (4.84)
T_6	279.33 (16.66)	12.00 (3.58)	42.00 (6.55)	37.83 (6.23)
T_7	256.33 (15.93)	13.33 (3.78)	61.00 (7.84)	28.67 (5.44)
T_8	345.33 (18.55)	257.00(16.06)	273.66(16.57)	250.75 (15.84)
SE(m)±	0.72	0.26	0.18	0.30
CD (0.05)	2.191	0.796	0.557	0.918

The data subjected to square root transformation and transformed values given in parentheses

4.2.1.2.2. Weed density at 30 DAS

At 30 DAS, penoxsulam + cyhalofop butyl 6 % OD @ 150 g ha^{-1} at 20 DAS fb HW at 35-40 DAS (T_4) resulted in lesser weed count of 4 m^{-2} which is at par with T_5 (metsulfuron methyl+chlorimuron ethyl @ 4gha^{-1} at 20 DAS fb HW at 35-40 DAS) with a weed density of 8 m^{-2}. Higher weed density values were reported in weedy check 257 m^{-2}.

4.2.1.2.3. Weed density at 45 DAS

At 45 DAS, the lowest weed count of 14.67 m^{-2} was recorded in T_4 (penoxsulam + cyhalofop butyl 6 % OD @ 150 g ha^{-1} at 20 DAS fb HW at 35-40 DAS) which is at par with T_5 (metsulfuron methyl + chlorimuron ethyl @ 4gha^{-1} at 20 DAS fb HW at 35-40 DAS) with weed density of 18.67 m^{-2} . Weedy check recorded higher weed density values of 273.66 m^{-2}.

4.2.1.2.4. Weed density at 60 DAS

At 60 DAS also, lesser weed count of 10 m^{-2} was observed in penoxsulam + cyhalofop butyl 6 % OD @ 150 g ha^{-1} at 20 DAS fb HW at 35-40 DAS (T_4) which was superior to all the weed management practices. Metsulfuron methyl + chlorimuron ethyl @ 4gha^{-1} at 20 DAS fb HW at 35-40 DAS (T_5) reported weed density of 23 m^{-2} which is statistically at par with HW at 20 and 40 DAS (T_7) with weed count of 28.66 m^{-2}. Highest weed density m^{-2} was registered in weedy check with a value of 250.75 m^{-2}.

4.2.1.3. Weed dry weight

The results on effect of weed management practices on weed dry weight in wet seeded rice at various developmental stages viz. 15, 30, 45, and 60 DAS are represented in Table 11.

Dry weight of weed plants in unit area differed with growth stages of crop and weed management treatments experimented.

4.2.1.3.1 Weed dry weight at 15 DAS

At 15 DAS, pre-emergent application of bensulfuron methyl + pretilachlor @

Table 11. Effect of weed management practices on weed dry weight at 15, 30, 45 and 60 DAS, g m^{-2}

Treatments	15 DAS	30 DAS	45 DAS	60 DAS
T_1	0.08 (1.04)	6.4 (2.71)	15.57 (4.07)	22.49 (4.84)
T_2	0.22 (1.11)	8.48 (3.08)	19.88 (4.56)	27.64 (5.35)
T_3	10.17 (3.34)	14.25 (3.90)	7.87 (2.98)	22.23 (4.82)
T_4	9.87 (3.29)	10.94 (3.45)	1.35 (1.53)	4.61 (2.37)
T_5	9.94 (3.31)	11.66 (3.56)	3.12 (2.03)	10.28 (3.31)
T_6	10.30 (3.36)	15.93 (4.07)	8.39 (3.06)	15.99 (4.12)
T_7	10.40 (3.37)	7.09 (2.84)	12.24 (3.62)	12.45 (3.67)
T_8	12.20 (3.63)	170.27 (13.08)	306.10 (17.52)	400.84 (20.04)
SE(m)$\pm$	0.15	0.09	0.08	0.06
CD (0.05)	0.468	0.275	0.259	0.187

The data subjected to square root transformation and transformed values given in parenthesis

60+600g ha^{-1} at 5 DAS fb HW at 35-40 DAS (T_1) reported lower weed dry weight of 0.08g m^{-2} and was on par with T_2 (pyrazosulfuron ethyl @ 25g ha^{-1} at 5 DAS fb HW at 35-40 DAS) recording dry weight of 0.22 g m^{-2}. Maximum weed dry weight was recorded in un-weeded control with 12.2 g m^{-2}. Weed dry weight in T_4, T_5, T_3, T_6, T_7, and T_8 were comparable with weedy check and recorded 9.87, 9.94, 10.16, 10.3, 10.4 and 12.19 g m^{-2}, respectively.

4.2.1.3.2. Weed dry weight at 30 DAS

At 30 DAS, all treatments except un-weeded control resulted in considerable reduction in weed biomass as represented by its lower dry weight values. Pre-emergent application of bensulfuron methyl + pretilachlor @60+600g ha^{-1} at 5 DAS fb HW at 35-40 DAS (T_1) reported the lowest weed dry weight of 6.41 g m^{-2} which was on par with T_7 (HW twice at 20 and 40 DAS) and T_2 (pyrazosulfuron ethyl @ 25g ha^{-1} at 5 DAS fb HW at 35-40 DAS) with dry weights of 7.08 and 8.48 g m^{-2} respectively. This was followed by T_4 with weed dry weight of 10.94 g m^{-2} and was on par with T_5 (11.66 g m^{-2}). Highest weed dry weight of 170.27 g m^{-2} was observed in un-weeded plot (T_8).

4.2.1.3.3. Weed dry weight at 45 DAS

At 45 DAS, penoxsulam+cyhalofop butyl 6 % OD @ 150 g ha^{-1} at 20 DAS fb HW at 35-40 DAS (T_4) was significantly superior to all the treatments and resulted in lesser weed biomass of 1.35 g m^{-2}. This was followed by T_5 (metsulfuron methyl+ chlorimuron ethyl @ 4g ha^{-1} at 20 DAS fb HW at 35-40 DAS) with a lower weed dry weight of 3.12 g m^{-2}. Higher weed dry weight of 306.10 g m^{-2} was observed in weedy check plot (T_8).

4.2.1.3.4. Weed dry weight at 60DAS

At 60 DAS, T_4 (penoxsulam + cyhalofop butyl 6 % OD @ 150 g ha^{-1} at 20 DAS fb HW at 35-40 DAS) recorded the lowest weed dry weight of 4.61 g m^{-2} and was significantly superior to rest of the treatments. It was followed by T_5 (metsulfuron methyl+ chlorimuron ethyl @ 4g ha^{-1} at 20 DAS fb HW at 35-40 DAS) with weed dry weight of 10.28 g m^{-2} and was on par with HW twice at 20 and 40 DAS (T_7) with 12.45 g m^{-2}.

Un-weeded check (T_8) reported higher dry weight of 400.84 g m^{-2}.

4.2.1.4. Relative weed density

Relative density refers to the numerical strength of a species in relation to the total number of individuals of all the species. Relative density of *Sphenoclea zeylanica* as influenced by weed control practices were analysed statistically and depicted in Table 12.

Number of *Sphenoclea zeylanica* plants per unit area compared to other weed species differed with stage of crop growth and weed management practices.

4.2.1.4.1. Relative density of Sphenoclea zeylanica at 15 DAS

At 15 DAS, pre-emergence spraying of bensulfuron methyl +pretilachlor @60+600g ha^{-1} at 5 DAS fb HW at 35-40 DAS (T_1**)** reported lower relative weed density of *Sphenoclea zeylanica* (6.67 per cent). This was followed by pyrazosulfuron ethyl @ 25g ha^{-1} at 5 DAS fb HW at 20 and 40 DAS (T_2) with a relative weed density of 18.7 per cent. As no other weed management practices were functional at that period of observation, all the other plots reported higher relative weed density of *Sphenoclea*. Relative weed density of T_8, T_6, T_4, T_3, T_7 and T_5 were 60.54, 63.14, 65.09, 67.26, 66.17 and 70.33 per cent, respectively.

4.2.1.4.2. Relative density of Sphenoclea zeylanica at 30 DAS

At 30 DAS, penoxsulam+cyhalofop butyl 6 % OD @ 150 g ha^{-1} at 20 DAS fb HW at 35-40 DAS (T_4) gave a better control of *Sphenoclea zeylanica* with the lowest relative weed density of zero. This was at par with metsulfuron methyl + chlorimuron ethyl @ 4g ha^{-1} at 20 DAS fb HW at 35-40 DAS (T_5) , ethoxysulfuron@15 g ha^{-1} at 20 DAS fb HW at 35-40 DAS (T_6) and bispyribac sodium @ 25 g ha^{-1} at 15-20 DAS fb HW at 35-40 DAS (T_3) with relative weed density of 11.11, 11.11and 19.44 per cent, respectively. The treatments T_2, T_1 and T_7 were at par with each other with relative weed densities of 18.38, 21.74 and 30.55 per cent, respectively. Higher relative weed density of *Sphenoclea zeylanica* was reported in weedy check (62.24 per cent).

Table 12. Relative density of *Sphenoclea zeylanica* at 15, 30, 45 and 60 DAS, per cent

Treatments	15 DAS	30 DAS	45 DAS	60 DAS
T_1	6.67 (2.194)	21.74 (4.74)	9.27 (3.14)	6.71 (2.77)
T_2	18.70 (4.39)	18.38 (4.35)	12.08 (3.60)	6.42 (2.72)
T_3	67.26 (8.26)	19.44 (3.99)	5.74 (2.40)	4.76 (1.97)
T_4	65.09 (8.12)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T_5	70.33 (8.44)	11.11 (2.62)	5.55 (2.07)	5.80 (2.09)
T_6	63.14 (8.0)	11.11 (2.62)	6.47 (2.51)	3.14 (1.74)
T_7	66.17 (8.17)	30.55 (5.61)	12.55 (3.65)	14.05 (3.88)
T_8	60.54 (7.83)	62.24 (7.95)	56.16 (7.55)	37.36 (6.19)
SE(m)$\pm$	0.44	1.03	0.60	0.59
CD (0.05)	1.353	3.177	1.842	1.817

The data subjected to square root transformation and transformed values given in parenthesis

4.2.1.4.3. Relative density of Sphenoclea zeylanica at 45 DAS

At 45 DAS, penoxsulam +cyhalofop butyl 6 % OD @ 150 g ha^{-1} at 20 DAS fb HW at 35-40 DAS (T_4) gave a better control of *Sphenoclea zeylanica* with the lowest relative weed density of zero per cent. This was at par with metsulfuron methyl + chlorimuron ethyl @ 4g ha^{-1} at 20 DAS fb HW at 35-40 DAS (T_5), bispyribac sodium @ 25 g ha^{-1} at 15-20 DAS fb HW at 35-40 DAS (T_3) and ethoxysulfuron@15 g ha^{-1} at 20 DAS fb HW at 35-40 DAS (T_6) with relative weed densities of 5.55, 5.73 and 6.47 per cent respectively. T_1, T_2 and T_7 were at par with each other with relative density of of 9.27, 12.08 and 12.55 per cent, respectively. In weedy check, more than 50 per cent of weed species composition was represented by (56.16 per cent) *Sphenoclea zeylanica.*

4.2.1.4.4. Relative density of Sphenoclea zeylanica at 60 DAS

At 60 DAS, lowest relative weed density of zero per cent was reported in plots that received post emergent spray of penoxsulam +cyhalofop butyl 6 % OD @ 150 g ha^{-1} at 20 DAS fb HW at 35-40 DAS (T_4) which is at par with T_6, T_3, T_5, T_2 and T_1 with relative weed density values of 3.14, 4.76, 5.80, 6.42 and 6.71, respectively. T_7 reported a relative weed density of 14.05 per cent. As crop growth progressed, the relative density of *Sphenoclea zeylanica* (37.36 per cent) also showed a decline from previous month as reported in weedy check.

4.2.1.5. Relative weed biomass

Relative weed biomass of *Sphenoclea zeylanica* pertaining to concerned weed control practices were analysed statistically and represented in Table 13.

Dry weight of *Sphenoclea zeylanica* per unit area compared to remaining weed species differed with crop growth stages of the crop and weed management practices followed.

4.2.1.5.1. Relative weed biomass of Sphenoclea zeylanica at 15DAS

At 15 DAS, pre-emergent spraying of bensulfuron methyl +pretilachlor

@60+600g ha^{-1} at 5 DAS fb HW at 35-40 DAS (T_1) reported lower relative weed biomass of *Sphenoclea zeylanica* with 0.42 per cent which was at par with pyrazosulfuron ethyl @ 25g ha^{-1} at 5 DAS fb HW at 35-40 DAS (T_2) reporting a relative weed biomass of 1.29 per cent. As no other weed management practices were operational at that period of observation, all the other plots reported higher relative weed biomass of *Sphenoclea zeylanica*. Relative weed biomass of T_7, T_6, T_8, T_3, T_4 and T_5 were 47.19, 50.37, 50.49, 55.30, 58.33 and 59.78 per cent, respectively.

4.2.1.5.2. Relative weed biomass of Sphenoclea zeylanica at 30DAS

At 30 DAS, penoxsulam+cyhalofop butyl 6 % OD @ 150 g ha^{-1} at 20 DAS fb HW at 35-40 DAS (T_4) gave a better control of *Sphenoclea zeylanica* with the lowest relative weed biomass of 0 per cent. This was at par with ethoxysulfuron@15 g ha^{-1} at 20 DAS fb HW at 35-40 DAS (T_6), metsulfuron methyl + chlorimuron ethyl @ 4g ha^{-1} at 20 DAS fb hand weeding at 35-40 DAS (T_5), bensulfuron methyl +pretilachlor @60+600g ha^{-1} at 5 DAS fb HW at 35-40 DAS (T_1) and pyrazosulfuron ethyl @ 25g ha^{-1} at 5 DAS fb HW at 35-40 DAS(T_2) with relative weed biomass of 0, 3.62, 4.98, 6.32 and 6.46 per cent, respectively. T_3 and T_7 are at par with each other with a relative weed biomass of 8.19 and 14.31 per cent, respectively. Higher relative weed biomass of *Sphenoclea zeylanica* (48.24 per cent) was reported in weedy check (T_8).

4.2.1.5.3. Relative weed biomass of Sphenoclea zeylanica at 45DAS

At 45 DAS, penoxsulam +cyhalofop butyl 6 % OD @ 150 g ha^{-1} at 20 DAS fb HW at 35-40 DAS (T_4) provided a better control of *Sphenoclea zeylanica* with the lowest relative weed biomass of zero per cent. This was at par with T_5 metsulfuron methyl + chlorimuron ethyl @ 4g ha^{-1} at 20 DAS fb HW at 35-40 DAS (4.49 per cent). T_6, T_3, T_1, T_2 and T_7 were at par with each other recording relative weed biomass of 7.05, 8.19, 8.24, 8.78 and 10.23 per cent, respectively. Higher relative weed biomass of *Sphenoclea zeylanica* (49.56 per cent) was reported in weedy check (T_8).

Table 13. Relative weed biomass of *Sphenoclea zeylanica* at 15, 30, 45 and 60 DAS, per cent

Treatments	15 DAS	30 DAS	45 DAS	60 DAS
T_1	0.42 (1.17)	6.32 (2.69)	8.24 (3.02)	4.14 (2.27)
T_2	1.29 (1.50)	6.46 (2.73)	8.78 (3.12)	4.26 (2.29)
T_3	55.30 (7.46)	8.19 (2.76)	8.19 (3.01)	3.57 (1.80)
T_4	58.33 (7.70)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T_5	59.78 (7.78)	4.98 (1.99)	4.49 (1.93)	1.72 (1.49)
T_6	50.37 (7.17)	3.62 (1.81)	7.05 (2.60)	1.92 (1.53)
T_7	47.19 (6.94)	14.31 (3.91)	10.23 (3.35)	5.84 (2.59)
T_8	50.49 (7.17)	48.24 (7.02)	49.56 (7.11)	50.91 (7.20)
SE(m)$\pm$	0.26	0.57	0.47	0.40
CD (0.05)	0.808	1.753	1.432	1.228

The data subjected to square root transformation and transformed values given in parenthesis

4.2.1.5.4. Relative weed biomass of Sphenoclea zeylanica at 60DAS

At 60 DAS, the lowest relative weed biomass of zero per cent was reported in plots that received post emergent spray of penoxsulam +cyhalofop butyl 6 % OD @ 150 g ha^{-1} at 20 DAS fb HW at 35-40 DAS (T_4). This was at par with T_5, T_6 and T_3 with relative weed biomass of 0, 1.72, and 1.92 per cent, respectively. T_1, T_2 and T_7 were at par with each other and reported relative weed density of 4.14, 4.26 and 5.84 per cent, respectively. Higher relative biomass of 50.91 per cent was reported in weedy check (T_8).

4.2.1.6. Weed control efficiency

Weed control efficiencies (WCE) of weed control treatments were analyzed statistically and furnished in table 14.

WCE denotes the magnitude of weed reduction due to weed control treatment. Among the weed management treatments applied, WCE differed at each and every stage of observation *viz.* 15, 30, 45, and 60 DAS.

4.2.1.6.1. Weed control efficiency at 15 DAS

At 15 DAS, pre-emergent spraying of bensulfuron methyl + pretilachlor @60+600g ha^{-1} at 5 DAS fb HW at 35-40 DAS (T_1) resulted in better WCE of 99.28 per cent which is statistically on par with pyrazosulfuron ethyl @ 25g ha^{-1} at 5 DAS fb HW at 35-40 DAS (T_2) recording WCE of 98.16 per cent. As no other weed management practices were applied at that period of observation, all the other plots reported lower WCE. T_5, T_4, T_3 and T_6 reported WCE of 18.49, 18.50, 16.78 and 14.78 per cent respectively.

4.2.1.6.2. Weed control efficiency at 30 DAS

At 30 DAS, bensulfuron methyl + pretilachlor @60+600g ha^{-1} at 5 DAS fb HW at 35-40 DAS (T_1) suppressed *Sphenoclea zeylanica* effectively with 96.23 per cent which is on par with HW at 20 and 40 DAS(T_8) registering a WCE of 95.82 per cent. It was followed by T_2 with WCE of 95.02 per cent. T_4 and T_5 were at par with each other with WCE of 93.55 and 93.13 per cent, respectively. Lower weed control efficiency of 90.86 per cent was observed in T_6 (ethoxysulfuron@15 g ha^{-1} at 20 DAS fb HW at 35-40 DAS) which was at par with T_3.

4.2.1.6.3. Weed control efficiency at 45 DAS

At 45 DAS, penoxsulam+cyhalofop butyl 6 % OD @ 150 g ha^{-1} at 20 DAS fb HW at 35-40 DAS (T_4) effectively suppressed *Sphenoclea zeylanica* with better WCE of 99.54 per cent which is significantly at par with metsulfuron methyl+chlorimuron ethyl @ 4gha^{-1} at 20 DAS fb HW at 35-40 DAS (T_5) with a WCE of 98.98 per cent. This was followed by T_3, T_6, T_7, and T_1 with WCE of 97.42, 97.25, 96.01 and 94.92 per cent, respectively. T_2 reported lower WCE of 93.26 per cent.

4.2.1.6.4. Weed control efficiency at 60 DAS

At 60 DAS, penoxsulam+cyhalofop butyl 6 % OD @ 150 g ha^{-1} at 20 DAS fb HW at 35-40 DAS (T_4) effectively suppressed *Sphenoclea zeylanica* with better WCE of 98.85 per cent. It was followed by metsulfuron methyl+chlorimuron ethyl @ 4 gha^{-1} at 20 DAS fb HW at 35-40 DAS (T_5) with WCE of 97.22 per cent which is at par with HW at 20 and 40 DAS (96.01 per cent). T_6, T_3, T_1 and T_2 reported WCE of 96.01, 94.46, 94.39 and 93.08 per cent, respectively.

4.2.1.7. Herbicide phytotoxicity on weeds

The symptoms of herbicide phytotoxicity varied among the herbicide molecules used. After seven days of herbicide spraying, phytotoxicity symptoms started to appear in weed plants. Yellowing of foliage and subsequent necrosis were the common symptoms observed in weeds treated with penoxsulam + cyhalofop butyl 6 % OD @ 150 g ha^{-1}. Chlorosis was noticed till 10 days after spraying in weeds treated with metsulfuron methyl+ chloriumuron methyl @ 4g ha^{-1}. This was followed by general necrosis for 5 more days. Withering and browning from tip to base was noticed from 8-10 days after herbicide application in weeds treated with ethoxysulfuron @ 15g ha^{-1}.

Table 14. Effect of weed management practices on weed control efficiency at 15, 30, 45 and 60 DAS, per cent

Treatments	15 DAS	30 DAS	45 DAS	60 DAS
T_1	99.28 (10.01)	96.22 (9.86)	94.92 (9.79)	94.39 (9.77)
T_2	98.16 (9.96)	95.02 (9.80)	93.26 (9.71)	93.08 (9.70)
T_3	16.78 (4.14)	91.62 (9.62)	97.42 (9.21)	94.46 (9.77)
T_4	18.50 (4.32)	93.55 (9.72)	99.54 (10.03)	98.85 (9.99)
T_5	18.49 (4.41)	93.13 (9.70)	98.98 (10.00)	97.22 (9.91)
T_6	15.62 (4.05)	90.86 (9.58)	97.25 (9.91)	96.01 (9.85)
T_7	14.78 (3.95)	95.82 (9.84)	96.01 (9.85)	96.88 (9.89)
T_8	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
SE(m)$\pm$	0.36	0.02	0.01	0.01
CD (0.05)	1.116	0.05	0.027	0.033

The data subjected to square root transformation and transformed valu es given in parentheses

4.2.2. Growth and yield attributes of crop

4.2.2.1. Plant height

Data pertaining to the influence of weed management practices on plant height at 30 DAS, 60DAS and harvest were analysed statistically and represented in Table 15.

4.2.2.1.1. Plant height at 30 DAS

At 30 DAS, plant height did not vary significantly with the weed control measures tested. Plant height ranged between 47.32 cm to 51.99 cm. The mean plant height at 30 DAS was observed to be 49.46 cm.

4.2.2.1.2. Plant height at 60 DAS

At 60 DAS**,** the weed management treatments tested had significant impact on plant height. Bensulfuron methyl + pretilachlor @ 60+600 g ha^{-1} fb HW at 35 and 40 DAS (T_1) resulted in greater plant height of 86.31 cm. Plant heights observed in T_2 (86.09 cm), T_4 (85.33 cm) and T_7 were statistically on par with T_1. Plants present in weedy check (T_8) reported lower height of 77.74 cm.

4.2.2.1.3. Plant height at harvest

At the time of harvest, plant height differed significantly with the weed control measures evaluated. Taller plants (109.33 cm) were observed in penoxsulam + cyhalofop butyl 6 % OD @ 150 g ha^{-1} at 20 DAS fb HW at 35 to 40 DAS (T_4)which is at par with (T_1)bensulfuron methyl+ pretilachlor @ 60+600 g ha-^{1} fb HW at 35 to 40 DAS (107.58 cm). Shorter plants (92 cm) were observed in weedy check (T_8).

4.2.2.2. Number of panicles m^{-2}

Data pertaining to the impact of weed control practices on number of productive tillers m^{-2} were statistically analysed and depicted n Table 16.

Table 15. Effect of weed management practices on plant height at 30, 60 DAS and at harvest, cm

Treatments	30 DAS	60 DAS	At harvest
T_1	51.99	86.31	107.58
T_2	50.82	86.10	104.55
T_3	48.09	79.95	107.19
T_4	48.24	85.33	109.33
T_5	47.32	82.23	105.19
T_6	49.87	82.14	101.98
T_7	51.49	84.55	105.64
T_8	47.86	77.74	92.00
SE(m)$\pm$	1.31	0.95	0.69
CD (0.05)	-	2.915	2.123

Under wet seeded condition the weed control practices had considerable influence on the number of productive tillers m^{-2}. Pre-emergent application of bensulfuron methyl + pretilachlor @ 60+600 g ha^{-1} fb HW at 35 - 40 DAS (T_1) resulted in higher productive tillers m^{-2} (320) which is at par with penoxsulam + cyhalofop butyl 6 % OD @ 150 g ha^{-1} at 20 DAS fb HW at 35 to 40 DAS(T_4) with 308 panicles m^{-2}. Though HW at 20 and 40 DAS (T_7) resulted in the production of 292 panicles m^{-2} it was not comparable with T_1 and T_4. Lowest number of productive tillers m-^{2} (107.67) was recorded in weedy check plot (T_8). The reduction in number of panicle m^{-2} in unweeded plot was 66.56 per cent when compared to the best treatment bensulfuron methyl + pretilachlor @ 60+600 g ha^{-1} fb HW at 35 - 40 DAS (T_1).

4.2.2.3. Number of grains per panicle

The variations in number of grains per panicle as influenced by weed control practices were statistically evaluated and furnished in Table 16.

The treatments displayed significant impact on the number of grains per panicle. Penoxsulam + cyhalofop butyl 6 % OD @ 150 g ha^{-1} at 20 DAS fb HW at 35 - 40 DAS (T_4) was superior to remaining treatments with 177 grains per panicle and was on par with T_1 (bensulfuron methyl + pretilachlor @ 60+600 g ha^{-1} fb HW at 35 - 40 DAS), T_5 (metsulfuron methyl + chlorimuron ethyl @ 4gha^{-1} at 20 DAS fb HW at 35 - 40 DAS) and T_7 (HW at 20 and 40 DAS) with 173,170.67 and 170.33 grains per panicle, respectively. Lesser number of grains per panicle was noted in weedy check plot (105). The reduction in number of grains per panicle was about 40.68 per cent in un-weeded plot when compared to superior treatment (T_4).

4.2.2.4. Sterility percentage

Perusal of the data on influence of weed control practices on sterility percentage was statistically evaluated and documented in Table 16.

Applied weed control measures exhibited significant impact on sterility percentage in wet seeded rice. The herbicide combination bensulfuron methyl + pretilachlor @ 60+600 g ha^{-1} fb HW at 35 - 40 DAS (T_1) reported lower sterility

Table 16. Effect of weed management practices on yield attributes of rice

Treatments	No. of panicles m-^{2}	No. of grains per panicle	Sterility percentage	Thousand grain weight(g)
T_1	320.00	173.00	13.34	24.90
T_2	271.00	161.67	15.04	23.90
T_3	252.00	158.00	14.50	24.90
T_4	308.33	177.00	13.93	24.33
T_5	289.34	170.67	15.43	24.63
T_6	256.33	162.00	16.08	24.72
T_7	292.00	170.33	14.31	25.14
T_8	107.67	105.00	16.93	23.27
SE(m)$\pm$	4.68	3.93	0.24	0.38
CD (0.05)	14.346	12.043	0.733	-

percentage (13.24) and was at par with penoxsulam + cyhalofop butyl 6 % OD @ 150 g ha^{-1} at 20 DAS fb HW at 35 - 40 DAS (T_4) with sterility percentage of 13.93 per cent while a higher sterility percentage of 16.93 was reported in weedy check treatment (T_8).

4.2.2.5. Thousand grain weight

Data pertaining to the influence of weed control practices on thousand grain weight were statistically evaluated and represented in Table 16.

The treatments applied did not show any significant impact on thousand grain weight. Thousand grain weight values were noticed in a range between 24.9 to 23.27g for Uma variety under wet seeded rice.

4.2.2.6. Grain yield

Grain yield acquired from the experimental plots were analysed statistically and depicted in Table 17.

The results revealed that weed management practices had significant influence on grain yield of direct seeded rice in wetlands. Bensulfuron methyl + pretilachlor @ 60+600g ha^{-1} at 5 DAS fb HW at 35-40 DAS (T_1) recorded higher grain yield of 5461 kg ha^{-1} which is at par with T_4 recording 5355 kg ha^{-1}. The plots which received HW twice at 20 and 40 DAS registered a grain yield of 5204 kg ha^{-1} and was at par with T_5 (metsulfuron methyl + chlorimuron ethyl @ 4g ha^{-1} at 20 DAS fb HW at 35-40 DAS (5091 kg ha^{-1}). Grain yield reported in ethoxysulfuron @15 g ha^{-1} at 20 DAS fb HW at 35-40 DAS (T_6), pyrazosulfuron ethyl @ 25g ha^{-1} at 5 DAS fb HW at 35-40 DAS (T_2), bispyribac sodium @ 25 g ha^{-1} at 15-20 DAS fb HW at 35-40 DAS (T_3) were 4750, 4601 and 4371 kg ha^{-1}. The lowest grain yield was observed in weedy check (2101 kg ha^{-1}).

4.2.2.7. Straw yield

The data gathered regarding straw yield from experimental plots were analysed statistically and furnished in Table 17.

Table 17. Effect of weed management practices on grain yield, straw yield, harvest index (HI) and weed index (WI)

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index	Weed index (%)
T_1	5461	7710	0.42	-5.14
T_2	4601	6715	0.41	8.98
T_3	4371	6562	0.40	15.95
T_4	5355	7646	0.42	-2.96
T_5	5091	7339	0.41	2.18
T_6	4750	6829	0.41	8.75
T_7	5204	7177	0.42	0.00
T_8	2101	4692	0.31	59.75
SE(m)$\pm$	70.75	152.99	0.01	1.92
CD (0.05)	216.677	468.564	0.025	5.892

Weed management practices showed a significant influence on straw yield of wet seeded rice. Bensulfuron methyl +pretilachlor @60+600g ha^{-1} at 5 DAS fb HW at 35-40 DAS (T_1) reported higher straw yield of 7710 kg ha^{-1} and was at par with T_4 with 7646 kg ha^{-1} and T_5 with 7339 kg ha^{-1}. The lowest straw yield was recorded in weedy check (T_8) with 4692 kg ha^{-1}.

4.2.2.8. Weed index

The degree of reduction in yield by weeds were assessed taking hand weeding twice as the control treatment, analysed statistically and represented in Table 17.

Reduction in yield by infestation of weed flora differed with the effectiveness of treatments. When compared with the control treatment of HW twice at 20 and 40 DAS (T_7), herbicide applied treatments showed superiority with negative values for weed index. Bensulfuron methyl +pretilachlor @60+600g ha^{-1} at 5 DAS fb HW at 35-40 DAS (T_1), penoxsulam+cyhalofop butyl 6 % OD @ 150 g ha^{-1} at 20 DAS fb HW at 35-40 DAS (T_4) exhibited superiority with negative reduction in grain yield (- 5.14 and -2.96, respectively) due to weeds. In weedy check (T_8), higher yield reduction of 59.75 per cent was noticed.

4.2.2.9. Harvest index

By using the data pertaining to grain and straw yield, harvest index was calculated and analysed statistically and documented in Table 17.

Under wet seeded condition, weed management practices have significant effect on harvest index. Higher harvest index of 0.42 was recorded in bensulfuron methyl +pretilachlor @60+600g ha^{-1} at 5 DAS fb HW at 35-40 DAS (T_1), penoxsulam+cyhalofop butyl 6 % OD @ 150 g ha^{-1} at 20 DAS fb HW at 35-40 DAS (T_4) and HW twice at 20 and 40 DAS (T_7). A lower harvest index of 0.31 was recorded in unweeded control.

4.2.2.10. Disease and pest incidence

Incidence of sheath blight disease (*Rhizoctonia solani*) was noticed at vegetative stage and was scored 3 (20-30 per cent damage) in the standard evaluation system (SES) (IRRI, 2013). Incidence of rice stem borer (*Scirpophaga incertulas*) was noticed at tillering and grain filling stages exhibiting dead heart and white ear head symptom, respectively and was scored 1 (1-5 per cent) in the SES at both stages developed by IRRI (2013). Incidence of rice bug (*Leptocorisa acuta*) at milk stage of the crop was noticed and was scored 7 (12-25 per cent damage) in the SES developed by International Rice Research Institute (IRRI, 2013). The SES by IRRI is given in appendix II.

4.2.3. Chemical analysis

4.2.3.1 Nutrient content of crop

Influence of the treatments on the N, P and K content of crop was analysed statistically and depicted in Table 18.

The weed management practices could not exert any significant influence on the N, P and K content of the crop.

4.2.3.2. Nutrient content of weed

Influence of weed control practices on N, P and K content of the weed was analysed statistically and presented in Table 19.

The results showed that the weed management practices had no significant effect on N, P and K content of weed. N content of weed samples varied from 1.896 to 2.147 per cent, P content varied from 0.146 to 0.171 per cent and K content was noticed to vary from 2.398 to 2.524 per cent.

Table 18. Effect of weed management practices on N, P and K content present in the crop, per cent

Treatments	N content	P content	K content
T_1	1.195	0.078	2.833
T_2	1.188	0.073	2.679
T_3	1.153	0.077	2.679
T_4	1.188	0.082	2.814
T_5	1.176	0.072	2.796
T_6	1.184	0.080	2.673
T_7	1.181	0.081	2.690
T_8	1.169	0.063	2.649
SE(m)$\pm$	0.04	0.01	0.04
CD (0.05)	NS	NS	NS

Table 19. Effect of weed control practices on N, P and K content in the weeds, per cent

Treatments	N content	P content	K content
T_1	1.90	0.15	2.44
T_2	2.09	0.16	2.47
T_3	2.10	0.17	2.52
T_4	1.98	0.15	2.37
T_5	1.96	0.17	2.43
T_6	2.12	0.17	2.44
T_7	1.90	0.16	2.40
T_8	2.15	0.15	2.40
SE(m)$\pm$	0.10	0.01	0.06
CD (0.05)	NS	NS	NS

4.2.3.3. Nutrient uptake by the crop

Perusal of the data on effect of treatments on nutrient uptake by the crop are depicted in Table 20.

Nutrient uptake by the crop was noticed to be influenced by the weed management options followed.

4.2.3.3.1. N uptake

Highest N uptake by the crop was registered in T_1 (157.44 kg ha^{-1}) and was at par with T_4, T_7 and T_5 (154.53, 146.70 and 145.80 kg ha^{-1}), respectively. Unweeded control (T_8) reported the lowest N uptake of 79.63 kg ha^{-1}.

4.2.3.3.2. P uptake

P uptake by the crop was higher in plots treated with T_1 (10.72 kg P ha^{-1}) and was at par with T_4 and T_7 (10.24 and 10.14 kg ha^{-1}, respectively). It was followed by T_6 (9.32) which is at par with T_3, T_5 and T_2 with 9.08, 8.92 and 8.34 kg ha^{-1}, respectively. Unweeded plot (T_8) resulted in lesser P uptake of 4.28 kg ha^{-1}.

4.2.3.3.3. K uptake

A higher K uptake of 373.29 kg ha^{-1} was recorded in T_1 which is at par with T_4 and T_5 (366.01 and 346.72 kg ha^{-1} respectively). It was followed by T_7 and at par with T_6 with K uptake of 333.78 and 309.77 kg ha^{-1}, respectively. Lesser K uptake of 180.19 kg ha^{-1} was recorded in un-weeded control plot (T_8).

4.2.3.4. Nutrient removal by the weed

The variations in nutrient removal by the weed with the treatments are presented in Table 21.

Nutrient removal by the weeds were noticed to be influenced by the weed management options followed.

Table 20. Effect of weed management practices on dry matter production and N, P and K uptake by the crop

Treatments	Dry matter ($t\ ha^{-1}$)	N uptake ($kg\ ha^{-1}$)	P uptake ($kg\ ha^{-1}$)	K uptake ($kg\ ha^{-1}$)
T_1	13.17	157.44	10.72	373.29
T_2	11.32	134.74	8.34	303.54
T_3	10.93	126.21	9.08	293.5
T_4	13.00	154.53	10.24	366.01
T_5	12.37	145.80	8.92	346.72
T_6	11.58	137.46	9.32	309.77
T_7	12.38	146.70	10.14	333.78
T_8	6.79	79.63	4.28	180.19
SE(m)$\pm$	0.18	6.51	0.38	8.61
CD (0.05)	0.567	19.941	1.154	26.366

Table 21. Effect of weed management practices on N, P and K removal by the weeds, kg ha^{-1}

Treatments	N removal	P removal	K removal
T_1	4.86	0.37	6.23
T_2	7.38	0.55	8.71
T_3	9.44	0.74	11.01
T_4	4.62	0.34	5.51
T_5	5.97	0.50	7.39
T_6	8.31	0.69	9.58
T_7	12.01	1.02	15.21
T_8	43.05	3.08	48.28
SE(m)$\pm$	0.72	0.06	0.93
CD (0.05)	2.213	0.175	2.852

4.2.3.4.1. N removal

N removal by the weed in T_4 reported the lowest removal of N (4.617 kg ha^{-1}) and was at par with T_1 and T_5 (4.86 and 5.97 kg N ha^{-1}, respectively). It was followed by T_2 that was at par with T_6 and T_3 reporting N removal of 7.38, 8.31 and 9.44 kg N ha^{-1}. T_7 reported N removal of 12.01 kg N ha^{-1}. Significantly higher N removal was reported in T_8 un-weeded control (43.05 kg N ha^{-1}).

4.2.3.4.2. P removal

Perusal of data on the effect of the treatments on P removal revealed that removal by the weed was lesser in T_4 (penoxsulam+cyhalofop butyl 6 % OD @ 150 g ha^{-1} at 20 DAS fb HW at 35-40 DAS 0.34 kg P ha^{-1}) and was at par with T_1, T_5 and T_2 (0.37. 0.50 and 0.55 kg P ha^{-1}, respectively). It was followed by T_6 which is at par with T_3 with P removal of 0.69 and 0.74 kg ha^{-1}, respectively. Weeds present in unweeded control (T_8) resulted in significantly higher P removal of 3.08 kg ha^{-1}.

4.2.3.4.3. K removal

The results revealed the significant influence of weed management on K removal. The lowest K removal of 5.51 kg ha^{-1} was noticed in plot treated with penoxsulam + cyhalofop butyl 6 % OD @ 150 g ha^{-1} at 20 DAS fb HW at 35-40 DAS (T_4) which is at par with T_1 and T_5 (6.23 and 7.39 kg ha^{-1}), respectively. It was followed by T_2 and at par with T_6 and T_3 with K removal of 8.71, 9.58 and 11.01 kg ha^{-1}, respectively. Significantly higher K removal of 48.28 kg ha^{-1} was recorded in un-weeded control (T_8).

4.2.3.5. Available N P and K status in soil after the experiment

Effect of weed management practices on availability of N, P and K status in soil are represented in Table 22.

The results revealed that weed management practices had no significant effect on available nitrogen, phosphorus and potassium status in soil after the experiment. Soil present in the experimental site was low in available N (273.97 kg ha^{-1}) before

Table 22. Effect of weed management practices on available N, P and K status of the soil, kg ha^{-1}

Treatments	Available N	Available P	Available K
T_1	197.23	33.74	194.86
T_2	167.84	32.64	142.99
T_3	134.51	30.77	138.43
T_4	188.86	34.37	188.53
T_5	176.20	33.42	170.05
T_6	147.05	31.55	135.07
T_7	159.59	33.58	178.90
T_8	117.78	29.84	139.44
SE(m)$\pm$	19.28	1.04	16.10
CD (0.05)	NS	NS	NS

commencement of experiment. After the completion of experiment, N available in the soil was noticeably lowered with values varied between 117.78 to 197.23 kg ha^{-1}.

Before the commencement of the experiment the status of P availability was high (38.80 kg ha^{-1}) and K availability status was medium (238 kg ha^{-1}). After the experiment, available P status in the soil ranged from 29.84 to 34.37 kg ha^{-1} and 135.07 to 194.86 kg ha^{-1}, respectively.

4.2.4. Economic analysis

Tables 23 shows the results of economic analysis of the effect of weed management practices on wet seeded rice cultivation

4.2.4.1. Net income

The data on net income indicated that weed management practices exerted a significant influence on the net income of broadcasted wet seeded rice. A higher net income of Rs.74,320 was registered from bensulfuron methyl + pretilachlor @60+600g ha^{-1} at 5 DAS fb HW at 35-40 DAS (T_1). Plots that received HW at 20 and 40 DAS (T_7) received a net income of Rs.52, 186. Unweeded plots (T_8) recorded a net loss of Rs. 1770.

4.2.4.2. B: C ratio

Effect of weed management practices on the benefit: cost ratio of wet seeded rice cultivation was computed and results are presented in Table 23.

From the results, it was evident that weed management practices had a significant influence on the benefit: cost ratio of wet seeded rice cultivation. Plots treated with bensulfuron methyl +pretilachlor @60+600g ha^{-1} at 5 DAS fb HW at 35-40 DAS (T_1) recorded higher B: C ratio of 1.83. While HW twice at 20 and 40 DAS (T_7) realized a B: C ratio of 1.50. Weedy check (T_8) recorded a lower B: C ratio of 0.97.

Table 23. Effect of weed management practices on economics of cultivation (Rs ha^{-1})

Treatments	Cost of cultivation (Rs ha^{-1})	Gross income (Rs ha^{-1})	Net income (Rs ha^{-1})	B:C ratio
T_1	89,831	1,64,151	74,320	1.83
T_2	88,304	1,39,392	51,088	1.58
T_3	89,726	1,33,343	43,617	1.49
T_4	90,876	1,61,385	70,509	1.77
T_5	88,519	1,53797	65,278	1.74
T_6	87,980	1,43,387	55,407	1.63
T_7	1,03,404	1,55,590	52,186	1.50
T_8	73560	71,790	-1770	0.97

4.3. EXPERIMENT III: ALLELOPATHIC EFFECT OF GOOSE WEED ON GERMINATION AND GROWTH OF RICE

Allelopathic influence of *Sphenoclea zeylanica* on germination and seedling growth of rice was observed and results are furnished in Table 24.

4.3.1. Germination at 4 DAS

At 4 DAS, aqueous extract of dry plant parts of *Sphenoclea zeylanica* recorded significant inhibitory influence on germination of rice seedlings. Rice seeds treated with dry leaves aqueous extract 10% (T_2) reported 88.11 per cent reduction in germination which is at par with dry inflorescence aqueous extract 10% (T_6) with a reduction of 79.02 per cent when compared to control (distilled water). Aqueous extract of fresh plant parts like leaves, stem and whole plant exerted the least inhibitory influence (0.63 per cent) on rice seed germination during the initial stage.

4.3.2. Germination at 14 DAS

At 14 DAS, the inhibitory influence of aqueous extract of *Sphenoclea zeylanica* was pronounced for the treatments T_2 and $T_{6.}$ These treatments recorded a germination percentage of 7.33 and 14 while that of control was100 per cent. No significant difference was observed between allelopathic effect of goose weed plants before and after flowering. The effect of other treatments on germination percentage of rice was not significant.

4.3.3. Fresh weight

The results revealed that aqueous extract of *Sphenoclea zeylanica* had significant inhibitory influence on fresh weight of rice seedlings. Significant reduction in fresh weight of seedlings was registered with dry plant parts. Aqueous extract of dry leaves(T_2) and inflorescence (T_6) reported lower fresh weight of seedlings (3 and 4.6 mg) and at par with each other with inhibition rate of 97 and 95.98 per cent, respectively compared to control. The growth stage of weed plant didn’t exhibit an influence on its allelopathic property.

Table 24. Allelopathic effect of *Sphenoclea zeylanica* on germination percentage, fresh weight and dry weight of rice

Treatments	Germination percentage		Fresh weight (mg plant^{-1})	Dry weight (mg plant^{-1})
	4 DAS	14 DAS		
T_1: fresh leaves aqueous extract 10%	94.67 (9.78)	91.33 (9.61)	91.30	14.70
T_2: dry leaves aqueous extract 10%	11.33 (3.06)	7.33 (2.85)	3.00	0.50
T_3: fresh stem aqueous extract 10%	94.67 (9.78)	96.67 (9.88)	84.26	14.00
T_4: dry stem aqueous extract 10%	87.33 (9.39)	91.33 (9.60)	81.70	15.10
T_5: fresh inflorescence aqueous extract 10%	90.66 (9.57)	96.67 (9.88)	73.00	15.90
T_6: dry inflorescence aqueous extract 10%	20.00 (4.34)	14.00 (3.86)	4.60	0.60
T_7: fresh whole plant aq. extract before flowering 10%	88.67 (9.46)	94.00 (9.74)	83.00	15.10
T_8: fresh whole plant aq. extract after flowering 10%	94.67 (9.57)	93.33 (9.71)	78.10	15.20
T_9: distilled water (control).	95.33 (9.81)	100 (10.05)	114.70	16.30
SEm (±)	0.53	0.18	6.39	0.63
CD (0.05)	1.602	0.553	19.125	1.890

The data were subjected to square root transformation and transformed values are given in parenthesis

4.3.4. Dry weight

The growth suppression was more pronounced in terms of dry weight of seedlings. Lower dry weight of seedlings was observed in T_2 and T_6 with 0.5 and 0.6 mg per seedling and these were on par among themselves. The influence of other treatments was not significant.

4.3.5. Shoot length

Significant reduction in shoot length of seedlings was observed in T_2 (3.7 cm) and T_6 (3.99 cm) compared to control (9.48 cm). Percentage reduction in shoot length when compared to control was 60.97 per cent with dry leaves aqueous extract and 57.91 per cent in dry inflorescence aqueous extract. Aqueous extract of fresh stem (8.93 cm) and whole plant before flowering (9.43cm) do not exert any significant effect on shoot length and was at par with control (9.48 cm).

4.3.6. Root length

Aqueous extract of dry leaves of *Sphenoclea zeylanica* could cause a drastic reduction in root length of rice seedlings registering a root length of 0.75 cm. The inhibition percentage was as high as 93.33 per cent when compared to control. Aqueous extracts of fresh plant parts recorded root lengths which were on par with each other.

4.3.7. Vigour Index

A drastic reduction in vigour index (98.35 per cent) was noticed for treatment with dry leaves aqueous extract (34.07) compared to control (2073.67). This was followed by dry inflorescence aqueous extract with a VI of 105.56. The VI values recorded by fresh plant parts of *Sphenoclea zeylanica* except leaves were on par with each other.

Table 25. Allelopathic effect of *Sphenoclea zeylanica* on shoot length, root length and vigour index of rice

Treatments	Shoot length (cm)	Root length (cm)	Vigour index (VI)
T_1: fresh leaves aqueous extract 10%	8.22	8.68	1545.11
T_2: dry leaves aqueous extract 10%	3.70	0.75	34.07
T_3: fresh stem aqueous extract 10%	8.93	9.26	1758.12
T_4: dry stem aqueous extract 10%	8.33	7.54	1444.27
T_5: fresh inflorescence aqueous extract 10%	7.61	8.08	1517.52
T_6: dry inflorescence aqueous extract 10%	3.99	3.47	105.56
T_7: fresh whole plant aq. extract before flowering 10%	9.43	9.22	1754.05
T_8: fresh whole plant aq. extract after flowering 10%	8.21	9.27	1635.92
T_9: distilled water (control)	9.48	11.25	2073.67
SEm(±)	0.33	0.31	61.20
CD (0.05)	0.986	0.929	183.233

DISCUSSION

5. DISCUSSION

Weed management is one of the most important aspects in crop production. *Sphenoclea zeylanica* Gaertner commonly called ‘goose weed’ is one among the emerging troublesome weeds in lowland rice fields of Kerala. Understanding the biological aspects becomes more significant in formulating new management practices. The allelopathic effect of the weed is another area of concern. In this chapter an attempt has been made to critically discuss the results of the experiments conducted with these objectives.

5.1 WEED BIOLOGY

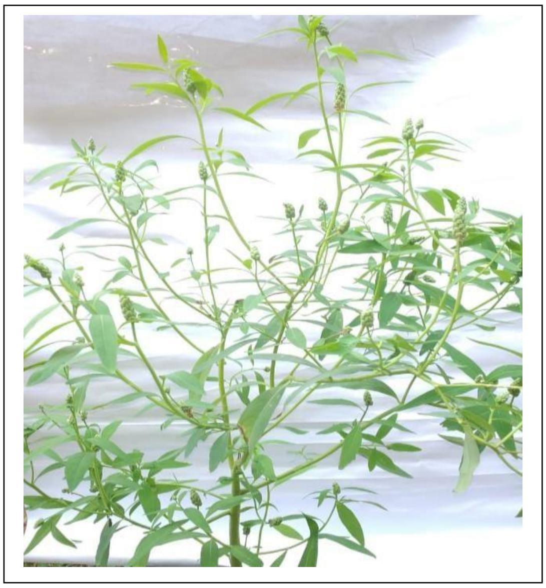
Weed biology is related to the study of weeds in relation to their geographic distribution, habitat, growth and population dynamics of weed species and communities (Rao, 2000). Information on weed biology provide key information on mode of propagation, susceptible stage of management and in turn will help to strengthen the management strategies. To learn the weed biology, ten randomly selected sample plants present in the weedy check plots of experimental field were observed from germination till maturity.

5.1.1. Phenology of goose weed

Goose weed or *Sphenoclea zeylanica* Gaertner belonging to Sphenocleaceae family has been reported to be a problematic weed in rice fields globally. Holm *et al.* (1977) reported it as one among the world’s worst weeds. IRRI (2020b) listed *Sphenoclea zeylanica* as one amongst the dirty dozen weeds and also in twelve most troublesome weeds under Asian rice field conditions. In the low land paddy fields, Goose weed was noticed to develop through 5 phenological stages in its life cycle. These included germination, seedling, flowering, spike maturity and plant maturity (Plate 1).

Seedling stage

Flowering stage



Stage of spike maturity

Mature plant of *S. zeylanica*

Plate 1. Different growth stages of *Sphenoclea zeylanica*

In the present study, growth of *Sphenoclea zeylanica* was observed upto maturity. In the puddled fields germination of the weed started from second day and continued upto 7 days after wet seeding. It was observed to start flowering from 10th day after emergence and continued till the end of its life cycle with some plants requiring 24 days to flower, with an average of 15 days to initiate flowering. The first formed spikes got matured within a month with an average maturity period of 36 days. The first lot of emerged plants completed its life cycle within 60 days with later emerged ones attaining maturity within 81 days. Shorter time span for emergence, flowering and spike maturity could thus ensure persistent and heavy infestation of goose weed in the field and can possibly reduce the rice yields. Saha and Rao (2010) reported higher weed densities of *S. zeylanica* when compared to other weeds at all growth stages of wet seeded rice. Moorthy and Manna (1985) reported that reduction in rice yields was 32-50 per cent due to goose weed infestation in wet seeded rice in India.

In the present investigation, the weed was observed to grow submerged, emergent or terrestrial along the water channels, bunds and with the crop in rice field. Cook (1996) reported the presence of goose weed in almost any kind of moist soil or on low riverbanks, along ditches, marshes, dry riverbeds, ponds, lowland- irrigated and rainfed rice fields. Along with lowlands, goose weed was also documented to inhabit, shallow margins of lakes and ponds, ditches, stream banks, wet disturbed soils, sandbars etc. according to Carter *et al.* (2014). It is often gregarious becoming a troublesome weed in rice fields.

5.1.2. Vegetative characteristics of goose weed

Sphenoclea zeylanica was observed to grow as an erect herbaceous branched annual with cylindrical stem that grew upto 104 cm height (Plate 2). Shoots were hollow with circular cross section. The leaves were alternate and arranged spirally. Holm *et al.* (1977) described *S. zeylanica* as a fleshy annual herb with erect stems often much-branched with a height ranging from 7 to 150 cm. *Sphenoclea zeylanica* recorded a mean shoot dry weight of 19.698g contributing to a dry matter production of 26.24 g per plant. The average biomass production per ha as noticed from the unweeded control plots was 3.75 t.

Being a tap rooted annual, the roots of goose weed extended to a depth of 29.84 cm with mean root dry weight of 6.55 g. The roots were found to be numerous, whitish to brown in colour with a spongy texture. Under submerged conditions, roots were observed to emerge from lower nodes. Similar observations were recorded by Carter *et al*. (2014) regarding rooting from lower nodes under submerged situation.

5.1.3. Reproductive characteristics of goose weed

The inflorescence of *Sphenoclea zeylanica* is observed to be born at the tip of the branches as a dense spike. The spike is cylindrical in shape and the progress of development was noticed from the base to tip. Number of spikes in each plant at maximum growth stage ranged in between 45-48 with an average spike length of 4.26 cm. Flower were sessile, bisexual and white in colour. The flowers were observed to bloom and mature from the basal part of spike. Each spike consisted of 56-69 fruits with each fruit or capsule carrying numerous seeds. These observations were in line with the reports of Carter *et al.* (2014) who described inflorescence of goose weed as terminal spike in dense acropetal, narrowly ovoid to cylindrical shape with white flowers (Plate 3).

One of the major attributes of weeds that decide their competing ability is the capacity to produce huge quantity of seeds. The tiny seeds observed within the capsule were white in colour at the time of formation and turned yellowish brown on maturity. On maturity, the capsule dehisced and the seeds were dispersed through air into the soil and water. As per the reports of CABI (2020), the seeds of goose weed are extremely small with a length of 0.5 mm and yellowish-brown colour. General description of goose weed is tabulated and presented in Table 26.

Goose weed and rice plant

Root of *Sphenoclea zeylanica*

Plate 2. Vegetative and root characters of *Sphenoclea zeylanica*

Flower of *S. zeylanica*

Dehiscence of fruits

Different stages of spike maturity

Plate 3. Floral characteristics of *Sphenoclea zeylanica*

5.1.4. Propagation

Sphenoclea zeylanica propagated mainly through the seeds as evident from its germination and emergence within 3 to 7 days following wet seeding. It was seen that almost every flower in every inflorescence set fruit and carried seeds. One or two flowers were seen open at once on any one head as seen in Plate 4. These factors coupled with the periodic dehiscence of individual capsules releasing seeds on to the soil and water might lead to the build-up of a seed bank in soil. The extremely small disseminules get dispersed in mud and water and perhaps also by other means. As the number of seeds produced is negatively correlated with seed size, the seeds produced by each plant was enormous. The seeds were oblong in shape, cream to off white in colour resembling poppy seeds when immature and turned yellowish brown on maturity. This is in agreement with the observations of Carter *et al.* (2014) that the seeds are numerous, oblong in shape and 0.4 to 0.5 mm in size.

The emergence of *Sphenoclea zeylanica* was observed under submerged condition too. Pons (1982) mentioned about germination of goose weed under submergence and recorded more than 25 percentage germination under submergence of 20cm. Even though the weed seeds germinated in field within no time, seeds collected after harvest when kept in petri plates haven't germinated under controlled laboratory conditions. The inability to germinate might be due to the presence of dormancy in newly harvested seeds. Mercado *et al*. (1990) reported presence of seed dormancy in all the three strains of *Sphenoclea*. The results find ample support from the observations of Migo *et al.* (1986) where *S. zeylanica* germination was noticed only after 2-3 months of storage and the percentage of germination was 12 and 14 under greenhouse and laboratory conditions, respectively. The heavy seed bank deposit of previous seasons flush which have overcome dormancy might have contributed to the greater emergence of *S. zeylanica* under field conditions

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Seeds of *S. zeylanica* Seeds under microscopic magnification of 10x

Plate 4. Seed characteristics of *Sphenoclea zeylanica*

Table 26. General description of goose weed (*Sphenoclea zeylanica* Gaertner)

Characteristics	Description
Habit	Erect, annual, herbaceous often much-branched that grows up to a height of upto 104 cm
Habitat	Low land paddy fields, water channels, bunds and waterlogged areas
Leaves	Leaves are light green in colour with alternate arrangement spirally
Inflorescence	Terminal dense spikes that are ovoid to cylindrical in shape that grows and matures from base to tip
Season of flowering	Throughout the cropping season
Flowers	Sessile, bisexual and white in colour.
Seeds	Numerous, extremely small and yellowish-brown in colour.
Propagation	Through seeds

5.2. MANAGEMENT OF GOOSE WEED

Providing the field free of weeds during initial growth stages of crop plays a major role in determining the final yield (Johnson *et al.,* 2004). Even though manual weeding is effective, it is tedious, laborious and uneconomical because of high labour wages and identifying weeds in initial growth stages in broadcasted rice is a cumbersome process. Utilization of low dose high efficiency herbicides seems to be an attractive alternative for controlling weeds because of its lower application rates. In the present study, application of pre-emergent/early post emergent/post emergent herbicides each followed by manual weeding was evaluated for their efficiency in controlling *Sphenoclea zeylanica* under wet seeded conditions. Manual weeding twice at 20 and 40 DAS and weedy check were the control treatments.

5.2.1 Effect on weeds

5.2.1.1. Weed flora

During the cropping season, a variety of weed species belonging to the group of grasses, sedges and BLWs were identified in the field. Among these, goose weed (*Sphenoclea zeylanica*) Gartner was the predominant one seen up to the first 2.5 to 3 months. IRRI (2020b) listed *Sphenoclea zeylanica* as one amongst the dirty dozen weeds and twelve most troublesome weeds of Asian rice field conditions.

From the initial stages of crop emergence up to critical growth stages, BLWs dominated the rice field. Among BLWs, *Sphenoclea zeylanica* was predominant along with *Ludwigia parviflora, Bergia capensis, Lindernia rotundifolia, Alternanthera sessilis, Limnocharis flava* and *Monochoria vaginalis* while *Ludwigia parviflora* dominated during later stages. Saha and Rao (2010) also stated the domination of BLW population, especially *Sphenoclea zeylanica* Gartner under wet seeded condition. Sedges commonly associated with the crop were *Fimbristylis miliacea, Cyperus difformis and Cyperus iria.* Grasses like *Echinochloa colona, Leptochloa chinensis* and *Ischaemum rugosum* were seen from initial stages and *Oryza sativa f spontanea* was observed from 60 DAS onwards.

Seedling stage

Active tillering stage

Flowering stage

At harvest

Plate 5. Crop at different growth stages in experimental field

Ludwigia parviflora

Bergia capensis

Lindernia rotundifolia

Alternanthera sessilis

Limnocharis flava

Echinochloa colona

Leptochloa chinensis

Fimbristylis miliacea

Cyperus iria

Plate 6. Weed flora associated with the crop in experimental field

5.2.1.2. Weed density

Puddling and wet seeding provide a favourable condition for flourishing of weed flora in wet seeded rice. Weed density indicates the number of weed plants per unit area. At 15 DAS, pre-emergent herbicide bensulfuron methyl +pretilachlor @60+600g ha^{-1} at 5 DAS registered 94.59 per cent reduction in weed density over unweeded control while early post emergent herbicide pyrazosulfuron ethyl @ 25g ha^{-1} at 5 DAS recorded 89.57 per cent reduction. Similar results were reported by Saha and Rao (2010) in wet seeded rice and Yakadri *et al.* (2016) on transplanted rice. Rest of the experimental plots reported higher weed densities at 15DAS owing to absence of application of any other treatment at the time of observation. During the critical stages, penoxsulam+cyhalofop butyl 6 % OD @ 150 g ha^{-1} at 20 DAS fb hand weeding at 35-40 DAS reported a significant decline in weed density with reduction in weed count of 98.78, 94.64 and 96.01 per cent respectively (Fig 3). Tall, healthy plants in penoxsulam+cyhalofop butyl treated plots could restrict the weed growth effectively. Singh *et al.* (2016) observed penoxsulam+cyhalofop butyl as an effective herbicide for controlling sedges, grasses and BLWs in transplanted rice. Accordingly, application of either bensulfuron methyl +pretilachlor or penoxsulam+cyhalofop butyl both fb HW could be effective in reducing weed density of *S. zeylanica* all over the cropping season.

At all crop growth stages, un-weeded plot resulted in higher weed densities. However, the data showed a declining trend in weed density from the initial count to that at harvest. The declining trend can be attributed to the completion of life cycle of some weeds and also could be due to the suppression of late emerged weeds by other competitive weeds. Upsurge in weed count per unit area led to heavy competition for nutrients, space, water and solar radiation.

5.2.1.3. Weed dry weight

Weed dry weight was statistically reduced by bensulfuron methyl + pretilachlor @60+600g ha^{-1} at 5 DAS for a month over other treatments as the effect of herbicides sprayed on 5th day prolonged till 30 DAS. In transplanted rice, Sureshkumar *et al.* (2016) stated that pre-emergent application of bensulfuron methyl + pretilachlor

@60+600g fb HW at 35 DAT reduced the weed count per unit area and weed dry weight effectively. At 15 and 30 DAS pyrazosulfuron ethyl @ 25g ha^{-1} at 5 DAS was on par with bensulfuron methyl + pretilachlor @60+600g ha^{-1} at 5 DAS and its effect lasted till 30 days. Yakadri *et al*. (2016) observed reduction in weed dry weight by application of pyrazosulfuron ethyl @ 25g ha^{-1} fb HW at 45 DAS. However, penoxsulam+cyhalofop butyl fb HW, registered lower dry weights at 45 and 60 DAS. (Fig 4) This is in agreement with the findings of Yadav *et al*. (2018) where penoxsulam+cyhalofop butyl @ 135 g ha^{-1} at 15-20 DAT gave effective control of sedges, grasses and BLWs resulting in lesser weed dry weights.

Amongst the treatments, weed dry weights in herbicide applied plots (T_4 and T_1) were 87.82 and 62.97 per cent lower than control plots with hand weeding twice indicating its supremacy over rest of the treatments. Singh *et al.* (2008) stated the common flaws in HW practices as easy regrowth and weed escape leading to its ineffectiveness. A steady progression in dry weights was recorded in unweeded plots from 15 to 60 DAS with dry weights of 12.20, 170.27, 306.10 and 400.84 g m^{-2} respectively. This progressive increase in dry weight parallel to decline in weed density could be ascribed to higher dry matter contribution from individual weeds.

5.2.1.4 Relative weed density of Sphenoclea zeylanica

Among the weed control methods, T_1 (bensulfuron methyl + pretilachlor fb HW) registered lesser relative weed density of *S. zeylanica* up to one month and later taken over by T_4 (penoxsualm + cyhalofop-butyl fb HW). Unweeded plot showed dominance of the weed over other flora with a relative density of 70.33 per cent. (Fig 5) Saha and Rao (2010) reported that bensulfuron methyl + pretilachlor controlled *S. zeylanica* effectively and reported a lower relative weed density of 1.44 per cent. Singh *et al.* (2016) observed that penoxsulam + cyhalofop butyl 6 % OD @ 150 g ha^{-1} gave an effective control of BLWs. As crop growth progressed, the relative density of *S. zeylanica* (37.36 per cent) also showed a decline from previous month as observed in un-weeded plot.

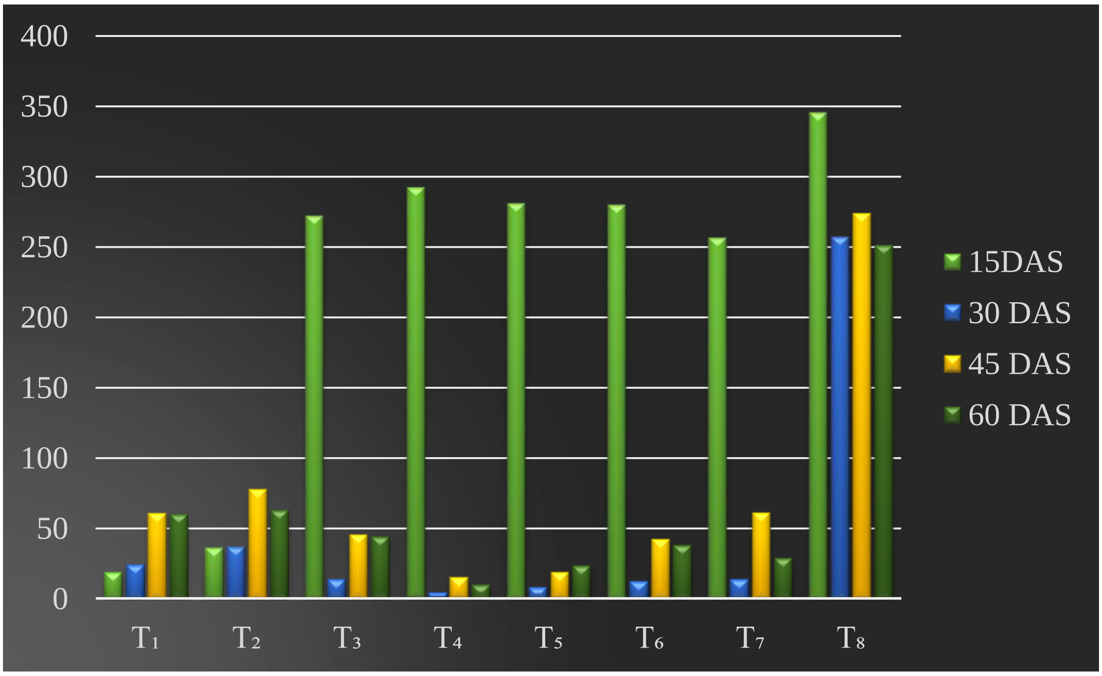


Fig 3. Effect of weed management practices on weed density at 15, 30, 45 and 60 DAS, number m^{-2}

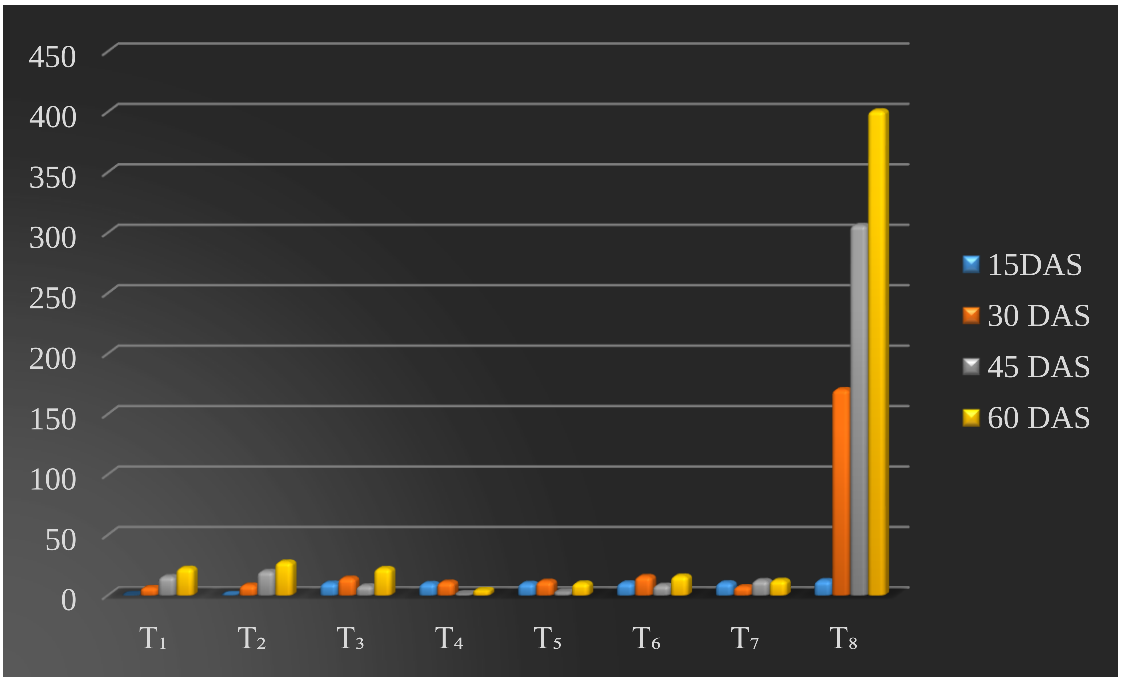


Fig 4. Effect of weed management practices on weed dry weight at 15, 30, 45 and 60 DAS, g m^{-2}

5.2.1.4 Relative weed density of Sphenoclea zeylanica

Among the weed control methods, T_1 (bensulfuron methyl + pretilachlor fb HW) registered lesser relative weed density of *S. zeylanica* up to one month and later taken over by T_4 (penoxsualm + cyhalofop-butyl fb HW). Unweeded plot showed dominance of the weed over other flora with a relative density of 70.33 per cent. (Fig 5) Saha and Rao (2010) reported that bensulfuron methyl + pretilachlor controlled *S. zeylanica* effectively and reported a lower relative weed density of 1.44 per cent. Singh *et al.* (2016) observed that penoxsulam + cyhalofop butyl 6 % OD @ 150 g ha^{-1} gave an effective control of BLWs. As crop growth progressed, the relative density of *S. zeylanica* (37.36 per cent) also showed a decline from previous month as observed in un-weeded plot.

5.2.1.5 Relative weed biomass of S. zeylanica

The mean dry matter accumulation of the weed in study followed the same trend as in relative weed count. Initially, application of bensulfuron methyl + pretilachlor resulted in lower dry matter accumulation of *S. zeylanica*. Later, dry matter accumulation of goose weed is effectively restricted by both penoxsulam + cyhalofop butyl and metsulfuron methyl + chlorimuron ethyl (Fig 6). Thus, it could be inferred that these three premix herbicide combinations are effective for the pre and post emergent control of *S. zeylanica.* Relative weed biomass was lesser in all the experimental plots except in un-weeded plot. The results are in accordance with findings of Yadav *et al* (2018).

5.2.1.6. Weed control efficiency

Weed control efficiency indicates the relative efficacy of weed management treatments over weedy check. Amongst the weed management treatments, higher WCE of 99.28 and 96.23 per cent was recorded in bensulfuron methyl + pretilachlor @60+600g ha^{-1} at 15 and 30 DAS. The superiority of bensulfuron methyl + pretilachlor @60+600g ha^{-1} as pre and early post emergence herbicide was evidenced with its lower

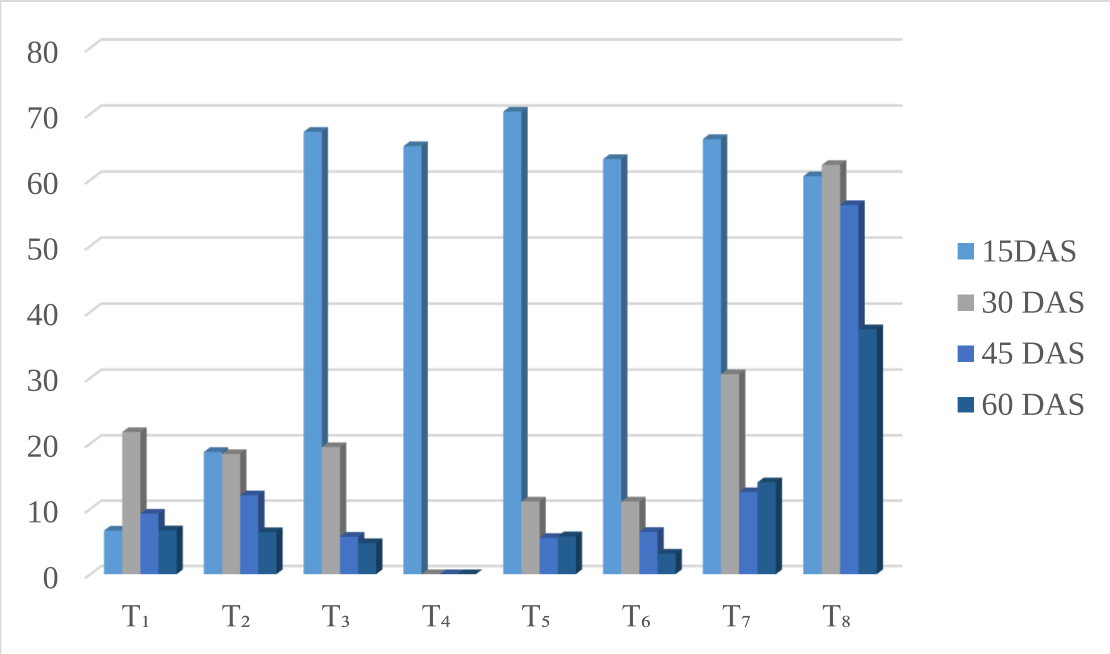


Fig 5. Effect of weed management practices on relative weed density of *Sphenoclea zeylanica* at 15, 30, 45 and 60 DAS, number m^{-2}

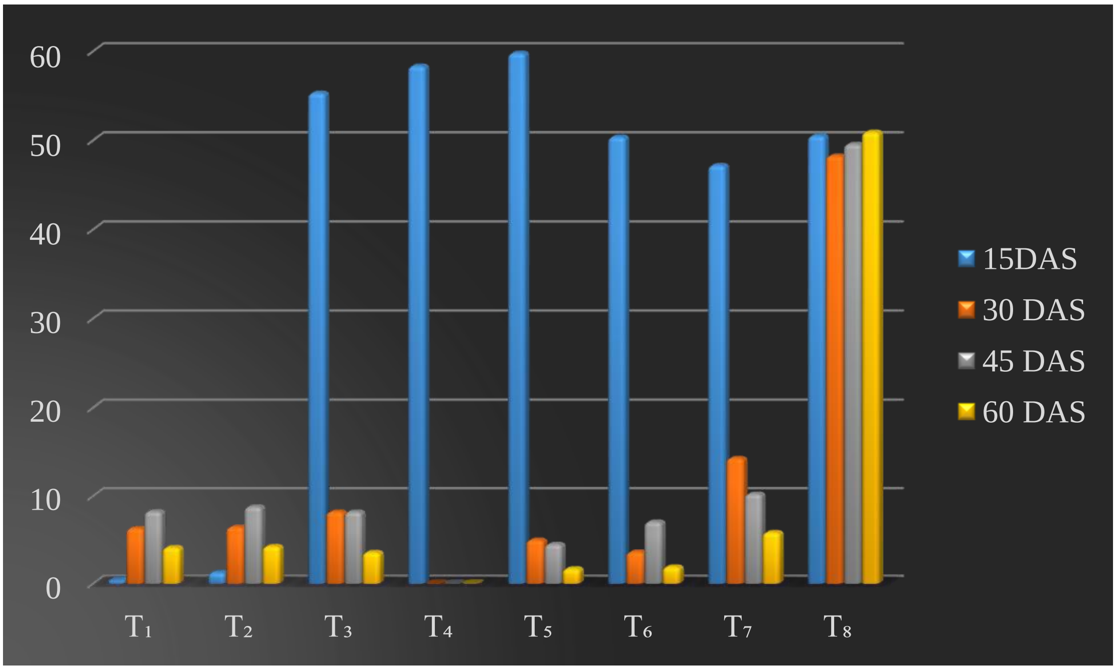


Fig 6. Effect of weed management practices on relative weed biomass of *Sphenoclea* at 15, 30, 45 and 60 DAS, g m^{-2}.

weed dry matter accumulation. The results find ample support from the findings of Saha and Rao (2010) in wet seeded rice and Arya and Ameena (2016) in dry sown direct seeded rice.

Pyrazosulfuron ethyl @ 25g ha^{-1} at 5 DAS was equally effective as bensulfuron methyl + pretilachlor @60+600g ha^{-1} at 5 DAS with WCE of 96.18 per cent and could be recommended for initial weed control in wet seeded rice. The findings of Ramesha *et al*. (2017) is in conformity. The premix herbicide penoxsulam+cyhalofop butyl applied at 20 DAS fb HW reported superior weed control efficiencies due to effective suppression of sedges, grasses and BLWs during initial stages of crop growth followed by manual weeding at late emerging weeds (Fig 7). These findings are similar with the results reported by Singh *et al*. (2016) with penoxsulam+cyhalofop butyl @ 150 g ha^{-1} in transplanted paddy.

5.2.1.7 Herbicide phytotoxicity on weeds

Phytotoxicity symptoms seen in weeds differ based on the active ingredient present in it. Yellowing and chlorosis were the first phytotoxicity symptoms shown by the weed plants in the plots treated with penoxsulam + cyhalofop butyl 6 % OD @ 150 g ha^{-1} and metsulfuron methyl+ chloriumuron methyl @ 4g ha^{-1}. Chlorosis was followed by necrosis of leaf margins and curling of midrib inwards with general necrotic symptoms which persisted till 15 days after herbicide spray. Later the affected plants decayed out. Browning and withering from tip to base was noticed in ethoxysulfuron @ 15g ha^{-1} treated plots from 7 days after application. This was in accordance with the reports of Vencill (2002) where sulfonyl urea herbicides led to wilting, chlorosis and subsequent necrosis in weed plants.

5.2.1.8 Nutrient removal by the weeds

Removal of nutrients by weeds results in lesser availability of nutrients to crop resulting in yield reduction. Higher nutrient content together with higher dry matter production will result in enormous nutrient removal by weeds (Fig 8). Nutrient removal by weeds were statistically influenced by weed management practices. Removal of N, P

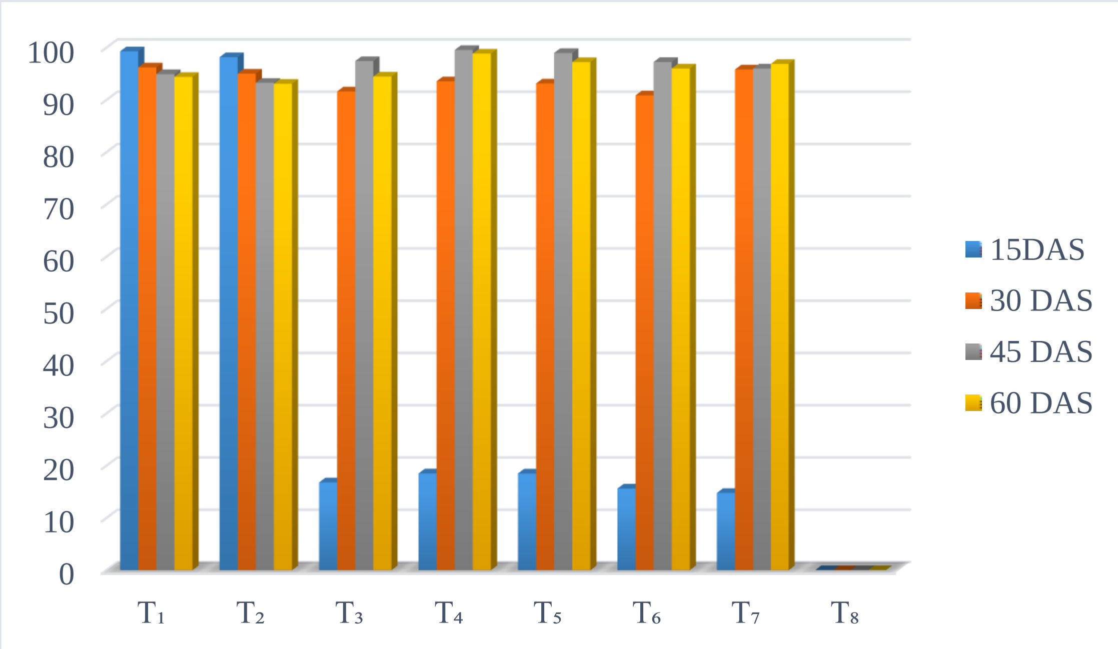


Fig 7. Effect of weed management practices on weed control efficiency at 15, 30, 45 and 60 DAS, per cent

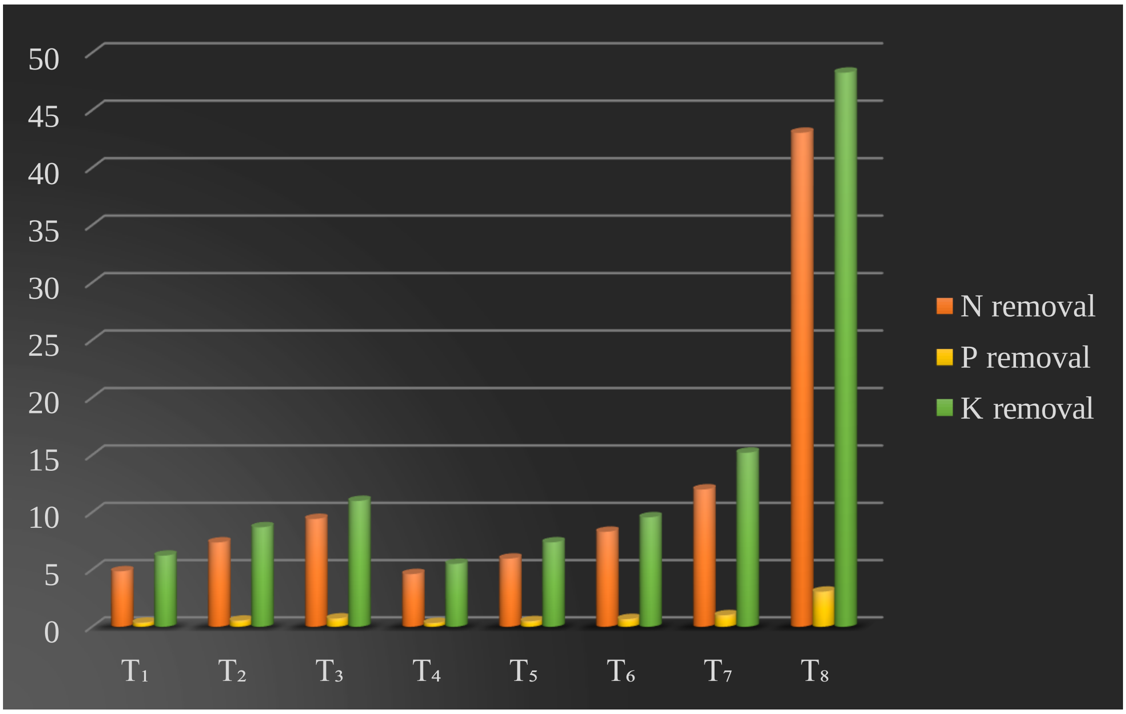


Fig 8. Effect of weed management practices on N, P and K removal by the weed, kg ha^{-1}

and K by weeds were more in weedy check which can be attributed to the higher dry weights. Amongst the management strategies, T_4, T_1 and T_5 recorded minimum NPK removal and to be precise only one tenth of N removal registered in weedy check in comparison to others due to lower weed dry matter accumulation. Maity and Mukherjee (2008) also observed that weed management practices reduced the nutrient depletion by weeds in direct seeded rice. Manhas *et al.* (2012) reported nutrient removal of 53 kg N, 15.5 kg P and 58 kg K_2O ha^{-1} compared to weed free plot in transplanted rice due to greater weed density and biomass that suppressed the growth and nutrient uptake by the crop.

5.2.2. Effect on crop

5.2.2.1. Growth and Yield attributes of rice

Growth of plant is characterized by plant height, no. of tillers and dry matter accumulation and grain yield is the ultimate result of yield attributing characters like number of panicles m^{-2}, grains per panicle and thousand grain weight. Pre-emergent application of bensulfuron methyl + pretilachlor @60+600g ha^{-1}, pyrazosulfuron ethyl @ 25g ha^{-1}, penoxsulam+cyhalofop butyl 6 % OD @ 150 g ha^{-1} each fb HW and HW twice suppressed the weed growth effectively and resulted in taller plants at 60 DAS. Application of these treatments controlled the weeds at initial stage and hand weeding controlled the late emerging weeds. Madhukumar *et al.* (2013) supported these findings. Lesser crop weed competition at initial and critical period of crop growth would result in superior crop growth and gains competitive advantage over resource use. Yadav *et al.* (2018) stated the positive correlation of penoxsulam + cyhalofop butyl 6 % OD @ 150 g ha^{-1} with rice plant height. Plant height reported in weedy check was 92 cm where Sahu (2016) reported that under direct seeded lowland condition, reduction in height of rice plants was 14.25 per cent.

Grain yield is the ultimate result of yield attributing characters, such as number of panicles m^{-2}, number of grains per panicle, sterility percentage and thousand grain weight. Amongst the weed management practices, T_1 and T_4 were superior in number of panicles m^{-2}, number of grains per panicle and low sterility percentage (Fig. 9). These treatments provided almost a weed free condition during the critical period of weed crop competition. Mubeen *et al.* (2014) found that lesser crop weed competition at critical growth stages augmented the rice grain yield. Sunil *et al.* (2011) reported that spraying of bensulfuron methyl + pretilachlor @ 0.06 + 0.60 kg ha^{-1} at 3 DAS fb intercultivation at 40 DAS resulted in more no number of productive tillers per hill, spikelets per panicle, lower sterility per cent and test weight due to broad spectrum weed control. Yadav *et al.* (2018) stated that ready mix application of penoxsulam + cyhalofop @135 g ha^{-1} or 150 g ha^{-1} resulted in superior yield parameters similar to weed free treatment.

Grain yield obtained was higher in T_1 (5461 kg ha^{-1}) and at par with T_4 (5354 kg ha^{-1}). Pre-emergent and early post emergent herbicide application and subsequent hand weeding at 35- 40 DAS extended the period of effective weed control and helped the crop to utilize the inputs effectively for better growth. Rao *et al.* (2000) stated that grain yield was mainly decided by the number of panicles m^{-2}, grains per panicle, fertility percentage and thousand grain weight. Better weed control at initial stages was extended by means of sequential hand weeding whereas early post emergent application of penoxsulam + cyhalofop butyl gave broad spectrum of weed control at critical growth stages of the crop. Arya and Ameena (2016) quantified an improvement in grain yield with bensulfuron methyl + pretilachlor @60+600g ha^{-1} in semidry rice. Minimum grain and straw yields were recorded under weedy check due to more weed infestation and their dry matter accumulation and lower yield attributes. Unrestricted weed growth led to the grain yield reduction of 59.03 per cent in comparison with T_1. These findings were supported by Pandey (2009) in transplanted rice and Mukharjee *et al.* (2008) in wet seeded rice. Straw yield recorded was higher in T_1 and T_4 with its indirect influence on number of tillers m^{-2} (Fig 9). Reduction in straw yield in unweeded plot was 39.14 per cent and could be related with the lesser crop stand and tiller count. Poor straw yield in un-weeded control in semi dry system was reported by Arya (2015) and low HI by Akbar *et al.* (2011).

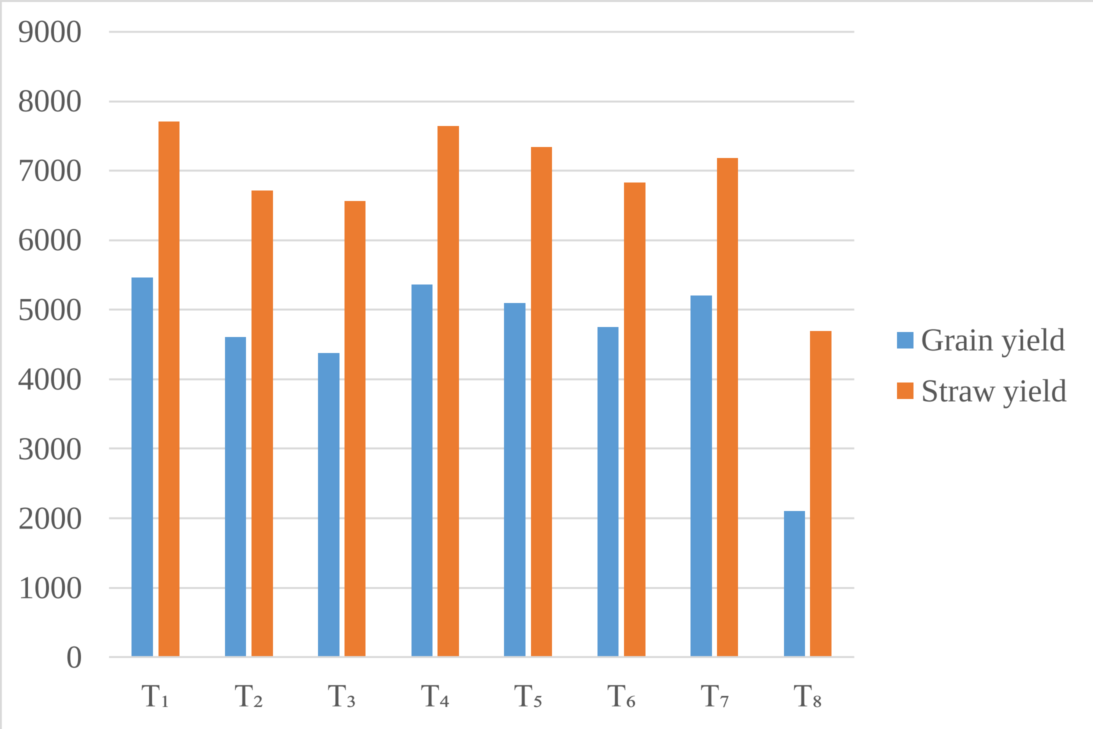


Fig 9.Effect of weed management practices on grain and straw yield, kg ha^{-1}.

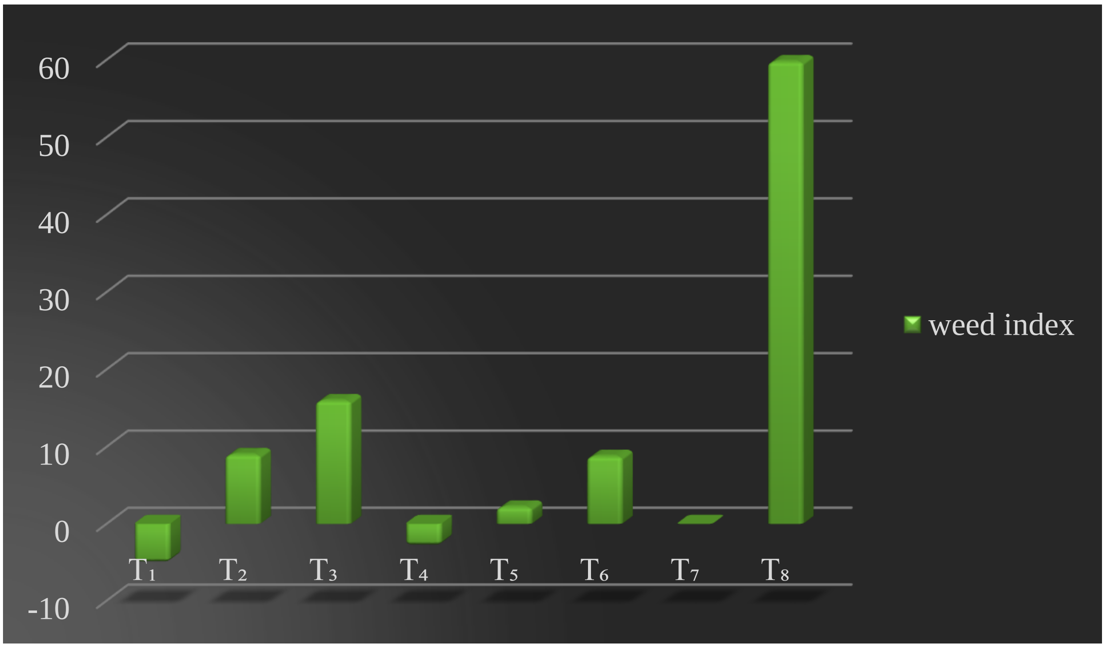


Fig 10. Effect of weed management practices on weed index.

5.2.2.2. Weed index

Weed index (WI) is a parameter to describe yield loss occurred due to weed infestation in comparison with weed free plots. Taking hand weeding twice as reference plot for weed free, the yield loss in wet seeded rice was estimated to be 59.75 per cent (Fig 10). Ramzan (2003) observed 53 per cent and Maity and Mukherjee (2008) realized 61 per cent yield loss due to unrestricted weed growth in wet seeded rice. Lower WI was registered in bensulfuron methyl + pretilachlor (-5.14 per cent) and penoxsulam + cyhalofop butyl (-2.96 per cent) which might be due to lower crop weed competition as lower dry weight of weeds and better weed control efficiency by which the grain yield was unaffected. These findings were corroborated by Sureshkumar (2016) and Umkhulzum and Ameena (2019). Moorthy and Manna (1985) reported 32-50 per cent yield reduction in wet seeded rice at higher densities of goose weed at Cuttack in India.

5.2.2.3. Nutrient uptake by the crop

There was no significant difference between treatments with respect to the nutrient composition of the crop. Higher nutrient uptake was noticed in bensulfuron methyl + pretilachlor (T_1), T_4 and T_5 due to higher dry matter production (Fig 11). Higher grain and straw yield realized in these treatments as a result of higher weed control efficiency due to broad spectrum weed control resulting in lesser nutrient depletion by weeds and greater nutrient uptake by rice. The results are in close proximity with the findings of Sanjay *et al*. (2006). Nanjappa and Krishnamurthy (1980) testified an inverse relation between nutrient uptake by rice crop and nutrient depletion by weeds.

5.2.2.4. Nutrient status of soil after the experiment

The weed management practices failed to improve the soil nutrient status after the harvest of rice. They had no significant effect on available nitrogen, phosphorus and potassium status in soil after the experiment. Before the experiment, soil was low in available N, high in available P, medium in available K. Compared to preliminary values, the available N, P and K content of soil noticeably reduced after the experimentation. Compared to initial values of available N, P and K content in soil, unweeded plot reported reduction of 40.0, 13.2 and 28.4 per cent, respectively.

5.2.3 Economics of cultivation

The adoption of any technology is found feasible and acceptable to farmers only if it is economically viable. The actual comparison between two performing treatments can be done based on economic viability. In the present study, bensulfuron methyl + pretilachlor fb HW reported higher gross income (Rs 1, 64,151 ha^{-1}), net income (Rs 74, 320 ha^{-1}), and B: C ratio (1.83) (Fig 12). This was possible because of lesser herbicide cost in addition to superior grain and straw yield. Thus, for weed management in gooseweed (*Sphenoclea zeylanica*) dominated rice fields under wet seeded situation, bensulfuron methyl + pretilachlor @ 60+600g ha^{-1} at 5DAS fb HW at 35-40 DAS (T_1) could be suggested as a feasible option as the returns obtained per rupee spent was 1.83. Eventhough, hand weeding was efficient, herbicidal treatment was simple, economical, time and labour saving than manual weeding (Rekha *et al*., 2003). Gross income (Rs 1, 55,590 ha^{-1}), net income (Rs 52,186 ha^{-1}), and B: C ratio (1.50) obtained in manual weeding was less than T_1 due to higher wage rates.

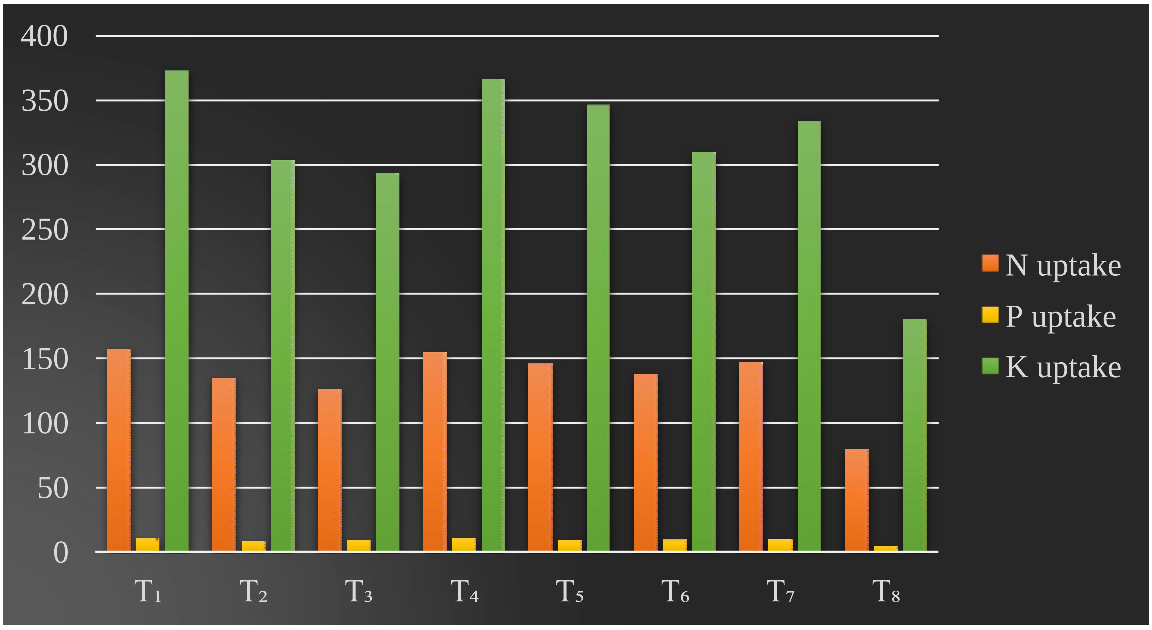


Fig 11. Effect of weed management practices on N, P and K uptake by the crop, kg ha^{-1}

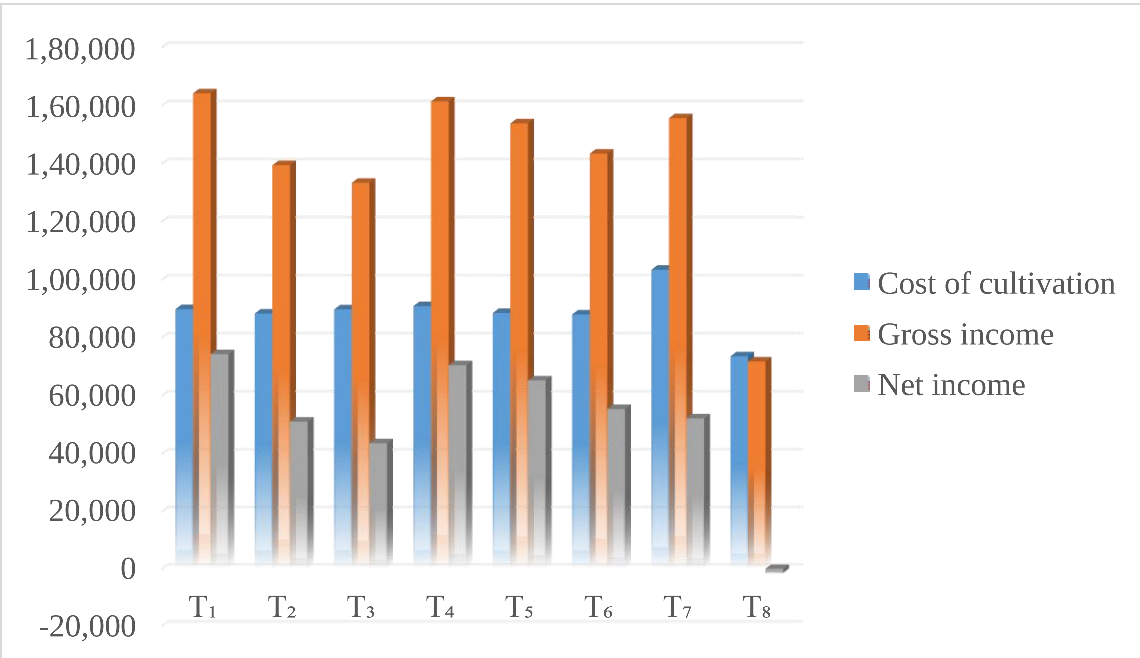


Fig 12. Effect of weed management practices on cost of cultivation, gross income and net income, ₹ ha^{-1}.

5.3. ALLELOPATHIC EFFECT OF GOOSE WEED ON RICE

Goose weed is a common dominant annual broad leaf weed in wet seeded rice fields which grows all year round. As a part of the experiment, the allelopathic effect of fresh and dried plant aqueous extract of *Sphenoclea zeylanica* on germination and growth of rice seedlings was examined. The results revealed that fresh aqueous extract didn't have any allelopathic effect whereas dry aqueous extract have profound inhibitory influence on germination and growth of rice seedlings. (Fig 13). At 4 DAS, 10 per cent aqueous extract of dry leaves and inflorescence reported 88.11 and 79.02 per cent reduction in germination, respectively over control (distilled water). Earlier Premasthira and Zungsontiporn (1985) stated that *Sphenoclea zeylanica* produced substances which strongly inhibited the growth of rice seedling.

A practical implication of this finding is that in low land rice fields where the dry biomass of the weed is incorporated into soil, the leachate is likely to inhibit the germination and emergence of rice seeds. Premasthira and Zungsontiporn (1996b) studied the allelopathic effect of goose weed and reported lower tiller number of rice plants in fields where goose weed was incorporated and decomposed.

No significant difference was observed between allelopathic effect of goose weed plants before and after flowering. Premasthira and Zungsonthiporn (1996b) further indicated that the plant growth inhibitor in goose weed was released in to the environment by root exudation and Hirai *et al*. (2000) identified them as thiosulfinate and secoiridoids glucoside.

Amongst the treatments, fresh plant aqueous extract had least influence on shoot and root length (Fig. 14), fresh and dry weight (Fig. 15) and vigour index (Fig. 16) whereas dry plant aqueous extract had a greater negative correlation on rice seedling growth. Greater inhibitory influence of dry extract might be due to higher concentration of allelochemicals. Inhibitory influence of aqueous extract of weed plants on rice seedlings have been reported earlier by Ameena (1999) and Navaz (2002). Among different plant parts, the decreasing order of allelopathic effect was leaf, inflorescence

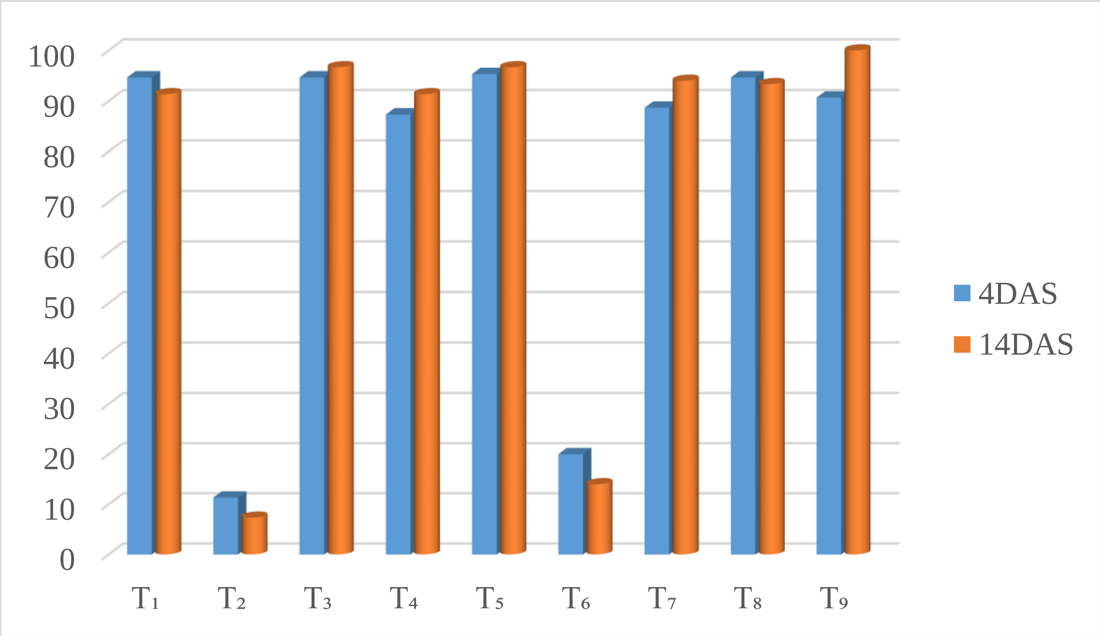


Fig 13. Allelopathic effect of *Sphenoclea zeylanica* on germination of rice seedlings, per cent

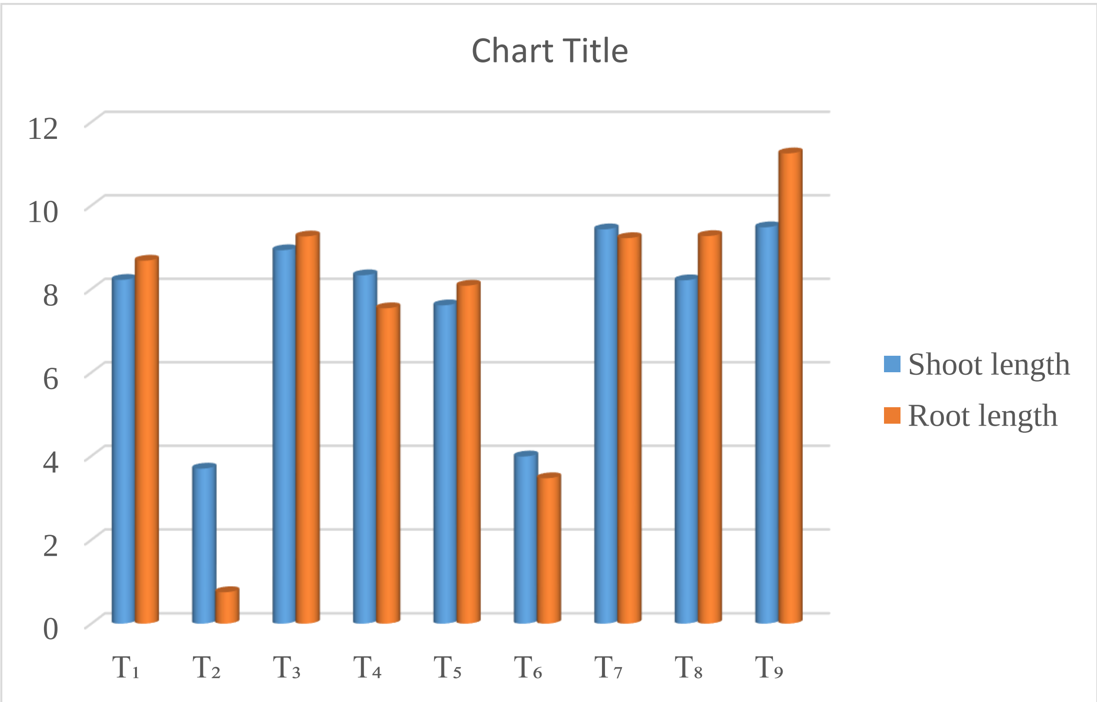


Fig 14. Allelopathic effect *Sphenoclea zeylanica* on shoot length and root length of rice seedlings, cm

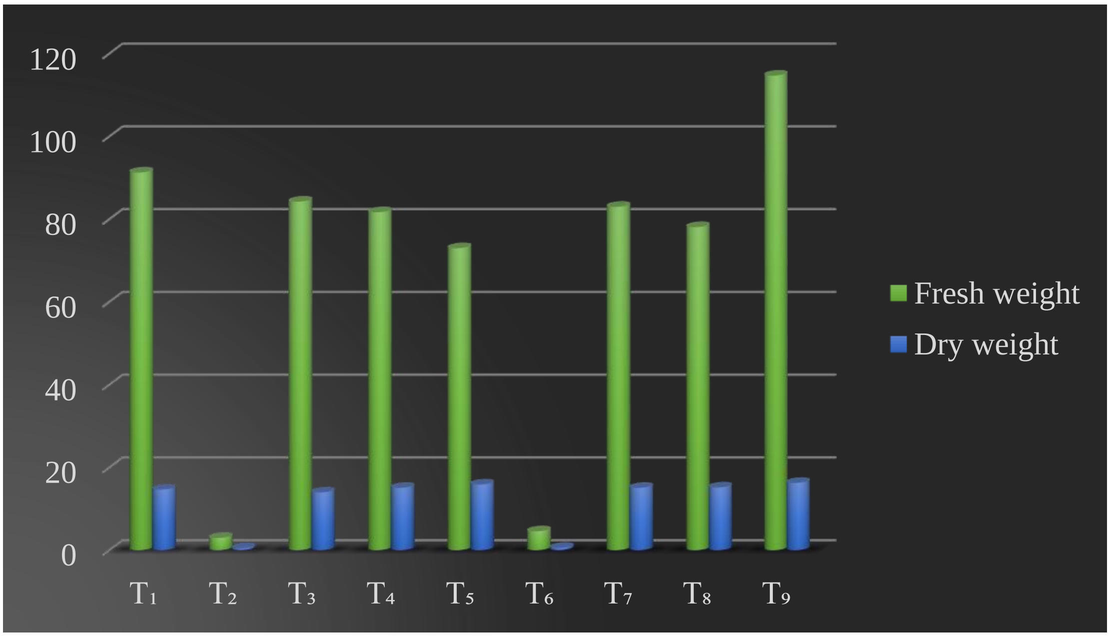


Fig 15. Allelopathic effect of *Sphenoclea zeylanica* on fresh weight and dry weight of rice seedlings, mg per plant

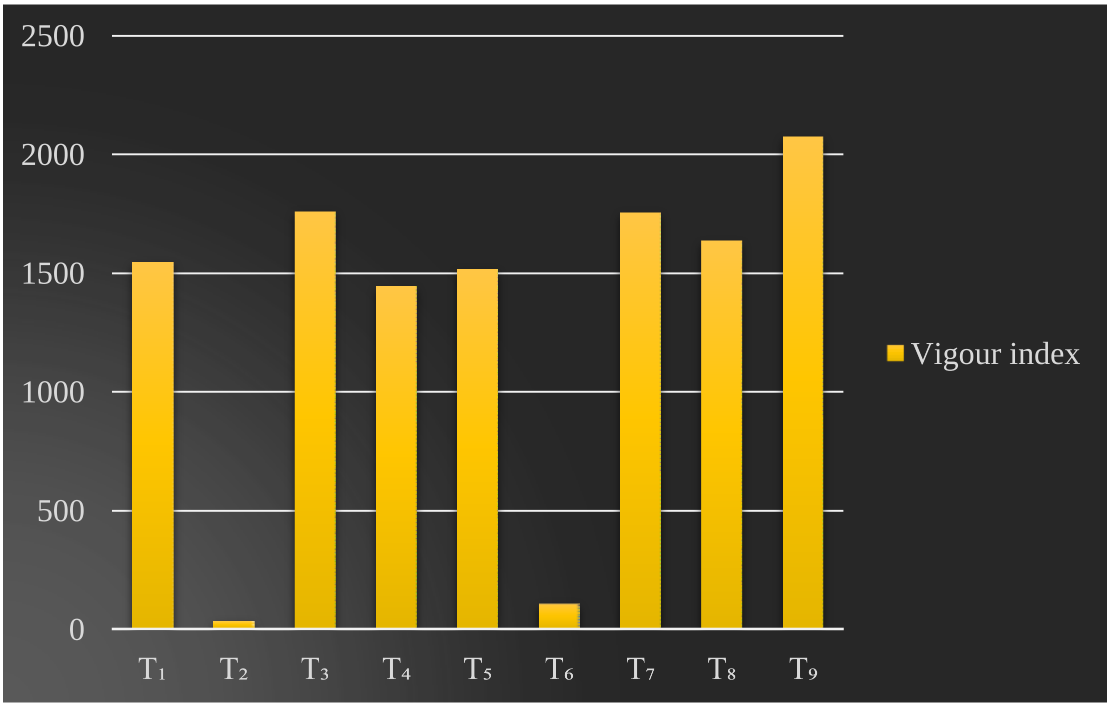


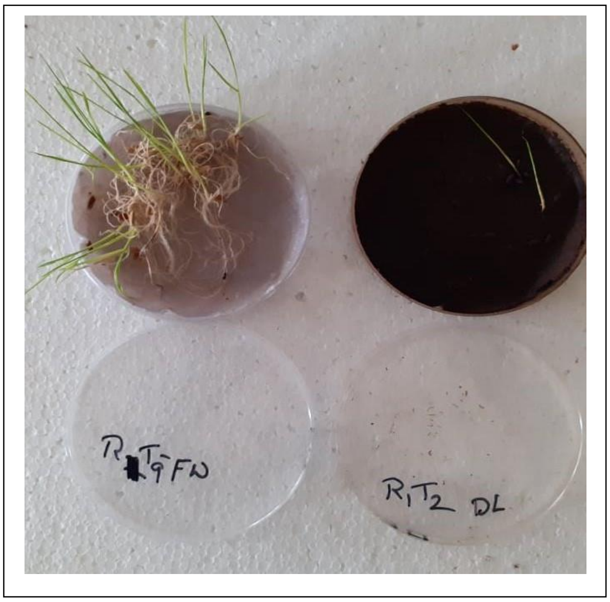
Fig 16. Allelopathic effect of *Sphenoclea zeylanica* on vigour index of rice seedlings.

and stem. It is apparent that among the plant parts, leaves contain higher concentration of allelochemicals followed by seeds and stem. According to Premasthira and Zungsontiporn (1996a), growth inhibiting components were produced at the time of metabolic activities where leaves are the key site of plant metabolism and the seeds act as sink of metabolic products leading to greater inhibition by leaves and seeds. Aqueous extract of fresh stem and whole plant before flowering did not exert any significant effect on shoot length and was at par with control. Premasthira and Zungsontiporn (1996a) opined that allelopathic effect of extracted materials from leaves and inflorescences was more on root and shoot inhibition compared to stem and root extracts of goose weed.

The above results showed that aqueous extracts of dry plant parts of *Sphenoclea zeylanica* especially leaves and spike exerted a strong inhibitory influence on rice germination and seedling growth. The results find ample support from the findings of Premasthira and Zungsontiporn (1985) that goose weed extract exhibited inhibitory effect on rice seedling growth. Hence, the allelopathic characters of soil incorporated goose weed plants in wet lands may unfavourably affect establishment of next crop.

However, Abeysekera *et al.* (2012) reported that there was no negative effect of decomposed goose weed in soil on rice germination and growth. The contrasting results might be due to difference in concentrations and rate of decomposition.

Based on the above findings, it can be inferred that the life cycle of the weed coincides with the critical period of crop weed competition and hence it need to be controlled during the initial stages itself. Adoption of integrated weed management practice with an initial pre-emergent herbicide followed by a hand weeding can effectively and economically control the weed. Allelopathic property of the weed is well established under laboratory condition especially of leaves and spikes in inhibiting rice seed germination and growth.



Dry leaf aqueous extract

Dry inflorescence aqueous extract

Plate 7. Allelopathic effect of goose weed extracts on rice seedling growth

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SUMMARY

6. SUMMARY

An investigation entitled 'Biology and management of goose weed (*Sphenoclea zeylanica* Gaertner) in wetland rice' was undertaken in the wetlands of IFSRS, Karamana during *kharif* season of 2019 (June to October) with the main aim of understanding the biology of *Sphenoclea zeylanica*; to develop an efficient management strategy using low dose high efficiency herbicides and to study its allelopathic effect on rice seeds.

The biology of the weed (*Sphenoclea zeylanica* Gaertner) was studied through keen observation of randomly selected sample plants from weedy check plot (20 m^2 area) starting from emergence and for the purpose of destructive sampling, a separate set of weed plants were selected. To develop an effective and economic management strategy with special reference to goose weed the following treatments were tested. T_1-bensulfuron methyl + pretilachlor @ 60 + 600 g ha^{-1} at 5 days after sowing (DAS) followed by (fb) hand weeding (HW) at 35-40 DAS; T_2-pyrazosulfuron ethyl @ 25g ha^{-1} at 5 DAS fb HW at 35-40 DAS; T_3-bispyribac sodium @ 25 g ha^{-1} at 20 DAS fb HW at 35-40 DAS; T_4-penoxsulam + cyhalofop butyl @150g ha^{-1} at 20 DAS fb HW at 35 - 40 DAS; T_5- metsulfuron methyl + chlorimuron ethyl @ 4gha^{-1}at 20 DAS fb HW at 35-40 DAS; T_6- ethoxysulfuron@15 g ha^{-1} at 15 DAS fb HW at 35-40 DAS; T_7-HW at 20 and 40 DAS; T_8: weedy check (un-weeded control). The experimental area was partitioned into three blocks with 24 plots each of size 5m x 4m and the sprouted paddy seeds of Uma variety were broadcasted in the field. The crop was grown and managed in line with the cultivation practices as per the recommendations of KAU Package of Practices. The study on allelopathic effect of *Sphenoclea zeylanica* on rice seeds were conducted in laboratory, and the treatments framed were T_1- Fresh leaves aqueous extract 10%; T_2-Dry leaves aqueous extract 10% ; T_3- Fresh stem aqueous extract 10%; T_4- Dry stem aqueous extract 10%; T_5- Fresh inflorescence aqueous extract 10%; T_6-Dry inflorescence aqueous extract 10%; T_7-Fresh whole plant aqueous extract before flowering 10%; T_8: Fresh whole plant aqueous. The weed plants collected both fresh and dry from the experimental field separated into leaves, stem, and inflorescence and 10 per cent aqueous extract prepared according to the treatments. The salient findings of the above experiments are summarized in this chapter.

- Goose weed (*Sphenoclea zeylanica* Gartner) belonging to the family Sphenocleaceae is an upcoming broad-leaved weed in rice fields of Kerala.
- *Sphenoclea zeylanica* was observed to be an erect, herbaceous, much branched broad-leaved plant that coexisted along with rice having additional habitats at water channels, bunds and waterlogged areas surrounding the field.
- Goose weed was noticed to develop through 5 phenological stages in its life cycle. These included germination, seedling, flowering, spike maturity and plant maturity.
- Seed germination of *Sphenoclea zeylanica* initiated from 2nd day and continued up to 7thday after wet seeding; initial flowering in 15 days, spike maturity in 36 days and plant maturity in 69 days under field conditions.
- Stem of *S. zeylanica* was hollow with circular cross section with profuse branching habit that grows upto a height of 104.1 cm with mean dry weight of 19.69 g plant.
- Goose weed was found to have fibrous root system which extends upto a depth of 29.84 cm with mean dry weight of 6.55g per plant. Under submerged conditions roots were found to produce from the lower nodes.
- Inflorescence of goose weed was noted to be a spike that appeared terminally. Flower were sessile, bisexual white in colour initially appeared and matured from bottom of spike. The dehiscence and dispersal of seeds were found to occur from base to tip.
- *Sphenoclea zeylanica* produced nearly 55 spikes plant^{-1} with average length of 4.26cm. The flowering was seen throughout its life cycle. It produced nearly 63 fruits spike^{-1}.
- *Sphenoclea zeylanica* produced numerous tiny brown colour seeds and at spike maturity the capsule of fruit dried up and seeds were shed in the field.
- Average biomass production observed from unweeded control was estimated to be 3.75 t ha^{-1}.
- The nutrient composition of goose weed was analyzed and found to contain 1.306 N, 0.087 P_2O_5 and 1.695 K_2O per cent, respectively and recorded a nutrient removal of 49, 3.26 and 63.59 kg N, P_2O_5 and K_2O ha^{-1}, respectively.

- In weedy check plot, the reduction in yield due to vigorous weed growth was found to be 59.75 per cent.
- At 15 DAS bensulfuron methyl + pretilachlor @60+600g ha^{-1} at 5 DAS fb HW at 35-40 DAS (T_1) resulted in lower weed density of 18.67.
- At 30, 45 and 60 DAS penoxsulam + cyhalofop butyl 6 % OD @ 150 g ha^{-1} at 20 DAS fb HW at 35 - 40 DAS (T_4) recorded lesser weed densities of 4, 14.67 and 10, respectively.
- At 15 and 30 DAS lesser weed dry weight of 0.08 and 6.4 g m^{-2} respectively was reported in T_1 while at 45 and 60 DAS T_4 recorded lesser weed biomass of 1.35 and 4.61 g m^{-2} respectively.
- At 15 DAS T_1 recorded lesser relative weed density of *S. zeylanica* (6.67 per cent) and T_4 recorded lesser relative weed density at 30, 45 and 60 DAS, respectively.
- Lower relative weed biomass of *S. zeylanica* was noticed in T_1 (0.42 per cent) at 15 DAS while at 30, 45 and 60 DAS lesser weed biomass of *S. zeylanica* was noticed in T_4.
- At 15 and 30 DAS, weed control efficiency (WCE) was higher in T_1 (99.28 and 96.22 per cent, respectively) while at 45 and 60 DAS T_4 reported higher WCE of 9.54 and 98.85 per cent, respectively.
- Grain yield produced was higher in plots treated with T_1 (5461 kgha^{-1}) and was at par with T_4 (5355 kg ha^{-1}).
- Higher NPK uptake by the crop (157.44, 10.72 and 373.29 kg ha^{-1} N, P and K respectively) was found in T_1 and was at par with T_4 (154.53, 10.24 and 366.01 kg ha^{-1} N, P and K respectively).
- T_4 recorded lesser nutrient removal of 4.62, 0.34 and 5.51 kg NPK ha^{-1} and was at par T_1 (4.86, 0.37 and 6.23 kg NPK $ha^{-1)}$
- *Sphenoclea zeylanica* could be controlled efficiently by penoxsulam + cyhalofop butyl 6 % OD @ 150 g ha^{-1} at 20 DAS fb HW at 35 - 40 DAS (T_4) or .bensulfuron methyl +pretilachlor @ 60+600g ha^{-1}at 5 DAS fb HW at 35-40 DAS (T_1).

- Bensulfuron methyl + pretilachlor @ 60+600g ha^{-1}at 5 DAS fb HW at 35-40 DAS recorded higher gross returns (₹ 1, 64,151 ha^{-1}), net returns (₹ 74,320 ha^{-1}) and B:C ratio (1.83).
- Considering economics, bensulfuron methyl +pretilachlor @ 60+600g ha^{-1}at 5 DAS fb HW at 35-40 DAS could be considered as the finest option for managing *S. zeylanica* Gaertner in wet land rice.
- At 4 DAS, rice seeds treated with dry leaves aqueous extract 10% (T_2) and dry inflorescence aqueous extract 10% (T_6) of *S. zeylanica* showed a reduction in germination percentage of 88.11 and 79.0 per cent, respectively compared to control (distilled water).
- At 14 DAS, the germination percentage of T_2 and T_6 was 7.33 and 14 per cent while the control plot reported 100 per cent germination.
- T_2 and T_6 reported lower fresh weight of seedlings (3 and 4.6 mg) with inhibition rate of 97 and 95.98, per cent respectively compared to control.
- Lower dry weight of rice seedlings was observed in T_2 and T_6 with 0.5 and 0.6 mg per seedling.
- Significant reduction in shoot length of rice seedlings was observed in T_2 (3.7 cm) and T_6 (3.99 cm) compared to control (9.48 cm). Percentage reduction in shoot length when compared to control was 60.97 per cent in T_2 and 57.91 per cent in T_6.
- Aqueous extract of dry leaves of *S. zeylanica* could cause a drastic reduction in root length of rice seedlings registering a root length of 0.75 cm.
- A drastic reduction in vigour index (98.35 per cent) was noticed for treatment with dry leaves aqueous extract (34.07) compared to control (2073.67).
- *S. zeylanica* dry leaves aqueous extract 10% (T_2) and dry inflorescence aqueous extract 10% (T_6) showed significant allelopathic effect on rice seedling growth whereas fresh aqueous extracts didn't show any effect on rice seedlings.
- No significant difference was observed between allelopathic effect of goose weed plants before and after flowering.

FUTURE LINE OF WORK

Allelopathic influence of goose weed as evidenced in the present study need to be verified under field conditions and its effect on other weeds need to be investigated.

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APPENDICES

APPENDIX I

Weather parameters during the cropping period – 14 th June to14th October, 2019

Standard weeks	Temperature (^0C)		Relative humidity (%)		Rainfall (mm)	Rainy days
	Max	Min	Max	Min		
24	31.13	24.83	93.37	81.17	114.40	6
25	31.91	24.93	90.00	78.71	28.60	3
26	32.09	26.06	87.14	75.29	0.00	0
27	32.20	25.91	90.29	77.14	32.10	2
28	30.79	25.37	90.29	79.00	42.10	2
29	30.06	23.74	94.14	81.57	100.80	4
30	30.37	24.33	92.29	82.43	7.70	2
31	31.46	25.63	89.29	77.57	17.50	1
32	30.00	23.61	94.57	81.71	198.10	6
33	30.44	24.07	91.57	76.57	18.20	2
34	31.11	24.23	92.14	77.43	34.90	3
35	30.67	23.91	93.14	77.86	91.90	6
36	30.87	24.37	90.57	80.14	84.00	3
37	31.33	24.39	88.86	76.43	12.90	2
38	30.94	24.90	91.14	77.86	19.40	2
39	31.01	24.21	93.29	75.57	123.80	4
40	31.50	24.57	91.29	72.14	7.00	1
41	31.10	24.40	91.71	77.00	133.10	4

APPENDIX II

SES (Standard Evaluation System for Rice) scoring chart of sheath blight infestation

SCALE ((based on relative lesion height)	
0	No infection observed
1	Lesions limited to lower 20% of the plant height
3	20-30%
5	31-45%
7	46-65%
9	More than 65%

APPENDIX III

SES (Standard Evaluation System for Rice) scoring chart of stem borer infestation

SCALE	Dead hearts	White heads
0	No damage	No damage
1	1-10%	1-5%
3	11-20%	6-10%
5	21-30%	11-15%
7	31-60%	16-25%
9	61% and above	26% and above

APPENDIX IV

SES (Standard Evaluation System for Rice) scoring chart of rice bug infestation

SCALE	Damaged grains per panicle (%)
0	No damage
1	Less than 3
3	4-7
5	8-15
7	12-25
9	26-100

BIOLOGY AND MANAGEMENT OF GOOSE WEED (*Sphenoclea zeylanica* Gaertner) IN WETLAND RICE

by

MALLU SAI SARATH KUMAR REDDY

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2020

ABSTRACT

An investigation entitled 'Biology and management of goose weed (*Sphenoclea zeylanica* Gaertner) in wetland rice' was conducted at College of Agriculture, Vellayani during 2018-2020. The major objectives were to study the biology of the weed, its allelopathic effect on crop and also to develop an effective and economic management strategy using herbicides in wet seeded rice.

The field experiment was undertaken at IFSRS, Karamana during *kharif* 2019. Weed biology was studied by observing randomly selected sample plants in weedy check plots starting from the emergence of the weed. The field experiment was laid out in randomized block design with eight treatments and three replications. The weed control treatments included T_1: bensulfuron methyl + pretilachlor @ 60+600 g ha^{-1} at 5 days after sowing(DAS), T_2: pyrazosulfuron ethyl @ 25g ha^{-1} at 5 DAS, T_3: bispyribac sodium @ 25 g ha^{-1} at 15-20 DAS, T_4 :penoxsulam + cyhalofop butyl 6% OD at 150 g ha^{-1} at 20 DAS, T_5: metsulfuron methyl + chlorimuron ethyl @ 4g ha^{-1} at 20 DAS, T_6: ethoxysulfuron @ 15 g ha^{-1} at 20 DAS, T_7 : hand weeding at 20 and 40 DAS, T_8 **:** weedy check (unweeded control) and the treatments T_1 to T_6 were followed by hand weeding at 35-40 DAS. The lab experiment on allelopathic effect of goose weed on germination and growth of rice seedlings was evaluated with treatments T_1: Fresh leaves aqueous extract 10%, T_2: Dry leaves aqueous extract 10%, T_3: Fresh stem aqueous extract 10%, T_4: Dry stem aqueous extract 10%, T_5: Fresh inflorescence aqueous extract 10%, T_6: Dry inflorescence aqueous extract 10%, T_7: Fresh whole plant aqueous extract before flowering 10%, T_8: Fresh whole plant aqueous extract after flowering 10%, T_9: Distilled water (control).

The data on weed biology identified goose weed as an annual. The weed seeds took 3-7 days for germination, 15 days for flowering and 36 days for first spike maturity with an average duration of 69 days in wet seeded rice fields. The weed was observed to propagate by seeds with enormous seed production potential. The average dry matter produced per plant and total dry matter production were to the tune of 26.24 g per plant and 3.75 t ha^{-1} respectively in the weedy check. The weed was analysed to

contain 1.306, 0.087 and 1.695 per cent N, P and K respectively.

In the field experiment, *Sphenoclea zeylanica* was the dominant weed flora during all the growth stages of the crop. Initially, a lower weed density was recorded in T_1, but taken over by T_4 at 30, 45 and 60 DAS. The weed dry weight was the lowest in T_1 at 15 and 30 DAS (0.08 and 6.41 g m^{-2}), whereas at 45 and 60 DAS, T_4 recorded the lowest values (1.35 and 4.61 g m^{-2}). T_1 registered lesser relative weed density of *S. zeylanica* up to one month and later by T_4. Unweeded plot showed dominance of the weed over other flora with a relative density of 70.33 per cent. Though weed control efficiency was higher in T_1 upto 30 DAS (99.28 and 96.22 per cent), T_4 recorded higher values during critical stages of crop growth at 45 and 60 DAS (99.54 and 98.85 per cent). T_4, T_1 and T_5 recorded minimum NPK removal and to be precise only one tenth of N removal registered in weedy check in comparison to others due to lower weed dry matter accumulation

Among the weed management practices tested, T_1 recorded higher plant height at 30, 60 DAS and at harvest. Both T_1 and T_4 recorded higher yield and yield attributes like number of panicles m^{-2}(320 and 308.3), number of grains panicle^{-1} (173 and 177), grain yield (5461 and 5355 kg ha^{-1}) and straw yield (7710 and 7646 kg ha^{-1}). Bensulfuron methyl + pretilachlor @ 60+600 g ha^{-1} at 5 DAS followed by hand weeding at 35-40 DAS turned out to be the most economic weed management practice with a higher B: C ratio of 1.83. This was followed by penoxsulam + cyhalofop butyl 6% OD at 150 g ha^{-1} at 20 DAS followed by hand weeding at 35-40 DAS with a B: C ratio of 1.77. Higher nutrient uptake by the crop was noticed in bensulfuron methyl + pretilachlor (T_1), T_4 and T_5 due to higher dry matter production. The extent of yield reduction due to presence of weeds in wet seeded rice was estimated to be 57 per cent.

The study on allelopathic influence of goose weed revealed strong inhibitory influence for its dry leaves and dry inflorescence on germination percentage (92.67 and 80%) and dry weight (96.98 and 96.12%) of rice seedlings. Shoot length, root length, fresh weight, dry weight and vigour index were also recorded the lowest in T_2 and T_6.

From the results of the study, it could be concluded that *Sphenoclea zeylanica* could become a serious weed in wetland rice fields being a prolific seed producer with high dry matter production. Application of bensulfuron methyl + pretilachlor @ 60+600 g ha^{-1}at 5 DAS followed by hand weeding at 35-40 DAS was found to be the most effective and economic management strategy. The inference of allelopathic studies indicated that dry leaves and inflorescence of goose weed have strong inhibitory influence affecting germination and growth of rice.

സംഗ്രഹം

നെല്ലിൽ ചേറ്റുവിത രീതി അവലംബിക്കുമ്പോൾ വരുന്ന പൊങ്ങൻ കള അഥവാ സ്ഫിനോക്ലീയാ സിയ്ലാനിക്ക എന്ന വിസ്തൃതപത്ര കളയുടെ വളർച്ചാ രീതിയും നിയന്ത്രണമാർഗ്ഗവും കണ്ടെത്താൻ സംയോജിത കൃഷി സമ്പ്രദായ ഗവേഷണ കേന്ദ്രത്തിൽ 2019 വിരിപ്പ് കാലത്തിൽ ആണ് ഈ പഠനം നടത്തിയത്. ഈ കളയുടെ ജീവശാസ്ത്രം, വിളയെ ബാധിക്കുന്ന അല്ലിലോപ്പതി എന്നിവ പഠിക്കുകയും ചേറ്റുവിതയിൽ കളനാശിനികൾ ഉപയോഗിച്ച് ഫലപ്രദവും ലാഭകരവുമായ കളനിയന്ത്രണ മാർഗം കണ്ടെത്തുക എന്നിവയായിരുന്നു പ്രധാന ലക്ഷ്യങ്ങൾ.

റാൻഡംഡ് ബ്ലോക്ക് ഡിസൈൻ അവലംബിച്ചു നടത്തിയ പരീക്ഷണത്തിൽ എട്ടു വ്യത്യസ്ത കളനിയന്ത്രണ മാർഗ്ഗങ്ങളുടെ മികവാണ് പരീക്ഷിച്ചത്. ബെൻസൾഫ്യൂറോൺ മെഥൈൽ + പ്രെറ്റിലാക്ലോർ 60 + 600 ഗ്രാം ഹെക്ടറിന് എന്ന തോതിൽ വിതച്ചു 5 ദിവസങ്ങൾക്കു ശേഷവും (T1) , പൈറാസോസൾഫ്യൂറോൺ എഥൈൽ 25 ഗ്രാം ഹെക്ടറിന് എന്ന തോതിൽ വിതച്ചു 5 ദിവസങ്ങൾക്കു ശേഷവും (T2), ബിസ്പിരിബാക് സോഡിയം 25 ഗ്രാം ഹെക്ടറിന് എന്ന തോതിൽ വിതച്ചു 15-20 ദിവസങ്ങൾക്കു ശേഷവും (T3), പെനോക്സുലം + സൈഹാലോഫോപ്പ് ബ്യൂട്ടിൽ 6% OD 150 ഗ്രാം ഹെക്ടറിന് എന്ന തോതിൽ വിതച്ചു 20 ദിവസങ്ങൾക്കു ശേഷവും (T4), മെറ്റ്സൽഫ്യുറോൺ മെഥൈൽ + ക്ലോറിമ്യുറോൺ എഥൈൽ 4 ഗ്രാം ഹെക്ടറിന് എന്ന തോതിൽ വിതച്ചു 20 ദിവസങ്ങൾക്കു ശേഷവും (T5), എതോക്സിസൽഫ്യുറോൺ 15 ഗ്രാം ഹെക്ടറിന് എന്ന തോതിൽ വിതച്ചു 20 ദിവസങ്ങൾക്കു ശേഷവും (T6) (തുടർന്ന് കളപറിച്ചു നീക്കൽ 35-40 ദിവസങ്ങൾക്കു ശേഷവും T1 മുതൽ T6 വരെ), രണ്ടു തവണ കളപറിച്ചു നീക്കൽ - വിതച്ചു 20 ദിവസത്തിനു ശേഷവും 40

ദിവസത്തിനു ശേഷവും (T7), കളകൾ നീക്കം ചെയ്യാത്ത വീഡി ചെക്ക് (T8) എന്നീ രീതികൾ ആണ് പഠന വിധേയമാക്കിയത്. പൊങ്ങൻകളയുടെ അല്ലെലോപ്പതി നെൽ വിത്തിന്റെ അങ്കുരണ ശേഷിയേയും വളർച്ചയെയും എങ്ങനെ ബാധിക്കുന്നു എന്നുള്ള പഠനവും പരീക്ഷണശാലയിൽ നടത്തുകയുണ്ടായി. ഇതിനായി കളയുടെ പച്ചിലയുടെ സത്ത് 10% (T1), ഉണങ്ങിയ ഇലയുടെ സത്ത് 10% (T2), തണ്ടിന്റെ സത്ത് 10% (T3), ഉണക്കിയ തണ്ടിന്റെ സത്ത് 10% (T4), പൂങ്കുലയുടെ സത്ത് 10% (T5), ഉണക്കിയ പൂങ്കുലയുടെ സത്ത് 10% (T6), പുഷ്പിക്കുന്നതിനു മുന്നേയുള്ള മൊത്തം സസ്യത്തിന്റെ സത്ത് 10% (T7), പുഷ്പിച്ചതിന് ശേഷമുള്ള മൊത്തം സസ്യത്തിന്റെ സത്ത് 10% (T8) എന്നിവ ആണ് ഉപയോഗിച്ചത് .

കളയുടെ വളർച്ച രീതി നിരീക്ഷിച്ചതിൽ ഒരു വാർഷിക കളയായി തിരിച്ചറിഞ്ഞു. കള വിത്തുകൾ മുളയ്ക്കുന്നതിന് 3-7 ദിവസവും, പൂവിടുവാൻ 15 ദിവസവും, ആദ്യത്തെ പൂക്കുല /സ്പൈക്ക് വളർച്ചയെത്തുന്നതിന് 36 ദിവസവും, ചേറ്റുവിത പാടങ്ങളിൽ ശരാശരി ജീവിതചക്രം പൂർത്തിയാക്കുന്നതിന് 69 ദിവസവും വേണ്ടിവരുന്നതായി കണ്ടെത്തി. നിരീക്ഷണത്തിൽ ധാരാളം ഉൽപാദന ശേഷിയുള്ള വിത്തുകളാൽ കള വംശവർദ്ധനവ് നടത്തുന്നു എന്നും കണ്ടെത്താനായി. കളയിൽ യഥാക്രമം 1.306, 0.087, 1.695 ശതമാനം എൻ, പി, കെ അടങ്ങിയിരിക്കുന്നതായി രേഖപ്പെടുത്തി.

പരീക്ഷിച്ച കള പരിപാലന രീതികളിൽ, ഉയർന്ന വിളവും ഗുണങ്ങളും രേഖപ്പെടുത്തിയിട്ടുള്ളത് T1, T4 ലുമാണ്. മീറ്റർസ്കചയറിൽ കതിരുകളുടെ എണ്ണം (320, 308.3), കതിരുകളിൽ ധാന്യങ്ങളുടെ എണ്ണം (173, 177), ധാന്യ വിളവ് (ഹെക്ടറിന് 5461, 5355 കിലോഗ്രാം), വൈക്കോൽ വിളവ് (ഹെക്ടറിന് 7710, 7646 കിലോഗ്രാം) എന്നിങ്ങനെ T1 ഉം T4 ഉം യഥാക്രമം രേഖപ്പെടുത്തിയിരിക്കുന്നു.

ബെൻസൽഫ്യൂറോൺ മെഥൈൽ + പ്രെറ്റിലാക്ലോർ ഹെക്ടറൊന്നിനു 60 + 600 ഗ്രാം എന്ന തോതിൽ വിതച്ചു 5 ദിവസങ്ങൾക്കു ശേഷവും തുടർന്ന് കള പറിച്ചു നീക്കൽ 35-40 ദിവസങ്ങൾക്കു ശേഷം അവലംബിക്കുന്നത് ഏറ്റവും ഫലപ്രദവും ലാഭകരവുമായ കളനിയന്ത്രണ മാർഗ്ഗമായി കണ്ടെത്തി. പെനോക്സുലം + സൈഹാലോഫോപ്പ് ബ്യൂട്ടിൽ 6% OD 150 ഗ്രാം ഹെക്ടറിന് എന്ന തോതിൽ വിതച്ചു 20 ദിവസങ്ങൾക്കു ശേഷവും തുടർന്ന് കളപറിച്ചു നീക്കൽ 35-40 ദിവസങ്ങൾക്കു ശേഷവും ചെയ്യുന്നത് ഉയർന്ന ഉൽപ്പാദനം രേഖപ്പെടുത്തി. കളകൾ മൂലം ചേറ്റുവിതയിൽ വിളവ് കുറയുന്നതിന്റെ വ്യാപ്തി 57 ശതമാനമായി കണക്കാക്കപ്പെട്ടു.

നെൽ ചെടിയിൽ ഈ കളയുടെ അലലോപതിക് സ്വാധീനത്തെക്കുറിച്ചു നടത്തിയ പഠനത്തിൽ കളയുടെ ഉണങ്ങിയ ഇലകളും പൂങ്കുലയും നെല്ലിന്റെ അങ്കുരണശേഷിയെയും വളർച്ചയെയും ഹാനികരമായി ബാധിക്കുമെന്നു കണ്ടെത്തി.

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