COMPATIBILITY OF HERBICIDES AND INSECTICIDES FOR TANK MIX APPLICATION IN WET SEEDED RICE

By

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(2015-11-014)

THESIS

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DECLARATION

I, Anjana Devaraj G. (2015-11-014), hereby declare that the thesis entitled **"Compatibility of herbicides and insecticides for tank mix application in wet seeded 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 any degree, diploma, fellowship or other similar title of any other University or Society.

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Certified that the thesis entitled **"Compatibility of herbicides and insecticides for tank mix application in wet seeded rice"** is a bonafide record of research work done independently by **Miss. Anjana Devaraj G. (2015-11-014)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to her.

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EXTERNAL EXAMINER

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Introduction

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1. INTRODUCTION

Weeds, insect pests and diseases are the major biotic constraints in rice production. Yield as well as quality of rice is hindered by these factors. Weeds are more problematic in dry seeded rice than wet-seeded rice. They compete with the crop plants for nutrients, water, light, space and air (Walia, 2006). Uncontrolled weed growth causes about 64 per cent yield reduction in wet- seeded rice (Rao *et al*., 2007). Grasses, broad leaf weeds, sedges, ferns and algae are the major categories of weeds found in rice fields. Weeds not only cause yield reduction but also increase cost of production. Some weeds also act as alternate hosts for insect pests. Effective weed control is essential for successful rice cultivation. Keeping rice fields weed free up to 45 days by manual, mechanical or chemical means is inevitable to reap high yields. Hand weeding twice, at 20 and 40 DAS has been reported by many researchers as a very effective method of weed control in rice. However, it is more laborious, time consuming and expensive. Morphological similarities between certain grass species and rice plant make hand weeding much more difficult (Maity and Mukherjee, 2009). Because of these reasons, chemical control is becoming more popular.

Another major problem in enhancing rice productivity is insect pests. Rice is an ideal host for over 800 species of insects (Barr and Smith, 1975). High humidity and high temperature prevailing during most of the time have made Kerala a hot spot for insect pests. Major insect pests in rice growing tracts of Kerala are brown plant hopper, stem borer, gall midge, leaf roller and rice bug. They cause severe damage to grains, leaves and stem, leading to reduction in yield. Dhaliwal *et al*. (2004) reported a cumulative loss of 25 per cent in rice production due to insect pest attack. Devastation of the entire crop field by insect attack is also reported occasionally. Among the various methods used to control insect pests, use of insecticides is most common.

Weed infestation along with insect pest attack causes severe damage to the rice crop. Time of herbicide application often coincides with the appearance of insect pests so that farmers have to go for separate application of insecticides and

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herbicides within a short span of time. Many farmers opt for indiscriminate mixing of both the chemicals to reduce spraying costs, with the result that scorching of plant tissues, reduction in effectiveness of chemicals or production of more toxic intermediate products occur. An assessment of herbicide - insecticide compatibility will help in identifying chemicals which can be tank mixed and applied safely on the crop without deterioration in quality. This will save labour, time and cost of application.

Bispyribac sodium and cyhalofop-butyl are two commonly used herbicides in rice. Bispyribac sodium is a post-emergence broad spectrum herbicide. Its application at 20 or 25 g/ha at 20 to 25 DAS gives effective control of *Echinochloa colona, Eleusine indica, Cyperus rotundus* and *Fimbristylis miliacea* (Singh *et al*., 2014). Cyhalofop-butyl which is a post emergence graminicide, is very effective in control of barnyard grass. Flubendiamide and imidacloprid are two popular, new generation insecticides in rice. Imidacloprid is a systemic insecticide, which effectively controls plant and leaf hoppers. Flubendiamide is highly effective against lepidopteran pests.

Tank mix application of these herbicides and insecticides has never been studied. With meagre data on effect of mixing, rice farmers of Kerala are adopting combined application of herbicides and insecticides. There may be incompatibilities between these herbicides and insecticides, which may be physical, chemical or biological. Hence, before adopting a combined plant protection schedule, studies on compatibility and efficacy have to be carried out to find out the suitability of a particular spray combination.

Based on these considerations, the present study was undertaken to identify the best combination of the above mentioned popular herbicides and insecticides for tank mix application in wet seeded rice without any loss in their efficacy.

The main objectives of the study were

- To study the compatibility of the herbicides, bispyribac sodium and cyhalofop-butyl, with the new generation insecticides, flubendiamide and imidacloprid, for tank mix application in wet seeded rice

- To assess pest control efficiency of the above herbicides and insecticides

Review of literature

2. REVIEW OF LITERATURE

Rice yields are threatened by competition and destruction from weeds and pests. Weed infestation along with insect pests cause severe damage to rice crops under field conditions. Effective and economic management strategies need to be framed to resolve the problem. Chemical control of weeds and insects is gaining importance all over the world. Separate application of different chemicals though most effective, will enhance the cost of production. Cost effective method is tank mix application of herbicides and insecticides. This chapter reviews the weed flora of rice, insect pests attacking rice, effect of weed competition on the crop, damage caused by insect pests, chemical control of pests as well as tank mix application of herbicides and insecticides.

2.1 Weed flora of rice

Global weed spectra of rice are different. Favorable conditions for growth of rice also cause growth and reproduction of terrestrial, aquatic and semi-aquatic weeds in rice field (Smith, 1968). According to Joy *et al.* (1991) weed flora of rice includes 37 per cent grasses, 33 per cent sedges and 30 per cent broad leaf weeds. In south and south east Asia about 1800 plant species have been reported as weeds of rice (Moody, 1989). Among the 1800 weed species, cyperaceae and poaceae are predominant (Rao *et al.*, 2007). *Echinochloa* species and weedy rice species are the most frequent weeds in the world, followed by *Cyperus* species and other representatives of the cyperaceae family. At the end of the 20th century *Leptochloa* species has become a serious problem in rice (Kraehmer *et al.*, 2016) and it is one of the most dominant grass species in rice (Karim *et al.*, 2004).

Adoption of direct-seeding has always resulted in the relative abundance of weed species in rice crops. *Echinochloa* spp., *Ischaemum rugosum*, *Cyperus difformis* and *Fimbristylis miliacea* are the major weeds found in the direct seeded rice field (Rao *et al.*, 2007). Prasad *et al.* (2016) studied the different species of weeds competing with rice under direct wet seeding system and observed that the major grass weeds were *Echinochloa colonum, E. crus-galli* and *Panicum repens* accounting for 33 per cent among grasses. *Fimbristylis mileacea* and *Cyperus iria* were the important sedges and *Sphenoclea zeylanica* formed the major broad leaf weed. Ferrero (2003) reported that barnyard grass (*Echinochloa crus-galli*) was the dominant weed in lowland. He also observed that with increased adoption of direct seeding methods, weedy rice (*Oryza sativa* f.sp. *spontanea*) had become another major weed in rice production. This also caused reduction in milling quality of rice (Ottis *et al.*, 2005).

Kumari (2012) conducted a survey on rice weeds of Kerala and observed that the major weeds were *Alternanthera, Aeschynomene, Cleome* sp., *Cyperus* sp., *Echinochloa* sp. (*Echinochloa colona, Echinochloa crus-galli* and *Echinochloa glabrescens*), *Eichhornia, Fimbristylis miliacea, Grangea maderaspatana, Hydrolea, Monochoria, Lindernia, Ludwigia parviflora, Oldenlandia, Phyllanthus, Salvinia, Sphaeranthus indicus, Sphenoclea zeylanica,* wild rice *etc*. Of these, *Cyperus sp.* was the most abundant weed species present in all the rice growing tracts and *Grangea maderaspatana* was observed mainly in the Kole lands.

Menon *et al*. (2014) recorded that grasses were the major weed species found in Alappad Kole lands, which included *Echinochloa colona, Echinochloa crus-galli, Echinochloa stagnina* and *Leptochloa chinensis*. *Ludwigia perennis, Lindernia crustacea, Monochoria vaginalis, Sphaeranthes indicus* and *Alternanthera* sp. were the broadleaf weeds and *Fimbristylis mileacea, Cyperus iria* and *Cyperus difformis* were the sedges present.

2.2 Weed competition in rice

Crop-weed competition was a major yield limiting factor in rice production (Bastiaans *et al.,* 1997). Weeds competed for light, nutrients, water, space and air and caused reduction in yield and market value of the crop produce. They would also increase the cost of harvesting, drying and cleaning (Smith, 1968). Kaur *et al*. (2016) reported that weed population of rice under monoculture had increased due to the use of high yielding varieties along with the supply of water and nutrients.

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Azmi and Baki (1995) estimated yield losses caused by grasses, broad leaf weeds and sedges and arrived at values of 41, 28 and 10 per cent respectively. Hazanuzzaman *et al.* (2009) reported that yield loss due to weeds was more in direct seeded rice than transplanted rice. Weeds in transplanted rice cause a yield loss of 45-51 per cent (Veeraputhiran and Balasubramanian, 2013), but in direct-seeded rice it was up to 80 per cent (Jabran *et al.,* 2012). According to Ranjit (2007) yield loss by weeds in direct seeded rice was 14-93 per cent and in transplanted rice it was reduced to 7- 47 per cent. Raj *et al.* (2013) observed a yield reduction of 69.71 per cent during kharif season and 67.40 per cent during rabi season in wet seeded rice due to season long weed competition.

Weeds form the major biotic constraint affecting the success of direct seeded rice (Rao *et al.*, 2007). Emerging seedlings of direct sown crop are less competitive due to the absence of size advantage available for transplanted crop (Chauhan and Johnson, 2010). Puddled soil causes a severe infestation of weeds in direct sown rice (Pattar *et al.,* 2005). Singh *et al.* (2014) reported a yield loss up to 100 per cent in direct seeded rice when weeds were not controlled throughout the season. According to Maity and Mukherjee (2009), reduction in grain yield due to uncontrolled weeds in dry direct seeded rice and wet direct seeded rice is 96 per cent and 61 per cent respectively. The success of wet seeding entirely depends on efficient weed management practices (Lal *et al.,* 2014).

2.3 Critical periods of crop-weed competition in rice

A period during the crop growth cycles in which weeds must be controlled to prevent yield losses is known as critical period for weed control (Zimdahl, 1988). Knowledge about the weeds associated with rice and weed emergence patterns is essential for successful implementation of critical periods of crop weed competition concepts.

Singh *et al.* (2014) reported that critical weed-free period of direct seeded rice was longer than transplanted rice, which ranged from 11.8 to 83.2 days after sowing. Mukherjee *et al.* (2008) observed that critical periods of crop-weed competition in transplanted and wet seeded rice were from 20 to 40 DAT and 15 to 60 DAS respectively.

Dhammu and Sandhu (2002) observed that critical period of *Cyperus iria* in transplanted rice was 30-40 DAT. Maximum reduction in yield (35.2 per cent) was observed due to weed competition during this period. *Cyperus iria* competition for the first 30 days caused less than one fourth (12.9 per cent) of the total losses in yields, while competition for 40 days resulted in more than half (43.5 per cent) of the total losses due to the weeds.

2.4 Nutrient removal by weeds and crop

Kumar *et al.* (2010) reported that removal of N, P and K was maximum in weedy check. It was significantly lower in twice hand weeded plot. Singh and Namdeo (2004) observed that nutrient uptake by rice was maximum in plots hand weeded twice followed by pendimethalin +2,4-D applied plots.

Weeds in bispyribac sodium sprayed plots showed very low nitrogen uptake (1.5 kg/ha) at 60 DAS which was only one-twelfth of the uptake registered in unweeded control (41 kg/ha). Minimum uptake of 0.6 kg/ha was observed in hand weeded plot (Menon *et al.,* 2014).

2.5 Weed control in rice

Weed control is one of the most laborious and expensive operations in rice production. There are cultural, mechanical and chemical weed control practices. Cultural methods are an integral part of rice production. Combinations of cultural and chemical practices are more effective in controlling weeds in rice.

2.5.1 Effect of hand weeding

Hand weeding is an effective method of weed control for achieving maximum yields in direct seeded rice (Yadav *et al.*, 2009). Angiras and Sharma (1998) found that two hand weedings before 40 days after rice seeding will reduce the crop-weed competition. Rawat *et al*. (2012) reported that hand weeding at 20 and 40 DAS gave maximum grain and straw yield. The grain and straw yields recorded in hand weeded plot were 4.85 t/ha and 6.53 t/ha respectively whereas 18 the figures for weedy check were 1.62 t/ha and 3.05 t/ha respectively. Raghavendra *et al.* (2015) also found that hand weeding at 20 and 40 DAS resulted in maximum grain yield which was on par with herbicide treatments.

Saha *et al.* (2007) recorded higher nitrogen uptake by grain (75.03 kg/ha) and straw (25.26 kg/ha) in plots hand weeded at 20 and 40 DAS. Higher grain productivity of transplanted rice was obtained by hand weeding twice at 20 and 40 DAT (5.89 t/ha) and this was on par with application of butachlor 50 EC @ 1.5 kg a.i./ha at 3 DAT followed by cono-weeding at 20 DAT (5.78 t/ha) (Islam and Kalita, 2016).

2.5.2 Use of herbicides on weeds

Physical weed control methods like hand weeding and mechanical interculture are impractical in rice due to increasing labour cost and narrow row spacing (Kaur *et al.,* 2016). According to Chauhan *et al*. (2014), herbicides are superior to manual or mechanical method of weed control. Use of chemical herbicides is an easier, time and labour saving and economical method compared to hand weeding (Rekha *et al*., 2003). De Datta *et al.* (1989) reported that use of herbicides was most effective, viable and economic option for weed control in direct wet seeded rice. This reduced the cost of cultivation also (Jacob *et al.,* 2014).

Bandara *et al.* (2015) confirmed that oxyfluorfen @ 150 g/ha applied at 3 or 4 DAS controlled weeds effectively and gave grain yield on par with pretilachlor. Bharathalakshmi *et al*. (2015) reported higher grain yields with pre emergence application of anilophos @1.2 L /ha at 3-5 DAS in wet direct seeded rice. Spraying of fenoxaprop-p ethyl or cyhalofop-butyl along with metsulfuron methyl + chlorimuron ethyl or bispyribac sodium as post emergence were found effective for broad spectrum weed control and higher grain yield in direct seeded rice (Menon and Prameela, 2015).

In dry seeded rice, pre-emergence herbicides like butachlor, pretilachlor and oxyfluorfen are very effective. However they are not very popular in wet seeded rice due to phytotoxicity problems. Early post-emergence herbicides, pyrazosulfuron ethyl and benzsulfuron + pretilachlor are effective in wet seeded and transplanted rice. Cyhalofop-butyl and fenoxaprop-p ethyl are very effective against grass weeds, while 2,4-D, Almix®, ethoxysulfuron, and carfentrazone are good against broad leaf and sedge weeds. Bispyribac sodium, penoxsulam and azimsulfuron are promising broad spectrum herbicides (KAU, 2016).

Moorthy and Saha (2002) reported that pre-emergence application of quniclorac at 375 g/ha and butachlor and propanil at 560+500 to 840+840 g/ha at 10 DAS provided adequate weed control and yield was comparable to hand weeding twice in upland rice. Sairamesh *et al*. (2015) observed that effect on weeds by the pre-emergence application of oxadiargyl 100 g/ha followed by post - emergence application of penoxsulam 25 g/ha was on a par with hand weeding at 20 and 40 DAS.

2.5.3 Effect of unweeded control

Working with different weed management techniques in rice, Singh *et al.* (2016) found that unweeded control resulted in significantly lower grain yield due to higher weed competition and lesser availability of nutrients to the crop plants. Singh *et al*. (2005) observed a reduction in grain yield by 75.8, 70.6 and 62.6 per cent under dry-seeded rice, wet seeded rice and transplanted rice respectively in unweeded control.

2.6 Effect of bispyribac sodium

2.6.1 Effect on weeds

Bispyribac sodium is a post-emergence broad spectrum herbicide. It is effective against grasses, sedges and broadleaf weeds in rice fields (Schmidt *et al.*, 1999). It is aceto lactate synthase inhibitor in action (Raj and Syriac, 2016).

At 1-3 leaf stage or at 4-6 leaf stage of the weeds, post emergence application of bispyribac sodium @ 20 and 25 g/ha registered lowest weed density and biomass. They were less effective against *Leptochloa chinensis* (Singh *et al.*, 2014). Kumar and Rana (2013) reported that post emergence application of

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bispyribac sodium at 30 g /ha is effective for control of mixed weed flora in direct seeded rice.

Reduction in weed density due to application of bispyribac sodium at 15 and 25 DAT rice was reported by Yadav *et al*. (2009). Kumaran *et al*. (2012) also recorded lower weed density under bispyribac sodium than other weed management treatments in direct-seeded rice. Lower weed dry weight with the application of bispyribac sodium at 40 g/ha than with application of butachlor and anilophos in transplanted rice was reported by Nalini *et al*. (2012). The significant reduction of weed dry weight by bispyribac sodium at 30 g/ha than pre-emergence herbicide application in dry-seeded rice was also observed by Walia *et al*. (2008). According to Veeraputhiran and Balasubramanian (2013) post-emergence application of bispyribac sodium at the rate of 25 g/ha on 20 DAT is an economically efficient weed management practice for transplanted rice.

Das *et al*. (2017) observed a weed control efficiency of 94.67 per cent when bispyribac sodium at 25 g/ha was applied. Application of nominee gold 100 SC gave weed control efficiency of 90.50 per cent (Hussain *et al.,* 2008). Prameela *et al.* (2014) reported that application of bispyribac sodium had highest weed control efficiency, which was comparable to application of cyhalofop-butyl or fenoxaprop-p ethyl or metamifop with follow up spray of almix. Prakash *et al.* (2013) observed that application of bispyribac sodium @ 35 g/ha (15-20 DAT) resulted in lower weed density (9-10 no./ m^2), weed dry weight (12.5-13.7 g/m^2), weed persistence index (0.03), weed competition index (8.05-12.55 per cent), higher weed control efficiency (55.8-72.8 per cent) and herbicidal efficiency index (2.60- 2.96).

2.6.2 Effect on rice

Yadav *et al.* (2009) observed that post emergence application of bispyribac sodium did not show any phytotoxic symptoms on rice. Walia *et al*. (2008) reported that pre-emergence application of pendimethalin 0.75 kg/ha followed by bispyribac sodium @ 25 g/ha resulted in highest rice grain yield (50.16 q/ha). According to Singh *et al.* (2014), post emergence application of 21 bispyribac sodium @ 25 g/ha gave grain yield comparable to that of weed free check. Application of bispyribac sodium 50 g/ha at 15-20 DAT resulted in significantly higher grain yield (5.70 t/ha), which was on par with bispyribac sodium 35 g/ha at 15-20 DAT (Prakash *et al.,* 2013). Rawat *et al.* (2012) observed that bispyribac sodium @ 80 g/ha recorded maximum grain yield (4.59 t/ha) which was on par with other lower doses of bispyribac sodium except 10 g/ha and was significantly higher as compared to cyhalofop-butyl and butachlor treatments. Veeraputhiran and Balasubramanian (2013) observed per cent yield increments of 7.9, 2.2 and 73.5 due to application of bispyribac sodium @ 25 g/ ha over hand weeding twice, butachlor application and unweeded control respectively. Application of bispyribac sodium 10% SC at 10 g/ha resulted in grain yield of 4196 kg/ha which is 17.0 per cent less than bispyribac sodium 10% SC at 20 g/ha. Maximum harvest index of 0.59 was recorded by early post-emergence application of bispyribac sodium 10% SC at 40 g/ha (Kumaran *et al.,* 2015). Combined application of bispyribac sodium with metamifop @ 90g/ha recorded highest test grain weight which was on a par with hand weeding twice (Raj and Syriac, 2016).

2.7 Effect of cyhalofop-butyl

2.7.1 Effect on weeds

Cyhalofop-butyl is an effective herbicide against grass weeds (Saini *et al.,* 2001). It is an aryloxyphenoxy herbicide, effective against barnyard grass at its 5 leaf stage (Matsumoto *et al.,* 1994). Ruiz-Santella *et al.* (2006) reported that site of action of cyhalofop-butyl is inhibition of Acetyl CoA Carboxylase. The herbicide reduces the ability of plants to produce malonyl- coenzyme, which is needed for fatty acid synthesis.

Pre-emergence application of butachlor at 1500g/ha and post- emergence application of cyhalofop-butyl at 80g/ha were found equally effective in controlling *Echinochloa colona* and significantly enhanced grain yield of rice (Choubey *et al.,* 2001). Saini (2005) reported loss of herbicidal property of cyhalofop-butyl when mixed with 2,4- D. Application of cyhalofop-butyl 90g/ha

(15 DAS) followed by 2,4-D 1.0 kg/ha (20 DAS) or vice versa was found more effective. Application of clincher, the commercial formulation of cyhalofop-butyl, @ 2000 cc/ha and 2500 cc/ ha significantly reduced the number as well as dry weight of weeds over weedy check and lower dose of clincher (Samui *et al.*, 2005). According to Matsumoto *et al*. (1993) cyhalofop-butyl had highest selectivity between rice and *Echinochloa crus-galli.* The granular formulation of 0.6 per cent cyhalofop-butyl @ 180 and 360 g a.i./ ha effectively controlled *E. crus-galli* at its 3 and 4 leaf stage. Park *et al.* (1994) observed inhibition of *Echinochloa crus-galli* seedling growth when cyhalofop-butyl was applied at the rate of 180 ppm at 4 leaf stage.

Chin (2001) reported that application of cyhalofop-butyl at 15- 20 DAS as spot treatment resulted in effective control of red sprangle top at its nearly flowering stage or end of vegetative stage. Withering of the emerging leaves is the critical visual symptom produced by the plants when treated with cyhalofop-butyl (Ito *et al.,* 1998). According to Ruiz-Santaella *et al.* (2003), *Echinochloa oryzoides, E. oryzichola* and *E. hispidula* were cyhalofop tolerant biotypes of *Echinochloa*. Cyhalofop-butyl applied at 280 g a.i./ha at the two to three leaf or four to six leaf stage did not injure rice greater than 5 per cent, and rice yields were not reduced (Buehring *et al.,* 2006). Anurudhka *et al.* (2004) observed that application of cyhalofop-butyl 100% EC at 1L/ha was effective for 90 per cent control of *Leptochloa chinensis*. Weed control with cyhalofop-butyl applied at 200g/ha was reduced when applied to four-leaf compared to two-leaf barnyard grass (Ntanos *et al.,* 2000).

2.7.2 Effect on rice

Saini (2003) observed that effectiveness of cyhalofop-butyl application at 10, 15 and 20 DAS were on par and resulted in higher grain yield over its application at 25 DAS. Choubey *et al.* (2001) reported that post emergence application of cyhalofop-butyl at 80g/ha and pre emergence application of butachlor at 1500g/ha resulted in comparable grain yields of 2384 and 2571 kg/ha respectively. Application of cyhalofop-butyl (15 DAS) followed by hand weeding at 45 DAS was found very effective and resulted in highest number of panicles per m^2 and yield. The treatment was on par with hand weeding twice (Sangeetha *et al.*, 2009). Matsumoto *et al.* (1993) reported that there was no phytotoxicity on rice seedlings when granular formulation of cyhalofop-butyl at 180 g/ ha was applied.

2.8 Insect pests of rice

The insect pests at various crop growth stages are one of the major constraints in rice production and it has been reported that protected rice crop yielded 28.8 per cent more than the unprotected. About 300 species of insect pests attack the paddy crop at various stages, of which only 23 species cause notable damage (Pasalu and Katti, 2006). Among them few act as vectors of virus diseases (Pradhan, 1971). Warm and humid environment of rice is suitable for the survival and proliferation of lepidopteran pests (Aulakh *et al.*, 2016). Singh *et al.* (2002) reported that *Scirpophaga incertulas* (yellow stem borer), *S. innotata* (white stem borer), *Sesamia inference* (pink stem borer), *Sogatella furcifera* (white backed plant hopper) and *Cnaphalocrocis medinalis* (leaf folder) caused extensive damage to rice plants. Among them yellow stem borer was most problematic to various rice ecosystems (Deka and Barthakur, 2010). Mahar *et al.* (1985) also reported that yellow stem borer was the predominant insect pest in India. Lal (1996) reported that stem borer and brown plant hopper were the worst pests of rice, causing severe damage and yield loss in the later stages of the crop.

2.9 Damage caused by insect pests

Gupta and Raghuraman (2003) observed that insect pest damage during vegetative phase (50 per cent) contributed more to yield reduction than the reproductive (30 per cent) or ripening phase (20 per cent). Puri (2000) reported that yellow stem borer, gall midge and brown plant hopper were the key pests in rice causing 10 to 70 per cent, 15-60 per cent and 25-30 per cent loss, respectively. Varma *et al.* (2008) also reported that brown plant hopper (*Nilaparvata lugens)* is a major sucking pest and caused a yield loss of 20-60 per cent. Misra *et al.* (2005) reported that yellow stem borer would attack the rice 24 crop from seedling to maturity. Globally, yellow stem borer alone caused yield loss of 10 million tons in rice and 50 per cent of the insecticides are used for their management in the rice field (Huesing and English, 2004). According to Catinding and Heong (2003), yellow stem borer caused a yield loss of 1 to 19 per cent and 38 to 80 per cent in early planted and late planted rice crop respectively. It caused dead hearts at active tillering stage and white ears at harvest stage and led to complete failure of the crop (Karthikeyan and Purushothaman, 2000). Parwez *et al.* (2005) observed that critical stages of infestation of stem borer in boro rice were vegetative and reproductive stages.

Cnaphalocrocis medinalis also gained the status of major pest due to changes in cultural practices and use of high yielding varieties (Teng *et al.,* 1993). It caused 18.30 to 58.40 per cent damage in rice (Ramasamy and Jaliecksono, 1996). Boot leaf stage of rice was more suffered by leaf folder attack which caused a yield reduction of 48.8-56.9 per cent (Uthamasamy, 1985).

Another important pest was rice bug, which sucked sap from milky grains and made them chaffy (Gupta *et al.,* 1993). Infestation of rice bug caused reduction in grain viability (Rao and Prakash, 1995). This also resulted in yield loss of 10-40 per cent (Rao and Kulshrestha, 1985). According to Pasalu and Katti (2006) *Orseolia oryzae* is a major pest of rice in India, causing a yield loss of 12-35 per cent. Reduction in yield caused by stem borer alone was 21-51 per cent (Singh and Dhaliwal, 1994). Murugesan and Chellaiah (1983) reported that loss in yield due to stem borer and leaf folder was 48.8 to 56.9 per cent. Attack of brown plant hopper caused a yield loss of 10-75 per cent according to Rao (1950). Hopper burn due to white backed plant hopper caused an extensive economic loss to farmers (Singh *et al.,* 2002). Raj and Khan (2002) reported that green leaf hopper *Nephotettix virescens* acted as a vector of tungro virus disease.

2.10 Use of insecticides

Misra and Parida (2004) observed a positive impact of insecticides on rice production. Grain yield of basmati rice increased significantly due to insecticidal application (Aulakh *et al.,* 2016).

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2.11 Flubendiamide

Flubendiamide is a novel class of insecticides, used for broad spectrum control of lepidopteran insect pests (Tohnishi *et al.,* 2005). Sekh *et al.* (2007) reported that flubendiamide 480 SC @ 24 and 30 g a.i./ha was effective for the control of yellow stem borer. There was no effect on egg parasitoids of yellow stem borer and the per cent parasitisation was similar to the untreated plots. Bioefficacy of flubendiamide against stem borer was observed by Rao *et al.* (2008) also. Bhanu and Reddy (2008) observed that flubendiamide 20 WDG @ 25 g a.i./ha and flubendiamide 48 SC @ 24 g a.i./ha were effective for the control of stem borer and leaf folder and recorded significantly low per cent white ears (0.7 and 0.9 respectively) as compared to untreated control (6.4). Devi and Singh (2016) reported that flubendiamide 39.35 SC was most effective against dead heart incidence which resulted in minimum dead heart incidence of 3.48 per cent as compared to 16.64 per cent in the untreated control. Highest mean grain yield of 6.03 t/ha was also recorded from flubendiamide treated plot. Kubendran *et al.* (2006) and Thilagam (2006) found that flubendamide is less toxic against beneficial arthropods. Chormule *et al.* (2014) also observed that flubendiamide 480 SC @ 30 g a.i./ha was moderately safe to natural enemies. Prasad *et al.* (2014) reported that flubendiamide 20 WDG @ 175 g/ha was effective for the control of yellow stem borer. Sandhu and Dhaliwal (2016) also observed a reduction in dead heart, white ear head and leaf folder incidence when fame 480 SC was applied at 50 ml/ha. No phytotoxicity symptoms were observed when flubendiamide 480 SC was applied on crop at 100, 200 and 400 ml/ha (Kubendran *et al.*, 2008).

2.12 Imidacloprid

Imidacloprid is a systemic neonicotinoid insecticide, used for broad spectrum control of insects (Liu *et al.* 2002). The chemical inhibits nicotinic acetylcholine receptors in the nervous system and is an ideal insecticide against sucking pests (Jiania *et al.,* 2013). It has low mammalian toxicity and high insecticidal activity. In the aquatic environment it is degraded by photodegradation (Fossen, 2006). After direct contact, imidacloprid would readily be translocated through plant tissues (Steward *et al.,* 1998). Bhandari *et al.* (2016) reported that imidacloprid 0.3% GR @ 30 kg/ha resulted in a significant reduction in brown plant hopper population compared with its lower doses of 10, 15 and 25 kg/ha. At any dose of the chemical tried, there was no phytotoxicity problem. Kang *et al.* (2007) observed that residues of imidacloprid in rice grain, straw and husk were 0.01, 0.05 and 0.055 mg/kg respectively, which were below the limit of determination. Imidacloprid was highly effective for the control of rice brown plant hopper (Zang-Hong and Zang, 1996). Ramu *et al.* (2005) reported that sucking pests such as brown plant hopper, green leaf hopper and white backed plant hopper were controlled by imidacloprid @ 0.25 ml/L. Hedge (2005) also observed that imidacloprid 17.8 SL at 50 g a.i./ha was effective for the control of brown plant hopper. Phytotonic effect of imidacloprid at 0.05 % on semi -dry rice was reported by Mohanasarida (2002).

2.13 Relation between weeds and insect pests

Co-existence of weeds and insects causes yield reduction in agricultural systems. Presence or absence of certain weeds may increase or decrease insect infestations in crops (Ali and Reagan, 1985). Weeds act as alternate hosts for rice insect pests. Odglen and Warren (1962) reported that barnyard grass (*Echinochloa crus-galli*) was a preffered host for rice sting bug. Pathak (1968) reported that *Echinocloa* spp. acted as alternate host for several insects, especially for plant hoppers and leaf hoppers. Karthikeyan and Sosamma (2009) reported that *Panicum repens* acted as an alternate host for blue beetle. Weed management practices also interfered with insect pest infestation and use of herbicides altered their feeding behavior (Adams, 1960). Injury to rice crop due to insect pests was higher in unweeded control than weed free plots.

2.14 Tank mix application of herbicides and insecticides

No previous works are reported on mixing of bispyribac sodium and cyhalofop-butyl with flubendiamide or imidacloprid. In this part literature on mixed application of herbicides and insecticides in general are reviewed. 27

Herbicide- insecticide combination resulted in synergistic phytotoxicity to oats and corn (Nash, 1968). Tank mixing of herbicides with insecticides would save fuel, labor costs, machine depreciation, soil compaction and mechanical damage to dry bean (*Phaseolus vulgaris* L.) leaves (Jordan *et al.,* 2003). Combined application of herbicides and insecticides may enhance or reduce pest infestation (Smith and Tungwell, 1975). According to Pankey *et al*. (2004), combined application of glyphosate with dicrotophos and imidacloprid reduced infestation of cotton aphid and thrips better than individual application of insecticides. Bowling and Hudgins (1966) reported that combined application of propanil with carbamate or organophosphate will cause greater injury to rice. Deepa and Jayakumar (2003) observed that there was no crop toxicity and no change in grain and straw yield when pretilachlor was tank mixed with monocrotophos. Combined application of metribuzin with organophosphate insecticide resulted in crop injury in soybean (Waldrop and Banks, 1983). Hamill and Penner (1973) observed that tank mixing of alachlor with carbofuran caused a synergistic effect on barley but not on corn. Waywell *et al.* (1967) observed incompatibility of herbicide propanil with insecticides malathion, carbaryl or phorate on potato.

2.15 Economics

Experimenting with different weed control methods in rice, Prameela *et al.* (2014) observed that hand weeding recorded highest cost of cultivation of Rs. 45,825 per ha and highest return of Rs. 1,08,900 per ha. The treatment resulted in a B:C ratio of 1.4. Atheena (2016) reported that combined application of herbicides cyhalofop-butyl+ pyrazosulfuron- ethyl resulted in a higher B:C ratio of 2.5. A net return of Rs. 38,970 and B:C ratio of 2.79 was reported by the application of bispyribac sodium 10 % SC at 40 g/ha (Kumaran *et al.,* 2015).

Materials & methods

3. MATERIALS AND METHODS

The field experiment for studying the compatibility of herbicides and insecticides for tank mix application in wet seeded rice was conducted in Purathoor *padasekharam*, a part of Alappad Kole land of Thrissur district. The work was started in August 2016 and was completed in January 2017. The details of materials used and methods adopted are presented below.

3.1 General details

3.1.1 Location

Kole lands of Thrissur district are located at $10^0 31'$ N latitude and $76^0 13'$ E longitude and 1m below mean sea level (MSL).

3.1.2 Climatic and weather conditions

The area experiences a humid tropical climate. The mean maximum and minimum temperature and the mean rainfall during the cropping period are presented in Appendix I.

3.1.3 Soil characteristics

Soils of Kole lands, in general, come under the clayey textural class. The physico-chemical characteristics of the soil of the experimental plots are given in Table 1.

3.1.4 Season

The crop was raised in second crop season (*Mundakan*/winter), from August 2016 to January 2017.

3.1.5 Variety

Uma (MO 16), a medium duration (115-120 days), red kernelled and bold grained variety, released from Rice Research Station, Moncompu, was used for the experiment. It is non lodging and resistant to BPH and GM biotype-5. The variety exhibits dormancy up to three weeks and is suited to all the three seasons of Kerala.

3.1.6 Cropping history of the experimental site

Alappad Kole lands are single cropped wetland areas. During major part of the year the land will be inundated with water and cultivation is done after pumping out water, during *Mundakan* season (August-September to December-January).

Table 1. Physico-chemical characteristics of the soil

Particulars	Value
A. Particle size analysis	
Sand (%)	20.5
Silt (%)	22.3
Clay (%)	57.2
B. Chemical composition	
Organic C (%)	2.75
Available N (kg/ha)	242.51
Available P (kg/ha)	26.51
Available K (kg/ha)	419.46
pH	5.25

3.2 Experimental details

3.2.1 Treatments

The field experiment was conducted in a farmer's field (Mr. Kesavaraj, Kudappully House, Alappad (P.O), Thrissur district). The experiment was laid out in Randomized Block Design (RBD) with 14 treatments and three replications (Fig.1) and with a plot size of 5m x 4m. Details of 14 treatments are given in Table 2.

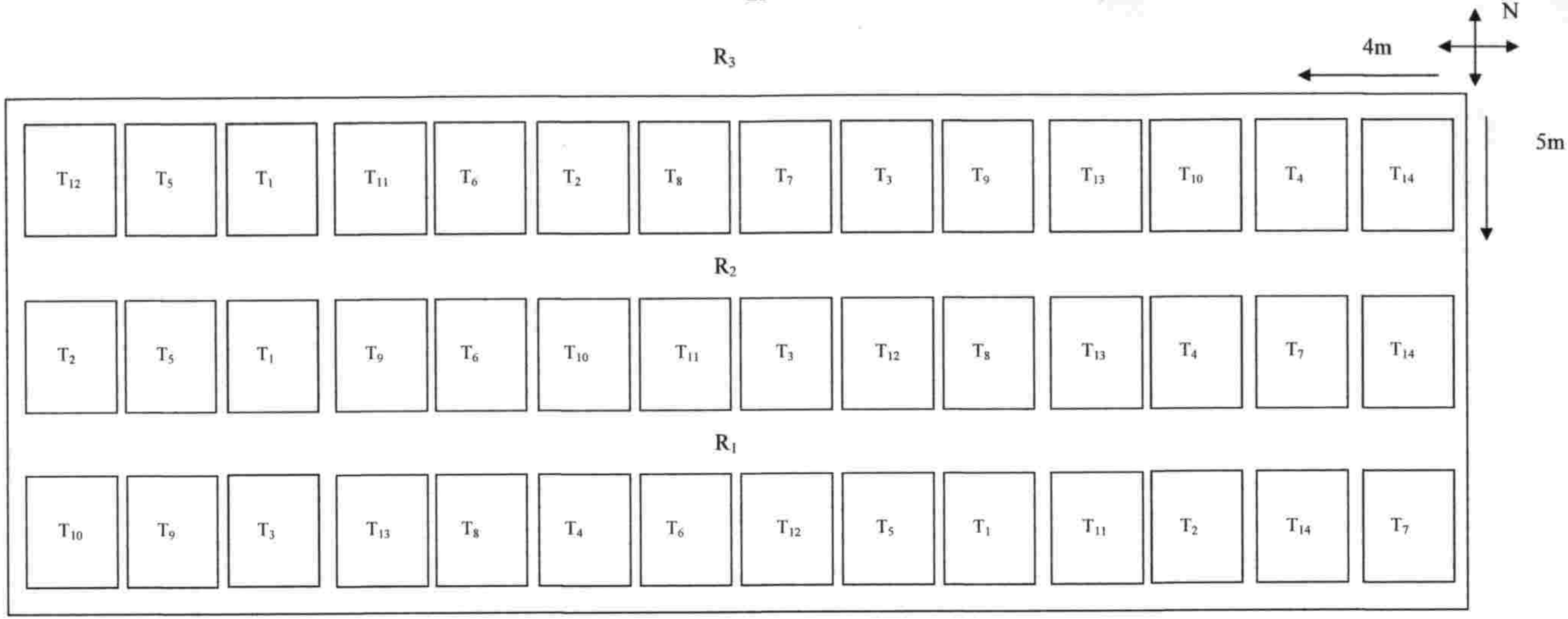

Fig. 1. Layout of the experiment

T_1- Bispyribac sodium *f.b.* *Flubendiamide the next day

T_2- Bispyribac sodium *f.b.* Imidacloprid the next day

T_3- Bispyribac sodium+ Flubendiamide

T_4- Bispyribac sodium + Imidacloprid

T_5- Cyhalofop-butyl *f.b.* Flubendiamide the next day

T_6- Cyhalofop-butyl *f.b.* Imidacloprid the next day

T_7- Cyhalofop-butyl + Flubendiamide

T_8- Cyhalofop-butyl + Imidacloprid

T_9- Hand weeding + Flubendiamide

T_{10}- Hand weeding + Imidacloprid

T_{11}- Bispyribac sodium

T_{12}- Cyhalofop-butyl

T_{13}- Hand weeding

T_{14}- Unweeded control

**f.b.*- followed by

Table 2. Treatments, trade name and recommended dose per ha

No.	Treatments	Trade name, formulation and recommendation per ha
T_1	Bispyribac sodium at 0.025 kg/ha at 20 DAS and Flubendiamide at 25 g/ha the next day	Nominee gold 10 SC (250 ml/ha), Fame 480 SC (50 ml/ha)
T_2	Bispyribac sodium at 0.025 kg/ha at 20 DAS and Imidacloprid at 30 g/ha the next day	Nominee gold 10 SC (250 ml/ha), Confidor 17.8 SL (150 ml/ha)
T_3	Bispyribac sodium at 0.025 kg/ha + Flubendiamide at 25 g/ha at 20 DAS	Nominee gold 10 SC (250 ml/ha) + Fame 480 SC (50 ml/ha)
T_4	Bispyribac sodium at 0.025 kg/ha + Imidacloprid at 30 g/ha at 20 DAS	Nominee gold 10 SC (250 ml/ha) + Confidor 17.8 SL (150 ml/ha)
T_5	Cyhalofop-butyl at 0.08 kg/ha at 20 DAS and Flubendiamide at 25 g/ha the next day	Clincher 10 EC (800 ml/ha), Fame 480 SC (50 ml/ha)
T_6	Cyhalofop-butyl at 0.08 kg/ha at 20 DAS and Imidacloprid at 30 g/ha the next day	Clincher 10 EC (800 ml/ha), Confidor 17.8 SL (150 ml/ha)
T_7	Cyhalofop-butyl at 0.08 kg/ha + Flubendiamide at 25 g/ha at 20 DAS	Clincher 10 EC (800 ml/ha) + Fame 480 SC (50 ml/ha)
T_8	Cyhalofop-butyl at 0.08 kg/ha + Imidacloprid at 30 g/ha at 20 DAS	Clincher 10 EC (800 ml/ha) + Confidor 17.8 SL (150 ml/ha)
T_9	Hand weeding + Flubendiamide at 25 g/ha	Fame 480 SC (50 ml/ha)
T_{10}	Hand weeding + Imidacloprid at 30 g/ha	Confidor 17.8 SL (150 ml/ha)
T_{11}	Bispyribac sodium at 0.025 kg/ha at 20 DAS	Nominee gold 10 SC (250 ml/ha)
T_{12}	Cyhalofop-butyl at 0.08 kg/ha at 20 DAS	Clincher 10 EC (800 ml/ha)
T_{13}	Hand weeding at 20 and 40 DAS	-
T_{14}	Unweeded control	-

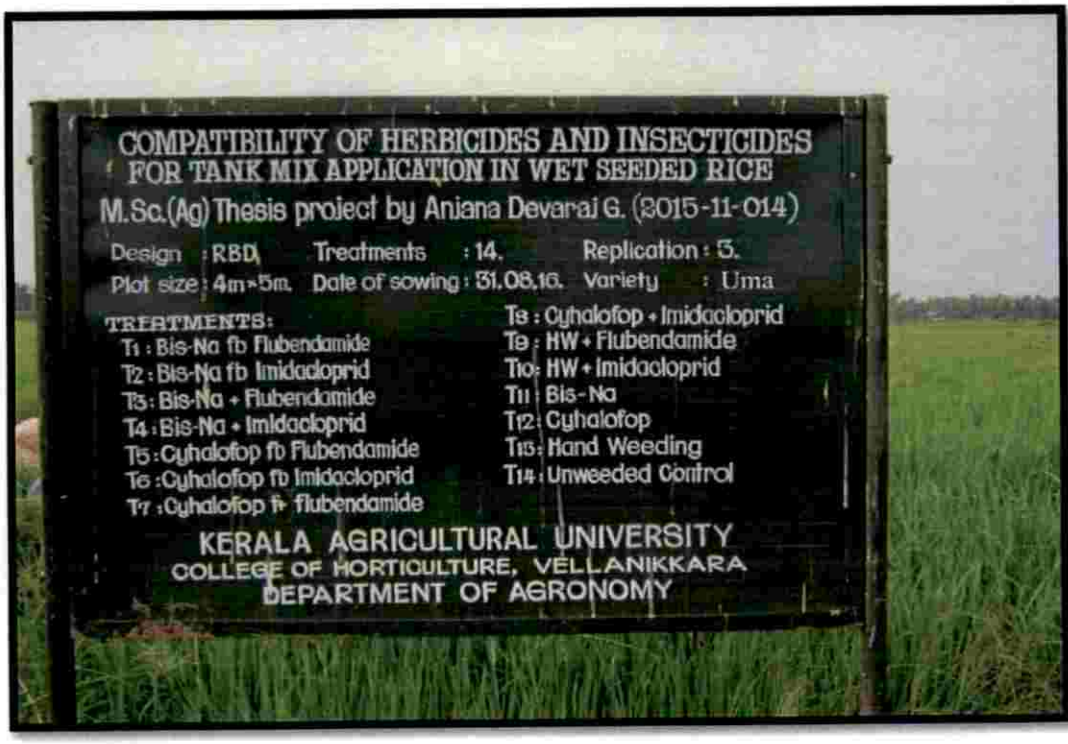

Plate 1. General view of the experimental plot

Plate 2. Spraying at 20 days after sowing

Plate 3. Hand weeding at 20 days after sowing

Bispyribac sodium

Cyhalofop - butyl

Flubendiamide

Imidacloprid

Plate 4. Herbicides and insecticides

Bispyribac sodium
+
Flubendiamide

Bispyribac sodium
+
Imidacloprid

Cyhalofop - butyl
+
Flubendiamide

Cyhalofop - butyl
+
Imidacloprid

Plate 5. Herbicides mixed with insecticides

3.2.2 Field operations

The field operations carried out during the experimental period (29/08/16-04/01/17) are given below.

Land preparation, sowing and fertilizer application

After pumping out the inundated water, the land was thoroughly ploughed and levelled. Layout of the experiment and bund preparation was done after leveling. Fertilizer application at the rate of 110: 45: 45 kg N:P_2O_5: K_2O per ha was done in the field as per the POP recommendations (KAU, 2016). N and K were applied in three equal split doses at the time of land preparation, maximum tillering and panicle initiation stages. Full dose of P was applied basally. After the basal application of fertilizers, wet seeding was done in each plot using pre-germinated seeds at the rate of 200 g/plot.

Harvesting

The crop was harvested during the first week of January when the grains were fully matured. Threshing and winnowing of the produce was done manually. Grain and straw yields from each plot were taken separately and expressed in t/ha.

3.3 Observations recorded

3.3.1 Biometric observations on crop

Plant height

Ten plants were selected from each plot randomly. The height from the ground level to the tip of longest leaf was measured at 30 DAS, 60 DAS and at harvest and expressed in centimetres. The average was recorded as plant height in each plot.

Tiller count

Number of tillers coming under 0.25 m^2 quadrat was counted from each plot at 30 DAS, 60 DAS and at harvest and expressed in number per m^2.

Number of panicles

Number of panicles in one metre square area was counted and recorded at the time of harvest using 1.0 m^2 quadrat.

Number of spikelets per panicle

Number of spikelets of ten panicles collected randomly from each plot was counted and the average was recorded as spikelets number per panicle.

Number of filled grains per panicle

Number of filled grains in ten panicles collected randomly from each plot was counted and average was recorded as number of filled grains per panicle.

Thousand grain weight

After harvesting, threshing and drying, 1000 grains from each plot were taken and their weight was recorded in grams.

Filling percentage

Filled grains and chaffy grains in ten panicles collected randomly from each plot were counted. The mean was worked out, and number of filled grains was expressed as percentage of total.

Grain and straw yield

After harvesting, threshing and winnowing, grain and straw yields of the different plots were measured separately and expressed in t/ha.

Dry matter production

Plants coming within in a quadrat of 0.25 m^2 area were uprooted from each plot at 30 DAS, 60 DAS and at harvest. After oven drying, weights were taken and expressed as t/ha.

Visual phytotoxicity at 3 and 7 days after spraying

Phytotoxicity of chemicals on crop was observed at 3 and 7 day after spraying and phytotoxicity scoring was done based on herbicide phytotoxicity rating in crop (Thomas and Abraham, 2007).

Table 3. Herbicide phytotoxicity rating in crop

Rating	Effect on crop
0	No injury
1	Slight injury
2	Moderate injury
3	Severe injury
4	Very severe injury
5	Complete destruction

3.3.2 Observations on weeds

Weed count

Species wise weed count was taken from each plot using 0.25 m^2 quadrat at 30 DAS, 60 DAS and at harvest, and expressed on per m^2 basis.

Dry matter production of weeds

Weeds coming within a quadrat of 0.25m^2 area in each plot were uprooted at 30 DAS, 60 DAS and at harvest. After oven drying, weights were taken and expressed as kg/ha.

***Weed Control Efficiency* (WCE)**

Efficiency of an applied herbicide was computed using the following formula

$$\text{WCE} = \frac{\text{WDMP* in unweeded control - WDMP in treatment plot} \times 100}{\text{WDMP in unweeded control}}$$

(Mani *et al.*, 1973)

*Weed Dry Matter Production

ho

3.3.3 Observations on insect pests

Number of insect pests coming within a $0.25m^2$ area were counted from each plot diagonally 4 times at intervals of 5, 7 and 11 days after spraying. Number of stem borers, defoliators and sucking pests were expressed as number per m^2.

3.4 Chemical analysis

3.4.1 Soil analysis

Soil samples were analysed both before and after the experiment to determine changes in pH, organic C and primary nutrient status. Standard procedure was followed for soil collection. After land preparation and layout, three representative samples were collected from each replication and analysed. Estimation after the experiment was done from soil samples collected from each plot. For the analysis, standard procedures as shown in Table 4 were used.

3.4.2 Plant analysis

Primary nutrient status of straw and grain were analysed. Plant samples were collected at the time of harvest, dried and powdered. For P and K estimation, samples were digested with diacid mixture and for nitrogen estimation, samples were digested with sulphuric acid and digestion mixture. Standard procedures used for analysis of plant samples are shown in Table 5.

3.5 Economics

Based on prevailing market value of various inputs and outputs, the cost of cultivation and gross returns were calculated, and expressed in rupees per ha. Current local market price of paddy grain and straw were taken as Rs. 21.50/- and Rs. 9/- per kg respectively. The benefit- cost ratio was computed using the formula.

$$\text{B:C ratio} = \frac{\text{Gross return}}{\text{Cost of cultivation}}$$

Table 4. Methods used for soil analysis

Particulars	Method
Particle size analysis	International pipette method (Piper, 1966)
pH	Soil water suspension of 1: 2.5 read in pH meter (Jackson, 1958)
Organic C (%)	Walkley and Black method (Jackson, 1958)
Available N (kg/ha)	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P (kg/ha)	Bray- 1 extractant, Ascorbic acid reductant method (Watnabe and Olsen, 1965)
Available K (kg/ha)	Neutral normal ammonium acetate extractant, flame photometry (Jackson, 1958)

Table 5. Methods used for plant analysis

Particulars	Method
N	Microkjeldhal digestion and distillation method (Jackson, 1958)
P	Vanadomolybdate phosphoric yellow colour in nitric acid system (Piper, 1966)
K	Diextract using flame photometry (Piper,1966)

3.6 Data analysis

The data on various parameters were statistically analysed using WASP 2.0(Web Based Agricultural Statistics Software Package). Square root transformation ($\sqrt{x + 0.5}$) was done for the data on weed count, weed biomass and insect pest count. Duncan's Multiple Range Test (DMRT) was used for multiple comparisons between treatment means

Results

4. RESULTS

An experiment on "Compatibility of herbicides and insecticides for tank mix application in wet-seeded rice" was conducted in a farmer's field at Alappad Kole lands of Thrissur district from August–January (*Mundakan*) of 2016-17. Data generated under the experiment are classified and presented here, after statistical analysis.

4.1 Studies on weeds

4.1.1 Weed spectrum

Grasses and sedges mainly dominated the experimental field. Grass species included *Echinochloa crus-galli, Echinochloa stagnina and Leptochloa chinensis.* The broad leaf weeds present in the field comprised of *Ludwigia parviflora* and *Limnophila heterophylla. Cyperus iria* was the only sedge species observed. Species wise weed counts were taken at 30 DAS, 60 DAS and at harvest and are presented in Table 6, 7 and 8 respectively.

4.1.2 Species wise weed count

At 30 DAS, *Cyperus iria and Echinochloa crus-galli* were the dominant weeds (Table 6). Count of *Cyperus iria* was high in all cyhalofop-butyl treated plots irrespective of the insecticide combinations, but was less than unweeded control. *Ludwigia parviflora and Limnophila heterophylla* were the broad leaf weeds present at 30 DAS. Population of individual broad leaf weed species was less compared to *Echinochloa* and *Cyperus*. Count of broad leaf weeds was highest in unweeded control (23.00 no./m^2), followed by cyhalofop-butyl and its combination treatments. All other treatments were free of broad leaf weeds. Total number of weeds was less in hand weeded treatments. Among tank mix applications of bispyribac sodium with insecticides lowest weed count was recorded in bispyribac sodium + imidacloprid (T_4) and among cyhalofop-butyl with insecticides, cyhalofop-butyl + flubendiamide (T_7) treatment. Bispyribac sodium + flubendiamide (T_3) treated plot showed highest number of *Echinochloa crus-galli* (18.00 no./m^2).

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At 60 DAS, *Cyperus iria* and *Leptochloa chinensis* were the major weeds. Total weed count was highest in unweeded control (130.50 no./m^2). Count of *Cyperus iria* was high in cyhalofop-butyl treatments. Population of *Leptochloa chinensis,* a newly observed weed at this stage was high in bispyribac sodium sprayed treatments. Population of broad leaf weeds was very less at this stage. *Ludwigia parviflora* was the only broad leaf weed observed. Its population was high in cyhalofop-butyl + imidacloprid (T_8) treated plot (4.50 no./m^2), followed by cyhalofop-butyl alone (4.00 no./m^2), cyhalofop-butyl *f.b.* flubendiamide (3.33 no./m^2), cyhalofop-butyl + flubendiamide (2.50 no./m^2), cyhalofop-butyl *f.b.* imidacloprid (2.00 no./m^2) and hand weeding + flubendiamide (2.00 no./m^2). All other treatments were free of *Ludwigia parviflora.* Lowest weed count was recorded in hand weeded treatments. At this stage also, count of *Echinochloa crus-galli* was high in bispyribac sodium + flubendiamide (T_3) treatment (18.66 no./m^2).

At harvest, *Echinochloa crus-galli* and *Cyperus iria* were the major weeds. Plants of *E. stagnina* could also be identified at this stage. Total weed count was high in unweeded control (137.00 no./m^2), followed by cyhalofop-butyl *f.b.* imidacloprid (T_6) treatment. Counts of *Echinochloa crus-galli* and *Echinochloa stagnina* were high in cyhalofop-butyl + flubendiamide (T_7) and bispyribac sodium *f.b.* flubendiamide (T_1) treatments. The count of *Cyperus iria* was highest in cyhalofop-butyl treatments and the count of *Leptochloa chinensis* was highest in bispyribac sodium treated plots. At the time of harvest the field was free of broad leaf weeds. Among tank mix treatments, lowest weed count was noticed in bispyribac sodium + flubendiamide treatment (25.75 no./m^2) and highest in cyhalofop-butyl + imidacloprid treatment (81.83 no./m^2).

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Table 6. Effect of treatments on species wise weed count at 30 DAS (no./m^2)

Treatments		Weed count at 30 DAS (no./m^2)			
		Echinochloa crus-galli	*Limnophila heterophylla*	*Ludwigia parviflora*	*Cyperus iria*
T_1	Bispyribac sodium *f.b.* Flubendiamide the next day	*2.64^d (7.00)	0.71^e (0.00)	0.71^e (0.00)	2.19^e (4.33)
T_2	Bispyribac sodium *f.b.* Imidacloprid the next day	2.76^{cd} (7.66)	0.71^e (0.00)	0.71^e (0.00)	2.52^d (6.00)
T_3	Bispyribac sodium + Flubendiamide	4.24^b (18.00)	0.71^e (0.00)	0.71^e (0.00)	2.91^c (8.00)
T_4	Bispyribac sodium + Imidacloprid	2.81^{cd} (8.00)	0.71^e (0.00)	0.71^e (0.00)	2.33^{de} (5.00)
T_5	Cyhalofop-butyl *f.b.* Flubendiamide the next day	2.70^d (7.33)	2.19^{bcd} (4.33)	2.47^{cd} (5.66)	3.43^b (11.33)
T_6	Cyhalofop-butyl *f.b.* Imidacloprid the next day	3.10^c (9.66)	2.03^d (3.66)	2.73^{abc} (7.00)	3.48^b (11.66)
T_7	Cyhalofop-butyl + Flubendiamide	2.82^{cd} (8.00)	2.11^{cd} (4.00)	2.33^d (5.00)	3.43^b (11.33)
T_8	Cyhalofop-butyl + Imidacloprid	2.75^{cd} (7.66)	2.27^{bc} (4.66)	2.85^{ab} (7.66)	3.62^b (12.66)
T_9	Hand weeding + Flubendiamide	1.27^e (1.66)	0.71^e (0.00)	0.71^e (0.00)	0.71^f (0.00)
T_{10}	Hand weeding + Imidacloprid	1.13^e (1.33)	0.71^e (0.00)	0.71^e (0.00)	0.71^f (0.00)
T_{11}	Bispyribac sodium	2.75^{cd} (7.66)	0.71^e (0.00)	0.71^e (0.00)	2.66^{cd} (6.66)
T_{12}	Cyhalofop- butyl	3.10^c (9.66)	2.33^b (5.00)	2.60^{bcd} (6.33)	3.58^b (12.33)
T_{13}	Hand weeding	1.41^e (2.00)	0.71^e (0.00)	0.71^e (0.00)	0.71^f (0.00)
T_{14}	Unweeded control	5.09^a (26.00)	3.93^a (15.00)	2.91^a (8.00)	5.24^a (27.00)

*$\sqrt{x + 0.5}$ transformed values, original values in paranthesis. In a column, means followed by common letters do not differ significantly at 5 % level in DMRT.

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Table 7. Effect of treatments on species wise weed count at 60 DAS (no./m^2)

Treatments		Weed counts at 60 DAS (no./m^2)			
		Echinochloa crus-galli	***Leptochloa chinensis***	***Ludwigia parviflora***	***Cyperus iria***
T1	Bispyribac sodium *f.b.* Flubendiamide the next day	*2.99^{cd} (8.50)	4.63^{abc} (21.00)	0.71^{e} (0.00)	3.31^{bcd} (10.50)
T2	Bispyribac sodium *f.b.* Imidacloprid the next day	2.12^{de} (4.00)	4.52^{bc} (20.00)	0.71^{e} (0.00)	2.19^{cd} (4.33)
T3	Bispyribac sodium + Flubendiamide	4.27^{ab} (18.66)	3.53^{c} (12.00)	0.71^{e} (0.00)	3.55^{bcd} (12.33)
T4	Bispyribac sodium + Imidacloprid	2.99^{cd} (8.50)	5.45^{ab} (35.66)	0.71^{e} (0.00)	0.71^{d} (0.00)
T5	Cyhalofop-butyl *f.b.* Flubendiamide the next day	2.44^{de} (5.50)	0.71^{d} (0.00)	1.95^{bc} (3.33)	7.58^{a} (58.66)
T6	Cyhalofop-butyl *f.b.* Imidacloprid the next day	2.23^{de} (4.50)	0.71^{d} (0.00)	1.58^{d} (2.00)	5.42^{abc} (38.66)
T7	Cyhalofop-butyl + Flubendiamide	2.82^{cde} (7.50)	0.71^{d} (0.00)	1.72^{cd} (2.50)	6.86^{ab} (46.66)
T8	Cyhalofop-butyl + Imidacloprid	2.19^{de} (4.33)	0.71^{d} (0.00)	2.23^{b} (4.50)	7.45^{a} (64.00)
T9	Hand weeding + Flubendiamide	0.71^{f} (0.00)	0.71^{d} (0.00)	1.55^{d} (2.00)	0.71^{d} (0.00)
T10	Hand weeding + Imidacloprid	3.60^{bc} (12.50)	0.71^{d} (0.00)	0.71^{e} (0.00)	3.46^{bcd} (11.50)
T11	Bispyribac sodium	3.46^{bc} (11.50)	4.33^{bc} (18.33)	0.71^{e} (0.00)	2.23^{cd} (4.50)
T12	Cyhalofop-butyl	1.99^{e} (3.50)	0.71^{d} (0.00)	2.11^{b} (4.00)	6.83^{ab} (46.60)
T13	Hand weeding	2.33^{de} (5.00)	1.67^{d} (2.33)	0.71^{e} (0.00)	2.23^{cd} (4.50)
T14	Unweeded control	4.58^{a} (20.50)	6.20^{a} (38.00)	2.54^{a} (6.00)	8.15^{a} (66.00)

*$\sqrt{x + 0.5}$ transformed values, original values in paranthesis. In a column, means followed by common letters do not differ significantly at 5 % level in DMRT.

Table 8. Effect of treatments on species wise weed count at harvest (no./m^2)

	Treatments	Weed count at harvest (no./m^2)			
		Echinochloa crus-galli	*Echinochloa stagnina*	*Leptochloa chinensis*	*Cyperus iria*
T_1	Bispyribac sodium *f.b.* Flubendiamide the next day	4.26^{abc} (18.00)	3.28^{a} (10.33)	3.84^{a} (14.33)	0.71^{c} (0.00)
T_2	Bispyribac sodium *f.b.* Imidacloprid the next day	2.12^{def} (4.00)	2.85^{bc} (7.66)	2.85b (7.66)	0.71^{c} (0.00)
T_3	Bispyribac sodium + Flubendiamide	3.57^{bcd} (12.50)	0.71^{e} (0.00)	3.67^{a} (13.00)	0.71^{c} (0.00)
T_4	Bispyribac sodium + Imidacloprid	2.12^{def} (4.00)	3.23^{ab} (10.00)	3.76^{a} (13.66)	0.71^{c} (0.00)
T_5	Cyhalofop-butyl *f.b.* Flubendiamide the next day	3.58^{bcd} (12.33)	0.71^{e} (0.00)	0.71^{d} (0.00)	7.63^{a} (58.33)
T_6	Cyhalofop-butyl *f.b.* Imidacloprid the next day	3.09^{cde} (10.00)	0.71^{e} (0.00)	0.71^{d} (0.00)	8.57^{a} (73.00)
T_7	Cyhalofop-butyl + Flubendiamide	4.80^{ab} (25.00)	2.19^{d} (4.33)	0.71^{d} (0.00)	5.28^{b} (28.00)
T_8	Cyhalofop-butyl + Imidacloprid	2.91^{cde} (8.00)	0.71^{e} (0.00)	0.71^{d} (0.00)	8.61^{a} (73.66)
T_9	Hand weeding + Flubendiamide	0.71^{f} (0.00)	0.71^{e} (0.00)	2.03^{c} (3.66)	0.71^{c} (0.00)
T_{10}	Hand weeding + Imidacloprid	1.58^{ef} (2.00)	0.71^{e} (0.00)	2.12^{c} (4.00)	0.71^{c} (0.00)
T_{11}	Bispyribac sodium	2.12^{def} (4.00)	2.51^{cd} (6.00)	2.97^{b} (8.33)	0.71^{c} (0.00)
T_{12}	Cyhalofop- butyl	0.71^{f} (0.00)	0.71^{e} (0.00)	0.71^{d} (0.00)	7.56^{a} (66.00)
T_{13}	Hand weeding	2.12^{def} (4.00)	0.71^{e} (0.00)	2.12^{c} (4.00)	0.71^{c} (0.00)
T_{14}	Unweeded control	5.65^{a} (32.00)	3.07^{ab} (9.00)	3.48^{a} (12.00)	9.19^{a} (84.00)

*$\sqrt{x+0.5}$ transformed values, original values in paranthesis. In a column, means followed by common letters do not differ significantly at 5 % level in DMRT.

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4.1.3 Weed dry matter production

Data on the effect of treatments on weed dry matter production are presented in Table 9. At 30 DAS, unweeded control (T_{14}) recorded highest weed dry matter production of 304.35 kg/ha, followed by cyhalofop-butyl alone (T_{12}) producing 78.26 kg/ha. The lowest production was recorded in hand weeded plots. Among sequential and tank mix treatments of bispyribac sodium with insecticides, both the tank mix treatments resulted in a weed dry matter production which was statistically on par with their sequential application. Also in the case of sequential and tank mix applications of cyhalofop-butyl with insecticides, both tank mix treatments resulted in weed dry matter production statistically on par with their sequential applications.

At 60 DAS also highest weed dry matter production of 2404.44 kg/ha was recorded in unweeded control (T_{14}) and the lowest was recorded in hand weeded (T_{13}) treatment (104.16 kg/ha). Considering the sequential and tank mix treatments of bispyribac sodium with insecticides, bispyribac sodium + flubendiamide (T_3) recorded higher weed dry matter production of 1418.54 kg/ha than its sequential application (418.33 kg/ha) and bispyribac sodium + imidacloprid (T_4) recorded a weed dry matter production which was statistically on par to its sequential application. Among the sequential and tank mix applications of cyhalofop-butyl with insecticides, cyhalofop-butyl + flubendiamide (T_7) recorded a weed dry matter production lower than its sequential application and cyhalofop-butyl + imidacloprid (T_8) resulted in a weed dry matter production which was statistically on par with its sequential application.

At the time of harvest weed dry matter production in all plots decreased with highest production of 1722.16 kg/ha in unweeded control (T_{14}). Hand weeding + flubendiamide (T_9) recorded the lowest weed dry matter production. Comparing the sequential and tank mix application of bispyribac sodium with insecticides, bispyribac sodium + flubendiamide (T_3) recorded a lower weed dry matter production than its sequential application and bispyribac sodium + imidacloprid (T_4) resulted in a weed dry matter production which was statistically on par to its sequential application. Among sequential and tank mix applications of cyhalofop-butyl with insecticides, all the treatments were on par.

Table 9. Effect of treatments on weed dry matter production

Treatments		Weed dry matter production (kg/ha)		
		30 DAS	60 DAS	Harvest
T_1	Bispyribac sodium *f.b.* Flubendiamide the next day	*6.18^{bcd} (38.54)	20.09^{ef} (418.33)	23.26^{b} (543.10)
T_2	Bispyribac sodium *f.b.* Imidacloprid the next day	5.34^{de} (30.26)	17.40^{fg} (344.27)	21.75^{bc} (473.38)
T_3	Bispyribac sodium + Flubendiamide	7.64^{bcd} (58.49)	37.61^{bc} (1418.54)	19.42^{c} (378.23)
T_4	Bispyribac sodium + Imidacloprid	6.71^{bcd} (45.05)	24.89^{def} (630.52)	25.01^{b} (626.01)
T_5	Cyhalofop-butyl *f.b.* Flubendiamide the next day	8.21^{bc} (68.44)	39.18^{b} (1538.50)	23.66^{b} (568.17)
T_6	Cyhalofop-butyl *f.b.* Imidacloprid the next day	7.74^{bcd} (60.28)	37.14^{bc} (1398.53)	23.33^{b} (544.32)
T_7	Cyhalofop-butyl + Flubendiamide	8.41^{bc} (72.18)	32.05^{bcd} (1028.46)	23.41^{b} (550.54)
T_8	Cyhalofop-butyl + Imidacloprid	7.41^{bcd} (61.27)	38.59^{b} (1510.35)	25.03^{b} (632.33)
T_9	Hand weeding + Flubendiamide	1.83^{f} (3.44)	10.25^{g} (106.25)	10.73^{d} (115.27)
T_{10}	Hand weeding + Imidacloprid	2.22^{f} (5.05)	17.75^{fg} (316.35)	11.41^{d} (130.39)
T_{11}	Bispyribac sodium	6.01^{cd} (38.40)	28.74^{cde} (844.22)	19.24^{c} (370.32)
T_{12}	Cyhalofop-butyl	8.81^{b} (78.26)	33.03^{bcd} (1106.49)	19.02^{c} (362.39)
T_{13}	Hand weeding	2.77^{ef} (7.76)	10.17^{g} (104.16)	12.45^{d} (156.26)
T_{14}	Unweeded control	17.44^{a} (304.25)	49.03^{a} (2404.44)	41.49^{a} (1722.16)

*$\sqrt{x + 0.5}$ transformed values, original values in paranthesis. In a column, means followed by common letters do not differ significantly at 5 % level in DMRT.

4.1.4 Weed control efficiency

At 30 DAS, hand weeding + flubendiamide (T_9) treatment recorded the highest WCE of 98.84 per cent. Handweeding + imidacloprid (T_{10}) and hand weeding alone (T_{13}) resulted in WCE of 98.35 per cent and 97.50 per cent respectively. These were on par with each other and with the treatments bispyribac sodium *f.b.* imidacloprid the next day (T_2), bispyribac sodium *f.b.* flubendiamide the next day (T_1), bispyribac sodium alone (T_{11}) and bispyribac sodium + imidacloprid (T_4). Lowest WCE of 74.36 was recorded in cyhalofop-butyl alone treatment. All the tank mix treatments recorded a weed control efficiency which was statistically on par to its sequential application.

At 60 DAS, hand weeded treatment registered the highest WCE of 95.67 per cent and was statistically on par with hand weeding + flubendiamide (T_9), hand weeding + imidacloprid (T_{10}), bispyribac sodium *f.b.* imidacloprid the next day(T_2), bispyribac sodium *f.b.* flubendiamide the next day (T_1) and bispyribac sodium + imidacloprid (T_4). Cyhalofop-butyl *f.b.* flubendiamide the next day (T_5) recorded lowest WCE of 36.03 per cent. Comparing the sequential and tank mix applications of bispyribac sodium with insecticides, bispyribac sodium + flubendiamide (T_3) recorded a weed control efficiency of 41.02 per cent which was lower than its sequential application. Bispyribac sodium + imdaloprid recorded a weed control efficiency which was statistically on par with its sequential application. In case of cyahalofop- butyl with insecticides, cyhalofop-butyl + flubendiamide (T_7) recorded higher weed control efficiency than its sequential application and cyhalofop-butyl + imidacloprid (T_8) recorded a weed control efficiency which was statistically on par to its sequential application.

At harvest, there was no significant variation among treatments. Highest WCE of 93.32 per cent was recorded by hand weeding + flubendiamide (T_9) treatment and the lowest by cyhalofop-butyl + imidacloprid (T_8) treatment (63.33 per cent).

Table 10. Effect of treatments on weed control efficiency

Treatments		Weed control efficiency (%)		
		30 DAS	60 DAS	Harvest
T_1	Bispyribac sodium *f.b.* Flubendiamide the next day	87.50[abc]	82.59[ab]	68.46[a]
T_2	Bispyribac sodium *f.b.* Imidacloprid the next day	90.63[ab]	85.69[ab]	72.53[a]
T_3	Bispyribac sodium + Flubendiamide	80.93[bc]	41.02[de]	78.04[a]
T_4	Bispyribac sodium + Imidacloprid	85.20[abc]	73.79[abc]	63.64[a]
T_5	Cyhalofop-butyl *f.b.* Flubendiamide the next day	77.64[bc]	36.03[e]	67.01[a]
T_6	Cyhalofop-butyl *f.b.* Imidacloprid the next day	80.11[bc]	41.83[de]	68.40[a]
T_7	Cyhalofop-butyl + Flubendiamide	76.33[bc]	57.24[cde]	68.29[a]
T_8	Cyhalofop-butyl + Imidacloprid	80.27[bc]	37.19[e]	63.33[a]
T_9	Hand weeding + Flubendiamide	98.84[a]	95.56[a]	93.32[a]
T_{10}	Hand weeding + Imidacloprid	98.35[a]	86.89[ab]	92.45[a]
T_{11}	Bispyribac sodium	87.34[abc]	64.89[bcd]	78.51[a]
T_{12}	Cyhalofop-butyl	74.36[c]	53.99[cde]	78.97[a]
T_{13}	Hand weeding	97.50[a]	95.67[a]	90.94[a]
T_{14}	Unweeded control	-	-	-

In a column, means followed by common letters do not differ significantly at 5 % level in DMRT.

4.2 Studies on insect pests

4.2.1 Insect pests

Eighteen days after sowing when the crop was in the tillering stage, field scouting was done and beneficial and harmful insects were noted. In general, pest population was low in the field. Infestation of rice leaf folder and white backed plant hopper (WBPH) was observed. The natural enemies included long horned grass hopper, dragonfly, damsel fly, ground beetle and ladybird beetle. Insecticide spray was given 20/21 DAS, 20 in the case of tank mix application and 21 for sequential application, given the next day after herbicide spray.

Major insect pests found in the field were defoliators, sucking pests and shoot borers. *Cnaphalocrocis medinalis* (leaf folder) was the only defoliator present during the experiment. Sucking pests comprised of *Sogatella furcifera* (WBPH) and *Menida versicolor* (red spotted earhead bug). *Scirpophaga incertulas* (yellow stem borer) was the borer observed during the season.

Counts of insect pests were taken at 5, 7 and 11 days after spraying and the data are presented in Table 11, 12 and 13 respectively.

4.2.2 Insect pest population

Five days after spraying, leaf folder and WBPH were the only insect pests found in the field. At 7 days after spraying, leaf folder, WBPH and red spotted earhead bug were the important pests. At 11 days after spraying, yellow stem borer, leaf folder, red spotted earhead bug and WBPH were the insect pests present. Population of yellow stem borer and red spotted earhead bug were less compared to leaf folder and WBPH. At all stages of observation, treatments were on par with regard to count of individual insect pests.

Table 11. Effect of treatments on incidence of insect pests at 5 days after spraying

Treatments		Defoliators	Sucking pests
		Leaf folder (*Cnaphalocrocis medinalis*)	**White backed planthopper (*Sogatella furcifera)***
T_1	Bispyribac sodium *f.b.* Flubendiamide the next day	*1.65[a] (2.66)[a]	0.71[a] (0.00)
T_2	Bispyribac sodium *f.b.* Imidacloprid the next day	1.65[a] (2.66)	0.71[a] (0.00)
T_3	Bispyribac sodium + Flubendiamide	1.17[a] (1.33)	0.71[a] (0.00)
T_4	Bispyribac sodium + Imidacloprid	1.65[a] (2.66)	0.71[a] (0.00)
T_5	Cyhalofop-butyl *f.b.* Flubendiamide the next day	0.71[a] (0.00)	0.71[a] (0.00)
T_6	Cyhalofop-butyl *f.b.* Imidacloprid the next day	0.71[a] (0.00)	0.71[a] (0.00)
T_7	Cyhalofop-butyl + Flubendiamide	0.71[a] (0.00)	1.17[a] (1.33)
T_8	Cyhalofop-butyl + Imidacloprid	1.17[a] (1.33)	0.71[a] (0.00)
T_9	Hand weeding + Flubendiamide	0.71[a] (0.00)	0.71[a] (0.00)
T_{10}	Hand weeding + Imidacloprid	1.65[a] (2.66)	0.71[a] (0.00)
T_{11}	Bispyribac sodium	1.17[a] (1.33)	0.71[a] (0.00)
T_{12}	Cyhalofop-butyl	1.17[a] (1.33)	0.71[a] (0.00)
T_{13}	Hand weeding	1.17[a] (1.33)	0.71[a] (0.00)
T_{14}	Unweeded control	1.65[a] (2.66)	1.56[a] (2.33)

*$\sqrt{x + 0.5}$ transformed values, original values in paranthesis. In a column, means followed by common letters do not differ significantly at 5 % level in DMRT.

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Table 12. Effect of treatments on incidence of insect pests at 7 days after spraying

Treatments		Defoliators	Sucking pests	
		Leaf folder (*Cnaphalocrocis medinalis*)	**White backed planthopper (*Sogatella furcifera*)**	**Red spotted earhead bug(*Menida versicolor)***
T_1	Bispyribac sodium *f.b.* Flubendiamide the next day	*2.12^a (5.33)	0.71^a (0.00)	1.17^a (1.33)
T_2	Bispyribac sodium *f.b.* Imidacloprid the next day	2.85^a (8.00)	0.71^a (0.00)	0.71^a (0.00)
T_3	Bispyribac sodium + Flubendiamide	2.85^a (8.00)	1.91^a (4.00)	0.71^a (0.00)
T_4	Bispyribac sodium + Imidacloprid	3.12^a (9.33)	1.17^a (1.33)	1.17^a (1.33)
T_5	Cyhalofop-butyl *f.b.* Flubendiamide the next day	2.59^a (6.66)	1.17^a (1.33)	0.71^a (0.00)
T_6	Cyhalofop-butyl *f.b.* Imidacloprid the next day	2.85^a (8.00)	0.71^a (0.00)	0.71^a (0.00)
T_7	Cyhalofop-butyl + Flubendiamide	2.59^a (6.66)	1.65^a (2.66)	0.71^a (0.00)
T_8	Cyhalofop-butyl + Imidacloprid	2.85^a (8.00)	0.71^a (0.00)	1.17^a (1.33)
T_9	Hand weeding + Flubendiamide	3.12^a (9.33)	1.17^a (1.33)	0.71^a (0.00)
T_{10}	Hand weeding + Imidacloprid	2.59^a (6.66)	0.71^a (0.00)	1.17^a (1.33)
T_{11}	Bispyribac sodium	3.12^a (9.33)	0.71^a (0.00)	0.71^a (0.00)
T_{12}	Cyhalofop-butyl	3.86^a (16.00)	0.71^a (0.00)	1.17^a (1.33)
T_{13}	Hand weeding	3.12^a (9.33)	0.71^a (0.00)	0.71^a (0.00)
T_{14}	Unweeded control	3.56^a (12.33)	1.91^a (4.00)	1.17^a (1.33)

*$\sqrt{x + 0.5}$ transformed values, original values in paranthesis. In a column, means followed by common letters do not differ significantly at 5 % level in DMRT.

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Table 13. Effect of treatments on incidence of insect pests at 11 days after spraying

Treatments		Borers	Defoliators	Sucking pests	
		Yellow stem borer (*Scirpophaga incertulas*)	**Leaf folder** (*Cnaphalocrocis Medinalis*)	**White backed planthopper** (*Sogatella furcifera*)	***Red spotted earhead bug*** ***(Menida versicolor)***
T_1	Bispyribac sodium *f.b.* Flubendiamide the next day	*0.707[a] (0.00)	1.91[a] (4.00)	1.91[a] (4.00)	0.71[a] (0.00)
T_2	Bispyribac sodium *f.b.* Imidacloprid the next day	1.17[a] (1.33)	2.59[a] (9.33)	1.17[a] (1.33)	0.71[a] (0.00)
T_3	Bispyribac sodium + Flubendiamide	0.71[a] (0.00)	1.17[a] (1.33)	1.82[a] (5.33)	0.71[a] (0.00)
T_4	Bispyribac sodium + Imidacloprid	0.707[a] (0.00)	2.85[a] (8.00)	1.65[a] (2.66)	0.71[a] (0.00)
T_5	Cyhalofop-butyl *f.b.* Flubendiamide the next day	1.17[a] (1.33)	0.71[a] (0.00)	1.65[a] (2.66)	0.71[a] (0.00)
T_6	Cyhalofop-butyl *f.b.* Imidacloprid the next day	0.71[a] (0.00)	2.38[a] (6.66)	0.71[a] (0.00)	0.71[a] (0.00)
T_7	Cyhalofop-butyl + Flubendiamide	0.71[a] (0.00)	1.65[a] (2.66)	0.707[a] (0.00)	0.71[a] (0.00)
T_8	Cyhalofop-butyl + Imidacloprid	0.71[a] (0.00)	3.50[a] (12.00)	1.65[a] (2.66)	1.17[a] (1.33)
T_9	Hand weeding + Flubendiamide	1.17[a] (1.33)	2.38[a] (6.66)	0.71[a] (0.00)	0.71[a] (0.00)
T_{10}	Hand weeding + Imidacloprid	0.71[a] (0.00)	2.85[a] (8.00)	0.71[a] (0.00)	0.71[a] (0.00)
T_{11}	Bispyribac sodium	0.71[a] (0.00)	1.82[a] (5.33)	1.65[a] (2.66)	1.17[a] (1.33)
T_{12}	Cyhalofop-butyl	1.17[a] (1.33)	2.38[a] (6.66)	1.91[a] (4.00)	0.71[a] (0.00)
T_{13}	Hand weeding	1.17[a] (1.33)	3.50[a] (12.00)	0.71[a] (0.00)	0.71[a] (0.00)
T_{14}	Unweeded control	1.17[a] (1.33)	4.37[a] (18.66)	1.82[a] (5.33)	1.65[a] (2.66)

*$\sqrt{x+0.5}$ transformed values, original values in paranthesis. In a column, means followed by common letters do not differ significantly at 5 % level in DMRT.

4.3 Studies on rice growth and yield parameters

4.3.1 Phytotoxicity scoring

Phytotoxicity scoring on crop was done at 3 and 7 days after spraying of chemicals. No visual phytotoxicity symptoms were observed on rice crop. All the treatments were scored as zero.

4.3.2 Plant height

Data on effect of various treatments on height of plants at 30 DAS, 60 DAS and at harvest are given in Table 14. There was no significant difference in plant height among treatments. The height recorded by the treatments at 30 DAS, 60 DAS and at harvest ranged from 44.20 to 48.39 cm, 78.78 to 86.33 cm and 93.56 to 99.85 cm respectively.

4.3.3 Number of tillers

Data on tiller count per m^2 are presented in Table 15. There was no significant difference in tiller count among treatments at 30 DAS and 60 DAS. At harvest, highest tiller count was recorded in the treatment cyhalofop-butyl *f.b.* imidacloprid (T_6). The next best treatment was bispyribac sodium *f.b.* flubendiamide (T_1). Tiller count was least in unweeded control (T_{14}). All the tank mix treatments recorded lower tiller count than their sequential application treatments.

4.3.4 Dry matter production

Data on crop dry matter production are shown in Table 16. There was no significant difference among treatments at 30 DAS and 60 DAS. At harvest, hand weeding (T_{13}) registered highest dry matter production (11.92 t/ha); it was on par with other treatments except unweeded control (T_{14}) which recorded only 7.13 t /ha.

Table 14. Effect of treatments on height of rice plants at various stages

Treatments		Plant height (cm)		
		30 DAS	60 DAS	Harvest
T_1	Bispyribac sodium *f.b.* Flubendiamide the next day	47.80[a]	82.36[a]	99.85[a]
T_2	Bispyribac sodium *f.b.* Imidacloprid the next day	46.56[a]	85.79[a]	97.16[a]
T_3	Bispyribac sodium + Flubendiamide	46.39[a]	85.18[a]	97.35[a]
T_4	Bispyribac sodium + Imidacloprid	48.39[a]	85.31[a]	98.36[a]
T_5	Cyhalofop-butyl *f.b.* Flubendiamide the next day	45.40[a]	82.84[a]	95.70[a]
T_6	Cyhalofop-butyl *f.b.* Imidacloprid the next day	44.93[a]	83.36[a]	94.53[a]
T_7	Cyhalofop-butyl + Flubendiamide	47.83[a]	83.34[a]	95.23[a]
T_8	Cyhalofop-butyl + Imidacloprid	45.00[a]	81.46[a]	96.46[a]
T_9	Hand weeding + Flubendiamide	48.00[a]	86.33[a]	98.66[a]
T_{10}	Hand weeding + Imidacloprid	46.50[a]	84.74[a]	98.36[a]
T_{11}	Bispyribac sodium	46.35[a]	79.62[a]	97.10[a]
T_{12}	Cyhalofop-butyl	44.96[a]	83.94[a]	93.70[a]
T_{13}	Hand weeding	47.16[a]	86.20[a]	99.36[a]
T_{14}	Unweeded control	44.20[a]	78.78[a]	93.56[a]

In a column, means followed by common letters do not differ significantly at 5 % level in DMRT.

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Table 15. Effect of treatments on tiller count at various stages

Treatments		Tiller count (no./m^2)		
		30 DAS	60 DAS	Harvest
T_1	Bispyribac sodium *f.b.* Flubendiamide the next day	287.50^{a}	402.50^{a}	483.00^{ab}
T_2	Bispyribac sodium *f.b.* Imidacloprid the next day	267.95^{a}	405.95^{a}	442.75^{bc}
T_3	Bispyribac sodium + Flubendiamide	248.40^{a}	409.40^{a}	385.25^{ef}
T_4	Bispyribac sodium + Imidacloprid	264.50^{a}	409.40^{a}	385.25^{ef}
T_5	Cyhalofop-butyl *f.b.* Flubendiamide the next day	264.50^{a}	402.50^{a}	471.50^{bc}
T_6	Cyhalofop-butyl *f.b.* Imidacloprid the next day	264.50^{a}	420.90^{a}	520.95^{a}
T_7	Cyhalofop-butyl + Flubendiamide	267.95^{a}	428.95^{a}	448.50^{bc}
T_8	Cyhalofop-butyl + Imidacloprid	244.95^{a}	417.45^{a}	431.25^{cde}
T_9	Hand weeding + Flubendiamide	313.95^{a}	405.95^{a}	448.50^{bc}
T_{10}	Hand weeding + Imidacloprid	271.40^{a}	397.90^{a}	425.50^{cde}
T_{11}	Bispyribac sodium	248.40^{a}	409.40^{a}	437.00^{bcd}
T_{12}	Cyhalofop-butyl	241.50^{a}	420.90^{a}	443.90^{bc}
T_{13}	Hand weeding	313.95^{a}	397.90^{a}	394.45^{def}
T_{14}	Unweeded control	230.00^{a}	391.00^{a}	374.90^{f}

In a column, means followed by common letters do not differ significantly at 5 % level in DMRT.

Table 16. Effect of treatments on rice dry matter production at various stages

Treatments		Rice dry matter production (t/ha)		
		30 DAS	60 DAS	Harvest
T_1	Bispyribac sodium *f.b.* Flubendiamide the next day	4.06^a	5.42^a	11.04^a
T_2	Bispyribac sodium *f.b.* Imidacloprid the next day	3.78^a	5.51^a	11.24^a
T_3	Bispyribac sodium + Flubendiamide	3.83^a	5.34^a	10.67^a
T_4	Bispyribac sodium + Imidacloprid	3.94^a	5.57^a	11.85^a
T_5	Cyhalofop-butyl *f.b.* Flubendiamide the next day	4.21^a	5.44^a	10.54^a
T_6	Cyhalofop-butyl *f.b.* Imidacloprid the next day	3.70^a	5.44^a	10.27^a
T_7	Cyhalofop-butyl + Flubendiamide	3.93^a	5.15^a	11.27^a
T_8	Cyhalofop-butyl + Imidacloprid	4.52^a	5.09^a	10.15^a
T_9	Hand weeding + Flubendiamide	4.47^a	5.70^a	11.70^a
T_{10}	Hand weeding + Imidacloprid	4.20^a	5.79^a	11.86^a
T_{11}	Bispyribac sodium	4.19^a	5.51^a	10.92^a
T_{12}	Cyhalofop-butyl	4.48^a	5.15^a	10.58^a
T_{13}	Hand weeding	4.34^a	5.92^a	11.92^a
T_{14}	Unweeded control	3.53^a	4.53^a	7.13^b

In a column, means followed by common letters do not differ significantly at 5 % level in DMRT.

4.3.5 Grain and straw yield

Grain yield

Data on effect of various treatments on grain yield are shown in Table 17. The highest grain yield of 5.75 t/ha was obtained from hand weeding + flubendiamide (T_9) treatment. It was on par with hand weeding + imidacloprid (T_{10}) and hand weeding (T_{13}) treatments. Lowest grain yield of 1.91 t/ha was registered by unweeded control (T_{14}). Among the sequential and tank mix applications of bispyribac sodium with insecticides, bispyribac sodium + flubendiamide (T_3) recorded lower yield of 2.68 t/ha than its sequential application (4.18 t/ha) and bispyribac sodium + imidacloprid recorded an yield of 4.25t/ha which was statistically on par with its sequential application. Comparing the sequential and tank mix applications of cyhalofop-butyl with insecticides, cyhalofop-butyl + flubendiamide recorded significantly higher yield than its sequential application and cyhalofop-butyl + imidacloprid recorded an yield which was statistically on par with its sequential application.

Straw yield

Data on treatment effect on straw yield are shown in Table 17. The straw yield varied from 3.92 t/ha to 5.96 t/ha. However, there was no significant difference between treatments. Hand weeding + flubendiamide (T_9) resulted in highest straw yield and unweeded control (T_{14}) recorded lowest yield.

4.3.6 Yield attributes

Data on effect of treatments on yield attributes are shown in Table18.

Panicles per m^2 and spikelets per panicle

Hand weeded treatment recorded highest number of panicles per m^2 (290 no./m^2), which was on par with hand weeding + imidacloprid (T_{10}) and bispyribac sodium *f.b.* flubendiamide (T_1). Lowest number of panicles per m^2 was registered in unweeded control (148.66 no./m^2). Among applications of bispyribac sodium with insecticides, bispyribac sodium + flubendiamide recorded lower number of panicles per m^2 than its sequential application and bispyribac sodium +

imidacloprid recorded a panicle number which was statistically on par with its sequential application. In the case of cyhalofop-butyl with insecticides, cyhalofop-butyl + flubendiamide recorded significantly higher number of panicles per m^2 than its sequential application and cyhalofop-butyl + imdacloprid recorded a panicle number comparable its sequential application.

Highest number of spikelets per panicle was recorded in hand weeding + flubendiamide (T_9) treatment (118.40 no./panicle) followed by handweeding + imidacloprid (T_{10}) and bispyribac sodium *f.b.* flubendiamide (T_1). The lowest was recorded in unweeded control (70.41 no./panicle). Among combination treatments, bispyribac sodium + flubendiamide recorded lower spikelet number per panicle than its sequential application and bispyribac sodium + imidacloprid recorded higher spikelet number per panicle than its sequential application. Cyhalofop-butyl + flubendiamide and cyhalofop-butyl + imidacloprid recorded spikelet numbers which were statistically on par with their sequential applications.

Filled grains per panicle and test weight of grains

Number of filled grains was highest in handweeding + flubendiamide (T_9) treatment (110.68 no./panicle) followed by hand weeding + imidacloprid (T_{10}) and hand weeded (T_{13}) treatments. The lowest number of filled grains was recorded in unweeded control (51.39 no./panicle). Comparing the sequential and tank mix applications of bispyribac sodium with insecticides, bispyribac sodium + flubendiamide recorded lower number of filled grains per panicle than its sequential application. Bispyribac sodium + imidacloprid registered a filled grain number statistically on par with its sequential application. In the case cyhalofop-butyl with insecticides, cyhalofop-butyl + flubendiamide recorded significantly higher number of filled grains per panicle than its sequential application and cyhalofop-butyl + imidacloprid recorded a number which was statistically on par with sequential application.

In the case of 1000 grain weight (test weight) of seeds, there was no significant difference among treatments. The test weight recorded by various treatments ranged from 24.43 to 25.66g.

Filling percentage

Highest filling percentage of 96.15 per cent was recorded in hand weeded treatment which was statistically on par with sequential application of bispyribac sodium and imidacloprid (T_2), hand weeding + flubendiamde (T_9) and hand weeding + imidacloprid (T_{10}) treatments. Considering the tank mix treatments of bispyribac sodium with insecticides, both registered filling percentages which were statically on par with their sequential applications. In the case of cyhalofop-butyl with insecticides, cyhalofop-butyl + flubendiamide recorded higher filling per cent than its sequential application and cyhalofop-butyl + imidacloprid recorded a filling percentage which was statistically on par to its sequential application.

Table 17. Effect of treatments on grain and straw yield

Treatments		Grain yield (t/ha)	Straw yield (t/ha)
T_1	Bispyribac sodium *f.b.* Flubendiamide the next day	4.18[b]	5.52[a]
T_2	Bispyribac sodium *f.b.* Imidacloprid the next day	3.75[b]	5.24[a]
T_3	Bispyribac sodium + Flubendiamide	2.68[c]	5.19[a]
T_4	Bispyribac sodium + Imidacloprid	4.25[b]	5.70[a]
T_5	Cyhalofop-butyl *f.b.* Flubendiamide the next day	2.91[c]	5.84[a]
T_6	Cyhalofop-butyl *f.b.* Imidacloprid the next day	2.18[c]	5.32[a]
T_7	Cyhalofop-butyl + Flubendiamide	4.31[b]	5.22[a]
T_8	Cyhalofop-butyl + Imidacloprid	2.06[c]	5.31[a]
T_9	Hand weeding + Flubendiamide	5.75[a]	5.96[a]
T_{10}	Hand weeding + Imidacloprid	5.62[a]	5.81[a]
T_{11}	Bispyribac sodium	4.00[b]	5.19[a]
T_{12}	Cyhalofop-butyl	2.00[c]	5.31[a]
T_{13}	Hand weeding	5.56[a]	5.89[a]
T_{14}	Unweeded control	1.91[c]	3.92[a]

In a column, means followed by common letters do not differ significantly at 5 % level in DMRT.

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Table 18. Effect of treatments on yield attributes

Treatments		Yield attributes				
		Panicles (no./m^2)	Spikelets per panicle (no.)	Filled grains per panicle (no.)	1000 grain weight (g)	Filling percentage (%)
T_1	Bispyribac sodium *f.b.* Flubendiamide the next day	253.33^{ab}	103.52^{bc}	92.66^{cd}	28.00^{a}	89.50^{bcde}
T_2	Bispyribac sodium *f.b.* Imidacloprid the next day	218.33^{bc}	89.76^{fg}	84.45^{de}	27.00^{a}	94.09^{abc}
T_3	Bispyribac sodium + Flubendiamide	159.66^{d}	94.50^{def}	81.12^{ef}	27.00^{a}	85.86^{efg}
T_4	Bispyribac sodium + Imidacloprid	226.00^{b}	98.03^{cde}	86.90^{de}	28.00^{a}	88.65^{cdef}
T_5	Cyhalofop-butyl *f.b.* Flubendiamide the next day	171.33^{d}	90.19^{f}	67.30^{gh}	27.00^{a}	74.65^{ij}
T_6	Cyhalofop-butyl *f.b.* Imidacloprid the next day	158.00^{d}	83.20^{gh}	66.12^{gh}	27.33^{a}	79.45^{hi}
T_7	Cyhalofop-butyl + Flubendiamide	218.33^{bc}	94.48^{def}	78.92^{ef}	27.66^{a}	83.65^{fgh}
T_8	Cyhalofop-butyl + Imidacloprid	175.66^{d}	77.80^{h}	63.47^{h}	26.66^{a}	81.17^{gh}
T_9	Hand weeding + Flubendiamide	240.00^{b}	118.40^{a}	110.68^{a}	27.33^{a}	93.44^{abc}
T_{10}	Hand weeding + Imidacloprid	250.33^{ab}	109.15^{b}	101.18^{b}	28.00^{a}	92.68^{abcd}
T_{11}	Bispyribac sodium	162.66^{d}	91.66^{ef}	80.54^{ef}	27.33^{a}	87.87^{def}
T_{12}	Cyhalofop-butyl	154.00^{d}	97.46^{cde}	73.00^{fg}	27.00^{a}	74.87^{ij}
T_{13}	Hand weeding	290.00^{a}	100.78^{cd}	96.93^{bc}	28.00^{a}	96.15^{a}
T_{14}	Unweeded control	148.66^{d}	70.41^{i}	51.39^{i}	27.66^{a}	72.46^{j}

In a column, means followed by common letters do not differ significantly at 5 % level in DMRT.

4.3.7 Nutrient uptake by rice

Data on N, P and K uptake by grain and straw are presented in Table 19, 20 and 21 respectively.

Nitrogen

The N uptake in grain was highest in hand weeding + flubendiamide treatment (80.62 kg/ha) and was lowest in unweeded control (26.73 kg/ha). Bispyribac sodium + flubendiamide recorded lower nitrogen uptake than its sequential application. Bispyribac sodium + imidacloprid and cyhalofop-butyl + imidacloprid recorded uptake values which were statistically on par with their sequential applications. Cyhalofop-butyl + flubendiamide recorded an uptake higher than its sequential application. Nitrogen uptake by straw recorded no significant difference between various treatments. The values ranged from 51.45-73.79 kg/ha.

Phosphorus

Highest grain P uptake was recorded in hand weeded treatment (7.95 kg/ha). This was statistically on par with hand weeding + imidacloprid and hand weeding + flubendiamide treatments. Lowest P uptake was recorded in unweeded control (2.48 kg/ ha). P uptake by straw (9.44 kg/ha) was also highest in hand weeded treatment. The unweeded control recorded lowest P uptake of 2.95 kg/ha. Among tank mix applications, bispyribac sodium + imidacloprid registered an uptake of grain P which was statistically on par to its sequential application. In case of straw, it was less than the sequential application. Bispyribac sodium + flubendiamide recorded a lower uptake of P by grain than its sequential application but the straw recorded higher value. Cyhalofop-butyl + flubendiamide recorded higher P uptake by both grain and straw compared to its sequential application. Cyhalofop-butyl + imidacloprid recorded a grain uptake which was statistically on par with its sequential application, but uptake by straw was registered high.

Potassium

The K uptake in grain was highest in hand weeding + imidacloprid (15.45 kg/ ha) treatment, which was statistically on par with hand weeding (15.29 kg/ha) and hand weeding + flubendiamide (14.37 kg/ha) treatments. Lowest uptake was in unweeded control (4.77kg/ha). Considering herbicide-insecticide combinations, the treatments bispyribac sodium + flubendiamide recorded lower uptake and cyhalofop- butyl + flubendiamide recorded higher uptake than their corresponding sequential applications. Bispyribac sodium + imidacloprid recorded an uptake which was statistically on par with its sequential application. There was no significant difference among various treatments in K uptake by straw.

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Table 19. Effect of treatments on N uptake by grain and straw

Treatments		Uptake (kg/ha)	
		Grain	Straw
T_1	Bispyribac sodium *f.b.* Flubendiamide the next day	62.17^{ab}	67.62^{a}
T_2	Bispyribac sodium *f.b.* Imidacloprid the next day	55.78^{b}	73.79^{a}
T_3	Bispyribac sodium + Flubendiamide	49.24^{bc}	62.19^{a}
T_4	Bispyribac sodium + Imidacloprid	55.78^{b}	69.79^{a}
T_5	Cyhalofop-butyl *f.b.* Flubendiamide the next day	35.43^{cd}	61.31^{a}
T_6	Cyhalofop-butyl *f.b.* Imidacloprid the next day	28.61^{d}	65.17^{a}
T_7	Cyhalofop-butyl + Flubendiamide	64.11^{ab}	63.94^{a}
T_8	Cyhalofop-butyl + Imidacloprid	36.04^{cd}	53.96^{a}
T_9	Hand weeding + Flubendiamide	80.62^{a}	72.35^{a}
T_{10}	Hand weeding + Imidacloprid	78.68^{a}	71.13^{a}
T_{11}	Bispyribac sodium	63.00^{ab}	63.57^{a}
T_{12}	Cyhalofop-butyl	35.00^{cd}	60.07^{a}
T_{13}	Hand weeding	77.84^{a}	73.29^{a}
T_{14}	Unweeded control	26.73^{d}	51.45^{a}

In a column, means followed by common letters do not differ significantly at 5 % level in DMRT.

Table 20. Effect of treatments on P uptake by grain and straw

Treatments		Uptake (kg/ha)	
		Grain	Straw
T_1	Bispyribac sodium *f.b.* Flubendiamide the next day	5.18^{b}	6.69^{ab}
T_2	Bispyribac sodium *f.b.* Imidacloprid the next day	5.34^{b}	6.61^{ab}
T_3	Bispyribac sodium + Flubendiamide	3.92^{cd}	6.82^{ab}
T_4	Bispyribac sodium + Imidacloprid	5.18^{b}	5.40^{cd}
T_5	Cyhalofop-butyl *f.b.* Flubendiamide the next day	3.34^{de}	4.89^{de}
T_6	Cyhalofop-butyl *f.b.* Imidacloprid the next day	2.61^{e}	4.13^{e}
T_7	Cyhalofop-butyl + Flubendiamide	5.17^{bc}	5.80^{bcd}
T_8	Cyhalofop-butyl + Imidacloprid	2.59^{e}	5.96^{bcd}
T_9	Hand weeding + Flubendiamide	7.48^{a}	6.10^{abc}
T_{10}	Hand weeding + Imidacloprid	7.54^{a}	6.82^{ab}
T_{11}	Bispyribac sodium	5.37^{b}	6.61^{ab}
T_{12}	Cyhalofop-butyl	3.58^{de}	5.93^{bcd}
T_{13}	Hand weeding	7.95^{a}	7.08^{a}
T_{14}	Unweeded control	2.48^{e}	2.21^{f}

In a column, means followed by common letters do not differ significantly at 5 % level in DMRT.

Table 21. Effect of treatments on K uptake by grain and straw

Treatments		Uptake (kg/ha)	
		Grain	Straw
T_1	Bispyribac sodium *f.b.* Flubendiamide the next day	9.40^{b}	141.64^{a}
T_2	Bispyribac sodium *f.b.* Imidacloprid the next day	11.25^{b}	128.38^{ab}
T_3	Bispyribac sodium + Flubendiamide	5.69^{cd}	127.15^{abc}
T_4	Bispyribac sodium + Imidacloprid	10.09^{b}	136.83^{a}
T_5	Cyhalofop-butyl *f.b.* Flubendiamide the next day	5.34^{d}	127.02^{abc}
T_6	Cyhalofop-butyl *f.b.* Imidacloprid the next day	5.45^{d}	115.70^{bcd}
T_7	Cyhalofop-butyl + Flubendiamide	9.15^{b}	113.53^{bcd}
T_8	Cyhalofop-butyl + Imidacloprid	5.66^{cd}	110.84^{cd}
T_9	Hand weeding + Flubendiamide	14.37^{a}	143.03^{a}
T_{10}	Hand weeding + Imidacloprid	15.45^{a}	143.83^{a}
T_{11}	Bispyribac sodium	8.50^{bc}	103.92^{d}
T_{12}	Cyhalofop-butyl	5.50^{d}	138.72^{a}
T_{13}	Hand weeding	15.29^{a}	142.16^{a}
T_{14}	Unweeded control	4.77^{d}	63.69^{e}

In a column, means followed by common letters do not differ significantly at 5 % level in DMRT.

4.4 Characteristics of soil

4.4.1 pH

Soil analysis after completion of the field experiment indicated that soil pH was unaffected by various treatments. It ranged from 5.00 to 5.15.

4.4.2 Organic carbon

Soil organic carbon content did not show any significant difference among treatments. There was a decrease in organic carbon content from initial value and ranged from 1.50 to 2.28 per cent.

4.4.3 Available N

Available N content was recorded highest in hand weeding + flubendiamide treatment (271.06 kg/ha) and the lowest content was in unweeded control (200.70 kg/ha). All four treatments involving bispyribac sodium and insecticides (T_1-T_4) were on par.

4.4.4 Available P

The content of available soil P was the highest in unweeded control (49.04 kg/ha). The hand weeded treatment recorded lowest P content and was on par with hand weeding + flubendiamide and hand weeding + imidacloprid.

4.4.5 Available K

There was no significant difference among various treatments in the case of K content of soil. It ranged from 323.00 to 386.50 kg/ha.

Table 22. Effect of treatments on pH, organic C content, available NPK content of soil

	Treatments	p^H	O C (%)	N (kg /ha)	P (kg /ha)	K (kg/ ha)
T_1	Bispyribac sodium *f.b.* Flubendiamide the next day	5.06^a	2.02^a	238.71^{abc}	27.75^{de}	381.00^a
T_2	Bispyribac sodium *f.b.* Imidacloprid the next day	5.08^a	2.18^a	246.58^{abc}	45.37^{ab}	386.50^a
T_3	Bispyribac sodium +Flubendiamide	5.13^a	1.87^a	251.27^{abc}	33.73^{cd}	358.00^a
T_4	Bispyribac sodium + Imidacloprid	5.07^a	2.09^a	250.89^{abc}	33.31^{cd}	379.50^a
T_5	Cyhalofop-butyl *f.b.* Flubendiamide the next day	5.09^a	2.28^a	243.36^{abc}	47.55^{ab}	346.50^a
T_6	Cyhalofop-butyl *f.b.* Imidacloprid the next day	5.10^a	2.23^a	250.82^{abc}	29.81^{cde}	352.00^a
T_7	Cyhalofop-butyl + Flubendiamide	5.15^a	1.85^a	234.03^{bcd}	31.24^{cd}	379.00^a
T_8	Cyhalofop-butyl + Imidacloprid	5.13^a	1.84^a	231.23^{cd}	38.38^{bc}	368.00^a
T_9	Hand weeding + Flubendiamide	5.00^a	2.04^a	271.06^a	21.04^{ef}	385.00^a
T_{10}	Hand weeding + Imidacloprid	5.02^a	2.34^a	268.12^{ab}	20.86^{ef}	382.00^a
T_{11}	Bispyribac sodium	5.12^a	1.89^a	244.60^{abc}	30.02^{cde}	373.50^a
T_{12}	Cyhalofop-butyl	5.10^a	2.06^a	249.30^{abc}	38.33^{bc}	347.00^a
T_{13}	Hand weeding	5.03^a	2.23^a	267.60^{ab}	13.70^f	384.00^a
T_{14}	Unweeded control	5.09^a	1.50^a	200.70^d	49.04^a	323.00^a

In a column, means followed by common letters do not differ significantly at 5 % level in DMRT.

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4.5 Economics of cultivation

Among various treatments tried, the highest benefit-cost ratio of 2.84 was recorded by cyhalofop-butyl + flubendiamide treatment, followed by bispyribac sodium + imidacloprid treatment (2.82). Bispyribac sodium + imidacloprid recorded highest net return of Rs. 94052. The unweeded control recorded lowest B:C ratio of 1.78. Cost of cultivation as well as gross returns were higher in hand weeded treatments and lowest in unweeded control.

Table 23. Effect of treatments on economics of rice cultivation

Treatments		Cost of cultivation (Rs.)	Gross return (Rs.)	Net return (Rs.)	B:C ratio
T_1	Bispyribac sodium *f.b.* Flubendiamide the next day	50241	139550	89309	2.66
T_2	Bispyribac sodium*f.b.* Imidacloprid the next day	49973	127785	77812	2.47
T_3	Bispyribac sodium + Flubendiamide	48891	104330	55439	2.12
T_4	Bispyribac sodium + Imidacloprid	48623	142675	94052	2.82
T_5	Cyhalofop-butyl *f.b.* Flubendiamide the next day	48187	115125	66938	2.13
T_6	Cyhalofop-butyl*f.b.* Imidacloprid the next day	47919	94750	46831	2.00
T_7	Cyhalofop-butyl + Flubendiamide	46837	139645	92808	2.84
T_8	Cyhalofop-butyl + Imidacloprid	46569	92080	45511	2.01
T_9	Hand weeding + Flubendiamide	83561	177265	93704	1.99
T_{10}	Hand weeding + Imidacloprid	83293	173120	89827	1.96
T_{11}	Bispyribac sodium	47891	132710	84819	2.66
T_{12}	Cyhalofop-butyl	45837	90790	44953	2.02
T_{13}	Hand weeding	81211	172550	91339	2.00
T_{14}	Unweeded control	42711	76345	33634	1.78

Discussion

5. DISCUSSION

An experiment entitled "Compatibility of herbicides and insecticides for tank mix application in wet seeded rice" was conducted from August 2016 to January 2017 at Alappad Kole lands of Thrissur district to find out the compatibility and efficacy of selected herbicides and insecticides when tank mixed. The results of the experiment presented in the previous chapter are discussed here with available literature.

5.1 Weed species and weed density

The herbicides tried in the experiment were bispyribac sodium and cyhalofop- butyl. Bispyribac sodium is a broad spectrum herbicide whereas cyhalofop-butyl is a graminicide. This difference in selectivity towards broad leaf weeds and sedges was reflected in weed control efficiency of treatments, yield attributes and final yield.

Weeds in the experimental field included grasses, sedges and broad leaf weeds. With a view to analyse the effects of treatments on weed management, species wise weed count, weed dry matter production and weed control efficiency were studied at 30 DAS, 60 DAS and at harvest. Important weed species in the field included *Echinochloa crus-galli,Echinochloa stagnina, Leptochloa chinensis* and *Cyperus iria*. Population of broad leaf weeds was very low. *Ludwigia parviflora* and *Limnophila heterophylla* were noted in some plots. Similar distribution pattern of rice weeds had been reported by many researchers working with weed management (Acharya *et al*., 2007; Mahajan *et al.,* 2006; Sridevi *et al.,* 2013).

Fig. 2 depicts distribution of important weed species at different stages of rice crop. *Echinochloa crus-galli* and *Cyperus iria* were the major weeds found at 30 DAS. They contributed to 70 per cent of the total weed species. Broad leaf weeds viz. *Ludwigia parviflora* and *Limnophila heterophylla* were also observed at that time. *Limnophila heterophylla* was more dominant and contributed to 65.21 per cent of total broad leaf weeds. Weed control measures were more effective in controlling broad leaf weeds. Excepting unweeded control and cyhalofop-butyl treatments, all other treatments were free of broad leaf weeds. Comparing bispyribac sodium and cyhalofop-butyl, weed density was high with cyhalofop-butyl treatment. The difference between the two herbicides in weed control might be due to the inefficiency of cyhalofop-butyl to control broad leaf weeds and sedges. Ray *et al.* (1993) and Barotti *et al.* (1998) had reported similar results.

Cyperus iria and *Leptochloa chinensis* were the major weeds at 60 DAS. Total weed count was highest in unweeded control. Count of *Cyperus iria* was high in cyhalofop-butyl treatments and population of *Leptochloa chinensis* was high in bispyribac sodium sprayed treatments. Singh *et al.* (2014) had reported bispyribac sodium to be less effective against *Leptochloa chinensis. Ludwigia parviflora* was the only broad leaf weed observed. At the time of harvest, the field was free of broad leaf weeds. Ho and Itoh (1991) came across similar situations and reported that infestation of annual grasses such as *Echinochloa* sp. and *Leptochloa chinensis* had the capacity to dominate *Monochoria vaginalis* and *Ludwigia hyssopifolia.*

At all stages of crop growth, hand weeding registered lowest weed count. This is in agreement with the findings of Rekha *et al.* (2002) and Atheena (2016). Morphological similarities between rice and grasses caused reduction in hand weeding efficiency (Rahman *et al.*, 2012) and therefore hundred per cent weed control efficiency was not achieved under hand weeding. *Echinochloa* spp, *Leptochloa chinensis and Cyperus iria* were observed in bispyribac sodium sprayed plots. Even though it is considered as a broad spectrum herbicide, results obtained in the study showed that it was not highly effective against these weed species at the rate of application used in the experiment. Singh *et al.* (2016) reported that bispyribac sodium 25g/ha was not effective for the control of sedges. Kumar and Rana (2013) had reported the need for applying higher dose of bispyribac sodium (30 g/ha) for effective control of mixed weed flora in direct seeded rice.

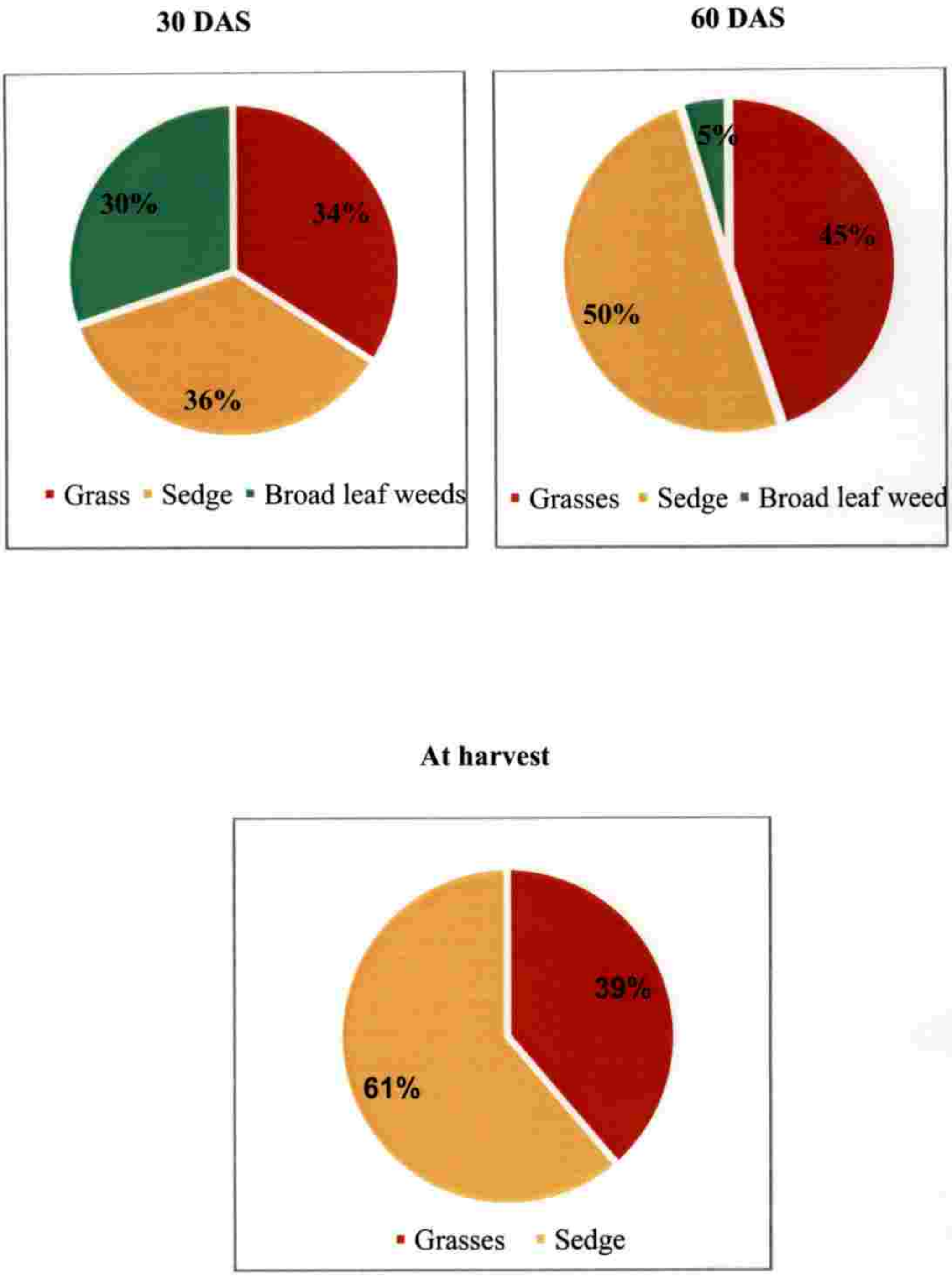

Fig.2. Weed spectrum at various stages of crop growth in unweeded control

5. 2 Weed dry matter production

Weed dry matter production was low at 30 DAS (304.25 kg/ha under unweeded condition). At 60 DAS, the value reached 2404.44 kg/ha. By the time of harvest there was reduction by 28.37 per cent in dry matter production and reached 1722.16 kg/ha. This may be due to drying and disintegration of plant tissues.

Correlation studies indicated that yield and yield attributes were highly correlated to weed dry matter production at 60 DAS. Comparing the sequential and tank mix applications of herbicides and insecticides, bispyribac sodium + flubendiamide recorded higher weed dry matter production than its sequential application. Efficiency of bispyribac sodium in controlling *Echinocloa crus-galli* is found to be reduced when mixed with flubendiamide. However, *Leptochloa, Ludwigia* and *Cyperus* were taken care of. Cyhalofop-butyl + flubendiamide recorded significantly lower weed dry matter production than corresponding sequential application. As with weed density, weed dry weight also was high in cyhalofop-butyl treated plots due to poor control of broad leaf weeds and sedges. At all stages of observation, hand weeded treatments recorded lowest dry matter production and unweeded control, the highest. Fig.3 shows weed dry matter production under different treatments at 60 DAS.

5. 3 Weed control efficiency

Highest weed control efficiency was recorded in hand weeded treatments. Comparing the sequential and tank mix applications of bispyribac sodium and insecticides, bispyribac sodium + flubendiamide recorded lowest weed control efficiency. It might be due to the poor performance of bispyribac sodium when mixed with flubendiamide. Similar cases of efficiency impairment of herbicides due to mixing with other chemicals were reported by Atheena (2016) and Busi *et al*. (2017). Mixing with imidacloprid resulted in weed control efficiency which was statistically on par with its sequential application. Tank mix application of cyhalofop-butyl and flubendiamide resulted in significantly higher weed control efficiency than its sequential application and performance of cyhalofop-butyl +

imidacloprid was on par with its sequential application. Fig.4. depicts the effect of treatments on weed control efficiency at 60 DAS.

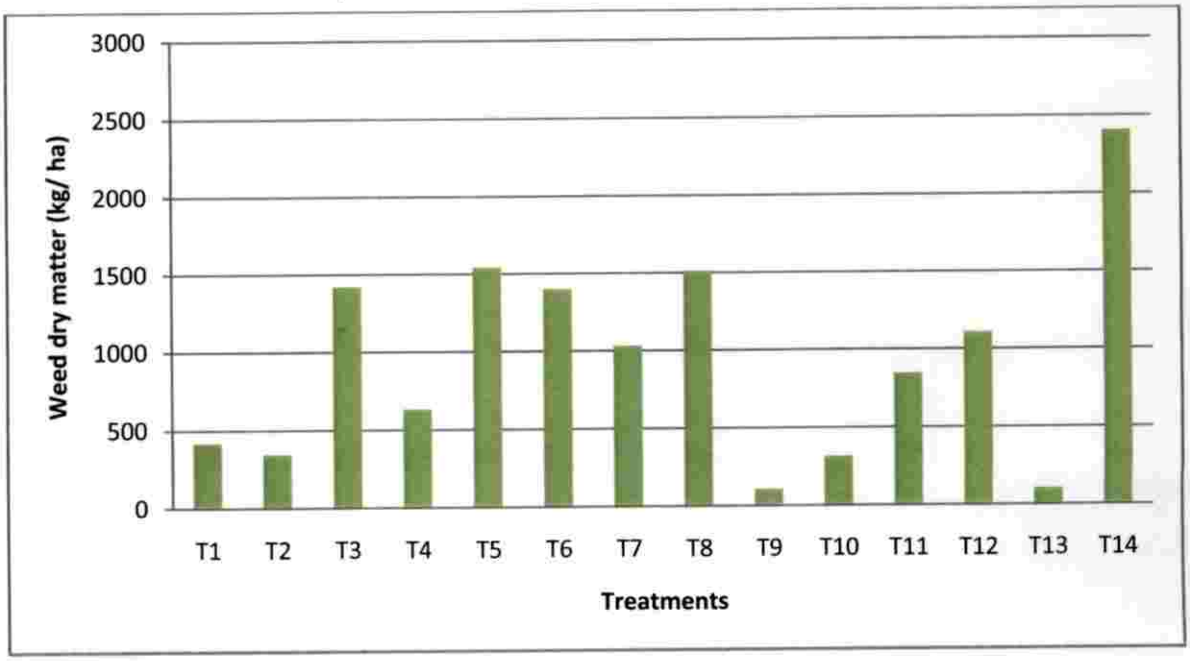

Fig. 3. Effect of treatments on weed dry matter production at 60 DAS

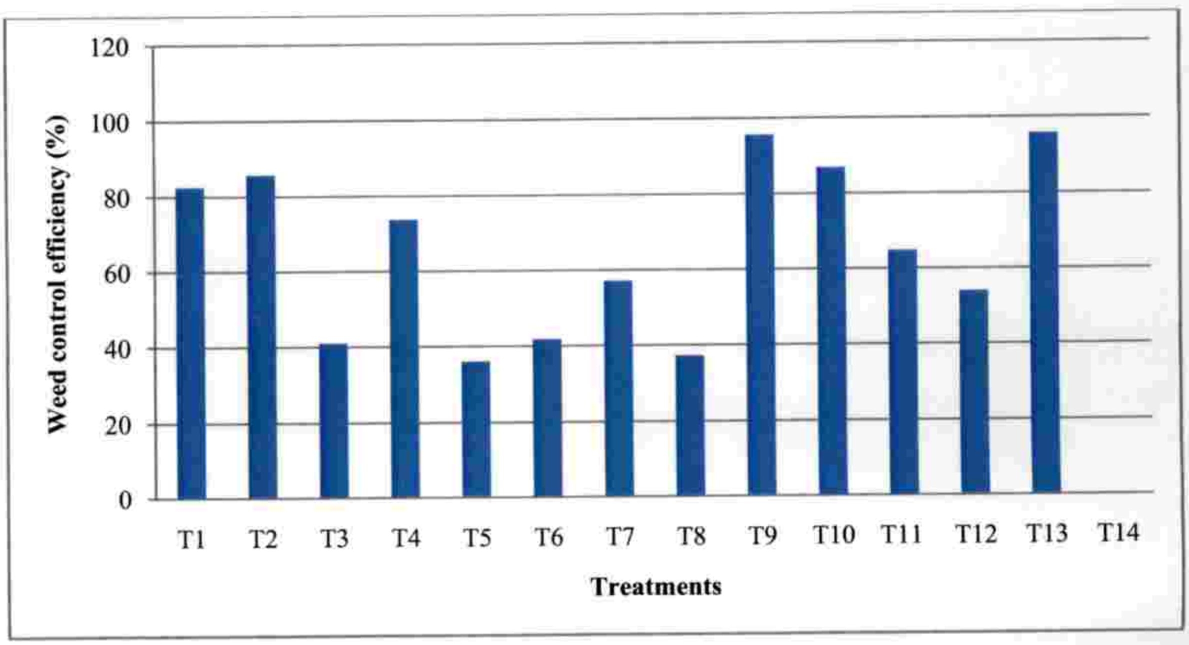

Fig.4. Effect of treatments on weed control efficiency at 60 DAS

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5. 4 Insect pests

The insect pests found in the experimental field were *Cnaphalocrocis medinalis, Scirpophaga incertulas, Menida versicolor* and *Sogatella furcifera.* The pest counts were highest in unweeded control. However all the treatments were on par. The values recorded were 4.99 no./m^2 at 5 days, 17.66 no./m^2 at 7 days and 27.98 no./m^2 at 11 days after spraying. Fig.5. depicts the insect pest population in the control plot (unweeded) at different intervals after spraying. Alvi *et al.* (2003) and Geanessi (2014) had reported yield losses to the tone of 63 to 80 per cent under leaf folder attack. Afun *et al.* (1999) reported that two insect pest groups were consistently more abundant in unweeded plots and had a consistent significant positive correlation between abundance and weed biomass.

Considering individual pests, leaf folder and white backed plant hopper were the major pests. Population of yellow stem borer and red spotted earhead bug was relatively low.

Pesticide spray had an immediate effect on control of the insect pests. Insects reappeared in the field after 3-4 days. Leaf folder and white backed plant hopper were the only insect pests observed 5 days after spraying. Their count was low in all treatments except unweeded control. At 7 days after spraying *Menida versicolor* was also observed. After 11 days of treatment, yellow stem borer was seen in the field. Count of leaf folder and yellow stem borer was comparatively high in imidacloprid treated plots as compared to flubendiamide applied. Since insect infestation was low, conclusive results on efficacy of insecticides on mixing with herbicides could not be obtained.

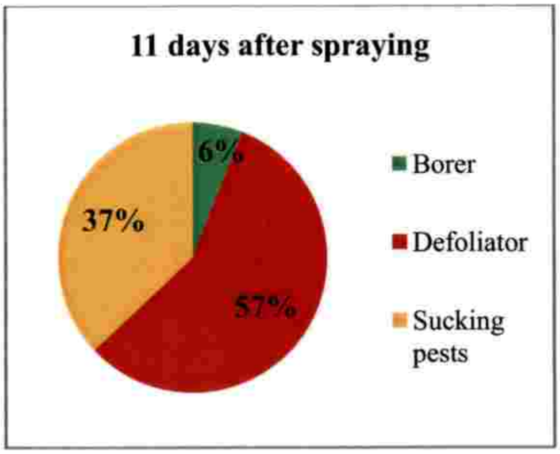

Fig.5. Insect pest population at 5, 7 and 11 days after spraying

5.5 Crop growth parameters

At 3 and 7 days after spraying of chemicals, the treatments were scored for crop phytotoxicity symptoms. All treatments were scored zero indicating that no intermediary product which caused toxicity problems was formed due to mixing of the chemicals.

Plant height was not at all affected by treatments; so also crop dry matter production and tiller number upto 60 DAS. At the time of harvest, crop dry matter production in unweeded control was significantly lower than all other treatments, which were on par. Severe competition from weeds might have resulted in growth retardation of the crop. At the time of harvest, there was significant difference between treatments in tiller count. But this was not reflected in no. of panicles produced and yield.

5.6 Yield and yield attributes

Out of the 14 treatments, highest grain yield of 5.75 t/ha was recorded under hand weeding + flubendiamide treatmentt, which was on par with hand weeding+ imidacloprid and twice hand weeded plots. Rath *et al.* (2015) observed an increase in yield by the application of imidacloprid 17.8 % @ 300 g/ha. Yield increase to the tone of 46.35 per cent was reported with application of flubendiamide by Devi and Singh (2016).

Correlation studies indicated high degree of correlation (r = - 0.821) between grain yield and weed density/weed dry matter production at 60 DAS. Unweeded control with highest weed infestation registered lowest yield. Yield reduction in unweeded control is 65.65 per cent compared to hand weeded treatment. Pratap *et al.* (2016) reported highest grain yield of 3.5 t/ha in hand weeded plot and a lowest grain yield of 352 kg/ha in weedy check plot. Begum (2006) reported that 42-100 per cent grain yield reduction could be seen in unweeded conditions. Johnson *et al*. (2004) reported that severe weed problems will cause reduction in the number of productive tillers, increase in the number of unproductive tillers and reduction in number of grains per panicle and lead to yield reduction.

Effect of treatments on grain yield is depicted in Fig.6. Comparing the sequential and tank mix applications of bispyribac sodium and insecticides, bispyribac sodium + flubendiamide recorded significantly lower yield than its sequential application and bispyribac sodium + imidacloprid recorded yield statistically on par with its sequential application. In the case cyhalofop-butyl with insecticides, cyhalofop-butyl + flubendiamide recorded significantly higher yield than its sequential application and cyhalofop-butyl + imidacloprid recorded yield comparable to its sequential application. Yield reduction in bispyribac sodium + flubendiamide might be due to high weed density and weed dry matter production at 60 DAS. This means that efficacy of bispyribac sodium is reduced when mixed with flubendiamide. In other treatments also, negative correlation between weed intensity and yield was apparent.

Production of straw was not significantly affected by different treatments. Hand weeding + flubendiamide application recorded highest straw yield of 5.96 t/ha whereas unweeded control recorded lowest yield of 3.92 t/ha. Season long weed competition and shading of crop by weeds are the reasons for lowest grain and straw yield in weedy check as suggested by Raj and Syriac, (2016). However, the difference between treatments was non- significant.

Yield parameters like number of panicles per m^2, spikelets per panicle and filled grains per panicle were highly correlated to weed count and weed dry matter production at all stages of observation except panicles per m^2 at harvest. Test grain weight had no significant correlation with weed count and dry matter production. Highest value for number of panicles per m^2 was recorded in hand weeded plot which was on par with hand weeding + imidacloprid treatment and bispyribac sodium *f.b.* flubendiamide treatment. In the case of herbicide-insecticide combination treatments, bispyribac sodium + imidacloprid showed highest panicle number which was statistically on par with its sequential application. In sequential application of cyhalofop-butyl and imidacloprid, number of tillers per plant at harvest was significantly high. However, this was not reflected in number of panicles per m^2 and also yield. The late formed tillers might not have contributed to panicle production and an advantage of higher yield was not obtained. All the treatments were on par with respect to 1000 grain weight (test weight). Test weight ranged from 24.45 g to 25.66 g.

Hand weeded treatments registered higher number of filled grains per panicle, with highest in hand weeding + flubendiamide treatment. Similar results of higher grain number with hand weeding were reported by Singh and Paikra (2014) and Atheena (2016). Hand weeding resulted in more number of panicles per m^2 and number of filled grains per panicle, finally leading to high grain and straw yield than chemical methods (Prasad *et al.,* 2001).

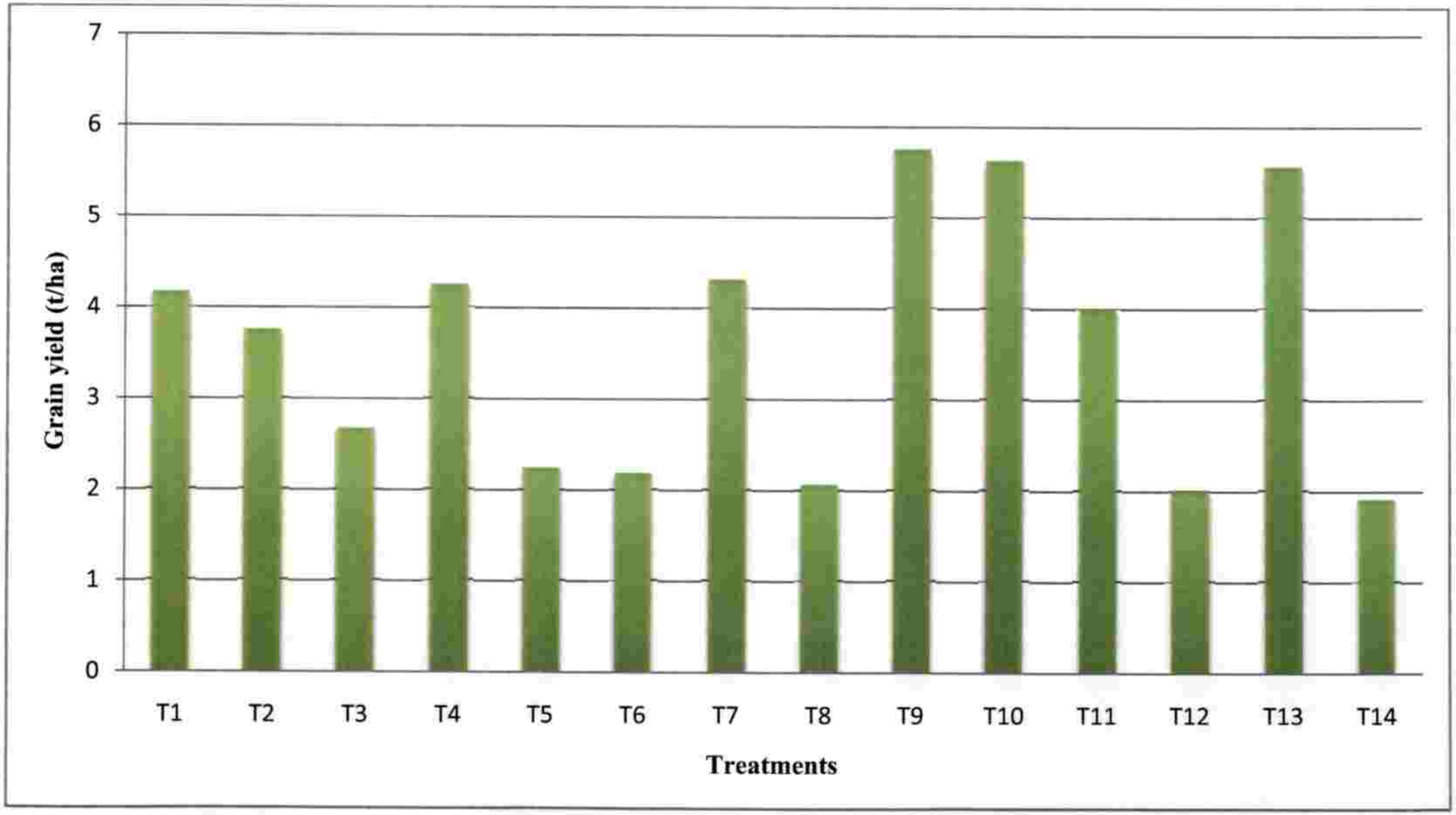

Fig.6. Effect of treatments on grain yield

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5.7 Benefit- cost analysis

Farmers opt for herbicide application with a view to reduce cost of production. For further reduction in cost, they try tank mixed applications of insecticides and herbicides. Since all these are intended to cut short expenditure, a benefit-cost analysis is needed before arriving at a cost effective recommendation.

Analysis of data on cost of cultivation of various treatments indicate that application of cyhalofop-butyl + flubendiamide and bispyribac sodium + imidacloprid recorded higher B:C ratios of 2.84 and 2.82 with net returns of Rs. 92808 and Rs. 94052 respectively. The cost of cultivation when compared to sequential application of herbicides and insecticides was less when they are tank mixed. Gross return and cost of cultivation were higher in hand weeded treatments. Unweeded control recorded the lowest gross return, cost of cultivation and B: C ratio.

Summary

6. SUMMARY

The research experiment on "compatibility of herbicides and insecticides for tank mix application in wet seeded rice" was conducted in the Kole lands of Alappad in Thrissur district from August 2016 to January 2017. The experiment aimed at finding out the compatibility and efficacy of two popular herbicides viz., bispyribac sodium and cyhalofop-butyl when tank mixed with two insecticides. The insecticides used were flubendiamide and imidacloprid which are of common use in rice. The experiment was laid out in RBD with 14 treatments and 3 replications. First four treatments were the sequential and mixed application of bispyribac sodium and two insecticides. The next four (*i.e.* T_5-T_8) included the same treatments as above, with bispyribac sodium substituted by cyhalofop-butyl. The remaining treatments were application of herbicides alone, hand weeding with and without application of insecticides and unweeded control. Observations on crop and weeds were taken at 30 DAS, 60 DAS and at harvest. Field scouting for insect pest infestation was done before pesticide application and extent of infestation was recorded at 5, 7 and 11days after spraying. Nutrient uptake by grain and straw and properties of soil before and after the experiment were also recorded.

Results of the experiment are summarized below.

- *Echinochloa crus-galli, Echinochloa stagnina, Leptochloa chinensis, Limnophila heterophylla, Ludwigia parviflora* and *Cyperus iria* were the weeds present in the field. Grasses and sedges dominated the field and controlled the growth of broad leaf weeds.
- Insect pests observed in the field included *Cnaphalocrocis medinalis, Scirpophaga incertulas, Sogatella furcifera* and *Menida versicolor.* Among these, *C. medinalis* was the major pest to invade the field.
- Application of herbicides caused no phytotoxic symptoms on crop at 3 and 7 days after spraying of the chemicals alone, sequentially or tank mixed. All the treatments were scored as zero.

- Both weed count and weed dry matter production was lowest in hand weeded treatments and highest in unweeded control. Weed dry matter production was highest at 60 DAS compared to production at 30 DAS and at harvest. Cyhalofop-butyl was ineffective to control broad leaf weeds and sedges. Therefore weed count and weed dry matter production was highest in cyhalofop-butyl treated plots compared to bispyribac sodium treated. Hand weeded treatments recorded highest weed control efficiency
- Comparing the sequential and tank mix applications of bispyribac sodium with insecticides, bispyribac sodium + flubendiamide recorded highest weed dry matter production and lowest weed control efficiency than its sequential application. Tank mixing of bispyribac sodium + imidacloprid recorded weed dry matter production and weed control efficiency which were statistically on par to its sequential application.
- Comparing sequential and tank mix applications of cyhalofop-butyl with insecticides, cyhalofop-butyl + flubendiamide recorded significantly lower weed dry matter production and higher weed control efficiency than its sequential application and cyhalofop-butyl + imidacloprid registered a weed dry matter production and weed control efficiency significant to its sequential application.
- There was no significant difference among different treatments in counts of insect pests at 5, 7 and 11 days after spraying. Total pest count was highest in unweeded control. Defoliator, stem borer and sucking pests were the types of pests observed in the field. Compared to shoot borer and sucking pests, defoliating pest- rice leaf folder- dominated the field. Flubendiamide turned to be more effective than imidacloprid for control of leaf folder. Appearance of borers occurred only after 11 days of spraying.
- Plant height at 30 DAS, 60 DAS and at harvest was not affected by various treatments. It ranged from 44.20 cm to 48.39 cm, 78.78 cm to 86.33 cm and 93.56 cm to 99.85 cm at 30 DAS, 60 DAS and at harvest respectively.

- At 30 DAS and 60 DAS, tiller count per plant was not affected by various treatments. At harvest time, cyhalofop-butyl *f.b.* imidacloprid the next day showed highest tiller production per plant.
- Crop dry matter production was also not affected by various treatments at 30 DAS, 60 DAS and at harvest except dry matter production in unweeded control at harvest.
- Grain yield was highest in hand weeded treatments. Among tank mix treatments cyhalofop-butyl + flubendiamide registered highest grain yield, followed by bispyribac sodium + imidacloprid. All the treatments were statistically on par for straw yield. Number of panicles per m^2, spikelets per panicle, filled grains per panicle and filling percentage were highest in hand weeded treatments. Comparing tank mix treatments, bispyribac sodium + flubendiamie recorded lower yield and yield attributes than its sequential application. Bispyribac sodium + imidacloprid and cyhalofop-butyl + imdacloprid recorded yield and yield attributes comparable to their sequential application. In case of cyhalofop-butyl and flubendiamide, yield and yield attributes were significantly higher with tank mix application.
- Soil pH and organic carbon content after the experiment was not affected by various treatments. A reduction from the initial value in organic carbon content was observed. Available nitrogen and potassium were higher in hand weeded treatments, but available phosphorus was higher in unweeded control.
- Nutrient uptake was highest in hand weeded treatment and lowest in unweeded control. Among tank mix treatments, bispyribac sodium + flubendiamide recorded lowest uptake. Bispyribac sodium + imidacloprid and cyhalofop-butyl + imdacloprid registered an uptake comparable to its sequential application. Cyhalofop-butyl + flubendiamide recorded significantly higher uptake than its sequential application.
- Highest B: C ratio was observed in cyhalofop-butyl + flubendiamide and bispyribac sodium + imidacloprid treatments. Due to higher cost of

production, hand weeded treatments recorded lower B:C ratio than chemical treatments. Unweeded control recorded least B:C ratio of 1.78.

- Efficacy of cyhalofop-butyl is not reduced when mixed with insecticides flubendiamide and imidacloprid. In the case of bispyribac sodium, the insecticide imidacloprid appeared to be compatible. But efficacy of bispyribac sodium is reduced when mixed with flubendiamide. So it cannot be recommended. Due to low population of insects so as to make any significant effect, efficacy of insecticides when tank mixed with herbicides could not be interpreted.

References

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REFERENCES

Acharya, L. P., Chaudhary, N. K., Mishra, N. K., and Amagain, L. P. 2007. Effect of nitrogen and weed management on yield of rainfed rice (*Oryza sativa* L. *var. indica*). *Res. Adv.* **1**: 23-29.

Adams, J. B. 1960. Effects of spraying 2,4-D amine on coccinellid larvae. *Can. J. Zoo.* **38**: 285-288.

Afun, J. V. K., Johnson, D. E., and Russell-Smith, A. 1999. Weeds and natural enemy regulation of insect pests in upland rice; A case study from West Africa. *Bull. Entomol. Res.* **89**: 391–402.

Ali, A. D. and Reagan, T. E. 1985. Vegetation manipulation impact on predator and prey populations in Louisiana sugarcane ecosystems. *J. Econ. Entomol.* **78**: 1409-1414.

Alvi, S. M., Ali, M. A., Chaudhary, S. U., and Iqbal, S. 2003. Population trends and chemical control of rice leaf folder (*Cnaphalocrocis medinalis*) on rice crop. *Int. J. Agric. Biol.* 5:615-617.

Angiras, N. N. and Sharma, V. 1998. Integrated weed management studies in direct seeded upland rice (*Oryza sativa*). *Indian J. Weed Sci.* 30: 32-35.

Anuruddhka, S. K., Abeysekera, and Wickrama, U. B. 2004. Control of *Leptochloa chinensis* (L.) Nees in wet-seeded rice fields in Sri Lanka. In: Toriyama, K., Heong, K. L., and Hardy, B. (eds.), *Proceedings of the World Rice Research Conference*, 4-7 November 2004, Tsukuba, Japan, pp. 215- 217.

Atheena, A. 2016. Tank mix application of cyhalofop-butyl with selected herbicides for weed control in wet seeded rice. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 101p.

Aulakh, S. S., Randhawa, H. S., and Mandeep, S. 2016. Bioefficacy of insecticidesfor management of stem borer and leaf folder on paddy in Punjab, India. *Agric. Sci. Digest* **36**(3): 224-227.

Azmi, M. and Baki, B. B. 1995. The succession of noxious weeds in tropical Asian rice fields with emphasis on Malaysian rice ecosystem. In: *Proceedings of 15th Asian Pacific Weed Science Society Conference*, Tsukuba, Japan, pp. 51-67.

Bandara, A. M. T. C., Abeysekara, A. S. K., Witharana, D. D., and Wickrama, U. B . 2015. Bio–efficacy evaluation of oxyfluorfen in wet – seeded rice in Sri Lanka. In: Shetty, S. V. R., Prasad, T. V. R., Chinnusamy, C., Sanjay, M. T., Sondhia, S., and Kumar, S. (eds.), *Proceedings of 25th Asian – Pacific Weed Science Society Conference on "Weed Science for Sustainable Agriculture, Environment and Biodiversity"Volume 3,* 13-16 October 2015, Hyderabad. Indian Society of Weed Science, Jabalpur, pp. 96-104.

Barotti, R., Carone, A., Dallavalle, N., and Gallizia, B. 1998. Cyhalofop-butyl (DE-537), a new graminicide for the post emergence control of *Echinochloa* spp. In paddy rice. In: *Proceedings of Giornate Fitopatologiche*, 3-7 May 1998, Scicli e Ragusa, Italy, pp. 321-326.

Barr, B. A. S. and Smith, R. F. 1975. *Crop Loss to Insects, Diseases and Other Pests*. University of California, Berkley, 64p.

Bastiaans, L., Kropff, M. J., Kempuchetty, N., Rajan, A., and Migo, T. R. 1997. Can simulation models help design rice cultivars that are more competitive against weed?. *F. Crop Res*. **51**: 101 – 111.

Begum, M. 2006. Biology and management of *Fimbristylis miliacea* (L.) Vahl. Ph.D. Thesis, Universiti Putra Malaysia, Malaysia, 297p.

Bhandari, P., Meenakshi, Tomar, A., and Rai, M. 2016. Effect of newer insecticide, imidacloprid 0.3% GR on rice stem borer & brown plant hopper (BPH) in rice crop. *Progress. Agric.* **16**(2): 251- 255.

Bhanu, K. V. and Reddy, P. S. 2008. Field evaluation of certain newer insecticides against rice insect pests. *J. Appl. Zool. Res.* **19** (1):11-14.

Bharathalakshmi, M., Devi, C. T., Gowri, V., Kumari, M. B. G. S., and Ramanamurthy, K. V. 2015. Evaluation of herbicides for effective weed management in wet – seeded rice. In: Shetty, S. V. R., Prasad, T. V. R., Chinnusamy, C., Sanjay, M. T., Sondhia, S., and Kumar, S. (eds.), *Proceedings of 25th Asian – Pacific Weed Science Society Conference on "Weed Science for Sustainable Agriculture, Environment and Biodiversity" Volume 3,* 13-16 October 2015, Hyderabad. Indian Society of Weed Science, Jabalpur, pp. 128-134.

Bowling, C. C. and Hudgins, H. R. 1966. The effect of insecticides on the selectivity of propanil on rice. *Weeds* **14**(1): 94- 95.

Buehring, N. W., Talbert, R. E., and Baldwin, F. L. 2006. Rice (*Oryza sativa*) response and annual grass control with graminicides. *Weed Technol.* **20**(3): 738-744.

Busi, R., Gaines, T. A., and Powles, S. 2017. Phorate can reverse P 450 metabolism-based herbicide resistance in *Lolium rigidum. Pest Manag. Sci.* **73**(2): 410-417.

Catinding, J. L. A. and Heong, H. L. 2003. *Rice Doctor.* International Rice Research Institute, Phillipines, pp.1-10.

Chauhan, B. S. and Johnson, D. E. 2010. The role of seed ecology in improving weed management strategies in the tropics. *Adv. Agron.* **105**: 221-262.

Chauhan, B. S., Kumar, V., and Mahajan, G. 2014. Research needs for improving weed management in rice. *Indian J. Weed Sci*. **46**: 1-13.

Chin, D. V. 2001. Biology and management of barnyard grass, red sprangletop and weedy rice. *Weed Biol. Manag.* **1**: 37-41.

Chormule, A. J., Kharbade, S. B., Patil, S. C., and Tamboli, N. D. 2014. Bioefficacy of new insecticide molecules against rice yellow stem borer, *Scirpophaga incertulas* (walker). *Ecosan.* **6**: 63-67.

Choubey, N K., Kolhe, S. S., and Tripathi, R. S. 2001. Relative performance of cyhalofop-butyl for weed control in direct seeded rice. *Indian J. Weed Sci.* **33**(3): 132- 135.

Das, T., Mandal, B., Banerjee, M., and Malik, G. C. 2017. Evaluation of bispyribac sodium and other herbicides in transplanted rice. *Int. J. Appl. Pure Sci. Agric.* **3**(4): 1-5.

De Datta, S. K., Bernasor, P. C., Migo, T. R., Llagas, M. A., and Nantasomsaran, P. 1989. Emerging weed control technology for broadcast seeded rice. In: *Progress in Irrigated Rice Research.* International Rice Research Institute, Philippines, pp. 133–146.

Deepa, S. and Jayakumar, R. 2003. Compatibility of pretilachlor with insecticides and fungicides in rice ecosystem. *Madras Agric. J.* **95**: 42-45.

Deka, S. and Barthakur, S. 2010. Overview on current status of biotechnical intervention on yellow stem borer *Scirpophaga incertulas* (Lepidoptera: Crambidae) resistance in rice. *Biotechnol. Adv*. **28**(1): 70 – 81.

Devi, P. R. and Singh, K. I. 2016. Efficacy of new molecules, spinosad and monocrotophos on the incidence of *Cnaphalocrocis medinalis* Guenee under *kharif* rice crop ecosystem of Manipur valley. *Int. J. Agric. Sci. Res.* **6**(1): 7-14.

Dhaliwal, G. S., Arora, R., and Dhawan, A. K. 2004. Crop losses due to insect pests in Indian agriculture: An update. *Indian J. Ecol.* **31**(1):1-7.

Dhammu, H. S. and Sandhu, K. S. 2002. Critical period of *Cyperusiria* L. competition in transplanted rice. In: Jacob, H. S., Dodd, J., and Moore, J. H. (eds.), *Proceedings of 13th Australian Weeds Conference: Weeds "Threats now and forever?"*, 8–13 September 2002, Western Australia. Plant Protection Society, Western Australia, pp. 79-82.

Ferrero, A. 2003. Weedy rice, biological features and control. In: Labrada, R. (Ed.) *Weed Management for Developing Countries: Addendum 1*. Food and Agricultural Organization, Rome pp. 89–107.

Fossen, M. 2006. Environmental fate of imidacloprid [online]. Available: http://www.cdpr.ca.gov/docs/emon/pubs/fatememo/Imidclprdfate2.pdf [05 June 2017].

Geanessi, L. 2014. Importance of pesticides for growing rice in south and south east Asia [online]. Available: https://croplife.org [11 June 2017].

Gupta, G. P. and Raghuraman, M. 2003. Plant protection in suppressing for food security. *Indian Farming* **53**: 31-34.

Gupta, S. P., Prakash, A., Rao, J., and Gupta, A. 1993.Qualitative losses of paddy grain due to bugs in farmer's field of coastal Orissa. *Indian J. Entomol*. **55**: 229-236.

Hamill, A. S. and Penner, D. 1973. Interaction of alachlor and carbofuran. *Weed Sci*. **2l**: 330-335.

Hasanuzzaman, M., Ali, M. H., Akther, M., and Alam, K. F. 2009. Evaluation of pre-emergence herbicide and hand weeding on the weed control efficiency and performance of transplanted Aus rice. *Am. Eurasian J. Agron.***2**: 138-43.

Hegde, M. 2005. Efficacy of new chemicals against brown plant hopper on rice. *J. Maharashtra Agric. Univ*. **30**: 107-105.

Ho, N. K. and Itoh, K. 1991. Changes in weed flora and their distribution in the Muda area. Paper Presented at the *8th MADA/TARC Quarterly Meeting,* 3 November 1991, *Malaysian* Agricultural Research and Development Institute, Malaysia.

Huesing, J. and English, L. 2004. The impact of Bt. crops on the developing world. *Ag. Bio. Forum* **7** (1-2): 84-95.

Hussain, S., Ramzan, M., Akhter, M., and Aslam, M. 2008. Weed management in direct seeded rice. *J. Anim. Plant Sci.* **18** (2-3): 86-88.

Islam, M. M. and Kalita, D. C. 2016. Weed dynamics and productivity of wetland rice as influenced by establishment methods and integrated weed management. *Bangladesh J. Bot.* **45**(1): 9-16.

Ito, M., Kawahara, H., and Asai, M. 1998. Selectivity of cyhalofop-butyl in poaceae species. *J. Weed Sci.Technol*. **43**(2): 122–128.

Jabran, K., Farooq, M., Khan, H. E. M. B., Shahid, M., and Jnlee, D. 2012. Efficient weed control with penoxsulam application ensures higher productivity and economic returns of direct seeded rice. *Int. J. Agric. Biol.* **14**: 901-907.

Jackson, M. L. 1958. *Soil Chemical Analysis*. Prentice Hall Inc, New Jersey, 498p.

Jacob, G., Menon, M. V., and Abraham, C. T. 2014. Comparative efficacy of new herbicides in direct seeded rice. *J. Trop. Agric*. **52**: 174- 177.

Jiania, S., Zhiwei, W., Kai, Z., Xiangrui, T., yanqiong, Y., Xueqing, Z., Aidong, S., and Cong, F. G. 2013. Status of insecticide resistance of the whitebacked plant hopper, *Sogatella furcifera* (Hemiptera: Delphacidae). *Florida Entomol.* **96**(3): 948-956.

Johnson, D. E., Wopereis, M. C. S., Mbodj, D., Diallo S., Powers S., and Haefele, S. M. 2004. Timing of weed management and yield losses due to weeds in irrigated rice in the Sahel. *F. Crop Res.* **85**: 31–42.

Jordan, D. L., Culpepper, A. S., Grichar, W. J., Ducar, T. J., Brecke, B. J., and York, A. C. 2003. Weed control with combinations of selected fungicides and herbicides applied post emergence to peanut (*Arachis hypogaea* L.). *Peanut Sci.* **30**: 1-8.

Joy, P. P., Syriac, E. K., Nair, P. K. C., and Joseph, C. A. 1991. Weed control in wet seeded rice in Kerala, India. *IRRI Newsl.* **16**(6): 25.

Kang, B. K., Jyot, G., Singh, B., Battu, R. S., and Cheema, H. K. 2007. Persistence of imidacloprid in paddy and soil. *Pestic. Res. J.* **19**: 237–238.

Karim, R. S. M., Azmi, B. M., and Ismail, B. S. 2004. Weed problems and their management in rice fields of Malaysia: An overview. *Weed Biol. Manag.* **4**(4): 177-186.

Karthikeyan, K. and Sosamma, J. 2009. New alternative weed hosts and comparative biology of the rice blue beetle *Leptispa pygmaea* Baly. *Oryza* **46**(3): 260- 262.

Karthikeyan, K. and Purushothaman, S. M. 2000. Efficacy of carbosulfan against rice yellow stem borer, *Scirpophaga incertulas* Walker (Pyralidae, Lepidoptera) in rabbi rice. *Indian J. Plant Prot.* **28**(2): 212-214.

KAU [Kerala Agricultural University]. 2016. Package *of Practices Recommendations: Crops* (15th Ed.). Kerala Agricultural University, Thrissur, 393p.

Kaur, S., Bhullar, M. S., and Kaur, T. 2016. Management of mixed weed flora in transplanted rice using herbicide combinations. *Agric. Res .J.* **53** (4) : 483-487.

Kraehmer, H., Jabran, K., Mennan, H., and Chauhan, B. S. 2016. Global distribution of rice weeds- A review. *Crop Prot.* **80**: 73- 86.

Kubendran, D., Chandrasekaran, S., Kumar, B. V., and Kuttalam, S. 2006. Assessment of safety of flubendiamide 480 SC to natural enemies. *Pestol.* **32**(12): 19-22.

Kubendran, D., Chandrasekaran, S., Kumar, V. B., and Kuttalam, S. 2008. Assessment of phytotoxicity and compatibility of flubendiamide 480 SC with other agrochemicals. *Pestol.* **32**(10): 65-67.

Kumar, J., Singh, D., Puniya, R., and Pandey, P. C. 2010. Effect of weed management practices on nutrient uptake by direct seeded rice. *Oryza* **47**(4): 291-294.

Kumar, S. and Rana, S. S. 2013. Bioefficacy of bispyricbac sodium for weed control in direct seeded rice. *Pestic. Res. J.* **25**(2): 123-127.

Kumaran, S. T., Kathiresan, G., Chinnusamy, C., andArthanari, P. M. 2012. Evaluation of new post-emergence herbicide bispyribac sodium for transplanted rice. In: *Biennial Conference on Weed Threat to Agriculture, Biodiversity and Environment*, 19-20 April 2012, Thrissur. Kerala Agricultural University, Thrissur, 74p.

Kumaran, S. T., Kathiresan, G., Arthanari, P. M., Chinnusamy, C., and Sanjivkumar, V. 2015. Efficacy of new herbicide (bispyribac sodium 10% SC) against different weed flora, nutrient uptake in rice and their residual effects on succeeding crop of green gram under zero tillage. *J. Appl. Nat. Sci.* **7** (1): 279 – 285.

Kumari, L. S. 2012. *Status paper on rice in Kerala* [online]. Rice Knowledge Management Portal (RKMP). Available: http://www.rkmp.co.in [27 May 2017].

Lal, B., Priyanka, G., Raja, R., Nayak, A. K., Mohammad, S., Tripathi, R., Bhattacharyya, B., Sangita, M., Chandrika, P., Kumar, A., and Panda, B. B. 2014. Weed community composition after 43 years of long-term fertilization in tropical rice–rice system. *Agric. Ecosyst. Environ.* **197**: 301-308.

Lal, O. P. 1996. *Recent Advances in Indian Entomology*. APC publication pvt. Ltd.,New Delhi, 392p.

Liu, W. P., Zheng, W., and Gan, J. Y. 2002. Competitive sorption between imidacloprid and imidacloprid-urea on soil clay minerals and humic acids. *J. Agric. Food Chem.* **50**: 6823–6827.

Mahajan, G., Sardana, V., Brar, A. S., and Gill, M. S. 2006. Effect of seed rates, irrigation intervals and weed pressure on productivity of direct seeded rice. *Indian J. Agric. Sci.* **76**: 156-159.

Mahar, M. M., Bhatti, I. M., and Dhuyo, A. R. 1985. Stem borer infestation and yield loss relationship in rice and cost- benefits of control. In: Paper Presented at *5th National Seminar on Rice and Production,* 23-25 April 1985. Pakistan Agricultural Research Station, Kalashakaku, pp. 145-156.

Maity, S. K. and Mukherjee, P. K. 2009. Integrated weed management in dry direct seeded summer rice. *Indian J. Agric. Sci.* **79**(12): 28-31.

Mani, V. S., Malla, M. L., Gautam, K. C., and Bhagwndas. 1973. Weed killing chemicals in potato cultivation. *Indian Farming* **22**: 17- 18.

Matsumoto, T., Matsuya, K., Katahashi, H., Kondo, N., and Imai, Y. 1994. Cyhalofop-butyl; control activity of a new grass herbicide on barnyard grass in rice. *Weed Res.* **39**: 48- 49.

Matsumoto, T., Matsuya, K., Katahashi, H., Kondo, N., and Imai, Y. 1993. Cyhalofop- butyl: grass herbicide- field performance in rice in Japan. In: Wilson, B. J. and Swarbrick, J. T. (eds.), *Proceedings of the 10th Australian Weeds Conference and 14th Asian Pacific Weed Science Society Conference*, 6-10 September 1993, Brisbane, Australia. pp.149-153.

Menon, S. S. and Prameela, P. 2015. Effect of new post– emergence herbicides in wet–seeded rice. In: Shetty, S. V. R., Prasad, T. V. R., Chinnusamy, C., Sanjay, M. T., Sondhia, S., and Kumar, S. (eds.), *Proceedings of25th Asian – Pacific Weed Science Society Conference on "Weed Science for Sustainable Agriculture, Environment and Biodiversity"Volume 3,*13-16 October 2015, Hyderabad. Indian Society of Weed Science, Jabalpur, pp. 124-128.

Menon, S. S., Prameela, P., and Abraham, C. T. 2014. Weed control in wet-seeded rice by post-emergence herbicides. *Indian J. Weed Sci.* **46**(2): 169–171.

Misra, A. K., Singh, S. P. N., and Parwez, A. 2005. Incidence of yellow stem borer (*Scirpophaga incertulas* Walker) in different cultivar of boro rice (*Oryza sativa* L.) at different crop stage. *Oryza* **42**(4): 329-332.

Misra, H. P. and Parida, T. K. 2004. Field screening of combination insecticides against rice stem borer and leaf folder. *Indian J. Plant Prot.* **32**: 133-135.

Mohanasarida, K. 2002. Effect of seed hardening on establishment, growth and productivity of semi-dry rice. M.Sc.(Ag) thesis, Kerala Agricultural University, Thrissur, 100p.

Moody, K. 1989. Weeds reported to occur in India. In: *Weeds reported in rice in South and South East Asia*. IRRI, Laguna, Philippines, pp. 115 - 162.

Moorthy, B. T. S. and Saha, S. 2002. Bio-efficacy of certain new herbicide formulations in puddle-seeded rice. *Indian J. Weed Sci.* **34**:46-49.

Mukherjee, P. K., Sarkar, A., and Maity, S. K. 2008. Critical period of crop-weed competition in transplanted and wet-seeded kharif rice (*Oryza sativa* l.) under Terai conditions. *Indian J. Weed Sci.* **40** (3 & 4): 147-152.

Murugesan, S. and Chellaiah, S. 1983. Rice yield losses caused by leaf folder damage at tillering stage. *Int. Rice Res. News Lett.* **8** (4):13-14.

Nalini, K., Arthanari, P. M., and Chinnusamy, C. 2012. Evaluation of new post-emergence herbicide bispyribac sodium for transplanted rice. In: *Biennial Conference on Weed Threat to Agriculture, Biodiversity and environment*, 19-20 April 2012, Thrissur. Kerala Agricultural University, Thrissur, pp.74-78.

Nash, R. G. 1968. Synergistic phytotoxicities of herbicide- insecticide combinations in soil. *Weed Sci.* **16**: 74-77.

Ntanos, D. A., Koutroubas, S. D., and Mavrotas, C. 2000. Barnyard grass (*Echinochloa crus-galli*) control in water seeded rice (*Oryza sativa*) with cyhalofop- butyl. *Weed Technol.* **14**:383- 388.

Odglen, G. E. and Warren, L. O. 1962. *The rice stink bug Oebalus pugnax F. in Arkansas*. Arkansas agricultural experiment Station, Fayetteville, pp. 16-19.

Ottis, B. V., Smith, K. L., Scott, R. C., and Talbert, R. E. 2005. Rice yield and quality as affected by cultivar and red rice (*Oryza sativa*) density. *Weed Sci.* **53**: 499-504.

Pankey, J. H., Griffin, J. L., Leonard, B. R., Miller, D. K., Downer, R. G., and Costello, R. W. 2004. Glyphosate – insecticide combination effects on weed and insect control in cotton. *Weed Technol*. **18**(3): 698-703.

Park, J. E., Ryu, G. H., Lee, I. Y., Lee, H. K., Shin, H. S., Lee, J. O., and Kim, K. U. 1994. Selective mechanism of cyhalofop-butyl ester between rice and *Echinochloa crus-galli*. 1. Differential response of rice and *Echinochloa crus-galli* to cyhalofop-butyl ester. *Korean J. Weed Sci.* **14**(2): 94-100.

Parwez, A., Misra, A.K., Mandal, S.K., and Sattar, A. 2005. Activity of *Scirpophaga incertulas* and *Lycosa pseudoannulata* in boro rice as influenced by meteorological parameters. *J. Appl. Biol*. **15**(2): 55-59.

Pasalu, I. C. and Katti, G. 2006. Advances in eco-friendly approached in rice IPM. *J. Rice Res*. **1** (1): 83 -90.

Pathak, M. D. 1968. Ecology of common insect pests of rice. *Ann.. Rev. Entomol.* **13**: 257-294.

Pattar, P. S., Reddy, B. G. M., and Kuchanur, P. H. 2005. Evaluation of halo-sulfuron methyl for weed control in puddled direct- seeded rice (*Oryza sativa*). *Indian J. Agric. Sci.* **75**: 230–231.

Piper, C. S. 1966. *Soils and Chemical Analysis.* Hans publishers, Bombay, 368p.

Pradhan, S. 1971. In tropics, protection research more needed than production research. *Indian J. Entomol.* **33**: 233-259.

Prakash, C., Shivran, R. K., and Koli, N. R. 2013. Bioefficacy of new herbicides in transplanted rice. *Indian J. Weed Sci.* **45**(4): 282–284.

Prameela, P., Menon, S. S., and Menon, M. V. 2014. Effect of new post emergence herbicides on weed dynamics in wet seeded rice. *J. Trop. Agric.* **52** (1): 94 -100.

Prasad, G. S. V., Prasadarao, U., Rani, N. S., Rao, L. V. S., Pasalu, I. C., and Muralidharan, K. 2001. Indian rice varieties released in countries around the world. *Curr. Sci.* **80**(12): 1508-1511.

Prasad, S. S., Gupta, P. K., and Mishra, J. P. 2014. Evaluation of certain new insecticides against yellow stem borer, *Scirpophaga incertulas* on semi deep water rice. *Int. J. Curr. Microbiol. App. Sci.* **3**(9): 736-740.

Prasad, T. V. P. R., Reddy, C. V., Bharathalakshmi, M., and Satyanarayana, P. V. 2016. Efficacy of new herbicide molecules for weed management in wet direct seeded rice. *Oryza* **53**(1): 98-101.

Pratap, T., Singh, V. P., Singh, R., and Rekha. 2016. Herbicides for weed management in direct dry-seeded rice. *Indian J. Weed Sci.* **48**(3): 275-278.

Puri, S. N. 2000. *Farmer-Led Integrated Pest Management fn India and the Pacific*. Asian Productivity Organization, Tokyo, pp. 83-96.

Raghavendra, B. M., Susheela, R., Madhavi, M., and Mahantheswara, B. 2015. Influence of weed management practices on nutrients uptake and wet seeded rice (*Oryza sativa* L.) sown through drum seeder. *Ann. Plant Prot. Sci.* **23**(1): 153- 157.

Rahman, M. M., Ismail, S., and Sofian-Azirun, M. 2012. Identification of resistant biotypes of *Leptochloa chinensis* in rice field and their control with herbicides. *Afr. J. Biotechnol.* **10**(15): 2904-2914.

Rai, A. K. and Khan, M. A. 2002. Light trap catch of rice insect pest, *Nephotettix virescens* (Distant) and its relation with climatic factors. *Ann. Plant Prot. Sci.* **10**:17-22.

Raj, S. K. and Syriac, E. K. 2016. A new herbicide mixture: bispyribac sodium + metamifop 14% SE for weed control in wet seeded rice. *Res. on Crops* **17** (3): 421-427.

Raj, S. K., Mathew, R., Jose, N., and Kumary, L. S. 2013. Evaluation of early postemergence herbicides on weed control and productivity of direct-seeded puddled rice in Kuttanad. *Madras. Agric. J.* **100**: 738- 42.

Ramasamy, C. and Jaliecksono, T. 1996. Inter country comparison of insect and disease losses. In: Evanson, R. E. R.W., Herdt, W., and Hossain, M (eds.), *Rice Research in Asia: Progress and Priorities*. CAB International and IRRI, Philippines, 26p.

Ramu, S. P., Punnaiah, K. C., Rao, R. G., and Rao, S. V. 2005. Bioefficacy of certain new insecticides against sucking insect pests of rice. *J. Entomol. Res*. **29**(3): 211-213.

Ranjit. 2007. Weeds Associated with different crops. In: *Paper presented to Training on Weed management in rice*, 25-27 April 2007, Nepal Agricultural Research Council, Khumaltar, pp. 234-248.

Rao, A. N., Johnson, D. E., Shivprasad, B., Ladha, J. K., and Mortimer, A. M. 2007. Weed management in direct-seeded rice. *Adv. Agron.* **93**: 153-255.

Rao, B. S., Mallikarjunappa, S., Bhat, G., and Koneripalli, N. 2008. Bioefficacy of new generation insecticide Takumi 20 WG against rice yellow stem borer *Scirpophaga incertulas. Pestol.* **34**(4): 33-34.

Rao, J. and Prakash, A. 1995. Biodegradation of paddy seed quality due to insects and mites and its control using botanicals. *Final report ICAR/CRRI Ad-hoc Scheme (1992-95)*. Central Rice Research Institute, Cuttack, 87 p.

Rao, V. T. 1950. *Nilaparvata lugens* Stal (Fulgoridae: Homoptera) as a pest of paddy cultivation in north Madras and its control. *Indian J. Entomol.* **12**: 241-248.

Rao, Y. S. and Kulshrestha, J. P. 1985. Pests of rice- gundhi bug. In: *Rice Research in India*. Indian Council of Agricultural Research, New Delhi, 726 p.

Rath, P. C., Chakraborty, K., Nandi, P., and Moitra, M. N. 2015. Field efficacy of some new insecticides against rice stem borer and gundhi bug in irrigated rice ecology. *Int. J. Plant Anim. Environ. Sci.* **5**(2): 94-96.

Rawat, A., Chaudhary, C. S., Upadhyaya, V. B., and Jain, V. 2012. Efficacy of bispyribac sodium on weed flora and yield of drilled rice. *Indian J. Weed Sci.* **44**(3): 183–185.

Ray, P. G., Pews, R. G., Flake, J., Secor, J., and Hamburg, A. 1993. Cyhalofop - butyl: a new graminicide for use in rice. In: Wilson, B. J. and Swarbrick, J. T. (eds.), *Proceedings of the 10th Australian Weeds Conference and 14th Asian Pacific Weed Science Society Conference*, 6-10 September 1993, Brisbane, Australia, pp. 41-45.

Rekha, B. K., Raju, M.S., and Reddy, M. D. 2003. Effect of herbicides on weed growth, grain yield and nutrient uptake in rainfed lowland rice. *Indian J. Weed Sci.* **35**: 121-122.

Rekha, K. B., Raju, M. S., and Reddy, M. D. 2002. Effect of herbicides in transplanted rice. *Indian J. Weed Sci.* **34**(1-2): 123-125.

Ruiz- Santaella, J. P., Pujadas, A., and De- Prado,R. 2003. Botanical identification of several *Echinochloa* biotypes collected in Spanish rice fields with control failures of cyhalofop-butyl. In: *Proceedings of the 55th International Symposium on Crop Protection*, Part1, 6 May 2003,Gent, Belgium, pp. 421- 424.

Ruiz-Santaella, J. P., Heredia, A., and De- Prado, R. 2006. Basis of selectivity of cyhalofop-butyl in *Oryza sativa* L. *Planta.* **223**(2): 191–199.

Saha, P.K., Ishaque, M., Salaque, M. A., Miah, M. A. M., Panuallah, G. M., and Bhuniyan, N. I.2007. Long term Integrated Nutrient Management for rice-based cropping pattern: effect on growth, yield, nutrient balance sheet and soil fertility. *Commun. Soil Sci. Plant Anal*. **38**(5-6): 579-610.

Saini, J. P. 2003. Efficacy of cyhalofop-butyl against weeds in direct seeded puddled rice under mid hill conditions of Himachal Pradesh. *Indian J. Weed Sci*. **35** (3&4): 205-207.

Saini, J. P. 2005. Effiacy of cyhalofop-butyl alone and in combination with 2,4- D against mixed weed flora in direct seeded upland rice. *Indian J. Agron.* **50**: 38- 40.

Saini, J. P., Angiras, N. N., and Singh, C. M. 2001. Efficacy of cyhalofop-butyl in controlling weeds in transplanted rice (*Oryza sativa*). *Indian J. Agron.* **46**(2): 222-226.

Sairamesh, K. V., Rao, A. S., Subbaiah, G., and Rani, P. P. 2015. Bio-efficacy of sequential application of herbicides on weed control, growth and yield of wet-seeded rice. *Indian J. Weed Sci.* **47**(2): 201–202.

Samui, R. C., Roy, A., and Manoal, S. 2005. Bioefficacy of Clincher (cyhalofop-butyl) in transplanted rice (*Oryza sativa* L.). *J. Crop Weed* **1**(1): 30-31.

Sandhu, G. S. and Dhaliwal, N. S. 2016. Evaluation of different insecticides against major insect pests of rice in Punjab. *Int. J. Plant Prot*. **9**(1): 187-192.

Sangeetha, C., Velayutham, A., Thavaprakash, N., and Chinnusamy, C. 2009. Crop establishment and weed management effects on rice productivity and weed dynamics. *Indian J. Weed Sci.* **47**(1): 6- 10.

Schmidt, L. A., Scherder, E. F., Wheeler, C. C., Rutledge, J. S., Talbert , R. E., and Baldwin, F. L. 1999. Weed performance of V-10029 (bispyribac sodium) in rice weed control programme. In: *Proceedingsof 52nd Southern Weed Science Society* Conference. Southern Weed Science Society, U. S. A, pp. 49-50.

Sekh, K., Nair, N., Gosh, S. K., and Somchoudhary, A. K. 2007. Evaluation of flubendiamide 480 SC against stem borer and leaf folder of rice and effect on their natural enemies. *Pestol.***31**(1): 32-34.

Singh, R., Pal, R., Singh, T., Singh, A. P., Yadaw, S., and Singh, J. 2014. Management of weeds in direct-seeded rice by bispyribac sodium. *Indian J. Weed Sci.* **46**(2): 126–128.

Singh, A. P., Tiwari, N., Bajaj, S. T., Gupta, S., and Chowdhury, T. 2016. Control of broadleaf weeds and sedges in direct seeded rice with carfentrazone-ethyl. *Agric. Res. J.* **53**(2): 271-272.

Singh, J. and Dhaliwal, G. S. 1994. Insect pest management in rice: A perspective. In: Dhaliwal, G. S. and Arora, R. (eds.), *Trends in Agricultural Pest Management*. Commonwealth Publisher, New Delhi, pp. 56-112.

Singh, J., Dhaliwal, G. S., Singh, J., and Shera, P. S. 2002. Changing scenario of rice insect pests in Punjab and their management strategies. *Indian J. Ecol.* **29**: 208-220.

Singh, M. and Paikra, P. R. 2014. Bio-efficacy of post-emergence herbicides in transplanted rice of Chhattisgarh plains. *Bioscan.* **9**(3): 973-976.

Singh, R. K. and Namdeo, K.N. 2004. Effect of fertility levels and herbicides on growth, yield and nutrient uptake of direct-seeded rice. *Indian J. Weed Sci.* **49**(1): 34-36.

Singh, V. P., Singh, G., Singh, R. K., Singh, S. P., Kumar, A., Sharma, G., Singh, M. K., Mortimer, M., and Johnson, D. E. 2005. Effect of weed management and crop establishment methods on weed dynamics and grain yield of rice. *Indian J. Weed Sci.* **37**: 188-192.

Smith, R. J. 1968. Weed competition in rice. *Weed Sci.* **16**: 252-255.

Smith, R. J. and Tugwell, N. P. 1975. Propanil-carbofuran interactions in rice. *Weed Sci.* **23**:176-178.

Sridevi, V., Jeyaraman, S., Chinnusamy, C., and Chellamuthu, V. 2013. Weed management in lowland rice (*Oryza sativa* L.) ecosystem a review. *Int. J. Agric. Sci. Res.* **3**(3): 13-22.

Steward, V. B., Braness, G., and Gill, S. 1998.Ornamental pest management using imidacloprid applied with the kioritz soil injector. *J. Arboric.* **20**: 344-346.

Subbiah, B. V. and Asija, G. L. A. 1956. A rapid procedure for estimstion of available nitrogen in soils. *Curr. Sci*. **25**: 259-260.

Teng, P. S., Heong, K. L., and Keith, M. 1993. Advances in tropical rice pest management research. In: Muralidharan, K. and Siddiq, E. A. (eds.), *New frontiers in rice research*. Directorate of Rice Research, Hyderabad, India, 255p.

Thilagam, P. 2006. Evaluation of flubendiamide 480 SC against bollworm complex in cotton and leaf folder and stem borer in rice. Ph. D. (Ag), Tamil Nadu Agricultural University, Coimbatore, 232p.

Thomas, C. G. and Abraham, C. T. 2007. *Methods in Weed Science*. AICRP on weed control, College of Horticulture, Vellanikkara, 108p.

Tohnishi, M., Nakao, H., Furuya, T., Seo, A., Kodama, H., Tsubata, K., Fujioka, S., Kodama, H., Hirooka, T., and Nishimatsu, T. 2005. Flubendiamide, a novel insecticide highly active against lepidopterous insect pests. *J. Pestic. Sci.* **30**(4): 354–360.

Uthamasamy, S. 1985. Problems and priorities in the management of rice leaf folder. In: Jayaraj, S (Ed.), *Proceedings of the National Seminar on Integrated Pest and Disease Management.* Tamil Nadu Agricultural University, Coimbatore, pp. 54-61.

Varma, N. R., Bhanu, K. V., and Reddy, D. R. 2008. Forecasting population of brown plant hopper, *Nilaparvata lugens* (Stal.). *J. Agrometeorol.* **10**: 197-200.

Veeraputhiran, R. and Balasubramanian, R. 2013. Evaluation of bispyribacsodium in transplanted rice. *Indian J. Weed Sci.* **45**(1): 12–15.

Waldrop, D. D. and Banks, P. A. 1983. Interactions of herbicides with insecticides in soybeans. *Weed Sci*. **31**: 730- 734.

Walia, U. S. 2006. *Weed Management* (2^{nd} Ed.). Kalyani Publishers, New Delhi, 425p.

Walia, U. S., Singh, O., Nayyar, S., and Sindhu, V. 2008. Performance of post emergence application of bispyribac in direct seeded rice. *Indian J. Weed Sci.* **40**: 157-160.

Watnabe, P. S. and Olsen, S. R. 1965. Test of an ascorbic acid method for determining phosphate in water and NH_4HCO_3 extracts from soil. *Proc. Soil Sci. Am*. **29**: 677- 678.

Waywell, C. G., Jones, G. E., Rowberry, R. G., Anderson, G. W., and Naylor, M. H. 1967. Postemergence weed control in potatoes with propanil. *Am. Potato J*. **44**: 30-37.

Yadav, D. B., Yadav, A., and Punia, S. S. 2009. Evaluation of bispyribac sodium for weed control in transplanted rice. *Indian J. Weed Sci.* **41** (1&2): 23-27.

Zang-Hong, H. and Zang, H.H., 1996. Control of rice hopper (Delphacidae) and leaf folder (*Cnaphalocrosis medinalis*) with imidacloprid alone and in mixture. *China Rice* **1**: 21-22.

Zimdahl, R. L. 1988. The concept and application of the critical weed-free period. In: M. A. Altieri, M. A. and Liebman, M. (eds.), *Weed Management in Agroecosystems: Ecological Approaches*. CRC Press, Boca Raton, pp. 145-155.

Appendices

Appendix- I

Monthly weather data during the cropping period

Month	Temperature		RH (%)		Rainfall (mm)	Rainy days	Mean evaporation	Sunshine hours
	Maximum	Minimum	Morning	Evening				
27/08/16 - 02/09/16	30.2	23.3	95	71	16.3	3	2.6	3.4
03/09/16 - 09/09/16	30.0	22.8	94	66	12.0	1	2.5	3.8
10/09/16 - 16/09/16	30.8	24.1	95	66	10.2	1	3.3	6.5
17/09/16 - 23/09/16	30.6	23.4	95	67	40.8	4	3.4	6.5
24/09/16 - 30/09/16	29.9	24.0	95	75	18.9	3	2.7	3.7
01/10/16 - 07/10/16	31.5	22.5	93	63	00.0	0	3.3	9.1
08/10/16 - 14/10/16	31.1	23.1	91	68	14.5	1	3.0	5.7
15/10/16 - 21/10/16	32.1	23.2	94	70	00.6	0	2.6	4.2
22/10/16 - 28/10/16	31.1	22.2	94	69	03.5	1	2.4	3.1
29/10/16 - 04/11/16	32.0	22.4	94	70	18.7	2	2.4	4.5
05/11/16 - 11/11/16	32.3	21.3	88	53	02.9	0	2.9	6.3
12/11/16 - 18/11/16	33.2	23.0	82	53	10.9	1	2.9	5.6
19/11/16 - 25/11/16	34.0	22.5	74	48	00.0	0	3.3	6.7
26/11/16 - 02/12/16	32.5	21.3	83	55	00.8	0	3.1	4.5
03/12/16 - 09/12/16	32.8	22.5	83	52	46.3	2	3.3	6.3
10/12/16 - 16/12/16	30.8	21.8	91	61	05.8	1	2.4	4.0
17/12/16 - 23/12/16	33.3	22.8	85	46	00.0	0	3.8	9.0
24/12/16 - 31/12/16	32.9	22.6	79	46	00.0	0	4.0	7.8
01/01/17 - 07/01/17	33.9	21.9	73	37	00.0	0	4.0	8.7

Appendix- II

Details of herbicides used

Herbicides	Trade name	Quantity per ha	Amount (Rs./ha)
Bispyribac sodium	Nominee gold	250 ml	3830
Cyhalofop - butyl	Clincher	800 ml	1776

Appendix- III

Details of insecticides used

Insecticides	Trade name	Quantity per ha	Amount (Rs./ha)
Flubendamide	Fame	50 ml	1000
Imidacloprid	Confidor	150 ml	732

Appendix- IV

Cost of inputs

Sl. No.	Particulars	Quantity/ha	Amount (Rs./ha)
1	Seed	80 kg	3200
2	Urea	142 kg	1136
3	Factom phos	225 kg	4500
4	MOP	75 kg	1425

Appendix- V

Cost of field operations

Sl. No.	Particulars	Men days (Rs. 450/ha)	Women days (Rs. 350/ha)	Amount (Rs./ha)
1.	Dewatering of field	-	-	7250
2.	Cleaning the field	-	17	5950
3.	Ploughing twice	-	-	6500
4.	Sowing + basal fertilizer application	3	3	2400
5.	Chemical spraying	3	-	1350
6.	Hand weeding	-	110	38500
7.	Fertilizer top dressing	3	-	1350
8.	Harvesting (mechanised) @ Rs. 2250/ hr	-	-	9000

Appendix- VI

Correlation between yield, yield attributes, weed dry matter and weed count

	Var 1	Var 2	Var 3	Var 4	Var 5	Var 6	Var 7	Var 8	Var 9	Var 10	Var 11	Var 12
Var 1	1.000	0.584	0.877	0.796	0.933	0.633	-0.595	-0.869	-0.586	-0.772	-0.821	-0.774
Var 2	0.584	1.000	0.609	0.633	0.656	0.136	-0.895	-0.744	-0.858	-0.875	-0.829	-0.736
Var 3	0.877	0.609	1.000	0.650	0.832	0.662	-0.554	-0.838	-0.484	-0.709	-0.730	-0.615
Var 4	0.796	0.633	0.650	1.000	0.782	0.481	-0.560	-0.772	-0.643	-0.702	-0.745	-0.720
Var 5	0.933	0.656	0.832	0.782	1.000	0.547	-0.643	-0.867	-0.620	-0.766	-0.838	-0.686
Var 6	0.633	0.136	0.662	0.481	0.547	1.000	-0.032	-0.403	0.009	-0.246	-0.232	-0.169
Var 7	-0.595	-0.895	-0.554	-0.560	-0.643	-0.032	1.000	0.820	0.952	0.958	0.906	0.867
Var 8	-0.869	-0.744	-0.838	-0.772	-0.867	-0.403	0.820	1.000	0.780	0.925	0.953	0.871
Var 9	-0.586	-0.858	-0.484	-0.643	-0.620	-0.009	0.952	0.780	1.000	0.907	0.911	0.886
Var 10	-0.772	-0.875	-0.709	-0.702	-0.766	-0.246	0.958	0.925	0.907	1.000	0.954	0.932
Var 11	-0.821	-0.829	-0.730	-0.745	-0.838	-0.232	0.906	0.953	0.911	0.954	1.000	0.920
Var 12	-0.774	-0.736	-0.615	-0.720	-0.686	-0.169	0.867	0.871	0.886	0.932	0.920	1.000

V1- Grain yield

V2- Straw yield

V3- Panicles/m^2

V4- Spikelets per panicle

V5- Filled grains per panicle

V6- 1000 garin weight

V7- Weed dry matter 30 DAS

V8- Weed dry matter 60 DAS

V9- Weed dry matter harvest

V10- Weed count 30 DAS

V11- Weed count at 60 DAS

V12- Weed count harvest

COMPATIBILITY OF HERBICIDES AND INSECTICIDES FOR TANK MIX APPLICATION IN WET SEEDED RICE

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ABSTRACT OF THE THESIS

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ABSTRACT

Weeds and insect pests are the major biotic constraints in rice production. Chemical methods of control of insects as well as weeds is very common in rice production. Separate application of the chemicals is expensive and labour intensive with the result that many farmers of Kerala adopt tank mix application of different chemicals without due consideration to efficacy and compatibility.

The present study entitled "compatibility of herbicides and insecticides for tank mix application in wet seeded rice" was conducted in a farmer's field at Alappad Kole lands of Thrissur district, from August 2016 to January 2017. The experiment aimed at studying the compatibility of two commonly used herbicides (bispyribac sodium and cyhalofop-butyl) with two new generation insecticides (flubendiamide and imidacloprid) for tank mix application in wet seeded rice. Another objective of the study was to assess the pest control efficiency of herbicides and insecticides. Out of 14 treatments, four treatments in the trial included sequential and mixed application of bispyribac sodium with two insecticides separately. The next four included cyhalofop-butyl substituted for bispyribac sodium. The remaining treatments were application of herbicides alone, hand weeding with and without application of insecticides and unweeded control.

Weed spectrum of the experimental field included barnyard grass (*Echinochloa crus-galli),* hippo grass (*Echinochloa stagnina*) and red sprangletop (*Leptochloa chinensis*) among grasses. Major broad leaf weed was water primrose (*Ludwigia parviflora*). Yellow nut sedge (*Cyperus iria*) was the only sedge species which was the major weed of the experimental plot.

Treatments were studied for their phytotoxic effects on rice and no toxicity symptoms were observed in tank mix or sequential application. Weed counts, weed dry matter production and weed control efficiency were estimated at different stages of crop growth.

Comparing sequential application and tank mix application of bispyribac sodium and flubendiamide, the mixed application resulted in high weed dry weight and low weed control efficiency. Yield parameters and yield were recorded low in this treatment. For sequential and combined applications of bispyribac sodium and imidacloprid, weed control efficiency, weed dry weight, yield and yield attributes were on par. Weed dry weight was low and weed control efficiency was high for mixed application of cyhalofop-butyl and flubendiamide. Yield and yield attributes were also high for this treatment. Weed dry weight, weed control efficiency, yield attributes and yield were comparable for sequential and mixed applications of cyhalofop-butyl and imidacloprid.

Insect pest infestation was very low in the experimental field. Rice leaf folder (*Cnaphalocrocis medinalis*), white backed plant hopper (*Sogatella furcifera*), red spotted earhead bug (*Menida versicolor*) and yellow stem borer (*Scirpophaga incertulas*) were the insect pests noted. Observation on insect count showed that there was no significant difference among treatments with respect to insect pest counts at 5, 7 and 11 days after spraying which was comparable to unweeded control. Hence efficacy of insecticides when tank mixed with herbicides could not be interpreted.

Hand weeding was the best treatment in terms of weed control efficiency, yield and yield attributes. However, the highest B: C ratios were registered by the treatments cyhalofop-butyl + flubendiamide and bispyribac sodium + imidacloprid. Highest net return was recorded in bispyribac sodium + imidacloprid. Unweeded control recorded lowest values for yield and B: C ratio.

With respect to efficacy of herbicides used, the study indicated that the two insecticides tried were compatible with cyhalofop-butyl. In the case of bispyribac sodium, the insecticide imidacloprid appeared to be compatible, but mixing of flubendiamide cannot be recommended since weed control efficiency was very low.