RESEARCH ARTICLE

BIOEFFICACY OF HERBICIDES AND EUCALYPTUS OIL FOR WEED MANAGEMENT AND THEIR EFFECT ON CROP GROWTH IN RICE (*ORYZA SATIVA* L.)

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Abstract: Severe competition from weeds is one of the most important factor affecting productivity and sustainability of rice. The present investigation was conducted during rainy seasons of 2011 and 2012 at Norman E. Borlaug Crop Research Centre, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar to determine the bio-efficacy of various herbicides and eucalyptus oil as well as their effect on crop growth and yield of transplanted rice. The treatments included four herbicides *viz.* butachlor, penoxsulam, bispyribac sodium and mixture of cyhalofop butyl with penoxsulam and eucalyptus oil at different concentrations. *Paspalum scorbiculatum, Leptochloa chinensis, Alternenthers sessilis, Ammania baccifera* and *Cyperus difformis* were the dominant weeds. Results indicated that butachlor, penoxsulam (22.5 g), bispyribac sodium and cyhalofop butyl+penoxsulam were very effective in controlling all the weeds and reducing their biomass except *Alternenthera sessilis* and *Leptochloa chinensis.* Eucalyptus oil (5%) was found to be effective against weeds but its efficacy was lower than the herbicides. Highest yield was obtained in penoxsulam (22.5 g) followed by butachlor and bispyribac sodium treatments. The higher grain yield of rice could be attributed to higher values of the physiological growth parameters relative growth rate (RGR), crop growth rate (CGR) and leaf area index (LAI).

Keyword: Bio-efficacy, Eucalyptus oil, Herbicides, Physiological growth parameters

INTRODUCTION

Rice is one of the most important staple food crop, with ninety percent of rice grown and consumed in South and Southeast Asia. The demand for rice is growing with an ever-increasing population. Among the biotic factors affecting rice productivity severe competition from weeds is one of the most important factor reducing its productivity and sustainability of production systems. Due to the competitive effect of weeds, the loss in rice yields ranges from 41% to 100% (Rao *et al.* 2007, Babu *et al*. 2008, Pacanoski and Glatkova 2009, Cavero *et al.* 2011,). To increase the total yield, as well as productivity it is necessary to manage the weeds during early growth stages of the crop. On the other hand, the growth, development and yield of rice are highly influenced by weed management practices. Weed management in rice involves a combination of different methods such as mechanical & manual, cultural, chemical and allelopathy. Labor scarcity, high labor cost and the presence of perennial weeds lowers the efficacy of manual and mechanical methods that leads to high yield losses (Rao *et al.* 2007, Rodenburg and Johnson 2009).

Use of herbicide is an attractive and alternative method to manual weeding due to its high efficacy and low cost. Herbicides are effective in controlling weeds alone or in combination with hand weeding (Jaya-Suria *et al*. 2011). Highest agriculture chemical input is seen in rice in the form of herbicides. Most agriculture systems collectively use three million tonnes of herbicides per year, and farmers are getting most profitable crops on the same piece of land by the use of herbicides and pesticides (Ahmad *et al.* 2000, Tomita *et al.* 2003). A number of herbicides such as butachlor, cyhalofop butyl, penoxsulam, bispyribac sodium, azimsulfuron, petrilachlor, fenoxaprop-ethyl, pendimethalin etc., either alone or in combination with hand weeding are used to control weed flora in transplanted rice. Recent trend of herbicide use is to find out an alternative and effective weed management by using low dose high efficiency herbicides, which will not only reduce the total volume of herbicide per unit area, but also application becomes easier and economical to the farmer (Kiran *et al*. 2010).

However, the chemical method of weed management comes at a prize. Continuous and intensive use of these herbicides leads to environmental pollution, weed flora shift and development of herbicide resistant weed biotypes. Problems also arise from their residual effects on soil and succeeding crop (Rodenburg and Johnson 2009). The use of synthetic herbicides cannot be discarded completely in the present situation, but their use can be reduced up to a certain extent by utilizing natural plant products as an alternative weed management strategy (Bhadoria 2011).

Natural plant products play a variety of physiological roles and serve as a source of novel herbicides. Among the natural plant products, volatile essential oil can be used as viable weed controlling agent. The advantage of using volatile oils is that they do not

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persist in soil or contaminate ground water and cause little or no mammalian toxicity but have high phyto-toxicity (Isman 2000). Eucalyptus is well known for releasing the volatile oils from its foliage, which have an inhibitory effect on the growth of under-storey vegetation (Jawahar *et al*. 2013). Essential oil extracted from eucalyptus leaves exhibit phytotoxicity against weeds and have a great potential for weed management. These natural products degrade quickly in environment and are eco-friendly (Batish *et al*. 2008). Thus, eucalyptus oil can be explored to be developed into a herbicide.

Keeping in view the above facts, present investigation was carried out to evaluate the efficacy of different herbicides and eucalyptus oil against weeds, as well as their effects on yield and growth of transplanted rice.

MATERIAL AND METHOD

Experimental Design and treatments: A field experiment was conducted during the rainy season of 2011 and 2012 at the Norman E. Borlaug Crop Research Centre, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar in randomized block design (RBD) with nine treatments replicated thrice. The treatments consisted of butachlor @ 1500 g a.i ha^{-1}, penoxsulam @ 22.5 (recommended) and 33.75 (1.5 x) g a.i.ha^{-1}**,** bispyribac sodium @20.0 g a.i.ha^{-1}**,** eucalyptus oil @ 5% and 7.5%**,** cyhalofop butyl + penoxsulam @ 150.0 g a.i.ha^{-1}**,** weed free and weedy. 30 day old rice seedlings of rice cultivar Sarju 52 were transplanted in small plots (size 2.0 x 3.0 m) with a row-to-row distance of 20 cm.

Observations:

*Weed flora and biomass***:** Observations on weed flora and their biomass were recorded at different growth stages for determining the efficacy of weed management practices.

Growth parameters of the rice crop

Leaf area index: The area of leaves collected from three plants in each plot was measured using a portable leaf area meter (LiCOR LI-3000A). The leaf area index (LAI) was calculated by dividing the leaf area by the ground area occupied by the plants. It was estimated as follows:

$$\text{Leaf Area Index (LAI)} = \frac{\text{Leaf area}}{\text{Ground area}}$$

*Relative growth rate***:** For this, plants were collected from each replication, dried and weighed. The RGR was calculated according the following formula (Leopold 1964) and expressed in units of g/g/week.

$$\text{RGR} = \frac{\ln W_2 - \ln W_1}{t_2 - t_1}$$

where,

W_1 = dry weight of the whole plant at start of the test period.

W_2 = dry weight of whole plant at the end of the test period.

$(t_2\text{-}t_1)$ = period in weeks between initial and final observations

*Crop growth rate***:** The crop growth rate was calculated by using the formula of (Radford 1967).

$$\text{CGR} = \frac{W_2 - W_1}{t_2 - t_1}\ \frac{1}{A}$$

Where W_1 and W_2 are shoot dry weights in area A at the time t_1 and t_2. It was expressed as g/cm^2/week.

Grain yield: After threshing and winnowing, total weight of grains was recorded for each treatment after harvest. Grains obtained from each net plot were weighed and finally grain yield was expressed in quintal per hectare.

Statistical Analysis: The data obtained from field trials during the course of present investigation were analyzed statistically by using randomized block design (RBD). Standard error of means (S.Em.±) and critical difference (CD) was evaluated at 5% level of significance by following standard statistical procedure.

RESULT AND DISCUSSION

Weed flora and weed biomass

In the experimental field nin weed species were recorded. Major grassy weeds included *Echinochloa crus-galli, E. colona, Paspalum scorbiculatum* and *Leptochloa chinensis*. The broad leaved weeds included *Alternenthera sessilis*, *Caesulia axillaris* and *Ammania baccifera*. Among the sedges, *Cyperus difformis* and *Cyperus iria* was observed. Effect of weed management practices on weed flora during 2011 and 2012 is presented in table 1a and 1b. among the weed species, *Paspalum scorbiculatum, Leptochloa chinensis, Alternenthera sessilis, Ammania baccifera* and *Cyperus difformis* were most prominent. Among all the herbicidal treatments, penoxsulam recorded lowest weed density. Between the two doses of penoxsulam, higher dose (33.75 g) was found more effective than its lower dose in reducing the weed density at 60 DAT. *Alternenthera* was not controlled by any of herbicidal treatments but *Ammania* was significantly controlled by penoxsulam (22.5 g) and butachlor treatments. *Caesulia axillaris* was found to be effectively controlled by penoxsulam (22.5 g) and bispyribac sodium treatments while *Sphenoclea zeylanica* was suppressed by butachlor, penoxsulam (22.5 g) and bispyribac sodium treatments. Among the grassy weeds, *Echinochloa crus-galli* was effectively controlled by penoxsulam (22.5 g) and bispyribac sodium treatments. However, Sedges were effectively controlled by butachlor, penoxsulam (22.5 g) and bispyribac sodium treatments. Eucalyptus oil (5%) was effective in the control of *Echinochloa crus-galli, Paspalum scorbiculatum, Sphenoclea zeylanica* and *Caesulia axillaris* but with

lower efficacy as compared to the chemical herbicides. Population of *Leptochloa chinensis* was higher in penoxsulam (33.75 g) and cyhalofop butyl+penoxsulam treatment that reduces their bioefficacy. The major weed species observed in present study are common in transplanted rice (Ghuman *et al.* 2008, Gnanavel and Anbhazhagn 2010, Khaliq *et al.* 2012). Dry matter of weeds is also important for determining the effectiveness of weed management practices. Effective weed control by herbicides is achieved by reducing weed biomass (Ashraf *et al*. 2006). All the herbicidal treatments reduced the dry matter of weeds significantly as compared to unweeded control. Weed biomass ranged from 51 to 116 g/m^2 in 2011 and from 49 to 257 g/m^2 in 2012 at 60 DAT (Fig. 1 Effect of herbicides and eucalyptus oil on weed biomass). Lowest weed biomass was recorded in pre-emergence application of butachlor followed by penoxsulam (22.5 g) and bispyribac sodium treatments, which were superior to all other treatments. Pre-emergence application of butachlor followed by post emergence application of bispyribac sodium have been reported very effective to reduce weed density and weed biomass in transplanted aromatic Basmati rice (Chaudhary *et al*. 2008, Gnanavel and Anbhazhagn 2010). Eucalyptus oil was also found to reduce weed biomass and its efficiency was comparable to the mixture of cyhalofop butyl with penoxsulam. It has been reported that eucalyptus oil suppress the growth of *Cyperus rotundus*, *Cynodon dactylon*, *Echinochloa crusgalli* and *Portulaca oleracea* and reduces their biomass under laboratory and green house condition (Chandra Babu and Kandasamy 1997, Batish *et al*. 2008, El - Rokiek and El – Nagdi 2011).

Grain yield

Yield losses in rice under the weedy condition have been observed by Fofana and Rauber, 2000, Haefele *et al.* 2004, Rodenburg *et al.* 2009 and Saito *et al.* 2010.Weed control treatments significantly increased the grain yield in rice as compared to weedy check (Fig. 2 Effect of herbicides and eucalyptus oil on grain yield of rice crop). Among the herbicidal treatments, the highest grain yield was recorded with the application penoxsulam @ 22.5 g which was comparable with bispyribac sodium and butachlor. It is attributed to increased production and translocation of photosynthate to the grains as there is adequate availability of growth resources due to better weed suppression through significant reduction in weed biomass and consequent reduction in crop-weed competition (Kiran and Subarmaniyam 2010, Khaliq *et al*. 2013). Our results are in confirmity with the Prasad *et al.* (2008) and Pal *et al*. (2009). Highest per cent reduction in grain yield was recorded in cyhalofop + penoxsulam (17.0%) treatment in the year 2011, whereas in 2012, the highest per cent reduction (25.7%) was recorded in eucalyptus oil higher dose ie. 7.5% as compared to weed free. Application of eucalyptus oil had some adverse effect on rice growth in the early stages as yellowing of leaves was observed primarily with 7.5% concentration but the plants recovered from these effects after 15 days (Abrahim *et al*. 2000, Jawahar *et al*. 2013, Puig *et al*. 2013).

Physiological growth parameters

Higher yield under effective management system in rice is attributed to improvement in physiological growth parameters such as RGR, CGR, LAI and leaf area. Grain yield was found to be positively correlated with physiological growth parameters at vegetative and flowering stage in rice crop (Lopez-Bellido *et al*. 2008, Ozalkan *et al*. 2010).

Leaf area index: It was observed that LAI was maximum in penoxsulam (33.75 g) treatment followed by penoxsulam (22.5 g) and bispyribac sodium treatments (Fig. 3 Effect of herbicides and eucalyptus oil on leaf area index of rice crop at 60 DAT). Higher leaf area index reduces soil water evaporation and imparts to the partitioning of dry matter to the grains efficiently resulting in higher yield (Irshad and Cheema 2002, Ozalkan *et al*. 2010, Hossain *et al*. 2011,).

Relative growth rate and crop growth rate: RGR and CGR are measure of dry matter production. RGR and CGR values in the present study varied significantly among the treatments. Highest RGR and CGR values were recorded under weed free situation at 45-60 DAT followed by penoxsulam (22.5 g), butachlor and bispyribac sodium treatments (Fig. 4 Effect of herbicides and eucalyptus oil on RGR of rice crop during 45-60 DAT and Fig. 5 Effect of herbicides and eucalyptus oil on CGR of rice crop during 45-60 DAT). It is well documented that high RGR and CGR allows crop to rapidly occupy space and capture resources leading to higher biomass production which is also associated with more nutrient uptake by the crop due to broad spectrum control of weeds (Prajapati *et al*. 2003, Kavitha *et al*. 2010, Gulshan *et al*. 2012,). Maintenance of high values of physiological growth parameters to near normal values is necessary to get high yields from the crop.

In the present study, higher values of these growth parameters in the three best treatments is attributed to effective weed management by these treatments.This study suggests that bio-efficacy of the herbicides butachlor, penoxsulam, bispyribac sodium and cyhalofop butyl+penoxsulam was much better than the eucalyptus oil treatment. Reduction in weed density and biomass results in better growth and development of the crop as evident from the values of the growth parameters CGR and RGR in the herbicide treated plots. Though eucalyptus oil at lower concentration (5%) had weed suppressing ability and gave comparable yield, its potential as a bioherbicide needs to be evaluated further because of its volatile nature and toxicity at higher concentration (7.5%). Possibilities of improving its herbicidal

properties by means of using adjuvants, surfactants or other chemical modifications will be worth investigating.

Table 1a. Population (no./m^2) of different weeds at 60 DAT in rice crop genotype Sarju 52 as affected by different herbicides and eucalyptus oil in 2011

Treatments	*Echinochloa colona*	*Echinochloa crusgalli*	*Paspalum scorbiculatum*	*Leptochloa chinensis*	*Alternenthera sessilis*	*Caesulia axillaris*	*Ammania baccifera*	*Cyperus difformis*	*Cyperus irria*	Total
T_1- Butachlor	-	-	2.08 (14.66)	-	3.77 (48.00)	-	-	-	-	62.67
T_2-Penoxsulam (22.5 g)	1.07 (2.66)	0.53 (1.33)	1.95 (12.00)	0.53 (1.33)	3.58 (36.00)	-	-	-	-	53.33
T_3-Bispyribac Na	-	0.53 (1.33)	2.97 (26.66)	1.39 (5.33)	2.40 (24.00)	-	-	0.53 (1.33)	-	58.67
T_4- Eucalyptus oil (5.0%)	0.53 (1.33)	-	0.73 (2.66)	0.53 (1.33)	4.05 (65.33)	-	-	0.53 (1.33)	-	72.00
T_5- Eucalyptus oil (7.5%)	0.73 (2.66)	1.07 (2.66)	2.05 (20.00)	0.73 (2.66)	3.86 (57.33)	-	-	1.07 (2.66)	-	88.00
T_6-Penoxsulam (33.75 g)	0.53 (1.33)	-	2.28 (21.33)	0.53 (1.33)	2.99 (20.00)	-	-	-	0.53 (1.33)	45.33
T_7-Cyhalo+Penox	-	-	1.80 (10.66)	0.53 (1.33)	3.31 (33.33)	-	-	-	0.73 (2.66)	48.00
T_8-Weed free	-	-	-	-	-	-	-	-	-	-
T_9-Weedy	-	0.53 (1.33)	2.00 (28.00)	0.85 (4.00)	2.90 (17.33)	0.53 (1.33)	-	-	0.53 (1.33)	53.33
Total	8.00	6.67	136.00	17.33	301.33	1.33	-	5.33	5.33	
S. Em.±	0.37 (1.12)	0.34 (0.84)	0.88 (12.37)	0.59 (2.27)	0.49 (15.12)	0.17 (0.44)		0.30 (0.75)	0.37 (1.14)	

*Figures in parenthesis indicate the actual values of weed number

Table 1 b. Population (no./m^2) of different weeds at 60 DAT in rice genotype Sarju 52 as affected by different herbicides and eucalyptus oil in 2012

Treatments	*Echinochloa colona*	*Echinochloa crusgalli*	*Paspalum scorbiculatum*	*Leptochloa chinensis*	*Alternenthera sessilis*	*Caesulia axillaris*	*Ammania baccifera*	*Cyperus difformis*	*Cyperus irria*	Total
T_1- Butachlor	0.54 (1.33)	2.25 (9.33)	0.85 (4.00)	-	-	0.54 (1.33)	1.39 (5.33)	0.54 (1.33)	-	22.67
T_2-Penoxsulam (22.5 g)	0.54 (1.33)	-	0.73 (2.67)	1.80 (5.33)	0.94 (5.33)	-	2.24 (18.67)	-	-	33.33
T_3-Bispyribac Na	-	-	-	1.61 (4.00)	-	-	2.07 (14.67)	1.16 (10.67)	-	29.33
T_4- Eucalyptus oil (5.0%)	0.73 (2.67)	1.39 (5.33)	-	1.39 (5.33)	-	0.54 (1.33)	1.12 (9.33)	1.30 (16.00)	1.27 (4.00)	44.00
T_5- Eucalyptus oil (7.5%)	-	1.48 (6.67)	0.94 (5.33)	2.59 (14.67)	1.16 (10.67)	-	-	-	-	37.33
T_6-Penoxsulam (33.75 g)	-	-	-	2.48 (12.00)	-	-	1.75 (9.33)	-	-	21.33
T_7-Cyhalo+Penox	0.54 (1.33)	0.54 (1.33)	-	1.46 (5.33)	-	0.54 (1.33)	2.94 (22.67)	1.71 (8.00)	-	40.00
T_8-Weed free	-	-	-	-	-	-	-	-	-	-
T_9-Weedy	-	2.33 (10.67)	-	0.73 (2.67)	-	-	1.95 (24.00)	2.31 (22.67)	-	60.00
Total	6.67	33.32	12.00	49.33	16.00	4.00	104.00	58.67	4.00	
S. Em.±	0.39 (1.17)	0.41 (2.33)	0.42 (2.10)	0.47 (3.23)	0.46 (3.77)	0.30 (0.76)	0.84 (9.81)	0.65 (6.87)	0.21 (0.76)	

*Figures in parenthesis indicate the actual values of weed number

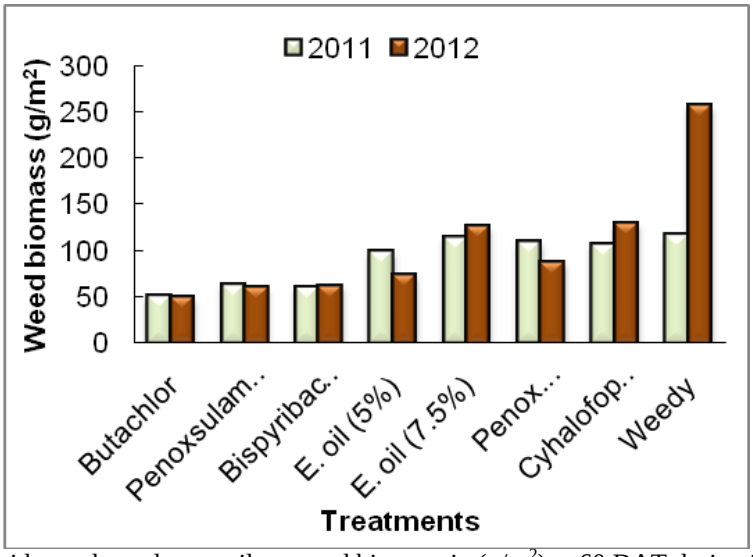

Fig. 1 Effect of herbicides and eucalyptus oil on weed biomass in (g/m^2) at 60 DAT during 2011 and 2012

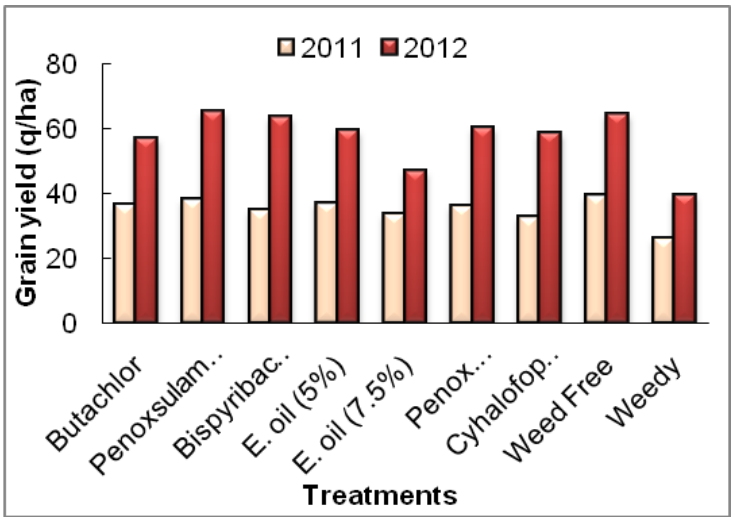

Fig. 2 Effect of herbicides and eucalyptus oil on grain yield of rice crop (q/ha) during 2011 and 2012

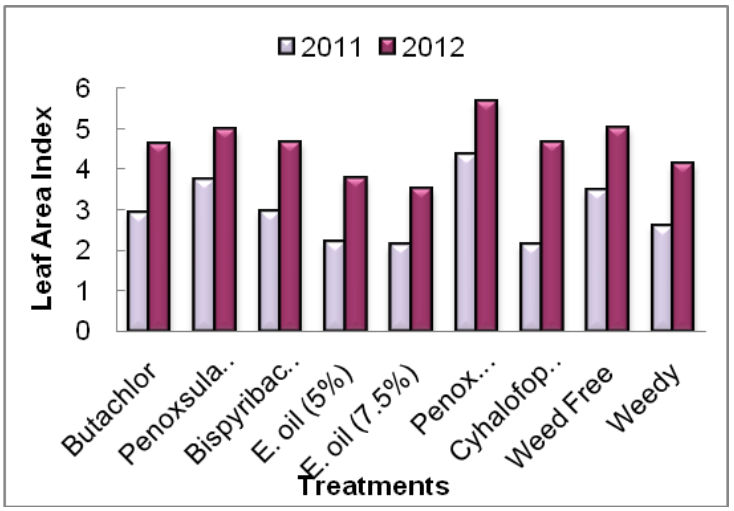

Fig. 3 Effect of herbicides and eucalyptus oil on leaf area index of rice crop at 60 DAT during 2011 and 2012

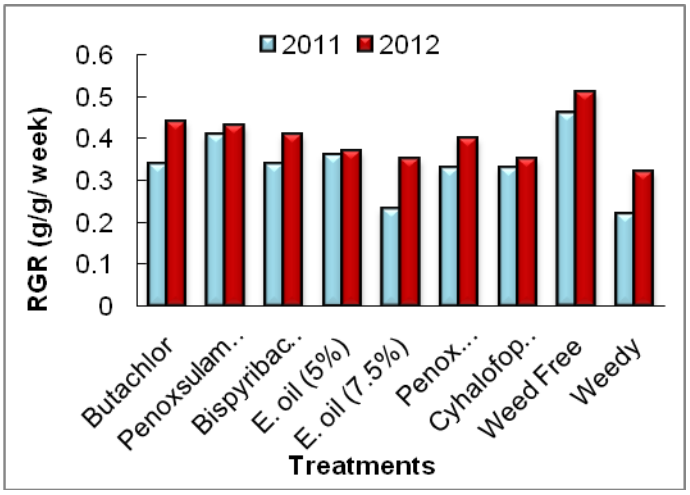

Fig. 4 Effect of herbicides and eucalyptus oil on RGR (g/g/week) of rice crop during 45-60 DAT in 2011 and 2012

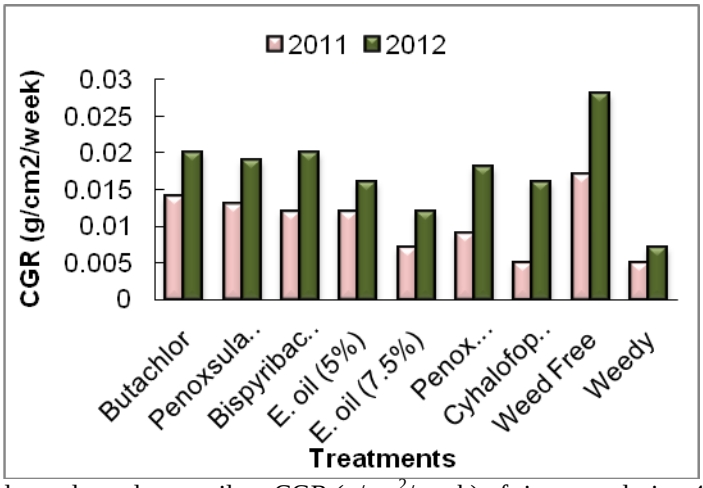

Fig. 5 Effect of herbicides and eucalyptus oil on CGR (g/cm^2/week) of rice crop during 45-60 DAT in 2011 and 2012

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