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EFFICACY OF RICE STRAW EXTRACTS IN CONTROLLING WEEDS AND ENHANCING THE PRODUCTIVITY OF WHEAT (*Triticum aestivum* L.)

Zubair Aslam[1,*], Qamar-uz-Zaman[1], Muhammad Zahid Ihsan[1], Sairah Syed[2], Yoshiharu Fujii[4], Abdul Khaliq[1], Raza Ullah[1], Misbah-ul-Islam[1] and Zahir Ahmad Zahir[3]

ABSTRACT

Rice straw extracts (RSEs) have allelopathic impacts on specific plant species. To study the negative impacts of RSEs (boiled and unboiled) on weeds and their positive impacts on the productivity of wheat, laboratory and field experiments were conducted at the Agronomic Research Area, University of Agriculture Faisalabad, Pakistan during the winter of 2011-12. In laboratory experiments, at certain concentrations both RSEs (boiled and unboiled) caused statistically similar inhibitory effects on wheat seedling growth. In the field experiment, both RSEs were significantly effective in decreasing the total density and dry weight of weeds as compared to the untreated control, and improved wheat productivity by 27%. For two treatments (unboiled RSE at 18 L ha^{-1} and boiled RSE at 9 L ha^{-1} applied at 30, 45 & 60 DAS), the maximum number of productive tillers (445 and 444), grains per spike (41.00 and 41.33), 1000 grain weight (40.00 and 40.33 g), grain yield (4435 and 4420 kg ha^{-1}) and straw yield (6230 and 6215 kg ha^{-1}) were observed, respectively. It was concluded that the efficacy of the unboiled RSE was similar to the boiled RSE, and both could enhance the productivity of wheat by suppressing the total weed density, especially for Convolvulus arvensis L.; Avena fatua L. and Phalaris minor Retz. The unboiled RSE produced maximum yield as compared to the boiled one and was more economic.

Key words: Allelopathy, rice straw extracts (RSEs), weed control, weed density.

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[1]Dept. of Agronomy, University of Agriculture, Faisalabad, Pakistan
[2]Dept. of Agronomy, Faculty of Agriculture, The University of Poonch, Rawalakot, Azad Jammu & Kashmir, Pakistan
[3]Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad-38040, Pakistan
[4]Dept. of International Environmental and Agricultural Sciences, Tokyo University of Agriculture and Technology, Fuchu, Tokyo 183-8509, Japan
[*]Corresponding author's email: zauaf@hotmail.com

rice straw extracts in controlling weeds and enhancing the productivity of wheat (*Triticum aestivum* L.). Pak. J. Weed Sci. Res. 22(2): 197-210.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the most important cereal crop followed by maize (*Zea mays* L.) and rice (*Oryza sativa* L.) in terms of production in Pakistan and around the world. It is grown as a food as well as cash crop. In Pakistan, wheat was grown on 8.69 m ha with a production of 24.20 m tons during 2012-13 (Anonymous, 2012-13). It provides 10.1% of the total agricultural production and 2.2% to GDP (Govt. of Pakistan, 2012-13). The post-harvest losses are about 10% at the farm level due to improper harvesting and threshing processes and improper storage conditions, however the losses caused by weeds can be as high as 25-50% (Marwat *et al*., 2006). There are many ways to control weeds in wheat including mechanical, chemical and manual approaches however, these are labour intensive and expensive ways to apply. Herbicides can provide a fast and smooth method for the control of weeds in wheat however, due to the need to reapply regularly and that in some cases can negatively affect human, animal and environment health, their use is limiting. Allelopathy provides a good alternative to manage weeds and minimize herbicide use (Einhellig, 1996).

Allelopathy is a phenomenon in which secondary metabolites released by plants, microorganisms (i.e. bacteria, fungi and algae) enhance or suppress the growth and development of biochemical systems of neighboring plants (Khalid *et al*., 2002). Much literature related to the use of allelopathy (Bhowmik and Inderjit, 2003; Singh *et al*., 2003) as a substitute to chemical weed control for achieving sustainable weed management is available. Allelochemicals often exhibit selectivity like synthetic herbicides (Weston, 1996). A promising and environment friendly weed control phenomenon in sustainable agriculture is through allelopathy. Numerous researches referred to the herbicidal potential of the extracts of wheat, maize, soybean (*Glycine max* L.), barley (*Hordeum vulgare* L.), rice and rye (*Secale cereale* L.) crops as good suppressors to many crop and weed species (Barnies and Putman, 1987; Wu *et al*., 1998, 2000, 2001a, 2001b).

Rice straw extracts (RSE) have been shown to contain various allelochemicals such as phenolic acids, fatty acids and terpenes (Rimando *et al.,* 2001; Seal *et al.,* 2004) for the application of such extracts may present a possible new strategy for controlling weeds, either in boiled or in an unboiled form. Although, previous studies explored that boiling had not significant effect on the nature and efficacy of allelochemicals (Jamil *et al.*, 2009) but still it is less economical as compared to unboiled one. Due to inexperience, farmers are still unaware about the possible use of boiled and unboiled RSEs to manage weeds. The main hypothesis tested in this study was that the unboiled RSE is equally potent in managing weeds as the boiled one but more economic to apply. The study was undertaken to achieve the following objectives. (a) to check the efficacy of RSEs (boiled and unboiled) on weed control, (b) to evaluate the efficacy of RSEs (boiled and unboiled) on the productivity of wheat (c) to check the phytotoxicity of RSEs (boiled and unboiled) on germination and seedling growth of wheat.

MATERIALS AND METHODS

Pot experiment

Germination and seedling data

To investigate the efficacy of rice straw extracts (RSEs) on seed germination and seedling growth of wheat, a laboratory experiment was carried out during the winter of 2011-12. The experiment was conducted using a completely randomized design (CRD) and replicated thrice. Wheat variety "Fareed-2006" was used for this study. The study was consisted of both unboiled and boiled extracts of rice straw each with three different concentrations (5, 10 and 15%).

Preparation of rice straw extracts

Allelopathic extracts of rice straw were prepared by following the method of Cheema and Khaliq (2000) with some modifications. Rice straw (Super basmati) was collected after harvesting during the kharif season in 2010-11 from the Agronomic Research Area, UAF. The rice straw was dried under shade, then chopped with an electric fodder chopper and put into distilled water in the ratio of 1:10 rice straw to water (w/v) at room temperature for 24 hours to prepare the unboiled RSE. The unboiled RSE was obtained by filtering the solution through a sieve and then through a Minisart non-pyrogenic 0.45 µm filter. The boiled RSE was prepared by boiling (100°C) the dried chopped rice straw in distilled water (ratio 1:10, w/v) until the water quantity was reduced to half of the initial volume. The boiled RSE was filtered and collected and stored in labeled glass bottles.

Ten seeds of wheat were placed evenly between two layers of Whatman grade no. 42 filter paper in 9 cm diameter Petri dishes. The seeds were imbibed with equal volumes of boiled and unboiled RSE filtrate. The seeds were determined to be germinated when their plumule or radical length were around > 2.0 mm in length.

Field experiment

The field experiment was conducted on a sandy clay loam soil at the research area of Agronomy Department, University of Agriculture, Faisalabad (30.35–31.47°N latitude and 72.08–73°E longitude) during the winter 2011-12. The experiment was designed in a RCBD and replicated three times. Wheat variety "Fareed 2006" was used in this study. The weed control treatments were

(a) hand weeding at 30 + 45 + 60 DAS,
(b) unboiled RSE (10%, w/v) spray at 30 DAS @ 18 L ha^{-1}
(c) unboiled RSE (10%, w/v) spray at 30 & 45 DAS @ 18 L ha^{-1}
(d) unboiled RSE (10%, w/v) spray at 30, 45 & 60 DAS @ 18 L ha^{-1}
(e) boiled RSE (10%, w/v) spray at 30 DAS @ 9 L ha^{-1}
(f) boiled RSE (10%, w/v) spray at 30 & 45 DAS @ 9 L ha^{-1}
(g) boiled RSE (10%, w/v) spray at 30, 45 & 60 DAS @ 9 L ha^{-1}.

A weedy check (control) plot was also maintained for comparison. The manual weed pulling was done directly with hand or cut with sickle close to the ground surface. Knapsack hand sprayer fitted with T-jet nozzle was used for to spray the extracts. The volume of the spray (250 L ha^{-1}) was determined after calibration using water and by following the Ross and Lembi (1985) procedure.

Prior to planting, the land was prepared by two ploughings each followed by planking with the help of a tractor drawn cultivator to achieve a fine seedbed. A fertilizer dose of 115-102-75 kg N.P.K. ha^{-1} in the form of urea, single super phosphate and sulphate of potash was applied to each experimental unit. All P and K with 1/3rd of N was applied at sowing while the remaining dose of N was applied in two splits i.e., 30 and 55 days after sowing. Seed rate of wheat was 125 kg ha^{-1}. Crop was sown on 12th of December 2011 with the help of single row hand drill in 20 cm spaced rows. First irrigation was given 30 days after seeding. Total 3-4 irrigations were applied. The crop was harvested at physiological maturity, sun-dried for a week and threshed mechanically.

Data recording

Petri dish experiment

Germination count

Germination of wheat seeds was observed on daily basis following the method of the seedling evaluation handbook of Association of Official Seed Analysts (AOSA 1990). Shoot and root length of all the seedlings from each replication were measured and then dried separately at 70°C till a constant weight had been achieved. The dried samples were weighed and the dry weight of the different plant parts expressed as mg per plant.

Field experiment

Total weed density and dry weight

A quadrate measuring 1.0 × 1.0 m^2 was randomly placed at three sites in each experimental plot to record total weed density at 40 and 70 days after sowing. Weeds were counted and collected for recording dry weight by drying in oven at 70°C until constant weight.

Yield and yield contributing parameters of wheat

Ten plants were selected at random from each plot to measure plant height (cm), productive tillers (m^2) and number of grains per spike. Three samples of 1000 grains each were taken at random from seed lot for recording 1000-grain weight (g). The grain yield (kg ha^{-1}) and straw yield (kg ha^{-1}) were recorded on whole plot basis and were converted on hectare basis. Harvest index was calculated by dividing the economic yield with biological yield. Benefit cost ratio was calculated by dividing the gross income to the total cost.

Statistical analysis

The data collected were recorded and then analyzed statistically by using the Fisher's analysis of variance procedure at 5% probability (Steel *et al.,* 1997).

RESULTS AND DISCUSSION

Petri dish experiment

Laboratory bioassays are mandatory part of allelopathic research because many bioassays show little or no correspondence to field interactions.

a) Total germination count

The comparative effect of boiled and unboiled rice straw extract (RSE) applied at different concentrations (5, 10 and 15%) on wheat germination count in Petri dishes in laboratory at 4 DAS depicted in Table 1 showed that maximum germination percentage 80% was observed in control which is statically at par (80%) with treatment where 5% solution of unboiled RSE was applied followed by 10 and 15% unboiled RSE and 5, 10% boiled RSE which give similar results (60%). On the other side, lowest germination percentage (40%) was observed where 15% boiled RSE was applied. Results revealed that 5% unboiled RSE showed promoting effect on the seed germination but it was concentration dependent because less germination percentage (40%) was observed where 15% boiled RSE was applied. These results are contradictory to El-Shahawy (2010) who reported that rice straw extract showed no significant effect on seed germination.

b) Shoot length (cm)

The effects of boiled and unboiled RSE with different concentrations (5, 10 and 15%) were significant on shoot length of wheat seedlings (Table. 1). The statically highest shoot length (16.2 cm) was recorded in wheat seedlings subjected to 10% of boiled as well as unboiled RSE and followed by 5% unboiled RSE (13.45 cm) which is statically at par with 15% unboiled RSE application (11.80 cm). However, minimum shoot length (5.4 cm) was observed in control. These results were supported by El-Shahawy (2010) who reported that seedling growth (root and shoot lengths) was affected by the rice extracts. Generally less inhibition was observed in shoot growth and the effect increased with increasing concentration.

c) Root length (cm)

The root length is an integral part of the plant growth and is usually influenced by many factors. The root length of wheat seedlings was significantly affected by boiled and unboiled RSEs as represented in Table. 1. The results showed that maximum root lengths of 10.5 cm and 10 cm were recorded in those seedlings where 10% of boiled as well as unboiled RSE, respectively was used and it was followed by 8.3 cm, 7.9 cm 7.5 cm and 6.9 cm in treatments 15, 5% unboiled and boiled RSE, respectively. Minimum root length (3.50 cm) was recorded in control. These results are in accordance with El-Shahawy (2010) who concluded that seedling growth was affected by the extracts. Generally more inhibition was observed in root growth than shoot growth and the effect increased with increasing concentration.

d) Fresh weight of seedlings (g)

The effects of boiled and unboiled RSEs were significant in terms of fresh weight of wheat seedlings (Table. 1). The highest value of fresh weight 0.92 g and 0.86 g of wheat seedlings were recorded in those treatments where 10% of boiled as well as unboiled RSEs were applied, respectively and followed by 0.70 g and 0.61 g in those treatments where boiled and unboiled RSEs (5%) were used and the results were at par with each other, while minimum seedlings weight 0.36 g was observed in control. The similar trend of fresh weight of seedlings was observed in cucumber by Tarek *et al*. (2010).

e) Dry weight of seedling (g)

Allelopathic effects of boiled and unboiled RSEs were significant in terms of dry weight of wheat seedlings (Table. 1). It showed that highest dry weights were recorded 0.18 g and 0.17 g in those experimental units where 10% of boiled and unboiled RSE were applied, respectively while lowest dry weight of wheat seedlings was observed 0.10 g in control. These findings were in line with Cheema *et al*. (2002) who reported that extract application reduced dry weight of weeds by 50%.

Field experiment

In this study, the efficacy of different concentrations of RSEs (boiled and unboiled) on weeds and the productivity of wheat was evaluated under field conditions. The results so obtained were collected and analyzed statistically using analysis of variance technique.

Total weed density (m^2)

The total weed flora density (Table 2) revealed that all the treatments were significantly effective in suppressing the total weed density as compared to control. The maximum weed density suppression of 84% was observed in the hand weeded plot and followed by 75 and 73% in the plots treated with boiled RSE at 30, 45 and 60 DAS applied at9 L ha^{-1} and unboiled RSE at 30, 45 and 60 DAS at 18 L ha^{-1}, respectively at 40 DAS. Maximum suppression (70%) of total weed density was observed in hand weeding as compared to control and was followed by 69 and 67% suppression in plots treated with boiled RSE at 30, 45 and 60 DAS at 9 L ha^{-1} and unboiled RSE at 30, 45 and 60 DAS @ 18 L ha^{-1}, respectively at 70 DAS. It was observed that as the number of sprays increased, the suppression was also increased. Ebanaa *et al,* (2001) find similar findings when he applied aqueous extracts of some rice plants which he observed the inhibition of the growth and germination of wild oats (*Avena sterilis* ssp *ludovicina* L.), field bindweed (*Convolvulus arvensis* L.), blue mud plantain (*Heteranthera limosa* Willd.), small canary grass (*Phalaris minor* Retz.), oval-leafed pondweed (*Monochoria vaginalis* Burm.f.), oats (*Avena sativa* L.), berseem clover *(Trifolium alexandrinum* L.), lentil *(Lens culinaris* Medikus), lettuce (*Lactuca sativa* L.) and rice in laboratory tests.

Total fresh weight of weeds (g m^{-2})

The effects of boiled and unboiled RSEs were significant in terms of total fresh weight of weeds (Table 2). After 40 days, high suppression (61%) rate was recorded in hand weeding and it was followed by 43 and 38% weed suppression in plots treated by boiled RSE at 30, 45 & 60 DAS @ 9 L ha^{-1} and unboiled RSE at 30, 45 & 60 DAS @ 18 L ha^{-1}, respectively. Minimum weed suppression of 12 and 15% was observed in treatments unboiled RSE at 30 DAS @ 18 L ha^{-1} and boiled RSE at 30 DAS @ 9 L ha^{-1} at 40 DAS and both treatments were at par. Maximum suppression 84% was recorded in hand weeding while minimum suppression (8%) was observed when we applied unboiled RSE at 30 DAS @ 18 L ha^{-1} at 70 DAS. The water extracts of some rice plants were found to suppress the growth and germination of *C. arvensis,* cabbage *(Brassica oleracea* L.), wheat,*P. minor, M. vaginalis,* oats berseem), lentil *(Lens culinaris),* lettuce and rice in laboratory tests (Chou *et al.,* 1991; Tamak *et al.,* 1994a, 1994b; Kawaguchi *et al.,* 1997; Das and Goswami, 2001)

Total dry weight (g) of weeds

There were significant effects of boiled and unboiled RSEs in influencing total dry weight of weeds as represented in (Table 3).

Maximum weed suppression of 87% was calculated in hand weeding and it was followed by 77% in that treatments where we applied unboiled RSE at 30, 45 & 60 DAS @ 18 L ha^{-1} and boiled RSE at 30, 45 & 60 DAS @ 9 L ha^{-1},which are statistically at par with each other at 40 DAS. At 70 DAS, highest weed suppression 84% was examined in hand weeding and it was followed by 51% in that treatment where we applied boiled RSE at 30, 45 & 60 DAS @ 9 L ha^{-1}. Minimum weed suppressions 13 and 15% were observed in those treatments where we applied unboiled RSE at 30 DAS @ 18 L ha^{-1} and boiled RSE at 30 DAS @ 9 L ha^{-1}. Supporting findings were obtained by Pramanik *et al*. (2001) who stated that rice straw extracts contain growth inhibitors against milk vetch (*Astragalus sinicus*) weed seedlings.

Plant height (cm)

Plant height is an important parameter in determining the overall extent of growth and it depends on genetics, soil and environmental factors in all crops. Data pertaining to plant height recorded at maturity was not significant for all the weed control treatments (Table 3). The results were contradictory to Tarek *et al.* (2010) who reported that mixing the rice straw into the soil at different concentrations significantly increased the plant height of cucumber plant as compared to control.

Number of productive tillers (m^{-2})

Stand density of productive tillers at harvest is the important and basic yield contributing factor in wheat. The numbers of productive tillers were significantly enhanced by all the weed control treatments as compared to control which are presented in Table 3. Maximum numbers of productive tillers (465) were calculated in hand weeding and followed by treatments where we applied boiled RSE at 30, 45 and 60 DAS @ 9 L ha^{-1} and unboiled RSE at 30, 45 and 60 DAS @ 18 L ha^{-1} ranging 446 and 445, respectively both were statistically at par. The lowest number of productive tillers (418) was calculated in those treatments where unboiled RSE applied at 30 DAS @ 18 L ha^{-1} and boiled RSE at 30 DAS @ 9 L ha^{-1} while these treatments were followed by control (407). Similar results were obtained by Pandy *et al*. (2001) who reported that maximum grain yield might be attributed to the improvement in number of productive tillers.

Number of grains per spike

Allelopathic effects of boiled and unboiled RSE were significant in terms of number of grains per spike of wheat (Table 3). The results showed that the numbers of grains per spike were significantly increased by all weed control treatments as compared to control. The maximum number of grains per spike (42) were recorded in hand weeding treatment which was at par with boiled RSE at 30, 45 & 60 DAS @ 9 L ha^{-1} while lowest number of grains per spike (31) were recorded in control treatment these findings are similar of Singh *et al*. (2002) who reported that maximum grain yield might be attributed to grains per spike. It means that due to control of weeds, the plants were able to take more nutrients from soil and eventually the size of the spike increased.

1000 grain weight (g)

The effects of boiled and unboiled RSEs were significant in terms of 1000 grain weight of wheat (Table 3). The higher (42.33 g) 1000-grain weight was obtained in hand weeding which is followed by treatment where we applied boiled RSE at 30, 45 and 60 DAS at 9 L ha^{-1} and it was statistically at par with unboiled RSE at 30, 45 and 60 DAS at 18 L ha^{-1}. Lowest 1000 grain weight (34.0 g) was recorded in control. These findings are in line with Pandy *et al*. (2001) and Singh *et al*. (2002) who reported that maximum grain yield might be attributed by highest 1000-grain weight. It was also proved by our findings.

Grain yield (kg ha^{-1})

Grain yield in wheat is a cumulative function of yield components like number of productive tillers per plant, number of grains per spike and 1000-grain weight. The data pertaining to the grain yield (Table 3) of wheat crop exhibited that all the treatments significantly influenced the grain yield as compared to the control treatment. Higher grain yield (4435 kg ha^{-1}) was observed when unboiled RSE were applied at 30, 45 and 60 DAS at 18 L ha^{-1} which is statistically at par with treatment where unboiled RSE were applied at 30, 45 and 60 DAS at 9 L ha^{-1} and hand weeding that were 4420.00 and 4415.0 kg ha^{-1}, respectively while lowest grain yield (3235.0 kg ha^{-1}) was recorded in control. Similar findings were obtained by Pandy *et al*. (2001) and Singh *et al*. (2002) who reported that maximum grain yield might be attributed to the improvement in number of tillers, spike length, grains/spike and 1000-grain weight.

Straw yield (kg ha^{-1})

The significant effect of boiled and unboiled RSE was found in influencing the wheat straw yield (Table 3). Data regarding straw yield showed that maximum yield (6230.0 kg ha^{-1}) was obtained when we applied unboiled RSE at 30, 45 and 60 DAS at 18 L ha^{-1} and it was at par with T_7 where we applied boiled RSE at 30, 45 and 60 DAS at 9 L ha^{-1} followed by hand weeding (6200.0 kg ha^{-1}). Minimum straw yield was observed in control (5035.0 kg ha^{-1}). It might be due to better stand establishment and maximum number of tillers.

Harvest index (%)

The ability of a cultivar to convert the dry matter into economic yield is indicated by its harvest index. The higher the harvest index value, the greater the physiological potential of the crop for converting dry matter to grain yield. Harvest index was affected statistically by all the treatments as compared to control (Table 3). Maximum harvest index 43% was recorded in treatment where boiled RSE at 30 DAS at 9 L ha^{-1} were statistically at par with that treatment where we applied unboiled RSE at 30 DAS @ 18 L ha^{-1} while the lowest harvest index was recorded in control (39%). Similar results were obtained by El-Rokiek *et al.* (2006) who reported that when ground soil was mixed with rice straw at 125-500 g m^{-2} three months before sowing of crop, it increased the productivity of cucumber and that might be due to increase in organic matter or allelopathic effects.

Benefit cost ratio

The effectiveness of any production system is ultimately scored on the basis of its benefit cost ratio. The maximum benefit cost ratio (BCR) of 1.22 was obtained by using unboiled RSE at 30, 45 and 60 DAS at 18 L ha^{-1}. This was due to proper weed management, high yield and less preparation charges on unboiled RSE while cost of production is increased in case of boiled RSE treatments.

Table-1. Effect of rice straw extracts (boiled and unboiled) on total germination and seedling growth of wheat

Treatment	Total germination % age	Shoot length (cm)	Root length (cm)	Seedlings fresh weight (g)	Seedlings dry weight (g)
Control*	80% a	5.4 d	3.5 c	0.36 e	0.10 d
5% unboiled RSE▪	80% a	13.4 b	7.9 b	0.70 b	0.13 b
10% unboiled RSE	60% b	16.2 a	10.5 a	0.92 a	0.18 a
15% unboiled RSE	60% b	11.8 bc	8.3 b	0.59 c	0.12 bc
5% boiled RSE	60% b	11.2 c	7.5 b	0.61 bc	0.11c
10% boiled RSE	60% b	16.2 a	10.0 a	0.86 a	0.17 a
15% boiled RSE	40% c	10.4 c	6.9 b	0.46 d	0.11 c
LSD value (5.0 %)	1.41	2.20	1.67	0.092	0.02

▪RSE= Rice straw extract;
*5 mL of each concentration per Petri dish while in control only distilled water was used.
Figures sharing the same case letters do not differ significantly at $p \leq 0.05$

CONCLUSION

It can be concluded from this study that the boiled and unboiled RSE enhanced the productivity of a wheat crop by 27%. These extracts suppressed the weed density, and the fresh and dry weights of *A. fatua*, *P. minor* and *C. arvensis*. There were no differences seen between the efficacies of the two types of RSEs on weed growth suppression. Therefore, the unboiled RSE was considered to be more economical than the boiled one with the similar efficacy. The study indicates that using rice straw biomass for controlling of weeds could be applied to other crops that follow at rice harvest. Such an approach to weed management should be economical and reduce environmental polluteon.

Table-2. Effect of rice straw extracts (boiled & unboiled) on total weed density, total fresh weight and total dry weight of weeds in wheat

Treatment	Total weed density (m^2)		Total fresh weight of weeds (g)		Total dry weight of weeds (g)	
	40 DAS	70 DAS	40 DAS	70 DAS	40 DAS	70 DAS
T_0 = Control	228 a	280 a	43.33 a	177.33 a	16.00 a	89.67 a
Hand weeding (30+45+60 DAS♦)	37 e (84%)	56 e (70%)	17.00 g (61%)	29.00 g (84%)	2.00 f (87%)	14.67 g (84%)
Unboiled RSE■ (10%, w/v) spray at 30 DAS @ 18L ha^{-1}	148 b (34%)	178 b (36%)	38.33 b (12%)	162.33 b (08%)	9.67 b (40%)	78.00 b (13%)
Unboiled RSE (10%, w/v) spray at 30 & 45 DAS @ 18L ha^{-1}	130 c (43%)	152c (43%)	33.67 c (22%)	130.33 d (27%)	7.33 c (54%)	58.00 d (17%)
Unboiled RSE (10%, w/v) spray at 30, 45 & 60DAS @ 18L ha^{-1}	60 d (73%)	92 d (67%)	27.00 e (38%)	107.67 (39%)	3.67 e (77%)	43.00 f (39%)
Boiled RSE (10%, w/v) spray at 30 DAS @ 9 L ha^{-1}	143 b (37%)	171 b (38%)	36.67 b (15%)	159.33 c (10%)	9.33 b (42%)	76.00 c (15%)
Boiled RSE (10%, w/v) spray at 30 & 45 DAS @ 9 L ha^{-1}	126 c (44%)	148 c (47%)	31.00 d (28%)	128.33d (28%)	6.33 d (60%)	55.00 e (39%)
Boiled RSE (10%, w/v) spray at 30, 45 & 60 DAS @ 9 L ha^{-1}	55 d (75%)	85 d (69%)	24.67 f (43%)	104.33 f (41%)	3.67 e (77%)	44.67 f (51%)
LSD value (5.0%)	5.65	7.63	1.72	1.64	0.96	1.75

*Percentage reduction of weeds compared with control;
DAS = ♦Days after sowing; ■RSE= Rice straw extract
Figures sharing the same case letters do not differ significantly at $p \leq 0.05$

Table-3. Effect of rice straw extracts (boiled and unboiled) on the productivity of wheat

Treatment	Plant height (cm)	Tillers (m^{-2})	No. of grains $spike^{-1}$	1000-grains weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest Index (%)	BCR*
Control	89.0	407 e	31 e	34.00 f	3235 d	5035 e	39.12 d	0.05
Hand weeding (30 + 45 + 60 DAS♦)	91.0	465 a	43 a	42.33 a	4415 a	6200 b	41.59 c	1.18
Unboiled RSE■ (10%, w/v) spray at 30 DAS @ 18 L ha^{-1}	89.0	418 d	36 d	35.67 e	3920 c	5130 d	43.31 a	1.08
Unboiled RSE (10%, w/v) spray at 30 & 45 DAS @ 18 L ha^{-1}	90.0	432 c	39 c	37.33 cd	4240 b	5854 c	42.00 b	1.18
Unboiled RSE (10%, w/v) at 30, 45 & 60DAS @ 18L ha^{-1}	90.3	445 b	41 b	40.00 b	4435 a	6230 a	41.59 c	1.22
Boiled RSE (10%, w/v) spray at 30 DAS @ 9 L ha^{-1}	89.7	418 d	36 d	36.33 de	3915 c	5115 d	43.35 a	1.08
Boiled RSE (10%, w/v) spray at 30 & 45 DAS @ 9 L ha^{-1}	89.3	433 c	39 c	37.67 c	4235 b	5836 c	42.05 b	1.17
Boiled RSE (10%, w/v) at 30, 45 & 60 DAS @ 9 L ha^{-1}	89.7	446 b	41 ab	40.33 b	4420 a	6215 ab	41.56 c	1.21
LSD value (5.0 %)		3.26	1.56	1.38	24.66	19.44	0.10	

*BCR= Benefit cost ratio; ♦DAS = Days after sowing; ■RSE= Rice straw extract
Figures sharing the same case letters do not differ significantly at $p \leq 0.05$

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