WEED MANAGEMENT BOOSTS YIELD IN FINE RICE UNDER SYSTEM OF RICE INTENSIFICATION[1]

Influência do Manejo de Plantas Daninhas no Aumento da Produção de Arroz Fino no Sistema de Intensificação de Arroz

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ABSTRACT - The system of rice intensification has emerged as a promising rice production package but weed infestation could lead to incomplete benefits from the system. A two-year field study was performed to determine an appropriate method of weed management in SRI. Weed management treatments were manual hoeing 20, 40 and 60 days after transplanting (DAT), hoeing with rotary hoe at 20, 40 and 60 DAT, hoeing with rotary hoe at 20 DAT + spray with sorghum and sunflower water extracts at 15 L ha^{-1} 40 DAT, manual hoeing 20 DAT + spray with sorghum and sunflower water extracts, both in equal amount, at 15 L ha^{-1} 40 DAT, orthosulfamuron at 145 g a.i. ha^{-1} 7 DAT, weedy check and weed free. Manual hoeing at 20, 40 and 60 DAT was the treatment that exhibited the maximum kernel yield i.e. 5.34 and 4.99 t ha^{-1}., which was 8.4 and 7.2% higher than orthosulfamuron and 61.0 and 64.9% higher than weedy check, during both years of study, respectively. The highest weed suppression was also achieved by manual hoeing at 20, 40 and 60 DAT with weed control efficiency of 87.89 and 82.32% during 2010 and 2011, respectively. Manual hoeing at 20, 40 and 60 DAT is an eco-friendly, non-chemical weed control method to increase kernel yield of fine rice under SRI.

Keywords: herbicide, manual hoeing, *Oryza sativa*, rotary hoeing, sorghum and sunflower water extracts.

RESUMO - O sistema de intensificação do arroz surgiu como um sistema promissor de produção de arroz, mas a infestação de plantas daninhas pode reduzir seus benefícios. Foi realizado um estudo de campo com duração de dois anos para a determinação de um método adequado de manejo de plantas daninhas sob o sistema SRI. Os tratamentos de manejo de plantas daninhas foram os seguintes: capina manual aos 20, 40 e 60 dias após o transplantio (DAT), capina com enxada rotativa aos 20, 40 e 60 DAT, capina com enxada rotativa aos 20 DAT + spray com extratos aquosos de sorgo e girassol a 15 L ha^{-1} aos 40 DAT, capina manual aos 20 DAT + spray com extratos aquosos de sorgo e girassol, ambos na mesma quantidade, a 15 L ha^{-1} de 40 DAT, ortossulfamurão a 145 g a.i. ha^{-1} aos 7 DAT, testemunha sem capina e testemunha com capina. A capina manual aos 20, 40 e 60 DAT foi o tratamento que resultou na produção máxima de grãos, ou seja, 5,34 e 4,99 t ha^{-1}, a qual foi 8,4 e 7,2% mais elevada do que o ortossulfamurão e 61,0 e 64,9% superior à testemunha sem capina, durante os dois anos de estudo, respectivamente. A supressão de plantas daninhas também foi maior com a capina manual aos 20, 40 e 60 DAT, com eficiência de controle de plantas daninhas de 87,89 e 82,32% em 2010 e 2011, respectivamente. A capina manual aos 20, 40 e 60 DAT é um método de controle de plantas daninhas ecológico e não-químico para aumentar a produção de grãos de arroz fino sob o sistema SRI.

Palavras-chave: herbicida, capina manual, *Oryza sativa*, capina com enxada rotativa, extratos aquosos de sorgo e girassol.

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INTRODUCTION

Rice is an important cereal crop. It meets food needs of more than 90% of the population in Asia (Tanji, 1990). Rice production worldwide is affected by scarcity of water and increased cost of inputs (Gujja & Thiyagarajan, 2009). Ecologically, increased use of synthetic fertilizers and pesticides is posing severe threats to the sustainability of crop production. In such conditions, the system of rice intensification (SRI) has emerged as an alternate intensive rice production method which is more productive, sustainable and eco-friendly compared to conventional rice production (Glover, 2011). The system of rice intensification offers two benefits: firstly, fewer requirements of inputs like seed, water and synthetic fertilizers and pesticides, and secondly, high yield (Styger et al., 2011).

Unchecked weed growth in rice can reduce crop yield up to 80% (Babu et al., 1992). Different weed management methods in rice have different effects on weed suppression and growth enhancement (Hasanuzzaman et al., 2007). No weed management method is equally effective under all conditions (Riaz et al., 2006). For instance, hoeing twice increased rice yield by decreasing weed density (Ekeleme et al., 2007). Furthermore, sorghum and sunflower water extracts could effectively suppress weeds in rice (Cheema et al., 2010). Also, by using allelopathic crop water extracts, herbicide usage could be reduced up to 50% (Iqbal et al., 2010). However, synthetic herbicides are considered to be a convenient means of weed management (Adeosun et al., 2009).

In SRI, an appropriate method of weed management needed to be developed. By developing further an economical weed management practice for SRI, we could help farmers with the maximum exploitation of yield benefits from the production system. Thus, we planned to test various weed management methods viz., hand hoeing and rotary hoeing, each used alone or together, with sorghum and sunflower water extracts, and a chemical herbicide named orthosulfamuron with two controls i.e. weedy check and weed free check. Our objective was to determine the most appropriate and yield-boosting weed management method for SRI.

MATERIALS AND METHODS

The experiment was performed for two consecutive years, 2010 and 2011, at the Students' Farm Area, Department of Agronomy, University of Agriculture, Faisalabad, Pakistan. The site was located at latitude 30.35 to 31.47° N and longitude 72.08 to 73° E at an altitude of 150 m. Soil type was sandy-clay loam. All crop and water management practices were followed while keeping in view principles and practices of SRI (Stoop et al., 2002).

The experiment was conducted in randomized complete block design with three replications. Net plot size was 3 m x 4.5 m. Plant and row spacing was maintained at 25 cm x 25 cm. Weed control treatments included weedy check, manual hoeing (20, 40 and 60 DAT), rotary hoeing (20, 40 & 60 DAT), hoeing with rotary hoe (20 DAT) + sorghum and sunflower water extracts at 15 L ha^{-1} (40 DAT), manual hoeing (20 DAT) + sorghum and sunflower water extracts, both mixed in equal amount, at 15 L ha^{-1} (40 DAT), orthosulfamuron at 145 g a.i. ha^{-1} (7 DAT) and weed free. We focused on non-chemical weed control methods, trying to keep SRI eco-friendly. Addition of chemical herbicide in the treatments was made to see if it yielded higher than non-chemical methods.

To raise rice nursery, the bed was prepared adjacent to the field where nursery was to be tranplanted in order to avoid trauma to seedlings at transplanting time (Thakur et al., 2010). Farm yard manure was thoroughly mixed with soil at the rate of 1 kg m^{-2}. Seeds of the variety Super Basmati of fine aromatic rice were put in a water filled bucket for 10 minutes. The seeds which floated on the surface of water were discarded because they were considered to be non-vigorous, while the soaked seeds were selected for sowing. Sowing was done by broadcasting at the rate of 1.25 kg seeds per 25.32 m^2. Seeds were covered with rice straw after sowing for ten days to conserve moisture and to protect germinating seeds from predators. The seedlings were ready for transplanting at the age of 21 days.

The field was prepared for transplanting by thoroughly mixing farm yard manure at the rate of 5 t ha^{-1}. The field was maintained for transplanting by creating muddy conditions

(Thakur et al., 2010). Synthetic fertilizer was not applied and one seedling was transplanted per hill, assuring that root tips were not inverted upward.

Irrigation was applied three times a week for first 14 days after transplanting to maintain 3 cm continuous flooding. A schedule of alternate wetting and drying was followed afterwards up to the start of grain formation making sure that each subsequent application of irrigation water was done four days after the ponded water had disappeared. From grain formation to harvesting, 3 cm irrigation was applied at five days interval.

The field was dominated by three major weeds viz., *Cyperus rotundus*, *Trianthema portulacastrum* and *Echinochloa colona* and the weeds negligible in number were removed by pulling them by hand. Weed density and biomass were recorded at 55 days after transplanting and 85 days after transplanting to observe the change in weed growth in the long run. A 0.5 m x 0.5 m quadrate was randomly placed at two points in each experimental unit and the weeds in such area were cut from the ground surface for measurement of density and dry weight. After obtaining two readings of density and dry weight per plot, they were averaged and converted to m^{-2}.

To record the number of fertile tillers m^{-2}, panicle-bearing tillers were counted in a randomly selected area of 100 cm x 100 cm from two places in each experimental unit and then averaged. Length of rice roots were recorded by removing the soil from the roots of individual dug-out plants, stretching them straight and measuring the length of the longest root; then the average was worked out at the end. Normal kernels, which were clear, translucent and spotless, were recorded after excluding all the abnormal kernels from total number of kernels and converted to percentage. After harvesting and threshing, the clean rough rice was air dried, bulked and weighed out. Yield of clean rough rice was measured in kg ha^{-1} after adjusting kernel weight to 14% moisture contents. To calculate crop growth rate (CGR), the formula of Hunt (1978) was used. Weed control efficiency of different weed management methods was calculated on the basis of total weed dry weight recorded at 85 DAT using the following formula;

$$\text{Weed control efficiency (\%)} = \frac{W1 - W2}{W1} \times 100$$

where W1 = Total dry matter of weeds at 85 DAT in weedy check plots; W2 = Total dry matter of weeds at 85 DAT in treated plots.

The data were analyzed by using Fisher's analysis of variance technique, and the least significant difference (LSD) test at $p > 0.05$ was employed to compare the significant means of the treatments (Steel et al., 1997). Year effect was significant, so data of both years are presented separately.

RESULTS AND DISCUSSION

Weed density and dry weight

Weed density and dry weight represented the extent of competition posed by weeds on the crop. The treatment which exhibited the minimum density and dry weight for the weeds was considered the best. We found that the SRI field was dominated by three major weeds viz., *Cyperus rotundus*, *Trianthema portulacastrum* and *Echinochloa colona*.

As data in Table 1 indicate, the maximum weed density was recorded in weedy check both at 55 DAT (*C. rotundus*; 61.7 and 78.0 m^{-2}, *T. portulacastrum*; 25.3 and 32.0 m^{-2} and *E. colona*; 11.7 and 13.7 m^{-2}) and 85 DAT (*C. rotundus*; 60.0 and 72.2, *T. portulacastrum*; 25.7 and 28.7 and *E. colona*; 15.3 and 16.7) during both years, respectively. Weed free treatment had no weed plant throughout the season and this result is at par with that of Akbar et al. (2011), who reported the maximum weed suppression by hand pulling. Among various weed control treatments, during both years, manual hoeing at 20, 40 and 60 DAT was found to be the most effective in reducing density of the three weeds at 55 DAT (*C. rotundus*; 10.7 and 21.0 m^{-2}, *T. portulacastrum*; 4.0 and 4.7 m^{-2} and *E. colona*; 2.3 and 3.3 m^{-2}), keeping them suppressed up to 85 DAT (*C. rotundus*; 9.7 and 15.2 m^{-2}, *T. portulacastrum*; 3.3 and 6.7 m^{-2} and *E. colona*; 2.3 and 3.3 m^{-2}). Ismaila et al. (2011) also recorded the maximum weed suppression in

Table 1 - Effect of different weed control treatments on weed density of *Cyperus rotundus*, *Trianthema portulacastrum* and Echinochloa colona at 55 DAT and 85 DAT

	Weed Density (m^{-2}) 55 DAT						Weed Density (m^{-2}) 85 DAT					
	Cyperus rotundus		*Trianthema portulacastrum*		*Echinochloa colona*		*Cyperus rotundus*		*Trianthema portulacastrum*		*Echinochloa colona*	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Weedy check	61.7 a	78.0 a	25.3a	32.0a	11.7a	13.7a	60.0a	72.2 a	25.7a	28.7a	15.3a	16.7a
Manual hoeing (20, 40 & 60 DAT*)	10.7d	21.0e	4.0c	4.7c	2.3e	3.3d	9.7e	15.2c	3.3d	6.7d	2.3d	3.3d
Hoeing with rotary hoe (20, 40 & 60 DAT)	18.3c	30.3d	8.7b	11.0b	6.0b	7.3bc	16.7cd	21.2c	10.3c	13.0bc	5.0c	5.3cd
Hoeing with rotary hoe (20 DAT) + Water extracts** @ 15 L ha^{-1} (40 DAT)	33.7b	43.0b	9.7b	12.3b	7.3b	8.3b	31.3b	37.5b	14.7b	15.7b	8.7b	10.3b
Manual hoeing (20 DAT) + Water extracts *@ 15 L ha^{-1} (40 DAT)	28.3b	38.3c	7.7b	9.7b	5.7bc	6.7bc	22.7c	21.2c	7.7c	13.0bc	8.0b	9.3b
Orthosulfamuron at 145 g a.i ha^{-1} (7 DAT)	19.3c	29.0d	9.3b	10.7b	4.0cd	5.7c	16.0d	21.5 c	10.7c	12.3c	4.0c	6.0c
Weed free	0	0	0	0	0	0	0	0	0	0	0	0
LSD Values (5%)	6.50	2.85	2.93	3.95	1.79	2.28	6.22	6.86	3.21	3.23	1.47	2.22

Two means within a column not sharing the same letter differ significantly from each other. *Days After Transplanting . **Sorghum and Sunflower crop water extracts in 1:1.

rice as a result of hoeing three times. Manual hoeing was followed by orthosulfamuron at 145 g a.i. ha^{-1} in suppressing the weeds and sustaining their reduced density as seen at 55 and 85 DAT. Furthermore, hoeing with rotary hoe was statistically at par with orthosulfamuron in suppressing all the weeds during both years except for *E. colona* at 55 DAT during 2010. Our results contradict the finding of Anbhazhagan & Kathiresan (2010), who stated that herbicide application alone leads to lower weed count. Combination of hoeing with sorghum and sunflower water extracts could not pose notable suppression to all the weeds during both years.

Weed dry weight, during both years, is quite similar to weed density (Table 2). The data showed that weedy check exhibited the maximum dry weight of weeds both at 55 DAT (*C. rotundus*; 63.6 and 68.0 g m^{-2}, *T. portulacastrum*; 18.9 and 24.3 g m^{-2} and *E. colona*; 12.6 and 14.8 g m^{-2}) and 85 DAT (*C. rotundus*; 44.3 and 48.4 g m^{-2}, *T. portulacastrum*; 22.9 and 28.6 g m^{-2} and *E. colona*; 13.1 and 14.6 g m^{-2}). Moreover, manual hoeing three times was the most efficient in reducing weed dry weight all the way from 55 DAT (*C. rotundus*; 6.8 and 9.7 g m^{-2}, *T. portulacastrum*; 1.7 and 3.1 g m^{-2} and *E. colona*; 2.3 and 3.2 g m^{-2}) to 85 DAT (*C. rotundus*; 7.3 and 10.1 g m^{-2}, *T. portulacastrum*; 1.7 and 4.3 g m^{-2} and *E. colona*; 0.7 and 1.9 g m^{-2}) during both years. It was followed by the chemical herbicide which caused a reduction in weed dry weight at 55 DAT (*C. rotundus*; 11.4 and 14.1 g m^{-2}, *T. portulacastrum*; 6.0 and 8.0 g m^{-2} and *E. colona*; 3.4 and 5.2 g m^{-2}) sustaining it to grain filling as evident from the data for 85 DAT (*C. rotundus*; 12.5 and 16.3 g m^{-2}, *T. portulacastrum*; 4.9 and 7.2 g m^{-2} and *E. colona*; 4.3 and 6.1 g m^{-2}). Combination of hoeing with sorghum and sunflower water extracts not only failed to reduce weed dry weight to a notable level for all the weeds, during both years, but also exhibited an increase in the dry weight of the weeds at 85 DAT. This finding contradicts the findings of Cheema et al. (2010) because crop water extracts failed to play their role in suppressing weeds and invigorating crop plants as reported by these scholars. Weed control efficiency of manual hoeing at 20, 40 and 60 DAT (87.89 and 82.32% during 2010 and 2011, respectively) was also the best among all weed management methods as evident from Table 3.

Weedy check exhibited the maximum density and dry weight of weeds at 55 DAT and

Table 2 **-** Effect of different weed control treatments on weed dry weight of *Cyperus rotundus*, *Trianthema portulacastrum* and *Echinochloa colona* at 55 DAT and 85 DAT

	Weed Dry Weight (g m^{-2}) 55 DAT						Weed Dry Weight (g m^{-2}) 85 DAT					
	Cyperus rotundus		*Trianthema portulacastrum*		*Echinochloa colona*		*Cyperus rotundus*		*Trianthema portulacastrum*		*Echinochloa colona*	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Weedy check	63.6a	68.0a	18.9a	24.3a	12.6a	14.8a	44.3a	48.47a	22.9a	28.6a	13.1a	14.6a
Manual hoeing (20, 40 & 60 DAT*)	6.8d	9.7d	1.7c	3.1c	2.3d	3.2d	7.3d	10.1d	1.7d	4.3c	0.7d	1.9e
Hoeing with rotary hoe (20, 40 & 60 DAT)	10.5cd	13.2d	3.1bc	5.2bc	6.1b	7.8b	10.2cd	14.5c	3.9bc	6.5b	3.7c	5.3d
Hoeing with rotary hoe (20 DAT) + Water extracts** @ 15 L ha^{-1} (40 DAT)	18.7b	22.8b	4.1bc	6.3b	6.9b	9.0b	15.1b	19.2b	4.9b	7.2b	7.2b	8.1bc
Manual hoeing (20 DAT) + Water extracts *@ 15 L ha^{-1} (40 DAT)	13.3c	18.1c	4.3bc	5.7bc	6.1b	7.5b	9.7cd	13.0cd	2.7cd	5.3bc	6.7b	8.7b
Orthosulfamuron at 145 g a.i ha^{-1} (7 DAT)	11.4c	14.1cd	6.0b	8.0b	3.4c	5.2c	12.5bc	16.3bc	4.9b	7.2b	4.3c	6.1cd
Weed free	0	0	0	0	0	0	0	0	0	0	0	0
LSD Values (5%)	3.99	4.53	3.36	2.82	1.00	1.71	3.43	4.10	1.89	2.17	1.32	2.14

Means within a column not sharing the same letter differ significantly from each other at 5% level of probability. *Days After Transplanting. **Sorghum and Sunflower crop water extracts with a 1:1 ratio.

85 DAT, during both years (Table 1 and 2), because the three weeds grew vigorously, competed with the crop and kept it suppressed throughout the growth season because of competitive stress. The rice plants in this condition could not maintain sufficient growth rate to shade the weeds and reduce supply of light and availability of space for them. On the contrary, weeds were carefully and regularly removed from weed free plots; as a consequence, we found zero density and, thus, zero dry weight of all the weeds during both years. Manual hoeing suppressed weed growth to the maximum extent most probably as a result of removing the weeds from the field in repeated intervals of 20 days. This method of weed control not only ensured the maximum removal of weeds from the field but also aerated the soil.

Elimination of the three weeds from the field up to 60 DAT helped the crop cover the soil due to profuse tillering and heavy canopy development, thereby reducing weed density and dry weight to the minimum at 85 DAT among all other weed management treatments, during both years. Orthosulfamuron gave good control to the three weeds at the early growth stage, but weeds germinated and grew to compete with the crop as time went by. Early canopy establishment due to absence of competitors at tillering stage helped the crop, to a great extent, to keep the density and dry weight of the weeds at a lower level; however, it could not compete with manual hoeing. On the contrary, Tabatabaekoloor et al. (2012) found that the maximum weed suppression in rice was achieved by a combination of herbicide and hoeing, which was followed by the suppression done by the herbicide used alone. Rotary hoeing was found to leave stubborn weed plants in the field which continued to compete with the crop, providing

Table 3 **-** Weed control efficiency (%) of different weed control treatments versus weedy check

	Weed control efficiency (%)	
	2010	2011
Manual hoeing (20, 40 & 60 DAT*)	87.89	82.32
Hoeing with rotary hoe (20, 40 & 60 DAT)	77.84	71.34
Hoeing with rotary hoe (20 DAT) + Water extracts** at 15 L ha^{-1} (40 DAT)	66.14	62.40
Manual hoeing (20 DAT) + Water extracts ** at 15 L ha^{-1} (40 DAT)	76.13	70.55
Orthosulfamuron at 145 g a.i ha^{-1} (7 DAT)	72.95	67.63
Weed free	100.00	100.00

* Days After Transplanting. **Sorghum and Sunflower crop water extracts in 1:1.

favourable conditions to other weed plants and unfavourable conditions to the crop and, thus, leading to higher density and dry weight of all the weeds at the end, during both years. In the combination of manual hoeing with sorghum and sunflower water extracts, hoeing at 20 DAT cleared the plots from the weeds, but the application of crop extracts at 40 DAT could have lowered crop growth along with weeds, as evident from Figure 1 and Figure 2. Under these conditions, new germinating weeds could have gained competitive advantage over the crop, subsequently resulting in high density and dry weight of the weeds at both readings. A similar condition could be in the case of combining rotary hoeing and crop extracts. This treatment would have shown the maximum weed density among all the weed control treatments because of competitive advantage gained by the weeds, over the crop, leftover by rotary hoe. Our results contradict the findings of Iqbal et al. (2010), who indicated 50% suppression of weeds by crop water extracts.

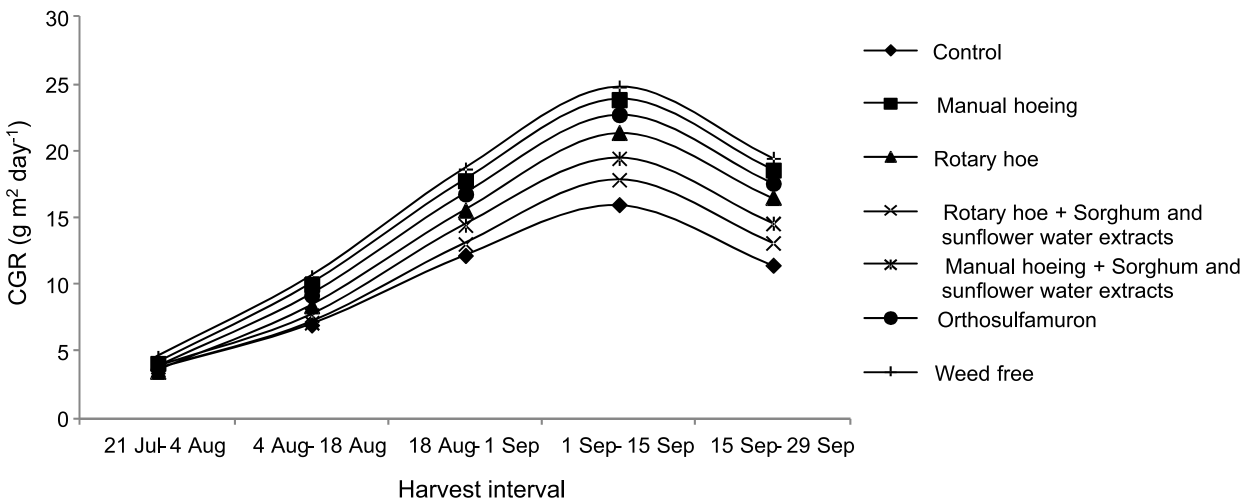

Figure 1 - Effect of different weed control treatments on CGR of fine rice under SRI during 2010.

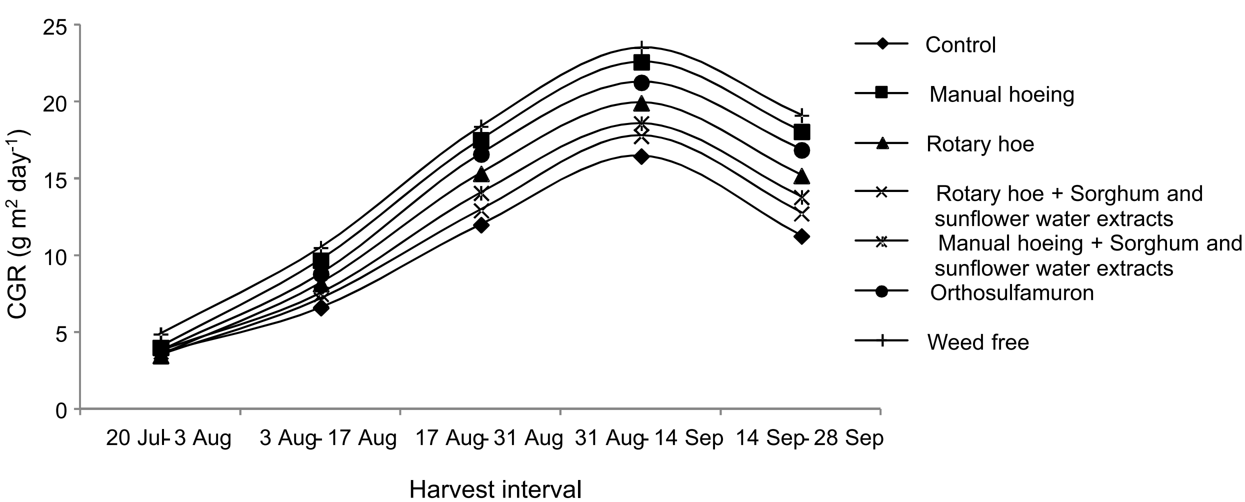

Figure 2 - Effect of different weed control treatments on CGR of fine rice under SRI during 2011.

Crop growth and yield attributes

All the weed control methods had different impact on the growth and yield attributes of rice under SRI. Crop growth rate (CGR) of rice was significantly affected by all the treatments, during both years, as clearly shown in Figure 1 and Figure 2. We observed the highest growth and yield attributes in weed free plots, while the lowest of them were recorded in weedy check during both years (Table 4). Akbar et al. (2011) also recorded the highest growth and yield of rice in weed free conditions. Among weed control methods, manual hoeing recorded maximum yield among the treatments in terms of fertile tillers m^{-2} (205.7 and 188.3), root length (28.7 and 26.2 cm) and mass (27.8 and 25.5 g per plant), 1000-kernel weight (20.2 and 18.4 g), percentage of normal kernels (76.9 and 74.3%) and kernel yield (5.34 and 4.99 t ha^{-1}) during 2010 and 2011, respectively. It was statistically followed by orthosulfamuron at 145 g a.i ha^{-1} in terms of enhancing growth and yield (Table 4). The results are in contradiction with those of Adeosun et al. (2009), who found that the combination of herbicide and hand weeding was the best source of yield improvement in rice. Manual hoeing and the combination of manual hoeing and sorghum and sunflower water extracts, and the combination of rotary hoeing and sorghum and sunflower water extracts could not perform notably as shown by the data in Table 4.

The maximum yield in weed free plots (Table 4) is understandable because the crop did not face any competition. In this case, during both years, rice plants had unchecked availability of space, light, nutrients and water, which helped the plants with exploitation of the maximum genetic potential. On the other hand, weedy check decreased the crop growth rate of rice (Figures 1 and 2), and we observed a weed dominated environment where the crop lacked sufficient space, nutrients and light to grow and develop. Less space and nutrients lead to a reduction in the number of tillers m^{-2} (Table 4). Competitive stress resulted in the minimum root growth which, ultimately, could have affected grain formation and, thus, kernel yield. Manual hoeing at 20, 40 and 60 DAT let the crop establish high tillering and canopy and vigorous roots (Table 4) in the absence of the weeds and in the availability of well aerated soil as a result of hoeing. This made the crop stronger and, at the reproductive stage of the crop, vigorous rice plants had easily beaten emerging weeds in

Table 4 - Effect of different weed control treatments on fertile tillers m^{-2}, root length at maturity (cm), root mass at maturity (g), 1000-kernel weight (g), normal kernels (%) and grain yield (t ha^{-1}) of fine rice under SRI

	Fertile tillers m^{-2}		Root length (cm per plant)		Root mass (g per plant)		1000-kernel weight (g)		Normal kernels (%)		Grain yield (t ha^{-1})	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Weedy check	80.7 f	71.7 e	11.9e	10.7e	11.3f	9.9f	14.4 d	13.4 e	69.1g	66.7g	2.08 f	1.75 g
Manual hoeing (20, 40 & 60 DAT*)	205.7 a	188.3 a	28.7a	26.2a	27.8ab	25.5b	20.2 a	18.4 b	76.9b	74.3b	5.34 a	4.99 b
Hoeing with rotary hoe (20, 40 & 60 DAT)	157.0 c	151.0 b	25.1b	23.7b	23.0cd	21.5c	17.1 bc	16.7 bc	73.7d	71.3d	4.45 c	4.26 d
Hoeing with rotary hoe (20 DAT) + Water extracts** at15 l ha^{-1} (40 DAT)	112.7 e	97.7 d	17.2d	14.9d	15.5e	13.6e	15.7 c	14.8 de	70.2f	67.5f	2.92 e	2.73 f
Manual hoeing (20 DAT) + Water extracts ** at 15 l ha^{-1} (40 DAT)	130.3 d	122.7 c	21.3c	19.8c	20.6d	17.9d	15.9 c	15.6 cd	72.4e	69.9e	3.98 d	3.66 e
Orthosulfamuron at 145 g a.i ha^{-1} (7 DAT)	190.0 b	183.3 a	26.0b	24.5b	26.3bc	24.5b	17.9 b	17.3 b	75.4c	73.2c	4.89 b	4.63 c
Weed free	204.3 a	196.7 a	29.1a	27.3a	30.5a	28.8a	20.7 a	20.1 a	79.0a	76.4a	5.48 a	5.24 a
LSD Values (5%)	7.692	14.612	1.02	1.34	3.56	1.94	1.461	1.662	0.90	0.73	0.321	0.217

Means within a column not sharing the same letter differ significantly from each other at 5% level of probability. * Days After Transplanting . ** Sorghum and Sunflower crop water extracts with a 1:1 ratio.

the race of competition to gain high economic yield. Ullah et al. (2009) also observed that effective tillers increased with proper weed management which increased yield. Ismaila et al. (2011) recommended hoe weeding three times for proper weed suppression and yield improvement in rice. Orthosulfamuron applications at 7 DAT helped the rice plants with profuse tillering and therefore, led to good stand establishment. Healthy canopy development due to absence of weeds, in this case, enabled the crop plants to fight with competing weeds for life resources. They competed well but yield results of this treatment were significantly lower than manual hoeing due to weed free field by hoeing up to 60 DAT and additional invigoration of crop through soil aeration. Our results contradict the findings of Ashraf *et al.* (2006), who showed that there was no significant difference with respect to yield between hand weeding and herbicides. Our findings also contradict the findings of Babar & Velayutham (2012), who reported that the combination of herbicide and cono-weeding was required to get the maximum yield from SRI. Soil was also aerated by rotary hoeing but the weeds left unchecked by this treatment kept the weed crop competition alive throughout the crop growth season. Thus, resource starved rice plants could not yield as high with rotary hoeing. In the case of combination of manual hoeing and sorghum and sunflower water extracts, manual hoeing played its part up to 40 DAT. However, as soon as crop extracts were applied, the CGR of rice declined (Figures 1 and 2) along with reduction in weed density and dry weight (Tables 1 and 2). The weeds growing afterwards kept on competing with the stressed crop to reduce its root growth and affected its 1000-grain weight, which translated into low kernel yield. Finally, the lowest growth and yield among all weed control treatments with the combination of rotary hoeing and crop water extracts, during both years, could be attributed to competition posed to crop by leftover weeds at the beginning, and competition for resources posed by newly emerging weeds at the late vegetative and reproductive stages because of weak rice plants, as indicated by reduced CGR.

Manual hoeing at 20, 40 and 60 DAT should be employed to get high yield of fine rice under the system of rice intensification without compromising the sustainability of agriculture, jeopardized by the use of synthetic pesticides.

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