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Weed control and sustainable rice production through rice intensification system and conventional practices of weed competition periods and age of transplanted seedlings

Controle de ervas daninhas e produção sustentável de arroz através do sistema de intensificação do arroz e práticas convencionais de períodos de competição de ervas daninhas e idade das mudas transplantadas

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Highlights

Rice is an important cereal crop.
Its sustainable production is very essential.
Weeds are the major cause of yield losses of rice crop.
The age of rice seedlings is the most crucial.

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Abstract

Rice is an important cereal crop of global interest based on its daily uses. It was observed that the average yield of rice is low than its potential production due to the traditional growing techniques and weed intensification. Recently, the rice intensification system (RIS) has emerged as an alternative to the conventional rice cultivation system. A two-year field study was carried out to investigate the impact of seedling age (14, 21 & 28 days) and the weed competition periods (weedy check, 20, 40, 60, 80 DAT and weed-free throughout the growing season) in rice cultivated through RIS. Weedy check and weed-free for the growing season were kept as a control treatment. The results of our study revealed that a maximum dry weight (108.7 and 111.79 gm^{-2}) and weeds density (101.7 and 110.6 plants m^{-2}) of weed recorded in weedy check plot where 28 days old seedlings was transplanted while minimum dry weight (11.01 and 10.3 gm^{-2}) and weeds density (9.7 and 10.9 m^{-2}) were achieved in plots where 21 days old seedlings were transplanted and remain weed free. It was noted that weed density and weed dry biomass were gradually increased with increasing weed competition period at all ages of the rice seedling. Purple nutsedge (*C. rotundus*) exhibited maximum relative proportion in total weed's density and dry biomass and also ranked first by weed summed dominance ratio (WSDR). Agronomic yield and yield contributing traits such as number of fertile tillers per hills (58.1 and 56.0), plant height (130.5 cm and 125.6 cm), kernels per plant (186.4 and 179.4), straw yield (7.8 t ha^{-1} and 7.5 t ha^{-1}) and kernel yield (5.2 and 5.0 t ha^{-1}) were maximum in plot that remained weed-free throughout the growing season with a seedlings age of 21 days during 2010 and 2011 respectively. Percent yield losses were minimum in plots with 21 days old seedling transplantation and at 20 days of weed competition period. Hence, present study concludes that 21 days old fine rice seedlings should be transplanted and weeds should be controlled within 20 DAT under SRI for effective weed control to avoid yield losses.

Key words: Cereal crop. Growing season. Seedling's age. Weed competition period. Yield losses.

Resumo

O arroz é um cereal importante de interesse global devido ao seu uso diário. Observou-se que o rendimento médio do arroz é inferior ao seu potencial de produção devido às técnicas tradicionais de cultivo e intensificação de plantas daninhas. Recentemente, o sistema de intensificação do arroz (RIS) surgiu como uma alternativa ao sistema convencional de cultivo de arroz. Um estudo de campo de dois anos foi realizado para investigar o impacto da idade das mudas (14, 21 e 28 dias) e os períodos de competição de ervas daninhas (verificação de ervas daninhas, 20, 40, 60, 80 DAT e livre de ervas daninhas ao longo da estação de crescimento) em arroz cultivado através do RIS. Controle de ervas daninhas e livre de ervas daninhas para a estação de crescimento foram mantidas como tratamento controle. Os dados mostraram que um peso seco máximo (108,7 e 111,79 gm^{-2}) e densidade de ervas daninhas (101,7 e 110,6 plantas m^{-2}) de plantas daninhas registradas na parcela livre de plantas daninhas e mudas com 28 dias de idade, enquanto peso seco mínimo (11,01 e 10,3 gm^{-2}) $^{-2}$) e densidade de plantas daninhas (9,7 e 10,9 m^{-2}) foram alcançadas em plântulas com 21 dias de idade em parcelas com 20 dias. Observou-se que a densidade e a biomassa seca das ervas daninhas aumentaram gradualmente com o aumento do período de competição das ervas daninhas em todas as idades da muda de arroz. A tiririca roxa (*C. rotundus*) exibiu proporção relativa máxima na densidade total de ervas daninhas e biomassa seca e também ficou em primeiro lugar pela razão de dominância somada de ervas daninhas (WSDR). Rendimento agronômico e características que contribuem para o rendimento, como número de perfilhos férteis por colinas (58,1 e 56,0), altura da planta (130,5 cm e 125,6 cm), grãos por planta (186,4 e 179,4), rendimento de palha (7,8 t ha^{-1} e 7,5 t ha^{-1}) e a produção de grãos (5,2 e 5,0 t ha^{-1}) foram máximos na parcela que permaneceu livre de ervas daninhas ao longo da estação de crescimento com uma idade das mudas de 21 dias durante 2010 e 2011, respectivamente. As perdas percentuais de produtividade foram mínimas nas parcelas com transplante de mudas de 21 dias e aos 20 dias de competição com as plantas daninhas. Portanto, o presente estudo conclui que as mudas de arroz fino com 21 dias de idade devem ser transplantadas e as ervas daninhas devem ser controladas dentro de 20 DAT sob SRI para um controle eficaz de ervas daninhas para evitar perdas de rendimento. Este é o primeiro estudo de avaliação dos impactos da idade das mudas e do período de competição das ervas daninhas no controle de ervas daninhas e na produção sustentável de arroz sob o sistema de intensificação do arroz.

Palavras-chave: Colheita de cereais. Estação de crescimento. Idade das mudas. Período de competição de ervas daninhas. Perdas de rendimento.

Introduction

Rice is an important cereal crop worldwide (Food and Agriculture Organization of the United Nations [FAO], 2019). It is evident that 90% of the Asian population alongside more than half of population the of the globe directly or indirectly rely on rice to satisfy their daily calorie intake (Fukagawa & Ziska, 2019). It is one of the top-consumed food crops and the second largest export commodity of Pakistan which adds to the agriculture and GDP sector by about 3.0% & 0.6%, respectively (Ali et al., 2021). Its sustainable production is very essential for the better livelihood of the community at large. Further, the availability of highly productive cultivars, fertilizers and pesticides is the dire need of time. Presently, its cultivation in irrigated lands is mostly influenced by poor input management, water shortage and losses come from weeds, other pests and diseases (Rao et al., 2017; Nadeem et al., 2021a; Arooj et al., 2021; Tariq et al., 2021). Moreover, some elements such as climate change, management practices, late sowing, early irrigation and, inadequate control of weeds may also hinder rice production and yield (Nadeem et al., 2020b; Maqbool et al., 2021a; Nadeem et al., 2020c,d). Weeds are a major cause of yield losses of rice crops, as previous studies reported 350 weed species as weeds of rice. Weeds cause about 11.5% yield losses of rice crops in Pakistan which are higher than the rest of the world (9.5%) (Rabbani et al., 2011; Maqbool et al., 2021b,c; Nadeem et al., 2021c, 2020c,d).

In sustainable agriculture production, a new method to rice production is RIS which has developed as an alternate method of rice cultivation being sustainable, eco-friendly and dynamic than conventional techniques of rice cultivation (Glover, 2011; Chadhar et al., 2020). Basically, it is a system than advanced technology and is depends on ideas of receiving more production from less input application (Uphoff, 2003). It needs less inputs such as water, pesticides, fertilizers and seeds with the provision of higher yield (Chadhar et al., 2020; Ali et al., 2021). It can be a method of management with low resources for more production of rice (Tsujimoto et al., 2009). It also plays a significant role in the mechanical management of weeds against main rice weeds (Chadhar et al., 2020). Moreover, it reduces the density of rice plants grown through the SRI is rewarded by improved yield by more panicles and fertile tillers (Menete et al., 2008). It also depresses chemical use, but can be applied if required (Thakur et al., 2010a). The additional important feature includes; transplantation of seedlings at younger age i.e. 12-15 days (Stoop et al., 2002).

The age of rice seedlings is the most crucial factor influencing both shoot and root characteristics after rice transplantation; the younger rice seedlings undertake better performance as compared to the older ones it more mineral uptake (Mishra & Salokhe, 2008). The yield of crop decreases as the time of transplanted rice increased (Menete et al., 2008). Thakur et al. (2010b) stated that early rice seedlings have more physiological ability and the ability to produce extra tillers as compared to older seedlings. Chadhar et al., (2020) documented that the leaf development starts first in the young ones leading to more tillers with a high production of dry matter. The productive tillers frequency is more in early rice seedlings, which resulted in more yield of grains. The young rice transplants also display a rise in panicles, panicle length and filled grains of rice (Chadhar et l., 2020). The seeds produced through seedlings transplantation with more row spacing showed a higher vigor index and germination of seed (Krishna et al., 2008). So, that is why young seedling transplantation is a more productive way to enhance the yield of rice (Chadhar et al., 2020).

It is very commonly known that weeds are the most important factor restricting high yield, so the effective management of weeds is a great challenge to rice growers (Singh et al., 2003). The weed density, period of completion, seed type, growth and development stage, sowing and technology are the most important reasons for the yield losses in rice (Chadhar et al, 2020, Maqbool et al., 2022a,b; Javaid et al., 2022). Approximately 80% of yield losses are due to weeds in the rice field (Nadeem et al., 2020a). All yield factors are influenced by the duration of weed competition (Uremis et al., 2009). Moreover, there is no significant evidence of yield losses in rice after the critical period of weed competition in the instant fields (Johnson et al., 2004). Therefore, this study was planned to investigate the impact of seedling age and weed competition periods on the production of rice cultivated through RIS.

Material and Methods

Experimental site and metrological conditions

Open field experiments were conducted at agricultural farms of the University of Agriculture Faisalabad, Pakistan during two growing years (2010 and 2011) to evaluate the weed control and sustainable production of Basmati rice under rice intensification system (RIS). The soil was loamy with basic pH (7.7 and 7.6), and sufficient contents of organic matter (1.08 and 0.98%), nitrogen (0.056 and 0.053%), phosphorus (13.3 and 12.9 mg kg^{-1}), and potassium (132 and 128 mg kg^{-1}) were measured in the soil during 2010 and 2011respectively. Meteorological data regarding average temperature, rainfall and relative humidity is presented in Figure 1 a, b and c.

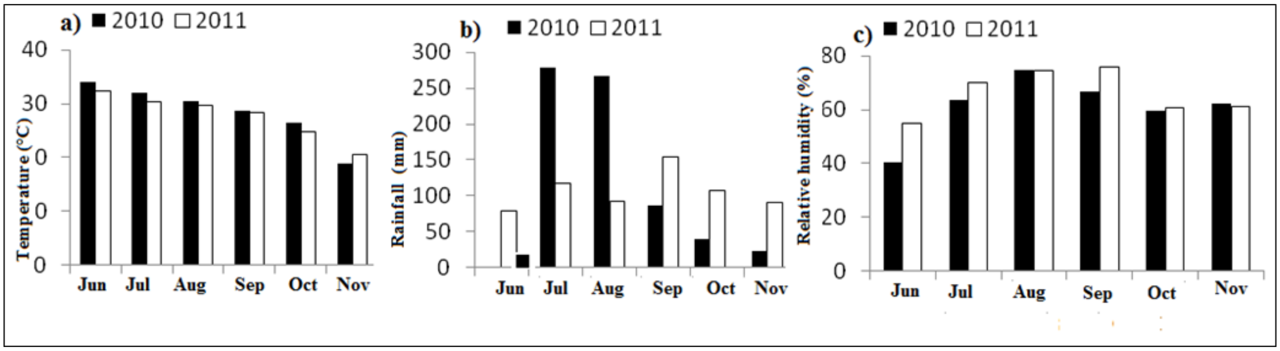


Figure 1. Agro-ecological conditions of experimental site (a) Temperature (C), (b) rainfall (mm), and (c) Relative humidity (%) data for growing period of rice 2010-11.

Experimental design and factors

The experimental area was divided into three main experimental units (SA_1, SA_2 and SA_3) with an area of 3 m × 4.5 m and each experimental unit was subdivided into six sub-units (WCP_1, WCP_2, WCP_3, WCP_4, WCP_5 and WCP_6) to evaluate the effects of age of seedling transplantation and weed competition periods on rice production and weed control. In this study, 14 (SA_1), 21 (SA_2), and 28 (SA_3) days old rice seedlings were transplanted under six different weed competition periods of 20 days (WCP_1), 40 days (WCP_2), 60 days (WCP_3), 80 days (WCP_4), full season weeds or weed check (WCP_5) and weed free condition (WCP_6). Weed-free and weedy check throughout the growing season were kept as a control treatment. The experiment was carried out in RCBD design with split plot and 3 replications of each combination.

Crop husbandry

For beds raising, the nursery was firstly prepared followed by well-rotten farm yard manure @ 1 kg m^{-2} was thoroughly mixed in soil prior to seed sowing. Super Basmati variety seeds were dipped in a bucket and all sank rice seeds were utilized for growing purposes whereas all floated seeds were dissipated. Seeds were broadcasted @ 1.25 kg per 25.32 m^2 for sowing purpose and protected with the rice straw to reserve moisture and secure seed from the predators. The muddy soil conditions were maintained by continuous application of water in the rice field (Thakur et al., 2010b). Moreover, no chemical fertilizer was applied in the field. Consequently, alternate drying and wetting schedule was followed before the formation of grains. From the formation of grains to harvesting; irrigation of three cm was given to the field at 5 days intervals.

Crop harvesting and data collection

In the rice field three most prominent weed species such as purple nutsedge (*Cyperus rotundus* L.), Broad-leaved black pigweed (*Trianthema portulacastrum* L.), and jungle rice grass weed (*Echinochloa colona* L.) were targeted in present study. Two main weed growth characteristics i.e. weed density and dry biomass of total and individual weeds were noted to determine the weed dynamics. A quadrate (0.5 × 0.5 m) was retained randomly at two diverse places and number of weeds was counted to know their total and individual density and were further used to measure total and individual dry weight from each sub-unit (sub-plots). Dominance ranking of each weed specie was determined by weed summed dominance ratio (WSDR) calculated by following equations (Chadhar et al., 2020).

$$\mathbf{1}.\, WSDR = \frac{Relative\ WeedDensity\ (RWD) + Relative\ Weed\ Dry\ Biomass(RWDB)}{2}$$

$$\mathbf{2}.\, RWD = \frac{Density\ of\ a\ given\ weed\ species}{Total\ Weed\ Density}\ ^{x}\ 100$$

$$\mathbf{3}.\, RWDB = \frac{Dry\ Biomassof\ a\ Given\ Weed\ Species}{Total\ Weed\ Dry\ Biomass}\ ^{x}\ 100$$

At the time of harvest, area of about 1 m2 were randomly selected in each plot to measure agronomic data of yield and yield contributing traits including the number of fertile tillers, plant height, panicle length, kernel per panicle, straw yield and kernel yield from each plot. A numberer of fertile tillers was counted per ten hills, and number of kernels were counted per ten panicles. Plant height from leaf tip to ground surface and length of panicle was measured in cm for ten hills while, straw and kernel yield was measured in kg and converted into tons per hectare.

Statistical analysis

Collected data during both years (2010 and 2011) regarding weed growth dynamics and agronomic traits was subjected to statistical analysis. Mixed linear model (equation 4) was used for analysis of variance (ANOVA) for all measurements related weed growth and agronomic traits on the basis of seedling age and weed competition periods.

$$\mathbf{4}.\ \ Y_{ijk} = \mu + WCP_i + SA_j + R_k + \mathcal{E}_{ij}$$

Where Y_{ij} = the value of the measurements for the j^{th} weed competition period i^{th} Seedling age in the k^{th} replication where i = 1, 2, 3; j = 1, ..., 6; and k = 1, 2, 3; μ = total mean (constant), R_k = effect of the kth replication (random effect) on the response measurement, WCP_j = effect of the i^{th} weed competition period (fixed effect) on the response measurement SA_j = effect of the j^{th} seedling age (fixed effect) on the response measurement, and $\mathcal{E}_{ij}$ = effect of the experimental error associated with ij^{th} observation. All analyses were performed in R. 3.4.4 (R Core Team [R], 2018). The lmer function in the lme4 package was used for analysis of variance (ANOVA) test (Bates et al., 2018). The mean separation analysis on the basis of region of origin of carrot accession was performed using LSD. test function found in the agricolae package with alpha = 0.05 (De Mendiburu, 2014). Figures were drawn using ggplot2 (Elegant graphics) package R. 3.4.4. (Chadhar et al., 2020).

Results

Weed growth characteristics

Seedling age and weed competition periods significantly (P ≤ 0.001) affected the weed growth characteristics (weed density and weed dry biomass) of three perilous weeds including purple nutsedge (*C. rotundus*), broad-leaved black pigweed (*T. portulacastrum*), *and jungle rice* grass weed (*E. colona*) in RIS (rice intensification system) field. Interactive effect of seedling age and weed competition period (SA x WCP) on weed growth characteristics was highly significant (*P* ≤ 0.0001) in both growing years (Table 1). A strong association of 90.6% and 90.4% was observed between total density of three weeds and weed competition periods during 2010 and 2011(Figure 2 a and b). It was observed in present study that total weed density was minimum (< 10 m^{-2}), when the combination was SA_2×WCP_1 (21 days and 20 DAT) during both growing years. Total weed density in RIS fields was gradually increased with increase in age of rice seedlings from SA_2 to SA_3 (21 days to 28 days) and weed competition period from WCP_1 to WCP_5 (20 DAT to complete growth period). Total weed density reached to more than 110 weed plants m^{-2} during both growing years (2010 and 2011), when the combination was SA_3× WCP_5 i.e. 28 days and complete weed growth or weedy check respectively (Figure 3 a & b). Similar trend was observed for individual density of three weeds (*C. rotundus, T. portulacastrum,* and *E. colona*) with reference to seedling ages and weed competition periods during both growing years. However, the maximum weed density was recorded for *C. rotundus* (74.7 m^{-2} and 75.0 m^{-2}) followed by *T. portulacastrum* with 19 and 23 plants m^{-2} during both experimental years of study respectively. *E. colona* exhibited less number of plants i.e. 9 and 8 m^{-2} during 2010 and 2011 among all three weeds under rice intensification system respectively (Figure 4 a-f).

Table 1
Mean square values of two-factorial (seedling age: SA and weed competition period: WCP) ANOVA for eed growth characteristics under rice intensification system.

SOV	DF	Weed density	Weed dry biomass
SA	2	172.66**	398.21**
WCP	4	96.87**	72.34**
SA × WCP	8	529.53***	638.45***
Error	64	1.96	3.87

SOV: Source of variation, DF: Degree of freedom, ***: Significant P ≤ 0.0001, **: Significant P ≤ 0.001, *: Significant P ≤ 0.05.

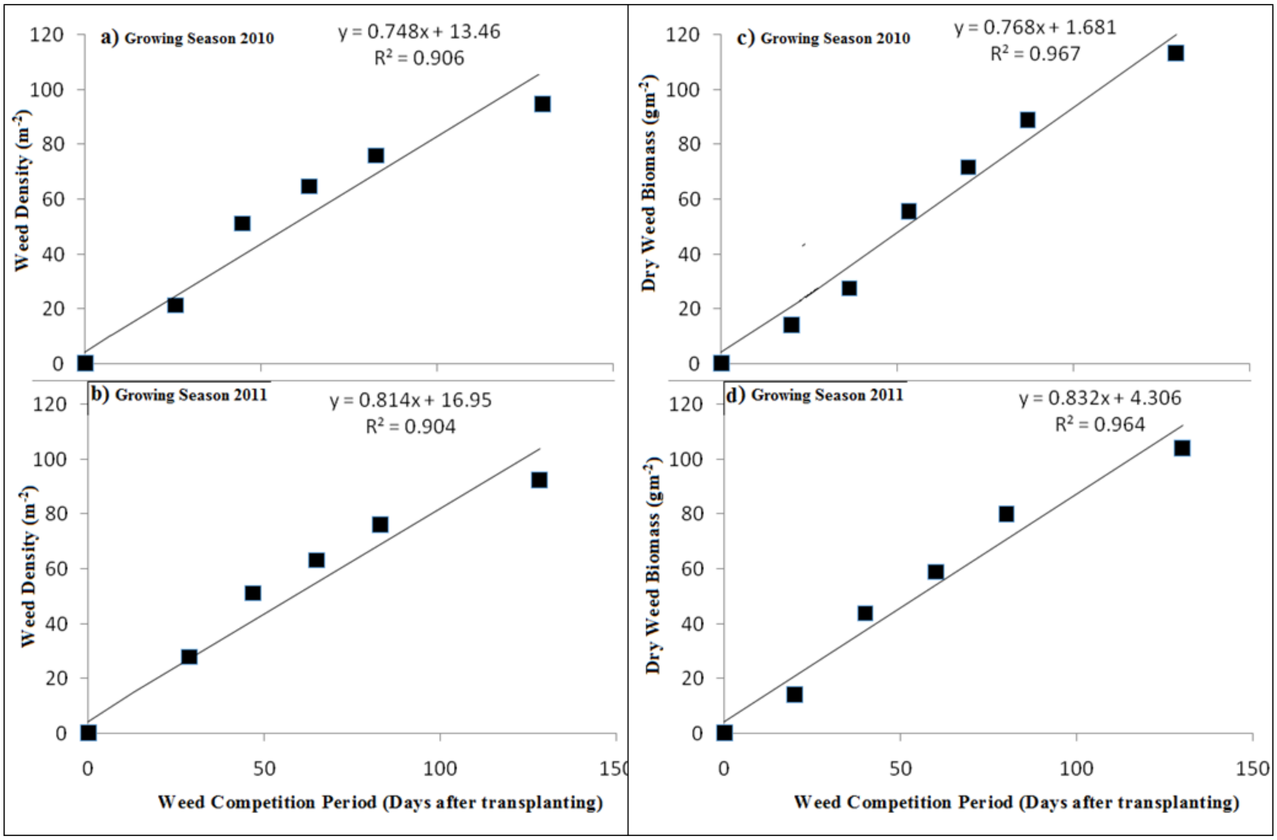


Figure 2. Relationship among competition period and (a) total weed density during 2010, (b) total weed density during 2011, (c) total weed dry biomass during 2010, and (d) total weed density during 2011 under rice intensification system.

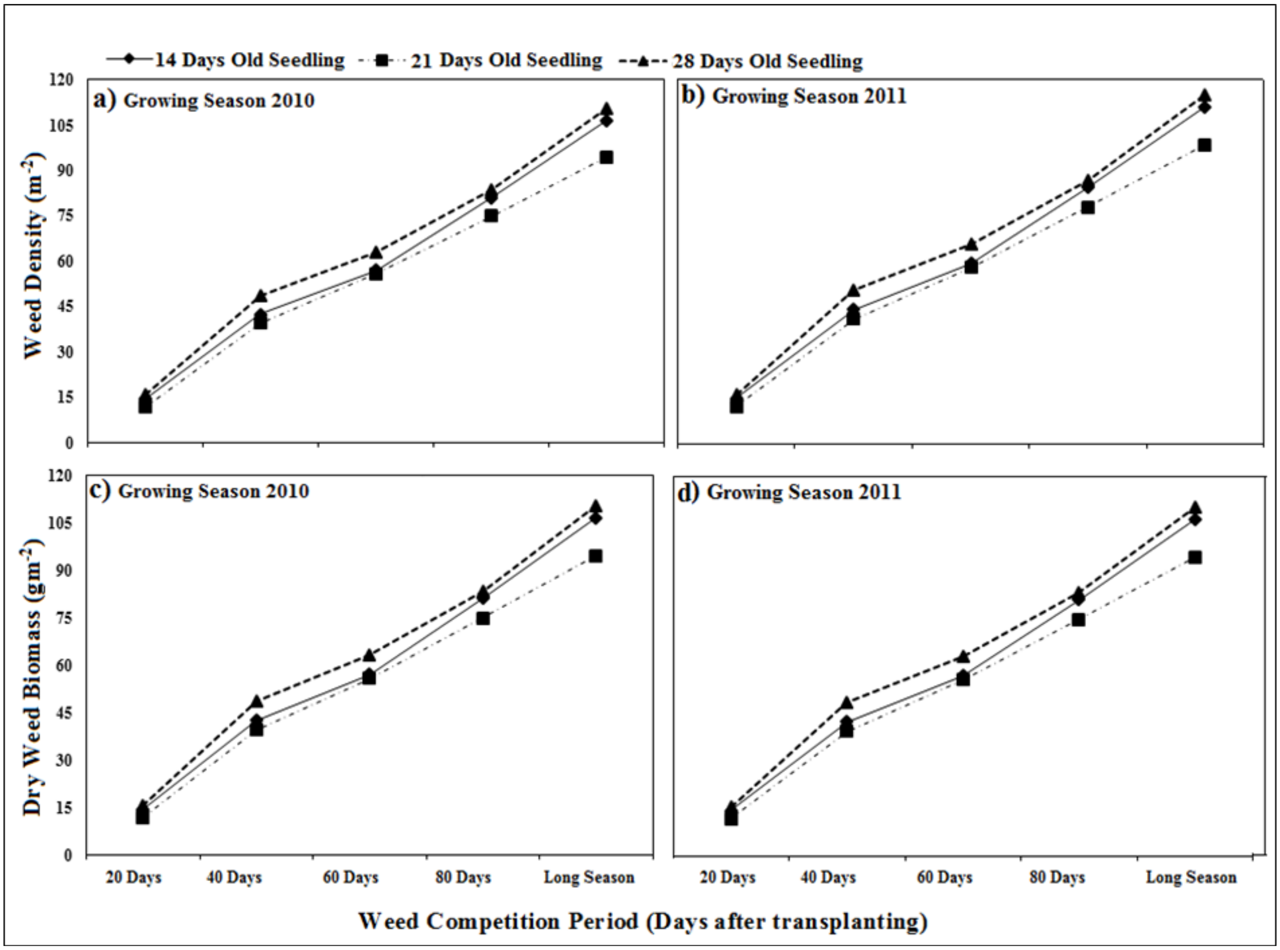


Figure 3. Effects of different weed competitions and age of transplanted seedlings on (a) total weed density during 2010 (b) total weed density during 2011, (c) total weed dry biomass during 2010, and (d) total weed dry biomass during 2011 under rice intensification system.

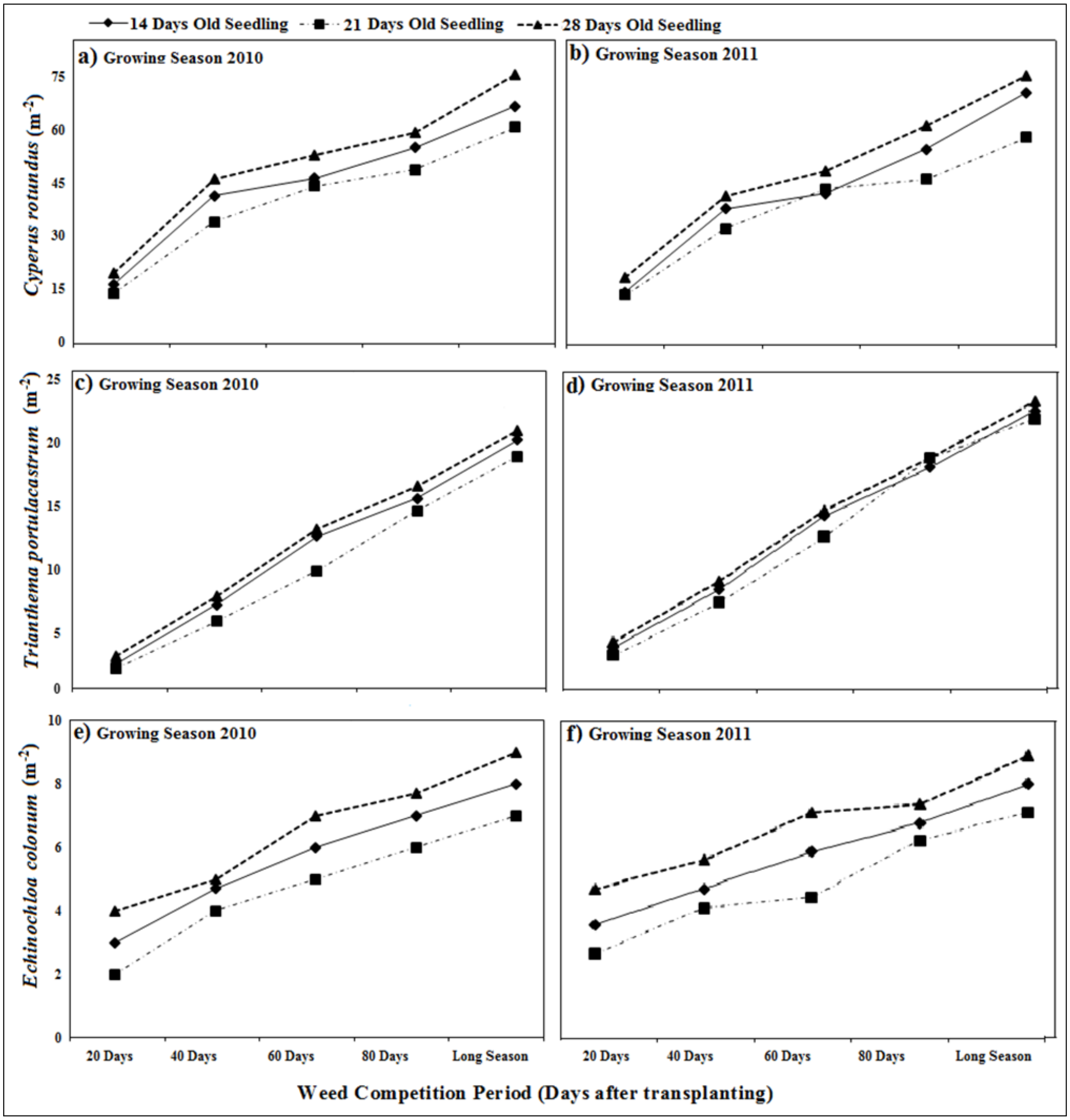


Figure 4. Effects of different weed competitions and age of transplanted seedlings on (a) individual density of C. rotundus during 2010 (b) individual density of C. rotundus during 2011, (c individual density of T. portulacastrum during 2010, (d) individual density of T. portulacastrum during 2011, (e) individual density of E. colona during 2010 and (f) individual density of E. colona during 2011 under rice intensification system.

Furthermore, weed dry biomass was found to be in strong association (96.7% and 96.4%) with weed competition periods (Figure 2 c and d). Like weeds density, total dry weed biomass was also minimum (< 15 gm^{-2}) at SA_2×WCP_1 and maximum at SA_3× WCP_5 (> 100 gm^{-2}) during both growing years (Figure 3 c and d). Individual dry biomass of three weeds (*C. rotundus, T. portulacastrum,* and *E. colona*) exhibited similar trend like individual weed density with respect to different combinations of seedling ages and weed competition periods during both growing years. *C. rotundus* produced maximum dry biomass (64.2 gm^{-2} and 69.7 gm^{-2}) followed by *T. portulacastrum* (27.2 gm^{-2} and 29.7 gm^{-2}) and *E. colona* (16.4 gm^{-2} and 18.3 gm^{-2}) during 2010 and 2011 respectively (Figure 5 a-f).

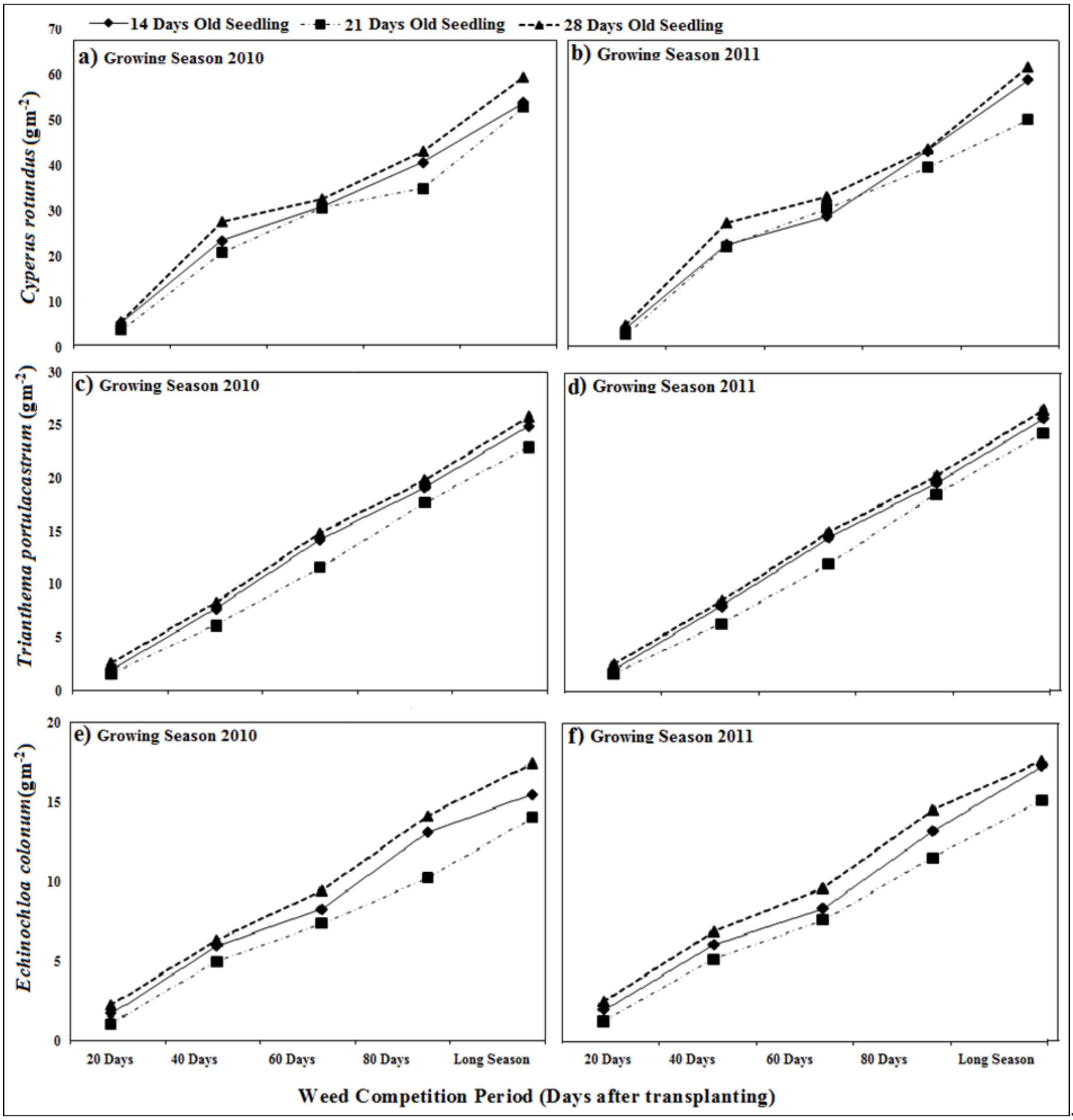


Figure 5. Effects of different weed competitions and age of transplanted seedlings on (a) individual dry biomass of *C. rotundus* during 2010 (b) individual dry biomass of *C. rotundus* during 2011, (c individual dry biomass of *T. portulacastrum* during 2010, (d) individual dry biomass of *T. portulacastrum* during 2011, (e) individual dry biomass of *E. colona* during 2010, and (f) individual dry biomass of *E. colona* during 2011 under rice intensification system

Relative proportion and summed dominance of three weeds

Percentage based relative proportion of three weeds in total weed density and total weed dry biomass at five weed competition periods in 14, 21, and 28 days old transplanted seedlings of rice during two consecutive growing years (2010 and 2011) was expressed in figure 6. A sedge weed (*C. rotundus*) exhibited > 70% of total weed density and >50% of total weed dry biomass, higher than other two weeds during 2010 and 2011. Relative proportion of sedges weed's density and dry biomass were maximum at 40 days weed competition period during both growing years of study. Broad-leaved weed (*T. portulacastrum*) presented minimum relative proportion of total weed's density and dry biomass at 20 days weed competition period. Grass weed (*E. colona*) showed the maximum relative proportion of total weed's density and dry biomass during 20 days weed competition period between 2010 and 2011. The Relative proportion of total weed's density and dry biomass of grass weed were statistically at par at 40, 60 and 80 days competition periods in both years.

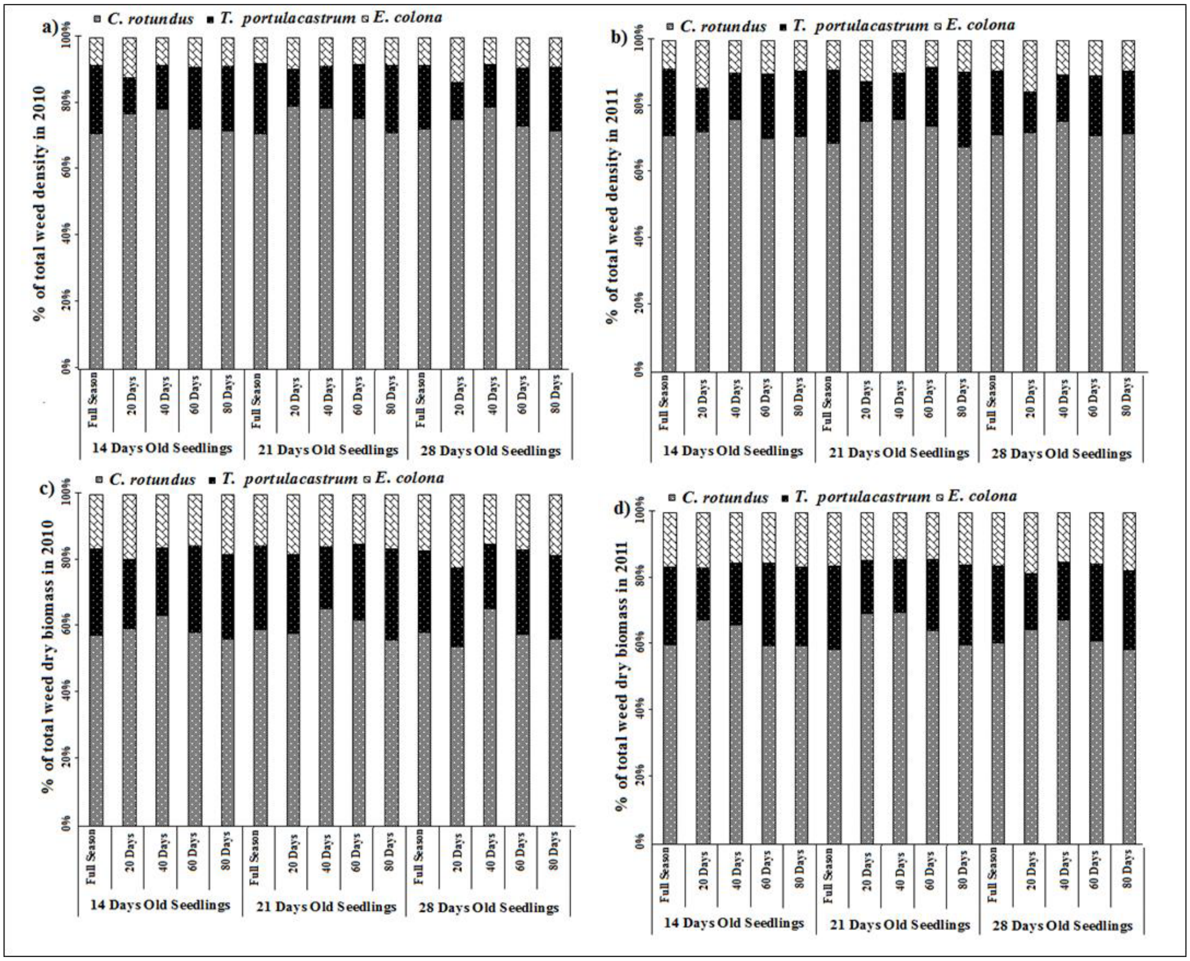
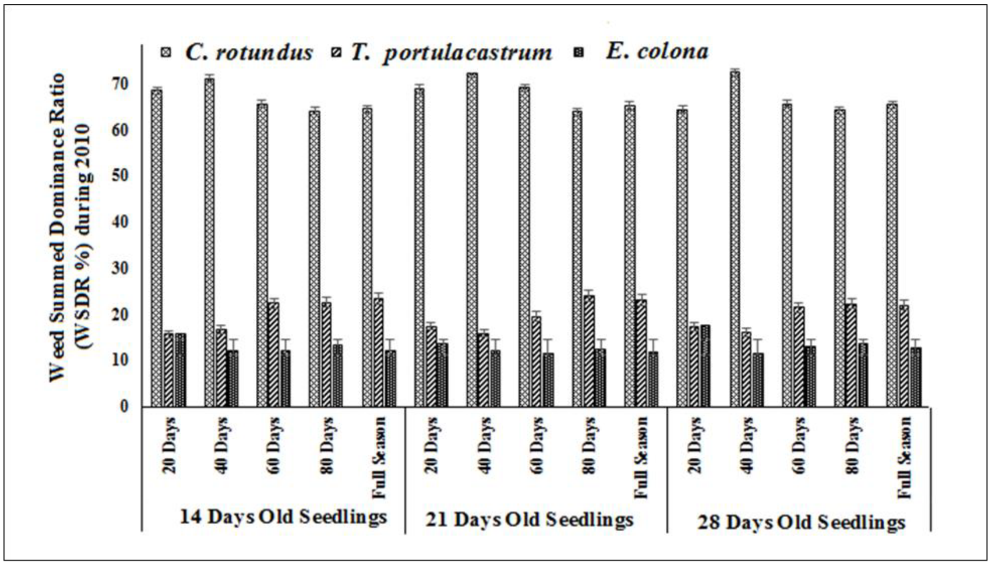


Figure 6. Relative proportion of each weed in (a) total weed density during 2010 (b) total weed density during 2011, (c) total weed dry biomass during 2010, and (d) total weed dry biomass during 2011 under rice intensification system.

Weed summed dominance ratio (WSDR) of three weeds under consideration under rice intensification system was presented in figure 7. Sedges species (C. rotundus) was the most dominating weed with 63% to 73% summed dominance ratio in rice at each competition period and seedling ages followed by broad-leaved and grass weeds presenting 14% to 23% and 11% to 17% WSDR ratio during 2010 and 2011. Moreover, summed dominance ratio of sedge weed was maximum at 40 days competition period while broad-leaved and grass weed exhibited maximum WSDR ratio at 60, 80 and full season competition periods. Figure 6 also indicates that summed dominance ratio of all weeds were a little bit lower in rice field where 21 days old seedlings were planted.



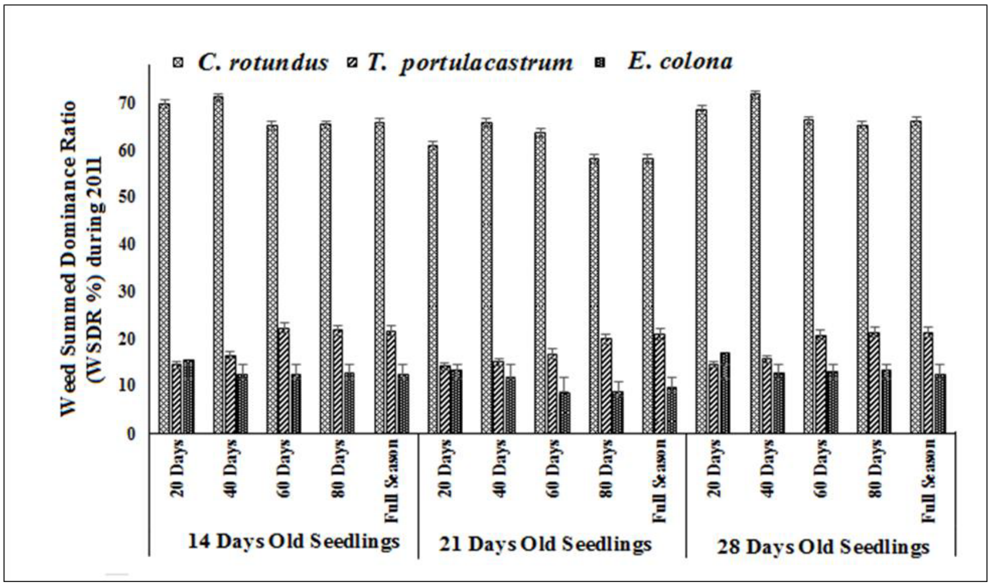


Figure 7. Relative proportion of each weed in (a) total weed density during 2010 (b) total weed density during 2011, (c) total weed dry biomass during 2010, and (d) total weed dry biomass during 2011 under rice intensification system.

Agronomic traits of rice

Seedling age and weed competition periods significantly (*P* ≤ 0.001) affected the agronomic traits (fertile tillers hill^{-1}, plant height, panicle length, kernel panical^{-1}, straw yield and kernel yield) of rice under rice intensification system. Interactive effect of seedling age and weed competition period (SA x WCP) on all agronomic traits also remained highly significant (P ≤ 0.0001) (Table 2). Outcomes of this study indicated that number of fertile tillers per hill (58.1 and 56.0), plant height (130.5 cm and 125.6 cm), kernel per panicle(186.4 and 179.4), straw yield(7.8 ton ha^{-1} and 7.5 ton ha^{-1}), and kernel yield (5.2 ton ha^{-1} and 5.0 ton ha^{-1}) were higher in plants harvested from experimental unit where 21 days old seedlings were transplanted and weeds were removed throughout the growing season (SA_2 × WCP_6) during both growing years. A linear decline was recorded in agronomic traits with increase in age of transplanted seedlings from 21 days to 28 days during both years. Minimum values for all agronomic traits were recorded in plants harvested from experimental units where 28 days old seedlings were transplanted and weeds were not removed throughout the growing season (SA_3 × WCP_5) during both years i.e. 2010 and 2011. Data indicated that plants harvested from experimental unit with no weed infestation throughout the growing season showed highest kernel yield i.e. 4.9 ton ha^{-1}, 5.2 ton ha^{-1}, and 4.9 ton ha^{-1} during 2010 and 4.7 ton ha^{-1}, 5.0 ton ha^{-1}, and 4.7 ton ha^{-1} during 2010 and 2011 from 14, 21, and 28 days old transplanted seedlings respectively (Table 3). Yield losses due to various weed competition periods or weed infestation level during 2010 and 2011 in figure 8. It was observed that minimum yield losses were recorded in rice plant harvested from RIS fields where 21 days old seedlings were transplanted with 20 days of weed infestation during both years.

Table 2
Mean square values of two-factorial (seedling age: SA and weed competition period: WCP) ANOVA for agronomic traits of rice crop under rice intensification system.

SOV	DF	Fertile tillers hill^{-1}	Plant height	Panicle length
SA	3	62.66*	93.12**	53.27**
WCP	5	6.87**	6.034**	5.27**
SA × WCP	15	39.53***	23.97***	16.29*
Error	225	0.81	0.027	0.05
SOV	**DF**	**Kernels panicle^{-1}**	**Straw yield**	**Kernel yield**
SA	3	11.24**	76.21**	34.16**
WCP	5	9.24***	31.42**	11.20**
SA × WCP	15	29.14**	93.66***	28.28**
Error	225	0.52	3.12	0.22

SOV: Source of variation, DF: Degree of freedom, ***: Significant P ≤ 0.0001, **: Significant P ≤ 0.001, *: Significant P ≤ 0.05

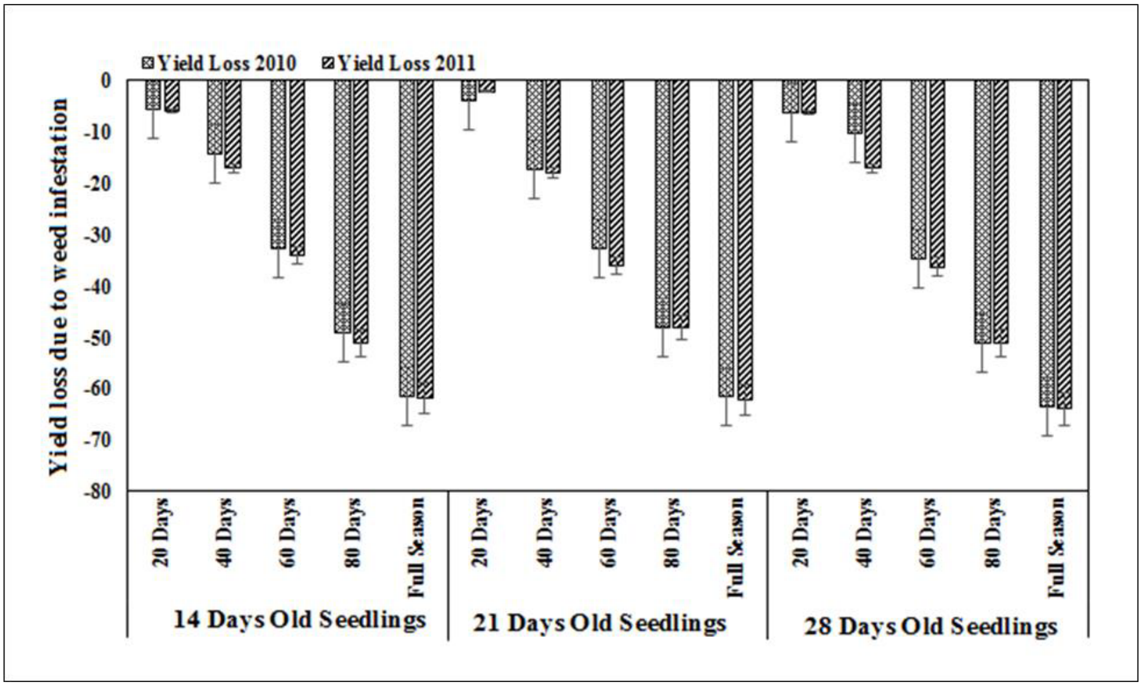


Figure 8. Effects of different weed competitions and age of transplanted seedlings on yield losses during 2010 and 2011 under rice intensifications.

Table 2

Mean square values of two-factorial (seedling age: SA and weed competition period: WCP) ANOVA for agronomic traits of rice crop under rice intensification system.

Treatments		Tillers hill^{-1}		Plant height (cm)		Panicle length (cm)		Kernels panicle^{-1}		Straw yield (ton ha^{-1})		Kernel yield (ton ha^{-1})	
Seedling Age	Weed competition period (DAT)	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
SA1	WCP1	47.9c	45.4bc	117.1b-e	116.8bc	28.8de	28.2c	159.7c	153.4cd	7.0cd	6.9b	4.7cd	4.6c
	WCP2	38.6ef	38.0de	114.8c-f	110.3c-f	26.6f	26.2d	153.3cd	147.1d	6.4e	5.9e	4.2f	3.9ef
	WCP3	29.5h	27.9fg	108.6efg	106.4efg	23.6gh	22.0fg	126.4g	116.4f	5.0fg	4.8f	3.3h	3.1g
	WCP4	20.0jk	18.3hi	98.2h	92.6hi	20.0j	18.4hi	97.3i	94.6h	3.9hi	3.6i	2.5j	2.3j
	WCP5	16.8jk	16.0i	80.7i	75.8j	16.9l	16.5j	71.4k	65.9j	3.0j	2.8j	1.9k	1.8kl
	WCP6	54.9ab	49.6b	124.7ab	120.4ab	31.1bc	30.7ab	175.5b	71.6b	7.2b	7.1b	4.9b	4.7b
SA2	WCP1	51.4bc	48.3b	122.9abc	120.3ab	31.7ab	30.9ab	179.0ab	174.4ab	7.3b	7.1b	4.9b	4.7b
	WCP2	40.0def	37.6de	117.2b-e	115.9bcd	27.0f	26.6d	161.2c	157.0c	6.3e	6.1d	4.3ef	4.1e
	WCP3	31.1gh	29.3fg	113.0def	110.3c-f	24.2g	23.3ef	141.1f	137.2e	5.2f	4.9f	3.5g	3.2g
	WCP4	22.1ij	19.9hi	100.9gh	99.6gh	20.7ij	19.6h	108.9h	104.1g	4.1h	3.9h	2.7i	2.6i
	WCP5	20.3jk	19.0hi	85.3i	79.9j	18.2kl	17.2ij	85.2j	83.0i	3.0j	2.9j	2.0k	1.9k
	WCP6	58.1a	56.0a	130.5a	125.6a	32.8a	32.1a	186.4a	179.4a	7.8a	7.5a	5.2a	5.0a
SA3	WCP1	41.4de	40.1cd	116.2b-e	113.1cde	27.6ef	27.4cd	150.9de	146.6d	6.9d	6.6c	4.6d	4.4d
	WCP2	35.8fg	32.9ef	112.3def	108.9def	25.0g	24.2e	144.1ef	137.8e	6.5e	5.8e	4.4e	3.9f
	WCP3	26.6hi	23.7gh	107.6fg	104.7fg	22.2hi	21.8g	118.8g	114.7f	4.8g	4.6g	3.2h	3.0h
	WCP4	17.9jk	16.3i	97.4h	90.1i	18.5k	18.2hi	93.3ij	86.9i	3.7i	3.5i	2.4j	2.3j
	WCP5	15.7k	15.2i	79.5i	74.0j	16.7l	16.1j	65.3k	58.3k	2.8j	2.6j	1.8k	1.7l
	WCP6	45.4cd	44.0bc	119.7bcd	115.4bcd	30.1cd	29.8b	161.1c	157.4c	7.2bc	6.9b	4.9bc	4.7b

The means in a column which are not sharing the same differ significantly from one another at probability level of 0.05, Seedling age (SA1=14; SA2=21 and SA3=28 days), weed competition period (WCP1= 20 DAT (days after transplanting), WCP2= 40 DAT(days after transplanting) , WCP3= 60 DAT(days after transplanting), WCP4= 80 DAT(days after transplanting), WCP5= weedy check/ control, WCP6= weed free throughout growing season).

Discussions

Weeds are a major biotic challenge for rice breeders as total of 350 plant species has been reported as weeds of rice (Nadeem et al., 2021a). In Pakistan, 11.5% yield losses in rice were reported due to weed infestation (Rabbani et al., 2011; Nadeem et al., 2020d; Maqbool et al., 2022c). Other rice growing Asian countries including China, India and Bangladesh are also facing yield losses in rice due to weed infestation (Rabbani et al., 2011). Different conventional and technical managements were practiced to avoid yield losses of rice in response to weed infestation but results were not satisfactory during last decades. Globally, 23% of total rice are being cultivated by direct seeding (DS) but in dry season DS gives $1/4^{th}$ (< 60%) of normal production that reaches to 100% in response to severe weed infestation (Rao et al., 2007; Farooq et al., 2011).

Seedling emergence and establishment from direct seeding is more critical in comparison of seedling transplantation due to various abiotic and biotic stresses including weed infestation (Farooq et al., 2011). This study focuses on seedling age used for transplantation and competition periods of three weeds (*C. rotundus, T. portulacastrum,* and *E. colona*) to avoid yield losses. Significant variation in weed density and dry biomass existed among different seedling ages and weed competition periods during two growing years (Table 1). Weed density and dry biomass were increased in response to increasing seedling age and extending the weed competition periods (Figure 3-5). It is probably due to consumption of available resources only by weeds which facilitates the more and fast weed emergence and growth in case of late transplantation of older seedlings. On the other hand, early transplanted seedlings compete with weeds and utilize the available resources and lowers the weed population. Moreover, weed density increases with increasing the weed competition period because more seeds can germinate from seed bank of weed in soil with time extension. Likewise, dry biomass of weeds increased with late transplantation of older seedlings and extended competition period due to less competition offered by rice crop. On the other hand, weed dry biomass was decreased by early plantation of young seedlings and early weed control (Figure 3-5).

Weed control lessens the competition among crop and weeds and improves growth and development of crop plants while if weeds are not controlled, they may absorb and utilize the available resources and disrupt the growth and development of rice (Chadar et al., 2022). In present study, weeds density and dry biomass was maximum in RIS fields where 28 days old seed were transplanted (Figure 3-5). It may be due to no competition between weeds and rice plants resulting in the maximum utilization of nutrients and water than rice seedlings in plots where weeds are present. s (Dass et al., 2017; Jat et al., 2019). The Present study also revealed that 21 days old seedlings enjoyed more growth with appropriate biomass production and inhibited the growth flourishment of weed population (Figure 3-5). These findings also confirmt seedling transplantation time is more or less controlled by genetic factors which are positively regulated by early transplantation and limits their expression during delayed transplantation (Koo et al., 2013).

Furthermore, the relative proportion of total weed's density and total dry biomass for all three weeds was evaluated and weed summed dominance ratio (WSDR) to know the dominance ranked and individual contribution of each weed towards rice yield losses. During both growing years (2010 and 2011), maximum relative proportion was expressed by purple nutsedge weed followed by broad-leaved black pigweed (*T. portulacastrum*) and jungle rice grass weed (*E. colona*) (Figure 6). Similar trend was observed by each weed in weed summed dominance ratio and purple nutsedge was ranked first, black pigweed and jungle rice weed remained second and third in WSDR ranking respectively (Figure 7). A similar ranking for sedges, broad-leaved and grass weeds was reported by (Juraimi et al., 2009) and this variation among weeds dominating ability could be attributed to their genetic potential of competitiveness for utilization of available resources (Olajumoke et al., 2016).

In the rice intensification system, biomass production and kernel yield were drastically reduced to > 60% with longer weeds presence throughout growth season (figure 8). Previous evaluations also reported severe rice yield losses when weeds were left unrestrictedly (Chadar et al., 2022). This may happened due to severe and long term weed competition because weed population get flourished and denser due to availability of more germination time of seeds from weed seed bank in soil (Chadar et al., 2020). Rice biomass and kernel production were also severely affected during both years (2010 and 2011) at each competition period in comparison to weed free condition or no weed infestation (Table 3). These findings confirms the rice sensitivity towards weed infestation that might be attributed to C_3 nature of rice crop and have cannot compete weeds (C_4) effectively for available resources. C_4 (weeds) are grow quickly due to more efficient photosynthesis, suppressed photorespiration and more economical in water use than C_3 (rice) plants (Levey et al., 2019). In present study, minimum yield losses were recorded at 20 days of weed competition period (Table 3; Figure 8), as previously reported by Chadar et al. (2020) under rice intensification system because crop plants face less weed pressure if they removed earlier. With reference to seedling age, minimum yield losses were observed in 21 days old transplanted plants in comparison to 14 and 28 days old transplanted plants. Fourteen days old seedlings suffered longer weed competition and were not enough mature to bare the weed pressure as well while 28 days old seedlings facilitated the more weed germination and their initial establishment with no competition. Vigorous growth and establishment was observed in 21 days old seedlings with maximum production of fertile tillers per hill, biomass and kernel production at 20 days competition period in comparison to 14 and 28 days old transplanted seedlings during both years (Table 3; Figure 8) as they were physiologically mature enough and genetically active to compete and overcome the weed pressure (Chadhar et al., 2020).

Conclusion

Rice is an important crop and interaction between plant age and weed density significantly affected the crop yield. The evidence from this study suggested that 21 days old fine rice should be transplanted and weed should be controlled within 20 DAT under SRI for better control of weed and to avoid yield losses.

References

Ali, A., Arooj, K., Khan, B. A., Nadeem, M. A., Imran, M., Safdar, M. E., Amin, M. M., A. Aziz, A. & Ali, M. F. (2021). Optimizing the growth and yield of mungbean (*Vigna radiata* l.) cultivars by altering sowing dates. *Pakistan Journal of Agricultural Research, 34*(3), 559-568. doi: 10.17582/journal.pjar/2021/34.3.559.568

Arooj, M., Khan, B. A., Nadeem, M. A., Javaid, M. M., Rashid, E., Jilani, M. S. Qamar, J., Ali, F., Javaria S., & M. Faisal (2021). Low Doses of atrazine cause hormesis in tribulus terrestris. *Pakistan Journal of Weed Science Research, 27*(3), 351-358. doi: 10.28941/pjwsr.v27i3.983

Bates, D., Maechler, M., Bolker, B., Walker, S., Christensen, R. H. B., Singmann, H., Dai, B., Scheipl, F., Grothendieck, G., & Green, P. (2018). Linear mixed-effects models using 'Eigen' and S4. *R Package, Version, 17*(1), 42-44. doi: 10.1205/18752160-1273090

Chadhar, A. R., Nadeem, M. A., Ali, H. H., Safdar, M. E., Raza, A., Adnan, M., Hussain, M., Ali, L., Kashif, M. S. & Javaid, M. M. (2020). Quantifying the impact of plant spacing and critical weed competition period on fine rice production under the system of rice intensification. *International Journal of Agriculture and Biology, 24*(5), 1142-1148. doi: 10.17957/IJAB/15.1543.

Dass, A., Shekhawat, K., Choudhary, A. K., Sepat, S., Rathore, S. S., Mahajan, G., & Chauhan, B. S. (2017). Weed management in rice using crop competition-a review. *CropProtection, 95*(1), 45-52. doi: 10.1016/j.cropro.2016.08.005

De Mendiburu, F. (2014). Agricolae: statistical procedures for agricultural research. *R Package Version, 1*(1), 1-4. doi: 10.1215/18752162-1273070

Farooq, M., Siddique, K. H., Rehman, H., Aziz, T., Lee, D. J., & Wahid, A. (2011). Rice direct seeding: experiences, challenges and opportunities. *Soil and Tillage Research, 111*(2), 87-98. doi: 10.1016/j.still.2010.10.008

Food and Agriculture Organization of United Nations (2019). *World food and agriculture statistical pocketbook.* FAO.

Fukagawa, N. K., & Ziska, L. H. (2019). Rice: importance for global nutrition. *Journal of Nutritional Science and Vitaminology, 65*(Suppl.), S2-S3. doi: 10.3177/jnsv.65.S2

Glover, D. (2011). A system designed for rice? Materiality and the invention/discovery of the system of rice intensification. *East Asian Science, Technology and Society: an International Journal, 5*(2), 217-237. doi: 10.1215/18752160-1273080

Jat, R. K., Singh, R. G., Gupta, R. K., Gill, G., Chauhan, B. S., & Pooniya, V. (2019). Tillage, crop establishment, residue management and herbicide applications for effective weed control in direct seeded rice of eastern Indo-Gangetic Plains of South Asia. *Crop Protection, 123*(1), 12-20. doi: 10.1016/j.cropro.2019.05.007

Javaid, M. M., Mahmood, A., Alshaya, D. S., AlKahtani, M. D., Waheed, H., Wasaya, A., Khan, S. A., Naqvi, M., Haider, I., Shahid, M. A., Nadeem, M. A., Azmat, S., Khan, B. . A., Balal, R. M., Attia, K. A., & Fiaz, S. (2022). Influence of environmental factors on seed germination and seedling characteristics of perennial ryegrass (*Lolium perenne* L.). *Scientific Reports, 12*(1), 1-11. doi: 10.1016/j.cropro.2022.05.007

Javaid, M. M., Mahmood, A., Alshaya, D. S., AlKahtani, M. D., Waheed, H., Wasaya, A., Khan, S. A., Naqvi, M., Haider, I., Shahid, M. A., Nadeem, M. A., Azmat, S., Khan, B. A., Balal, R. M., Attia, K. A., & Fiaz, S. (2022). Influence of environmental factors on seed germination and seedling characteristics of perennial ryegrass (*Lolium perenne* L.). *Scientific Reports, 12*(1), 1-11. doi: 10.1071/FP19338

Johnson, D. E., Wopereis, M. C. S., Mbodj, D., Diallo, S., Powers, S., & Haefele, S. M. (2004). Timing of weed management and yield losses due to weeds in irrigated rice in the Sahel. *Field Crops Research, 85*(1), 31-42. doi: 10.1016/S0378-4290(03)00124-2

Krishna, A. (2008). Influence of system of rice intensification (SRI) cultivation on seed yield and quality. *Karnataka Journal of Agricultural Science, 21*(3), 369-372. doi: 10029236058

Levey, M., Timm, S., Mettler-Altmann, T., Luca Borghi, G., Koczor, M., Arrivault, S., & Westhoff, P. (2019). Efficient 2-phosphoglycolate degradation is required to maintain carbon assimilation and allocation in the C4 plant Flaveria bidentis. *Journal of Experimental Botany, 70*(2), 575-587. doi: 10.1093/jxb/ery370

Maqbool, R., Anwar, I., Nadeem, M. A., Inqalabi, T. E. I., Raza, A., Khan, B. A., Raza, M. Irfan, A. U. Rehman & Abbas, M. (2022b). Exploring the phytotoxic effects of *Glycyrrhiza glabra* l. on emergence and seedling growth of *Pisum sativum* L. *Pak. J. Weed Sci. Res, 28*(3), 213-220. doi: 10.28941/pjwsr.v28i3.1044

Maqbool, R., Anwar, I., Nadeem, M. A., Inqalabi, T. I., Raza, A., Khan, B. A., Hassan, A., Rehman A. U., & Saeed, H. Z. (2022c). Identifications of phenolic compounds and allelopathic effect of *Glycyrrhiza glabra* on germination and seedling growth Phalaris minor. *Pak. J. Weed Sci. Res, 28*(3), 221-229. doi: 10.28941/pjwsr.v28i3.1045

Maqbool, R., Khan, B. A., Nadeem, M. A., Parvez, S., Amin, M. M., Qamar, J., Hassan, A., Elahi, M. A., Haider, J., Irfan M., & Shahid, M. G. (2021c). Allelopathic effect of Cinnamomum verum on emergence and seedling growth of radish. *Pakistan Journal of Weed Science Research, 27*(4), 485-494. doi: 10.28941/pjwsr.v27i4.975

Maqbool, R., Khan, B. A., Naqi, A. H., Nadeem, M. A., Qamar, J., Nijabat, A., Inayat, I., din, M., Amin, M. M., Sohail, M. K., Shaheen, M., & Parvez, S. (2022a). Exploring the allelopathic effect of *Cinnamomum verumon* emergence and seedling growth of wild pea (*Pisumsativum subsp. elatius*). *Pakistan Journal of Weed Science Research, 28*(1), 19-28. doi: 10.28941/pjwsr.v28i1.976

Maqbool, R., Khan, B. A., Parvez, S., Nadeem, M. A., Din, M. M., Qamar, J., Waqas, M., Amin M. M., & Khalid, B. (2021b). Identifying the hermetic potential of Khatami (*altheae officinalis*) emergence and seedling growth of wild pea (pisum l. sativum subsp. elatius). *Pakistan Journal of Weed Science Research, 27*(3), 331-340. doi: 10.28941/pjwsr.v27i3.973

Maqbool, R., Khan, B. A., Parvez, S., Nadeem, M. A., Hassan, A., Qamar, J., Nawaz, A., Adnan, M., Khalid, R. & Usman, M. (2021a). Exploring the allelopathic and hermetic effect of khatami (*Altheae officinalis*) on emergence and seedling growth of radish (*Raphanus sativus*). *Pakistan Journal of Weed Science Research, 27*(3), 321-330. doi: 10.28941/pjwsr.v27i3.965

Menete, M. Z. L., Van Es, H. M., Brito, R. M. L., DeGloria, S. D., & Famba, S. (2008). Evaluation of system of rice intensification (SRI) component practices and their synergies on salt-affected soils. *Field Crops Research, 109*(1-3), 34-44. doi: 10.1016/j.fcr.2008.06.003

Mishra, A., & Salokhe, V. M. (2008). Seedling characteristics and the early growth of transplanted rice under different water regimes. *Experimental Agriculture, 44*(3), 365-384. doi: 10.1017/S0014479708006388

Nadeem, M. A., Khan, B. A., Afzal, S., Abbas, H., Dar, M. K., Safdar, M. E., Hassan, I., Asif, M., Adnan, M., & Aziz, A. (2020c). Allelopathic influence of Poppy (*Papaver somniferum* L.) on emergence and initial seedling growth of Red Rice (*Oryza punctata* L.). *Pakistan Journal of Weed Science Research, 26*(4), 381-392. doi: 10.28941/pjwsr.v26i4.850

Nadeem, M. A., Khan, B. A., Afzal, S., Aziz, A., Maqbool, R., Amin, M. M., Aziz, A., Ali, A., Adnan, M., & Durrishahwar. (2020b). Allelopathic effects of aqueous extracts of *Carthamus tinctorius* L. on emergence and seedling growth of *Echinochloa crus-galli* L. *Pakistan Journal of Weed Science Research, 26*(3), 365-379. doi: 10.28941/pjwsr.v26i3.861

Nadeem, M. A., Khan, B. A., Afzal, S., Khan, M. A., Abbas, T., Javaid, M. M., Amin, M. M., Farooq, N., & Azim, A. (2020a). Effect of aqueous extract of *Carthamus tinctorius* L. on germination and initial seedling growth of *Oryza punctata* L. *Pakistan Journal of Weed Science Research, 26*(3), 331-342. doi: 10.28941/pjwsr.v26i3.849

Nadeem, M. A., Khan, B. A., Afzal, S., Maqbool, R., Waheed, H., Nijabat, A., Ikram, M., Aziz, A., Adnan, M., Mehmood, Q., & Umer, H. (2021c). Allelopathic effects of *Papaver somniferum* on germination and initial seedling growth of *Echinochloa cruss-galli. Pakistan Journal of Weed Science Research, 27*(2), 239-252. doi: 10.28941/pjwsr.v27i2.951

Nadeem, M. A., Khan, B. A., Anwar, S., Abbas, H., Yasin, M., Maqbool, R., Amin, M. M., Aziz, A., Hayyat, M. S., & Javed, M. S. (2020d). Phytotoxic effects of *Sonchus oleraceus* on emergence and seedling growth of *Echinocloa cruss-galli. Pakistan Journal of Weed Science Research, 26*(4), 433-446. doi: 10.28941/pjwsr.v26i4.882

Nadeem, M. A., Khan, B. A., Anwar, S., Aziz, A., Maqbool, R., Safdar, M. E., Javaid, M. M., & Aziz, A. (2021a). Assessing the allelopathic potential of milk thistle (*Sonchus oleraceus* L.) on germination and seedling growth of red rice (*Oryza punctata* L.). *Pakistan Journal of Weed Science Research, 27*(1), 1-12. doi: 10.28941/pjwsr.v27i1.884

Nadeem, M. A., Khan, B. A., Anwar, S., Maqbool, R., Amin, M., Aziz, A. Batool, I., Mahmood, A., Rehman, A., Ali, A., & Nijabat, A. (2021b). Allelopathic potential of aqueous extracts of sow thistle weed on emergence and seedling growth of red rice. *Pakistan*

Journal of Weed Science Research, 27(2), 201-212. doi: 10.28941/pjwsr.v27i2.903

Olajumoke, B., Juraimi, A. S., Uddin, M., Husni, M. H., & Alam, M. (2016). Competitive ability of cultivated rice against weedy rice biotypes: a review. *Chilean Journal of Agricultural Research, 76*(2), 243-252. doi: 10.4067/S0718-58392016000200015

Rabbani, N., Bajwa, R., & Javaid, A. (2011). Interference of five problematic weed species with rice growth and yield. *African Journal of Biotechnology, 10*(10), 1854-1862. doi: 10.5897/AJB10.1866

Rao, A. N., Johnson, D. E., Sivaprasad, B., Ladha, J. K., & Mortimer, A. M. (2007). Weed management in direct-seeded rice. *Advances in Agronomy, 93*(2), 153-255. doi: 10.1016/S0065-2113(06)93004-1

Tariq, M. H., Iqbal, A., Maqbool, R., Naqi, A. H., Khan, B. A., Nadeem, M. A., Qamar, J., Sohail, M. K. Irfan, M., din, I. U., Nawaz, H., & Khalid, B. (2022). Comparative efficacy of different herbicides for weed management in lentil (*Lens culinaris*). *Pakistan Journal of Weed Science Research, 28*(1), 29-44. doi: 10.28941/pjwsr.v28i1.994.

Thakur, A. K., Rath, S., Roychowdhury, S., & Uphoff, N. (2010b). Comparative performance of rice with system of rice intensification (SRI) and conventional management using different plant spacings. *Journal of Agronomy and Crop Science, 196*(2), 146-159. doi: 10.1111/j.1439-037X.2009.00406.x

Thakur, A. K., Uphoff, N., & Antony, E. (2010a). An assessment of physiological effects of system of rice intensification (SRI) practices compared with recommended rice cultivation practices in India. *Experimental Agriculture, 46*(1), 77-98. doi: 10.1017/S0014479709990548

Tsujimoto, Y., Horie, T., Randriamihary, H., Shiraiwa, T., & Homma, K. (2009). Soil management: the key factors for higher productivity in the fields utilizing the system of rice intensification (SRI) in the central highland of Madagascar. *Agricultural Systems, 100*(1-3), 61-71. doi: 10.1016/j.agsy.2009.01.001

Uphoff, N. (2003). Higher yields with fewer external inputs? The system of rice intensification and potential contributions to agricultural sustainability. *International Journal of Agricultural Sustainability, 1*(1), 38-50. doi: 10.3763/ijas.2003.0105