Effects of Seeding Time and Competition Period on Weeds, Growth and Yield of Direct Seeded Fine Rice (Oryza Sativa L.)

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Abstract

The information on combined effect of seeding time and competition period on weeds, phenology and yield of directly sown rice is very limited. Field experiments were conducted for two years during 2008 and 2009 to study these effects. Rice cultivar "Super basmati" was seeded during 1st and 3rd week of June and 1st week of July and weeds were allowed to compete for 15, 30, 45, 60 days after seeding (DAS). Weed free treatment along with a weedy check was also maintained for comparison. Interaction effect of seeding time and competition period was significant. Weed crop competition until 15 DAS gave statistically similar kernel yield to weed free in different seeding times with better yield in plots sown in first week of June during both years. However an increase in competition period from 15 DAS to 30 DAS could not exhibit significant differences. Further increase in competition periods increased the weed density and biomass with significant reduction in yield. So rice may be direct seeded in first week of June and weeds be controlled from 15 to 30 DAS in direct seeded culture in agro physiological conditions of Faisalabad (Pakistan). However more research is needed on checking the competition between weeds and direct seeded rice in terms of density of weeds.

Keywords: *Oryza sativa, competition period, seeding time, weed, yield, hoeing.*

1. Introduction

Rice is life for more than half of the world population. It is one of the most important cereal crops in Pakistan. Farmers will likely have to face limited availability of irrigation water in many rice-growing areas therefore, it is predicted that 17 million hectare of irrigated rice area in Asia may suffer from ''physical water scarcity'' and 22 million hectare area may have ''economic water scarcity'' by 2025 (Bouman and Tuong, 2001). Therefore, water shortage poses a significant threat to the sustainability of irrigated rice ecosystems as it may not be feasible for farmers to flood the fields to control weeds and to ensure good crop establishment (Johnson and Mortimer, 2005). Rice can be established in field primarily by transplanting nursery or by direct seeding.

Farmers are shifting towards direct seeding as it reduces crop establishment cost. Direct-seeding can potentially save water through earlier establishment of rice crop and facilitates early sowing of wheat (Ladha et al., 2003). Drill-seeding rice at optimum soil moisture conditions produced the maximum grain yield and net return. Other advantages of direct seeding over transplanting include stable growth, reduced lodging, less drought risks and flooding damage. Low herbicide price, availability of early maturing improved rice variety and shortage of labor have motivated rice farmers of several Asian countries to shift from transplanting to direct seeding (Pane, 2003). Dry-seeding on flat land with subsequent saturated soil conditions reduces the amount of water required during land preparation thereby reducing the water demand for rice production (Bouman and Tuong, 2001). On the other hand, there are serious problems associated with direct-seeded rice. Weed infestation is the most important constraint in achieving high yield of direct-seeded rice. Weeds adversely affect yield and quality of harvest and increase production costs, resulting in high economic losses (Alam, 1991).

Among different factors responsible for lower yields, weed interference is of supreme importance. Compared to transplanted rice, the yield losses in DSR is greater due to absence of flooding water at the early stage of the crop to suppress weed growth (Singh et al. 2007). The critical weed crop competition period is very important for planning efficient weed control strategy. During this period, weeds offer maximum competition and cause significant yield losses. Critical period of competition varies from crop to crop depending on weed emergence time, weed type, weed density and management practices. It is important to determine critical period of weed-crop competition to plan effective weed control strategy (Mubeen et al. 2009).

There are three relationships that can exist in critical period studies: a) When the critical weed free period is of no longer duration than the critical timing of weed removal, the crop must be kept weed free between these timings to prevent yield loss; b) the crop must be kept weed-free for the same duration that a weed infestation can be tolerated. In this situation, yield loss will be avoided if weed control is performed at this one critical time; c) when the critical timing of weed removal is longer than the critical weed-free period. In this case, yield loss will not occur if weeds are controlled at any point between these critical stages. To realize full economical and yield potential of rice, agronomic and cultural practices will have to be optimized to improve weed control efficiency and reduce cop-weed competition. In order to develop efficient herbicide use and provide a logical basis for the development of an integrated weed management system, information on critical period of weed control is essential. This information may lead to less reliance on the use of residual herbicides and to more reliance on well-timed post-emergence herbicides. Reductions in quantities of herbicide applied will reduce potential environmental contamination and will reduce selection pressure for herbicide resistant weeds. In addition, timing of cover crop seeding and cultivations could be improved based upon critical period of weed competition in this crop. The value of critical period studies rests with the eventual uncovering of the physiological bases for crop-weed competition and its eventual use for weed control.

Sowing of rice at the optimum time is very important for obtaining high yield and good quality of kernels (Anonymous, 1992). Delay in seeding increased yield losses of rice in competition of rice and red stem (Caton et al., 1999). Plant may exhibit its yield potential only when it is exposed to proper temperature by sowing at the proper time. The decreasing trend in grain yield with delayed seeding might be associated with significantly less number of filled grains per panicle, lower number of panicles m^{-2}, and low 1000 kernel weight (Mishri and Kailash, 2005). Thus, to improve the yield potential of fine rice, optimum seeding time needs to be determined.

Therefore, the present study was designed to determine the effects of weed competition periods and seeding time on the growth and yield of rice.

2. Materials and Methods

2.1 General Information

Field experiments were conducted for 2 years in 2008 and 2009 at the research farm of the Department of Agronomy, University of Agriculture, Faisalabad, Pakistan. The research site was located at 30.35° to 31.47' N latitude and 72.08° to 73.0' E longitude with an altitude of 150 m above sea level. The experimental soil was loam with pH 7.6, sand 36%, silt 45%, clay 17%, organic matter 1.0%, and total nitrogen 0.5%.

2.2 Treatment details

Three seeding time of rice (1^{st} and 3^{rd} week of June, and 1^{st} week of July) and six competition period treatments were included in the experiment viz. Weed free, competition for 15, 30, 45, and 60 days after seeding (DAS). A weedy check (control) was also included in the experiment for comparison. After prescribed period weeds were removed from plot by hoeing and were kept weed free till harvest.

The field experiment was set up in a randomized complete block design with split plot arrangement with planting time in main plots and competition period treatments in sub plots with four replications. The net plot size was 5 m × 2.6 m. To protect the crop from seed borne diseases, seeds were treated with thiophanate-methyl (Topsin-M fungicide, Arysta Life Science, 2^{nd} floor, Horizon Vista, Block No 4, Clifton, Karachi-75600, Pakistan) at 2 g kg^{-1}. The seeds were soaked in water for 24 h and kept under shade in a gunny bag for sprouting. The nitrogen at 140 kg ha^{-1}, phosphorus 80 kg ha^{-1}, and potash 60 kg ha^{-1} was applied in the form of urea, diammonium phosphate, and sulfate of potash, respectively. All of the P and K and $1/3^{rd}$ of the N was incorporated into the soil at the time of seed bed preparation, while remaining N was top dressed in split dose at the time of booting and anthesis stage of the crop. The rice variety "Super Basmati" was planted in 20 cm rows using a single row hand driller (designed and manufactured at the University of Agriculture, Faisalabad, Pakistan) at a seed rate of 75 kg ha^{-1}. First irrigation was given to the crop 4-5 d after planting in such a way that emerging seedlings are not submerged and this practice was continued for 2 weeks, after that irrigation was given until harvest of the crop. The crop was harvested manually at physiological maturity then allowed to be sun dried in the field. After a week, the crop was threshed depending on moisture level.

2.3 Data Collection

The weed densities were assessed during the growing season within 0.5 m^2 quadrates (two quadrates per plot) for each competition period treatment at 30 DAT and at harvest. The weeds within a randomly selected 0.5 m^2 quadrates (two quadrates per plot) were cut at the stem base close to the soil surface, placed in paper bags, dried in an oven for 72 h at 60 °C and total weed biomass was recorded (Table 1). Total number of tillers was counted within a randomly selected 0.5 m^2 quadrates (two quadrates per plot). Ten rice panicles were randomly selected to determine seeds per panicle and 1000 kernel weight. The crop was harvested manually and grain yield was recorded. Harvest index was calculated as the ratio of rice yield to total above ground biological yield and expressed in percent. Leaf area index was calculated as the ratio of leaf area to land area (Watson 1947). Plants were harvested four times from an area of 30 x 30 cm^2 and leaf area was measured using leaf area meter (CI-202, CID, Inc. Pakistan Land Scientific Production, 30 Nisbet Road, Lahore, Pakistan). Leaf area duration (LAD) was estimated by using the following formula (Hunt 1978).

$$LAD = (LAI_1 + LAI_2)\ (T_2 - T_1) / 2$$

Where,

LAD = Leaf are duration
LAI_1 = Leaf area index at first harvest
LAI_2 = Leaf area index at final harvest
T_1 = Date of observation of first leaf area index
T_2 = Date of observation of final leaf area index

2.4 Statistical Analysis

All data were subjected to ANOVA using statistical analysis software version 9.2 (SAS, 2009) to test for treatment effects and possible interactions. Normality, homogeneity of variance, and interactions of treatments and years were tested. Interactions among years were significant; therefore, data were presented separately for each year. Weed density data were collected for each species; however, the data were combined and a total weed density data were presented. The data of weed density and biomass were square root transformed however; non-transformed means are presented with mean separation based on transformed values. Where the ANOVA indicated that treatment effects were significant, means were separated at $P \leq 0.05$ and adjusted with Fisher's Protected Least Significant Difference (LSD) test.

3. Results and Discussion

3.1 Weed density and biomass

Crowfootgrass [*Dactyloctenium aegyptium* (L.) Willd.], Horse purslane (*Trianthema portulacastrum* L.), goosegrass (*Eleusine indica* L.), and sedges (*Cyperus* spp.) were the common weed species found in the experimental area during both the growing seasons. At the harvest of crop not a single *T. portulacastrum* plant was observed as this weed had completed the life cycle before harvest of the crop during both the years. Treatment by year interaction was significant therefore, weed density and biomass data were presented separately for each year (Table 2 and 3). The results revealed statistically significant differences for total weed density and biomass at 60 days after applying the treatment in 2008 and 2009 for individual and interactive response of seeding time and competition periods. Crop seeded earlier (first week of July) revealed maximum weed density and biomass after 60 days of applying the treatment which differed significantly to plots where crop was seeded late (first week of July) during both the growing seasons. The results are in accordance with the outcome of Mishra (2000) who reported that timely sown crop face more competition from jungle rice compared with delay in sowing of crop. Most of the weed seeds also require same environmental conditions as crop suitable for their growth and development. Furthermore rainfall early in the season favored the growth of weeds better than crop resulting in more density and biomass of weeds. Among competition period treatments significantly maximum density and biomass of weeds was noted in plots where weeds were allowed to compete with crop plants without adopting any control measure. The weed density increased gradually with increase in competition periods during both the years (Table 2). The combined effect of seeding time and competition period showed the maximum total weed density (182.77 m^{-2}) and biomass (215.51 g m^{-2}) when crop was sown late (first week of July) in 2008 where weeds were not removed at any stage (W_6S_3). However, it could not differ significantly from crop sown earlier in weedy check condition (W_6S_1 and W_6S_2), respectively. Seeding time also could not bring significant variation in total weed density and biomass when weeds competed with crop for 15 DAS (Table 2). Similar trend was found in second growing season. This non-significant effect of delaying the seeding in weedy check and for 15 DAS might be owing to less variation in climatic conditions over time.

3.2 Growth attributes

Significantly maximum leaf area index (LAI) was noted in weed free plots sown earlier among all treatments with minimum in plots sown late (first week of July) where weeds were not controlled throughout the growing season. Similar trend was observed during second growing season. Leaf area duration (LAD) highlights the importance of photosynthetic parts. Variation in yield between the treatments sometimes also determined based on leaf area duration as differences in kernel and straw yield may not truly explain the differences in their maximum LAIs. Significantly maximum leaf area duration was recorded in weed free plots with minimum in weedy check. LAD increased progressively with time (Table 4). Delaying the sowing of rice crop and increasing the competition period resulted in reduced leaf area duration. Second year of study also revealed similar results. Decreasing the competition period between crop and weeds will help in improving the growth of rice. Weed free plots with improved leaf area index (LAI) and leaf area duration (LAD) in rice could be due to the lack of weed competition which improved the growth of crop. Absence of early weed competition improved the rate of crop growth which also improved the LAI. This confirms the previous finding of Oudhia and Tripathi (2000) that reducing the competition improved the growth and development of rice crop.

3.3 Rice yield attributes

There was a significant difference among the years for rice yield attributes so the data of both the years is separately discussed. Difference in seeding time could not bring significant variation in total number of tillers during both the growing seasons. Among competition period significantly the maximum number of tillers (462.17 and 497.51) was observed in plots where weeds were not allowed to compete with crop throughout the season during 2008 and 2009, respectively. Significantly the maximum number of tillers per m^2 in weed free treatment was due to the availability of growth resources only to the crop where crop efficiently used all the growth resources as weeds were kept out of field by continuous removal until harvest. As the period of allowing weeds to compete with crop increased, the resources were also utilized by weeds. In weedy check plots where weeds competed with crop until harvest of the crop; significantly lowest number of tillers per m^2 was observed due to competition for resources between crop and weeds. With each increasing competition period the number of tillers decreased significantly (Table 5). Data on interactive effect of seeding time and competition period revealed that rice planted earlier (first week of June) showed the maximum number of tillers (463.06 and 509.40) when kept weed free throughout the growing season (W_1S_1) during 2008 and 2009, respectively. Minimum number of tillers (345.35 and 375.74) was found when rice seeds were sown in third week of June and first week of July in weedy check plots (W_6S_2 and W_6S_3) during both the years, respectively. Maximum number of tillers m^{-2} in early sown crop (first week of June) during both the years could be attributed to more time available to crop for growth and development with quick and better canopy cover at early stage of the growth thereby suppressing weeds and subsequent increase in number of productive tillers per m^2. Whereas, in late sown rice (first week of July); less time was available to crop for providing the canopy cover. High rainfall at early stage also favored the weed germination and growth resulting in higher density and greater competition. Thereby, weed cover on soil reduced the growth of crop and ultimately the stand of the crop.

Altering the seeding dates could not reveal significant variation in weedy check plots and those where competition for 60 DAS was allowed during both the growing seasons. Crop seeded in first week of June showed no significant differences in plots with competition periods of 15 and 30 DAS during both the years. Almost similar trend was also observed for other seeding times (Table 5). Significantly less number of tillers in year 2008 over 2009 could be attributed to frequent and more rainfall in 2008 which favored the germination and growth of weed resulting in greater biological stress to crop due to weeds.

Significant reduction in 1000 kernel weight was observed by delaying the seeding during both the years. Weed competition periods also had a pronounced effect on the kernel weight. The 1000 kernel weight decreased significantly with each increased competition period and the minimum 1000 kernel weight (13.65 and 14.66 g) was noted in plots where weeds competed with rice plants throughout the growing period during 2008 and 2009, respectively. The interaction between weed competition periods and seeding times for 1000 kernel weight was significant. The early sown crop under weed free condition exhibited maximum 1000 kernel weight (18.87 and 19.77 g) during both the years, respectively. Furthermore, among seeding times significantly more 1000 kernel weight in first week of June could be attributed to more time available for normal growth and development of rice. While delaying the sowing from first week of June to first week of July caused significant reduction in 1000 kernel weight due to gradual decrease in time available for crop growth and development to function efficiently and shifted to reproductive phase in less days with less assimilates and photosynthates in kernels. Reduction in kernel length and kernel length width ratio might also have caused reduction in 1000 kernel weight with each increase in competition period. Results are quite in consonance with the findings of Mishri and Kailash (2005) who reported that yield components of rice like tillers number m^{-2}, number of filled grains $panicle^{-1}$ and 1000-grain weight was found in the decreasing trend from the seeding of 15^{th} of June onward. The seeding time could not yield significant difference for kernel weight between (a) weed free, (b) competition for 15 DAS and (c) weedy check treatment during 2008. Whereas, during 2009; competition for 15 and 30 DAS was similar in all seeding times (Table 5). Relatively less and significantly lower 1000 kernel weight in 2008 than in growing season of 2009 might be attributed to relatively high rainfall during early growth period which favored the growth and emergence of weeds. So a subsequent reduction in growth and development of crop was recorded.

Management practices and growing conditions determine the kernel yield which is also dependent on cumulative effect of yield components. The data presented in Table 6 shows that seeding time and competition period affected the kernel yield significantly during both the years. The significantly maximum kernel yield of 2448 kg ha^{-1} and 2656 kg ha^{-1} was recorded when rice was sown early (first week of June) during 2008 and 2009, respectively. The kernel yield decreased significantly with each delay in sowing during both the growing seasons. The effect of competition period on kernel yield of rice was also significant with maximum kernel yield in weed free plots (W_1) during both the years. The plots with weed free situation and competition period for 15 DAS were statistically similar and thereafter each increase in competition period significantly decreased the kernel yield and with least in weedy check plots.

The interactive effect of weed competition periods and seeding time for kernel yield was also significant during both the years. Rice sown in first week of June showed maximum kernel yield of 2973 and 3176 kg ha^{-1} when no competition was allowed between rice crop and weeds (W_1S_1) during both the years, respectively. Whereas, the least kernel yield (1578 and 1723 kg ha^{-1}) was found in case of interactive effect of rice sown in first week of June and weed competition throughout the growing season during both the years, respectively. These results confirm the previous finding of Sreedevi and Thomas (1993) who reported lower grain yield in weedy check. Significant reduction in kernel yield with delay in sowing could be attributed to the fact that as the time available for normal growth and development was reduced the plants tend to complete their life cycle therefore forced early shift towards reproductive stage with less photosynthates accumulation. Delay in sowing significantly reduced 1000 kernel weight thereby causing a significant reduction in kernel yield. The differences between rice plants under weedy check situation and competition for 60 DAS were non-significant for late and medium sowing during both the years of study (Table 6).

Due to an increase in competition duration between crop and weeds kernel yield decreased significantly from 1.75 % to 45.17 % during 2008 and from 1.54 % to 42.10 % during growing seasons of 2008 and 2009 respectively. Increase in period of weed crop competition resulted in increase in the resource sharing between weeds and rice ultimately showing less number of productive tillers, spikelets per panicle, panicle length and 1000 kernel weight. At 15 DAS the loss caused by weeds was not significant as at that stage weeds were at early seedling stage which could not significantly fetch the growth resources of rice. Therefore the interactive effect of seeding time and rice plants under weed free plots beside rice plants facing weed competition for 15 DAS showed non-significant differences. Resource sharing was increased with each increase in competition period therefore kernel yield showed a linear and significant reduction in kernel yield. Among seeding times, maximum kernel yield in early sown crop (first week of June) in both the years might be due to the sufficient time available for crop to complete the physiological processes.

Maximum kernel yield in weed free is due to lack of weed competition where crop plants had full chance to utilize the growth resources. Whereas the minimum yield in weedy check is due to the poor crop growth owing to presence of weeds throughout the growing season depleting the soil moisture and nutrients. The significant reduction in kernel yield observed in 2008 over 2009 could be attributed to lower 1000 kernel weight, panicle length, number of spikelets per panicle, kernel length and number of productive tillers per m^2 in 2008.

Harvest index is the ratio of crop yield to total biological yield. Results obtained were similar as observed for kernel yield. Significantly maximum harvest index of rice (21.36 and 22.02 %) was noted when crop was sown in first week of June (S_1) during 2008 and 2009, respectively. Delay in seeding time caused significant reduction in harvest index of rice crop with minimum (18.65 and 19.87 %) when crop was directly sown in first week of July (S_3) during 2008 and 2009, respectively.

In weed free (W_1) treatment maximum harvest index (23.20 and 23.60 %) was noted while harvest index decreased significantly with each increase in competition period during 2008 and 2009, respectively. The significantly minimum harvest index (15.61 and 17.13 %) was recorded in weedy check (W_6) in growing seasons of both years. The interaction between weed competition periods and seeding times were also significant during both the years. Crop sown early (first week of June) in plots kept weed free (W_1S_1) yielded highest harvest index (23.85 and 24.13 %) during 2008 and 2009, respectively. Whereas the minimum (15.14 and 17.08 %) was noted when weeds competed with crop throughout the growing season (W_6S_3) during 2008 and 2009, respectively (Table 6). Significantly higher harvest index (HI) in 2009 was due to higher kernel yield beside other yield components like 1000 kernel weight and number of productive tillers per m^2 etc.

Economic threshold level is monitored in terms of the (a) duration for which weed compete with crop and (b) density of the weed/s competing with crop. This research based on duration of competition for evaluating the economic threshold level shows that rice may be direct seeded in first week of June and weeds be controlled within 15 to 30 DAS in direct seeded culture in agro physiological conditions of Faisalabad (Pakistan). However more research is required to investigate the economic threshold level in terms of density of the common weeds in direct seeded rice in Pakistan for planning an effective, economical and eco friendly weed management plan.

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Apendix

Table 1: Dates of agronomic operations conducted during the research experiment in 2008 and 2009

Name of operation[a]	2008	2009
Seeding date in 1st week of June (S_1)	03 June	06 June
Seeding date in 3rd week of June (S_2)	18 June	20 June
Seeding date in 1st week of July (S_3)	03 July	06 July
Competition for 15 DAS	Kept weed free after 18 June, 03 July and 18 July respectively for 3 seeding dates S_1, S_2, and S_3	Kept weed free after 21 June, 05 July and 21 July respectively for 3 seeding dates S_1, S_2, and S_3
Competition for 30 DAS	Kept weed free after 03 July, 18 July, and 03 Aug. respectively for 3 seeding dates S_1, S_2, and S_3	Kept weed free after 06 July, 20 July and 06 Aug. respectively for 3 seeding dates S_1, S_2, and S_3
Competition for 45 DAS	Kept weed free after 18 July, 03 Aug. and 18 Aug. respectively for 3 seeding dates S_1, S_2, and S_3	Kept weed free after 21 July, 04 Aug. and 21 Aug. respectively for 3 seeding dates S_1, S_2, and S_3
Competition for 60 DAS	Kept weed free after 03 Aug., 18 Aug. and 03 Sept. respectively for 3 seeding dates S_1, S_2, and S_3	Kept weed free after 06 Aug., 20 Aug. and 06 Sept. respectively for 3 seeding dates S_1, S_2, and S_3
Plants harvested for leaf area index	20 Aug., 5 Sep., 20 Sep., 5 Oct.	21 Aug., 6 Sep., 21 Sep., 6 Oct.
Harvesting of rice	05 Nov. (for all seeding dates)	06 Nov. (for all seeding dates)
Threshing	08 Nov. (for all seeding dates)	09 Nov. (for all seeding dates)

[a] Abbreviations: DAS, days after seeding.

Table 2: Interaction effects of seeding time and competition period treatments on total weed density at 60 days after treatment in DSR[a] in 2008 and 2009[b]

Treatment	Total weed density 60 days after treatment (m^{-2})					
	2008			2009		
	S_1	S_2	S_3	S_1	S_2	S_3
No competition (Weed free)	00.00f	00.00f	00.00f	00.00g	00.00g	00.00g
Competition for 15 DAS	27.82e	31.14e	42.44e	16.67f	22.14f	33.99ef
Competition for 30 DAS	50.28de	66.40d	85.55cd	37.21ef	48.88e	61.77de
Competition for 45 DAS	97.86c	115.88bc	120.22b	68.88d	93.33c	97.44bc
Competition for 60 DAS	122.58b	111.18bc	115.88bc	109.64b	102.30bc	101.66bc
Competition throughout the season (Weedy check)	166.22a	180.99a	182.77a	135.99a	141.44a	140.66a

[a] DSR= Direct seeded rice
[b] The data were arc-sine transformed for homogenous variance prior to analysis; however, data presented are the means of actual values for comparison.

Table 3: Interaction effects of seeding time and competition period treatments on total weed biomass at 60 days after treatment in DSR in 2008 and 2009[a]

Treatment	Total weed biomass 60 days after treatment ($g\ m^{-2}$)					
	2008			2009		
	S_1	S_2	S_3	S_1	S_2	S_3
No competition (Weed free)	00.00 f	00.00 f	00.00 f	00.00 f	00.00 f	00.00 f
Competition for 15 DAS	42.29 e	49.50 de	55.47 de	23.58 e	33.66 e	45.55 de
Competition for 30 DAS	72.99 de	79.44 d	84.55 cd	49.44 de	56.77 d	71.77 cd
Competition for 45 DAS	121.22 c	132.42 bc	141.22 bc	85.55 c	109.44 b	119.45 b
Competition for 60 DAS	148.44 bc	156.04 bc	168.02 b	121.04 b	112.44 b	111.47 b
Competition throughout the season (Weedy check)	192.88 ab	205.77 a	215.51 a	152.33 a	155.44 a	153.55 a

DSR= Direct seeded rice

Table 4: Interaction effects of seeding time and competition period treatments on leaf area index and leaf area duration in 2008 and 2009

Treatment	LAI						LAD					
	2008			2009			2008			2009		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
No competition (Weed free)	2.53 a	2.49 ab	2.43b	2.57a	2.52ab	2.46b	130.56a	129.05ab	126.21bc	132.76a	130.15ab	127.64b
Competition for 15 DAS	2.43 b	2.38 bc	2.31c	2.47b	2.40bc	2.34c	127.27b	124.02c	120.93d	128.43b	125.06bc	121.98cd
Competition for 30 DAS	2.31 c	2.25 cd	2.19de	2.35c	2.28cd	2.21d	121.42cd	118.23de	115.36ef	123.47c	119.84cd	116.3de
Competition for 45 DAS	2.22 d	2.16 de	2.08e	2.26cd	2.18de	2.12de	116.70e	113.75ef	110.25fg	118.7d	115.08de	111.7e
Competition for 60 DAS	2.14 e	2.07 e	1.99f	2.17de	2.10e	2.03ef	112.65f	109.59g	106.82g	114.35e	110.72ef	107.37f
Competition throughout the season (Weedy check)	1.99 f	1.95 f	1.85g	2.07e	1.97f	1.87g	105.61h	103.15h	98.69i	106.83f	104.10f	99.23g

Table 5: Interaction effects of seeding time and competition period treatments on number of rice tillers and 1000 kernel weight in 2008 and 2009

Treatment	Number of tillers (m^{-2})						1000 kernel wt. (g)					
	2008			2009			2008			2009		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
No competition (Weed free)	463.06a	461.12a	462.33a	509.40a	497.17ab	485.96ab	18.87a	18.72ab	18.63ab	19.77a	19.41ab	19.28ab
Competition for 15 DAS	424.03 b	420.71 b	417.01 b	466.61 b	451.2bc	443.45bc	18.15ab	18.02 b	17.96 b	19.25ab	18.98 b	18.67 b
Competition for 30 DAS	401.02bc	403.34bc	402.09bc	448.49bc	430.37 c	420.96cd	16.70 c	16.38cd	15.42de	17.41 c	17.08 c	16.89 c
Competition for 45 DAS	386.37 c	384.50 c	382.62 c	430.57 c	420.43cd	411.43cd	16.06cd	15.85 d	13.07 g	16.93 c	16.17 d	13.97 f
Competition for 60 DAS	371.28cd	369.89cd	367.83cd	411.50cd	401.22cd	396.51 d	15.28de	13.27 fg	13.14 fg	16.03 de	14.06 f	13.42 f
Competition throughout the season (Weedy check)	351.16 d	345.35 d	347.34 d	396.76 d	384.50 d	375.74 d	13.86 f	13.64 fg	13.44 fg	15.17 e	14.88 e	13.94 f

Table 6: Interaction effects of seeding time and competition period treatments on rice yield, percent reduction in yield, and harvest index in 2008 and 2009

Treatment	Kernel Yield (kg ha^{-1})						% reduction in yield in first ST over weed free		H.I. (%)					
	2008			2009			2008	2009	2008			2009		
	S_1	S_2	S_3	S_1	S_2	S_3			S_1	S_2	S_3	S_1	S_2	S_3
No competition (Weed free)	2973 a	2902 ab	2847 ab	3176 a	3118 ab	3052 ab	-	-	23.85 a	23.52 ab	22.24 b	24.13 a	23.78 ab	22.88 ab
Competition for 15 DAS	2921 ab	2839 ab	2807 ab	3127 ab	3045 ab	3016 ab	1.75	1.54	23.73 ab	23.15 ab	22.12 b	23.98 a	23.57 ab	22.90 ab
Competition for 30 DAS	2580 b	2495 bc	2378 bc	2789 b	2604 bc	2587 bc	13.22	12.19	22.55 b	21.80 b	19.96 c	23.11 ab	22.64 ab	20.97 b
Competition for 45 DAS	2410 bc	2394 bc	1919 cd	2619 bc	2603 bc	2224 cd	18.49	17.54	21.74 b	21.27 bc	16.91 d	22.80 a	22.29 b	18.91 c
Competition for 60 DAS	2176 c	1709 d	1680 d	2385 c	1915 d	1849 d	26.81	24.91	20.22 c	16.39 de	15.50 e	20.94 b	18.25 cd	16.48 d
Competition throughout the season (Weedy check)	1630 d	1602 d	1578 d	1839 d	1758 d	1723 d	45.17	42.10	16.07 de	15.61 e	15.14 e	17.16 d	17.14 d	17.08 d