Pak. J. Weed Sci. Res. 17(3): 229-243, 2011

WEED-CROP COMPETITION PERIOD IN THREE FINE RICE CULTIVARS UNDER DIRECT-SEEDED RICE CULTURE

Abdul Khaliq[1*] and Amar Matloob

ABSTRACT

Weeds are a serious biological constraint to rice production. The establishment of critical period of weed competition is central in the development of an effective weed management program. A field study was carried out to determine the critical period of weed competition in three cultivars of fine direct-seeded rice viz. Super Basmati, Basmati 2000 and Shaheen Basmati. Weeds were allowed to initially grow and compete with rice for 10, 20, 30, 40, 50 days after sowing (DAS) and a season long competition plot was also maintained. Weed flora of the experimental site comprised of Echinochloa crus-galli, E. colona, Dactyloctenium aegyptium, Leptochloa chinensis, Eleusine indica, Cyperus rotundus and C. iria and Trianthema portulacastrum, Ipomoea aquatica and Portulaca oleracea. The highest weed density was recorded between 20 and 30 DAS for all cultivars while maximum weed biomass was recorded at 50 DAS. Yield losses due to weed-crop competition were most pronounced during the period from 30 to 50 DAS. Rice yield continued to decline as the duration of weed competition increased. Weed competition beyond 20 DAS resulted in drastic reduction in the number of panicles m^{-2} and grains panicle^{-1} that accounted for lower rice yield. Broadleaved weeds represent >50% of total weed dry biomass in Super and Shaheen Basmati during early season while grasses and sedges contributed over 80% at harvest, with grasses alone contributing by ca. 65%. The period within 20 to 50 DAS appeared to be an important factor in crop weed competition in dry direct-seeded rice.

Key words: Biomass, weed competition period, density, direct-seeded, interference, rice, yield loss.

INTRODUCTION

Rice holds a prominent position in the agro-based economy of Pakistan. It is a high value cash crop, accounting for 6.4% of the value-added in agriculture and 1.4% in gross domestic product (Govt. of Pakistan, 2010). It is the second largest agricultural export commodity of Pakistan after cotton. Transplanting in puddle soils (wet tillage), with continuous flooding, is the most common method of rice crop establishment. However, this seeding technique is very laborious, cumbersome, expensive and time consuming and results in delayed transplanting with above-optimal age of rice seedlings. Scarcity of

[1]Department of Agronomy, University of Agriculture, Faisalabad.
[*]Corresponding author: khaliquaf@gmail.com

skilled labor and high cost of this operation results in improper planting densities in farmer's field primarily (Awan *et al.*, 1989; Baloch *et al.*, 2000). In rice-wheat system, soil management practices for rice render consequent deleterious effects on the soil environment for the succeeding wheat and other upland crops and also require more energy for tillage operations in succeeding crops (Singh *et al*., 2002). On the basis of a diagnostic survey conducted in several rice-wheat areas in South Asia, Fujisaka *et al*. (1994) observed low wheat yields in a rice-wheat system, mainly due to deterioration in soil structure and the development of subsurface hardpans. Increasing water scarcity in the country has further threatened the sustainability of transplanted rice production.

Direct seeding of rice seems a viable alternative in rescuing farmers (Farooq *et al*., 2011). It has potential for attaining high water productivity and eliminating the possible edaphic conflicts in rice-wheat cropping system. Sustainability of dry direct-seeded rice is however adversely affected by weeds. It is estimated that direct-seeded rice yield is reduced by 60% and even 100% due to huge weed infestation (Rao *et al*., 2007). Proper time and method of weed control are also a complex phenomenon as the weeds and rice emerge simultaneously. There is a relationship between the timing of weed emergence and the pressure exerted to the crop through competition and resultant losses in crop yield. Yield losses are usually higher when weeds emerge earlier or at the same time as the crop (Aldrich, 1987). In field trials of direct-seeded irrigated rice, 95% of weed-free rice yield was obtained when weeds were controlled up to 32 days after sowing (DAS) in wet season and 83 DAS in dry season (Johnson *et al*., 2004).

Zimdahl (1988) identified the period during which weeds must be controlled to prevent economic yield loss. Critical period studies are indispensable in making weed control recommendations, as they indicate optimum time for implementing and maintaining weed control (Van-Acker *et al*., 1993). Crop cultivars differ regarding their competitive ability against weeds and degree of competition offered by a crop determines the level of weed control achieved with herbicides. Productivity of direct-seeded rice is believed to largely dependent on effective and timely weed control. This, in turns requires knowledge about critical period of weed competition. Information on the critical period of weed competition in direct-seeded rice could help improve timing of post emergence herbicides application. Reducing the number of herbicide treatments as a result of better timing and efficiency may reduce potential environment contamination and the selection pressure for herbicide resistant weeds. Moreover, to give more precise recommendation to growers, such a critical period must be worked out for specific rice cultivars grown in a particular region keeping in view the floristic composition of weeds and climatic conditions.

Very little is known about critical period of weed competition in fine rice cultivars of Pakistan under direct-seeded rice culture. The present study therefore was undertaken to unravel the optimum time for weed control and to determine the influence of different weed crop competition periods on yield and yield components of fine rice cultivars under the growing conditions of Faisalabad, Pakistan.

MATERIALS AND METHODS

Seed source

Seeds of rice cv. Super Basmati and Basmati-2000 were obtained from Rice Research Institute, Kala Shah Kaku. Shaheen Basmati seeds were obtained from Soil Salinity Research Institute, Pindi Bhattian. For all cultivars, selected healthy seeds were used. Cultivar characteristics are listed in Table-1.

Site description

The study was conducted at Agronomic Research Farm, University of Agriculture Faisalabad, (184 m above sea level). The soils of experimental site belongs to Lyallpur soil series (Aridisol-fine-silty, mixed, hyperthermic Ustalfic, Haplargid in USDA classification and Haplic Yermosols in FAO classification). The pH of saturated soil paste was 7.6 and total soluble salts were 0.79 dS m^{-1}. Organic matter, total nitrogen, available phosphorus and potassium were 0.71%, 0.062%, 13.1 ppm, and 179 ppm, respectively. Due to high evapo-transpiration, Faisalabad features an arid climate with mean annual rainfall of about 200 mm.

Experimentation

The experiment was laid out in randomized complete block design (RCBD) under split plot arrangement with four replications. The experiment was conducted during summer 2008. The net plot size was 6 m x 2.70 m. The seed of fine rice cultivars were osmo-hardened with 2.2 % $CaCl_2$ prior to sowing (Farooq *et al*., 2007). The rice crop was sown in the first week of July with single row hand drill, using a seed rate of 75 kg ha^{-1} and maintaining 22.5 cm distance between crop rows. A basal fertilizer dose of 125 kg N, 55 kg P_2O_5 and 40 kg k_2O ha^{-1} was applied. Fertilizers used were urea (46% N), diammonium phosphate (18% N, 46% P_20_5) and sulphate of potash (50% K_2O). The whole phosphorus and potassium and half of nitrogen were applied at the time of sowing. The remaining half nitrogen was applied in two splits at tillering and panicle initiation, respectively. Weeds were allowed to compete with rice till 10, 20, 30, 40, 50 DAS and removed manually thereafter. A weedy check (season-long competition) was also maintained for each cultivar.

Table-1. Characteristics of rice cultivars used in the study.

Characteristics	Super Basmati	Basmati-2000	Shaheen Basmati
Year of release	1996	2000	2001
Parentage	Basmati 320 x 10486	Basmati 385 x 4048-3	Basmati 385 x Super Basmati
Breeding Station	RRI, KSK	RRI, KSK	SSRI, Pindi Bhattian
Present Status	Recommended	Recommended	Recommended
Agronomic Traits			
Plant height (cm)	115	134	150
Tiller per hill	15	21	
Maturity (days after transplanting)	120-125	115	95
Leaf orientation	Erect	Erect	Erect
Leaf color	Green	Green	Green
Stem	Stiff	Stiff	Stiff
Grains/panicle	130	140	112
1000 grain weight (g)	22.5	23.0	20.5
Paddy yield (kg ha^{-1})	3200	3500	4000

Source: Akram (2009).

Data on weed dynamics (density, dry biomass) were recorded twice at the completion of each competition period from two randomly selected quadrats (100 x 100 cm) from each experimental unit. The crop was kept weed free for the rest of growing period. Weed density was measured on the basis of weed type, i.e., grasses, sedges and broad-leaved. The dry biomass of weeds was recorded after drying in an oven at 70 ºC for 48 h. Data on rice yield attributes was recorded from 15 randomly selected plants taken from each plot and then their average was computed. Productive tillers (m^{-2}) were counted from two randomly selected sites from each plot and averaged. A random sample of kernels was taken from the produce of each plot, 1000-kernels were counted manually and weighed on an electric balance. Crop was harvested, tied into bundles in respective plots, biological yield of sun dried samples were recorded from each treatment. Each experimental plot was manually threshed to determine grain yield and then converted into t ha^{-1}.

Statistical analysis

The data collected were subjected to Fisher's analysis of variance technique (Steel *et al*., 1997) using "MSTATC" statistical package (Freed and Scott, 1986) and HSD Tukey's test at p <0.05 probability was applied to compare the differences among treatments' means.

RESULTS AND DISCUSSION

Weed growth

Weed flora of the experimental site comprised of *Echinochloa crus-galli*, *Echinochloa colonum*, *Dactyloctenium aegyptium*, *Leptochloa chinensis* and *Eleusine indica* (grasses), *Cyperus rotundus* and *Cyperus iria* (sedges) and *Trianthema portulacastrum*, *Ipomoea aquatica* and *Portulaca oleracea* (broad-leaved). Significant interaction between cultivars and competition periods was observed regarding weed density. Weeds emerged profusely between 20 and 30 DAS, so that peak weed densities were recorded in all the cultivars during this period (Fig. 1a). At 30 DAS, maximum weed count (386.30 m^{-2}) was recorded for Shaheen Basmati, while Super Basmati and Basmati-2000 recorded statistically similar weed count of 340.50 and 309.30 m^{-2}. After 30 DAS, a sharp decline in weed density was noticed for all the tested cultivars. This drop in weed density could be in part due to inter and intra-specific competition and also due to reduction in horse purslane density which initially dominated the field for one month or so. Afterwards (40-50 DAS), weed density achieved a plateau which persisted until harvest. The weed density observed at harvest after season long competition was although less but statistically alike with that observed at 40 and 50 DAS for all cultivars. Grasses and broad-leaved weeds contributed a major share with peak density of both grassy and broad-leaved weeds observed at 30 DAS (Fig. 2). Sedges were the least of the three weed types in all the cultivars at different durations of weed competitions. After their dominance for 30 DAS, broad-leaved weed density dropped dramatically and later on, weed stand comprised chiefly of grassy weeds consisting of *E. colonum*, *D. aegyptium*, *L. chinensis* and *E. indica* and a few sedges. Figure-4a provides an insight into percentage change in different weed types. It showed that broad-leaved weeds represent >50% of total weed density but later on the same figure was shared by grasses.

Significant interaction (P<0.05) was noticed between different rice cultivars and weed crop competition periods for weed dry biomass. Dry matter accumulation by weeds showed gradual increase at each subsequent competition period and achieved a steady state at 50 DAS that decline a bit at harvest (Fig. 1b). Shaheen Basmati experienced maximum weed pressure in terms of dry weed biomass (173.30 g m^{-2})

when weeds were allowed to compete for 50 DAS. Similarly at harvest, after season-long weed competition, maximum weed dry biomass was also observed for the same cultivar. Shaheen Basmati was overwhelmed by weeds than rest of the cultivars and increase in weed dry biomass at successive competition periods for each weed type was much higher as compared with rest of the cultivars (Fig. 3). At 30 DAS, maximum grass and broad-leaved weed dry biomass was observed for Super and Shaheen Basmati, respectively while dry biomass of sedges was almost equally distributed among all the cultivars. The relative proportions of different weed types in total weed dry biomass at each competition period on percentage basis are expressed in Fig. 4b and depict that broad leaved weeds represent >50% of total weed dry biomass in Super and Shaeen Basmati during early season while grasses and sedges contributed over 80% at harvest, with grasses alone contributing by *ca.* 65%.

Rice is a poor competitor with weeds (Saito, 2010). However genetic variation occurs regarding weed competitive ability among rice cultivars (Haefele *et al*., 2004; Zhao *et al*., 2006). Weed competitive ability of a particular rice cultivar can be assessed in terms of weed number and biomass under weedy conditions (Zhao *et al*., 2006). The outcome of competition between rice and weeds is the differential acquisition of resources and this acquisition is density dependent provided the two species can co-exist (Rao *et al*., 2007). Such outcomes tend to be influenced by composition of weed stand and type of rice cultivar (Chauhan and Johnson, 2010). The findings of present study concur with previous findings of Singh (2008) who found that in direct-seeded rice, during first 30 DAS, broad leaved weeds dominated the grassy weeds and sedges, and constituted more than 62% of the total weed population. *Trianthema monogyna* alone accounted for more than 50 and 60% of total density at 15 and 30 DAS. Later on weed stand comprised chiefly of grasses which dominated broad-leaved and sedges and represented more than 90% of total weed count at 75 DAS. The contribution of *E. colona* alone was 80% of the total weed population at 60 DAS and afterwards. Rodenburg *et al*. (2009) while screening diverse rice genotypes for their weed competitive ability found that of the frequently distributed weed types, 44% were broad-leaved, 31% grasses and 25% sedges.

The local climate and hydrology of experimental site was conducive to luxurious weed growth and diverse composition as the fields were not immersed in water. The weeds that otherwise are non-native to rice fields as well those which are controlled by flooding were in abundance. The variation in weed pressure encountered in terms of density and dry biomass and also in relative proportion of different weed types can be in part due to morphological difference in rice cultivars, different rates of canopy closure and tillering capacity, and partially owing to inherent weed flora of the site. However, contrary to our results, Rodenburg *et al*. (2009) found a significant effect of cultivar on weed biomass only at harvest after season long competition.

Rice yield and yield components

Rice yield and its components were negatively influenced by increasing periods of weed competition (Fig. 5). Statistically significant ($P<0.05$) interactions between rice cultivars and weed competition periods were observed for all the yield related traits. Yield continued to decline as the duration of weed competition increased. Weed competition for 20 DAS caused drastic reduction in the number of panicles m^{-2} and grain yield that accounted for lower rice yield. Differences in number of panicles and grain yield between cultivars and significant interaction between cultivars and competition period was also reported (Namuco *et al*., 2009; Rabbani *et al*., 2010). Delaying weed control from 10 DAS incurred a grain yield loss of 12 and 25%, 17 and 26% and 20 and 34% at 20 and 30 DAS in Super Basmati, Basmati-2000 and Shaheen Basmati, respectively. These losses became more pronounced with increasing duration of weed competition, and respective grain yield losses were 48, 54 and 59% when weed were allowed to compete for 50 DAS. It has been estimated that rice yield is lowered by 0.75 kg for 1 kg of weed biomass produced (Anon, 2003). Chauhan and Johnson (2011) recorded a grain yield loss of 24% when weeds were allowed to grow for 28 DAS. Weed competition throughout the growing season forced a grain yield loss of >80% with maximum (89%) grain yield loss recorded for Shaheen Basmati. For each competition period, yield losses were less for Super Basmati than rest of the cultivars. Rabbani *et al*. (2010) concluded that Super Basmati is a better weed competitor than Basmati-385. Sultana (2000) observed that weed infestation of 100-200 weeds m^{-2} reduced rice yield by 51-64% compared with weed-free conditions. Rice plots without such competition recorded higher number of productive tillers over control because of the greater space capture by rice plants. During early part of the growing season, weeds accomplished 20-30% of their growth while rice had only 2-3% (Moody, 1990). Our data showed that delaying weed control beyond 20 DAS led to grain yield loss of 15% which tend to amplify, if the weeding is further delayed. The period within 20 to 50 DAS appeared to be an important factor in crop weed competition in dry direct-seeded rice. This period coincides with the tillering and subsequent canopy closure (Yaduraju and Mishra, 2004). The relationship between duration of weed competition (time of removal) and associated yield reduction in rice is approximately sigmoidal (El-Desoki, 2003) and a weed competition after 20 days of rice seeding had drastic bearing in number of panicles and grain yield per unit area. Moreover, yield increase was proportional to increasing duration of weed-free period.

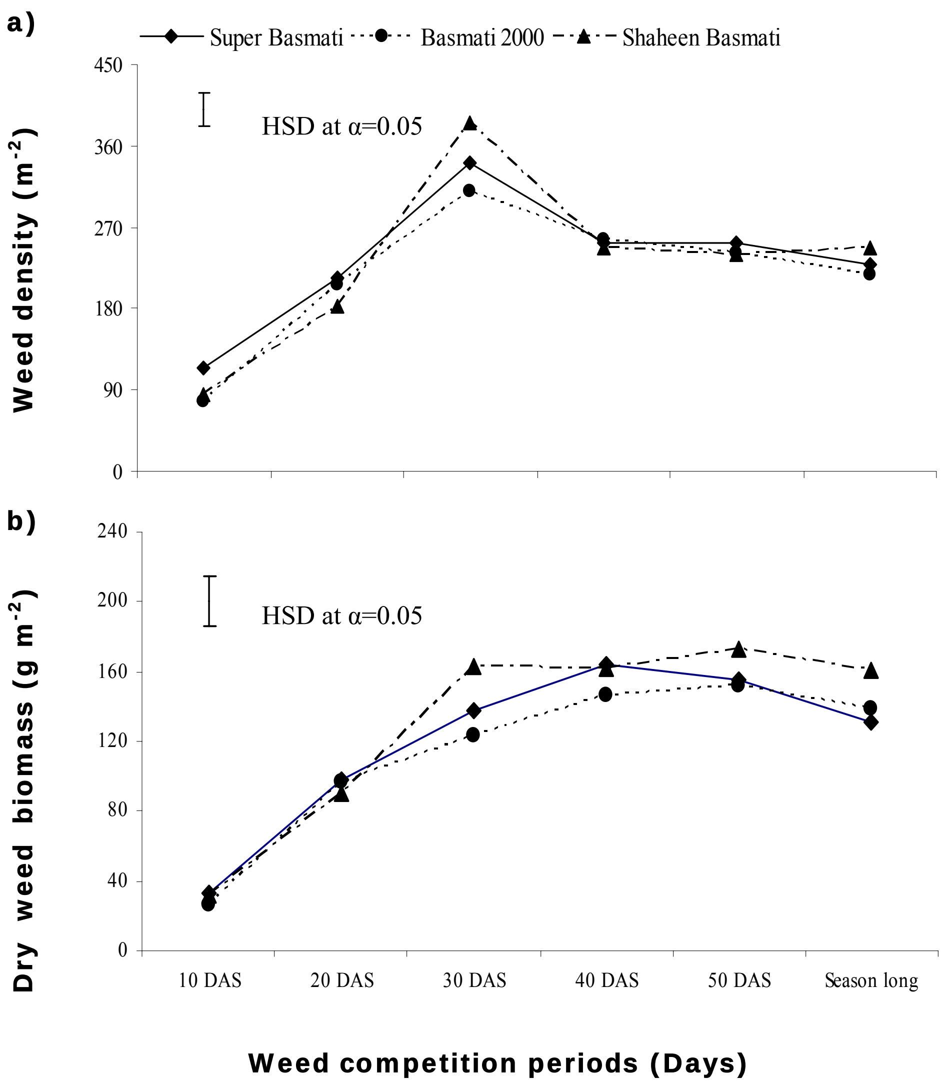

Figure 1. Effect of different weed competition periods on (a) weed density and (b) dry weed biomass in three cultivars of fine rice.

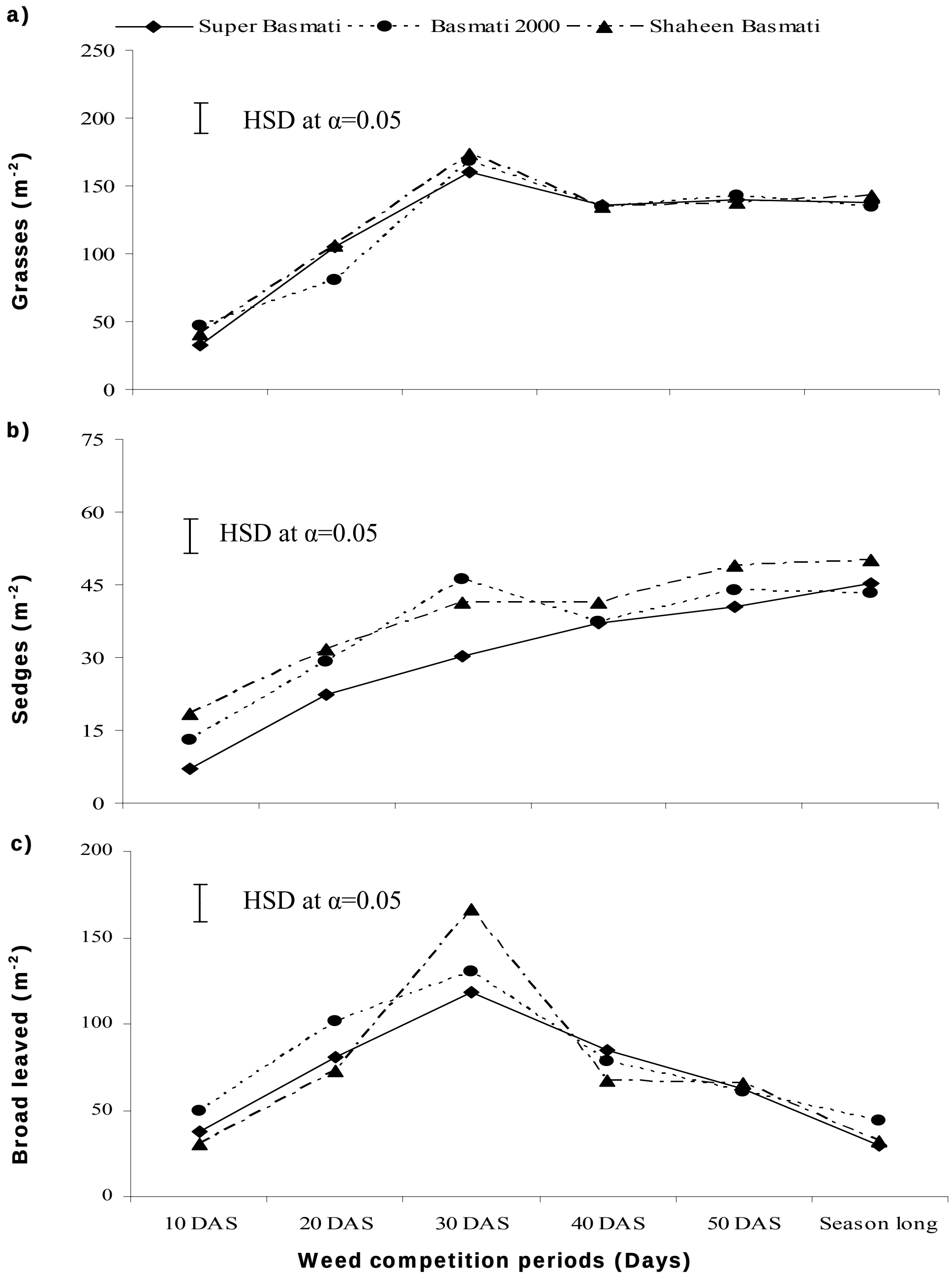

Figure 2. Effect of different weed competition periods on density (m^{-2}) of different weed types (a) grasses (b) sedges and (c) broad-leaved.

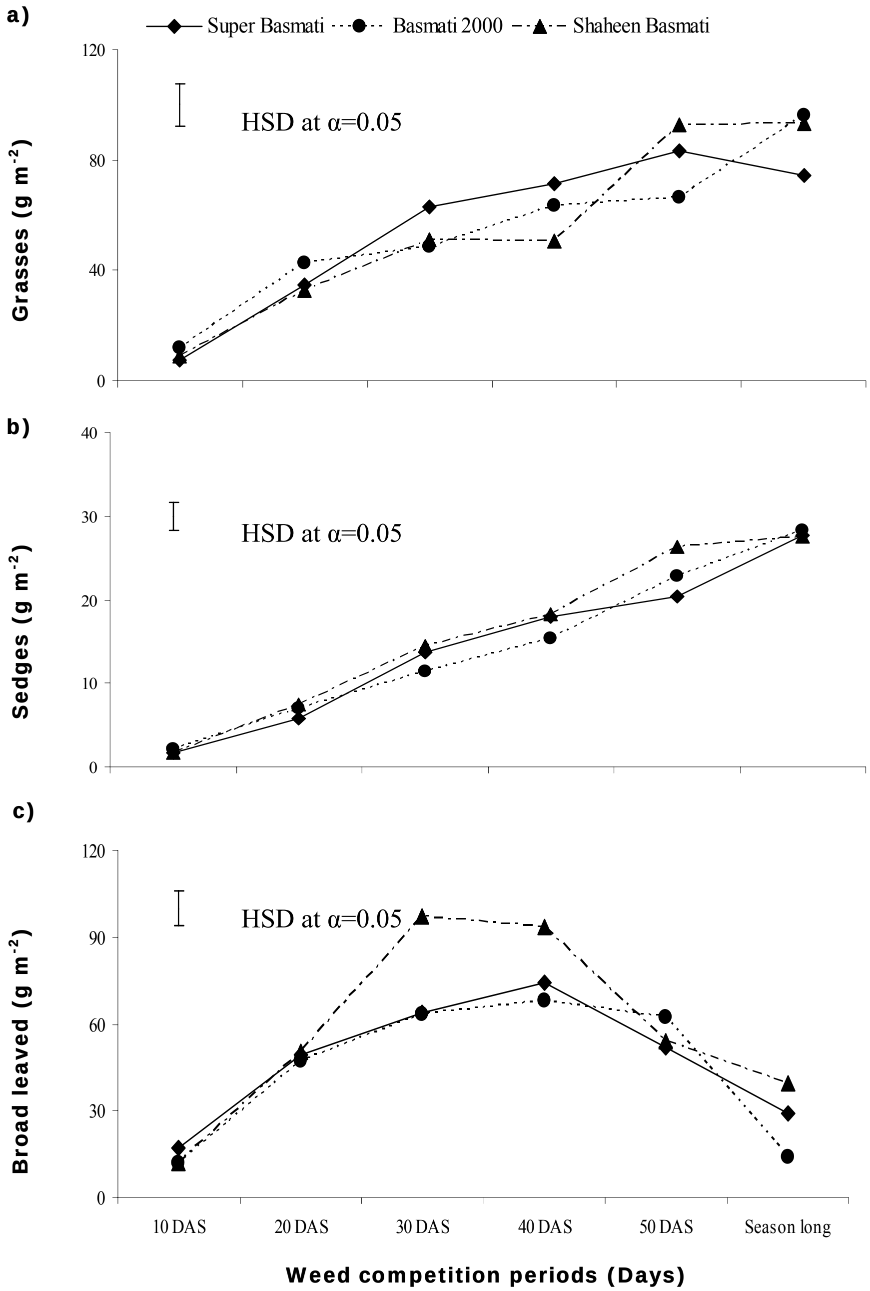

Figure 3. Effect of different weed competition periods on dry biomass ($g\ m^{-2}$) of different weed types (a) grasses (b) sedges and (c) broad-leaved.

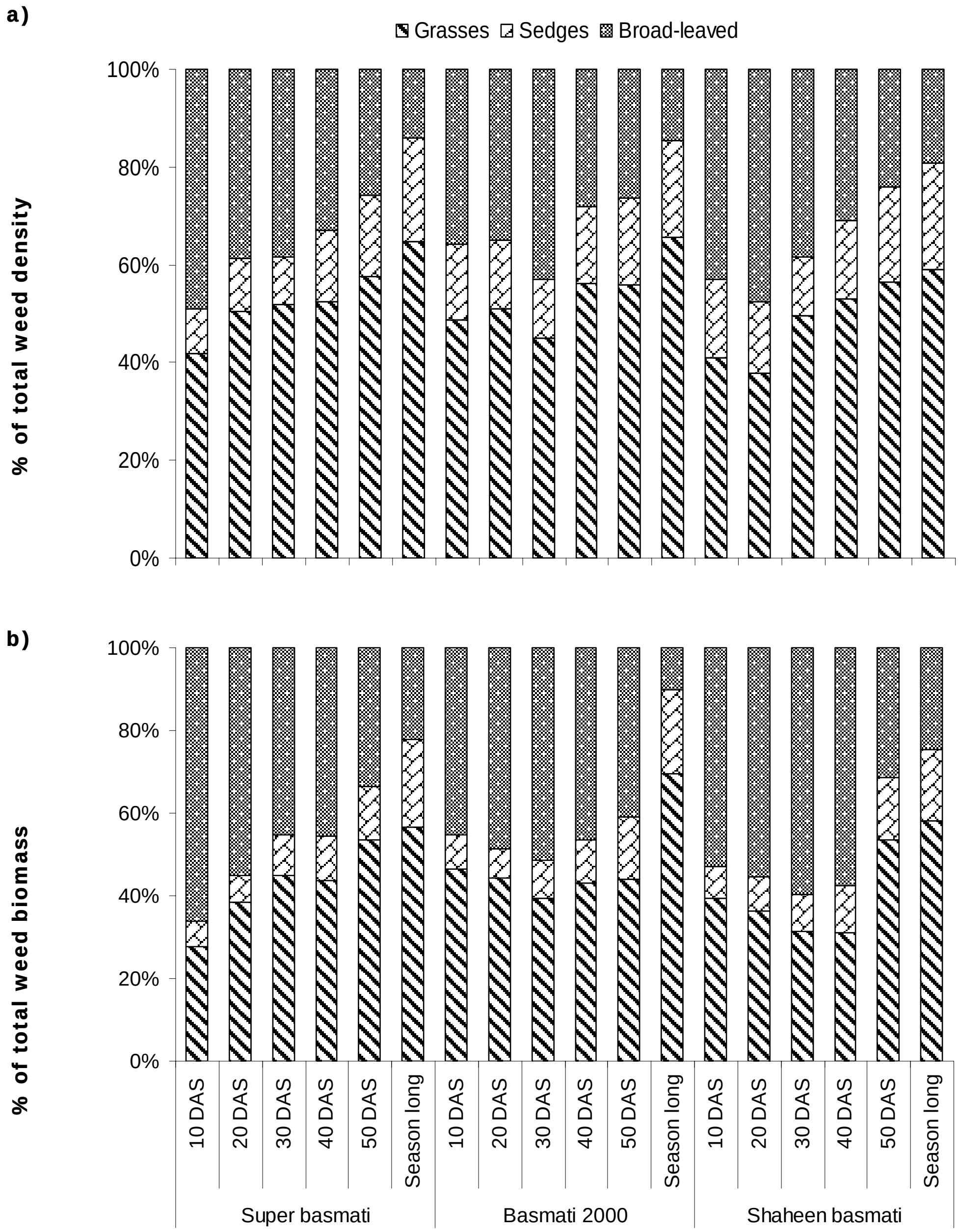

Figure 4. Relative proportion of different weed types on percentage basis in total (a) weed density and (b) biomass in three cultivars of fine rice.

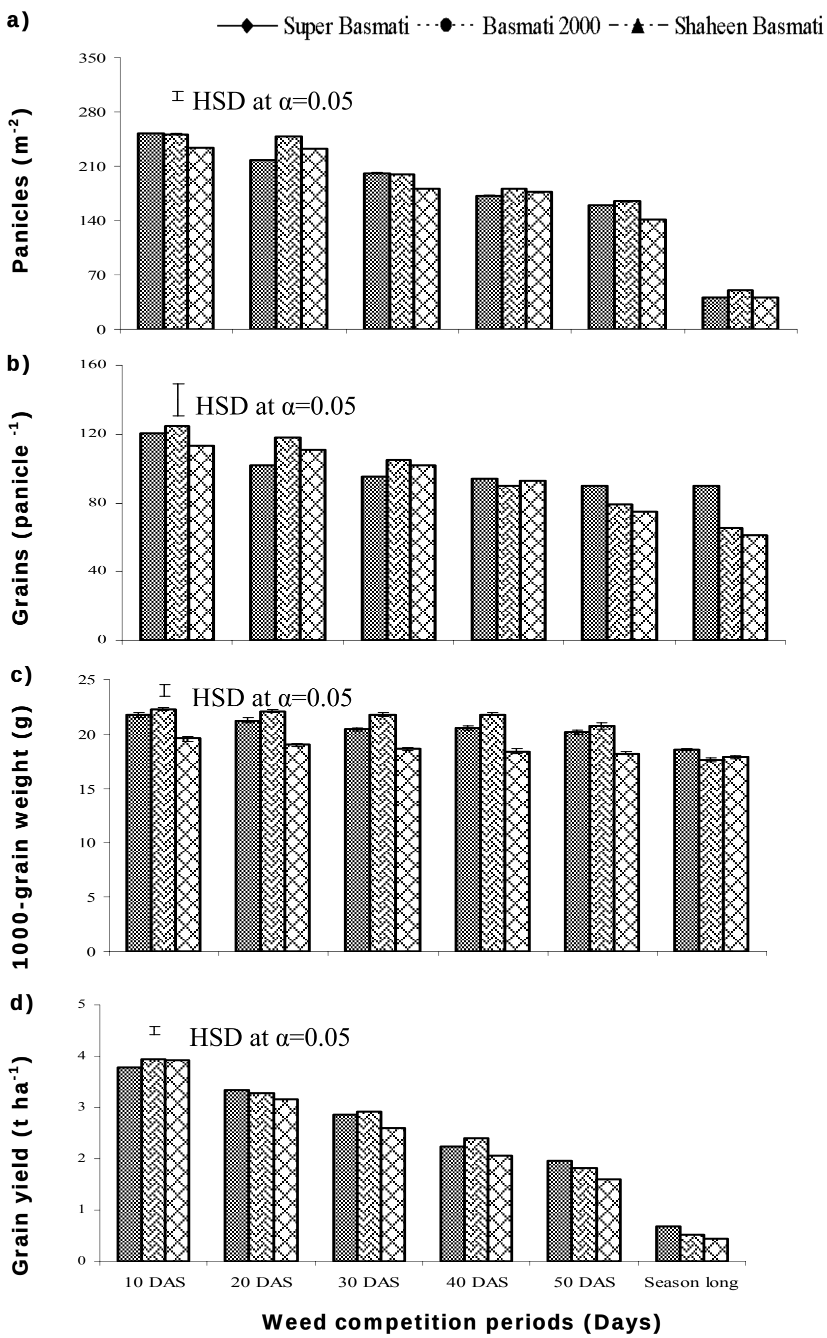

Figure 5. Effect of different weed competition periods on yield and yield components of direct-seeded rice.

REFERENCES CITED

Akram, M. 2009. Aromatic Rices of Pakistan-A Review. Pak. J. Agric. Res. 22: 154-160.

Aldrich, R.J. 1987. Predicting crop yield reduction from weeds. Weed Technol. 1: 199-206.

Anon. 2003. Principles of Weed Management. International Rice Research Institute, Philippines. http://www.knowledgebank.irri.org/IPM/WeedMgmt/default.htm (October 23, 2008).

Awan, I.U., H.U. Alizai, and F.M. Chaudhary. 1989. Comparative study of direct seeding and transplanting methods of planting of rice. Sarhad J. Agric. 5: 119-24.

Baloch, M.S., I.U. Awan, S.A. Jatoi, I. Hussain and B.U. Khan. 2000. Evaluation of seeding densities in broadcast wet seeded rice. J. Pure Applied Sci. 19: 63-65.

Chauhan, B.S. and D.E. Johnson. 2010. Implications of narrow crop row spacing and delayed *Echinochloa colona* and *Echinochloa crus-galli* emergence for weed growth and crop yield loss in aerobic rice. Field Crops Res. 117: 177-182.

Chauhan, B.S. and D.E. Johnson. 2011. Row spacing and weed control timing affect yield of aerobic rice. Field Crops Res. 121: 226-231.

El-Desoki, E.R. 2003. Weed competition in the field of direct-seeded rice. Bull. NRC (Cairo), 28: 527-534.

Farooq, M., S.M.A. Basra and N. Ahamd. 2007. Improving the performance of transplanted rice by seed priming. Plant Growth Regul. 51: 129-137.

Farooq, M., K.H.M. Siddique, H. Rehman, T. Aziz, D.J. Lee and A. Wahid. 2011. Rice direct seeding: Experiences, challenges and opportunities. Soil Till. Res. 111: 87-98.

Freed, R.D. and D.E. Scott. 1986. MSTATC. Crop and Soil Sci. Dept., Michigan State University, Michigan, USA.

Fujisaka, S., L. Harrington and P.R. Hobbs. 1994. Rice-wheat in South Asia: systems and long-term priorities established through diagnostic research. Agric. Syst. 46: 169-187.

Govt. of Pakistan. 2010. Pakistan Economic Survey 2009-10. Economic Advisor’s Wing, Finance Division, Islamabad, p. 19.

Haefele, S.M., D.E. Johnson, D. MBodj, M.C.S. Wopereis and K.M. Miézan. 2004. Field screening of diverse rice genotypes for weed competitiveness in irrigated lowland ecosystems. Field Crop Res. 88: 39-56.

Johnson, D.E., M.C.S. Wopereis, D. Mbodj, S. Diallo, S. Powers and S.M. Haefele. 2004. Timing of weed management and yield losses due to weeds in irrigated rice in the Sahel. Field Crops Res. 85: 31-42.

Moody, K. 1990. Post-planting weed control in direct-seeded rice. Paper presented at a Rice Symposium, 25-27 September 1990, MARDI, Penang, Malaysia.

Namuco, O.S., J.E. Cairns and D.E. Johnson. 2009. Investigating early vigor in upland rice (*Oryza sativa* L.): Part I. Seedling growth and grain yield in competition with weeds. Field Crops Res. 113: 197-206.

Rabbani, N., R. Bajwa and A. Javaid. 2010. Interference of five problematic weed species with rice growth and yield. Afr. J. Biotech. 10: 1854-1862.

Rao, A.N., D.E. Jhonson, B. Sivaprasad, J.K. Ladha and A.M. Mortimer. 2007. Weed management in direct-seeded rice. Advan. Agron. 93: 153-255.

Rodenburg, J., K. Saito, R.G. Kaka, A. Toure, M. Mariko and P. Kiepe. 2009. Weed competitiveness of the lowland rice varieties of NERICA in the southern Guinea Savanna. Field Crops Res. 114: 411-418.

Saito, K. 2010. Weed pressure level and the correlation between weed competitiveness and rice yield without weed competition: An analysis of empirical data. Field Crops Res. 117: 1-8.

Singh, G. 2008. Integrated weed management in direct-seeded rice. *In* Singh, Y., V.P. Singh, B. Chauhan, A. Orr, A.M. Mortimer, D.E. Johnson and B. Hardy (eds.). Direct Seeding of Rice and Weed Management in the Irrigated Rice-Wheat Cropping System of the Indo-Gangetic Plains. International Rice Research Institute, Los Bańos, Philippines: Directorate of Experiment Station, G.B. Pant University of Agriculture and Technology, Pantnagar. pp. 163-166.

Singh, Y., G. Singh, V.P. Singh, R.K. Singh, P. Singh, R.S.I. Srivastava, A. Saxena, M. Mortimer, D.E. Johnson and J.L. White. 2002. Effect of different establishment methods on rice–wheat and the implication of weed management in Indo-Gangetic plains. *In* Proc. Inter. Workshop Herbicide Resistance Management & Zero Tillage in Rice-Wheat Cropping System, 4–6 March 2002, Department of Agronomy, CCS Haryana Agricultural University, Hisar, India, pp. 188-192.

Steel, R.G.D., J.H. Torrie and D. Dickey. 1997. Principles and Procedures of Statistics: a biometrical approach. 3rd Ed. McGraw Hill Book Co. Inc. New York. pp. 172-177.

Sultana, R. 2000. Competitive ability of wet-seeded boro rice against *Echinochloa crusgalli* and *Echinochloa colonum*. M.Sc. thesis. Bangladesh Agricultural University, Mymensingh, Bangladesh.

Van-Acker, R.C., C.J. Swanton and S.F. Weise. 1993. The critical period of weed control in soybean (*Glycine max*). Weed Sci. 41:194-200.

Yaduraju, N.T. and J.S. Mishra. 2004. Weed management in rice with special orientation to export. *In* ''SAARC Rice Expo 2004,'' Maharashtra Chamber of Commerce and Industry and Rice Exporters Association of Pakistan, Mumbai, India. pp. 111-115.

Zhao, D.L., G.N. Atlin, L. Bastiaans and J.H.J. Spiertz. 2006. Developing selection protocols for weed competitiveness in aerobic rice. Field Crops Res. 97: 272-285.

Zimdahl, R.L. 1988. The concept and application of the critical weed-free period. *In* Altieri, M.A. and F.M.L. Eibman (eds.). Weed Management in Agroecosystems: Ecological Approaches. CRC Press, Boca Raton, FL, USA. pp. 145-155.