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Weed management improves yield and quality of direct seeded rice

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Abstract

Severe water shortage in Pakistan has led the researchers to develop different sowing methods of rice such as direct drilling of seed in the soil as an alternative or substitute to the flooded transplanted rice. But direct drilling of rice severs the weed proliferation which reduces crop yields. Weed control methods including hand hoeing, mechanical and chemical control were tested for weed management in direct seeded rice. All the weed control methods were effective in decreasing the total weed density and dry weight over control and improving the rice yield and quality. Higher weed suppression and increase in rice yield was resulted by hand pulling than by the mechanical hoeing. Both hand pulling and mechanical hoeing were better than herbicides in suppression of weed and increasing yield. All the herbicides resulted in more than 80 % reduction in weed density and 74-87 % decrease in weed dry weight. Maximum increase of 30 % in grain yield over control was observed in hand pulling and that of 25 % in mechanical hoeing. Both methods also resulted in improved quality and gave maximum percentage of normal kernels that is 60.47 in mechanical hoeing and 60.03 hand pulling. Increase in rice yield due to application of herbicides was 7-19 %. The order of herbicides in suppressing the weeds as well as increasing rice yield was pretilachlor>butachlor>pendimethalin.

Keywords: Direct seeding, quality, rice, weed control, yield.

Introduction

Rice is the staple food for billions of people worldwide. Rice is the second most important cereal crop of Pakistan grown on an area of 2.96 m ha^{-1} with total production of 6.95 m tons and average yield of 2.3 t ha^{1} (Govt. of Pakistan, 2008-09). Fine grain rice named as 'Basmati' is an important brand of Pakistan fetching special price in the international market and has a major share in the rice export earnings of Pakistan. Total export value of rice in Pakistan is 1150.1 million US $ (Govt. of Pakistan, 2008-09). Pakistan exports quality rice to countries of West Africa, Malaysia, Bangladesh, Iran, Indonesia, United Arab Emirates and Saudi Arabia. Conventional method of rice growing in Pakistan is the raising of rice nursery in a nursery bed and transplanting one month old nursery seedlings in a puddled and flooded field (Ehsanullah et al. 2007). This method not only effectively suppresses the rice weeds by preventing the light to reach the weeds through a layer of the standing water and also provides the rice plants with a better growing environment (Rao et al. 2007; Begum et al. 2006; Chauhan and Johnson, 2009; Farooq et al. 2011). However, immense labor and water is required to grow rice by conventional flooded method (Bouman et al. 2007; Bhushan et al. 2007). In the backdrop of the declining water resources and reduced availability of the labor, the conventionally flooded rice system is losing its sustainability and economic viability (Guerra et al. 1998; Bhushan et al. 2007). Declined water table, increasing costs of diesel and electricity and climatic changes have further aggravated the problem (Vörösmarty et al. 2000; Rosegrant et al. 2002). Due to these reasons there is a need to shift from the conventionally flooded transplantation to direct seeding of rice in Pakistan. Direct seeding of rice is an alternative option to cope with the problems of water and labor scarcity associated with conventionally flooded rice (Weerakoon et al. 2011). Direct seeding of rice is accomplished by either of the methods as water seeding, wet seeding and dry seeding (Ehsanullah et al. 2007; Bouman et al. 2007; Farooq et al. 2011). Direct seeded rice is being cultivated successfully in many parts of the world like China, Australia, Malaysia, United States, and Sri Lanka etc. (Tabbal et al. 2002; Farooq et al. 2011; Weerakoon et al. 2011). Weeds are the serious constraint to the productivity of direct seeded rice (Caton et al. 1999; Zhao et al. 2006; Singh et al. 2006; Rao et al. 2007; Sanusan et al. 2010). There is abundance of weeds of diverse nature in fields under direct seeded rice (Sharma et al. 1977; Chin, 2001; Tomita et al. 2003; Singh et al. 2008a; Kamoshita et al. 2010). Weeds grow quickly in direct seeded rice compared with the weeds growth in transplanted flooded rice and other crops (Karim et al. 2004; Begum et al. 2006; Chauhan and Johnson, 2009; Kamoshita et al. 2010). These weeds severely disturb the growth of rice and sometimes result in the failure of the crop (Phuong et al. 2005). Different weed control practices have been evaluated to minimize the weed pressure in direct seeded rice (Phuong et al. 2005; Chauhan et al. 2010). Application of weedicides effectively suppress the weeds and provide the direct seeded rice a weed competition free environment (Gitsopoulo and Froud-Williams, 2004). Pendimethalin, butachlor, oxadiazon and nitrofen are among the herbicides which have been tested worldwide for controlling weeds and improving the yield of direct seeded rice (Rao et al. 2007; Farooq et al. 2011).

Mechanical weed control and hoeing may also suppress the weeds and increase grain yield in direct seeded rice (Rao et al. 2007). As weeds are the main hindrance in the direct seeded rice in Pakistan so an urgent solution is needed to suppress weeds and enhance yield of direct seeded rice. This study was planned to determine the effectiveness of different weed control measures to enhance the yield and quality of direct seeded fine rice.

Materials and methods

Experimental site, design and layout

The field experiment was conducted on a sandy clay loam soil at the research area of Agronomy Department, University of Agriculture, Faisalabad (30.35 – 31.47°N latitude and 72.08–73°E longitude) for two consecutive years. The experiment was laid out in a randomized complete block design and replicated four times. Fine rice variety "Super Basmati" was used for this study.

Weed control treatments

Weed control treatments were a) manual pulling (35, 45 and 60 days after sowing) b) mechanical hoeing using kasola (30, 45 and 60 days after sowing) c) butachlor (1.8 kg a.i. ha^{-1}) d) pendimethalin (1.65 kg a.i. ha^{-1}) and e) pretilachlor (1.25 kg a.i. ha^{-1}). A weedy check (control) plot was also maintained for comparison. In manual pulling weeds were either pulled directly with hand or cut with sickle close to the ground surface. Mechanical hoeing was done with Kasola. Kasola is a manual instrument bit smaller than spade in size used for hand weeding. Pendimethalin was applied immediately after sowing while butachlor and pretilachlor were applied 4 days after sowing with the first irrigation. Knapsack hand sprayer fitted with T-jet nozzle was used to spraying herbicides. The volume of the spray determined after calibration was 325 L ha^{-1}.

Crop husbandry

The land was prepared by giving two ploughings each followed by planking with the help of a tractor drawn cultivator to achieve the fine seed bed. A fertilizer dose of 100-67-63 kg N.P.K. ha^{-1} in the form of urea, single super phosphate and sulphate of potash was applied to each experimental unit. All P and K with 1/3rd of N was applied at sowing while the remaining dose of N was applied in two splits i.e., 30 and 55 days after sowing. Zinc sulphate (20%) was applied @ 25 kg ha^{-1}. Seed rate of rice was 80 kg ha^{-1}. The seed was treated with fungicide thiophanate methyl @ 2 g kg^{-1} of seed. The seed was soaked in water for 24 hours before sowing and then kept under shade in the form of a heap covered with a gunny bag for 36 hours for sprouting. Crop was sown on 25th of June during both the years with the help of hand drill in 20 cm spaced rows. First irrigation was given 4 days after seeding and the same interval was maintained until two weeks after sowing. Subsequently, the irrigation was applied after weekly interval. Total number of irrigations applied were 15 and 16 for the two years respectively. Each irrigation was of 3 acre inches. Carbafuran was applied at 20 kg ha^{-1} at the tillering stage to control yellow and white stem borer of rice. The crop was harvested at full physiological maturity, sun-dried for a week and threshed manually.

Data recording

Total weed density and dry weight

A quadrate measuring 0.5 x 0.5 m was randomly placed at three sites in each experimental plot to record total weed density at 70 days after sowing. Weeds were counted and collected for recording dry weight by drying in oven at 70 °C until constant weight. The data of weed density and dry weed was converted to m^2.

Yield and yield contributing parameters of rice

Plant height of 20 primary tillers selected randomly from each of the experimental unit was recorded from soil level to the tip of flag leaf with the help of a meter rod and then averaged. The number of panicle bearing tillers were recorded at harvesting time from an area of 30 cm x 30 cm from three different places in each plot and the averaged to calculate the number of tillers m^{-2}. Twenty panicles of primary tillers were randomly selected from the earmarked area in each plot at harvesting time to determine the number of grains per panicle.

Thousand grain weight of normal kernels replicated thrice from each experimental unit was recorded in grams using electric balance. After harvesting and threshing, the clean rough rice was air-dried, bulked and weighed. Moisture content in grain was determined by using LKB-PRODUUKTERAB-Sweden Grain Moisture Meter. The grain weight was adjusted at 14% moisture content. The yield of clean rough rice was expressed in tones ha^{-1}. Straw yield per plot was determined after sun-drying for one week and expressed in tones ha^{-1}. The harvest index was calculated as the ratio of economic yield to the biological yield and expressed in percentage.

Quality parameters

Sterile spikelets, opaque, abortive and normal kernels were counted from 20 panicles of primary tillers randomly selected from each experimental plot. The whole panicles were carefully sketched to differentiate between sterile spikelets, abortive, opaque and normal kernels (Nagato and Chaudhry, 1969). A common electric lamp with a flexible stand was used as a source of light and panicle was positioned in front of it. Unfilled and unfertilized spikelets were taken as sterile spikelets while the abortive kernels were dull, did not permit light to pass through them and did not attain full size due to ceasing of kernel development after fertilization. The kernels which attained full size but were not translucent due to poor carbohydrate contents were considered as opaque kernels. Normal kernels were those that attained full size, translucent and allow light to pass through them. Number of sterile spikelets, abortive, opaque and normal kernels from each sketch of all the treatments were counted, averaged and then expressed in percentage. For recording the degree of chalkiness, 20 panicles from each experimental plot were hulled and polished using a Stake Rice Machine (Model THU-35A) and McGill Polisher No. 3. After dehulling and polishing, the samples were sorted out by using a seed working board and table lamp.

Table 1. Effect of weed control practices on weed density and dry weight in direct sown rice

Treatments	Weed density (m^{-2})	Weed dry weight ($g\ m^{-2}$)
Control (weedy check)	34.88 a	20.83 a
Hand pulling (30, 45 and 60 days after sowing)	1.75 e (94.98)	1.03 e (95.05)
Mechanical hoeing using kasola (30, 45 and 60 days after sowing)	9.75 b (72.04)	8.84 b (57.56)
Butachlor (1.8 kg a.i. ha^{-1})	6.75 c (80.64)	5.47 c (73.74)
Pendimethalin (1.65 kg a.i. ha^{-1})	6.62 c (81.02)	4.54 cd (78.2)
Pretilachlor (1.25 kg a.i. ha^{-1})	4.50 d (87.09)	2.75 de (86.79)
LSD at $p \leq 5\%$)	1.98	1.87

Means in column having different letters differ significantly at $p \leq 0.5$. The figures in the parenthesis shows percent weed inhibition over control

Table 2. Effect of weed control practices on yield and yield contributing parameter of direct sown rice

Weed control practices	Plant height (cm)	Panicle bearing tillers m^{-2}	Kernels per panicle	1000-grain weight (g)	Grain yield t ha^{-1}	Straw yield t ha^{-1}	Harvest index (%)
Control (weedy check)	91.15 c	324.87 c	108.35 c	17.27 d	2.47 c	9.28 c	21.03 b
Hand pulling (30, 45 and 60 days after sowing)	95.97 a	402.50 a	135.14 a	19.27 a	3.22 a (30.3)	10.26 ab	23.77 a
Mechanical hoeing using kasola (30, 45 and 60 days after sowing)	95.00 a	403.25 a	132.70 a	19.12 b	3.09 ab (25.1)	10.46 a	22.88 ab
Butachlor (1.8 kg a.i. ha^{-1})	94.01 ab	390.01 a	123.00 b	18.17 c	2.91 b (17.8)	10.06 ab	22.63 ab
Pendimethalin (1.65 kg a.i. ha^{-1})	91.14 c	363.25 b	114.04 c	17.49 d	2.61 c (5.6)	9.90 ab	20.89 b
Pretilachlor (1.25 kg a.i. ha^{-1})	91.70 bc	392.75 a	122.84 b	18.53 c	2.94 b (19.02)	9.79 bc	23.86 a
LSD at $p \leq 5\%$	2.37	21.29	8.54	0.53	0.27	0.64	2.21

Means in column having different letters differ significantly at $p \leq 0.5$. The figures in the parenthesis show percent increase in grain yield over control

The chalky kernels were visually separated from normal kernels on the basis of chalky area present in different parts of the kernel with the help of a high power magnifying glass. Chalky kernels of panicle were separated, counted and then expressed in percentage. Kernel, length and width were recorded for 100 normal kernels from each experimental plot with the help of a dial caliper and thereafter length-width ratio was calculated from the respective values. Protein concentration of rice kernels was determined by first carrying out Micro–Kjeldhal digestion and ammonia distillation and then accomplishing the colorimetric ammonia assay of the digest to determine nitrogen concentration which was converted to protein by multiplying with the factor 5.95. Amylose concentration in the milled rice grains was determined according to the method of Juliano (1971). The water absorption ratio was expressed as a ratio of cooked rice weight and raw rice weight (Juliano *et al*. 1965).

Statistical analysis

The data collected were statistically analyzed using computer statistical package MSTAT-C. Fisher's analysis of variance technique was applied to test the significance of the treatments. The year's effect was non-significant on the treatments so two years data means have been presented. Least significance difference test at $p \leq 0.05$ was used to compare the treatments means (Steel et al., 1997).

Results

Effect of weed control treatments on weeds density and weeds dry weight of rice

The weed flora of the experimental site was similar during both the years and comprised of purple nutsedge (*Cyprus rotundus*), jungle rice (*Echinochloa colonum*), barnyard grass (*Echinochloa crussgalli*), Egyptian grass (*Dactyloctenum aegyptium*) and bitter weed (*Eclipta alba*). All the weed control treatments significantly reduced the weed population m^{-2} (Table 1) over the control treatment. Maximum reduction (94.9% and 95.1% respectively) in total weed density (m^{-2}) and total weed dry weight ($g\ m^{-2}$) was recorded in hand pulling treatment (Table 1). All the chemical weed control treatments resulted in more than 80% reduction in weed density m^{-2} over the control treatment while hoeing resulted in the least reduction (72%) in total weed density m^{-2} compared with the untreated control. Pretilachlor resulted in 86.8% reduction in total weed dry weight $g\ m^{-2}$ (Table 1). Pendimethalin and butachlor resulted in 78.2% and 73.74% reduction in total weed dry weight ($g\ m^{-2}$) respectively and was not different (p> .05 Table 1).

Table 3. Effect of weed control practices on quality parameters of direct sown rice

Weed control practices	Sterile spikelets (%)	Abortive kernels (%)	Opaque kernels (%)	Chalky kernels (%)	Normal kernels (%)
Control (weedy check)	10.84 a	3.80^{NS}	8.64 a	23.36 b	56.40 b
Hand pulling (30, 45 and 60 days after sowing)	9.41 bc	3.59	7.37 c	25.82 a	62.03 a
Mechanical hoeing using kasola (30,45 and 60 days after sowing)	8.54 c	3.31	7.30 c	24.85 ab	60.47 a
Butachlor (1.8 kg a.i. ha^{-1})	9.54 bc	3.98	7.79 bc	24.14 ab	53.67 b
Pendimethalin (1.65 kg a.i. ha^{-1})	10.10 ab	3.87	8.18ab	25.52 a	54.96 b
Pretilachlor (1.25 kg a.i. ha^{-1})	9.08 bc	3.57	7.97 abc	24.10 ab	56.25 b
LSD at $p \leq 5\%$	1.28		0.80	1.80	3.74

Means in column having different letters differ significantly at $p \leq 0.5$, NS = Non-significant

Table 4. Effect of weed control practices on quality parameters of direct sown rice

Weed control practices	Kernel length (mm)	Kernel width (mm)	Kernel length-width ratio	Kernel protein concentration (%)	Kernel amylose concentration (%)	Kernel water absorption ratio
Control (weedy check)	7.65 d	1.66 c	4.59 a	7.23 b	20.56 b	3.30 cd
Hand pulling (30, 45 and 60 days after sowing)	7.83 a	1.82 a	4.29 b	7.97 a	22.39 a	4.35 a
Mechanical hoeing using kasola (30,45 and 60 days after sowing)	7.81 a	1.79 a	4.34 b	7.95 a	22.04 a	3.89 ab
Butachlor (1.8 kg a.i. ha^{-1})	7.75 c	1.69 bc	4.57 a	7.30 ab	19.89 c	3.76 bc
Pendimethalin (1.65 kg a.i. ha^{-1})	7.77 bc	1.68 bc	4.61 a	6.52 c	18.76 d	292 b
Pretilachlor (1.25 kg a.i. ha^{-1})	7.80 ab	1.71 b	4.55 a	7.50 ab	19.33 cd	3.74 bc
LSD at $p \leq 5\%$	0.03	0.03	0.09	0.68	0.62	0.52

Means in column having different letters differ significantly at $p \leq 0.5$

Weed dry weight reduction over control was recorded minimum (57.5%) in the mechanical hoeing (Table 1).

Effect of weed control treatments on yield and yield parameters of rice

Maximum (95.9 cm) plant height was recorded for hand pulling and the minimum for weedy check. The number of panicle bearing tillers m^{-2} varied significantly among different weed control treatments (Table 2). Significantly greater and statistically equal number of tillers per unit area were recorded for hand pulling (402.50), mechanical hoeing (403.25), pretilachlor (392.75) and butachlor (390.12) against the minimum in weedy check (Table 2). Maximum kernels per panicle were noted in hand pulling and mechanical hoeing followed by butachlor and pretilachlor. Statistically similar kernel numbers were noted in pendimethalin and weedy check. Highest 1000-grain weight was recorded from the hand pulling treatment followed by mechanical hoeing. Butachlor and pretilachlor produced statistically equal 1000-grain weight. Minimum 1000-grain weight was recorded in weedy check which was statistically equal to pendimethalin. Grain yield varied significantly among different weed control treatments (Table 2). Maximum grain yield was recorded from hand pulling against the minimum in weedy check. Nevertheless, the grain yield in hand pulling treatment was statistically at par with mechanical hoeing which in turn was statistically similar to butachlor and pretilachlor. Grain yield in pendimethalin was statistically equal to weedy check. Maximum increase in grain yield (30.3%) over control was recorded in the hand pulling treatment followed by mechanical hoeing (25.1% increase in grain yield over control). Chemical weed control treatments also resulted in significant increase in grain yield over the control treatment. Pretilachlor, butachlor and pendimethalin resulted in 19.0, 17.8 and 5.8% increase in grain yield over the control treatment (weedy check). Different weed control practices showed a significant effect on straw yield ha^{-1} (Table 2). Significantly higher (10.46 t ha^{-1}) straw yield was recorded for mechanical hoeing which was statistically at par with other weed control treatments against the minimum in the weedy check. Harvest index was significantly affected by different weed control treatments (Table 2). Statistically the higher harvest index was recorded for pretilachlor (23.8%) and hand pulling (23.8%) which were at par with each other. Weedy check and pendimethalin had a lower and statistically equal harvest index.

Effect of weed control treatments on quality of rice

The effect of different weed control treatments on the percentage of sterile spikelets was significant (Table 3). The higher percentage (10.84) of sterile spikelets was recorded for weedy check which was at par with pendimethalin (10.1%). Minimum percentage (8.54) of sterile spikelets was recorded in the mechanical hoeing. Hand pulling, butachlor and pretilachlor were significantly at par with mechanical hoeing regarding the sterile spikelets percentage. Nevertheless the percentage of abortive kernel was statistically similar for all the weed control treatments. The effect of different weed control practices on the percentage of opaque kernels was found significant (Table 3). Opaque kernels were noted maximum (8.6%) in the weedy check followed by the pendimethalin (8.2% opaque kernels). Minimum opaque kernels were noted for hand pulling and mechanical hoeing. Significant variation of kernel chalkiness among different weed control treatments was noted (Table 3). Highest percentage of chalkiness (25.8 and 25.5 respectively) was recorded for hand pulling and pendimethalin while minimum (23.4) in the weedy check. Mechanical hoeing, butachlor and pretilachlor had statistically the similar percentage of chalky kernels. Normal kernels were significantly affected by different weed control practices (Table 3). Normal kernels percentage was noted maximum in hand pulling and mechanical hoeing (62.0 and 60.5 respectively). The percentage of normal kernels in the weedy check was statistically similar with the chemical weed control treatments. Kernel length and width were significantly affected by different weed control treatments (Table 4). Weedy check produced the grains with minimum length and width against the maximum in the hand pulling and mechanical hoeing which were followed by the chemical weed control treatments (pretilachlor, pendimethalin and butachlor respectively). Kernel protein and amylose contents were noted maximum for the hand pulling and mechanical hoeing followed by the weedy check while they were noted minimum for the chemical weed control treatments (Table 4). Kernel water absorption ratio was noted maximum in the hand pulling treatment and the minimum in pendimethalin.

Discussion

The rice weeds especially barnyard grass (*Echinochloa crussgalli*), purple nutsedge (*Cyprus rotundus*) and jungle rice (*Echinochloa colonum*) are very troublesome and difficult to control (Smith Jr., 1981; Rodenburg and Johnson, 2009). Direct cultivation of rice in non-flooded lands makes weed control more difficult than the conventionally flooded transplanted rice (Begum et al. 2006; Chauhan and Johnson, 2009). Water shortage and climate change have made it inevitable to investigate the direct seeding of rice in water short environment of the Pakistan (Ehsanullah et al. 2007; Farooq et al. 2009). A number of investigations carried out worldwide gave encouraging results regarding weed control in direct seeded rice (Rao et al. 2007; Singh et al. 2006; Farooq et al. 2011). In our study, the weed control treatments were quite effective in suppressing the weeds and reducing their density and dry weight (Table 1). More than 80% reduction in the total weed density over control by the applied herbicides (butachlor, pendimethalin and pretilachlor) indicates their effectiveness against the weeds (Koger et al. 2006; Singh et al. 2006; Singh et al. 2008a; Mahadi et al. 2007). The herbicides also reduced the total weeds dry weight over control treatment (weedy check) very effectively (73.7-86.8%; Table 1) which represents their weed control efficiency (Koger et al. 2006; Singh et al. 2006; Mahadi et al. 2007; Singh et al. 2008a). Highest reduction in total weed density and total dry weed in hand pulling over the weedy check was possible with the involvement of the intense labor and frequency of the weeding i.e. three times during the growing season (Rao et al. 2007). Although hand pulling resulted in highest weed reduction but intense labor involvement may render it an uneconomical and unfeasible weed control method (Donald, 2000). Even though the mechanical control resulted in least reduction in weed density and dry weight over control but that was in a reasonable range (Table 1). The lower efficiency of the mechanical weed control than the hand pulling and chemical weed control treatments may be due to the inefficient weeding instrument and the weeds growing in the intra-row which were not cut by "kasola". Weedy check negatively influenced the plant height, panicle bearing tillers, kernels per panicle, 1000-kernel weight, grain yield, straw yield and harvest index. All these parameters were improved in the weed control treatments compared with the weedy check. This was attributed to the weed free environment provided by these weed control treatments (Donald, 2000; Arif et al. 2004; Jabran et al. 2008; Singh et al. 2008b; Jabran et al. 2010). Increased plant height in weed control treatments than the weedy check indicated the improvement in crop growth due to relative weed free environment as a result of implemented treatments (Carey and Kells, 1995). Improvement in yield contributing parameters including panicle bearing tillers, kernels per panicle and 1000-kernel weight in the treated plots compared with the weedy check resulted in improved grain yield (Carey et al. 1992; Jabran et al. 2008; Jabran et al. 2010). The kernel yield was higher in all the plots with herbicide application. The increase in kernel yield by application of pendimethalin@1.65 kg a.i. ha^{-1} was comparatively less than the application of pretilachlor@1.25 kg a.i. ha^{-1} and butachlor@1.8 kg a.i. ha^{-1} which might be due to some phytotoxic damages caused to the crop plants by the pendimethalin (Smith, 2004). Plant height and the yield contributing parameters were also lower in this treatment compared with the other herbicides applied (Table 2). Mechanical hoeing resulted in significant increase (25.1 %) in grain yield over control despite lower percentage inhibition in total weed density and dry weight over control compared with the other weed control treatments. This may be due to the enhanced nutrient availability due to soil stirring during carrying out the mechanical hoeing (Arif et al. 2004). Higher harvest index recorded in hand pulling and pretilachlor was due to more grain yield and comparatively lower straw yield recorded in these treatments. Higher percentage of sterile spikelets, opaque and chalky kernels in the weedy check compared with the weed control treatments may be the result of rigorous competition among crop and weeds for nutrients, space, light and carbon dioxide (Tindal et al. 2005). Weed free environment was helpful in improving the kernel quality of rice (Singh, 2008c; Farooq et al. 2011). Better kernel quality like increased grain length and improved amylose and protein concentrations in the weed control treatments compared with the weedy check were due to less weed competition and healthy rice kernels (Tindal et al. 2005; Rao et al. 2007; Singh, 2008c; Farooq et al. 2011).

Conclusion

Manual, mechanical and chemical weed control was effective in suppressing weeds and improving rice yield and quality. Hand pulling was more effective in decreasing weed density and dry weight and increasing rice yield than the mechanical hoeing. The order of herbicides in suppressing the weeds and increasing rice yield as well was pretilachlor> butachlor> pendimethalin. Hand pulling and mechanical hoeing resulted in increased rice yield than herbicides. However three times repetition of the weed control practice may not be economically viable due to expensive labor.

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