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CHEMICAL WEED CONTROL IN WHEAT UNDER DIFFERENT RICE RESIDUE MANAGEMENT OPTIONS

Abdul Khaliq[1*], Muhammad Riaz Gondal[2], Amar Matloob[1], Ehsan Ullah[1], Saddam Hussain[1] and Ghulam Murtaza[3]

ABSTRACT

Rice residue management can influence weed dynamics and productivity of subsequent wheat crop. A field experiment was conducted at Agronomic Research Area, University of Agriculture, Faisalabad during Rabi 2010-11 to evaluate the influence of two broad spectrum post-emergence herbicides (isoproturon+carfentrazone and iodo+mesosulfuron) on wheat and associated weeds under different rice residue management options (residue incorporation, residue burning and zero tillage). The experiment was laid out in randomized complete block design under split plot arrangements. Residue management options were assigned to main plots while weed control treatments were maintained in sub-plots. Zero tillage was helpful in averting weed growth and recorded more wheat grain yield even under weedy check as compared to the rest of the residue management options. Residue incorporation resulted higher weed density and biomass than residue burning. Both the herbicides provided >80% suppression in weed density and dry biomass with upper limit (100%) recorded when isoproturon+carfentrazone was applied to zero tillage plots. The herbicide treatments also improved wheat leaf area indices, crop growth rate and dry matter accumulation over weedy check under all residue management options. Maximum grain yield (3742 kg ha^{-1}) was obtained when isoproturon+carfentrazone was applied to zero tillage plots. Highest economic net benefits were also associated with the same treatment combination. Zero tillage seems more appropriate residue disposal method in rice-wheat cropping system than residue burning and incorporation.

Key words: Burning, herbicide, rice residues, weed, wheat yield, zero tillage.

INTRODUCTION

Rice-wheat cropping system is the core production system in many Asian countries including Pakistan. It is the most popular and prevalent sequence covering an area of about 2.2 m ha in Pakistan (Mann *et al.,* 2008). Unfortunately, productivity of this cropping system is stagnant and total factor productivity is declining because of a fatigued natural resource base (Timsina and Connor, 2001). A huge amount (7-10 t ha^{-1}) of crop residues is produced annually in this cropping system (Gupta *et al*., 2004). Farmers commonly remove wheat straw for feeding the animals. However, rice straw due to its high lignin and silica and low protein content demerits for this

[1]Department of Agronomy, University of Agriculture, Faisalabad
[2]Fodder Research Institute, Sargodha
[3]Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad
[*]Corresponding author's email: khaliquaf@gmail.com

purpose (Pathak *et al.,* 2006). Short turn-around time for rice residues disposal or management compel farmer towards burning (Gupta *et al.,* 2003). Hence, its management remains a key issue as it interferes with tillage and seeding operations for subsequent wheat crop. Nonetheless, crop residues are valuable natural resource whose management is vital for sustainability and productivity of this system (Kumar and Goh, 2000). Moreover, weed infestation is a major biological constraint to higher yields of both crops in this rotation (Yadvinder-Singh *et al.,* 2005) and mix stand of grassy and broad-leaved weeds has been reported to inflict a yield penalty of 48-52% in wheat (Khan and Haq, 2002).

Management practices opted for one crop can have definite implications for productivity of subsequent crop followed in sequence. Management of residues of previous crop can also inflict qualitative and quantitative changes in weed flora associated with succeeding crop (Kumar and Goh, 2000). Several residue management options like incorporation, surface mulching or retention and direct drilling in residues can be opted as an alternative to current detrimental practice of rice residue burning. Residue incorporation suppress weed growth through release of phytotoxins (Weston and Duke, 2003) while mulching produces smothering effect posing physical hindrance (Reddy, 2003). Residue burning depletes seed bank by removal of viable seeds (Yadvinder-Singh *et al.,* 2005). On the other hand, burning is also reported to stimulate emergence of weed species such as wild oats and silver grass (Chitty and Walsh, 2003). With the advent of modern drills that enable wheat sowing in rice residues without land preparation, zero tillage has emerged as the most promising resource conservation technology in rice-wheat cropping systems (Erenstein and Laxmi, 2008). Under zero tillage, several authors reported less weed density in wheat crop than conventional tillage (Mehla *et al.,* 2000; Mann *et al.,* 2008; Usman *et al.,* 2010). Besides having direct consequences for weed growth, these residue management options can influence herbicide efficacy (Kumar and Goh, 2000). Burning or incorporation of residues can increase ash and organic matter content thereby decreasing herbicide efficacy due to greater adsorption potential (Yadvinder-Singh *et al.,* 2005).

It is believed that various residue disposal methods can alter weed response thus influencing the level of weed control that can be attained with a particular herbicide. A voluminous body of information is available on the influence of tillage, herbicides, fertilizers, seeding densities, row spacing and their possible interactions on dynamics of weed-crop competition and herbicide performance in wheat. Nevertheless, few studies have addressed rice residue management in the scenario of weed management in wheat fields. Thus, interaction of various rice residue management techniques with herbicides remains a germane issue. Hence, it needs to be considered in the perspective of integrated weed management for enhanced productivity of subsequent wheat crop in rice-wheat cropping system. The present study;

therefore was designed to ascertain the influence of rice residue management options and chemical weed control on wheat productivity under agro-ecological conditions of Faisalabad.

MATERIALS AND METHODS

Site description

To assess the impact of different rice residues management options and herbicides on weeds and performance of wheat, a field experiment was conducted at Agronomic Research Area, University of Agriculture, Faisalabad (31.25° N, 73.09° E, and 184 m above sea level). Due to high evapotranspiration, Faisalabad features a semi-arid climate with mean annual rainfall of about 200 mm. The soil of the experimental site was a sandy clay loam with proportion of sand, silt and clay as 53.25, 20.55 and 26.20%. Soil pH and EC was 7.6 and 0.85 dSm^{-1}, respectively. The organic matter, total nitrogen, available phosphorus and potassium were 0.66%, 0.060%, 14 mg kg^{-1} and 185 mg kg^{-1}, respectively. The Bulk density and cation exchange capacity was 1.40 g CC^{-1} and 4.1 $cmol_c$ kg^{-1}.

Experimentation

The proposed study was laid out in randomized complete block design under split plot arrangements with four replications. Different rice residues management options, viz. residues incorporation (RI), burning (RB) and zero tillage (ZT) were assigned to main plots (25 m × 15 m) while herbicide treatments were kept in subplots (6 m × 2.70 m). A soaking irrigation (10 cm) was applied 10 days before wheat planting to keep zero tillage plots soften and moist while other plots to working conditions to prepare root and seed bed. Under field, rice residue incorporation was accomplished with a disc plough and then cultivating twice with a tractor mounted cultivator followed by planking each time. For residue burning, rice residues were burnt *in situ* and above mentioned tillage operations were carried out. ZT plots received glyphosate (Roundup, Monsanto Agritech, Pakistan) at 20 days before sowing to curtail established weeds that otherwise were killed through cultivation in rest of the tillage systems. Zero tillage was performed using happy seeder, a machine that facilitates wheat sowing into undisturbed seed bed in a single pass operation. The previous crop in ZT plots was direct seeded rice that followed the same tillage practices as for preceding wheat. A standard fertilizer dose of 120:60 kg N:P ha^{-1} was applied in the form of urea and triple super phosphate. Whole of the phosphorus and 1/3rd of the N was applied as a starter basal dose while residual N was equally splitted at tillering and booting. Seed of wheat *cv*. Sehar-2006 was collected from Wheat Research Institute, Faisalabad. Test crop was sown in the first fortnight of November using a seed rate of 125 kg ha^{-1} in 22.5 cm apart rows during Rabi 2010-11 growing season. The first irrigation was applied 14 days after crop emergence, and subsequent irrigations were applied at tillering, jointing, booting, anthesis and grain filling. In all, five irrigations were applied to mature a crop besides soaking irrigation. Meteorological data during the course of experimentation are presented in Fig. 1.

Two commonly used broad-spectrum herbicides with contrasting mode of action were purchased from local market. Iodo+mesosulfuron (Atlantis 3.6WG, 14.4 g a.i. ha^{-1}) and isoproturon+carfentrazone (Affinity 50WP, 1000 g a.i. ha^{-1}) were applied at 30 days after sowing (DAS) to subplots using a Knapsack sprayer fitted with a T-Jet nozzle at a pressure of 207 kPa. Volume of spray (320 L ha^{-1}) was calibrated using water prior to spray. A weedy check was maintained for comparison.

Data Collection

Data on weed density and dry biomass were recorded from two randomly selected quadrants (50 cm × 50 cm) from each subplot. In general, weed flora of the experimental site comprised of wild oat (*Avena fatua* L.), canary grass (*Phalaris minor* Retz.), swine cress (*Coronopus didymus* L. Sm.), broadleaf dock (*Rumex dentatus* L.), yellow clover (*Melilotus indicus* L. All.), fumitory (*Fumaria indica* [Hausskn.] Pugsley) and blue pimpernel (*Anagallis arvensis* L.). Weeds were counted and clipped off the soil surface. These weeds were dried in an oven at 70 ºC for 48 h and dry biomass was recorded till a constant weight was achieved. For wheat growth analysis, a randomly selected area of 25 cm × 25 cm was harvested at 10 days interval up to 105 DAS leaving appropriate borders. Harvested plant material was separated into respective fractions (stem, leaves and spikes). Fresh and dry weight of each plant fraction was measured and used in subsequent calculations. Leaf area index and crop growth rate of wheat crop were computed using the formulae of Watson (1947) and Hunt (1978), respectively. At physiological maturity, crop was manually harvested from an area of 4 m × 1.35 m from each subplot during first week of May, 2011. Crop was tied into bundles and sun dried for five days in respective subplots and manually threshed thereafter. Grain yield of individual subplot was recorded and expressed as kg ha^{-1}.

Statistical and economic analyses

Analyses of variance were performed with all data to confirm variability of data and validity of results. The differences amongst treatments were separated using least significance difference test at 0.05 probability level (Steel *et al.,* 1997). Graphical representation of the data was carried out using MS-Excel and standard errors were computed. To ascertain the relationship between different variables, regression analyses were also done using MS-Excel. Economic analyses based on prevailing costs of inputs and price of output were carried out (CIMMYT, 1988).

RESULTS AND DISCUSSION

Weed growth

Data regarding weed density and dry biomass revealed significant ($p \leq 0.05$) influence of various rice residue management techniques and herbicide treatments on these two weed attributes (Fig. 2).

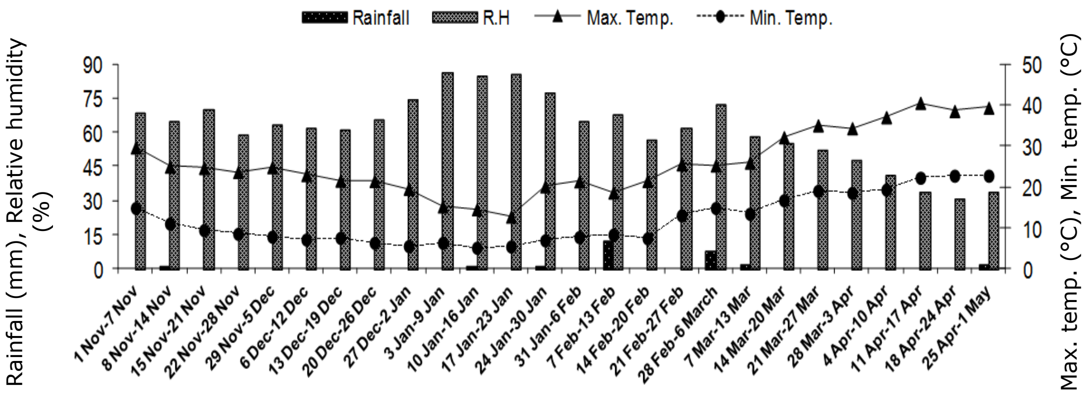

Figure 1. Metrological data during the course of present study (Source: AgroMet Observatory, Department of Crop Physiology, UAF).

Significant ($p \leq 0.05$) differences regarding weed growth were observed for residue management option and ZT recorded less weed count than RB and RI control plots. Both herbicide treatments furnished a fair level (>80%) of weed suppression over control in all the residue management options. Nonetheless, isoproturon+carfentrazone scored maximum inhibition (95%) of weed density as against (89%) recorded for iodo+mesosulfuron. Response of weed density to various herbicide treatments varied as a function of residue management options due to significant ($p \leq 0.05$) interaction among these two factors. Both herbicide treatments provided less weed count under ZT than rest of the two residue management options. Application of isoproturon+carfentrazone to ZT plots reduced weed density by 100% over control. The corresponding reduction in weed density amounted to 92% for iodo+mesosulfuron.

Weed dry biomass was also significantly ($p \leq 0.05$) affected by herbicides and residue management techniques (Fig. 2). Inhibition in dry weed biomass was less for RI than RB or ZT. Both the herbicides averted total dry weed biomass by >80%. Isoproturon+carfentrazone application to ZT plots recorded 100% reduction over weedy control that was at par ($p \leq 0.05$) with application of isoproturon+carfentrazone and iodo+mesosulfuron under RB. Khan *et al.* (2004), Arif *et al.* (2004) and Chhokar *et al.* (2007) also recorded significant reduction in weed growth with the application of herbicides. The minimal weed density and dry biomass in herbicide treatments are presumably due to their phytotoxicity against diverse and recalcitrant weed flora. Less weed infestation in ZT plots might be due to the physical hindrance posed by surface residues (Streit *et al.,* 2002) and absence of soil disturbance (Mehla *et al.,* 2000; Mann *et al.,* 2004).

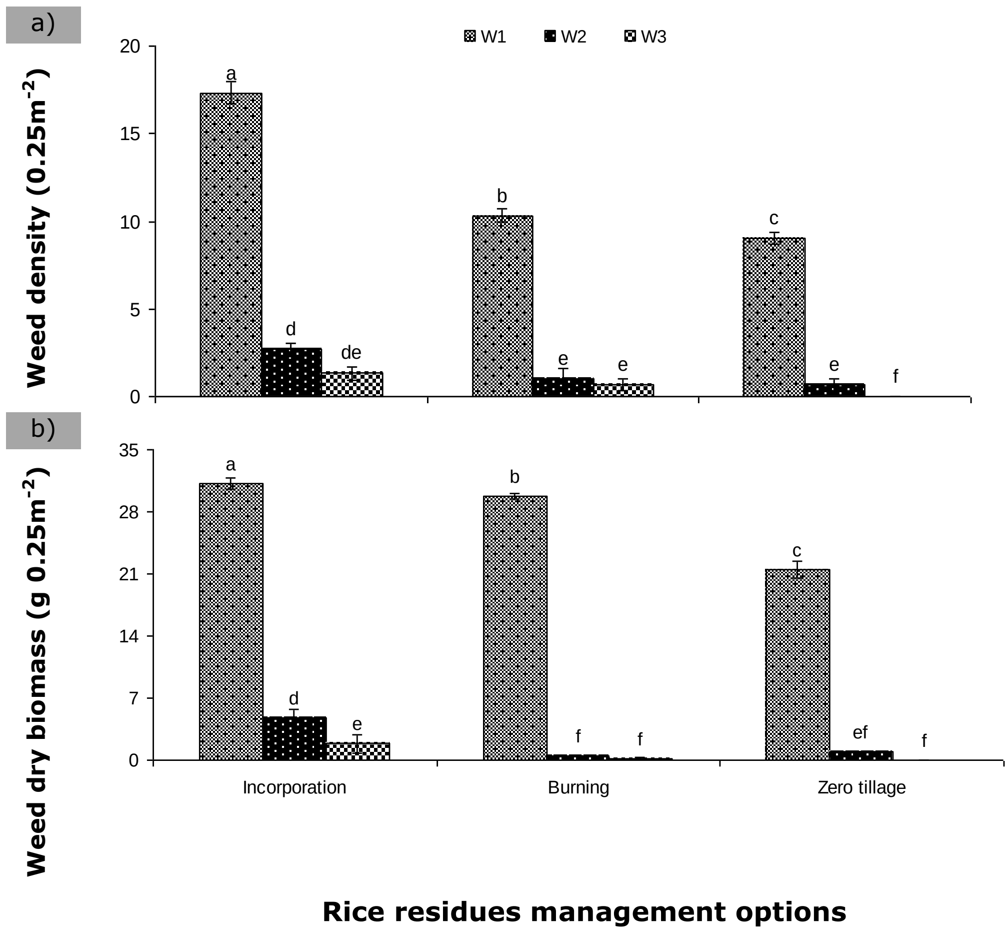

Figure 2. Influence of different rice residues management options and herbicide treatments on total weed density and biomass in wheat. Vertical bars above mean denote standard error of four replicates. Means with different letters differ significantly at 0.05 probability level by HSD Tuckey's Test. W_1: weedy control, W_2: iodo+mesosulfuron, W_3: isoproturon+carfentrazon.

This tillage system has been reported to alter the parameters of environment like moisture regimes, diurnal temperature and light availability to weed seeds (Chhokar *et al.,* 2007; Mishra and Singh, 2012) affecting germination timing and pattern. In conventional tillage systems, incorporation of weed seeds into soil breaks their dormancy (Chauhan and Opena, 2012) and suggests why weed densities are lower in ZT (Yenish *et al.,* 1992).

Burning was found to be more effective in retarding weed growth than incorporation presumably due to loss of viable weed seeds. Higher weed pressure under rice RI has been reported elsewhere (Yadvinder-Singh *et al.,* 2005). Difference in weed pressure in ZT and RI seems to have arisen in part also from variable release of phytotoxic allelochemicals from rice residues following pre-soaking irrigation. In RI plots, such chemicals are expected to release faster following incorporation and undergo rapid decomposition and degradation while under ZT, these processes expanded over a long span of time. It is assumed that delayed release of phytotoxic allelochemicals under ZT might have coincided with initial growth of weeds (as weeds emerged after 1^{st} irrigation). These allelochemicals under RI were presumably not available in biologically active form and concentration due to time lapse between their release and weed emergence. Variation in herbicide efficacy under different residue management options might have originated from variable weed infestation levels and variable soil properties mediated by different residues management and tillage practices (Kumar and Goh, 2000) which influence herbicide adsorption, movement, persistence and efficacy (Bhagat *et al.,* 1996). Our data showed the effectiveness of ZT in reducing weed menace in wheat fields than rest of the residue management options. Absence of soil disturbance and unavailability of light to seeds buried in soil seems the possible explanation. Presence of rice residues as surface mulch in ZT might also have contributed towards weed suppression by posing physical and chemical (allelopathic) effects. ZT could be opted as a part of integrated weed management approach and as a resource conservation technique in rice-wheat cropping systems.

Growth and yield components of wheat

Significant ($p \leq 0.05$) improvement in wheat growth over weedy control was recorded by different herbicide treatments under all rice residue management options (Fig. 3). Leaf area index (LAI) showed periodic increase under different rice residue management options. Nonetheless, such an increase was more pronounced in ZT as compared to RB and RI (Fig. 3). The maximum LAI was recorded at 85 DAS which declined thereafter. Averaged across weed control treatments, isoproturon+carfentrazone was superior in improving LAI of wheat than iodo+mesosulfuron. At 85 DAS, more LAI was noticed by application of isoproturon+carfentrazone under ZT that was greater when same herbicide was applied to RI and RB plots. Minimum values of leaf area index were recorded in weedy control plots. Nonetheless, at early stage of crop, weedy control plots depicted higher LAI than herbicide treated plots presumably due to transitory adverse effect on crop. Crop growth rate also followed similar trend (Fig. 3). Wheat growth was triggered under three rice residue management options by herbicide treatments but such an increase was more pronounced in zero tillage as compared to other options. Temporal increase in crop growth rate was observed with maximum values achieved at 75-85 DAS, which declined substantially with passage of time. Application of isoproturon+carfentrazone recorded maximum crop growth rate and it was followed by iodo+mesosulfuron application under ZT. The growth rate of weedy check treatment was lower in all rice residue management options due to weed competition. However, total dry matter accumulation in wheat was more in case of RI than burning and ZT. Both the herbicides recorded higher dry matter over weedy check in all residues management options. Nonetheless, isoproturon+carfentrazone was superior in improving total dry matter accumulation in wheat than iodo+mesosulfuron (Fig. 3).

Data regarding wheat yield indicated a positive influence of different herbicide treatments over control under different rice residue management options (Fig. 5). Higher grain yield (3573 kg ha^{-1}) was recorded for ZT than RI (3041 kg ha^{-1}) and RB (3277 kg ha^{-1}). Application of isoproturon + carfentrazone scored highest grain yield (3544 kg ha^{-1}), whereas statistically similar grain yield (3357 $kgha^{-1}$) was also furnished by iodo+mesosulfuron. Interaction of residue management options with weed control treatments was significant ($p \leq 0.05$) for wheat grain yield. Maximum yield (3742 kg ha^{-1}) was achieved when isoproturon+carfentrazone was applied to ZT plots. Whereas, this herbicide recorded 3579 and 3312 kg ha^{-1} in RB and RI, respectively. Overall, 5-24% more wheat grain yield was recorded for herbicides over weedy check. The negative implication of weed density and biomass for yield was evident regardless of the residue management options and regression accounted for >80% variability in wheat grain yield owing to these two weed attributes (Fig. 4). Wheat grain yield was also positively related with total dry matter accumulation by wheat (Fig. 4).

Higher grain yield in herbicide treated plots may be an outcome of efficient weed control. These results are in conformation with Baghestani *et al.* (2008), Chhokar *et al.* (2008) and Santos (2009) who reported that herbicides proffer sizeable increase in crop productivity corresponding to their weed control spectrum. The lower yield under RI may be due to higher weed infestation and immobilization of N due to slow decomposition of rice straw at low temperatures (Kumar and Goh, 2000, Yadvinder-Singh *et al.,* 2005). Whereas, higher yield in ZT is ascribed to reduced weed growth (Mann *et al.,* 2004; Chhokar *et al.,* 2007; Erenstein and Laxmi*,* 2008). Work carried out by Mann and his colleagues (Mann *et al.*, 2008) under wide array of soil type and farmers with contrasting socio-economic background in Pakistan also suggested the effectiveness of ZT technology as it saved irrigation (22%), fuel (78%), and cultivation (88%) simultaneously and increased yields and farmer's profits.

Economic analysis

All weed control treatments showed higher net benefits over control (Table 1). Economic analysis revealed that least (Rs. 84,721 ha^{-1}) net benefit was recorded in weedy control of rice RI that was quite lower than that observed for RB (Rs. 90,494 ha^{-1}) and ZT (Rs. 10,9458 ha^{-1}). Higher net benefits were associated with application of isoproturon+carfentrazone under all residue management options; nonetheless upper limit (Rs. 11,7763 ha^{-1}) was achieved under ZT (Table 1).

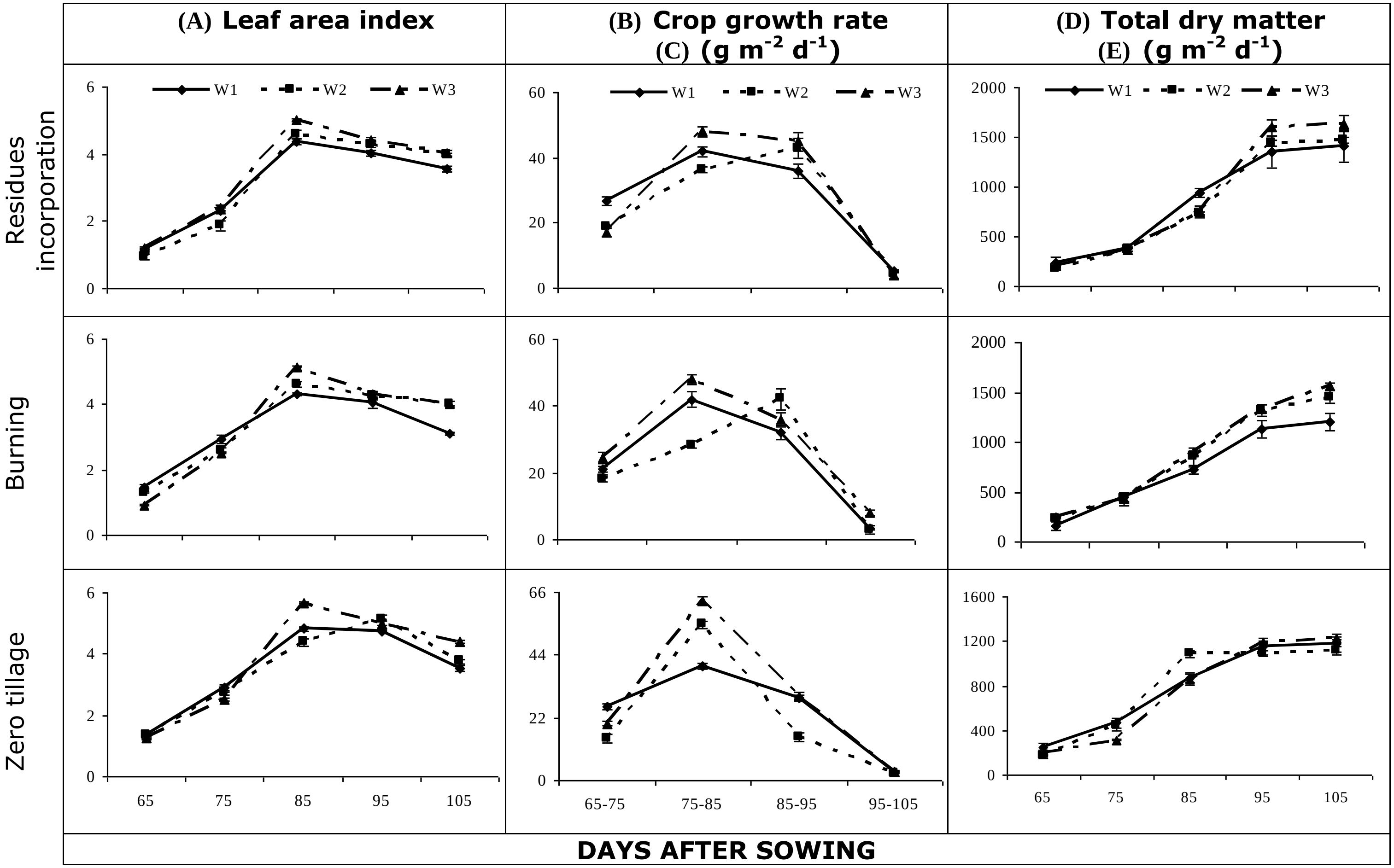

Figure 3. Influence of various rice residues management options on (A) Leaf area index (B) crop growth rate and (C) total dry matter accumulation in wheat. Vertical bars above mean denote standard error of four replicates. W_1: weedy control, W_2: iodo+mesosulfuron, W_3: isoproturon+carfentrazon.

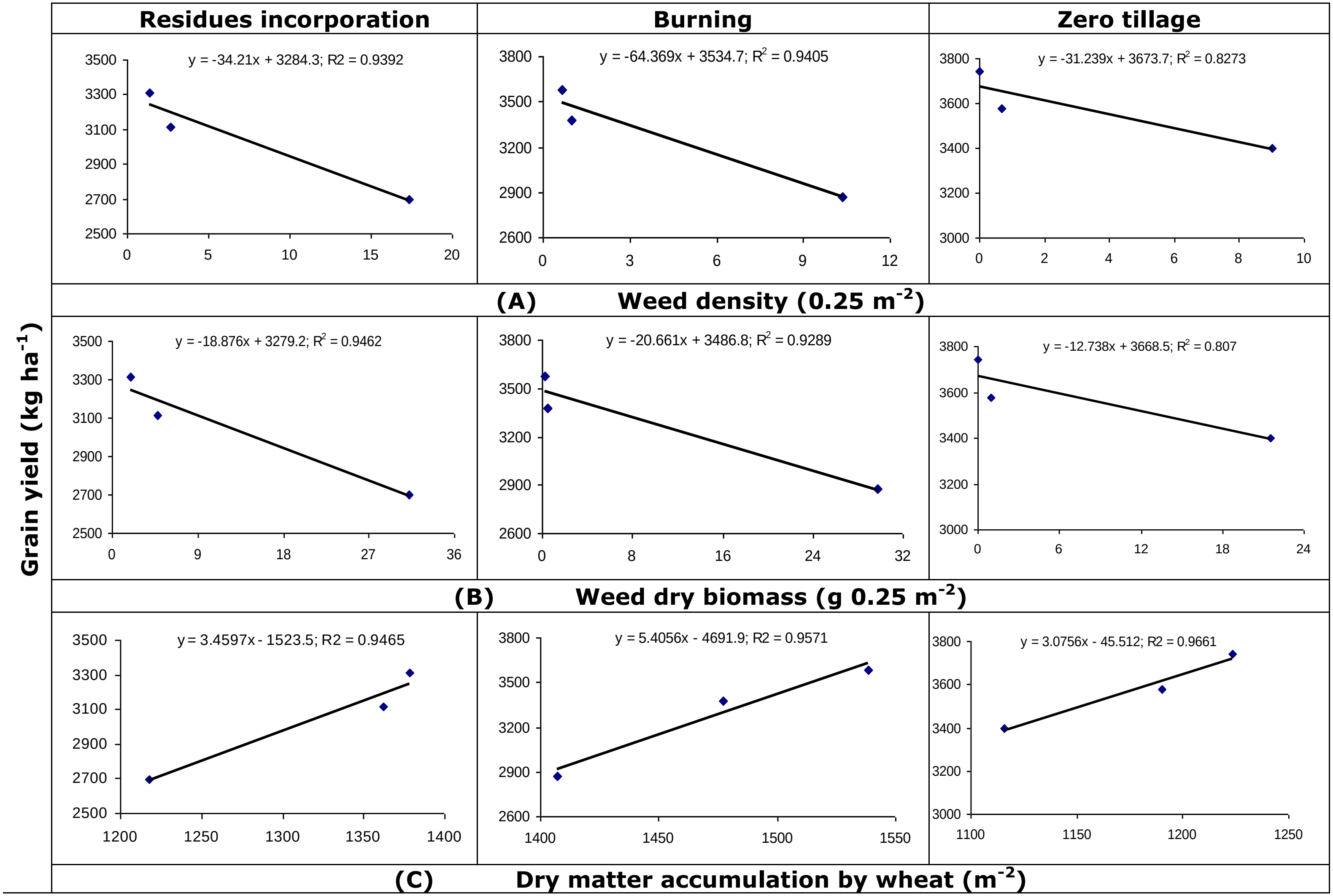

Figure 4. Relationship of wheat grain yield with (A) weed density, (B) weed dry biomass and (C) dry matter accumulation of wheat in three rice residues management options.

Table 1. Economic analysis of different rice residues management options and herbicide treatments in wheat.

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Remarks
Grain yield (G.Y)	2698	3112.6	3312.3	2872.6	3380	3579	3398	3548.66	3629	kg ha^{-1}
10% loss (grain)	269	311.26	331.3	287.26	338	357	339.8	354.86	362.9	To bring at farmer level
Adjusted G.Y.	2429	2801.34	2981	2585.34	3042	3242	3058.2	3193.8	3266	10% discount
Income from G.Y.	57689	66532	70799	61402	72248	76998	72632	75853	77570	Rs. 23.75/kg
Straw yield (S.Y)	6580	7360	7480	6980	7810	7920	7190	8090	8170	Kg ha^{-1}
10% loss (straw)	658	736	748	698	781	792	719	809	817	To bring at farmer level
Adjusted S.Y.	5922	6624	6732	6282	7029	7128	6471	7281	7353	10% discount
Income from S.Y	35532	39744	40392	37692	42174	42768	38826	43686	44118	Rs. 6/kg
Gross income	93221	106276	111191	99094	114422	119766	111458	119539	121688	
Cost of tillage	8500	8500	8500	8500	8500	8500	2000-	2000-	2000-	Prevailing operational cost of tillage implements
Cost of Atlantis	-	1625	-	-	1625	-	-	1625	-	Rs. 1625 ha^{-1}
Cost of Affinity	-	-	1625	-	-	1625	-	-	1625	Rs. 300/20 L
Cost of Burning	-	-	-	100	100	100	-	-	-	Rs.100 ha^{-1}
Spray application cost	-	200	200	-	200	200	-	200	200	Rs. 200/man one man day^{-1} ha^{-1}
Spray rent	-	100	100	-	100	100	-	100	100	Rs. 100 per spray
Cost that varied	8500	10425	10425	8600	10525	10525	2000	3925	3925	
Net benefit	84721	95851	100766	90494	103897	109241	109458	115614	117763	

T_1= Incorporation + weedy check, **T_2**= incorporation + iodo+mesosulfuron, **T_3**= incorporation + isoproturon+carfentrazone, **T_4**= burning + weedy check, **T_5**= burning + iodo+mesosulfuron, **T_6**= burning + isoproturon+carfentrazone, **T**7= zero tillage + weedy check, **T_8**= zero tillage + iodo+mesosulfuron, **T_9**= zero tillage + isoproturon+carfentrazone

The higher net benefit from ZT is ascribed to higher grain yield, lower production costs. The cost effectiveness of ZT in wheat is in line with Usman *et al.* (2010).

In crux, ZT seems more appropriate residue disposal method in rice-wheat cropping system than residue burning and incorporation as it simultaneously averted weed growth and recorded higher wheat yield. Although capable of reducing weed burden, residue burning might pose deleterious effects on environment and hence needs to be avoided.

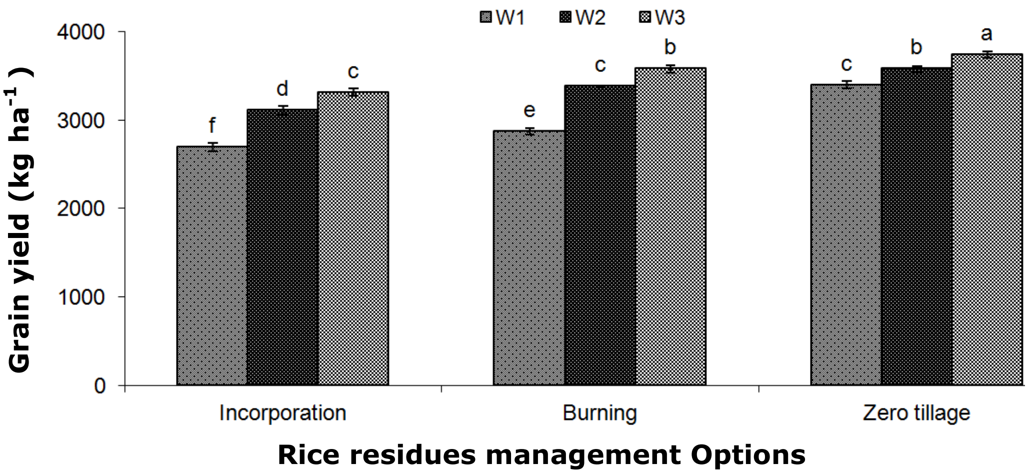

Figure 5. Influence of different rice residues management options and herbicide treatments on grain yield of wheat. Vertical bars above mean denote standard error of four replicates. Means with different letters differ significantly at 0.05 probability level by HSD Tuckey's Test. W_1: weedy control, W_2: iodo + mesosulfuron, W_3: isoproturon + carfentrazon.

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