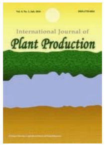

International Journal of Plant Production 10 (1), January 2016
ISSN: 1735-6814 (Print), 1735-8043 (Online)
www.ijpp.info

GUASNR

Weed management and conservation tillage for improving productivity, nutrient uptake and profitability of wheat in soybean (*Glycine max*)-wheat (*Triticumaestivum*) cropping system

A. Monsefi[a,*], A.R. Sharma[b], N. Rang Zan[c]

[a]*Former Ph.D Student, Division of Agronomy, Indian Agricultural Research Institute, New Delhi, India.*
[b]*Director, ICAR-Directorate of Weed Research, Jabalpur, India.*
[c]*Assistant Professor, Department of Soil Science, Ramin Agricultural and Natural Resources University, Iran.*
*Corresponding author. E-mail: a.monsefi@yahoo.com

Received 5 July 2014; Accepted after revision 5 September 2015; Published online 23 November 2015

Abstract

The effect of tillage, crop establishment and weed management was studied on the performance of wheat grown after soybean at New Delhi, India during 2010-11 to 2011-12. Sixteen treatment combinations involved 2 tillage, viz. conventional tillage (CT) and zero tillage (ZT), two crop establishment practices, viz. raised-bed and flat-bed and four weed management, viz. isoproturon + hand weeding, mesosulfuron+ iodosulfuron, soybean stover + isoproturon and unweeded control. Population density and dry weight of weeds was significantly more under raised-bed than flat-bed, particularly under ZT condition, while under flat-bed, the differences between CT and ZT were on par. Weed control efficiency was the highest (90.7-91.4%) under isoproturon + hand weeding and significantly higher than other treatments (86.5-90.2%). Yield losses under unweeded control were 23.1-26.1%. Grain yield of wheat under ZT-flat-bed (4.46-4.73 ton ha^{-1}) was equal to that under CT-flat-bed (4.44-4.79 ton ha^{-1}), which was comparatively more than raised-bed conditions. All weed control practices were on par and equally effective improving the yield of grain (19.2-27.5%) as well as straw (14.0%) compared with unweeded control. Nutrient uptake by crop decreased linearly with increase in nutrient removal by weeds. The highest net benefit: cost ratio was under ZT-flat-bed and mesosulfuron + iodosulfuron (3.04) followed by soybean stover mulch + isoproturon (2.84). It was concluded that wheat can be grown underzero-till condition with post-emergence herbicide application for realizing higher productivity and profitability in the Indo-Gangentci plains of India.

Keywords: Economics; Grain yield; Raised-bed; Soybean stover; Weed control; Zero tillage.

Introduction

Modified tillage and crop establishment practices are being advocated for improving resource-use efficiency and crop productivity in diversified cropping systems. Technologies such as zero-tillage, raised-bed and residue management have been followed in different crops for conserving resources, improving yield and soil health. Wheat (*Triticumaestivum* L. emend. Fiori & Paol.) is the most important cereal crop globally and has received the highest attention for development and promotion of such technologies. In India it is grown on 26 M ha largely under irrigated conditions following intensive tillage operations. Zero tillage allows early and timely sowing of wheat and reduces the cost of the production. In zero tillage, the crops are sown with minimum disturbance of soil by placing the seeds in a narrow slit 3-4 cm wide and 4-7 cm deep without land preparation. Another new technique of wheat sowing, namely, furrow-irrigated raised-bed planting system (FIRBS) is a form of tillage wherein sowing is done on raised-beds. This optimizes tillage operation, saves water, reduces lodging, and ensures better fertilizer use. The weeds are major constraint in the adoption of zero tillage technology in wheat. Although zero tillage reduces the infestation of *Phalaris minor*, it aggravates the problem of broad-leaved weeds (Yaduraju and Mishra, 2002). Effective weed control is important not only to check the yield losses due to weeds but also to reduce the nutrient losses. Singh et al. (2002) found in his long term experiment in Karnal (Haryana) that the intensity of *P. minor* decreased by 30-40% in ZT when compared to conventional tillage, while the intensity of broad leaf weeds increased. Laxmi et al. (2003) and Pratap Singh et al. (2010), reported that 51% of farmers in Haryana and 85% of farmers in Bihar perceived that weed infestation had decreased due to adoption of ZT in wheat. The lower *P. minor* population and dry weight was recorded under ZT and higher under conventional tillage system of wheat cultivation. Optimizing tillage, crop establishment and weed control through is essential for improving resource-use efficiency and crop productivity. Therefore, the present study was undertaken to evaluate the effect of tillage and crop establishment and weed management practices on weed growth, productivity,economics and nutrient uptake of wheat.

Materials and Methods

A field experiment was conducted at the Research Farm of Division of Agronomy, Indian Agricultural Research Institute, New Delhi, situated at 28° 35’ N latitude and 77° 12’ E longitude and at an altitude of 228 m above mean sea level during 2010-11 and 2011-12. The soil was sandy loam in texture, neutral in pH (7.5) with bulk density of 1.57 Mg m^{-3} and infiltration rate of 1.02 cm hr^{-1}. It was low in organic C, $KMnO_4$ oxidizable N and $NaHCO_3$ extractable P and medium in NH_4OAc exchangeable K. The field had an even topography and good drainage system. New Delhi has a semi-arid and sub-tropical climate with hot dry summers and severe cold winters. There was a record of 43.8 mm rainfall in 2011-12 (November-April), while it was much less (-33.3%) in 2010-11.

The field was under cotton-wheat cropping system during the previous two years, where both the crops were grown in a fixed layout under four methods of tillage and crop establishment, viz. conventional tillage (CT)-raised-bed, CT-flat-bed, zero tillage (ZT) raised-bed and ZT-flat-bed. This experimental set-up was used for growing soybean followed by wheat with the same tillage and crop establishment. Ploughing was done with a disc-harrow followed by cultivator and rotavator in conventional tillage plots, while no ploughing was done in zero-tillage plots.

Sixteen treatments combinations involved four methods of tillage and crop establishment and four weed management practices, viz. isoproturon + hand weeding, mesosulfuron + iodosulfuron, soybean stover + isoproturon and unweededcontrol. A split-plot design with tillage and crop establishment in main plots and weed management practices in sub-plots was followed. The gross plot size was 6.0 × 2.8 m and net plot size was 6.0 × 1.4 m.

Wheat cv. 'HD 2894' was sown using seed-cum-fertilizer drill under CT and ZT flat-bed conditions at 23 cm row spacing. In case of raised-bed, sowing was done with bed-planter with three rows of wheat on the bed at 13 cm, thus maintaining a similar plant population under both the methods of crop establishment (Figure 1). A seed rate of 100 kg ha^{-1} along with recommended fertilizer dose of 120:60:40 kg N-P_2O_5-K_2O ha^{-1} was followed uniformly.

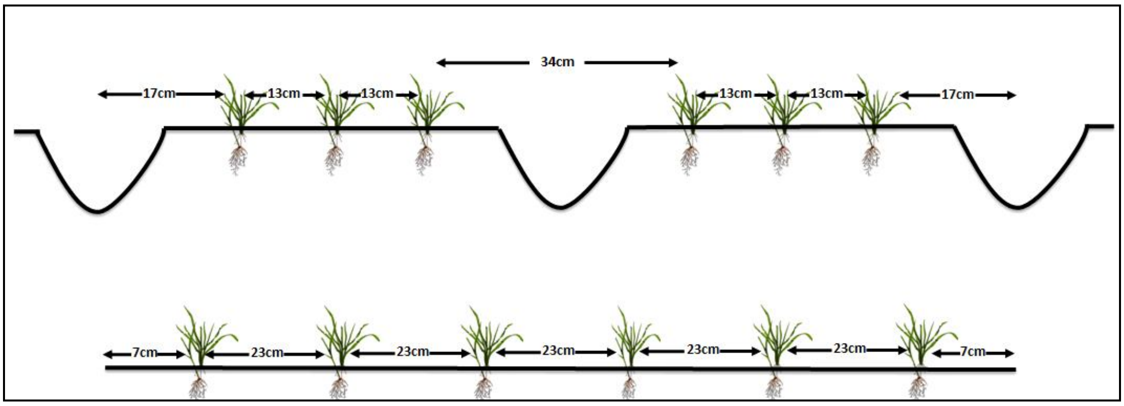

Figure 1. Sowing geometry of wheat on raised-bed and flat-bed.

Glyphosate @ 1.0 kg ha^{-1}was applied in ZT plots one week before sowing. Isoproturon @ 1.0 kg ha^{-1} was applied at 30 days of growth. Hand-weeding was done at 45 days of growth with help of hand-hoe. Herbicide mixture, mesosulfuron + iodosulfuron @ 400 g ha^{-1} was applied at 30 days of growth. Soybean stover mulch was applied @ 3 ton ha^{-1} after sowing. The crop was raised under irrigated conditions, with three and four irrigations applied during 2010-11 and 2011-12, respectively.

Observations were recorded on weed species and weed dry matter, growth and yield of wheat. Economic analysis was done as per the prevailing cost of inputs and price of output. According to the cost of operation machine (tillage, sowing machine in flat-bed as well as raised-bed and threshing), labor charge for hand weeding, seed, herbicide, diesel, irrigation water, fertilizer and storage the cost of cultivation in wheat treatments were calculated. Cost of treatments was defined as total income from selling seed and straw minus total expenditure for individual treatment. Data collected were subjected to analysis of variance (ANOVA) using the Statistical Analysis System (SAS). Differences between treatment means were separated using the least significant difference (LSD) test at 95% confidence interval.

Results and Discussion

Weed density

Major weed flora comprised of *Chenopodiumalbum* (12%), *Melilotusindica* (11.5%), *Anagallisarvensis* (10%), *Criciumarvensis* (15%) and *Rumexdentatus* (9%) among broad-leaved species and *Phalaris minor* (20%) and *Avenafatua* (17%) among grassy species. In general grassy weeds were more under ZT than CT and under raised-bed than flat-bed at 90 DAS (Table 1). The highest total weed population was under ZT-raised-bed, followed by CT-raised-bed in 2010-11, but in 2011-12, the population of broad-leaved species was significantly higher under CT-raised-bed than ZT-raised-bed. Higher weed population under ZT and raised-bed was presumably due to no soil disturbance and ample soil moisture for the weeds to grow in the furrows (Chhokar et al., 2007; Usman et al., 2010).

In 2010-11, the lowest weed population was under isoproturon + HW, which was significantly lower than mesosulfuron + iodosulfuron and soybean stover + isoproturon. The grassy weeds under the latter two treatments were similar but the broad-leaved weeds were significantly higher under soybean stover + isoproturonthan mesosulfuron + iodosulfuron. In 2011-12, the grassy weeds were lower under soybean stover + isoproturon than other treatments, while the population of broad-leaved species was similar under all treatments but significantly lower than unweeded control. Isoproturonapplication is known to be quiet effective for controlling weeds in wheat, particularly *Phalaris minor* (Chhokar et al., 2008; Yadav et al., 2011), while mesosulfuron + iodosulfuron provided effective control of all weeds species including broad-leaved ones. Supplementation with HW in isoproturon-treated plots virtually eliminated all weed species (Punia et al., 2004).

Table 1. Weed density and dry weight at 90 days of growth of wheat as influenced by tillage and crop establishment and weed management practices.

Treatment	Weed density (no. m^2)		Weed dry weight (g m^{-2})		Weed control efficiency (%)	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Tillage and crop establishment						
CT-raised-bed	9.44(96.5)	10.25(120.3)	122.7	100.3	67.6	70.7
CT-flat-bed	8.80(79.0)	9.63(94.0)	109.9	92.2	65.1	65.1
ZT-raised bed	10.34(119.0)	10.54(119.0)	127.1	105.7	66.4	66.6
ZT-flat-bed	8.99(83.2)	9.89(101.2)	99.9	88.3	66.2	68.8
SEm±	0.20	0.15	1.9	2.6	0.56	0.46
LSD (P=0.05)	0.69	0.53	6.6	9.1	NS	1.58
Weed management						
Unweeded control	13.39(183.1)	14.29(208.3)	341.8	289.5	-	-
Isoproturon + HW	7.49(55.7)	8.52(72.7)	31.8	28.2	90.7	91.4
Mesosulfuron + iodosulfuron	8.15(66.0)	8.85(78.3)	45.7	38.3	86.5	89.7
Soybean straw mulch + isoproturon	8.55(72.8)	8.65(75.1)	40.2	30.6	88.1	90.2
SEm±	0.08	0.18	1.7	1.9	0.3	0.3
LSD (P=0.05)	0.23	0.52	4.9	5.7	0.7	0.9

* Data given within parentheses are original values and that given outside are square root transformed values $\sqrt{(x+0.5)}$.

Weed dry weight

Dry weight of weeds was also significantly higher under raised-bed than flat-bed under both CT and ZT conditions (Table 1). In 2010-11, the dry matter of weeds was on par under ZT-raised-bed and CT-raised-bed, but CT-flat-bed resulted in higher dry matter than ZT-flat-bed. On the other hand, in 2011-12, the highest weed dry matter under ZT-raised-bed was on par with CT-raised-bed. These results indicated that mean weed dry weight was not much different under CT and ZT, particularly in 2010-11, but raised-bed had relatively greater weed infestation that flat-bed under the both tillage practices. Weed control efficiency was the highest under CT-raised-bed, while it was lower under other treatments, although the differences were marginal.

Weed dry weight decreased significantly under different weed control treatments compared with unweeded control. The largest decrease was obtained under isoproturon + HW, while the weed dry weight under mesosulfuron + iodosulfuron was significantly more than other two treatments. However, the magnitude of weed dry weight was considerably lower (< 50 g m^{-2}) under different treatments and was unlikely to make an impact on the crop performance.The weed control efficiency under different weed control treatments was 86.7-91.7%, suggesting highly effective weed control.

The interaction between tillage and crop establishment and weed management treatments was significant on total weed population in 2010-11 and 90 DAS in 2011-12, and weed dry matter in both years. In general, the weed population was more in ZT than CT when any treatment was applied for control of weeds. This indicated that the effect of CT alone can also reduce the weed population in soybean. The effect of weed control treatments was more under ZT than CT and raised-bed than flat-bed system. Similar, trend was observed in case of weed dry matter.

Yield performance

Although same variety (‘HD 2894’) was sown the almost at the same time and similar management practices were followed in both years, the crop performance varied due to weather conditions particularly rainfall and temperature. More favorable weather condition in 2011-12 including no terminal heat stress, led to better performance of the crop. Grain yield of wheat was not influenced in 2010-11, but the grain yield in 2011-12 and straw yield in both years showed significant variation due to tillage and crop establishment practices (Table 2). In 2010-11, the grain yield was comparatively more under flat-bed than raised-bed, but the differences were not significant. Similarly, CT and ZT did not make much difference in grain yield. On the other hand in 2011-12, the flat-bed sown crop produced significantly higher yield than the raised-bed. The grain yield of raised-bed sown crop was similar under CT and ZT and significantly lower than flat-bed sown crop.

Harvest index was more under flat-bed sown crop than raised-bed, but no difference between CT and ZT was observed. These results suggest that sowing of wheat under ZT and flat-bed condition was a better practice for improving crop productivity. Raised-bed planting might result in higher water-use efficiency, but the crop productivity was not improved compared with flat-bed condition. However, it was quite apparent that there was no need to go in for intensive tillage operations and zero tillage was an equally good practice under the present condition.

Table 2. Yield performance of wheat as influenced by tillage and crop establishment and weed management practices.

Treatment	2010-11			2011-12		
	Grain yield (ton ha^{-1})	Straw yield (ton ha^{-1})	Harvest index (%)	Grain yield (ton ha^{-1})	Straw yield (ton ha^{-1})	Harvest index (%)
Tillage and crop establishment						
CT-raised-bed	4.29	4.86	0.47	4.39	5.78	0.43
CT-flat-bed	4.44	5.46	0.45	4.79	6.35	0.43
ZT-raised bed	4.27	5.18	0.45	4.39	6.22	0.41
ZT-flat-bed	4.46	4.88	0.48	4.73	6.87	0.41
SEm±	0.09	0.12	0.01	0.10	0.15	0.02
LSD (P=0.05)	NS	0.43	0.04	0.34	0.54	0.06
Weed management						
Unweeded control	3.56	4.58	0.44	3.62	5.70	0.39
Isoproturon + HW	4.67	5.29	0.47	4.96	6.69	0.43
Mesosulfuron + iodosulfuron	4.52	5.38	0.46	4.92	6.18	0.44
Soybean straw mulch + isoproturon	4.69	5.13	0.48	4.81	6.66	0.42
SEm±	0.07	0.14	0.01	0.07	0.14	0.01
LSD (P=0.05)	0.20	0.42	0.03	0.20	0.41	0.02

The losses in yield due to unweeded control were 23.1-26.1%, while the mean increase in grain yield due to adoption of weed control measures raised from 19.2-27.0%. In 2010-11 all weed control practices, viz. isoproturon + HW, mesosulfuron + iodosulfuron and soybean stover + isoproturon were on par and equally effective in improving the yield grain as well as straw. On the other hand in 2010-11, mesosulfuron + iodosulfuron was on par with isoproturon + HW, but the straw yield was equal under isoproturon + HW and soybean stover + isoproturon, both of which, were significantly higher than mesosulfuron + iodosulfuron. Harvest index was comparatively lower under unweeded condition, but improved with adoption of weed control practices. Favourable environment due to weed control probably led to more capture of available resources including sunlight, which resulted in effective translocation of assimilated carbohydrates to the sink and thus in higher harvest index. Application of isoproturon provided effective control of weeds and the later flushes were controlled by hand weeding. Mesosulfuron + iodosulfuron controlled grassy and broad-leaved species affectively, although there was some dispressing effect on the growth of wheat plants (Zhang et al., 2009). This might have led to decreased straw yield under this treatment. Soybean stover mulching checked initial emergence of weeds and post-emergence application of isoproturon at 30 DAS controlled all the emerged weeds. Subsequently, there was no major weed problem in these plots. Stover retention on soil surface was particularly essential under ZT conditions for mitigating the adverse effect of soil compaction and bringing about favourable changes in physical and chemical properties. These results suggested that effective weed control can be achieved by chemical + cultural methods in wheat crop.

Regression analysis indicated that grain yield decreased linearly with increase in weed dry matter (Figures 2). The grain yield decreased by a magnitude of 0.003-0.004 ton ha^{-1} with increase of each ton of weed dry matter. This indicates that grain yield is loss due to weed dry matter and it can be increased by decreasingweed dry matter production. Crop and weeds compete for nutrients and lights and weeds being more vigorous than crop, their control should be ensured from early stages.

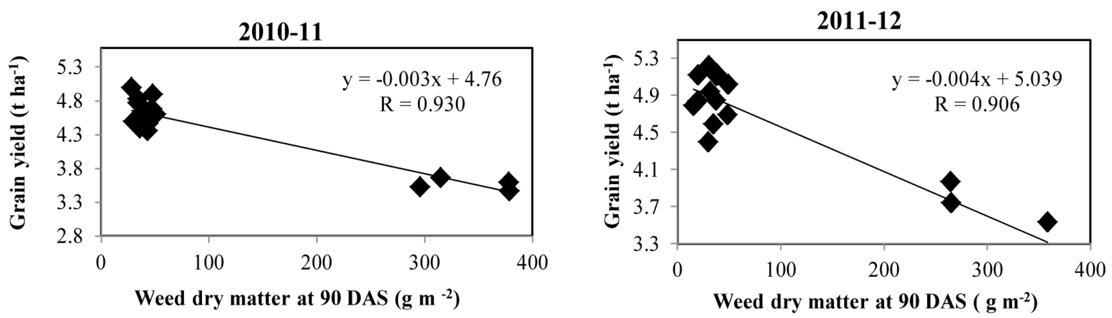

Figure 2. Relationship between grain yield and weed dry matter at 90 days of growth (R>0.895 is Significant).

Nutrient uptake by wheat

Concentration of N, P and K in grain and straw of wheat did not vary significantly due to tillage and crop establishment and weed management practices. However, the nutrient uptake showed significant increase presumably due to higher production of grain and straw. The highest N uptake was under ZT-flat-bed followed by CT-flat-bed and both of these treatments were on par with each other. Similar trend was observed in P and K uptake (Table 3). In fact, the total uptake of different nutrients followed the trend of yield obtained under different treatments. The uptake of K was maximum, closely followed by N, both of which, resulted in much higher uptake than P. Evidently, the higher productivity of wheat under the flat-bed treatments led to higher nutrient uptake without influencing the concentration of nutrients in grain as well as straw (Ishaq et al., 2011).

Total nutrient uptake increased significantly with control of weeds due to chemical and cultural means. As the nutrient concentration was not influenced, better weed control with application of herbicide alone or with cultural methods led to higher growth and yield of wheat, which resulted in higher nutrient uptake. The losses of N, P and K due to unweeded control were 42.7% for N, 20.6% for P and 15.3% for K. The increase in nutrient uptake was presumably due greater availability of nutrients in soil following removal of weeds under different weed control treatments compared with unweeded control.

Table 3. Nutrient uptake (kg ha^{-1}) by wheat as influenced by tillage and crop establishment and weed management practices.

Treatment	2010-11			2011-12		
	N	P	K	N	P	K
Tillage and crop establishment						
CT-raised-bed	88.5	16.7	96.4	95.6	17.7	114.2
CT-flat-bed	94.3	17.6	108.5	105.3	19.6	125.8
ZT-raised bed	90.5	16.8	102.3	98.8	18.3	123.8
ZT-flat-bed	93.3	17.6	100.8	108.2	19.9	137.7
SEm±	1.0	0.4	1.0	1.51	0.3	1.9
LSD (P=0.05)	3.5	NS	3.6	5.24	1.0	6.6
Weed management						
Unweeded control	76.4	14.6	89.8	83.3	15.6	110.4
Isoproturon + HW	98.3	18.3	106.3	110.8	20.4	133.3
Mesosulfuron + iodosulfuron	95.0	17.6	107.4	106.6	19.7	124.9
Soybean straw mulch + isoproturon	96.9	18.2	104.4	107.1	19.8	132.8
SEm±	1.0	0.3	1.6	1.0	0.2	2.5
LSD (P=0.05)	2.8	0.9	4.7	3.0	0.7	7.2

Nutrient removal by weeds

Nutrient uptake by wheat and weeds followed opposite trends, i.e. the treatments which caused higher nutrient uptake by wheat, resulted in reduced nutrient removal by weeds and *vice-versa* (Figure 3). Mean value of nutrient removal by weeds showed that the uptake of K was maximum, followed by N and P (Table 4). The highest uptake of N, P and K was under ZT-raised-bed, closely followed by CT-raised-bed, both of which, were significantly higher than flat-bed conditions. Sowing of wheat on flat-bed, whether under CT or ZT, resulted in almost equal and relatively lower nutrient removal by weeds than raised-bed condition. Evidently, higher weed biomass production under these treatments resulted in greater removal of nutrients. These results suggested that flat-sowing of wheat under ZT condition was beneficial for reducing nutrient losses by weeds compared with raised-bed and CT conditions.

The highest nutrientremovalwas under unweeded control, which was reduced to only about 10% under different weed control treatments. Isoproturon + HW was the best treatment for reducing N, P and K losses by weeds. Besides providing complete weed control, manual weeding may have also loosened the top soil and thus aerated the rizosphere, which led to greater nutrient availability to the crop.

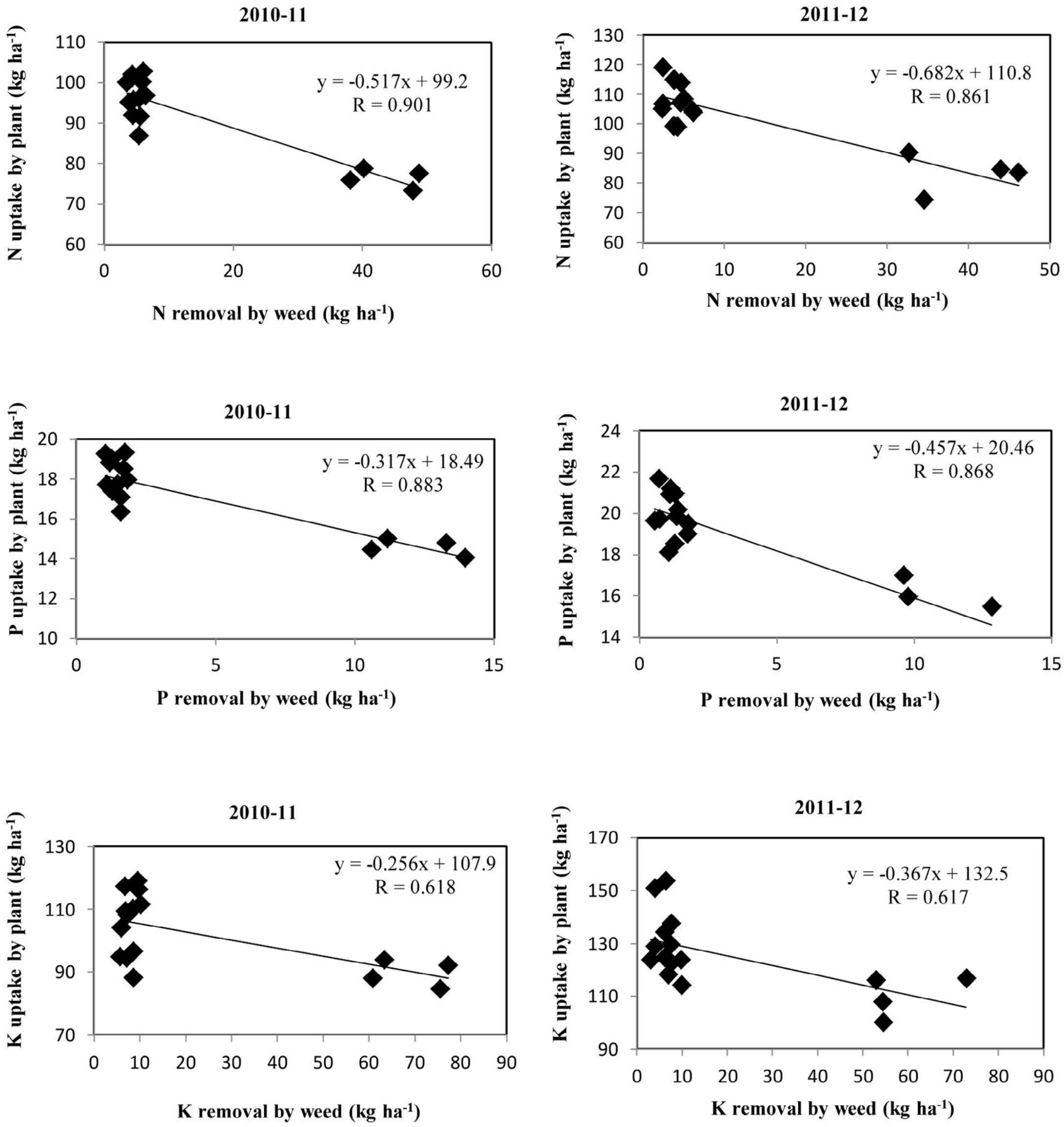

Figure 3. Relationship between nutrient removal by weed and nutrient uptake by wheat (R>0.591 significant).

Economics

Evidently, the total cost of cultivation was higher under CT than ZT and raised-bed than flat-bed (Table 5). Accordingly, the highest cost of cultivation was under CT-raised-bed and the lowest under ZT-flat-bed. Among the weed control treatments, the highest cost was under isoproturon + HW because of the labour required for hand weeding, while the lowest cost was under mesosulfuron + iodosulfuron. Soybean stover mulch + isoproturon incurred relatively higher cost than herbicide alone, because of the cost involved in straw. The total cost was marginally higher in 2011-12 due to one additional irrigation compared with 2010-11.

Net benefit: cost ratio (net B:C ratio) was the highest under ZT-flat-bed when the weeds were control effectively. The highest net benefit: cost ratio was under ZT-flat-bed and mesosulfuron + iodosulfuron or soybean stover mulch + isoproturon. This was followed by CT-flat-bed under the same weed control treatments. In general, net benefit: cost ratio was the lowest under raised-bed than flat-bed. The net benefit: cost ratio decreased under isoproturon + HW, followed by soybean stover mulch + isoproturon due to lower yields under these treatments and cost of labour for HW and soybean stover. However, application of crop residues might prove beneficial in the long-run due to several indirect benefits, such as improved physical, chemical and biological properties of soil (Monsefi, 2009; Amin et al., 2012; Mishra and Singh, 2012).

Conclusion

It was concluded the sowing of wheat on flat-bed was more beneficial than raised-bed for improving productivity, profitability and nutrient uptake. Further, wheat could be grown very successfully under ZT condition as the productivity was nearly similar or even higher compared with CT condition. Weeds were effectively controlled with application of isoproturonfollowed by hand weeding or pre-mix combination of mesosulfuron + iodosulfuron. Although mulching with soybean residue and post-emergence application of isoproturonresulted in higher cost, this practice was particularly beneficial under ZT condition and might result in favorable effects on soil health in the long-run.

Table 4. Nutrient uptake (kg ha^{-1}) by weeds at 90 days of growth as influenced by tillage and crop establishment and weed management practices.

Treatment	2010-11			2011-12		
	N	P	K	N	P	K
Tillage and crop establishment						
CT-raised-bed	15.5	4.5	24.5	12.8	3.7	20.2
CT-flat-bed	14.0	3.9	22.1	11.6	3.4	18.5
ZT-raised bed	16.3	4.5	25.9	13.7	3.8	21.5
ZT-flat-bed	12.8	3.6	20.5	13.8	3.2	18.1
SEm±	0.3	0.1	0.4	0.4	0.1	0.5
LSD (P=0.05)	1.1	0.3	1.3	1.3	0.4	1.8
Weed management						
Unweeded control	43.7	12.3	69.3	39.4	10.5	58.6
Isoproturon + HW	4.1	1.2	6.4	3.7	1.0	5.7
Mesosulfuron + iodosulfuron	5.7	1.7	9.2	5.0	1.4	7.8
Soybean straw mulch + isoproturon	5.1	1.5	8.1	3.8	1.1	6.2
SEm±	0.3	0.1	0.4	0.3	0.1	0.4
LSD (P=0.05)	0.8	0.3	1.1	0.7	0.3	1.1

Table 5. Economic analysis of wheat cultivation as influenced by tillage and crop establishment and weed management practices.

Treatment	2010-11			2011-12		
	Cost of cultivation (US$ /ha)	Net returns (US$ /ha)	Net B:C ratio	Cost of cultivation (US$ /ha)	Net returns (US$ /ha)	Net B:C ratio
Conventional tillage raised-bed						
Unweeded control	265.3	453.2	1.71	273.1	417.5	1.53
Isoproturon + HW	303.6	685.0	2.26	311.4	666.2	2.14
Mesosulfuron + iodosulfuron	279.7	604.6	2.16	286.4	743.1	2.59
Soybean stover mulch + isoproturon	287.2	641.7	2.23	295.0	658.5	2.23
Conventional tillage flat-bed						
Unweeded control	260.6	501.8	1.93	268.4	569.3	2.12
Isoproturon + HW	298.9	625.6	2.09	306.7	777.1	2.53
Mesosulfuron + iodosulfuron	275.0	696.2	2.53	281.7	771.8	2.74
Soybean stover mulch + isoproturon	282.5	727.0	2.57	290.3	721.8	2.49
Zero tillage raised-bed						
Unweeded control	247.6	501.8	2.03	255.4	500.6	1.96
Isoproturon + HW	285.9	626.4	2.19	293.7	700.7	2.39
Mesosulfuron + iodosulfuron	264.1	687.1	2.60	269.0	655.0	2.44
Soybean stover mulch + isoproturon	269.5	624.5	2.38	277.3	730.6	2.63
Zero tillage flat-bed						
Unweeded control	242.9	486.4	2.00	250.7	534.5	2.13
Isoproturon + HW	281.2	724.8	2.58	289.0	789.2	2.73
Mesosulfuron + iodosulfuron	259.3	662.9	2.56	264.0	804.0	3.04
Soybean stover mulch + isoproturon	264.8	724.2	2.73	272.6	774.6	2.84

References

Amin, R., Khan, A.Z., Khalil, S.K., Khalil, I.H., 2012. Effect of osmopriming sources and moisture stress on wheat. Pak. J. Bot. 4 (3), 867-871.

Chhokar, J.S., Brodbeck, F., House, R.J., 2007. Culture and Leadership around the World: The GLOBE Book of In-depth Studies of 25 Societies. Mahwah, NJ: Lawrence Erlbaum Associates.

Chhokar, R.S., Singh, S., Sharma, R.K., 2008. Herbicides for control of isoproturon-resistant littleseedcanarygrass (*Phalaris minor*) in wheat. Crop Protection. 27, 719-726.

Ishaq, M., Ibrahim, M., Lal, R., 2011. Tillage effect on nutrient uptake by wheat and cotton as influenced by fertilizer rate. Soil and tillage research. 62 (1-2), 41-53.

Laxmi, V., Gupta, R.K., Swarnalatha, A., Perwaz, S., 2003. Environmental impact of improved technology farm level surveys and farmers' perception on zero tillage (case study). In: Workshop on Roles of Agriculture 20-22 October, 2003 Rome, Italy.

Mishra, J.S., Singh, V.P., 2012. Tillage and weed control effects on productivity of a dry seeded rice-wheat system on a Vertisol in Central India. Soil and Tillage Research. 123, 11-20.

Monsefi, A., 2009. Productivity of soybean and weed dynamics as influenced by tillage and weed management options. M.Sc. Dissertation, Indian Agricultural Research Institute. New Delhi, India.

Paratp Singh, V., Kumar, A., Banga, A., 2010. Current status of zero tillage in weed management. Ind. J. Weed Sci. 42 (1-2), 1-9.

Punia, S.S., Malik, R.K., Shoeren, P., 2004. Bio-efficacy of tank mix combinations of fenoxaprop and clodinafop with broad leaf herbicides for broad spectrum weed control in wheat (*Triticum aestivum* L.). Ind. J. Ecol. 31, 128-132.

Singh, S., Yadav, A., Malik, R.K., Singh, H., 2002. Long Term effect of zero tillage sowing technique on weed flora and productivity of wheat in rice-wheat cropping zones of Indo-Gangetic plains. In: Herbicide resistance management and zero tillage in rice - wheat cropping system. Hisar, India. (Eds.) Malik RK, Balyan RS, Yadav A and Pahwa SK CCSHAUH. pp. 155-157.

Usman, K., Khalil, S.K., Khan, M.A., 2010. Impact of tillage and herbicides on weed density and some physiological traits of wheat under rice-wheat cropping system. Sarhad J. Agric. 26, 475-488.

Yadav, S.K., Pandey, P., Kumar, B., Suresh, B.G., 2011. Genetic architecture, inter-relationship and selection criteria for yield improvement in rice (*Oryza sativa* L.). Palestinian J. Biol. Sci. 14, 540-545.

Yaduraju, N.T., Mishra, J.S., 2002. Zero-Tillage in rice-wheat cropping system on vertisols in Madhya Pradesh-prospects and problems. In: Proceedings of International Workshopon Herbicide Resistance Management and Zero-Tillagein Rice-Wheat Cropping system, March 4-6, 2002. CCSHAU, Hisar India, pp. 117-119.

Zhang, X.R., Li, H.W., He, J., Wang, Q.J., Golabi, M.H., 2009. Influence of conservation tillage practices on soil properties and crop yields for maize and wheat cultivation in Beijing, China. Austr. J. Soil Res. 47, 362-371.