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Tillage and weed management effect on productivity of wheat under soybean-wheat-greengram cropping system in conservation agriculture

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ABSTRACT

The effect of tillage and weed management practices on density and biomass of *Medicago denticulata*, *Chenopodium album* and *Phalaris minor* as well as productivity of wheat in soybean-wheat-greengram cropping system was evaluated during 2013-14 and 2014-15 at ICAR-DWR, Jabalpur. The density and biomass of weeds were reduced to maximum when conventional tillage was done in wheat under CT-CT-fallow system followed by conventional tillage in wheat under CT-ZT-ZT system. While, weed density and biomass were minimum with zero tillage in wheat in the presence of residues of preceding soybean under ZT+R-ZT+R-ZT+R system followed by ZT-ZT+R-ZT+R system, which recorded higher grain and straw yields as well as gross and net monetary returns. Metsulfuron + clodinafop (4 + 60 g/ha) ready mixture applied at 25 DAS recorded the lowest weed density as well as biomass and higher crop yield and monetary returns. The interaction indicated that metsulfuron + clodinafop (4 + 60 g/ha) applied in wheat with zero tillage in presence of residues of preceding soybean under ZT+R-ZT+R-ZT+R and ZT-ZT+R-ZT+R system has resulted in lower weed density and biomass with higher weed control efficiency, grain and straw yields, higher gross and net monetary returns including B:C ratio than other combinations.

Key words: Conventional tillage, Economics, Productivity, Weed management, Wheat, Zero tillage

Soybean-wheat cropping system is commonly practiced in the semi-arid to sub-humid tropical regions of Malwa, Vindhyan plateau and some part of Kymore plateau and Satpura hill zones of Madhya Pradesh on 4.5 Mha area, and contributes nearly 57.6 and 8.8% of the total soybean and wheat production in the country respectively (Monsefi *et al.* 2011). Tillage has been found an essential component of wheat however, intensive tillage has been found to have adverse effect on soil structure leading to soil erosion and carbon loss. Besides, concentration of greenhouse gases in the atmosphere is increasing due to burning of preceding rice residues and in turn helping in global warming. Therefore, many countries switching towards conservation agriculture in which minimum or zero soil disturbance and retention of crop residues is done on soil surface, and legumes are included in crop rotation. The conventional practices of intensive tillage, involving 6-8 tillage operations, consume a high proportion (25-30%) of total operational energy used in crop production (Sindhu *et al.* 2004). Conservation tillage practices, such as no tillage combined with previous crop residues may offset production costs and other constraints associated with land preparation (Hobbs 2001). The potential benefits of no tillage can be fully realized only when it is practiced continuously and soil surface remain covered with previous crop residues (Sindhu *et al.* 2007). Despite lower energy requirement for tillage and more efficient energy use under zero tillage conditions, the input requirement especially of fertilizers and weed control either manually or through herbicides affect crop growth (Gajri *et al.* 1992). In conventional-tilled farming of wheat in soybean-wheat cropping system, weeds are effectively controlled by tillage, due to better uprooting of weeds and their deep burial into the soil. But lack of tillage, promotes weeds growth in conservation agriculture, if effective weed control measures are not followed in nick of time. Weed control in conservation agriculture is a greater challenge because weed seed burial by tillage operations and soil applied herbicides are not incorporated well, resulting in reduced efficiency of herbicides (Chauhan and Johanson 2009). Besides this, the presence of crop residues over the soil surface, may intercept and bind the herbicides before reaching the soil surface. Henceforth, post-emergence herbicides are becoming potent tool for control of weeds in conservation agriculture. Keeping aforesaid facts in view, the comprehensive study was undertaken to see the effect of tillage and weed control practices on weeds, yields and economics of wheat in soybean-wheat-greengram cropping system.

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MATERIALS AND METHODS

The field experiment was conducted at Research Farm, ICAR- Directorate of Weed Research, Maharajpur Jabalpur (M.P.), situated at 23^0 09' North latitude and 79^0 58' East longitudes with an altitude of 411.78 meters above the mean sea level during *Rabi* season 2013-14 and 2014-15. The soil was clayey loam in texture, neutral in pH (7.2) with bulk density of 1.12 Mg/m^3. It was medium in organic carbon content (0.6%), available nitrogen (251.0 kg/ha), phosphorus (18.5 kg/ ha) and high in available potassium (289.7 kg/ ha). The total rainfall of the area was 116.4 and 218.3 cm during the year 2013-14 and 2014-15 respectively.

A split plot design with three replications was used. Fifteen treatments were tested with five tillage treatments in the main plots *viz*. conventional tillage in soybean-conventional tillage in wheat and fallow in summer (CT-CT-fallow), conventional tillage in soybean-zero tillage in wheat-zero tillage in greengram (CT-ZT-ZT tillage system), zero tillage with preceding crop residues in soybean - zero tillage in wheat- zero tillage with preceding crop residues in greengram (ZT+R-ZT-ZT+R tillage system), zero tillage in soybean- zero tillage with preceding crop residues in wheat-zero tillage with preceding crop residues in greengram (ZT-ZT+R-ZT+R tillage system), zero tillage with preceding crop residues in soybean- zero tillage with preceding crop residues in wheat- zero tillage with preceding crop residues in greengram (ZT+R-ZT+R-ZT+R tillage system) and three weed management treatments in sub plots, *viz*. weedy check in all crops, pendimethalin 750 g/ha *fb* imazethapyr 100 g/ha in soybean - mesosulfuron 12 g/ha + iodosulfuron 2.4 g/ha (Atlantis) in wheat - pendimethalin 750 g/ha in greengram, metribuzin 500 g/ha + 1 HW at 25 DAS in soybean - metsulfuron 4 g/ ha + clodinafop 60 g/ha (Vesta) in wheat-pendimethalin 750 g/ha + 1 HW in greengram. Observation were recorded on density and biomass of weeds at 60 DAS by quadrate count method and yields of wheat. The weed density and biomass were subjected to square root transformation to normalize their distribution. WCE was calculated by using the formulae suggested by Gomez and Gomez (1984). Economic analysis was done as per the prevailing cost of inputs and selling price of output.

RESULTS AND DISCUSSION

Weed density and biomass

The higher density and biomass of *Medicago denticulata*, *Chenopodium album* and *Phalaris minor* were recorded when conventional tillage was done in wheat under CT-CT tillage system followed by CT-ZT-ZT tillage system being minimum when zero tillage was done in presence of residue of preceding soybean crop in wheat under ZT+R-ZT+R-ZT+R tillage system (**Table 1**). Higher density and biomass of *M. denticulata* and *P. minor* were observed under conventional tillage in wheat because of soil disturbance caused by tillage may have brought the deep buried weed seeds near to soil surface, where favourable environment, in terms of better availability of light, oxygen and moisture facilitated the germination and emergence of weed seeds. Besides, tillage caused abrasion/rapture of seed coat of weed seeds and thus facilitated germination of weed seeds and in turns had more density and biomass of former weeds. Chhokar *et al.* (2009) found that density of *P. minor* was higher under conventional tillage. But, the infestation of broad-leaved weeds like *Rumex dentatus* and *M. denticulata* was maximum under zero tillage condition. However, the density and biomass of *C. album* was maximum when conventional tillage was done in wheat under CT-CT tillage system. Seed germination of *C. album* also manifested by absolute light requirement. Deep buried weed seeds remain inactive for germination due to absence of red light. After tillage, deep buried weed seeds come up to the upper layer of soil surface and exposure to red light after by phytochrome (pr), later convert into Pfr (active form) and series of physiological events leads to germination of *C. album* (Gallagher and Cardina 1998). The lower density and biomass of all weeds under zero tillage in presence of residues of soybean in wheat (ZT+R-ZT+R-ZT+R tillage system) was due to fact that seed buried deeper, tends to enhance seed dormancy and led to less emergence (Eltiti 2003 and Colbach *et al.* 2005). In addition to this, deep buried smaller seeds and weed seedlings either died due to deep burial or lack of oxygen in plough sole layer on account of zero soil manipulation/disturbance and resulted in lower density and biomass of former weeds (Hakansson 2003). In an another study, surface residues retention supports a wide variety of surface invertebrates and insects including carabit beetles and spiders. Carabid beetles shown to have considerable preference for seed of some weed species (Eltiti 2003).

Ready mixture of mesosulfuron + iodosulfuron 12+2.4 g/ha (Atlantis) was found more effective in controlling grasses as well as broad-leaved weeds as compared to ready mixture of metsulfuron + clodinafop 4 + 60 g/ha. Das (2008) found that tank mixture of alternative herbicides metsulfuron and clodinafop showed antagonism and decreasd the efficiency of herbicide mixture but sequential application of both these herbicides curtailed the density and biomass of weeds.

Density and biomass were maximum when no weed control was done after conventional tillage in wheat under CT-CT tillage system followed by no weed control after zero tillage in wheat under CT-ZT-ZT tillage system. Hossain and Begum (2015) also observed that soil disturbance with tillage expose weed seed to a flash of light that releases seeds from dormancy. The identical reduction in weed density as well as biomass in plots receiving ready mixture of mesosulfuron + iodosulfuron 12+2.4 g/ha after zero tillage in presence of residues of soybean in wheat under ZT+R-ZT+R-ZT+R tillage system followed by ZT-ZT+R-ZT+R tillage system was observed. No soil disturbance under zero tillage also encourages higher predator populations. No tilled fields increase the number, diversity or activity of seed consuming fauna as compared to conventionally tilled fields (Blubaugh and Kaplan 2015).

Weed control efficiency in wheat

Weed control efficiency was minimum when conventional tillage was done in wheat under CT-CT tillage system because of more weed biomass production being higher in zero tillage in wheat under CT-ZT-ZT tillage system (**Table 2**). Whereas, weed control efficiency was maximum when zero tillage was done in presence of residues of preceding soybean in wheat under ZT+R-ZT+R-ZT+R tillage system. Lower weed biomass production due to better control of weeds increased the weed control efficiency. Besides, weed seed germination and emergence were hampered by thick layer of residues of preceding crop. Khaliq *et al.* (2013) also endorsed similar views from their studies.

Ready mixture of mesosulfuron + iodosulfuron 12+2.4 g/ha attained higher weed control efficiency than ready mixture of metsulfuron +clodinafop 4+60 g/ha. Walia *et al.* (2005) also found that mesosulfuron + iodosulfuron provided effective control of grasses and broad-leaved weeds.

Interaction of tillage and weed control practices caused identical variation on weed control efficiency. Weed control efficiency was minimum when no weed control was done after conventional tillage in wheat under CT-CT tillage system. This may be attributed to the fact that tillage brought the deep buried weed seeds near to soil surface, where favourable conditions in soil facilitated germination and emergence of weed seeds (maximum weed seeds were found at the 5-10 cm soil depth under conventional tillage). In addition to this, no weed control measures were adopted in weedy check plots, which in turn had more dry matter of all weeds and finally lower weed control efficiency. However, it was higher when no weed control was done after zero tillage in presence of residues of preceding soybean in wheat under ZT+R-ZT+R-ZT+R tillage system being maximum when ready mixture of mesosulfuron + iodosulfuron 12+2.4 g/ha was applied after zero tillage in presence of residues of preceding soybean in wheat under ZT+R-ZT+R-ZT+R tillage system. It was observed that weed seeds were not germinated in plots where soil surface was covered by preceding crop residues and does not provided congenial condition for germination and emerged weeds were effectively controlled by ready mixture of mesosulfuron + iodosulfuron 12+2.4 g/ha.

Grain and straw yields of wheat

The grain and straw yields (5.24 and 5.54 t/ha) were minimum when conventional tillage was done in wheat under CT-CT tillage system being at par to zero tillage in wheat under CT-ZT-ZT (5.28 and 5.95 t/ha) and ZT+R -ZT-ZT+R (5.46 and 6.23t/ha) tillage

Table 1. Density and biomass (no./m^2) of *Medicago denticulata, Chenopodium album* and *Phalaris minor* in wheat as affected by tillage and weed control practices at 60 DAS (mean of two years)

Treatment	*Medicago denticulata*		*Chenopodium album*		*Phalaris minor*	
	Weed density	Weed biomass	Weed density	Weed biomass	Weed density	Weed biomass
Tillage						
CT-CT	6.8(45.5)	3.3(10.6)	2.5(5.9)	1.27(1.12)	1.60(2.06)	1.04(0.59)
CT-ZT-ZT	5.8(32.9)	3.1(8.9)	2.0(3.6)	1.12(0.76)	1.25(1.07)	0.96(0.42)
ZT+R-ZT-ZT+R	5.5(29.7)	3.0(8.5)	1.5(1.7)	0.96(0.42)	1.06(0.62)	0.83(0.19)
ZT-ZT+R-ZT+R	5.1(25.9)	2.8(7.2)	1.3(1.3)	0.87(0.26)	0.97(0.44)	0.85(0.22)
ZT+R-ZT+R-ZT+R	4.9(23.8)	2.6(6.4)	1.3(1.3)	0.87(0.25)	0.91(0.32)	0.79(0.12)
LSD (p=0.05)	0.47	0.26	0.18	0.11	0.33	0.11
Weed management						
Mesosulfuron + iodosulfuron 12 + 2.4 g/ha	2.8(7.4)	0.9(0.4)	0.9(0.4)	0.83(0.19)	0.72(0.41)	0.79(0.12)
Metsulfuron + clodinafop 4 + 60 g/ha	3.4(11.1)	1.3(1.2)	1.4(1.4)	0.90(0.30)	0.74(0.48)	0.82(0.17)
Weedy check	10.6(112.9)	6.6(43.4)	2.9(8.12)	1.33(1.26)	1.38(1.84)	1.07(0.65)
LSD (p=0.05)	0.32	0.18	0.13	0.09	0.16	0.08

systems (**Table 2**). However, maximum grain and straw yields (5.78 and 6.73 t/ha) were recorded when zero tillage was done in presence of residues of preceding soybean in wheat under ZT+R-ZT+R-ZT+R tillage system and proved significantly superior over other tillage system but at par to zero tillage in presence of residues of preceding soybean in wheat under ZT-ZT+R-ZT+R tillage system (5.63 and 6.23 t/ha, respectively). Lesser yields of wheat in case of conventional tillage attributed to poor availability of growth resources on account of more weeds, which affected the growth and developments of crop plants and finally had inferior values of yield attributing traits. Superior yield attributes in wheat were recorded due to availability of more space, light and nutrients for optimum growth and development of crop plants due to zero/least interspecies competition as plants were equally spaced under zero tillage in presence of residues of soybean in wheat under ZT+R-ZT+R-ZT+R tillage system.

The present findings corroborated with the results of Singh (2014). The lowest grain and straw yields (4.49 and 4.62 t/ha) were recorded in weedy check plots where no weed control was done. Grains yield was appreciably increased (5.37and 5.63 t /ha) in plots receiving ready mixture of metsulfuron + clodinafop 4 + 60 g /ha being maximum (5.98 and 6.38 t/ha) when ready mixture of mesosulfuron + iodosulfuron 12 + 2.4 g/ha was applied in experimental plots and both herbicidal treatments were superior as both caused 33.18 and 38.09% increase in grain and straw yields over weedy check plots (4.49 and 4.62 t/ha). Singh *et al.* (2003) also reported mesosulfuron + iodosulfuron 12+2.4 g/ha had produced grain yields similar to weed free plots.

Interaction of tillage and weed control practices caused significant variation on grain and straw yields of wheat. Both were minimum when no weed control was done after conventional tillage in wheat under CT-CT tillage system. However, higher grain and straw yields were recorded when no weed control was done after zero tillage in presence of preceding crop residues of soybean in wheat under ZT+R-ZT+R-ZT+R tillage system and proved significantly superior over no weeding after conventional tillage in wheat under CT-CT tillage system and zero tillage in wheat under CT-ZT-ZT tillage system but at par to no weed control after zero tillage in presence of residues of preceding soybean in wheat under ZT-ZT+R-ZT+R tillage system and no weed control after zero tillage in wheat under ZT+R-ZT-ZT+R tillage system in soybean-wheat-greengram cropping system. However, grain and straw yields of wheat were further increased under metsulfuron + clodinafop 4+60 g/ha after all tillage systems being the maximum when ready mixture of mesosulfuron + iodosulfuron 12+2.4 g/ha was applied after zero tillage in presence of residues of preceding soybean in wheat under ZT+R-ZT+R-ZT+R tillage system and proved significantly superior over ready mixture of mesosulfuron + iodosulfuron 12+2.4 g/ha after conventional tillage in wheat under CT-CT tillage system, zero tillage in wheat under CT-ZT-ZT and ZT+R-ZT-ZT+R tillage systems but at par to ready mixture of mesosulfuron + iodosulfuron 12+2.4 g/ha applied after zero tillage in presence of residues of preceding soybean in wheat under ZT-ZT+R-ZT+R tillage system. Singh *et al.* (2010), Singh *et al.* (2017) also reported higher grain yield of wheat under zero tillage system after use of post-emergence herbicides.

Economics

The minimum cost of cultivation was recorded when zero tillage was done in wheat under CT-ZT-ZT tillage system followed by zero tillage in wheat under ZT+R-ZT-ZT+R tillage system, zero tillage in presence of residues of preceding soybean in wheat under ZT+R-ZT+R-ZT+R tillage system being maximum when conventional tillage was done in wheat under CT-CT tillage system (**Table 2**). Due to more number of tillage operations in conventional tilled plots, the cost of cultivation was higher under conventional tillage than zero tilled plots. GMRs, NMRs and B:C ratio were maximum in plots receiving zero tillage in presence of previous crop residues in case of wheat under ZT+R-ZT+R-ZT+R and ZT-ZT+R-ZT+R tillage (Bullock 2004). Reverse trends was observed in case of gross, net monetary returns and B:C ratio in other tillage systems. Higher cost of cultivation was recorded with ready mixture of metsulfuron + clodinafop 4+60g/ha in wheat followed by ready mixture of mesosulfuron + iodosulfuron 12+2.4 g/ha in wheat relative to weedy check. But GMRs, NMRs and B:C ratio were higher when ready mixture of mesosulfuron + iodosulfuron 12+2.4 g/ha was applied in wheat. Interaction between tillage and weed control practices also caused marked influence on economics of wheat. The GMRs, NMRs and B:C ratio were lower in plots where weed control practices were not adopted after each tillage. However, these were higher when ready mixture of mesosulfuron + iodosulfuron (12+2.4 g/ha) was applied after zero tillage in wheat in presence of previous crop residues of soybean under ZT+R-ZT+R-ZT+R and ZT+R-ZT+R-ZT+R than other combinations.

Thus, it was concluded that zero tillage in presence of residues of soybean in wheat along with PoE application of mesosulfuron + iodosulfuron

Table 2. Weed control efficiency, grain and straw yields as affected by tillage and weed control practices in wheat (mean of two years)

Treatment	Weed control efficiency (%)	Grain yield (t/ha)	Straw yield (t/ha)	Cost of cultivation (x10^3 `/ha)	Gross monetary returns (x10^3 `/ha)	Net monetary returns (x10^3 `/ha)	B:C ratio
Tillage							
CT-CT	64.22	5.24	5.54	33.12	101.70	68.58	3.07
CT-ZT-ZT	69.32	5.28	5.95	32.47	103.58	71.11	3.18
ZT+R-ZT-ZT+R	71.35	5.46	6.23	32.47	107.41	74.94	3.30
ZT-ZT+R-ZT+R	75.91	5.63	6.32	32.87	110.52	77.66	3.35
ZT+R-ZT+R-ZT+R	79.38	5.78	6.73	32.87	114.13	81.26	3.46
LSD (p=0.05)	-	0.22	0.86	-	-	-	-
Weed management							
Mesosulfuron + iodosulfuron 12 + 2.4 g/ha	98.68	5.98	6.38	33.06	121.71	88.65	3.68
Metsulfuron + clodinafop 4 + 60 g/ha	96.70	5.37	5.63	33.46	112.19	78.72	3.35
Weedy check	20.73	4.36	4.62	31.75	88.50	56.75	2.79
LSD (p=0.05)	-	0.27	0.61	-	-	-	-

12+2.4 g/ha found effective for control weeds in wheat and attained higher productivity and profitability of wheat.

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