<u>Original Research Article</u>

Response of crop establishment methods and weed management practices on weed flora, crop growth and yield of wheat in maize-wheat-greengram cropping system

.abstract :

Sustainable agriculture mostly relies on conservation tillage, crop residue retention and crop diversification. Weeds are major production hurdles in adoption of conservation agriculture (CA), therefore, weed management is important for sustainable crop yield. Designing efficient integrated weed management (IWM) practices under zero-tillage with crop residue (ZT+R) is helpful in getting optimum yield. A field experiment was carried out at research farm of ICAR-Directorate of Weed Research, Jabalpur (M.P.), India with eight treatment combinations, two crop establishment methods (conventional tillage and conservation tillage) in main plots and four weed management practices (weedy check, recommended herbicide, IWM, and herbicide rotation) in sub-plots wereevaluated using a split plot design with three replications. The results indicated that the wheat sown under ZT+R led to significantly less weed density (105.9 no. m^{-2} in 2020-21 and 122.8 no. m^{-2} in 2022-23) and biomass (149.7 and 174.2 g m^{-2}, respectively) hence, registered the highest weed control efficiency (WCE, 72.3% and 71.2%, respectively). Higher WCE helped in producing better wheat growth indices like plant height (106.3 and 101.1 cm, respectively), biomass (12.0 and 9.0 g plant^{-1}, respectively) and no. of tillers (488.0 and 391.3 no. m^{-2}, respectively) ultimatelygrain yield (4164 and 3814 kg ha^{-1}, respectively) and straw yield (7265 and 6834 kg ha^{-1}, respectively) compared with conventional tillage during both the years. Among the weed management practices, ready-mix application of clodinafop + metsulfuron at 60+4 g ha^{-1} (30-35 days after sowing, DAS) followed by (*fb)* hand weeding at 45 DAS increased growth indices like plant height (110.2 and 105.0 cm, respectively), plant biomass (14.9 and 12.1 g plant^{-1}, respectively) and no. of tillers (547.2 and 436.7 no. m^{-2}, respectively) ultimately grain yield (4708 and 4299 kg ha^{-1}, respectively) and straw yield (7836 and 7610 kg ha^{-1}, respectively), and WCE (97.4% and 96.8% respectively) with significantly less weed density (25.7 and 35.0 no. m^{-2}, respectively) and biomass (13.6 and 19.9 g m^{-2}, respectively) at 90 days after sowing. IWM also completely reduces the weed density and biomass over the other weed management practices during both the years. Therefore, wheat sown under ZT+R coupled with IWM was superior in terms of weed control, crop growth and yields.

Keywords: *Conservation agriculture, growth parameters, tillage, weed management, wheat*

1. INTRODUCTION

Wheat (*Triticumaestivum* L.) is one of the most important cereal crops in the world. In India, it covers an area of 31.61 million hectares (Mha), with the production of 109.52 million tonnes (MT) and productivity of 3464 kg ha^{-1} during the year 2021 [1]. In Madhya Pradesh, it is grown over an area of 9.82 Mha with the production of 35.66 MT and 3629 kg ha^{-1} productivity during the year 2021 [2], which clearly indicates that the average yield is slightly more than the national average. Madhya Pradesh is a landlocked state, which is enclosed by five states of India. Most of the area of Madhya Pradesh (Except eastern part) comes under semi-arid regions with short length of growing period (less than 90 days after sowing, DAS)and it has water scarcity during the winter season. Furthermore,there is more time taken by farmer between harvesting of rainy crop and sowing of next crop in October, Which results in late sowing of winter crop affected bywater stress from flowering to maturity due to the early depletion of water from the different sources. Delay in sowing and lack of moisture significantly reduces wheat grain yield [3]. Water scarcity during the winter seasons can be minimized by early or timely sowing with well mechanized zero-till machinery which reduces the extra time required in land preparation for the succeeding crop and residue management of preceding crop. Conservation agriculture (CA) is characterized by inclusion of three basic strategies, namely minimum disturbance of soil, residue retention over the years and crop diversificationand these are known to help with water scarcity to a large extant [4]. Happy seeder technology has been shown to be a panacea in the ZT-based CA system [5]. It shares many advantages to the farmers such as reducing the extravagance in the land preparation, minimize the problems of crop residue which is left over after the preceding crop, and reduce the fuel consumption in the crop production.

Weeds are amajor constraint in wheat production[6]. It would be no exaggeration to say that weeds contribute to reduce production of wheat. Uncontrolled weed may lead to 15-40 percent or more yield loss and lowering the quality of crop [7]. CA lowered the weed biomass by 14% and improved yield by 6.9% over conventional tillage (CT) in wheat crop [8]. Crop residue retention efficiently controls weed by reducing light penetration into the soil surface directly [9]. Also, herbicides play an important role in weed management under CA. Various new combinations of selective post-emergence (PoE) herbicides like clodinofop + metsulfuron and mesosulfuron + iodosulfuron effectively control most of the weed flora growing with the wheat. Integration of two or more methods of weed control also proved as an excellent practice for weed control. Furthermore, wheat growers prefer to use herbicides alone to control diverse weed flora which may lead to serious problems of resistance among weeds and cause loss of agro-ecosystem [10] and [11]. Therefore, there is a need for rotational use of herbicides under CA-based practices to control weeds and also to avoid or delay the resistance development on weeds. Under these circumstances, there is a paucity of information related to weed management under CA, especially suitable herbicide combination against the prevalent weed flora. Thus, present studies were undertaken in order to examine the effectiveness of different tillage and weed management practices on associated weed flora, growth and yield of wheat in long-term maize-wheat-greengram system.

2. MATERIAL AND METHODS

The field experiment was carried out during the winter seasons of 2021-22 and 2022-23 atthe research farm of ICAR-Directorate of Weed Research, Jabalpur (M.P.) India. The soil of experimental site was clayey in texture, neutral in pH (6.9), low in available nitrogen (256.5 kg ha^{-1}), high in available potassium (342.6 kg ha^{-1}) and phosphorus (62.5 kg ha^{-1}) with medium organic carbon (0.68%) during the period of experimentation. The eight treatment combinations comprising of two tillage management methods, conventional tillage [CT(maize, M)-CT(wheat, W)-CT(greengram, G)] and conservation tillage[ZT(M)+R(G)-ZT(W)+R(M)-ZT(G)+R(W)] in main plot and four weed management practices [weedy check, recommended herbicide [RH; mesosulfuron + iodosulfuron at 12.2+2.4 g ha^{-1}(PoE)], integrated weed management [IWM; clodinafop + metsulfuron at 60+4 g ha^{-1}(PoE) *fb* hand weeding at 45 DAS], herbicide rotations [HR; clodinafop + metsulfuron at 60+4 g ha^{-1}(PoE) during the first year, mesosulfuron + iodosulfuron at 12.2+2.4 g ha^{-1}(PoE) during second year] in sub-plots were evaluated under asplit-plot design with three replications. The wheat variety "GW322" selected for the experiment was sown at the rate of 100 kg ha^{-1}. All the package of practices were done as per the recommendation for this regions. The soil samples were analyzed at the soil testing laboratory, ICAR-DWR, Jabalpur. Immediate after sowing uniform irrigation was imposed for uniform germination. Fertilizers were applied at 120:60:40 kg ha^{-1} NPK through urea, di-ammonium phosphate and muriate of potash. Weed management practices were applied as per the treatments to the experimental plots. Treatment-wise total weed density and biomass were observed at 90 DAS by using 0.25 m^2 quadrats sampled twice per plot and this was then converted in number of weeds m^2(no. m^{-2}). The collected weeds samples initially sun dried followed by oven dried at 65 ± 2^0 C until a constant weight is achieved. These were expressed in g m^{-2}. Before the analysis, the data were subjected to square root transformation $\sqrt{X + 0.5}$ to normalize the variation. The weed control efficiency was analyzed as per the formula suggested by [12].

$$WCE\ (\%) = \frac{WBC - WBT}{WBC} \times 100$$

Where,

WBC= Weed biomass in control plot

WBT= Weed biomass in treated plot

Various growth characters viz., plant height, plant biomass and no. of tillers per m^{-2} were recorded at 90 DAS. Leaf area index was worked out as per the formula suggested by [13].

$$LAI = \frac{\text{Total green leaf area of the plant } (cm^2)}{\text{Total ground area } (cm^2)}$$

Grain and straw yield were recorded and expressed in kg ha^{-1}. Harvest index was analyzed among different treatments and is expressed in percentage.

Statistical analysis

The field data were statistically analyzed using OPSTAT software available online at CCS, HAU, Haryana[14]obtained was tabulated and statistically analyzed by using analysis of variance (F-test) as suggested by [15]. The significant difference between the treatments were compared with the critical different at 5% level of probability.

3. RESULTS AND DISCUSSION

3.1 Weed flora

The experimental field was infested with complex weed flora comprising grasses and broadleaves. The predominant weeds were *Medicago polymorpha* (L.), *Convolvulousarvensis* (L.), *Avenaludoviciana*(L.). However, *Sonchus oleraceus* (L.) and *Digitariasanguinalis* (L.) were also observed in minor dominance (Figure1).

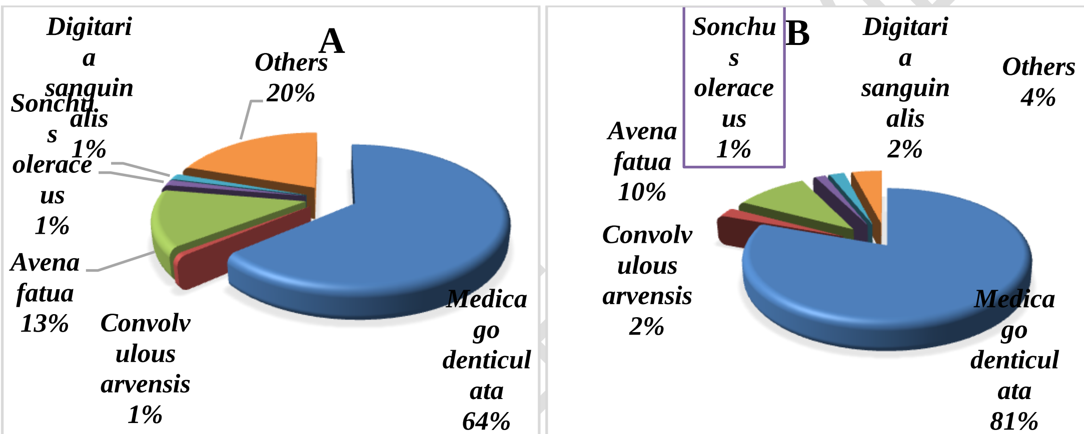

Fig.1. Weed flora in wheat field during 2021-22 (A) and during 2022-23 (B)

3.2 Effect on weed parameters

Weed density and biomass per unit area is an important parameter to studythe influence of different treatment on weed control. Result shown in Table 1, indicated that all the treatments convincingly suppressed the weed growth. It is evident from that the total weed density (105.9 no. m^{-2} in 2021-22 and 122.6 no. m^{-2} in 2022-23) and biomass (149.7 and 174.2 g m^{-2}, respectively) were significantly lower in ZT+R over CT. This might be because of thepresence of crop residue that inhibited weed seed emergence by avoiding penetration of light to weed seed. Also, mechanical impediment might have suppressed weed seedlings to emerge out of soil thereby reducing weed density and hence, biomass. As also observed by [16] and [5] that residue has significant impact on weed dynamics. Among the weed management practices, IWM practices observed significantly lower weed density (25.7 and 35.0 no. m^{-2}, respectively) and biomass (13.6 and 19.9 m^{-2} g m^{-2}, respectively) over the others. HR was the second to efficiently control the weeds during both the years. Application of PoE herbicide clodinofop + metsulfuron at 64 g ha^{-1} *fb* HW at 45 DAS during both the years controlled the weeds. As also noted by [17] and [18].

3.3 Weed control efficiency

The WCE was suggestively affected by different treatments in the experiment. It is evident from the Table 1 that the highest WCE was obtained with the crop sown under ZT+R (71.3 and 71.2%, respectively). This might be because of lower weed biomass recorded in ZT+R than CT. Singh *et al.* (2017) also revealed the lowest weed population and biomass of the weeds under ZT with crop residue. Among the weed management practices IWM practices noted maximum WCE (97.4% and 96.7%, respectively) over weedy check. This was also reported earlier by [19], [20] and [17].

Table 1. Effect of crop establishment methods and weed management practices on total weed density, total biomass and weed control efficiency at 90 DAS of wheat in maize-wheat-greengram system

Treatment	Total density (no. m^{-2})		Total biomass (g m^{-2})		Weed control efficiency (%)	
	2021	**2022**	**2021**	**2022**	**2021**	**2022**
Crop establishment methods (M)						
CT(M)-CT(W)-CT(G)	9.9* (121.8)	10.7 (140.9)	10.7 (170.2)	11.7 (201.7)	67.3	66.7
ZT(M)+R(G)-ZT(W)+R(M)-ZT(G)+R(W)	9.1 (105.9)	9.9 (122.8)	9.9 (149.7)	10.8 (174.2)	71.3	71.2
SEm±	**0.05**	**0.02**	**0.03**	**0.08**	**-**	-
CD (P=0.05)	**0.33**	**0.11**	**0.18**	**0.51**	**-**	-
Weed management practices (S)						
Weedy check	17.6 (318.5)	19.0 (359.83)	22.8 (520.8)	24.6 (604.8)	0.00	0.00
RH	7.6 (58.0)	8.5 (71.2)	7.7 (58.3)	8.5 (72.2)	88.8	88.1
IWM	5.1 (25.7)	9.9 (35.0)	3.8 (13.6)	4.5 (19.9)	97.4	96.7
HR	7.3 (53.3)	7.9 (61.3)	6.9 (47.1)	7.4 (55.0)	91.0	90.9
SEm±	**0.15**	**0.22**	**0.06**	**0.18**	**-**	-
CD (P=0.05)	**0.46**	**0.66**	**0.18**	**0.57**	**-**	-

*values are √x +0.5 square root transformed and original values are given in parenthesis, CT(M); Conventional tillage (Maize), CT(W); Conventional tillage (Wheat), CT(G); Conventional tillage (Greengram), ZT(M)+R(G); Zero tillage (Maize)+residues(Greengram), ZT(W)+R(G); Zero tillage (Wheat)+Residues(Maize), ZT(G)+R(W); Zero tillage (Greengram)+Residues(Wheat)

3.4 Effect on growth parameters

Data pertaining to plant height (cm), plant biomass (g $plant^{-1}$) and tillers (no. m^{-2}) showed a significant difference among crop establishment methods and weed management practices (Table 2). It is clear from the Table 2 that crop sown under ZT+R gave significantly higher plant height (106.3 and 101.1 cm, respectively), biomass (12.0 and 9.0 g plant^{-1}, respectively) and tillers (488.0 and 391.3 no. m^{-2}, respectively) over CT during both the years of experimentation. This might be because of lower weed density in ZT+R that favored better crop growth by availing more space, water and nutrients to the plants [17] and [18]. Among the weed management practices, IWM practices recorded significantly higher plant height (110.2 and 105.0 cm, respectively), plant biomass (14.9 and 12.1 g plant^{-1}, respectively) and tillers (547.2 and 436.7 no. m^{-2}, respectively) followed by HR during both the years of experimentations. This might be because of better crop stand supplemented with chemical weed management *fb*HW that reduce weed density. [17] also reported IWM practices contributed to weed suppression thereby reducing crop-weed competition that favored the crop to efficiently use the space and available nutrients. In the second year, plant height was shorter because of application of mesosulfuron+iodosulfuron that inhibited the crop growth and some other factors like temperature during the crop growth may be responsible for short plant height.

Table 2. Effect of crop establishment methods and weed management practices on plant height, biomass and no. of tillers at 90 DAS of wheat in maize-wheat-greengram cropping system

Treatment	Plant height (cm)		Plant biomass (g plant^{-1})		Tillers (no. m^{-2})	
	2021	2022	2021	2022	2021	2022
Crop establishment methods (M)						
CT(M)-CT(W)-CT(G)	101.2	96.0	8.1	6.3	433.7	352.4
ZT(M)+R(G)-ZT(W)+R(M)-ZT(G)+R(W)	106.3	101.1	12.0	9.0	488.0	391.3
SEm±	**0.80**	**0.68**	**0.13**	**0.24**	**3.41**	**5.43**
CD (P=0.05)	**4.84**	**4.16**	**0.77**	**1.45**	**20.74**	**33.07**
Weed management practices (S)						
Weedy check	96.9	90.7	4.4	3.3	302.8	269.4
RH	101.1	97.4	9.0	6.2	478.0	378.1
IWM	110.2	105.0	14.9	12.1	547.2	436.7
HR	106.8	101.1	11.9	8.8	515.4	403.3
SEm±	**0.72**	**1.08**	**0.55**	**0.49**	**10.04**	**9.20**
CD (P=0.05)	**2.21**	**3.33**	**1.68**	**1.51**	**30.94**	**28.33**

CT(M); Conventional tillage (Maize), CT(W); Conventional tillage (Wheat), CT(G); Conventional tillage (Greengram), ZT(M)+R(G); Zero tillage (Maize)+residues(Greengram), ZT(W)+R(G); Zero tillage (Wheat)+Residues(Maize), ZT(G)+R(W); Zero tillage (Greengram)+Residues(Wheat)

3.5 Leaf area index (LAI)

Data regarding LAI at different intervals (Fig. 2) revealed that LAI increased up to 60 DAS and thereafter marginally decreased up to 90 DAS. There was no significant difference observed at 30 DAS under different crop establishment methods and weed management practices. At 60 DAS, significantly higher LAI was noted under ZT+R over CT. A similar trend was observed at 90 DAS during both years of experimentation. This might be due to more availability of soil moisture that favored plant growth under ZT with crop residue. [21] alsoshowed a significant influence of tillage practices on LAI. Among the weed management practices, clodinofop + metsulfuron*fb* HW at 45 DAS recorded significantly higher LAI which was at par with HR during both the years of experimentation. A similar trend was also observed at 90 DAS during both the years of experimentation. This might be because of more availability of space and nutrients because of lower weed density which favored crop growth and development. [22] also noted more LAI with the application of clodinofoppropargyl + metsulfuron methyl in the wheat.

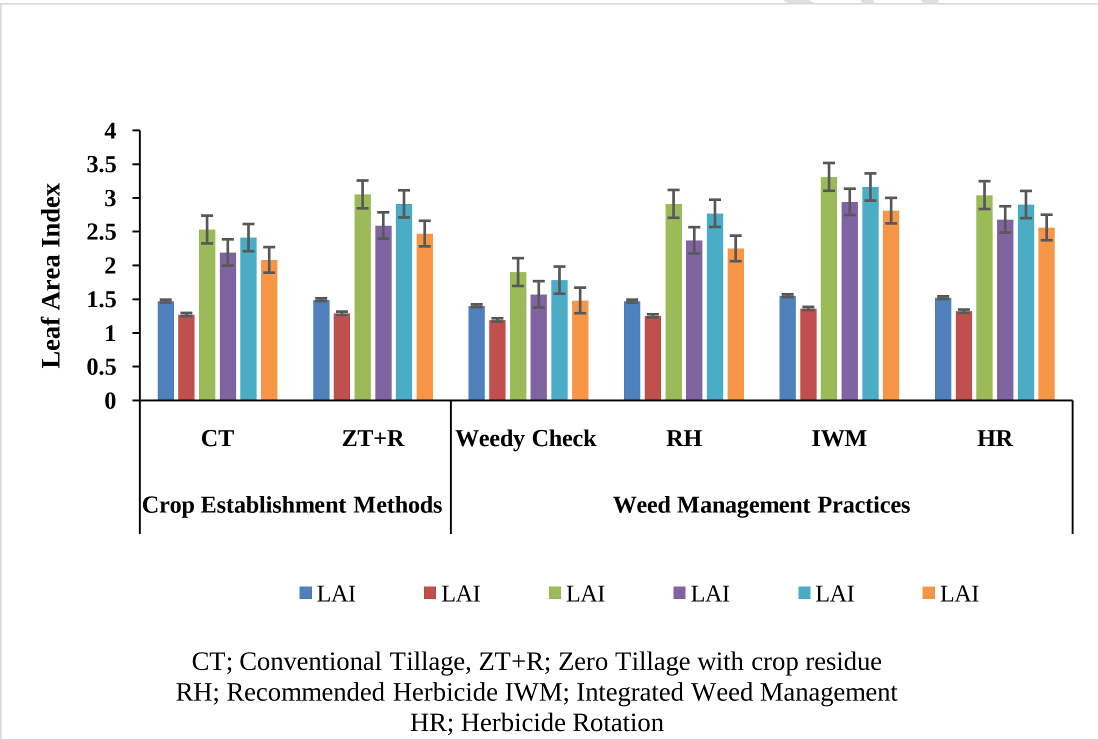

Figure 2. Effect of crop establishment methods and weed management practices on leaf area index at 30 days interval of wheat in maize-wheat-greengram cropping system

3.6 Grain and straw yields

Data pertaining to grain and straw yields are presented in Table 3 for both `years of experiment and were significantly influenced by tillage and weed management practices. Grain and straw yields of wheat were higher under ZT+R (4164 and 3814 kg ha^{-1}, respectively) and straw yield (7269 and 6834 kg ha^{-1}, respectively) over CT. This might be because of ZT with crop residue retention that enhance organic matter on the soil. There was also, more moisture conservation which resulted in more yield. This was also previously observed by [21]. Among the weed management practices, the grain and straw yields were significantly higher under clodinofop + metsulfuron*fb* HW at 45 DAS which was followed by HR. The application of clodinofop + metsulfuron*fb* HW it was found effective for controlling weeds thereby enhancing grain and straw yields as also observed by [23] and [22]. The interaction effect among crop establishment methods and weed management practices was significant during both the years of experimentations. The treatment ZT+R coupled with IWM recorded maximum grain yield over rest of the treatment.

3.7 Harvest index

Data related to HI as influenced by different crop establishment methods and weed management practices is presented in Table 3. There was no significant difference observed among different crop establishment methods and weed management practices during both the years of experimentations.

Table 3. Effect of crop establishment methods and weed management practices on grain and straw yield and harvest index of wheat in maize-wheat-greengram cropping system

Treatment	Grain yield (kg ha^{-1})		Straw yield (kg ha^{-1})		Harvest index (%)	
	2021	2022	2021	2022	2021	2022
Crop establishment methods (M)						
CT(M)-CT(W)-CT(G)	3713	3450	6499	6377	35.66	34.95
ZT(M)+R(G)-ZT(W)+R(M)-ZT(G)+R(W)	4164	3814	7265	6834	36.53	35.52
SEm±	**45.98**	**30.52**	**125.07**	**46.72**	**0.62**	**0.1**
CD (P=0.05)	**279.81**	**185.69**	**761.05**	**284.25**	**NS**	**NS**
Weed management practices (S)						
Weedy check	2201	2114	4235	4272	33.98	33.12
RH	4308	3933	7740	7101	35.77	35.64
IWM	4708	4299	7836	7610	37.58	36.16
HR	4538	4181	7717	7437	37.06	36.03
SEm±	**78.44**	**48.57**	**272.02**	**214.62**	**0.95**	**0.87**
CD (P=0.05)	**241.69**	**149.65**	**838.18**	**661.3**	**NS**	**NS**
M×S						
SEm±	**110.93**	**68.68**	**384.70**	**303.52**	**1.34**	**1.23**
CD (P=0.05)	**341.81**	**211.64**	**NS**	**NS**	**NS**	**NS**

CT(M); Conventional tillage (Maize), CT(W); Conventional tillage (Wheat), CT(G); Conventional tillage (Greengram), ZT(M)+R(G); Zero tillage (Maize)+residues(Greengram), ZT(W)+R(G); Zero tillage (Wheat)+Residues(Maize), ZT(G)+R(W); Zero tillage (Greengram)+Residues(Wheat)

4. CONCLUSION

Based on the experimental findings, it can be concluded that the CA practices have a significant influence on weed density, weed biomass and weed control efficiency of the wheat. Application of clodinofop + metsulfuron*fb* HW at 45 DAS significantly lowered weed density and biomass and enhanced WCE. The ZT+R coupled with IWM brought about maximum crop growth parameters and the highest grain yield. Therefore, for getting better weed control and crop growth with optimum yield, ZT with crop residues and integrated weed management practices couldbe adopted under CA-based maize-wheat-greengram cropping system.

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