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Research Communication

Integrated weed management in wheat under conservation agriculture-based maize-wheat-mungbean system

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ABSTRACT

A field experiment was conducted on integrated weed management in wheat (*Triticum aestivum* L.) under conservation agriculture-based maize (*Zea mays* L.)–wheat–mung bean [*Vigna radiata* (L.) R. Wilczek] system during the winter (*rabi*) season of 2020–2021 at the ICAR–Indian Agricultural Research Institute, New Delhi. The experiment was carried out in a split-plot design, with 4 main plots having different establishment techniques, viz. conventional tillage (CT)–wheat, zero tillage (ZT)–wheat, ZT–wheat with previous brown manuring in maize and stale seed bed (SSB)–ZT wheat; and 4 subplots, viz. unweeded check, weed-free check, 1 hand-weeding at 25 days after sowing (DAS) and clodinafop-propargyl (60 g/ha) + carfentazone (20 g/ha) as tank-mix at 25–30 DAS. The results revealed that, the yield attributes and yield of wheat were significantly influenced by the weed-management practices under different establishment techniques. The establishment method, ZT–wheat with brown manuring in previous maize resulted in the highest crop yield, followed by SSB–ZT wheat. Among the weed-management options, clodinafop-propargyl (60 g/ha) + carfentazone (20 g/ha) as tank-mix at 25–30 DAS resulted in the highest growth, yield attributes and economics, which remained at par with hand-weeding. The highest grain yield (4.85 t/ha), straw yield (9.03 t/ha), and biological yield (14.32 t/ha) were recorded under ZT–wheat, with brown manuring in previous maize. A 16.5, 7.3 and 9.94% increase in grain, straw and biological yield, respectively, was recorded with clodinafop-propargyl (60 g/ha) + carfentazone (20 g/ha) as post tank-mix 25–30 DAS over unweeded check. The ZT–wheat showed 51.4% higher net returns over CT, followed by ZT–wheat and SSB–ZT wheat which showed 22.1 and 19.2% higher values, respectively, over CT. The highest benefit : cost (B : C) ratio was found in weed-free check which showed 21.9% higher value over unweeded check.

Key words: Brown manuring, Herbicides, Integrated weed-management, Residue retention, Wheat, Zero tillage

The quest for sustainable crop-production systems capable of feeding the world, maintaining and enhancing ecosystem services, has increased the worldwide adoption of conservation agriculture (CA). The major concerns with CA are proper crop establishment and weed menace. Weed interference is more severe under zero tillage (ZT) due to poor management of surface crop residues, especially in the initial years of conversion (1–3 years). As a result, an integrated weed-management strategy is being suggested in CA-based wheat (*Triticum aestivum* L.) cultivation by combining agro-technologies like diversifying cropping systems, integrating weed-management techniques and improving crop-establishment methods. Wheat is the second most important crop in India after rice, particularly in the northern part of the country. Globally, India occupies the first position in terms of area and second in terms of production of wheat (IPCC, 2020). But the national average productivity of wheat remains 3.5 t/ha only, which is far less as compared to European countries. The emerging problems of stagnating or low yields, soil organic carbon exhaustion, resource shortage as well as receding groundwater and negative environmental externalities are often faced in the conventionally grown rice–wheat system in the Indo-Gangetic Plains (IGP). Likewise, nutrient leaching, increasing soil-water salinity and the adverse effects of climate modification caused by the conventional crop-production system has resulted in the growing adoption of CA technologies for the cereal-production systems of South Asia, including India (Das *et al.,* 2014).

Continuous rice–wheat system has also buildup of obnoxious weed population, particularly of small canary grass

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(*Phalaris minor* Retz.) in wheat (Singh and Singh, 2005). Thus, sustainable crop production capable of feeding the world now and also for future, while preserving and enhancing ecosystem services can be developed following the principles of CA (Kassam *et al.,* 2014). In India, since the introduction of CA noteworthy advancements have been made with reducing tillage particularly for wheat. A systematic and detailed study on the impact of crop-establishment methods and weed-management approaches in wheat under CA-based maize (*Zea mays* L.)–wheat system under trans-Gangetic plains would give an insight about the issues in current practices and the prospects for future strategies. Hence, the present study was initiated to evaluate the effect of different crop-establishment methods and weed-management options, and their judicious integration on weed dynamics, agronomic productivity and profitability in wheat under maize–wheat–mung bean system.

The field experiment was conducted during the winter season of 2020–21 at the Research Farm of the Indian Agricultural Research Institute, New Delhi, Northwest IGP (28°40' N, 77°11' E; 228 m above sea-level). Conventional tillage, zero tillage and stale seed bed was executed as per the treatment in the experimental field. The climate of the research farm is semi-arid, with dry, hot summers from May to June, with average maximum temperatures of 40° to 45°C and cold winters from December to January, with average minimum temperatures of 2°C. The average annual rainfall is about 650 mm, almost 75% of which is received between July and September. The experiment was laid in a split-plot design with 3 replications. Four crop-establishment methods, viz. conventional tillage wheat (CT–wheat), zero tilled-wheat (ZT–wheat), zero tilled wheat (ZT–wheat) with brown manuring in previous maize crop, stale seed bed– wheat (SSB–wheat), were taken as the main plot and 4 weed-management options, viz. unweeded check, weed-free check, hand-weeding at 25 days after sowing (DAS) and post-emergence herbicide application, was taken in the subplots. The crop was sown on 24 November, 2020. The initial surface residue (i.e. 40% of residue biomass produced plot-wise) was retained from previous cropping, while the harvested maize residues were left *in-situ* on surface soil in respective plots for the current experiment (i.e. 50% of maize above-ground residues). To ensure managed traffic and minimal soil disturbance in a CA mode, a no-till ‘Turbo Happy Seeder’-cum-fertilizer drill was used for sowing.

The predominant weed species among narrow leaf (NLW) and broad-leaf weeds (BLW) were: *P. minor* and *Chenopodium album* L., respectively, at 40 DAS. The CT–wheat plot showed the highest *P. minor* population (11.9/m^2), while the lowest population was associated with ZT–wheat (2.7/m^2). Among the BLW, *C. album* showed the highest population of 9.5/m^2 in CT–wheat plot and the lowest in ZT–wheat where *Sesbania* brown manure was done in previous maize crop (3.9/m^2). A similar trend was also observed at 60 DAS (Table 1), but the weed population was higher at 60 DAS than 40 DAS. Among the weed-management options, the maximum weed control was seen in weed-free check, followed by herbicide application. The weed density of NLW was higher than that of BLW at both 40 and 60 DAS. The highest weed density was observed at 60 DAS in CT–wheat plot, with total weed density of 62.1 No./m^2 (26.4 No./m^2 and 35.7 No./m^2 in BLW and NLW respectively). The ZT–wheat-treated plot was observed with the lowest weed density among all the crop-establishment methods with total weed density of 26.1 No./m^2 (BLW 13.3, NLW 12.8). Herbicide weed suppression at the commencement of sowing was found to be effective under CA systems (Muoni *et al.,* 2013; Nichols *et al*., 2015). Total weed density differed significantly in the crop-establishment treatments at 40 and 60 DAS (Table 1). Weed density increases vigorously under unweeded conditions over time, especially under CT–wheat (Shekhawat *et al*., 2021). At 20 DAS, ZT–wheat with brown manuring in previous maize crop exhibited the best result by showing a weed suppression of 45%. Similarly, ZT–wheat and SSB–wheat showed a suppression of 39.3 and 9.5%, respectively, from the control. Among the weed-management treatments, clodinafop – propargyl + carfentazone showed a decrease of 35.9% and hand-weeding at 25 DAS revelaed 31.8% decreased weed density compared to the unweeded check plot.

At harvesting, the plant height ranged between 91.4 and 100.3 cm. The maximum plant height was recorded in weed-free check plot (100 cm). Under different establishment methods, the mean dry-matter accumulation at harvesting was 481.4 g/m^2. The leaf-area index (LAI) increased till 90 DAS. The mean value of LAI at 60 DAS was 3.80. Kebede and Bekelle (2008) also reported similar findings in wheat. At 60 DAS, the maximum LAI was recorded with ZT–wheat where *Sesbania* results brown manuring was done in previous maize crop and with weed-free check. Singh (2013) also found that, the ZT planting method had a substantial impact on wheat crop growth metrics owing to favourable soil rhizospheric activities.

The maximum ear-bearing tillers (EBT) were maximum (344.1) under ZT–wheat where *Sesbania* brown manure was done in previous maize crop which remained significantly higher over SSB–ZT–wheat and CT–wheat (Table 2). The maximum EBT were 320.3/m^2 under weed-free check, followed by herbicide-applied plot (308.6/m^2) and hand-weeding at 25 DAS plot (300.4/m^2) and unweeded check (292.8/m^2). The number of grains/spike ranged from 45.9 to 55.5 under different crop-establishment methods. The maximum number of grains/spike was

Table 1. Effect of crop-establishment methods and weed-management on species-wise weed distribution (No./m²) in wheat

Treatment	40 DAS					60 DAS				
	NLW			BLW		NLW			BLW	
Weeds/CEM	*Phalaris minor*	*Avena fatua*	*Cynodon dactylon*	*Chenopodium album*	*Convolvulus arvensis*	*Phalaris minor*	*Avena fatua*	*Cynodon dactylon*	*Chenopodium album*	*Convolvulus arvensis*
Crop–establishment methods										
CT–wheat	11.9	7.4	4.4	9.5	5.1	17.8	9.6	8.1	17.2	9.2
ZT–wheat	3.3	1.7	1.6	4.7	2.5	8.1	4.8	3.3	10.9	5.8
ZT–wheat*	2.7	1.4	1.3	3.9	2.1	6.4	3.9	2.4	8.6	4.6
SSB–ZT–wheat**	9.1	6	3	7	3.8	14	7.7	6.2	13.3	7.2
SEm±	0.2	0.1	0.1	0.3	0.1	0.2	0.1	0.1	0.3	0.1
CD (P=0.05)	0.8	0.4	0.4	1	0.5	0.8	0.4	0.4	1	0.5
Weed–management options										
Unweeded check	17.8	9.9	7.9	19.8	10.6	27.3	14.6	12.6	32.2	17.3
Weed-free check	0	0	0	0	0	0	0	0	0	0
HW at 25 DAS	5.8	3.9	1.8	4.1	2.2	11.8	6.9	4.9	11.9	6.4
Herbicide application§	3.6	2.8	0.7	1.3	0.7	7.2	4.6	2.6	6	3.2
SEm±	0.2	0.1	0.1	0.3	0.1	0.2	0.1	0.1	0.3	0.1
CD (P=0.05)	0.7	0.3	0.3	0.9	0.5	0.7	0.3	0.3	0.9	0.5

*Preceding maize with brown manure (*Sesbania* co-culture); **Stale seed bed fb paraquat–ZT–Wheat; §clodinafop-propargyl + carfentazone as tank mix at 25–30 DAS
DAS, Days after sowing; NLW, naroow leaf weeds; BLW, broad leaf weeds; CT, conventional tillage; ZT, zero tillage; SSB, stale seed bed

Table 2. Effect of crop-establishment methods and weed-management on growth parameters of wheat

Treatment	Plant height (cm) at harvest	Dry weight (g/plant) at harvest	Leaf-area index (60 DAS)	Tillers (90 DAS)
Crop-establishment methods				
CT–wheat	92.6	457.4	3.67	307.1
ZT–wheat	97.6	498.9	3.93	354.5
ZT–wheat*	98.0	501.6	4.03	384.1
SSB–ZT Wheat**	94.6	467.7	3.71	333.3
SEm±	2.7	13.0	0.12	9.1
CD (P=0.05)	NS	45.2	0.43	31.3
Weed-management options				
Unweeded check	91.4	485.3	4.68	332.1
Weed-free check	100.3	475.9	4.94	359.5
Hand-weeding at 25 DAS	94.8	481.0	4.83	339.5
Herbicide application§	96.3	483.5	4.89	347.9
SEm±	0.9	2.8	0.01	1.9
CD (P=0.05)	2.6	8.2	0.06	5.7

*Preceding maize with brown manure (*Sesbania* co-culture); **Stale seed bed fb paraquat–ZT–Wheat; §clodinafop-propargyl + carfentazone as tank mix at 25–30 DAS
DAS, Days after sowing; NLW, narrow leaf weeds; BLW, broad leaf weeds; CT, conventional tillage; ZT, zero tillage; SSB, stale seed bed

recorded under ZT–wheat where *Sesbania* brown manure was done in previous maize crop, followed by ZT–wheat which were significantly higher than remaining crop-establishment methods. The ZT–wheat where *Sesbania* brown manure was done in previous maize crop showed the highest values of yield attributes, followed by ZT–wheat, while conventional tillage exhibited the lowest (Yield attributes). The highest grain weight/spike was recorded under ZT–wheat where *Sesbania* brown manure was done in previous maize crop (1.9 g), closely followed by ZT–wheat (1.9 g), SSB–wheat (1.8 g), and these crop-establishment methods resulted in significantly higher values over CT–wheat plot (1.5 g). Under different establishment methods, 1,000-seed weight ranged from 38.5 to 42.0 g, with a mean value of 39.87 g. The ZT–wheat where *Sesbania* brown manure was done in previous maize crop resulted in the maximum 1,000-seed weight (42.0 g) which remained at par with other treatments. Among weed-management options, 1,000-seed weight ranged from 39.0 to 42.1 g, with a mean value of 40.1 g. A significantly higher 1,000-seed weight (42.1g) was recorded with weed-free check, and the other treatments remained at par.

The highest grain yield (4.85 t/ha) was observed under ZT–wheat where *Sesbania* brown manure was done in previous maize crop (4.85 t/ha) which remained significantly higher over the other crop-establishment methods. Weeds cause huge losses in yield, especially when not controlled during the critical stages (Shekhawat *et al*., 2020). The maximum total biological yield was recorded under ZT–wheat where *Sesbania* brown manure was done in previous maize. This establishment method remained statistically at par with ZT–wheat and SSB–wheat but significantly higher than over CT–wheat. The increased yield effects in CA-based wheat are mostly owing to timely sowing and weed-control efficiency (Erenstein and Laxmi, 2008).

The total biological yield varied with a range of 12.17–13.92 t/ha. The harvest index of wheat was not affected by different crop-establishment methods and it ranged from 36.0 to 36.9.

The net returns ranged from 44,900 to 63,630 ₹/ha among different crop-establishment methods. The crop-establishment methods clearly influenced the net returns and the maximum net returns were realized under ZT–wheat where *Sesbania* brown manure was done in previous maize crop (₹ 63,630 /ha) and the minimum in CT–wheat (Table 3). Under the weed-management options, the highest net returns were found in weed-free check plot (₹ 60,930 /ha) and the lowest in unweeded check plot (₹ 47,550 /ha). The benefit: cost ratio ranged from 1.40 to 2.12 under the crop-establishment methods, being the highest in ZT–wheat where *Sesbania* brown manuring (1.71) was done in previous maize crop. Among various weed-

Table 3. Effect of crop-establishment methods and weed-management on yield attributes, grain, biological yield and economics of wheat

Treatment	Grain weight/ spike (g)	Grains/ spike (No.)	Ear-bearing tillers/m²	1,000-seed weight (g)	Biological yield (t/ha)	Grain yield (t/ha)	Harvest index (%)	Net returns (× 10³₹/ha)	Benefit: cost ratio
Crop-establishment methods									
CT–wheat	1.5	45.9	268.0	38.5	11.80	3.79	36.1	44.90	1.40
ZT–wheat	1.9	55.1	316.5	40.0	13.29	4.34	36.0	53.97	1.71
ZT–wheat*	1.9	55.5	344.1	42.0	14.32	4.85	36.9	63.63	2.12
SSB–ZT Wheat**	1.8	48.7	293.3	39.0	13.03	4.29	36.4	53.20	1.67
SEm±	0.08	1.4	8.6	0.3	0.39	0.13	0.17	16.03	—
CD (P=0.05)	0.3	5.2	29.9	NS	1.33	0.44	NS	53.64	–
Weed-management options									
Unweeded check	1.5	50.5	292.8	39.0	12.17	3.80	35.1	47.55	1.55
Weed-free check	2.1	52.1	320.3	42.1	13.92	4.88	38.2	60.93	1.89
Hand-weeding at 25 DAS	1.8	52.9	300.4	39.3	12.97	4.15	35.5	51.83	1.74
Herbicide application§	1.9	51.6	308.6	40.3	13.38	4.43	36.5	55.39	1.79
SEm±	0.08	0.24	2.21	0.60	0.15	0.10	0.30	13.20	–
CD (P=0.05)	0.22	0.72	6.42	1.81	0.43	0.30	0.91	37.49	–

DAS, Days after sowing; NLW, narrow leaf weeds; BLW, broad leaf weeds; CT, conventional tillage; ZT, zero tillage; SSB, stale seed bed management methods, the highest value was seen in case of weed-free check plot (1.89), as it was free from weed meanace. Singh *et al.* (2019) noted that, under ZT the net returns were highest compared to CT.

We conclude that, the efficiency of weed management by brown manuring in the *kharif* crop under CA-based systems and its synergy with herbicide combinations suppress weeds, and contribute to crop productivity and farm profitability.

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