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Role of tillage practices and organic mulches in weed suppression and wheat growth

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Abstract
A field experiment was conducted during the rabi seasons of 2020–21 and 2021–22 under irrigated conditions at the Main Agricultural Research Station (MARS), University of Agricultural Sciences, Dharwad, located in the Northern Transition Zone of Karnataka, to evaluate the role of tillage practices and organic residue mulches on weed suppression, weed control efficiency and growth parameters of wheat. The experiment was laid out in a split-plot design, comprising two tillage practices, conventional tillage (T_1) and minimum tillage (T_2) as main plot treatments and five residue mulch treatments no residue, soybean residue, maize residue, groundnut residue and *Gliricidia* mulch as subplot treatments, along with a weed-free check. Results revealed that conventional tillage significantly reduced weed density and weed dry weight (14.1 g) compared to minimum tillage (18.7 g), resulting in higher weed control efficiency. Among residue mulches, *Gliricidia* mulch proved most effective in suppressing weeds, recording the lowest density of grasses (15.2/m^2), sedges (8.2/m^2) and broad-leaved weeds (13.2/m^2), followed by maize and soybean residues. The interaction of conventional tillage with *Gliricidia* mulch resulted in the lowest weed dry weight (10.0 g) and the highest WCE (60.6%), whereas minimum tillage without residue recorded maximum weed infestation. Conventional tillage and residue mulching, particularly with *Gliricidia*, significantly enhanced plant height (84.4 cm), tiller density (439.3/m^2) and dry matter accumulation (107 g). Overall, the study demonstrated that conventional tillage combined with *Gliricidia* or maize residue mulching is an effective and sustainable strategy for weed suppression and improved wheat growth under irrigated conditions of the Northern Transition Zone of Karnataka.

Keywords: Conventional tillage, mulching, weed flora composition, weed dry weight, growth parameters

Introduction

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops globally and plays a pivotal role in food and nutritional security in India. Despite advances in varietal improvement and crop management, wheat productivity in many agro-ecological regions remains constrained by weed infestation, declining soil health and inefficient resource use. Among these constraints, weeds are recognized as the most persistent and yield-limiting biotic factor, capable of causing yield losses ranging from 20 to 60% depending on weed flora, management practices and environmental conditions (Chauhan & Johnson, 2010; Singh *et al*., 2013) [2, 10]. The composition and dominance of weed flora in wheat are strongly influenced by tillage systems and residue management practices. Tillage modifies soil physical properties, seed placement and the soil microenvironment, thereby regulating weed seed germination, emergence and survival (Mohler, 2001) [8]. Conventional tillage, through soil inversion and mechanical disturbance, often suppresses early weed emergence by burying weed seeds below their optimum germination depth and disrupting seedlings. In contrast, minimum or reduced tillage systems tend to concentrate weed seeds near the soil surface, which may increase weed pressure if not complemented by other weed-suppressive practices (Chauhan *et al*., 2012) [3].

Organic residue mulching has emerged as a key component of sustainable weed management in cereal-based systems. Surface application of crop residues such as maize, soybean, groundnut and leguminous biomass like *Gliricidia* alters the soil microclimate by conserving moisture, moderating temperature fluctuations and improving soil organic carbon dynamics. Residue mulches suppress weed emergence through physical impedance, reduced light transmission, modification of the red: far-red light ratio and allelopathic interactions, leading to reduced weed density and biomass (Jabran, 2017) [4]. Leguminous residues are particularly effective due to their rapid decomposition and nutrient release, which enhance crop growth while suppressing weeds (Lal, 2015) [7]. Therefore, the present study was undertaken to evaluate the effects of different tillage methods and organic residue mulches on weed composition (grasses, sedges, and broad-leaved weeds), weed dry weight, weed control efficiency and key growth parameters of wheat, with the objective of identifying effective and sustainable management practices for irrigated wheat production.

Materials and Methods

A field experiment to evaluate the role of tillage practices and organic mulches in weed suppression and wheat growth was conducted at the Main Agricultural Research Station (MARS), University of Agricultural Sciences, Dharwad, Karnataka, located in the Northern Transition Zone of Karnataka, during the rabi seasons of 2020–21 and 2021–22 under irrigated conditions. The soil of the experimental site was loamy in texture with a pH of 7.4 and an electrical conductivity of 0.25 dS m^{-1}. The soil was low in organic carbon and available nitrogen (158.41 kg ha^{-1}), high in available phosphorus (32.15 kg ha^{-1}), and medium in available potassium (291.52 kg ha^{-1}).

The experiment consisted of two tillage practices, namely T_1: conventional tillage and T_2: minimum tillage, assigned to the main plots, and five residue mulch treatments, namely M_1: no residue, M_2: soybean residue, M_3: maize residue, M_4: groundnut residue, and M_5: *Gliricidia* mulch, assigned to the subplots. In addition, a weed-free check was included as a control treatment. The experiment was laid out in a split-plot design with ten treatment combinations and the weed-free check was compared with the treatment combinations using a randomized complete block design.

Wheat variety UAS-334 was sown at a seed rate of 125 kg ha^{-1} during the second fortnight of November 2020 and harvested in the second fortnight of March 2021 during the first year. In the second year, the crop was sown in the first fortnight of November 2021 and harvested in the second fortnight of March 2022. The recommended fertilizer dose of 120:60:40:20:20 kg ha^{-1} of N, P_2O_5, K_2O, $ZnSO_4$, and $FeSO_4$, respectively, was applied through urea, di-ammonium phosphate, muriate of potash, zinc sulphate, and ferrous sulphate.

Weed density was recorded at harvest by counting the number of weeds present in a fixed 1 m^2 area in each treatment. The weed flora was categorized into grasses, sedges and broad-leaved weeds were recorded separately for each group. Weed dry matter was also determined at harvest. Weeds were uprooted randomly from a 1 m^2 area in each plot, air-dried initially and subsequently oven-dried at 70 °C until a constant weight was attained. The total weed dry weight was expressed as g m^{-2}. Weed control efficiency (WCE) was calculated at harvest using the formula proposed by Singh *et al.* (2013) [10] and expressed as a percentage (%).

$$\text{WCE (\%)} = \frac{\text{Dry matter of weeds in control plot (g)} - \text{Dry matter of weeds in treated plot (g)}}{\text{Dry matter of weeds in control plot (g)}} \times 100$$

Plant height was recorded at harvest by measuring five randomly selected plants from each treatment, from the base of the plant to the base of the panicle and the values were expressed in centimetres (cm). The number of tillers per square metre was also recorded in each treatment at harvest. For estimation of dry matter production, destructive plant sampling was carried out at harvest. Plant samples were collected from the second row on either side of each plot, covering a row length of 0.5 m on each occasion. The collected plant material was initially air-dried and subsequently oven-dried at 70 °C until a constant weight was attained. Dry matter accumulation was then computed and expressed as grams per metre row length.

The data recorded during the course of the experiment were compiled and subjected to statistical analysis following the analysis of variance appropriate for a split-plot design. The randomized complete block design was employed to compare the control treatment with the treatment combinations. Statistical analysis was carried out using Fisher's ANOVA technique as described by Gomez and Gomez (1984). The least significant difference values were calculated at the 5% level of significance ($P = 0.05$) wherever the F-test indicated significant differences. In addition, the mean values of main plot treatments, subplot treatments and their interactions were separately compared using the Duncan Multiple Range Test by applying the appropriate error mean sum of squares and degrees of freedom.

Results and Discussion

Grasses

Grassy weed density at harvest was significantly influenced by tillage practices and residue mulches (Table 1). Conventional tillage recorded a significantly lower population of grasses (compared to minimum tillage. The reduction in grassy weeds under conventional tillage can be attributed to soil disturbance, which buries weed seeds deeper in the soil profile and disrupts early-emerging seedlings, thereby reducing establishment (Chauhan *et al*., 2012) [3].

Among residue mulch treatments, *Gliricidia* mulch resulted in the lowest grassy weed density, followed by maize residue mulch and soybean residue mulch. In contrast, the no-residue treatment recorded the highest grassy weed population. Organic mulches suppress grassy weeds by restricting light penetration, creating physical barriers to emergence and through possible allelopathic effects, particularly in leguminous residues such as *Gliricidia* (Teasdale & Mohler, 2000) [15, 8]. The interaction effect revealed that conventional tillage combined with *Gliricidia* mulch significantly reduced grassy weed density, whereas minimum tillage without residue recorded the highest grassy weed infestation. Similar findings were reported by Singh *et al*. (2017) [13] observed reduced grassy weed emergence under conventional tillage combined with surface mulching.

Sedges

Sedge population at harvest followed a trend similar to grasses. Conventional tillage significantly reduced sedge density compared to minimum tillage. Sedges, particularly *Cyperus* spp., thrive under minimum soil disturbance and moist conditions; therefore, reduced tillage favors their persistence (Rao *et al.*, 2007) [9]. Among residue treatments, *Gliricidia* mulch and maize residue mulch recorded significantly lower sedge density, while the highest sedge population was observed under no-residue treatment. Mulching reduces soil surface exposure and modifies the microenvironment, which is unfavorable for sedge emergence and growth (Kumar *et al*., 2019) [5]. The interaction of conventional tillage with *Gliricidia* mulch proved most effective in minimizing sedge infestation, whereas minimum tillage without residue showed maximum sedge density. These findings corroborate earlier reports emphasizing the role of tillage–mulch integration in managing sedges in cereal systems.

Broad-leaved weeds

Broad-leaved weed density was significantly affected by both tillage and residue mulch treatments. Conventional tillage recorded lower broad-leaved weed density than minimum tillage, likely due to burial of small-seeded broad-leaved weeds beyond their optimal germination depth (Mohler, 2001) [8]. Residue mulch treatments markedly reduced broad-leaved weed density compared to no residue. Among mulches, *Gliricidia* mulch recorded the lowest broad-leaved weed population, followed by maize residue mulch. The suppression of broad-leaved weeds under mulching may be attributed to reduced light ratio at the soil surface and allelopathic compounds released during residue decomposition (Teasdale & Mohler, 2000; Jabran, 2017) [15, 8, 4]. The interaction effect indicated that T_1M_5 and T_1M_3 were significantly superior in reducing broad-leaved weed density, while T_2M_1 recorded the highest infestation. Similar observations have been reported in wheat by Singh *et al.* (2018) [11], where residue retention combined with tillage significantly reduced broad-leaved weeds.

Weed dry weight

Weed dry weight at harvest closely followed trends observed in weed density. Conventional tillage significantly reduced weed dry matter compared to minimum tillage, reflecting effective suppression of weed growth through soil disturbance. Among residue mulches, *Gliricidia* mulch recorded the lowest weed dry weight, followed by maize residue mulch and soybean residue mulch. In contrast, the no-residue treatment accumulated the highest weed dry matter. The reduction in weed biomass under residue mulching is attributed to delayed weed emergence, reduced photosynthetic activity and restricted nutrient availability to weeds (Teasdale, 1998) [16]. The interaction of conventional tillage with *Gliricidia* mulch resulted in the minimum weed dry weight, whereas minimum tillage without residue recorded the maximum weed biomass. These results confirm that residue mulch enhances the effectiveness of tillage practices in suppressing weed growth (Chauhan & Johnson, 2010) [2].

Table 1: Effect of tillage and residue mulch on weed density and dry weight at harvest (mean data of 2 years)

Treatment	Grasses/m^2	Sedges/m^2	Broad leaved weeds/m^2	Weed dry weight (g)
Tillage				
T_1: Conventional tillage	4.3^{b}(18.1)	3.2^{b} (9.7)	4.0^{b} (15.7)	3.9^{b}(14.1)
T_2: Minimum tillage	4.7^{a} (21.7)	3.6^{a} (12.4)	4.4^{a} (18.9)	4.4^{a} (18.7)
S. Em. ±	0.05	0.05	0.05	0.08
Residue mulch				
M_1: No residue	5.1^{a} (25.2)	3.9^{a} (14.7)	4.9^{a} (23.1)	4.8^{a} (22.5)
M_2: Soybean residue	4.5^{c} (19.6)	3.4^{ab} (10.6)	4.2^{c} (16.8)	4.1^{c} (15.9)
M_3: Maize	4.3^{c} (17.7)	3.2^{b} (9.5)	3.9^{d} (14.8)	3.8^{d} (13.6)
M_4: Ground nut	4.8^{b} (22.1)	3.6^{ab} (12.5)	4.4^{b} (19.2)	4.4^{b} (18.9)
M_5: Gliricidia	4.0^{d} (15.2)	3.0^{b} (8.2)	3.7^{e} (13.2)	3.5^{e} (11.8)
S. Em. ±	0.06	0.14	0.04	0.03
Interaction				
T_1M_1	4.9^{bc} (23.8)	3.7^{a-c} (13.2)	4.7^{b} (21.8)	4.5^{c} (19.8)
T_1M_2	4.3^{ef} (17.6)	3.1^{c-e} (8.9)	4.0^{ef} (15.1)	3.8^{f} (13.8)
T_1M_3	4.1^{f} (16.1)	3.0^{de} (8.2)	3.7^{g} (13.3)	3.5^{g} (11.4)
T_1M_4	4.5^{d} (19.9)	3.4^{b-e} (11.2)	4.2^{cd} (17.3)	4.1^{e} (16.4)
T_1M_5	3.8^{g} (13.6)	2.9^{e} (7.5)	3.5^{h} (11.7)	3.3^{h} (10.0)
T_2M_1	5.3^{a} (27.4)	4.1^{a} (16.2)	5.0^{a} (24.5)	5.1^{a} (25.4)
T_2M_2	4.7^{cd} (21.6)	3.6^{a-d} (12.5)	4.4^{c} (18.7)	4.4^{d} (18.2)
T_2M_3	4.5^{de} (19.3)	3.4^{b-e} (11.0)	4.1^{de} (16.3)	4.1^{e} (15.9)
T_2M_4	5.0^{b} (24.3)	3.8^{ab} (14.0)	4.7^{b} (21.1)	4.7^{b} (21.3)
T_2M_5	4.2^{f} (16.8)	3.1^{c-e} (9.0)	3.9^{f} (14.7)	3.8^{f} (13.6)
S. Em. ±	0.09	0.18	0.07	0.09
Control (WFC)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
S. Em. ±	0.15	0.18	0.12	0.15
CD at 5%	0.45	0.54	0.36	0.44

Data in parenthesis are original values and subjected to $\sqrt{X+1}$

Weed control efficiency

Weed control efficiency (WCE) at harvest varied significantly among treatments. Conventional tillage achieved higher WCE compared to minimum tillage, indicating superior weed suppression under soil inversion practices. Among residue mulches, *Gliricidia* mulch recorded the highest weed control efficiency (53.8%), followed by maize residue mulch (46.5%) and soybean residue mulch (37.2%). The lowest WCE was observed under no-residue treatment, highlighting the importance of surface mulch in weed management. The interaction effect showed that conventional tillage combined with *Gliricidia* mulch recorded the highest WCE (60.6%), followed by T_1M_3, while T_2M_1 exhibited zero weed control efficiency. The weed-free check maintained 100% WCE, as expected. Higher WCE under tillage, mulch integration reflects the combined effects of mechanical disruption, reduced seedling emergence and physical suppression by residues. Similar enhancements in weed control efficiency through integrated tillage and residue management have been reported by Singh *et al.* (2013) [10] and Kumar *et al.* (2020) [6].

Plant height

Plant height of wheat at harvest was significantly influenced by tillage practices, residue mulch treatments, and their interactions. Conventional tillage recorded significantly taller plants compared to minimum tillage. Improved plant height under conventional tillage may be attributed to better soil tilth, enhanced root proliferation and improved availability of soil moisture and nutrients due to soil inversion and reduced soil compaction. These conditions favor early crop establishment and sustained vegetative growth, ultimately resulting in increased plant height. Residue mulch treatments also had a pronounced effect on plant height. Among the mulches, *Gliricidia* mulch resulted in the tallest plants, followed by maize and soybean residue mulches, whereas the no-residue treatment recorded the shortest plants. The beneficial effect of organic mulches on plant height can be attributed to improved soil moisture conservation, moderation of soil temperature and gradual nutrient release during residue decomposition. Leguminous residues such as *Gliricidia* further enhance nitrogen availability, promoting vegetative growth. The interaction effect revealed that conventional tillage combined with *Gliricidia* mulch produced the tallest plants, while minimum tillage without residue recorded the lowest plant height. Similar improvements in wheat plant height due to integrated tillage and residue management have been reported earlier (Singh *et al*., 2017; Kumar *et al*., 2020) [14, 6].

Number of tillers m⁻²

The number of tillers per square metre is a critical yield-determining trait in wheat and was significantly affected by tillage and residue mulch treatments. Conventional tillage produced a significantly higher number of tillers m^{-2} compared to minimum tillage. The higher tiller density under conventional tillage may be due to improved seed–soil contact, better root growth and enhanced nutrient uptake during the early growth stages, which promote tiller initiation and survival. Among residue mulch treatments, *Gliricidia* mulch recorded the highest number of tillers m^{-2}, followed by maize residue mulch and soybean residue mulch. In contrast, the lowest tiller count was observed under the no-residue treatment. Residue mulching conserves soil moisture and improves nutrient availability during the critical tillering phase, thereby enhancing tiller production and reducing tiller mortality. The positive influence of residue mulches on tillering has been well documented in wheat under irrigated and rainfed conditions (Teasdale & Mohler, 2000; Verhulst *et al*., 2011) [15, 8, 17]. The interaction effect indicated that conventional tillage with *Gliricidia* mulch resulted in the maximum number of tillers m^{-2}, whereas minimum tillage without residue recorded the minimum tiller population. These findings emphasize the importance of integrated soil and residue management for maximizing tiller density in wheat.

Table 2: Effect of tillage and residue mulch on weed control efficiency and growth parameters of wheat at harvest (mean data of 2 years)

Treatment	Weed control efficiency (%)	Plant height (cm)	No. of tillers/m^2	Plant dry weight (g)
Tillage				
T_1: Conventional tillage	43.9	82.0^a	420.6^a	102.8^a
T_2: Minimum tillage	25.7	79.9^b	396.3^b	98.2^b
S. Em. ±	-	0.13	2.08	0.64
Residue mulch				
M_1: No residue	11.1	78.4^b	392.3^d	97.3^e
M_2: Soybean residue	37.2	80.9^{ab}	406.1^c	100.1^c
M_3: Maize	46.5	81.9^{ab}	416.7^b	101.8^b
M_4: Ground nut	25.6	80.1^{ab}	399.5^{cd}	98.7^d
M_5: Gliricidia	53.8	83.5^a	427.7^a	104.4^a
S. Em. ±	-	1.04	1.66	0.21
Interaction				
T_1M_1	22.2	79.3^{bc}	408^e	99.3^e
T_1M_2	45.9	82.2^{a-c}	418.7^c	102.6^c
T_1M_3	55.3	83.0^{ab}	426.7^b	103.8^b
T_1M_4	35.6	81.3^{a-c}	410.3^{de}	101^d
T_1M_5	60.6	84.4^a	439.3^a	107^a
T_2M_1	0.0	77.5^c	376.7^g	95.3^h
T_2M_2	28.4	79.7^{a-c}	393.7^f	97.6^f
T_2M_3	37.8	80.8^{a-c}	406.7^e	99.8^e
T_2M_4	15.6	78.9^{bc}	388.6^f	96.5^g
T_2M_5	47.0	82.6^{ab}	416^{cd}	101.8^{cd}
S. Em. ±	-	1.32	2.96	0.69
Control (WFC)	100.0	85.3	447.0	109.3
S. Em. ±	-	1.48	5.53	0.63
CD at 5%	-	4.41	16.44	1.882

Plant dry weight

Dry matter accumulation at harvest was significantly influenced by tillage practices and residue mulches. Conventional tillage consistently recorded higher plant dry weight compared to minimum tillage. Enhanced dry matter accumulation under conventional tillage can be attributed to improved soil aeration, better root growth and increased photosynthetic efficiency due to improved nutrient and water uptake. Residue mulch treatments significantly enhanced dry matter production compared to no-residue plots. Among the mulches, *Gliricidia* mulch resulted in the highest plant dry weight at harvest, followed by maize residue mulch and soybean residue mulch. The increased biomass under residue mulching is primarily due to improved soil moisture retention, reduced evaporative losses, moderated soil temperature, and enhanced nutrient mineralization during crop growth. Similar findings have been reported by Lal (2015) [7] and Singh *et al*. (2018) [12], who observed higher biomass accumulation in cereal crops under organic residue mulching. The interaction of conventional tillage and *Gliricidia* mulch recorded the highest dry matter accumulation at harvest, while minimum tillage without residue produced the lowest biomass. The superior performance of integrated tillage and mulch treatments highlights the synergistic effect of soil disturbance and organic residue addition in enhancing wheat growth and biomass production.

Conclusion

The study demonstrated that tillage practices and organic residue mulches significantly influenced weed suppression and wheat growth. Conventional tillage effectively reduced grassy, sedge, and broad-leaved weed populations compared to minimum tillage. Among residue mulches, *Gliricidia* mulch was most effective in lowering weed density and dry weight and achieved the highest weed control efficiency. Integrated use of conventional tillage with *Gliricidia* and maize residue markedly improved plant height, tiller density, and dry matter accumulation. Enhanced crop growth under residue mulching was attributed to improved soil moisture conservation and nutrient availability. Overall, conventional tillage combined with organic residue mulching offers a sustainable strategy for effective weed management and improved wheat productivity under irrigated conditions.

Conflict of Interest
The authors declare that they have no conflicts of interest.

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