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Research Paper

Response of tillage method and residue management on productivity and soil biological properties of wheat

GUGULOTHU SUMITRA[1], RAJKUMARA S[2] AND KUMAR D. LAMANI[3]

College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka 580 005

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ABSTRACT

The field study was undertaken at the Main Agriculture Research station, University of Agricultural Sciences, Dharwad during the *rabi* season of 2020–21 and 2021–22 to find out the effects of tillage and residue mulch on yield and economic parameter of wheat and its soil enzymatic properties. Conventional tillage recorded higher number of productive tillers/m^2 (418.8), number of grains/spike (35.9), grain weight/spike (1.74 g) and thousand grain weight (34.88 g). The statistically highest grain (3.30 t/ha) and straw yield (5.44 t/ha) of wheat was obtained under conventional tillage compared to minimum tillage. The gross returns were highest with conventional tillage and B:C ratio was higher with minimum tillage. *Glyricidia* mulch recorded higher yield attributes, grain (3.50 t/ha), straw (5.64 t/ha) yield and harvest index (36.88%) compared to maize, soybean, groundnut and no residue. No residue recorded lower yield parameter. Soil enzymatic activity was higher with *glyricidia* mulch compared to no residue, maize, groundnut and soybean mulch. Minimum tillage with *glyricidia* residue mulch improved soil biological enzymes of dehydrogenase (45.4 and 27.4 µg), phosphatase (187.9 and 109.8 µg), urease (12.6 and 7.6 µg) activity. Weed free check registered markedly superior yield and economic parameter and lower enzyme activity.

Key words: Economics, Residue mulch, Soil enzymatic activity, Tillage, Yield

Globally, wheat is cultivated in an area of 221.88 Mha with a production of 780.25 Mt and having the productivity of 3.52 t/ha (Kamboj., 2023). In India, the area 31.13 Mha with production of 109.59 Mt and productivity of 3,521 kg/ha (Kamboj., 2023). Wheat (*Triticum aestivum* L.) is the second most important cereal crop of India and plays a vital role in food and nutritional security of the country (Sow *et al*., 2023). It is widely cultivated, produced and used throughout the world. The diverse environmental conditions and food habits of people in India supports the cultivation of bread, durum and dicoccum wheat. Among these, bread wheat is contributing major share of 95% to total production while another 4% comes from durum wheat and close to 1% from dicoccum. Wheat is an important source of carbohydrates. Globally, it is the leading source of vegetable protein in human food, having a protein content of about 13%, which is relatively high compared to other cereals but relatively low in protein quality for supplying essential amino acids. It contains a spongy protein gluten which is essential for baking.

To make the field loose, friable and well-pulverized for wheat sowing, often execute frequent tillage. Conventional tillage (CT) methods are in use for wheat cultivation for several decades. The CT is beneficial in improving soil fertility. However, it deteriorates soil structure and leads to soil compaction and erosion. Mostly use CT to incorporate previous crops residues into the soil. However, it involves several cultivations inverting the entire soil surface, which is not feasible and economical for winter crops. The CT is helpful in weed management during early growth stages of crop plants. However, severe weed infestation is observed at later growth stages. Furthermore, recurrent use of CT at the similar depth for seedbed preparation may create plough pan, which reduces crop yield and results in nutrients' depletion. Conservation agriculture (CA) practices include minimum tillage (MT) and zero tillage (ZT), which reduce production costs due to

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[1]**Corresponding author's Email**: gugulothusumitra@gmail.com
[1]Ph.D. Scholar, [2]Professor, Department of Agronomy, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka 580 005; [3]Principal Scientist (Agronomy), AICRP on Wheat and Barley, MARS, University of Agricultural Sciences, Dharwad, Karnataka 580 005

lesser tillage and ensure water and soil conservation. The MT is a viable option for wheat cultivation as it reduces cultivation costs and avoids a 2–3week delay in crop planting. Reduced or zero tillage is better than CT due to less greenhouse gases emissions and better crop yields. However, higher weed infestation is observed in MT compared to CT. If MT is practiced without proper soil cover, it can increase infestation of weeds, diseases, and pests, degrade soil structure and lower crop yields (Govaerts *et al.,* 2017). Weeds are a major barrier in the adoption of CA globally. Since tillage is not employed for weed management, cultural practices and integrated weed management are the primary tools for suppressing weed infestation in CA. Mulching is a soil covering technique, which expands soil surface area by adding organic carbon to the soil. The mulches act as a protective layer on the soil surface, conserve soil moisture and suppress weeds growth. Mulching helps in maintaining soil moisture and temperature for longer period and suppress weed infestation. Mulching increases soil temperature and covers the soil, which reduces weed growth. It also reduces weed-crop competition and helps plants in early fruiting and seed setting. Moreover, mulching reduces the use of herbicides, improves fertilizer use efficiency, reduces soil erosion, and improves grain yield and quality (Minhas *et al*., 2023). Mulching combined with deep and shallow cultivation has a higher influence on increasing grain yield. Therefore, an experiment was conducted to evaluate the performance of tillage and residue mulch practices on yield and economics of wheat and soil microbiological properties. was conducted to evaluate the effectiveness.

MATERIALS AND METHODS

The field research was carried out at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during winter *(rabi*) season of 2020–21 and 2021–22. The experimental field soil had a loamy texture and bulk density of 1.35 g/cc, low in organic carbon (0.47%), low in available N (158.41 kg/ha), high in available P (32.15 kg/ha) and available K (291.52 kg/ha) with normal range of *p*H (7.4) and electrical conductivity (0.25 ds/m) of the soil. The research was organized according to a split-plot design with 3 replications, comprising of two main plot treatments i.e. T_1, conventional tillage; and T_2, Minimum tillage. Five subplot treatments were different residue mulch application, i.e; M_1, No residue; M_2, soybean residue; M_3, maize residue; M_4, groundnut residue and M_5, *Glyricidia* mulch and control (weed free check) were imposed. The wheat was sown at 20 cm row spacing with a seed rate of 125 kg/ha. The recommended dose of N-P-K fertilizer for wheat crop was 120-60–40 kg N- P- K/ha using urea, diammonium phosphate and muriate of potash as source of fertilizers. The full dosage of P and K, along with half of the N, was administered as a basal application, and the remaining nitrogen was applied at 30 DAS. Grain and straw yields of wheat were noted from net plot area and converted into t/ha under different treatments.

The method of estimation of crude protein encompasses digestion, distillation and titration. Digestion: Transfer exactly weighed suitable quantity (as described under sampling) of sample into Kjeldahl flask. Add 20–50 ml commercial sulphuric acid depending upon the type of sample. Add 5–10 g of digestion mixture. Boil the contents for 2–3 hours on a digestion bench placed in digestion chamber till the solution is clear without leaving any undigested black particles. Adhering material inside walls of the flask needs one or two washings in between after cooling. To avoid bumping, a few glass beads may be placed inside the Kjeldahl flask. Transfer the digested material present after cooling by dissolving with nitrogen free tap water into volumetric flask followed by 5–6 repeated washings. Make up the final volume after cooling. Similarly run a blank without sample. Distillation: Place a conical flask containing 10 ml of Tashiro's indicator at the end of condenser of micro-Kjeldahl distillation apparatus. Care should be taken to see the tip of the condenser is completely dipped inside the indicator to avoid escape of released ammonia during distillation. Pipette out 5-10 ml of aliquot of digested sample from the volumetric flask into the distillation unit. Add 10–20 ml of 40% NaOH sufficient to make the content alkaline (i.e. till the contents turn blue or black). Wash with a small quantity of distilled water and close the receiving end immediately with a pinch cock. Seal the funnel with a little amount of distilled water to avoid escape of ammonia. Steam distils the contents of the distillation unit by boiling the water in a round bottom flask (avoid bumping by the addition of glass beads) connected to the distillation unit. Collect around 30–50 ml of distillate (or at least 2 times the quantity of indicator taken) to ensure all nitrogen in the form of ammonia is distilled. Red colour turns to green. Remove the conical flask with distillate after washing the tip of the condenser with a few ml of distilled water. Wash the distillation unit 2 or 3 times with distilled water with the help of back suction developed by vacuum due to displacement of boiling flask from the heater, to make the apparatus ready for distillation of next sample. Titration: Titrate the distillate in the conical flask against standard N/7 H_2SO_4 solution taken in a burette till the red colour just reappears. Note the volume of N/7 H_2SO_4 consumed.

The economics was calculated as per input cost and economic value of different crop produce in respective year of research as per the market. The market price was taken as 2,212 and 2,670/q for wheat during 2020–21 and 2021-22 in respect of economic produce. The cost of cultivation and gross returns (₹/ha) for all the treatments were calculated based on the current market price of inputs and produce. The net returns (₹/ha) were calculated by subtracting the cost of cultivation from the gross returns. The B:C ratio was calculated treatment-wise to evaluate the economic impact of the treatments by dividing the gross returns with the cost of cultivation.

Samples of soil were gathered from root zone of wheat at 0–15 cm soil depth from experimental field at flowering and harvest stage to assess the dehydrogenase, phosphatase and urease activity. The dehydrogenase activity was estimated using 2, 3, 5 triphenyl tetrazolium chloride using 1 g of field moist soil (<2mm) and expressed as µg of triphenyl formazan (TPF) formed per gram of oven dry soil per 24 hours (Casida *et al*., 1964). The phosphatase activity in the soil was determined according to the method of Evazi and Tabatabai (1979) with the determination of p-nitrophenol released by 1 g of soil to which 0.2 mL of toluene, 4 mL of MUB (*p*H 6.5 for acid phosphatase and *p*H 11 for alkaline phosphatase), and 1 mL of 0.025 M sodium p-nitrophenyl phosphate were added and the resulting mixture incubated at 37^0C for 1 h. Successively, the p-nitrophenol released by the mixture was determined colorimetrically after extraction with 1 mL of 0.5 M $CaCl_2$ and 4 mL of 0.5 M NaOH and filtration through Whatman No. 2 filter paper. Controls were performed, as described for the assay procedure, with sodium p-nitrophenyl phosphate added immediately before filtration. The common laboratory procedure used for urease activity determination is the method developed by Tabatabai and Bremner (1972). The method is designed for estimation of the rate of urea hydrolysis in soil. It involves colorimetric determination of the urea remaining after incubation at 37°C for 5h of soils with urea solution. The amount of urea hydrolysed per g of soil 5 per h is estimated from the difference between the initial amount of urea added and that recovered after incubation. The data were subjected to pooled analysis over 2 years as prescribed and following standard analysis of variance technique (ANOVA) of split plot design.

RESULTS AND DISCUSSION

Yield attributes of wheat

Yield attributes of wheat, *viz*. as number of productive tillers/m^2, number of grains/spike, grain weight/spike and thousand grain weight (Table 1). Increase in number of productive tillers/m^2 (13.04%) was noted in conventional tillage over minimum tillage. Similarly, other yield components like number of grains/spike (12.89%), grain weight/spike (9.43%) and thousand grain weight (13.14%) were higher with conventional tillage than minimum tillage.

Application of glyricidia residue as mulch noted significantly greater number of productive tillers/m^2 (433.3), number of grains/spike (37.9), grain weight/spike (1.89 g) and thousand grain weight (36.67 g). Rajkhowa and Borah (2008) noticed maximum effective tillers/m and grains/spike of wheat under rice straw retention over no residue. However, the conventional tillage along with glyricidia residue recorded notably higher yield components compared with rest of treatment combination. Whereas, minimum tillage with no residue treatment had lower yield attributes than remaining treatment because of higher weed population and crop weed competition which resulted reduction in yield attributing characters.

Grain and straw yield

Conventional tillage resulted in notably higher grain and straw yields of wheat compared to minimum tillage. The increase was to a level of 11.29 and 11.56% in grain and straw yield, respectively over minimum tillage (Table 1 and Fig. 1a).

Similarly, mulching of *glyricidia* residue registered significantly greater grain and straw yield of wheat as compared to different crop residue mulching practice. The increase with *glyricidia* residue was to an extent of 34.12 and 22.57% respectively over no residue practice (Table 1 and Fig. 1b). Egbe *et al*., (2012) noticed that utilization of *Gliricidia sepium* leaf litter improved the growth and yield of maize. On the other hand, grain and straw yield in maize residue was increased by 29.34 and 17.59%, soybean 24.13 and 13.19% and groundnut 12.52 and 7.65% compared with no residue, respectively. The mulching favours the decrease in evaporation and led to enhanced soil moisture level due to soil cover, increased infiltration and water holding capacity, reduction in weed growth and the decomposition of added mulches might have contributed to increased supply of nutrients and moisture for overall increase in crop yields.

Combination of conventional tillage with *glyricidia* residue produced a substantially greater grain (3.70 t/ha) and straw yield (6.04 t/ha). Conventional tillage with maize and soybean residue and minimum tillage with *glyricidia* and maize residue obtained higher yield compared to minimum tillage with no residue. This was due to the enhancement of growth and yield attributes owing to combination of tillage and crop residue application. This is confirmed by lower weed indices and higher weed control efficiencies. However, repeated hand weeding in weed free check during the entire crop growth season had higher yield parameters as a result of higher weed control.

Table 1. The impact of tillage and crop residue application on yield attributes of wheat (pooled data of 2 years)

Treatment	Productive tillers/m²	No. of grains/ spike	Grain weight/ spike (g)	Thousand grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
Tillage						
T_1, Conventional tillage	418.8	35.9	1.74	34.88	3.30	5.44
T_2, Minimum tillage	370.5	31.8	1.59	30.83	2.97	4.88
SEm±	1.85	0.25	0.02	0.19	0.03	0.07
CD (P=0.05)	12.13	1.67	0.13	1.26	0.22	0.45
Residue mulch						
M_1, No residue	342.1	28.2	1.36	27.32	2.61	4.59
M_2, Soybean	400.8	34.8	1.70	33.67	3.24	5.21
M_3, Maize	417.9	36.2	1.81	35.13	3.38	5.41
M_4, Groundnut	379.2	32.2	1.57	31.49	2.94	4.95
M_5, *Glyricidia*	433.3	37.9	1.89	36.67	3.50	5.64
SEm±	1.13	0.23	0.01	0.22	0.03	0.04
CD (P=0.05)	3.41	0.69	0.05	0.65	0.08	0.11
Interaction						
T_1M_1	375.8	30.7	1.43	29.49	2.71	4.84
T_1M_2	420.0	36.7	1.76	35.79	3.46	5.45
T_1M_3	436.7	38.0	1.89	37.00	3.55	5.72
T_1M_4	408.3	34.5	1.68	33.52	3.09	5.16
T_1M_5	453.3	39.8	1.96	38.61	3.70	6.04
T_2M_1	308.3	25.8	1.29	25.15	2.51	4.36
T_2M_2	381.7	33.0	1.65	31.55	3.02	4.96
T_2M_3	399.2	34.5	1.73	33.26	3.21	5.09
T_2M_4	350.0	29.8	1.46	29.47	2.79	4.74
T_2M_5	413.3	36.0	1.83	34.72	3.30	5.23
SEm±	2.34	0.39	0.03	0.33	0.05	0.08
Control (WFC)	471.7	41.3	2.10	40.65	4.22	6.31
SEm±	1.97	0.37	0.07	0.32	0.04	0.07
CD (P=0.05)	5.86	1.09	0.21	0.96	0.14	0.21

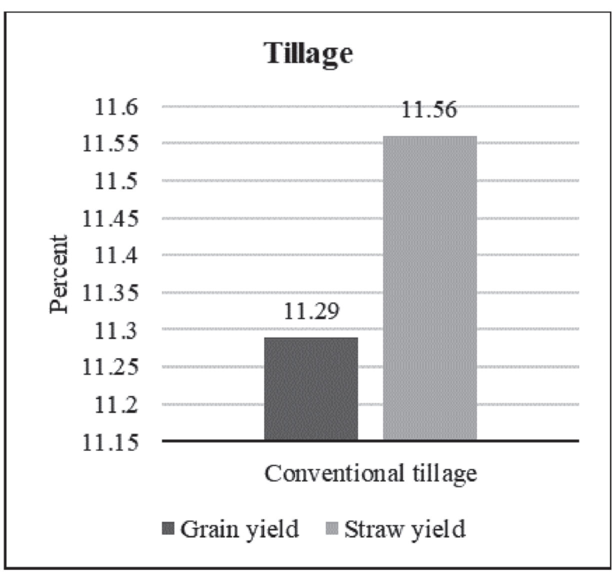

Fig. 1a. Per cent increase in grain and yield straw yield in conventional tillage over minimum tillage

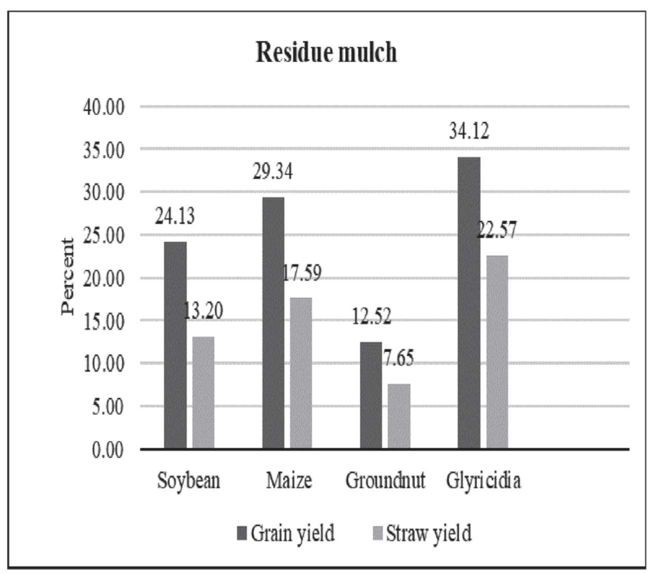

Fig. 1b. Per cent increase in grain and straw in residue mulch over no mulch

Harvest index

The maximum harvest index (35.66%) was noted in conventional tillage compared to minimum tillage (34.12%) (Table 2). Among the residue mulch application, *glyricidia* mulch recorded higher harvest index (36.88%) compared with other crop residues and was at par with maize residue (36.39%). The harvest index was significantly improved with the application of soybean (35.73%) and groundnut (33.79%) residue over no residue by 31.66%, respectively. Matthew *et al*., (2017) also concluded that *Glyricidia sepium* and other mulch noted substantially elevated harvest index over no residue mulch. Among the interactions, conventional tillage with *glyricidia* residue recorded superior harvest index (37.57%) compared with the remaining treatments and was at par with conventional tillage with maize (37.02%) and soybean (36.97%) residue. Lower harvest index (31.22 and 32.10%) was registered in minimum tillage with no residue and conventional tillage with no residue treatment.

Protein content and yield

The wheat protein content is considered as highly significant and genetically governed character. Tillage treatments did not influence wheat protein content but brought significant improvement on protein yield, due to enhancement in the grain yield. Kumar (2018) observed nonsignificant effect on protein in grain. Protein yield (430.4 kg/ha) was statistically higher under conventional tillage practices in comparison to minimum tillage (383.2 kg/ha). The increase was to the tune of 12.31%.

Significant variations in protein content occurred among the residue mulch application (Table 2). Significantly greater protein content (13.08%) of wheat was seen in glyricidia residue mulch and was on par with maize residue (13.01%) compared with no residue (12.74%), groundnut (12.86%) and soybean (12.94%) residue. Protein yield also was higher under *glyricidia* residue (459.4 kg/ha) compared with other crop residue application. Lower protein content (12.74%) and protein yield (334.1 kg/ha) were recorded under no residue treatment. According to Rafiq *et al*., (2010) mulching helps in conserving moisture content as well as improve soil fertility which could in turn increase protein content of the grains. Same results noticed by Matthew *et al.,* (2017) in maize crop. Among the interaction, conventional tillage with *glyricidia* residue treatments significantly higher protein content (13.15%) and protein yield (487.9 kg/ha). Lower protein content (12.64%) and protein yield (318.3 kg/ha) were recorded under minimum tillage with no residue treatment. This could be because of increased uptake of resources which led to increased protein content and protein yield. Whereas, protein content (13.20%) was higher in the weed free check compared to all interactions and was on par with conventional tillage with glyricidia residue. Whereas, protein yield (557.4 kg/ha) was recorded superior in weed free check than all interactions.

Economics

Among the tillage practices, conventional tillage resulted in higher gross returns (86647 /ha) due to increased grain and straw yield. However, net returns did not differ significantly with tillage practices, but increased B:C ratio with minimum tillage to an extent of 10.14% over conventional tillage (Table 2 and Fig. 2a). The increased net return (45,417 /ha) and B:C ratio (2.39) of wheat with minimum tillage were mainly due to lower expenditure on land preparation. Singh *et al.,* (2008) and Sallawar *et al*., (2023) reported that conventional tillage for all soybean-chickpea cropping sequence was found to be a better option for increasing the gross and net returns compared to the minimum tillage. Sarker *et al*., (2011) opined that zero till field recoded higher B: C ratio of 0.92 as compared to conventional tillage (0.43). This was simply due to higher net return and lower cost of cultivation.

Glyricidia residue mulch produced higher gross returns, net returns and B:C ratio (Fig. 2b) to the extent of 33.26, 58.23 and 24.27%, respectively compared to no residue treatment which could be the result of higher yields. Whereas, maize, soybean and groundnut residue recorded higher gross (28.47, 23.30 and 12.14 %) and net returns (47.01, 35.20 and 13.38%) and B:C ratio (17.47, 10.67 and 0.97%) compared to no residue treatment. All the residues improved the economics solely due to increased wheat yields. Archana, (2020) noticed that glircidia mulch in chickpea crop fetched highest gross returns (₹66,584 /ha) and net returns (₹37,975 /ha) with highest B:C ratio 2.32 and it was followed by paddy straw mulch with gross returns (₹61,053 /ha), net returns (₹33,644 /ha) and B:C ratio (2.22). Sesamum mulch recorded lower gross returns (₹56,594 /ha), net returns (₹28,985 /ha) and B:C ratio (2.05), which was on par with paddy straw mulch for gross returns. Control (without residue) could not result in higher gross returns (₹51,613 /ha) net returns (₹26,029 /ha) and B:C ratio (2.01). Rathod *et al.* (2021) also reported that highest gross returns (₹44,350 /ha), net returns (₹21,927 /ha) and benefit cost ratio (1.99) were recorded with crop residue @ 5t/ha + consortia @ 5kg/ha. Lower gross returns (₹31,020 /ha), net returns (₹10,746 /ha) and benefit cost ratio (1.53) was observed with without crop residue.

Conventional tillage with glyricidia residue recorded higher gross returns (₹97,118 /ha), net returns (₹57,321 /ha) which could result from a higher yield and monetary returns. B:C ratio (2.68) was highest under minimum till-

Table 2. Effect of tillage and crop residue on grain protein content, protein yield and economic parameter of wheat (pooled data of 2 years)

Treatment	Harvest index (%)	Grain protein content (%)	Protein yield (kg/ha)	Gross returns (/ha)	Net returns (₹/ha)	Benefit: cost ratio
Tillage						
T_1, Conventional tillage	35.66	12.99	430.4	86,647	46,700	2.17
T_2, Minimum tillage	34.12	12.86	383.2	77,864	45,417	2.39
SEm±	0.43	0.03	3.61	788.48	787.23	0.04
CD (P=0.05)	NS	NS	23.63	5,165.48	NS	0.25
Residue mulch						
M_1, No residue	31.66	12.74	334.1	68,869	35,222	2.06
M_2, Soybean	35.73	12.94	420.9	84,918	47,621	2.28
M_3, Maize	36.39	13.01	440.7	88,479	51,782	2.42
M_4, Groundnut	33.79	12.86	378.9	77,233	39,936	2.08
M_5, *Glyricidia*	36.88	13.08	459.4	91,780	55,733	2.56
SEm±	0.18	0.02	3.81	632.50	632.57	0.017
CD (P=0.05)	0.56	0.05	11.53	1,912.58	1,912.77	0.05
Interaction						
T_1M_1	32.10	12.85	349.8	71,605	34,208	1.91
T_1M_2	36.97	12.99	450.7	90,488	49,442	2.20
T_1M_3	37.02	13.06	463.9	92,904	52,457	2.29
T_1M_4	34.63	12.93	399.8	81,121	40,074	1.98
T_1M_5	37.57	13.15	487.9	97,118	57,321	2.44
T_2M_1	31.22	12.64	318.3	66,132	36,235	2.21
T_2M_2	34.48	12.89	391.1	79,348	45,801	2.37
T_2M_3	35.76	12.97	417.6	84,054	51,107	2.55
T_2M_4	32.96	12.80	358.0	73,346	39,799	2.18
T_2M_5	36.19	13.02	430.9	86,441	54,144	2.68
SEm±	0.49	0.04	6.02	1,123.30	1,122.48	0.04
Control (WFC)	40.82	13.20	557.4	10,9963	68,816	2.67
SEm±	0.47	0.04	6.25	1,120.89	1,120.54	0.04
CD (P=0.05)	1.40	0.10	18.57	3,329.92	3,328.87	0.12

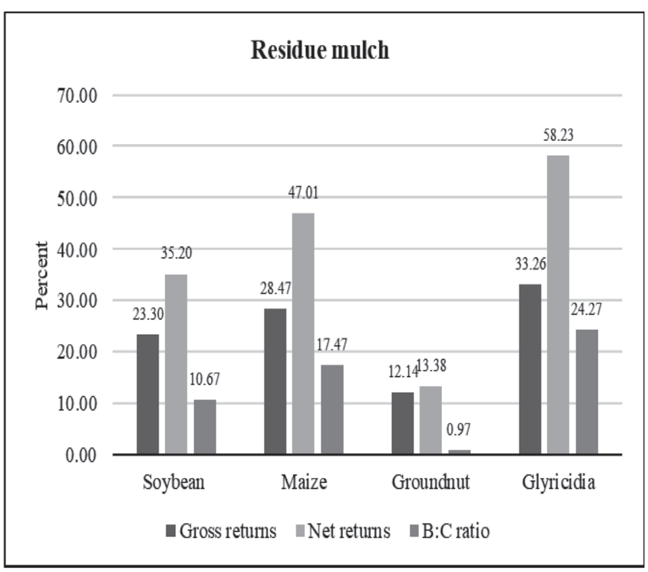

Fig. 2a. Per cent increase in economics in Conventional tillage over minimum tillage

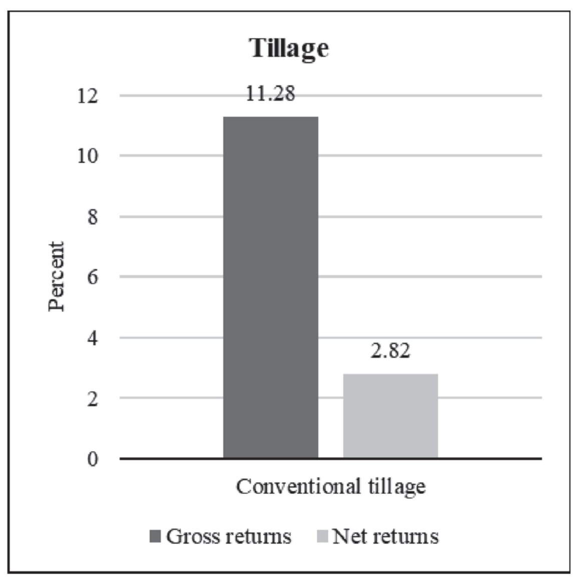

Fig. 2b. Per cent increase in economics inresidue mulch over no mulch

age with glyricidia residue treatment. Weed free check recorded highest gross returns (₹109,963 /ha) and net returns (₹68,816 /ha). It was a result of higher yield obtained because of less weed density throughout the growth stages and lower nutrient uptake by weeds which in turn improved the available nutrients to crop. Weed free check recorded higher B:C ratio (2.67) and was on par with minimum tillage with glyricidia, this might be due to higher labour requirement to maintain weed free condition. which could result from a higher yield.

Soil micro biological properties

The activity of enzymes in the rhizosphere soil correlated directly with the microbial population. At flowering, the activity soil enzyme was found to be higher and at harvest it was decreased probably due to the decreased moisture status of the soil and decline in root activity at late maturity stage of wheat. Metabolism and survival of the soil microorganisms are influenced by the soil moisture availability (Amritha and Devi 2017). Saikia *et al*., (2019) who recorded highest enzyme activity at flowering stage of wheat, which then decreased at later growth stage.

Minimum tillage showed notably greater dehydrogenase (40.6 and 24.0 µg), phosphatase (183.0 and 100.2 µg) and urease (10.8 and 6.1 µg) activity at flowering stage and at harvest stage (Table 3) of wheat crop as compared to conventional tillage. This was due to less soil disturbance, mulching, root exudates from plants, availability of soil moisture and nutrients encouraged higher dehydrogenase, phosphatase and urease activity by the organism (Alhammad *et al*., 2023). Similarly, residue mulch application as a mulching practice observed higher enzyme activ-

Table 3. Effect of tillage and crop residue on soil dehydrogenase, phosphatase and urease activity (pooled data of 2 years)

Treatment	Dehydrogenase (µg TPF formed/g soil/day)		Phosphatase (µg p NP/g of soil/hr)		Urease (µg NH_4-N/g soil/day)	
	At flowering	At harvest	At flowering	At harvest	At flowering	At harvest
Tillage						
T_1, Conventional tillage	36.3	20.9	175.7	93.4	9.0	4.9
T_2, Minimum tillage	40.6	24.0	183.0	100.2	10.8	6.1
SEm±	0.05	0.19	0.99	0.38	0.06	0.09
CD (P=0.05)	0.32	1.27	6.52	2.51	0.41	0.58
Residue mulch						
M_1, No residue	32.1	16.9	169.3	86.5	8.6	4.3
M_2, Soybean	41.2	24.9	183.5	101.6	10.6	6.0
M_3, Maize	36.3	21.2	176.4	93.1	9.1	4.9
M_4, Groundnut	39.3	23.2	180.6	97.6	9.8	5.4
M_5, *Glyricidia*	43.4	26.2	186.9	105.1	11.3	6.8
SEm±	0.32	0.22	0.38	0.19	0.16	0.07
CD (P=0.05)	0.96	0.66	1.14	0.58	0.48	0.22
Interaction						
T_1M_1	29.9	15.2	165.1	83.9	8.1	3.7
T_1M_2	39.1	23.4	179.6	97.7	9.5	5.5
T_1M_3	33.9	19.5	172.5	90.3	8.5	4.4
T_1M_4	36.9	21.8	177.0	94.6	8.9	4.8
T_1M_5	41.4	24.9	184.1	100.3	9.9	6.0
T_2M_1	34.2	18.8	173.7	89.1	9.1	4.8
T_2M_2	43.3	26.4	187.3	105.5	11.8	6.6
T_2M_3	38.6	22.9	180.2	95.9	9.7	5.5
T_2M_4	41.7	24.6	184.3	100.6	10.7	5.9
T_2M_5	45.4	27.4	189.7	109.8	12.6	7.6
SEm±	0.40	0.34	1.10	0.45	0.21	0.13
Control (WFC)	26.6	14.9	162.7	81.3	7.3	3.5
SEm±	0.41	0.34	0.91	0.49	0.23	0.14
CD (P=0.05)	1.21	1.02	2.72	1.47	0.83	0.41

ity of dehydrogenase, phosphatase and urease at flowering and harvest stages of crop growth. Decomposition of added material which increased organic carbon content and improved aggregate stability due to higher microbial multiplication. Besides, root exudates and mulching material acts as sources of organic carbon to microorganisms which resulted in higher microbial population. Among residue mulch application, glyricidia residue recorded higher enzyme activity due to enhancement of soil organic carbon and rhizo decomposition. Maximum soil enzyme activities of phosphatase and dehydrogenase and urease were noted in minimum tillage with residue retention Because of enhancements in the physical, chemical, and biological characteristics of the soil (Kumar *et al*., 2016). Conversely, increased weed presence led to elevated underground biomass, which serves as a carbon source for the growth and activity of microorganisms (Sebiomo *et al.,* 2011). Weed free check noted reduced dehydrogenase (26.6 and 14.9 µg), phosphatase (162.7 and 81.3 µg) and urease (7.3 and 3.5 µg) activity compared to interactions.

Thus, it can be concluded that highest yield attributes, grain and straw yield, gross, net returns, B:C ratio were recorded under conventional tillage with glyricidia residue. Whereas, activities of soil enzymes like dehydrogenase, phosphatase and urease were higher with the minimum tillage with glyricidia residue.

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