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The Effect of Tillage and Coverage on the Economic Productivity of Barley and Mung Beans in a Gypsiferous Soil

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Abstract
In the Lower Al-Jazeera region of western Iraq, a field experiment was conducted at latitude 34° 26' 26" N and longitude 41° 17' 46" E, aiming to study the effects of tillage and coverage factors on the production of crops, water, and economic parameters in gypsum soil. Straw was added to the abandoned soil when planting barley in the winter, and then barley residual remained when planting mung beans in the summer. Non-inversion tillage was used in tillage treatments T. The results showed that using the minimum tillage application is relatively better than the non-tillage method in terms of productivity and economy. The covering factor C significantly affected barely and mung bean yield (3096, 2159 kg ha^{-1}, respectively). Also, C and T's treatments significantly affected the field water productivity WPF. Economically, C treatments in the mung crop obtained an average of 1571266 IQD. hectare-1 as a gross margin, with a 2-time significant difference over NC. Also found superior interference treatments, NT.C and T.C, in weighted mean difference (WMD), which confirms the importance of using tillage at its minimum, with covering using straw or earlier crop residual stays. Notably, the covering factor is more effective than the tillage factor. A cover is necessary in case of non-tillage use.
Highlight: *Using the minimum tillage application is relatively better than the non-tillage method in terms of productivity and economy. The minimum tillage with covering, noting that the covering factor is more effective than the tillage factor. A cover is necessary in case of non-tillage use.*
Keywords: *field water productivity, gross margin, No-tillage, weighted mean difference.*

INTRODUCTION

Tillage and coverage are important parts of the conservation agriculture system (CA), an agricultural production that uses resource conservation techniques to reach high production intensification and high yields while improving the natural resource base by adhering to three interrelated principles: minimum tillage, covering, and crop rotation. In spot of the high increase in the prices of the production requirements without any effect impact of pricing policy on the production (Al-dujaili, 2016)and then reduce average economic yield in irrigation region compared to the cost of irrigation by cubic meter of water per donum (Al-Rawi & Bahia, 2020), using this integrated management practices (CA system) can lead to soil health (Al-Furaiji & Shawqi Ali, 2024) and then optimize the use of purchased inputs and reduce costs by using models that increase both yields and nutritional quality, while reducing costs to farmers and the environment by minimizing soil disturbance and using surface mulch and crop rotation (Rajaram & Pretty, 2016). The water consumption rate for grain crops is high in gypsum soils in arid and semi-arid regions due to their low water retention capacity and the problems due to gypsum dissolution. No-tillage applications may increase water infiltration and reduce evaporation, create a buffer zone for plants against rainfall fluctuations and high temperatures, and increased storage will provide more water during droughts (Farooq & Siddique, 2015), thus reducing the total cost. This has a positive impact on the performance of gypsum soils by reducing their problems, noting that reducing or stopping tillage without keeping crop residues leads to reduced crop productivity and soil degradation, and has the lowest water use efficiency (WUE) (Li et al., 2015). In an experiment conducted by Khalil et al. (2020) in Aridisols-Calcids soil in Sakran region, Anbar Governorate, west of Iraq, the minimum tillage treatment was superior in mung bean grain yield, reaching 2.52 tons.ha^{-1}, an increase of 41% compared to conventional tillage. In a Moderate rainfall region, northwest of Iraq-Nineveh Governorate, Chalcids-Inceptisol (Muhaimeed et al., 2014), the conservation tillage surpassed conventional tillage for wheat grain yield by 785.7 and 1195.2 kg.ha^{-1} in Hamdaniya and Talkef locations, respectively, according to (Antar & Almashhadany, 2020).While in the Jleokhan region, the interaction between the planting method (Zero Tillage, 17cm row spacing with pressure wheel) with all sowing rates, achieved the highest significant value in wheat grain yield by increasing 1.65 times compared with Conventional Tillage by using disc plough before sowing (Alhamadany & Alrijabo, 2020). Also, in Dara's Governorate in Syria, Othman et al., (2020) found that average biological yield, grain yield, and rainwater use efficiency were significantly higher during the first growing season, under conservation agriculture in the presence of crop rotation using lentils crop, in the wheat variety Douma3 (7466 kg. ha^{-1}, 4162 kg. ha^{-1}, and 19.006 kg ha-1 mm^{-1}, respectively). In Baghdad, Iraq, Al-Rubaie and Al-Ubaidi, (2018) revealed that the maize zero tillage (T1) was superior to surface and normal tillage in weight of 300 grains in both the spring and fall. The study by Shaima S. Dawod et al., (2024) showed that mini-Tillage was superior in giving the best values for the mechanical and technical properties and the soil's physical and hydraulic properties compared to conventional systems. The effect of coverage factor in minimum tillage system on water productivity seen by Ati et al., (2025) was highest water productivity of okra was achieved at the coverage treatment and reached 0.82 and 0.92 kg. m-3 for Batra and Lahloba cultivars, respectively. Knight, (2004) found that no-tillage yields the highest productivity in all years in light chalkland soil. By meta-analysis, Rusinamhodzi (2015)found that compared to conventional tillage systems, the weighted mean difference (WMD) of conservation tillage (CT) with continuous maize ranged from -1.32 to 1.27 with an average of 0.03 t ha^{-1}, and when crop rotation was included, the WMD ranged from -0.34 to 1.92 with an average of 0.64 t ha^{-1}. Nyamangara et al., (2014) accept the hypothesis that conservation agriculture practices improve maize grain yield over the rotation period, where the WMD for the experiments on sandy soil was 0.365 t ha-1 as significant ($p < 0.05$). More recent reviews have tended to reinforce its conclusion that CT has a small cost advantage over conventional tillage but that site-specific conditions could alter this result in various ways, were most analysts suggest that CA reduces machinery costs, so using zero or minimum tillage means that farmers can use a smaller tractor and make fewer passes over the field (Chichongue et al., 2020). Economic water productivity (EIWP) has emerged as an important indicator to evaluate the net value of agricultural output in terms of profit per unit of water used (Jaafar et al., 2024), EIWP can help improve on-farm irrigation practices and inform water allocation policies in agricultural water management (Pittelkow et al., 2015). Fernández et al., (2020) proposed gross economic water productivity (GEWPI) as one of the indicators for evaluating the economic performance of irrigation water. This indicator considers total revenue, total irrigation depth or irrigation water use, and gross margin. Economic water productivity is affected by irrigation conditions and climate, and therefore the irrigation needed is related to evapotranspiration ET, which affects total costs and then returns. (Zhang & Oweis, 1999)reported a linear relationship between wheat yield and ET due to climatic effect in supplemental irrigation regions in Syria, while Araya et al., (2019) found that the rate of ET increase did not result in a proportional yield increase, because evaporation and nutrient losses may increase with irrigation. This research aims to study the effect of applying conservation tillage and coverage principles on crop productivity and economic irrigation water productivity in gypsum soil using two cover crops (barley and beans) in winter and summer crop rotation. The research aims to study the best tillage method for these soils from a productive and economic perspective, and the extent of the impact of covering. Does it exceed the impact of tillage in improving soil productivity and increasing economic returns? What is the proper tillage and coverage pattern for such soils?

MATERIALS AND METHODS

The field experiment was conducted during the 2021-2022 season in the lower Jazirah region in Anbar Governorate, western Iraq, at latitude 34° 26' 26" north and longitude 41° 17' 46" east in an arid gypsum-calcareous soil. The study area was divided into three sectors, in each sector four treatments were randomly distributed: tillage with covering T.C, tillage without covering T.NC, no-tillage with covering NT.C, and no-tillage without covering (NT.NC). Two tillage treatments were chosen, namely Non-Tillage and Non-Inversion Tillage (NIT), based on the use of toothed and disc tools that do not turn the soil (Christian, 1994) using a digger plough. Using fixed sprinkler irrigation technology, two successive cover crops (barley and mung bean) were grown, the first in winter and the second in summer. Wheat straw was added as a coverage treatment when growing barley seeds, and barley crop residues were left in the summer when growing mung bean seeds. The crop seeds were planted using a seeder machine in the tillage treatments and a hand seeder in the non-tillage treatments. Once the crops reached the harvest stage, three samples were taken from each experimental unit. Each sample covered an area of 1 m^2 and was collected in bags for weighing. The harvested biomass for each experimental unit was recorded and calculated in (kg ha^{-1}). The grains were separated from the ears in the harvested mass, weighed in grams to find the grain yield per square meter, and converted to (kg ha^{-1}). Several parameters were evaluated to assess crop productivity and economic water productivity.

1- Gross Economic Irrigation Water Productivity (GEWPI):

Economic irrigation water productivity (GEWPI) in Iraqi dinars ($IQD.m^3$) refers to the ratio between the gross margin (GM) in Iraqi dinars (IQD) related to the crop during the growing season and the seasonal irrigation water applied (IWU) in ($m^3.ha^{-1}$) according to (Fernández et al., 2020).

$$GEWPI = \frac{GM}{IWU} \quad (1)$$

Gross margin (GM) is calculated as the difference between revenue (grain and straw) and variable costs, including tillage, fertilization, seed, sowing, harvesting, and fuel costs (Fernández et al., 2020).

$$GM = revenue - variable\ costs \quad (2)$$

2- Farm Water Productivity (WPf)

The ratio between marketable yield and total water use (TWU) was calculated by adding effective rainfall (Pe, mm), capillary rise (CR, mm), and irrigation water use (IWU) as mentioned in (Rodrigues & Pereira, 2009):

$$WP_f = \frac{Y_G}{TWU} \quad (3)$$

Where: WPf Water productivity on the farm ($kg.\ m^{-3}$), YG Grain productivity ($kg.\ ha^{-1}$), TWU Total amount of water used in the field ($m^3.\ ha^{-1}$), including IWU with precipitation (P).

3- Weighted Mean Difference (WMD):

By using meta-analysis, Weighted Mean Difference (WMD) can be used to measure a treatment's effect size (Khan, 2020)when evaluating grain productivity in experimental treatments by obtaining the effect range of the (WMD), as the results of grain productivity were compared between the interaction treatments representing conservation agriculture T.C, NT.C, and NT.NC and the comparison treatment representing conventional agriculture T.NC. WMD was extracted considering the meta-analysis considering applying the following equations (Rusinamhodzi, 2015):

$$SD_{\bar{x}} = \frac{\sum_i^n (x_i - x^-)^2}{n-1} \quad (4)$$

SD $\bar{x}$: Variance of assigned replicate values where xi is for (ton), x-mean of (ton) and n-number of replicates =3

$$MD = \bar{X}_{W\ treatment} - \bar{X}_{W\ control} \quad (5)$$

MD: Mean Deference ($tones.\ ha^{-1}$)

$\bar{X}_{W\ treatment}$: Mean productivity of treatment ($tons.\ ha^{-1}$)

$\bar{X}_{W\ control}$: Mean productivity of control treatment ($tons.\ ha^{-1}$)

$$wieght\ (wi) = \frac{1}{SD_{\bar{x}}} \quad (6)$$

Wi: Importance is the inverse of variance (without units)

$$WMD_{treated} = \frac{wi\ xi}{\sum_{i=1}^{n} wi} \quad (7)$$

$WMD_{treated}$: Weighted mean difference of treatment ($tons.ha^{-1}$)

$$WMD_{overall} = \frac{\sum_{i=1}^{i=n} (wi\ xi)}{\sum_{i=1}^{n} wi} \quad (8)$$

$WMD_{overall}$: Weighted mean difference of total transactions excluding control ($tons.ha^{-1}$)

Results:

Tables 1 and 2 show the rainfall and water use for barley and mung bean crops from the water balance and climate data. The table notes that the winter season had low rainfall, so it barely depended on irrigation water. Table 1 shows an increase in grain yield in the tillage T, coverage C, and the interactive treatments T.C by 4.4, 46.7 and 58.7% compared to the NT, NC, and T.NC treatments, respectively, but the significant difference was in the C treatments by 577.9 kg, as the least significant difference. The C treatments also gave the highest gross margin GM (2221035 IQD) with a significant difference of 66.4% compared to the NC treatments, despite the significant decrease in the total costs of the NC treatments (Table 1). The GM results were close in the tillage treatments. T.C treatment had the highest GM among the interaction treatments (2481085 IQD) without significant differences. The C treatments had the highest value in Gross Economic Irrigation Water Productivity (GEWPI), where one cubic meter of irrigation water got 315 IQD, a significant difference of 2.2 times over the NC treatments. Meanwhile, the T treatments advanced by 16% over NT without significance. Then the interaction treatment T.C had the highest value of GEWPI, reaching 355 IQD. m-3, a difference of 2.9 times over the lowest T.NC. Table 1 shows the superiority of the C treatments in field water productivity WPf, where one cubic meter gave 0.46 kg of barley grains with a significant difference of 77% compared to the NC treatments. T treatments and the interaction treatments T.C and NT.C gave 0.36 kg m-3 GEWPI with a non-significant difference of 24 and 57% compared to NT and T.NC, respectively.

Table 1: Parameters of Barely crop treatments.

Parameters		**Treatments**							
Cost	Unit	T	NT	C	N.C	T.C	T.NC	NT.C	NT.NC
Tillage	IQD	173611		173611	173611	173611	173611		
Liquid Fertil	IQD	347222	347222	347222	347222	347222	347222	347222	347222
Solid Fertil	IQD	350000	350000	350000	350000	350000	350000	350000	350000
straw	IQD	147569	147569	295139	0	295139	0	295139	0
Seed cost	IQD	145625	145625	145625	145625	145625	145625	145625	145625
Seedling	IQD	312500	312500	312500	312500	312500	312500	312500	312500
Harvesting	IQD	295139	295139	295139	295139	295139	295139	295139	295139
Oil cost	IQD	102712	112582	102625	112668	96897	108526	108353	116810
Total cost	IQD	1874378	1710637	2021861	1736765	2016133	1732623	1853978	1567296
$LSD_{0.05}$			13314*		13314*				
Grain Product		2659	2548	3096	2110	3262	2055	2930	2165
$LSD_{0.05}$				577.9*					
Straw	kg. ha^{-1}	12825	11687	13336	11176	14363	11287	12308	11065
Grain income	IQD	2659000	2548000	3096000	2110000	3262000	2055000	2930000	2165000
straw income	IQD	1102950	1005082	1146896	961136	1235218	970682	1058488	951590
Total income	IQD	3761950	3553082	4242896	3071136	4497218	3025682	3988488	3116590
G.M	IQD	1887572	1842445	2221035	1334371	2481085	1293059	2134510	1549294
$LSD_{0.05}$				691061*					
Precipitation (P)	mm	26.2	26.2	26.2	26.2	26.2	26.2	26.2	26.2
IWU	m^3. ha^{-1}	5055	5480	5045	5490	4800	5310	5290	5670
TWU	m^3. ha^{-1}	5317	5742	5307	5752	5062	5572	5552	5932
GEWPI	IQD. m^{-3}	223	191	315	98	355	91	275	106
$LSD_{0.05}$				163.5*					
WP_f	Kg. m^{-3}	0.36	0.29	0.46	0.26	0.36	0.23	0.36	0.29
$LSD_{0.05}$				0.143*					

In the summer season, superiority of T and C treatments was repeated when growing mung beans (Table 2), as T and C treatments and the interaction treatment T.C gave the highest yield of mung beans (1954, 2159 and 2310 kg. ha-1) with a significant increase of 23.3, 56.6 and 72%, and obtained the highest Gross margin GM with an increase of 31.1%, 2.1 and 3.9 times compared to NT, NC and NT.NC respectively. T and C treatments obtained 196 and 262 m^3.IQD as GEWPI with a significant difference of 31.1% and 2.3 times compared to NT and NC, respectively. T.C and NT.C treatments obtained 286 and 237 m^3.IQD, respectively, as the highest GEWPI with a difference of 4.5 and 3.5 times compared with the lowest NT.NC. While the productivity of one cubic meter of irrigation water used in the field WPF was 0.32 and 0.36 kg of mung beans in T and C treatments, with a significant difference of 24.7

and 69.5% compared to NT and NC, respectively. Also, TC and NT.C were 1.18 times and 81.3% compared to NT.NC.

Table 2: Parameters of Mung bean crop treatments.

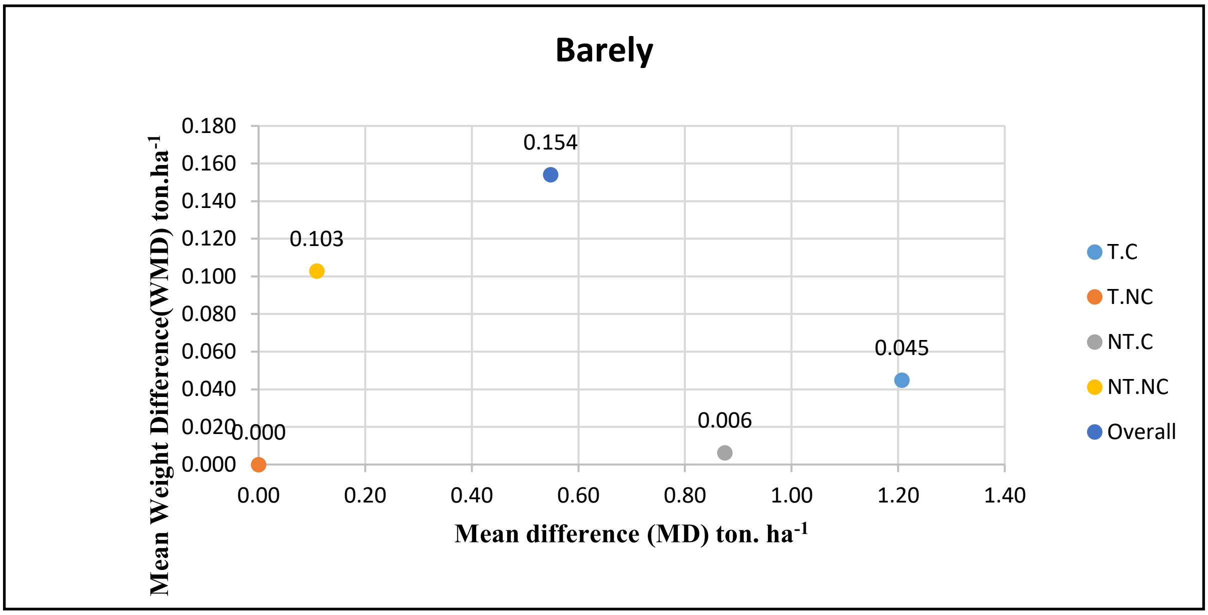
Mung bean		Treatments							
Cost	Unit	T	NT	C	N.C	T.C	T.NC	NT.C	NT.NC
Tillage	IQD	173611		173611	173611	173611	173611		
Liquid Fertil.	IQD	243056	243056	243056	243056	243056	243056	243056	243056
Solid Fertile.	IQD	173611	173611	173611	173611	173611	173611	173611	173611
Seeds	IQD	86806	86806	86806	86806	86806	86806	86806	86806
Seedling	IQD	173611	173611	173611	173611	173611	173611	173611	173611
Harvest	IQD	347222	347222	347222	347222	347222	347222	347222	347222
Oil	IQD	171052	172130	98091	245091	95943	246162	100239	244021
Total Cost	IQD	1368969	1196436	1209202	1356202	1293859	1444078	1124545	1268327
$LSD_{0.05}$			13314*	13314*					
Grain product	kg. ha^{-1}	1954	1584	2159	1379	2310	1597	2007	1338
$LSD_{0.05}$		8*		8*		11.3*			
Straw	kg. ha^{-1}	6552	6406	7230	5727	7690	5414	6771	6041
Grain income	IQD	1953617	1583700	2158667	1378650	2310433	1596800	2006900	1160500
straw income	IQD	598828	515537	621802	492564	661308	536348	582295	448780
Total income	IQD	2552445	2099237	2780468	1871214	2971742	2133148	2589195	1609280
Gross Margin	IQD	1183476	902801	1571266	515011	1677882	689069	1464650	340953
$LSD_{0.05}$		15127*		15127*		21393*			
Precipitation (P)	mm	0	0	0	0	0	0	0	0
IWU= TWU	m^3. ha^{-1}	6321	6388	6102	6607	5968	6673	6236	6540
GEWPI	IQD.m^{-3}	196	145	262	78	286	105	237	52
$LSD_{0.05}$		33.3*		33.3*					
WPf	kg. m^{-3}	0.32	0.25	0.36	0.21	0.39	0.24	0.33	0.18
$LSD_{0.05}$		0.044*		0.044*					

Comparing the results of barley productivity in the WMD, Figure 1 shows that the NT.NC treatment is the closest to the WMD of the total treatments overall. However, it is less productive among the treatments and the nearest to the productivity of the traditional comparison treatment, with an average difference of MD 0.11 t. ha-1 (Table 3), while T.C and NT.C treatments gave low values for WMD but with an average difference of MD 1.21 and 0.88 t. ha-1, respectively, compared to the traditional treatment. The results differed in the summer season, as the NT.C treatment was the nearest to the overall with a WMD of 0.138 t. ha-1, a difference of 34% from T.C (Table 3). While the NT.NC treatment gave a negative value for WMD, the productivity of mung beans was lower than that of the comparison treatment. T.C treatment outperformed WMD when barley-mung bean rotation was introduced and gave 0.08 t.ha-1 WMD with 31% difference from the overall with an average yield of 5.57 while NT.NC and NT.C were close to the control treatment.

Table 3: WMD calculation data for the treatments compared to the conventional T.NC treatment, which gives a value of 0.

Crop	Treatment	SD^2	wi	Mean production	Control Mean production	MD	WMD
				ton. ha^{-1}	ton. ha^{-1}	ton. ha^{-1}	ton.ha^{-1}

Barely	T.C	0.514	1.95	3.26	2.06	1.21	0.045
	T.NC	1.17	0.86	3.43	2.06	0	0.000
	NT.C	2.674	0.37	2.16	2.06	0.88	0.006
	NT.NT	0.02	49.13	2.06	2.06	0.11	0.103
	Overall	0.019	52.31	2.73	2.06	0.55	0.154
Mung Bean	T.C	0.0001	10000	2.31	1.42	0.89	0.045
	T.NC	0.00006	16393.44	1.42	1.42	0	0.000
	NT.C	0.00005	20408.16	2.01	1.42	0.59	0.138
	NT.NT	0.00003	40000	1.34	1.42	-0.08	-0.038
	Overall	0.00001	86801.61	1.77	1.42	0.35	0.203
Barely+ Mung	T.C	0.50	1.99	5.57	3.48	4.18	0.08
	T.NC	1.15	0.87	3.48	3.48	0.00	0.00
	NT.C	2.67	0.37	4.94	3.48	0.55	0.01
	NT.NT	0.02	48.98	3.5	3.48	1.35	0.03
	Overall	0.019	52.21	4.37	3.48	6.07	0.12



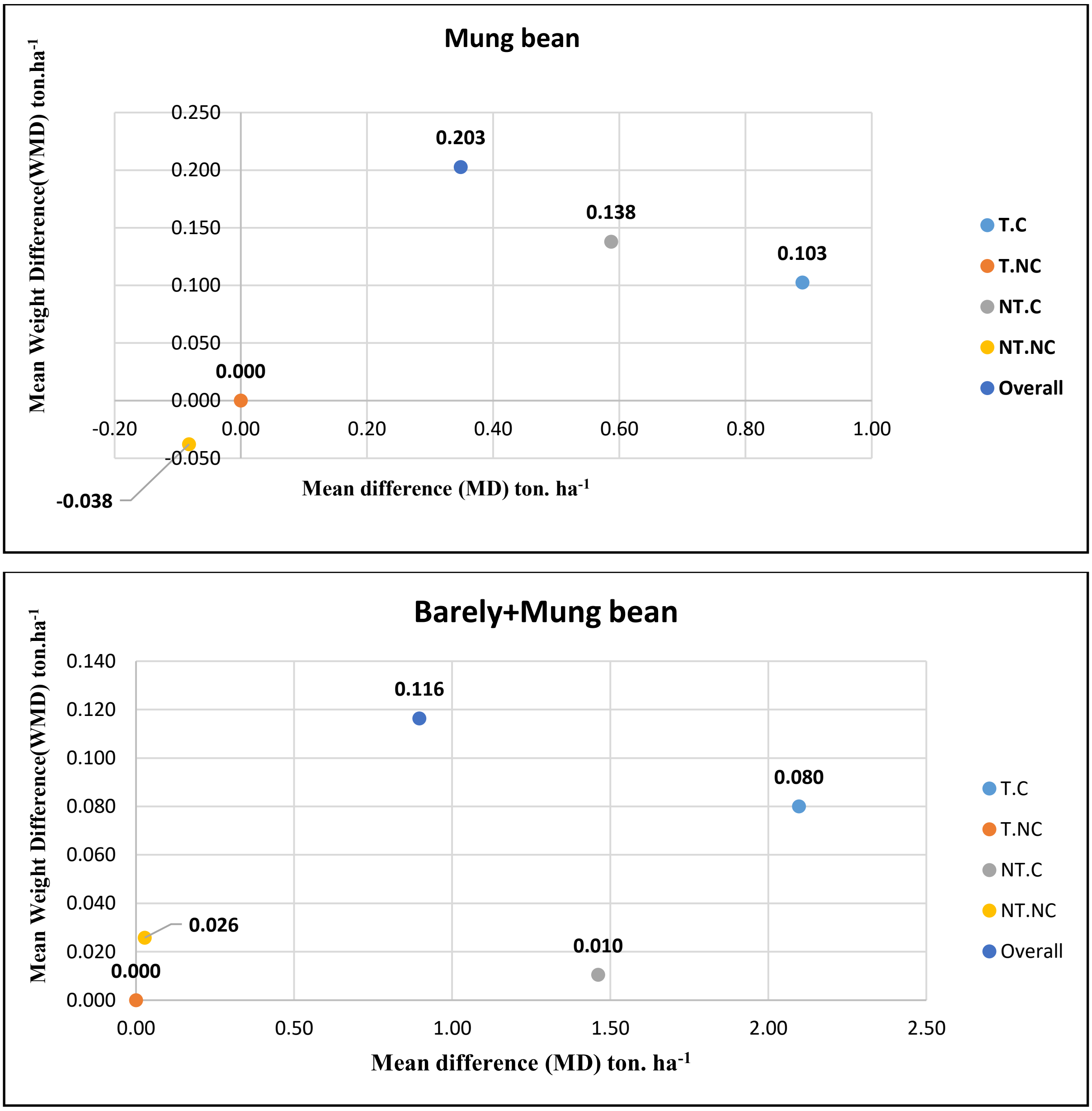


Figure 1: Effect of experimental treatments T.C, NT.C and NT.NC on grain production through the relationship between weighted mean difference (WMD) and mean difference (MD) t/ha for barley and mung bean, and total yield in barley and mung bean rotation compared with the control treatment T.NC.

DISCUSSION

The increase in productivity in tillage and coverage treatments and their interaction is due to the use of a minimum level of tillage using only primary, non-turning tillage that causes less soil disturbance, accompanied by the use of covering and previous crop residues, as tillage works at shallow depths not exceeding (15-20 cm) where crop residues are mixed into the surface soil, but a percentage is left on the soil surface (Carter et al., 2003). This helps increase roughness and keep moisture when needed (Womach, 1997). In addition, plant residues reduce the effect of falling raindrops, provide a barrier against high winds and temperature, reduce water evaporation, and improve water infiltration (Thierfelder & Wall, 2009). Therefore, the T.C treatment used less irrigation water compared to the other treatments (Table 1). Therefore, covering led to reducing the negatives of tillage, especially concerning evaporation from the soil surface and the formation of a surface crust because of raindrops. These results confirm the findings of Thakur & Kumar, (2021) and Zhou et al., 2009) that covering is effective in improving crop productivity and water use efficiency (WUE), especially because covering reduces water evaporation from the soil and increases crop transpiration (Jia et al., 2006). The increase in total costs of T treatments by 9-13% (table 1 and 2) did not affect the gross margin, as they were significantly higher than NT treatments, while C and T.C treatments had lower total costs and higher gross margins compared to N.C and the traditional treatment T.NC. This is due to the tillage costs in T treatments and the increase in fuel costs in NC and T,NC treatments due to the increase in used irrigation water (Tables 1 and 2). The results of productivity and gross margin were reflected in the results of GEWPI and WPf, with the coverage factor being more prominent in the winter season than the tillage factor, as evidenced by the fact that the no-coverage treatments NC gave the lowest values in productivity and economy, while the no-till treatments NT were higher in productivity and economy compared to NC, in addition to high difference between C and NC compared with T and NT. The weighted mean difference (WMD) results show that the ideal treatment of production did not appear in the winter season due to the high variance (SD^2) between replicates, which led to a decrease in weight (Table 3). This may be because the soil is not homogeneous in fertility since it has not been cultivated for the earlier times. The situation was different in the summer season, as the NT.C and T.C treatments appeared due to the low variance (SD^2) between replicates of treatments and thus increased weight. This is because the soil became more homogeneous after the winter season. When entering the total production of the barley-mung bean cropping cycle, only the T.C treatment appeared because the variance decreased when added the two productions. Therefore, we have two treatments that can be preferred, NT.C and T.C which are the coverage C treatments. This confirms what was previously mentioned about the importance of the coverage factor.

CONCLUSIONS AND RECOMMENDATIONS

Considering these results, we conclude that using the minimum tillage method is relatively better than the non-tillage method in terms of productivity and economy, even though the tillage costs may exceed 10% of the total costs. The covering factor has a greater effect than the tillage factor. In tillage with covering, there is higher productivity and superiority in economic standards, and there is a significant productivity improvement when the mulch is combined with un-tilled soils compared to uncovered soils (tilled and untilled). Therefore, using tillage with covering in the first seasons of conservation agriculture is necessary as Occasional Tillage (OT) mixes elements and organic materials and increases soil homogeneity. It is also necessary to use a covering in the case of no-tillage. When continuing to apply conservation agriculture principles in next years, the effect of tillage may decrease, and the trend towards zero tillage with covering becomes more beneficial from an economic point of view.

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