EFFECT OF CONSERVATION AGRICULTURE ON WATER CONSUMPTION OF BARLEY AND MUNGBEAN IN GYPSIFEROUS DESERT SOIL

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ABSTRACT

The field experiment was carried out during 2021-2022 in the Lower Al-Jazeera region at Anbar - Iraq. The study aimed to find the effect of conservation tillage and coverage practice on water use and consumption of crops in gypsum desert soil in two seasons using two cover crops (Barley and Mung bean). The experiment was carried out on abandoned land, so the covering (straw) was added when planting barley, and then the barley residual was kept when planting Mung bean. Non-inversion tillage was used by the digger plow. Randomly four treatments, tillage covering T.C, tillage no-covering T.NC, no-tillage covering NT.C, and no-tillage no-covering NT.NC was distributed on 12 experimental units by using RCBD design. Irrigation under sprinkler system. Results showed a significant effect of the T treatments on water consumption (ETa) in the winter season in the Mid-stage, with a difference of 16% from the NT, and for the C treatments in the Div-tage, with a difference of 37.6% from the NC. In the Inti-stage of the summer season, the T and C treatments used significantly less water by 18% and 13% compared to the NT and NC treatments, respectively. While in consumption ETa, showed a significant difference for T treatments by 6% less than NT in the Inti-stage and for C treatments in the Dev-stage by 13 % less than NC. The interference treatments T.C least and NT.NC higher used and consumed.

Keywords: No-tillage, evapotranspiration, cover crop, planting, residual, sustainability, wise resources consumption, climate change, Iraq, drought.

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تأثير الزراعة الحافظة في استعمال مياه الري والاستهلاك المائي للشعير والماش في التربة الصحراوية الجبسية

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المستخلص

نفذت التجربة الحقلية خلال عامي 2021–2022 في منطقة الجزيرة السفلى في الأنبار– العراق. يهدف البحث إلى دراسة تأثير ممارسات الحراثة الحافظة والتغطية في الاستعمال والاستهلاك المائي للمحاصيل في التربة الصحراوية الجبسية في موسمين باستخدام محصولي التغطية (الشعير والماش). أجريت التجربة في أرض مهجورة، فتم إضافة الغطاء (القش) عند زراعة الشعير، وتم الاحتفاظ ببقايا محصول الشعير عند زراعة الماش. تم استخدام الحراثة غير القلابة بواسطة المحراث الحفار. تم توزيع أربع معاملات، حراثة – تغطية T.C، حراثة – بدون تغطية T.NC، عدم حراثة – تغطية NT.C، وعدم حراثة – بدون تغطية NT.NC عشوائياً، على 12 وحدة تجريبية تحت نظام القطاعات العشوائية الكاملة RCBD. الري تحت نظام الرش. أظهرت النتائج وجود تأثير معنوي لمعاملات T في استهلاك المياه ETa في الموسم الشتوي في المرحلة المتوسطة بفارق 16% عن المعاملات NT ولمعاملات C في مرحلة التطور بفارق 60 % عن المعاملات NC. وفي المرحلة الابتدائية من الموسم الصيفي استخدمت معاملات T وC مياه أقل معنويا بنسبة 18٪ و13 % مقارنة بمعاملات NT وNC على التوالي. بينما وجد فرق معنوي في الاستهلاك Eta لمعاملات T بنسبة 6% أقل من NT في المرحلة الابتدائية، ولمعاملات C بنسبة 13 % أقل من NT في مرحلة التطور. وكانت معاملتي التداخل T.C الأقل و NT.NC الأعلى استخداما واستهلاكاً.

الكلمات المفتاحية: عدم الحراثة، التبخر– نتح، محصول التغطية، زراعة، بقايا، الاستخدام الواعي للموارد، تغير مناخي، عراق، جفاف.

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INTRODUCTION

Conservation Agriculture System (CA) is one of the most important systems that hase been applied in many countries of the world. It is a new method of agricultural production that is environmentally friendly and more productive than the prevailing style of agriculture based on tillage and intensive tillage of the soil (18). Conservation agriculture is a new paradigm for achieving sustainable agricultural production and is a major step in the transition to sustainable agriculture. It consists of four components: permanent soil cover, tillage soil abatement, diversified crop rotation, and integrated weed management, to achieve sustainable agriculture and protect the natural resources environment, the most important of which is water and nutrients (10). Conservation agriculture may reduce water use, but studies in irrigated systems are scarce (11). Generally, the main aim of agricultural management practices is to sustain soil production preserve it from degradation (10,21,3, and 17) in addition water sustain ability by reducing the quantities of added water by using different methods such as adding polymers (1, 16) organic amendments (1) straw or crop residue retention (24,23,22, and 13). Previous researches has confirmed the positive role of conservation agriculture practices in reducing irrigation water use and water consumption by various crops, and this could be attributed to reduced water loss via evaporation under conditions of increased organic matter, more water being available to the crop, resulting in increased transpiration and reducing water evaporation from the soil, surface runoff, and non-productive losses, which increases crop production for total dry matter, thereby increasing the productivity of a unit of water. Also, protecting the soil surface from the direct impact of high-energy raindrops prevents the movement of surface soil particles to close the pores, thus preserving the soil’s ability to percolate water and at the same time reducing water evaporation from the soil surface, according to (19, 8). The rate of water consumption of strategic crops is high in gypsum desert soils, which contain more than 3% gypsum in the surface layer and more than 14% in the subsurface layer (12). Alwan (6) showed that the surface layer of gypsum soils has a weak and hardened mass structure, and the hardening is due to the phenomenon of crusting, and the gypsum horizon is without building, and the hardness of the gypsum layers ranges between hard and very hard in the dry state. In addition, on irrigation excess water filtrating beneath the root zone will penetrate the gypsum-rich layer and will cause the gypsum to dissolve, causing subsidence of the ground level, furthermore lower water-holding capacity within the root zone makes it more difficult to apply irrigation water efficiently (5). Due to dry climatic conditions, for this reason, there is a need to use methods to reduce losses due to evaporation, and infiltration and enhance soil water conservation. In a 3-year experiment in the Mexican Baguio region, (11) showed that the average irrigation water used was 17% less in conservation agriculture than in conventional agriculture. Al-aridhee and Mahdi (2) found that the highest water consumption of maize was 709 mm season^{-1} for no cover crop by surface irrigation treatment, and the lowest water consumption was 362 mm season^{-1} for the cover crop by drip irrigation treatment, were contributed to saving irrigation water by reducing maize consumption of water. This research was aimed to study the effect of applying conservation agriculture principles on water consumption of two cover crops (Barley and Mung bean) in gypsum desert soil in a winter and summer crop cycle.

MATERIALS AND METHODS

A field experiment was carried out during the season 2021-2022 in the Lower Al-Jazeera region in the Rummana district of Anbar Governorate in western Iraq, at latitude 24 ′ 34 ″ 26 ′N and longitude 24 ̊ 41 17 ′E. A sprinkler irrigation system was designed according to (14, ana 25) The study area was divided into three blocks. In each block four treatments were randomly distributed: Tillage with Covering T.C Tillage without Covering T.NC No-Tillage with Covering NT.C No-Tillage without Covering NT.NC. The barley crop was sown on 20/12/2021, and after the barley harvest, the Mung bean crop was planted on 21/6/2022. The wheat straw covering was added in the winter season when planting barley. Tillage was done using Non-

Inversion Tillage (NIT) based on the use of tine and disc implements that do not invert the soil (9) by using a digger plow by 15-20 cm depth, which is widely used in gypsiferous soils. Planting was done by using a seeder machine in the tillage treatments and garden push seeder type Chapin 8701B in no-tillage treatments. In the summer season when planting Mung bean, the remnants of the previous Barely crop harvest were removed from the experimental units of the non-covering treatments and kept in the cover treatments. Irrigation management was based on two factors, the first is the climate factor using climatic data to calculate the amount of standard evapotranspiration (ETo), and the second factor is calculating the soil moisture percentage by the gravimetric method to apply the water budget equation. Near the site of the field experiment, an automatic ambient weather station of the type Ambient Weather WS 2902 WiFi manufactured by the American company Ambient LLC (7) was installed at a height of 5.6 m. The readings were corrected based on 2 meters high, as stated in (4). Specifications of study soil shown in Table (1).

Table 1. Specifications of study soil and irrigation water

Property	Measuring unit	Depth \ Value	
Depth	m	0-0.3 m	0.3-0.6 m
Sand	$gm.\ km^{-1}$	537	530
Silt		181	195
Clay		282	275
Soil Texture		Sandy Clay Loam	Sandy Clay Loam
Bulk density	$Mg.m^{-3}$	1.45	1.62
Particle density		2.97	2.37
Porosity	$cm^3.cm^{-3}$	0.512	0.316
Moisture content at 33 kpa		0.241	0.267
Moisture Content at 1500 kpa a		0.103	0.170
Available Water		0.138	0.097
Saturated Water Conductivity	$cm.day^{-1}$	28.56	2.88
Basic Infiltration Rate (double ring method)	$cm.h^{-1}$	1.1	---
Electrical Conductivity (EC) 1:1	$ds.m^{-1}$	2.69	8.59
Soil Reaction (pH) 1:1	--------	7.21	7.1
Gypsum percentage	%	27.31	30.81

Actual water consumption (ETa):

Actual evapotranspiration (ETa) was calculated, and irrigation scheduling was applied by measuring soil moisture before and after irrigation using oven-drying. Irrigation begins after at least 55% of the available water has been exhausted to reach the limits of field capacity. The Soil water balance equation was applied by Equation 1 according to (15) as follows:

$$ET_a = (P + I + C) - (R - D) - \Delta S \qquad (1)$$

where ET Actual evapotranspiration (mm), P is precipitation, I is irrigation, C is upward flow into the root zone, R is surface runoff, D is downward drainage out of the root zone, and ΔS is the change in stored soil water. Since the experimental field was level, surface runoff was ignored and the groundwater table was very low, with no upward flow into the root zone. Therefore, the water balance equation becomes as follows:

$$ET_a = (P + I) - \Delta S \qquad (2)$$

Reference water consumption (ET_O): By use daily weather data Reference Evapotranspiration (ET_0) were calculated by FAO-Penman-Monteith equation (Equation 3) using CROPWAT program according to (4) as follows:

$$ET_O = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T-237}U_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2} \qquad (3)$$

where ET_0 is reference evapotranspiration ($mm.day^{-1}$), Rn is net radiation at the crop surface ($MJ.m^{-2}.day^{-1}$), G is soil heat flux density ($MJ.m^{-2}.day^{-1}$), T is mean daily air temperature at 2 m height (°C), U2 is wind speed at 2 m height ($m.s^{-1}$), es is saturation vapor pressure (kPa), ea is actual vapor pressure (kPa), Δ is slope vapor pressure curve (kPa. $°C^{-1}$) and γ is psychrometric constant (kPa $°C^{-1}$).

Crop coefficient (K_C) calculated by to sum daily ET_0 for each growth stage and use equation 4 as to (4):

$$K_C = \frac{ET_a}{ET_0} \qquad (4)$$

Statistical analysis: The experiment was conducted according to the Randomized

Complete Block Design (RCBD), with the number of units being:

2 tillage methods (T) × 2 cover (C) × 3 replicates = 12 experimental unit

RESULTS AND DISCUSSION

Reference water consumption (ET_O) in Barely season: CROPWAT application by using equation 3 showed that daily reference evapotranspiration ranged between 1.77 to 6.61 mm. day^{-1} for time from December 2021 to May 2022 in Table (2), so ET_O for Barely crop season was 465.20 mm (Table 3) according to weather station data.

Table 2. Monthly mean of climate parameters of Barely and Mung bean seasons and values of radiation and reference evapotranspiration calculated by CROPWAT program.

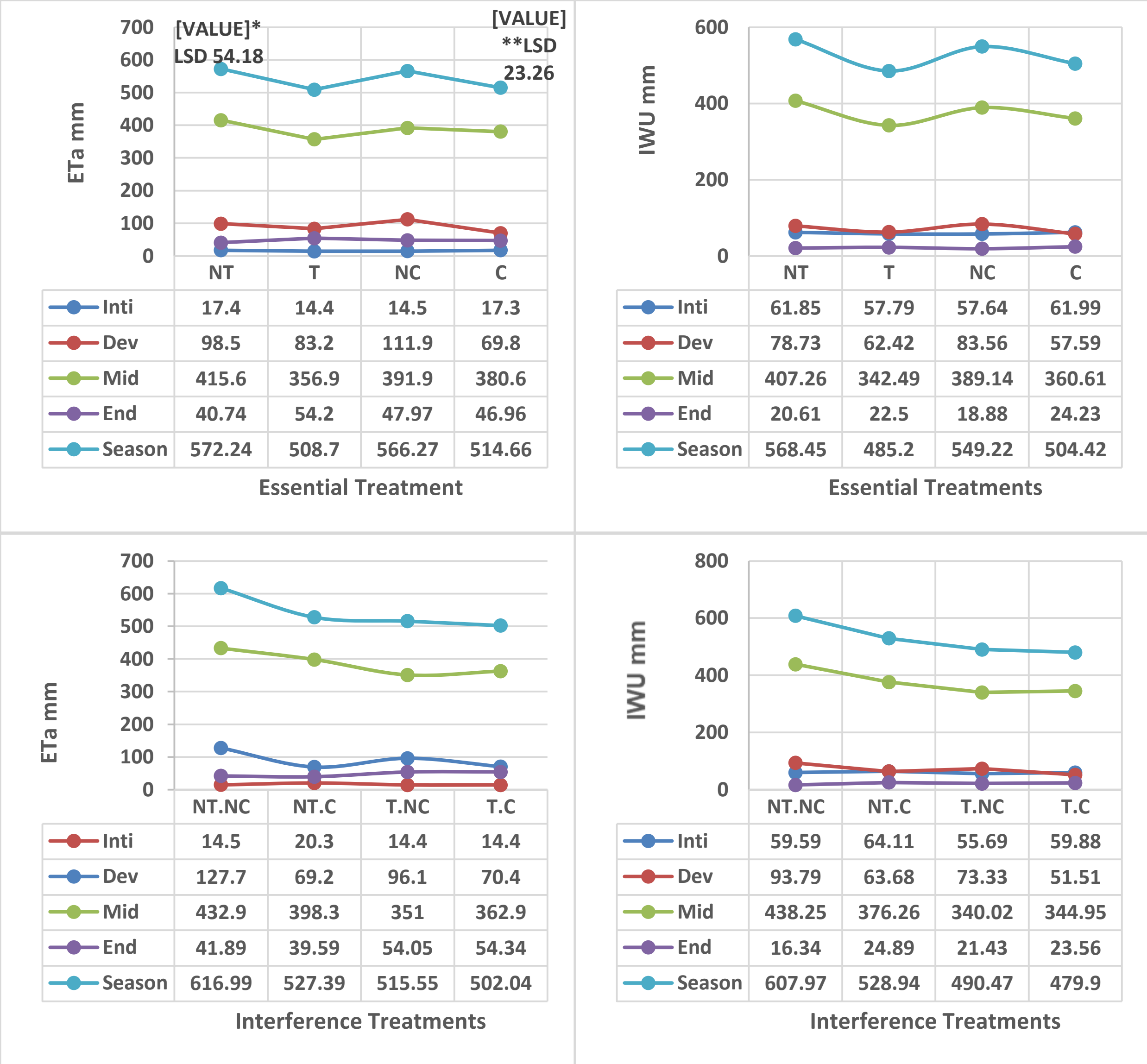
Month	Min Temp °C	Max Temp °C	Humidity %	Wind km/day	Sun hours	Rad MJ/m²/day	ETo mm/day
December	6	23.7	72	149	8.4	11.7	2.03
January	2.6	15.3	61	162	7.1	11.3	1.77
February	6.3	20.3	54	119	7.3	13.8	2.34
March	5.3	19.4	46	86	7.8	17.3	2.68
April	12.1	29.3	26	73	9.1	21.7	4.02
May	18.9	34.8	23	151	10.7	25.5	6.61
June	23.7	37.4	25	96	10.7	25.9	6.22
July	24.9	42.4	19	83	10.4	25.2	6.2
August	25.8	42.2	25	80	9.9	23.3	5.8
September	23.7	43.5	23	56	9.7	20.6	4.7
October	17.7	31.5	46	159	8.4	15.8	4.45
Average	14.9	30.2	40	113	9	18.8	4.11

Table 3. Reference evapotranspiration ET_O for each Barely growth stage calculated by FAO-Penman-Monteith equation using climate data in CROPWAT program.

Date	Stage	Day after plantation	Day of stage	Eto mm/Month
9-Jan	Init	20	20	40.06
18-Feb	Dev	60	40	77.02
4-May	Mid	135	75	259.63
19-May	End	150	15	88.50
Season		150		465.20

Effect of tillage and covering in barley crop irrigation water use and water consumption:

The results shows that T treatments were superior in IWU in most growth stages except the end, due to the increased water needs of the crop in areas of high vegetative growth in T treatment, and the highest difference reached 20.72% less than NT treatments in the Dev-stage without significance (Table 5). In ETa water consumption, the differences between T and NT ranged between 14-17% in the least consumed T, except for the initial stage, due to the water consumed to moisten the cover, which reduces water storage. A significant superiority was found for the T treatments in ETa in the Mid-stage, with 356.9 mm consumed less by 14% compared to NT, and the least significant difference was $LSD_{0.05}$ 54.18 mm (Figure 1). The same results shown in the crop coefficient Kc (Figure 2). Although the T treatments were superior in IWU and ETa in the season by 485 and 509 mm, with relative differences of 14.6. and 11%, respectively compared with NT, there is no statistically significant effect due to differences in soil fertility in the replicate positions. Also, the same result and reasons for coverage factor C, with high significant in the Dev-stage (LSD0.05 23.26 mm), as it consumed an average of 69.8 mm less by 37.6% compared to NC. Figure 2 shows that the T and C treatments have the lowest water use and consumption in total winter season, while the T.C intercropping treatments have the lowest and NT.NC have the highest due to lower water infiltration in no-tillage condition. While T.NC was slightly lower in IWU and ETa than NT.C as in Table 5 (7.4 and 2.1%, respectively).



ETa mm – Essential Treatment

	NT	T	NC	C
Inti	17.4	14.4	14.5	17.3
Dev	98.5	83.2	111.9	69.8
Mid	415.6	356.9	391.9	380.6
End	40.74	54.2	47.97	46.96
Season	572.24	508.7	566.27	514.66

IWU mm – Essential Treatments

	NT	T	NC	C
Inti	61.85	57.79	57.64	61.99
Dev	78.73	62.42	83.56	57.59
Mid	407.26	342.49	389.14	360.61
End	20.61	22.5	18.88	24.23
Season	568.45	485.2	549.22	504.42

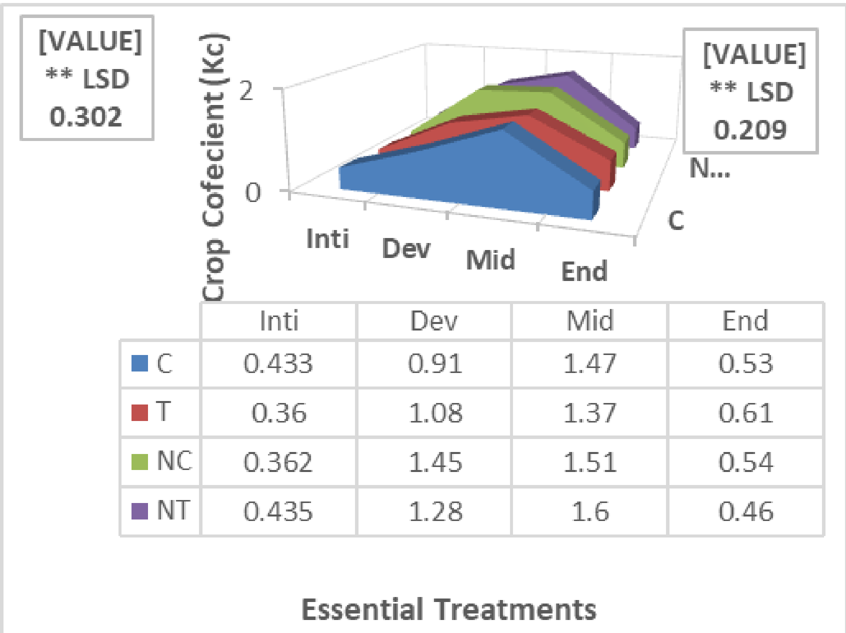
ETa mm – Interference Treatments

	NT.NC	NT.C	T.NC	T.C
Inti	14.5	20.3	14.4	14.4
Dev	127.7	69.2	96.1	70.4
Mid	432.9	398.3	351	362.9
End	41.89	39.59	54.05	54.34
Season	616.99	527.39	515.55	502.04

IWU mm – Interference Treatments

	NT.NC	NT.C	T.NC	T.C
Inti	59.59	64.11	55.69	59.88
Dev	93.79	63.68	73.33	51.51
Mid	438.25	376.26	340.02	344.95
End	16.34	24.89	21.43	23.56
Season	607.97	528.94	490.47	479.9

Figure 1. Mean values of Water Irrigation Use (IWT) and Actual Evapotranspiration (ETa) for essential and interference treatments in each season stage of Barely crop.



	Inti	Dev	Mid	End
C	0.433	0.91	1.47	0.53
T	0.36	1.08	1.37	0.61
NC	0.362	1.45	1.51	0.54
NT	0.435	1.28	1.6	0.46

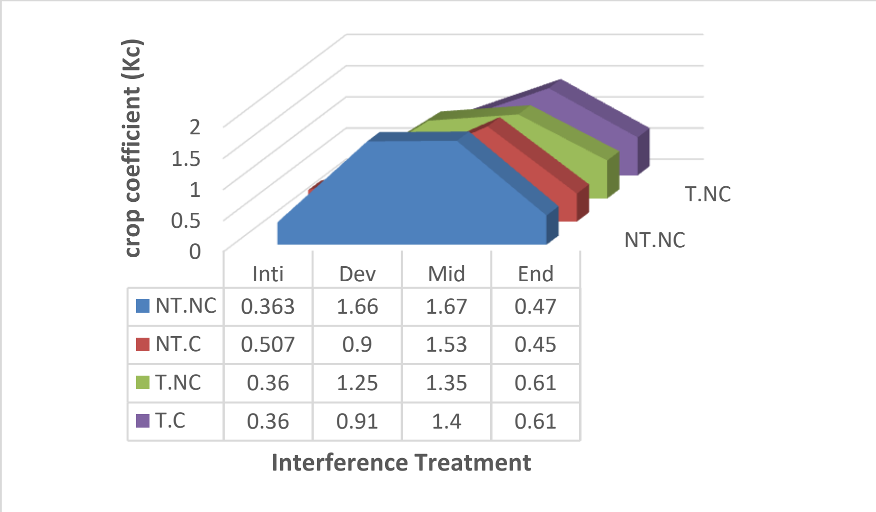


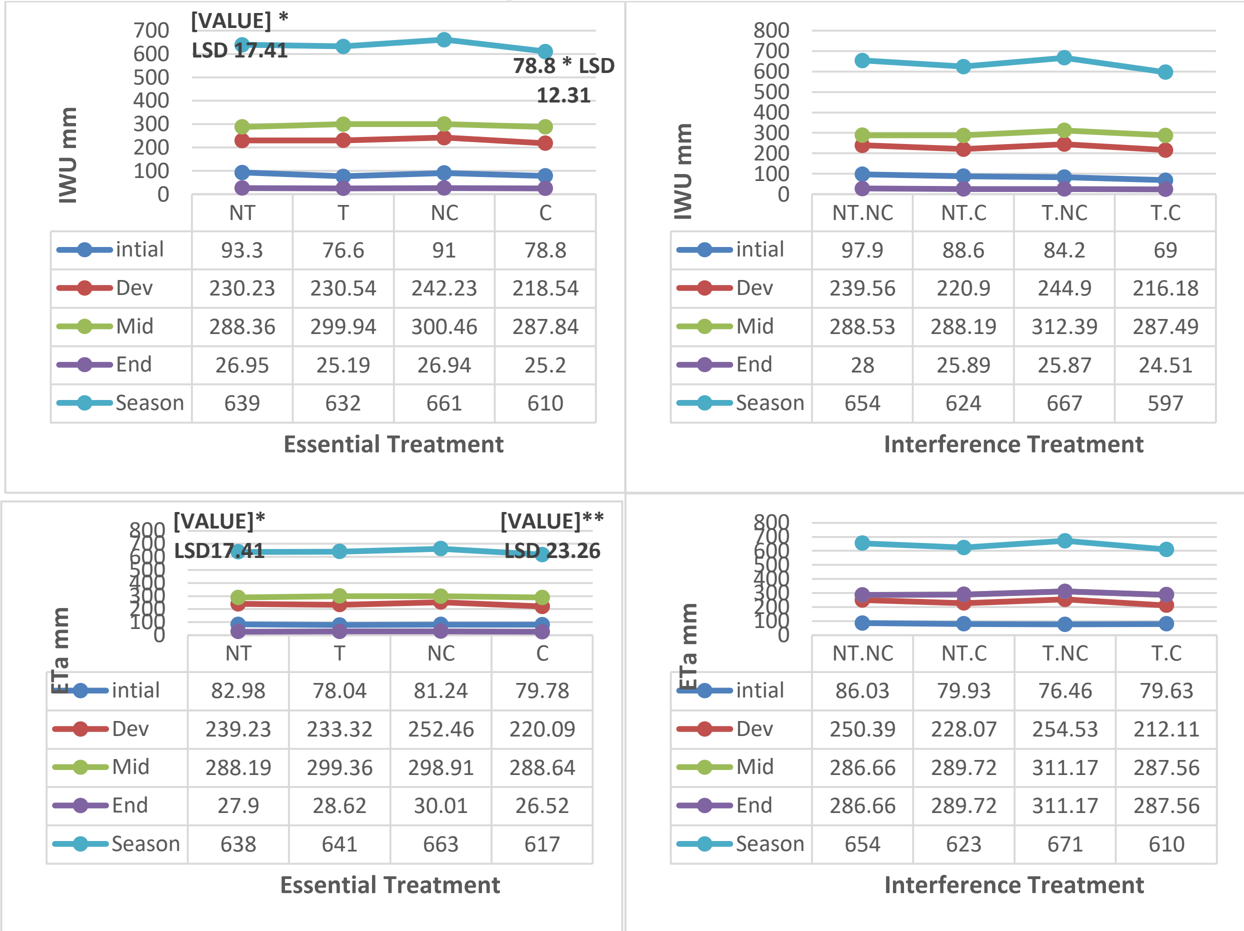
Figure 2. Crop Coefficient (Kc) values in essential and interference treatments in different stages of Barley crop season, were (*) mean significant.

Reference water consumption (ET_0) in mung bean season: Daily reference evapotranspiration ranged between 6.22 to 4.45 mm. day^{-1} for the time from June 2022 to October 2022, so ET_0 for the Mung bean crop season was 596.27 mm (Table 4) according to weather station data.

Table 4. Reference evapotranspiration ET_O for each Mung bean growth stage calculated by FAO-Penman-Monteith equation using climate data in CROPWAT program.

Date	Stage	Day after plantation	Day of stage	Eto mm/Month
12-Jul	Init	20	20	105.59
11-Aug	Dev	50	30	206.94
20-Sep	Mid	90	40	185.68
10-Oct	End	110	20	98.06
Season			110	596.27

Effect of tillage and covering in Mung bean crop irrigation water use and consumption: The summer season results were like that in the winter season in terms of the treatment effect. Were showed a significant effect of T treatments in IWU, in the initial stage, as it was 18% less water used compared to NT treatments, with LSD0.05 of 17.41 mm (Figure 4), the reason is related to the coverage effect. While were no differences worth noting in other stages, and then in season. Also in consumption ETa, the differences between T and NT did not exceed 6% in maximum, so no effect for the Tillage factor in the consumption of water in this season. Figure (3) shows a significant effect of the C factor in IWU for the inti stage ($LSD_{0.05}$ 12.31), where C treatments had less water use by 13 % than NC treatments, due to the role of residual previous Barley to keep water, other than that, the relative difference did not exceed 10 %, then had 7.72 % in season for C treatments compared with NC. Also in consumption ETa, shows a significant difference for T treatments by 6% less than NT in the Inti-stage (LSD0.05 17.41) and for C treatment in the Dev-stage by 13 % less than NC treatments ($LSD_{0.05}$ 23.26) due to the same. No significance in coefficient crop Kc despite the relative difference reaching 13 % in the Dev stage and had 7% in the season compared with NT treatments (Figure 4). Although no significant effect for Interaction appears in Mung bean water use and consumption, T.C treatment had the lowest water use for all stages and then for the season by a 10.5 % difference from the highest T.NC treatment, due to the ability of non-inversion tillage soil to store irrigation water, in addition to the role of coverage to keep water and decrease evaporation. Also, TC treatment is the lowest in consumption by 610 mm ETa in season, about 9.1 % less than T.NC the highest of water use and consumption because of no coverage. While NT.C treatment was superior by 6-7 % compared with traditional T.NC. When comparing the two Barely and Mung bean seasons, a higher amount of IWU and ETa for T treatments in the End stage in the first season, while a reduction in the second, in addition, the amount in C treatment higher in the inti stage in the first, while lower in the second season due to that added a transported residuals in the first season, required amount of water to wetted, opposite of residuals crop in the second which kept the water from the previous season and this caused significantly decrease use and consumption in inti stage for second season.



IWU mm – Essential Treatment

	NT	T	NC	C
intial	93.3	76.6	91	78.8
Dev	230.23	230.54	242.23	218.54
Mid	288.36	299.94	300.46	287.84
End	26.95	25.19	26.94	25.2
Season	639	632	661	610

IWU mm – Interference Treatment

	NT.NC	NT.C	T.NC	T.C
intial	97.9	88.6	84.2	69
Dev	239.56	220.9	244.9	216.18
Mid	288.53	288.19	312.39	287.49
End	28	25.89	25.87	24.51
Season	654	624	667	597

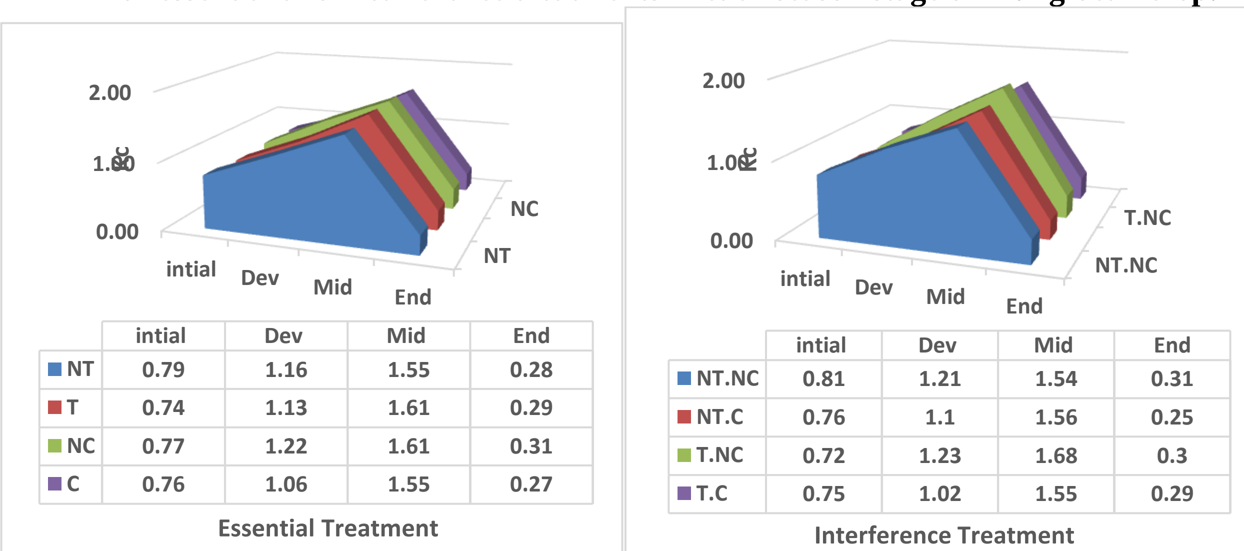
ETa mm – Essential Treatment

	NT	T	NC	C
intial	82.98	78.04	81.24	79.78
Dev	239.23	233.32	252.46	220.09
Mid	288.19	299.36	298.91	288.64
End	27.9	28.62	30.01	26.52
Season	638	641	663	617

ETa mm – Interference Treatment

	NT.NC	NT.C	T.NC	T.C
intial	86.03	79.93	76.46	79.63
Dev	250.39	228.07	254.53	212.11
Mid	286.66	289.72	311.17	287.56
End	286.66	289.72	311.17	287.56
Season	654	623	671	610

Figure 3. Mean values of Water Irrigation Use (IWT) and Actual Evapotranspiration (ETa) for essential and interference treatments in each season stage of Mung bean crop.



Kc – Essential Treatment

	intial	Dev	Mid	End
NT	0.79	1.16	1.55	0.28
T	0.74	1.13	1.61	0.29
NC	0.77	1.22	1.61	0.31
C	0.76	1.06	1.55	0.27

Kc – Interference Treatment

	intial	Dev	Mid	End
NT.NC	0.81	1.21	1.54	0.31
NT.C	0.76	1.1	1.56	0.25
T.NC	0.72	1.23	1.68	0.3
T.C	0.75	1.02	1.55	0.29

Figure 4. Crop Coefficient (Kc) values in essential and interference treatments in different stages of Mungbean crop season.

CONCLUSIONS

Using a minimum tillage system and covering the soil with straw or a previous crop residual reduces the water consumption of crops when cultivating gypsum soils, but when using a no-tillage or zero-tillage system, this must be combined with covering. The statistically significant effect does not necessarily appear in the first season, but the results indicate a strong possibility of significant superiority in successive seasons when continuing to use the principles of conservation agriculture. A high relative difference may appear without obtaining a significant difference because of the difference in soil fertility in different locations of the treatment replicates. There was no significant effect of the tillage factor on water consumption due to the use of non-inversion tillage, which showed good results when combined with the covering factor, which had the greatest effect.

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