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Effect of Cultivation Methods and Fertilization by Effective Microorganisms and/or Compost on Productivity and Water Use Efficiency of Wheat (*Triticum aestivum* L.)

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A FIELD experiment be located at Mallawi Agriculture Research Station, Minia Governorate, Egypt for two following seasons of 2021/ 2022 and 2022/ 2023, to examine effective of fertilization (100% NPK or control, 80 % NPK & EM (Effective microorganisms) applied at (12.35L ha $^{-1}$), 80 % NPK & compost 12.35 ton ha^{-1} and 80 % NPK & Mixture of EM and compost) on wheat that grown in clay soil via using three cultivation methods, i.e. broad casting, ridges, raised beds. The experiment was arranged in a split plot design by three replicates. Water productivity as well as water use efficiency were extremely improved under raised bed method compared with the values with the other two methods through two seasons. Likewise, the highest values of plant height (cm). grain yield (ton ha^{-1}), straw (ton ha^{-1}), 1000 grain and protein% in the two consecutive seasons, were gained when planting wheat on raised bed at combined 80% NPK+ mix (EM and compost). Nutrition contents in wheat grain and total uptake kg ha^{1} were increased with the same treatment.

Keywords: Wheat, Compost, EM, Raised beds, and WUE.

1. Introduction

Wheat (*Triticum astivum*, L) is considered one of the most significant crops grown in Egypt for both human and animal nourishment (Saad *et al*., 2023). Since increasing wheat production is a crucial national goal, many researchers have focused their efforts on increasing wheat productivity per unit area as well as increasing the cultivated area to close the gap between Egyptian needs and consumption.

One of the most severe environmental issues that face crop production is water stress especially in arid and semi-arid regions like Egypt. Researchers face many challenges with increasing population and changing climate conditions are expected to increase water scarcity, which will lead to further decline in crop productivity. Irrigation scheduling improved crop quality via reducing excessive vigour and increasing water use efficiency (Rashwan & El-Saied, 2022)**.** To help plants alleviate water stress and encourage plant growth, many additives may be used. For example, amending spoils with agricultural wastes like composts, protect water and improving soil fertility by reducing the use of chemical fertilizers hence minimize the use of synthetic chemical fertilizers needed for plant growth, yield, and quality (Zhai *et al.*, 2023). Excessive use of chemical fertilizers can harmfully deteriorate the environment while lessen nutrient use efficiency (Seleiman *et al.*, 2021; Elsherpiny, 2023; Elsherpiny *et al.* 2023). It has also, negative consequences on soil degradation, groundwater polluted, air polluted plus human and animals health harms (Kavvadias *et al*., 2023) Furthermore, soil organic matter and humus contents could be lower in soils that received excessive chemical fertilizers (Bisht & Chauhan, 2020). and this affect soil fertility and sustainability (Hussein et al., 2022). So it is important to introduce environmentally friendly amendments to increase plant growth and productivity for sustainable agriculture (Alhammad & Seleiman, 2023), and also minimize soil leachate and improve the physiochemical, and biological properties of soil. Accordingly, these additives could have positive impacts on crop productivity (Kavvadias *et al.*, 2023). Attributable to its positive influence on the soil, compost amendment significantly alleviated the harmful effects of drought resulting in better growth and yield. Bio stimulants like EM, have a positive roles in sustaining the ecosystem (Farrag and Bakr, 2023), such as: Lactobacillus Rhodopseudomonas, and Saccharomyces (Shalan, 2014)**.** They improved growth, yield and maturing of lettuce crop (Rashwan & El-Saied, 2022). Dual application of bio fertilizers and compost have further effects on promoting yield

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and yield components of crops than each treatment solely (El-Tahlawy *et al*., 2022)**.**

Cultivating methods put grains at appropriate depth, which finally effect on plant yield and growth. While using inappropriate cultivating method, causes decreasing in yield and growth. In Egypt, broadcasting method is used for growing wheat in a large area, that provide lower plant density, while raised bed cultivating method is suitable for seed distribution and better plant density, improving water and fertilizer use efficiency (Mohiy & Salous, 2022). Raised bed, a developed surface irrigation technique, which represents a practical and more sustainable substitute to conventional method, tends to be extremely ineffective and wastes scarce water resource. Raised bed planting absorbs water more effectively than the traditional method, instead of spreading excess of irrigated water over the entire surface area. Replacing the traditional flatbed by the raised bed allows effective control of irrigation and drainage, facilitates fertilizers application and enhances tillering, reduces weed infestation and lodging which in turn enhance crop yield while saving irrigation water (Ahmed & Hassan, 2019).

This study can be used to evaluate the dual application of compost and EM to substitute partially chemical hertilizers and increase wheat production. . It also identifies the appropriate cultivation methods for wheat production under water-restricted conditions.

2. Material and Methods

A field experiment was conducted at Mallawi Agriculture Research Station, Minia Governorate, Egypt (latitude 26° 34' N and longitude 31° 42' E and Elevation 61 meters through consecutive seasons of 2021/ 2022 and 2022/ 2023 to study the effect of fertilization (100%NPK, 80 % NPK & EM applied at (12.35L ha $^{-1}$), 80 % NPK & compost 12.35 ton ha^{-1} and 80 % NPK & Mixture of EM and compost) on wheat growth on a clay soil following three cultivation methods, i.e. broad casting, ridges and raised beds on Yield, chemical composition and WUE were determined in this investigation. Monthly mean temperature, monthly relative humidity, rainfall and wind speed were illustrated through 2021/2022 and 2022/2023 (Table 1). Before planting, soil's physical and chemical characteristics were examined. as stated by (Black (1965) and Ryan et al. (1996)

Table2. The field experiment included12 treatments and were organized in a split plot design with three replicates. The plot area was 16.8 m2 (48×3.5). Methods of cultivation were allocated the main plots, whereas fertilization treatments were arranged in the sub plots.

The main plots (Methods of cultivation)

1- Broad casting drilling (traditional method),
2- Ridges 60 cm wide.
3- Raised bed 120cm wide. Where the amount of irrigated water was reduced approximately 25%. (Amount of water applied was 5535.3 and 5488.3 for two seasons m3)

The sub plots (Fertilization treatments)

1- 100%NPK (control)
2- 80 % NPK & EM; Effective microorganisms) applied at (12.35L ha $^{-1}$).
3- 80 % NPK & compost 12.35 ton ha^{-1} (Rashwan & El-Saied, 2022)
4- 80 % NPK & Mixture of EM and compost.

Each sub-plot involved of 8 ridges or 4 raised beds according to treatment. Every row was 3.5 m. in length and 60 cm in width and each one of raised bed was 3.5 m. in length and 120 cm in width. The wheat seeds were sown on both sides of raised beds. Wheat grains were hand drilled in rows 20 cm apart, number of rows was 24 rows plot^{-1}on broad casting drilling (traditional method), 3 row/60 cm on ridges and 6 rows/ 120 cm on raised bed.

Experimental design

Wheat variety Beni Suef one was planted on 20th of November in both seasons. Nitrogen fertilizer (as ammonium nitrate 33.5% N) was added in three doses at a rate of 185.25 kg N ha^{-1}. i.e., 20 % N was added at sowing time, while, 40 % was applied at 25 days after sowing. Finally, the third dose equivalent to 40 % was applied 50 days after sowing. Super-phosphate fertilizer (15.5 % P_2 O_5) was applied before sowing at the rate of 370.5 kg ha $^{-1}$.Also, potassium fertilizer was added with the third dose of nitrogen fertilizer at a rate of 123.5 kg ha^{-1} in the form of potassium sulphate (48% k_2O). All treatments had the same sowing irrigation for wheat, and the amount of irrigation water were measured by using a flow – meter close to the irrigation pump in first and second season as shown in Tables 4&5. Samples of plants were taken randomly to measure plant height (cm), 1000 - grain weight (g). Grain yield (ton ha $^{-1}$). Straw yield (ton ha^{1}). Wheat grains samples (0.2g) were digested via a mixture of sulphuric plus perchloric acids (1:1) to assay nutrient elements; Total nitrogen (%) was assayed by the modified microkjeldahl method as described by (Jones Jr *et al*., 1991) Total phosphorus(%)was estimated using UV spectrophotometry (model no. UV 2100 S/N: BH16041603003) Total potassium (%) was determined by Flame-Photometer (JENWAY PFP7 model). Protein content was calculated by multiplying N content by 5.75 (Ranganna, 1977).

Water relations

Actual water consumptive use (WCU)

Soil samples were taken two days before and after each irrigation to calculate water consumption within the top 15 cm increment from soil surface down to 60 cm of soil profile. This process was determined as stated by (Israelsen & Hansen, 1962).

Water Productivity (WP)

Water productivity identified as a ratio of product output over water input. The output could be biological yield such bulbs, crop seeds ….etc. water productivity, is expressed as kilograms of wheat grain obtained per the unit volume of applied irrigation water (m^3). The water productivity data be calculated for various treatments as follows: WP (kg m^{-3}) = grain yield (kg ha^{-1}) / water applied (m^3 ha^{-1}),(FAO, 2003)

Water use efficiency (WUE)

Water use efficiency was calculated for totally treatments by (Vites, 1965).

WUE (kg m^{-3}) = yield grain (kg ha^{-1}) / water consumptive (m^3 ha^{-1}).

Table 1: Average monthly meteorological data of Minia weather station trough 2021/2022 and 2022/2023.

Month	Temperature (°C)			RH%	Wind speed (Km day-1)	Sun shine (hr) Max
	Max	Min	Mean			
2021/2022						
November	21.7	8.7	15.2	66	201	21.7
December	20.4	8.3	14.35	68	211	20.4
January.	18.2	6.6	12.4	65	192	18.2
February.	22.5	8.4	15.95	58	185	22.5
March	25.3	12.5	18.9	48	233	25.3
April	31.4	16.6	24	36	245	31.4
May	34.5	17.5	26	41	221	34.5
2022/2023						
November	20.4	8.4	14.4	67	188	20.4
December	19.6	7.5	13.55	67	185	19.6
January.	18.5	6.6	12.55	61	158	18.5
February.	20.3	6.4	13.36	58	182	20.3
March	24.8	11.1	17.95	49	202	24.8
April	30.9	14.3	22.6	41	228	30.9
May	33.8	16.8	25.3	51	231	33.8

Table 2: Physical and chemical properties of soil sample from surface layer (0-25 cm).

Character		2021/2022	2022/2023
Particle size distribution	Clay %	53.01	53.40
	Silt %	24.55	24.10
	Sand %	22.44	22.50
Texture		Clay	Clay
Bulk density (g cm-3)		1.28	1.32
Field capacity% (v v^{-1})		42.01	46.62
Wilting point% (v v^{-1})		30.44	32.27
pH (1: 5)		8.30	7.90
EC (dS m^{-1})		1.361	1.52
OM, %		1.4	1.45
Soluble cations (cmolc kg^{-1})	Ca^{++}	7.45	7.50
	Mg^{++}	2.15	2.20
	Na^{+}	3.22	3.27
	K^{+}	0.20	0.25
Soluble anions (cmolc kg^{-1})	Cl^{-}	4.10	4.15
	CO_3	--	--
	HCO_3^-	3.20	3.25
Available nutrients (mg kg^{-1})	N	20.25	20.52
	P	9.58	9.62
	K	186	188

Table 3: Physical and chemical properties of compost.

Properties	2021/2022	2022/ 2023	Properties	2021/2022	2022/ 2023
Organic	27.19	27.72	Humidity (%)	8.23	8.12
Carbon (%)	16.00	15.90	Fe mg kg^{-1}	988.4	828.6
Total N (%)	0.86	0.84	Zn mg kg^{-1}	261.1	259.2
C/N ratio	18.60	18.93	Mn mg kg^{-1}	223	239
K(%)	1.20	1.33	pH 1:10	7.47	7.39
P *(%)*	0.31	0.28	E. C. (dsm^{-1})	1.09	1.06

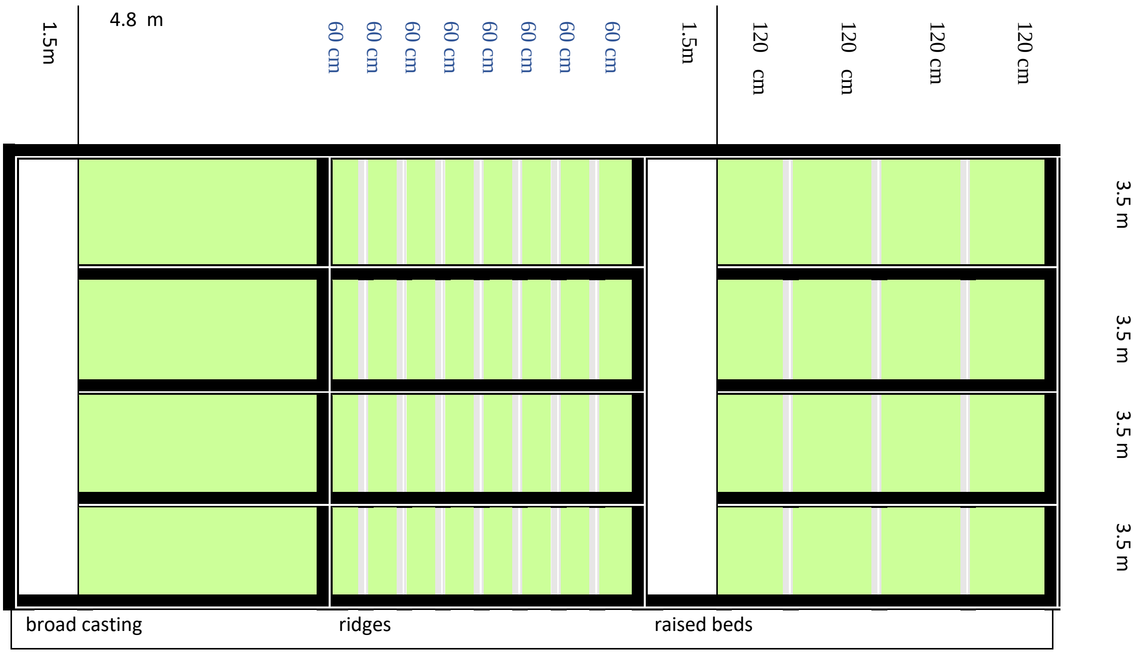

Fig. 1. Layout one replicate of the experimental site.

Table 4. Amount of water (m^3 ha^{-1}) applied to first season (2021/2022) under different cultivation methods and Fertilizers treatments.

Cultivation methods	Fertilizers treatments	No. of irrigation 1	2	3	4	5	6
		Data of irrigation 20/11	28/12	15/2	10/3	29/3	18/4
C1	F1	1099.2	810.16	864.5	889.2	933.7	938.6
	F2	1074.5	790.4	852.2	839.8	864.5	909.0
	F3	1049.8	802.75	839.8	827.5	842.3	894.1
	F4	1025.1	765.7	785.5	802.8	810.2	876.9
C2	F1	1062.1	785.46	852.2	864.5	894.1	913.9
	F2	1049.8	778.05	834.9	829.9	852.1	894.1
	F3	1034.9	773.11	815.1	825.0	844.7	881.8
	F4	1015.2	765.7	792.9	783.0	810.2	844.7
C3	F1	988	763.23	736.1	741.0	760.8	802.8
	F2	975.65	716.3	704.0	716.3	753.4	768.2
	F3	963.3	711.36	691.6	704	728.6	763.2
	F4	938.6	691.6	642.2	706.4	568.1	592.8

C1: Broad casting,, C2: Ridges C3: Raised bed , F1: 100% NPK **(control)**, F2: 80% NPK+ EM, F3: 80% NPK+compost) and F4: 80% NPK+ mix (EM and compost).

Table 5. Amount of water (m^3 ha^{-1}) applied to second season (2022/2023) under different cultivation methods and Fertilizers treatments.

Cultivation methods	Fertilizers treatments	No. of irrigation 1	2	3	4	5	6
		Data of irrigation 20/11	28/12	15/2	10/3	29/3	18/4
C1	F1	1094.2	802.8	854.6	881.8	921.3	933.7
	F2	1067.0	783.0	842.3	832.4	854.6	896.6
	F3	1039.9	795.3	837.3	817.6	842.3	894.1
	F4	1015.2	755.8	770.6	795.3	800.3	867.0
C2	F1	1094.2	802.8	854.6	881.8	921.3	933.7
	F2	1067.0	783.0	842.3	832.4	854.6	896.6
	F3	1039.9	795.3	837.3	817.6	842.3	894.1
	F4	1015.2	755.8	770.6	795.3	800.3	867.0
C3	F1	990.5	763.2	741.0	748.4	765.7	795.3
	F2	980.6	721.2	708.9	723.7	763.2	775.6
	F3	970.7	716.3	699.0	711.4	733.6	768.2
	F4	943.5	691.6	652.1	713.8	575.5	592.8

C1: Broad casting,, C2: Ridges C3: Raised bed , F1: 100% NPK (control), F2: 80% NPK+ EM, F3: 80% NPK+compost) and F4: 80% NPK+ mix (EM and compost).

3- Results

Water Relations

Irrigation Water Applied (IW)

Figures (2a & 3a) showed that there were significant ($P<0.05$) differences among fertilizer treatments as (100% NPK, 80% NPK + EM , 80% NPK +80% NPK + and 80% NPK + mix EM and compost and different cultivation methods (broad casting, ridges or raised beds) as well as fertilizer treatments as (100% NPK, 80% NPK + EM , 80% NPK +80% NPK + and 80% NPK + mix EM and compost on irrigation water applied, WCU, WP kg m^{-3} and WUE kg m-3. Results show that 100 % NPK used higher quantity of (IW) in the both seasons. 100 % NPK consumed water higher than 80% NPK with EM and compost by about 9.44 and 9.43% in the two growing seasons, respectively. The maximum standards of amount of applied water was used under cultivating on broad casting which gave the extreme values 5296.92 m^3ha^{-1} and 5250.23 m^3ha^{-1} in both seasons, in turn. On contrary, the lowest amount 4531.956 m^3ha^{-1} and 4561.69 m^3 ha^{-1}were obtained due to cultivating on raised bed. The data showing that possibly will save about 14.44 and 13.18% of applied irrigation water compared to broad casting for two seasons.

Table (6) Relating to with the interface between cultivation methods and fertilization treatments. Cleared that the highest average quantity of (IW) was obtained by growing wheat on broad casting at combined 100% NPK with a value of 4739.19 and 2715.23 m^3ha^{-1} in two consecutive seasons. While the lowest average quantity of (IW) was obtained by growing wheat on raised beds at Combined 80% NPK+ mix (EM and compost) with a value of 4139.72, 4169.36 m^3ha^{-1} in both seasons, respectively.

Actual Water Consumptive Use (WCU)

Figure (2b &3b) revealed that, seasonal WCU for wheat crop was affected by addition fertilizers, treated with 100 %NPK showed the highest water consumptive use value by 9.19 and 8.94% comparison with 80% NPK+ mix (EM and compost, in both seasons respectively. Concerning the effect of cultivation methods, the highest values were under broad casting compared with the other cultivation methods (ridges, raised beds). The highest mean WCU recorded by broad casting while the lowest by raised bed for both seasons. The increase in water consumptive use attributed to broad casting 19.96, 19.84 % more than raised bed through both seasons, respectively. Referring to the interface between cultivation methods with fertilization treatments, the highest water consumptive use value 4870.84 and 4853.55 m^3 ha^{-1} by 100% NPK treatment, while the highest water consumptive use (WCU m^3) value 3460.47 and 3470.35 m^3 ha^{-1} by sowing wheat at raised bed Combined 80% NPK+ mix (EM and compost) respectively in bath season.

Water productivity (WP)

Data in **Figures** (2c &3c showed that, for the water productivity (WP), Addition of fertilizers gave positive results where the maximum WP were obtained at 80% NPK+ mix (EM and compost, respectively in both seasons. the mean values of WP for wheat crop were higher in raised beds than in broad casting by 16.94 and 16.40% for 1st and 2nd seasons. The interaction between cultivation methods and fertilization treatments the highest water productivity (WP kg m^{-3}) value 5.66 and 5.64 kg m^{-3} by raised bed at Combined 80% NPK+ mix (EM and compost, respectively in both seasons.

Irrigation water efficiency (WUE kg m^{-3})

It identified as biomass amount that produced per unit volume of applied water as illustrated in Figures (2d&3d). Data showed that WUE kg m^{-3} has the same way that attained from the WP For the fertilizer treatments, the maximum mean values of WUE kg m^{-3} (5.72 and 4.94 kg m^{-3}) were recorded under treatment 80% NPK+ mix (EM and compost, respectively in both seasons recording an increase by 25.37 and 23.94% compared by 100% NPK. Concerning for various cultivation methods treatments, the mean values of WUE kg m-3 for wheat under the raised bed were 5.78 and 5.73 kg m−3 which were higher than broad casting by 22.20 and 22.78%. Referring with the interface among cultivation methods and fertilization treatments, the highest WUE values were 6.77 and 6.78 kg m-^{3}, which were attained in raised bed that received the combined 80% NPK+ mix (EM and compost treatment in both seasons.

Growth and Yield Attributes

Tables (7) showed that fertilization treatments recorded positive impacts on wheat plants, The highest increases were found due to the addition of 80% NPK+ mix (EM and compost) resulted in significant increases in plant height, Grain yield, straw, 1000 grain and protein content by (7.36 & 7.66%, 21.26 & 19.29%, 16.23 & 16.11%, 13.84 & 14.11% and 6.07 & 5.76% for 1st and 2nd season, respectively versus the control. When wheat plants were planted on raised beds significantly increased versus the other cultivation methods. In this concern, plant height increased by (2.47 & 3.20 %), while grain yield increased by (2.69& 3.70) straw by (5.50 &5.37%), 1000 grain by (3.36 &3.26%) and protein content by (2.14 &2.13%), for 1st and 2nd seasons separately also. Concerning interaction between cultivation methods and fertilizer treatments, the highest grain yield (9.48, 9.53 ton ha^{-1}) was acquired by sowing wheat on raised bed fertilized together with 80% NPK+ mix (EM and compost) in both seasons of study. This treatment also enhanced considerably straw yield (19.41, 19.56 ton ha^{-1}), 1000 grain (66.88, 67, 72 g) and protein content (7.60, 7.62 %). while the lowest values were observed with cultivating wheat using flat broadcast method fertilized by 100% NPK. Table (8).

Chemical constituents

Results in Table (9) cleared that Fertilizers exhibited positive effect especially the combined 80% NPK with EM and compost which recorded significant increase in nutrient contents comparing with 100% NPK by (5.98 &5.79%), (23.92 &19.51%) and (39.14 &38.92%) for N, P and K for both seasons respectively. in raised beds-planted wheat caused significant increase in nitrogen, phosphorous and potassium contents in grains by (2.13 and 2.14, 3.16 and 4.90 &7.60 and 6.39 %) respectively for both seasons. Regarding to the interaction between cultivating methods and fertilizers, raised bed cultivating method presented better values of mineral contents under combining 80% NPK with EM and compost. For nitrogen content (1.322 &1.326 %), for phosphorous content (0.437 &0.442%), and for potassium content (0.891 & 0.898%) respectively for both seasons. Similarly, Table (10) represented total uptake (kg ha^{-1}) that significantly increased (205.76&208.12 kg ha^{-1}) for total uptake N, (64.57 & 65.73kg ha^{-1}) for total uptake phosphorous and (380.45& 384.41 kg ha^{-1}) for total uptake potassium.

Chemical Properties of Soil and available N, P and K in soil post-harvest

Table (11,12) illustrated that combining 80% NPK with EM and compost gave positive effect on remaining nutrient compared with 100% NPK for N content increased by (1.63, 3.94 and 4.29%), P by (3.55, 3.76 and 5.32%), K by (0.79, 1.39and 4.77), OM% by (3.07, 6.21 and 9.66%) in the 1 st and 2 nd seasons, respectively. while pH decreased by (1.71, 1.70), EC decreased by (10.74, 9.26%) through two seasons. On other hand, raised bed cultivation methods had significant enhancing available macronutrients N, P, K (mg kg^{-1}) and OM%. Available nitrogen increased by (1.11%), available phosphorous increased by (2.87%) and available potassium increased by (1.08 %) in first season, the second season has the same trend. Additionally, organic matter increased by (2.68 & 2.67%) for both seasons. On other hand, pH and EC values slightly decreased due to cultivation with raised beds for about reaching (0.69, 0.33 and 1.80, 2.56%) in comparison with broad casting in the bath seasons, respectively.

The interaction among cultivation methods and fertilization treatments indicated that the application of raised beds at combined 80% NPK+ mix (EM and compost) gave highest available nutrients (21.24and 21.29, 10.20 and 10.24, 197.5 and196.2 &1.611 and 1.606) for N, P and K (mg kg^{-1}) content & OM% for 1^{st} seasons and the 2^{nd} season.

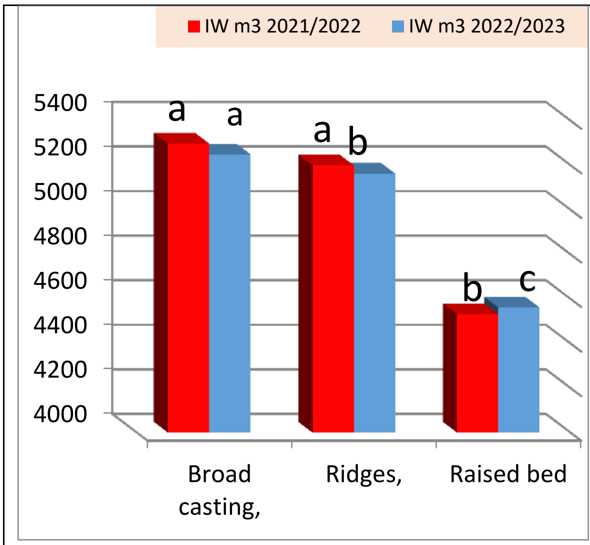

Fig (2a)

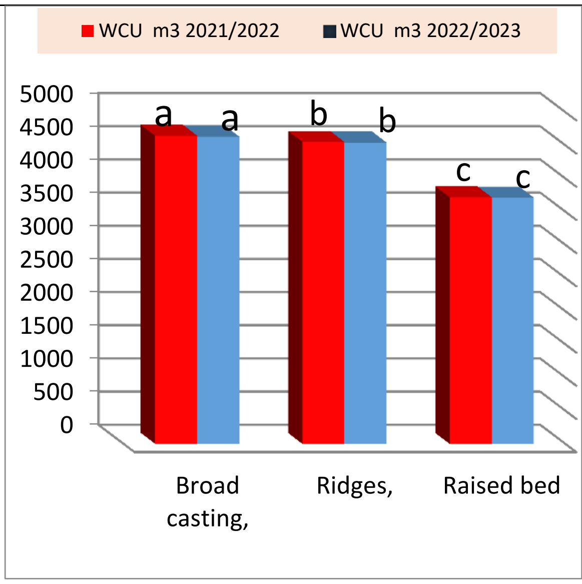

Fig (2b)

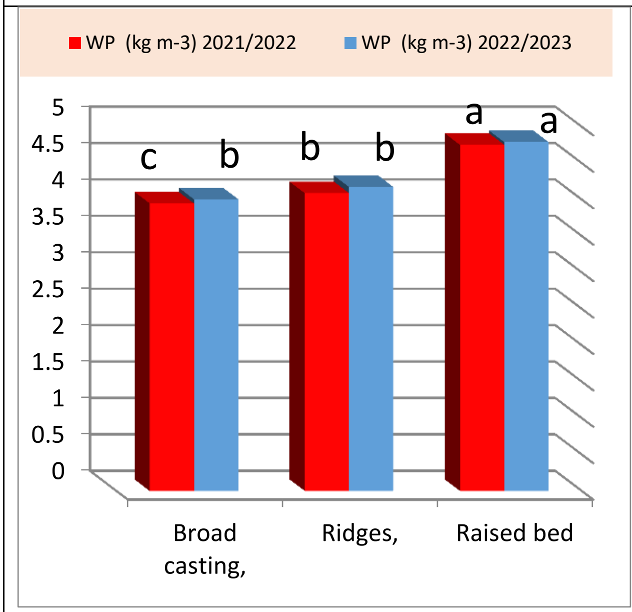

Fig (2c)

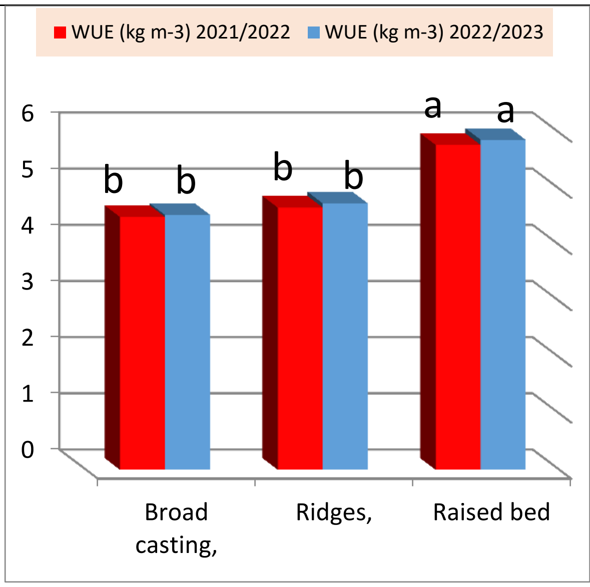

Fig (2d)

The means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P-value of ≤.0.05.

Figs. 2. Influence of cultivation methods application (as individual effect) on water applied (IW m^3), water consumptive use (WCu m^3), the water productivity (WP kg m^{-3}) and the water use efficiency (WUE kg m^{-3}).

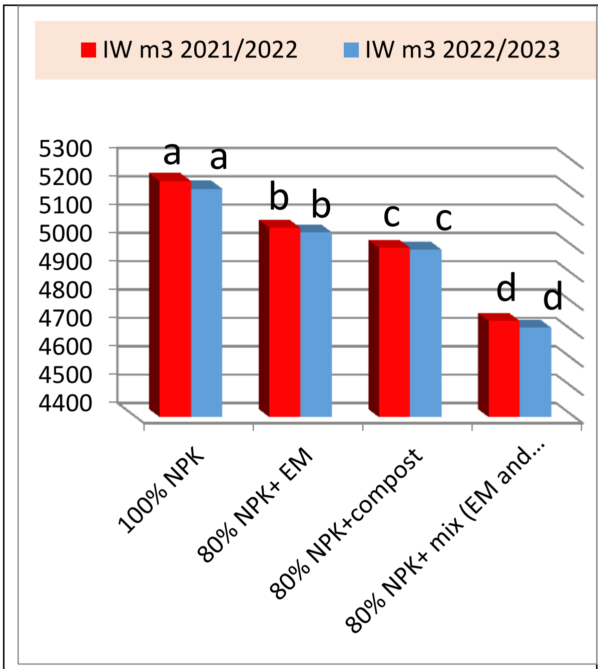

Fig (3a)

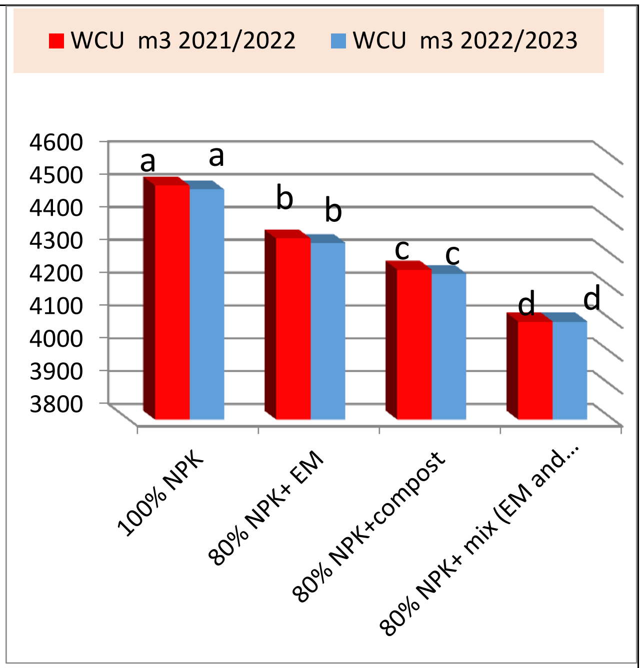

Fig (3b)

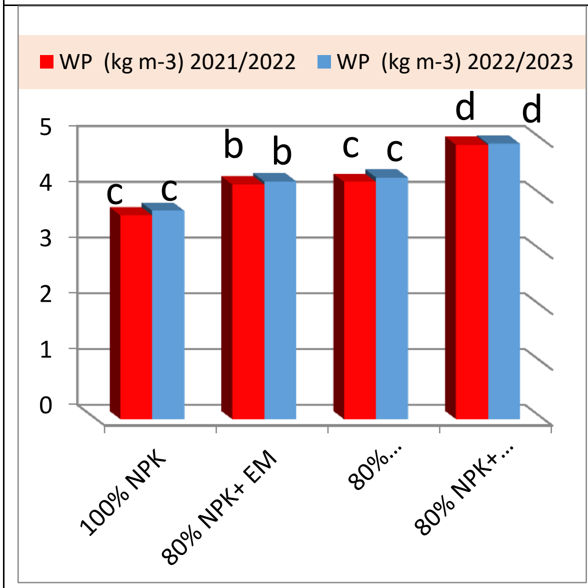

Fig (3c)

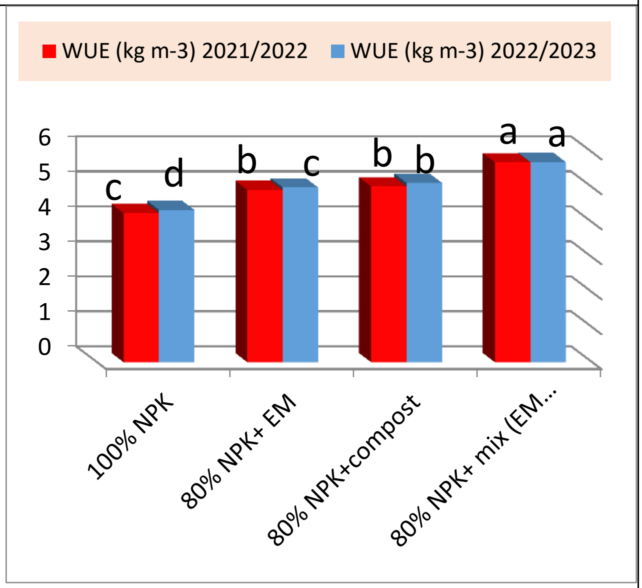

Fig (3d)

The means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P-value of ≤.0.05.

Figs (3a,b,c and d): Influence of fertilizers application (as individual effect) on water applied (IW m^3), water consumptive use (WCu m^3), the water productivity (WP kg m^{-3}) and the water use efficiency (WUE kg m^{-3}).

Table 6: Interaction effect of fertilizers application and cultivation methods o on water applied (IW m3), water consumptive use (WCU m^3), the water productivity (WP kg m^{-3}) and the water use efficiency (WUE kg m^{-3}).

Treatments		IW (m^3 ha^{-1})		WCU (m^3 ha^{-1})		WP (kg m^{-3})		WUE (kg m^{-3})	
		2021/ 2022	2022/ 2023	2021/ 2022	2022 /2023	2022 /2023	2021/ 2022	2022/ 2023	2021/ 2022
C1	F1	5535a	5488a	4871a	4854a	1.382i	1.401i	1.559g	1.567h
	F2	5330bc	5276bc	4671e	4649c	1.618g	1.624f	1.818f	1.837f
	F3	5256cd	5227cd	4589d	4577d	1.625g	1.645e	1.845f	1.882ef
	F4	5066e	5004e	4451ef	4446e	1.81cd	1.794d	2.065cd	2.062cd
C2	F1	5372b	5325b	4755b	4745b	1.456	1.496g	1.628g	1.672g
	F2	5239cd	5207cd	4574d	4567d	1.666f	1.661e	1.880ef	1.805f
	F3	5175d	5148d	4493e	4481e	1.692e	1.681de	1.917ef	1.958de
	F4	5012e	4972e	4384f	4379f	1.881c	1.845cd	2.134c	2.146c
C3	F1	4792f	4804f	3915g	3905g	1.711de	1.883c	2.000de	2.051cd
	F2	4634g	4673g	3809h	3799h	1.948b	2.115b	2.287b	2.329b
	F3	4562g	4599g	3688i	3676i	1.985b	2.168b	2.345b	2.392b
	F4	4140h	4169h	3460j	3470j	2.294a	2.413a	2.742a	2.745a
LSD 0.05		97.61	83.54	74.25	43.92	0.11	0.53	0. 27	0.25

C1: Broad casting,, C2: Ridges C3: Raised bed , F1: 100% NPK (control), F2: 80% NPK+ EM, F3: 80% NPK+compost) and F4: 80% NPK+ mix (EM and compost).The means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P-value of ≤.0.05.

Table 7: Influence of different Cultivation Methods and Fertilization on Plant height, Grain yield (ton ha^{-1}), straw(ton ha^{-1}) , 1000 grain and Protein%

Treatments	Plant height (cm)		Grain yield (ton ha^{-1})		straw(ton ha^{-1})		1000 grain (g)		Protein%	
	2021/ 2022	2022/ 2023	2021/ 2022	2022 /2023	2021 /2022	2022 /2023	2021 /2022	2022 /2023	2021/ 2022	2022/ 2023
Cultivation methods										
C1	93.53b	93.69b	8.438c	8.482c	17.30c	17.63c	58.39c	58.51c	7.02c	7.04c
C2	94.65b	94.87ab	8.583b	8.702b	17.88b	18.06b	59.16b	59.37b	7.06b	7.08b
C3	95.84a	96.69a	8.665a	8.796a	18.31a	18.57a	60.35a	60.42a	7.17a	7.19a
LSD 0.05	1.138	2.001	0.065	0.0445	0.057	0.052	0.238	0.398	0.014	0.020
Fertilization treatments										
F1	91.36c	91.53c	7.714c	7.850c	16.17d	16.36d	56.64d	56.83d	6.92c	6.95c
F2	94.32b	94.89b	8.578b	8.697b	17.96c	18.25c	57.70c	57.76c	7.03b	7.05b
F3	94.92b	95.38b	8.601b	8.729b	18.41b	18.74b	58.37b	58.29b	7.05b	7.07b
F4	98.08a	98.54a	9.354a	9.364a	18.79a	18.99a	64.48a	64.85a	7.34a	7.35a
LSD 0.05	1.364	0.991	0.052	0.059	0.0437	0.092	0.205	0.145	0.035	0.021

C1: Broad casting,, C2: Ridges C3: Raised bed , F1: 100% NPK (control), F2: 80% NPK+ EM, F3: 80% NPK+compost) and F4: 80% NPK+ mix (EM and compost).The means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P-value of ≤.0.05.

Table 8: Interaction effect of fertilizers application and cultivation methods o and Fertilization on Plant height, Grain yield (ton ha^{-1}), straw(ton ha^{-1}) , 1000 grain and Protein%.

Treatments		Plant height (cm)		Grain yield (ton ha^{-1})		straw(ton ha^{-1})		1000 grain (g)		Protein%	
		2021/ 2022	2022/ 2023	2021/ 2022	2022 /2023	2021 /2022	2022 /2023	2021/ 2022	2022/ 2023	2021/ 2022	2022 /2023
C1	F1	90.77f	90.81h	7.59h	7.61i	15.37j	15.61j	55.92h	56.22h	6.91h	6.95g
	F2	93.33de	93.51fg	8.49f	8.54g	17.76g	17.99g	57.62ef	57.54f	6.98efg	7.01f
	F3	94.01cd	94.21f	8.48f	8.62fg	17.88f	18.33e	57.88e	57.95e	7.00def	7.02ef
	F4	96.01c	96.22cde	9.19c	9.17c	18.19e	18.58d	62.12c	62.32c	7.18b	7.20c
C2	F1	91.44ef	91.88gh	7.74g	7.93h	16.39i	16.58d	56.55g	56.74g	6.92gh	6.95g
	F2	94.22cd	94.55ef	8.60e	8.70ef	17.92f	18.19f	57.65ef	57.82e	7.04cde	7.06de
	F3	94.88cd	94.92def	8.61e	8.77de	18.45d	18.63d	58.01e	58.41d	7.06cd	7.08d
	F4	98.05b	98.14b	9.38b	9.40b	18.77c	18.83c	64.43b	64.51b	7.22b	7.24b
C3	F1	91.88ef	91.91gh	7.81g	8.01h	16.74h	16.88h	57.45f	57.52f	6.94fgh	6.95g
	F2	95.41cd	96.61bcd	8.71d	8.85d	18.21e	18.58d	57.83ef	57.91e	7.06cd	7.08d
	F3	95.88c	97bc	8.65de	8.80d	18.89b	19.27b	59.22d	58.51d	7.08c	7.10d
	F4	100.17a	101.25a	9.49a	9.53a	19.40a	19.57a	66.88a	67.72a	7.60a	7.62a
LSD 0.05		2.003	1.716	0.090	0.133	0.085	0.079	0.251	0.251	0.061	0.037

C1: Broad casting,, C2: Ridges C3: Raised bed , F1: 100% NPK (control), F2: 80% NPK+ EM, F3: 80% NPK+compost) and F4: 80% NPK+ mix (EM and compost).The means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P-value of ≤.0.05..

Table 9: Influence of different Cultivation Methods, Fertilization and their interactions on nutrient content.

Treatments		N %		P %		K %	
		2021 /2022	2022 /2023	2021 /2022	2021 /2022	2022 /2023	2021 /2022
Cultivation methods							
C1		1.221c	1.224c	0.380b	0.388b	0.737c	0.751b
C2		1.228b	1.232b	0.382b	0.388b	0.756b	0.758b
C3		1.247a	1.250a	0.392a	0.407a	0.793a	0.799a
LSD 0.05		0.003	0.005	0.007	0.012	0.010	0.021
Fertilization treatments							
F1		1.204c	1.209c	0.347c	0.364c	0.626d	0.632d
F2		1.222b	1.226b	0.378b	0.386b	0.761c	0.771c
F3		1.225b	1.229b	0.383b	0.393b	0.789b	0.797b
F4		1.276a	1.279a	0.430a	0.435a	0.871a	0.878a
LSD 0.05		0.006	0.004	0.006	0.009	0.012	0.018
Interactions							
C1	F1	1.201h	1.208f	0.341e	0.363ef	0.621f	0.630f
	F2	1.214efg	1.219e	0.375d	0.379de	0.732e	0.741e
	F3	1.218def	1.221e	0.379d	0.382cd	0.745e	0.761de
	F4	1.249b	1.251c	0.425b	0.429a	0.851b	0.873ab
C2	F1	1.204gh	1.209e	0.349e	0.351f	0.627f	0.625f
	F2	1.224cde	1.228d	0.379d	0.382cd	0.752de	0.763de
	F3	1.227cd	1.231d	0.372d	0.386cd	0.771d	0.782cd
	F4	1.256b	1.259b	0.429ab	0.434a	0.872a	0.863b
C3	F1	1.207fgh	1.209f	0.351e	0.378de	0.631f	0.640f
	F2	1.228cd	1.231d	0.381d	0.396c	0.799c	0.808c
	F3	1.231c	1.234d	0.398c	0.412b	0.852b	0.849b
	F4	1.322a	1.326a	0.437a	0.442a	0.891a	0.898a
LSD 0.05		0.011	0.006	0.010	0.015	0.020	0.031

C1: Broad casting,, C2: Ridges C3: Raised bed , F1: 100% NPK (control), F2: 80% NPK+ EM, F3: 80% NPK+compost) and F4: 80% NPK+ mix (EM and compost).The means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P-value of ≤.0.05..

Table 10: Influence of different Cultivation Methods, Fertilization and their interactions on total uptake kgha-1.

Treatments		Total uptake N		Total uptake P		Total uptake K	
		2021 /2022	2022 /2023	2021 /2022	2021 /2022	2022 /2023	2021 /2022
				Cultivation methods			
C1		163.71c	166.24c	50.78c	52.36c	317.38c	324.44c
C2		170.13b	173.05b	52.64b	54.18b	330.02b	334.00b
C3		176.04a	179.80a	54.90a	57.37a	341.99a	348.00a
LSD 0.05		2.010	2.920	1.369	1.468	5.028	2.485
				Fertilization treatments			
F1		145.76d	149.01d	43.65d	46.06d	274.57d	278.94d
F2		167.09c	170.33c	52.12c	53.81c	334.097c	340.64c
F3		172.60b	176.56b	53.43b	55.66b	344.55b	351.96b
F4		194.39a	196.23a	61.89a	63.03a	365.97a	370.37a
LSD 0.05		2.311	2.012	1.180	0.863	4.168	3.334
				Interactions			
C1	F1	140.51i	142.29i	41.41h	43.67i	261.09g	256.83i
	F2	162.59g	165.10g	50.84f	51.99f	325.93e	331.19f
	F3	167.43f	171.36f	51.61ef	53.27f	330.64e	340.33e
	F4	184.30c	186.20c	59.26c	60.52c	351.84c	360.39v
C2	F1	147.12h	150.78h	44.23g	45.76h	278.15f	281.82h
	F2	167.81f	170.87f	51.96ef	53.24f	332.63e	338.92e
	F3	172.52e	176.17e	52.54ef	54.91e	343.68d	348.93d
	F4	193.09b	194.38b	61.83b	62.82b	365.60b	366.32b
C3	F1	149.64h	153.95h	45.31g	48.76g	284.47f	289.17g
	F2	170.88ef	175.01e	53.67e	56.20e	343.73d	351.81d
	F3	177.85d	182.14d	56.15d	58.79d	359.31b	366.61b
	F4	205.77a	208.12a	64.56a	65.73a	380.45a	384.39a
LSD 0.05		4.003	3.458	2.044	1.494	7.219	5.775

C1: Broad casting,, C2: Ridges C3: Raised bed , F1: 100% NPK (control), F2: 80% NPK+ EM, F3: 80% NPK+compost) and F4: 80% NPK+ mix (EM and compost).The means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P-value of ≤.0.05..

Table 11: Influence of different Cultivation Method, Fertilization and their interactions on soil contents post-harvest.

Treatments		N(mg kg-1)		P (mg kg-1)		K (mg kg-1)	
		2021 /2022	2022 /2023	2021 /2022	2021 /2022	2022 /2023	2021 /2022
				Cultivation methods			
C1		20.69c	20.74b	9.74c	9.79c	188.95c	188.58c
C2		20.77b	20.57c	9.89b	9.93b	189.88b	189.70b
C3		20.92a	20.98a	10.02a	10.08a	191.00a	191.08a
LSD 0.05		0.037	0.035	0.047	0.024	0.835	0.784
				Fertilization treatments			
F1		20.29d	20.36d	9.58c	9.64c	186.70d	186.64d
F2		20.62c	20.68c	9.92b	9.96b	188.17c	188.57c
F3		21.09b	20.80b	9.94b	9.99b	189.30b	189.70b
F4		21.16a	21.20a	10.09a	10.14a	195.60a	194.23a
LSD 0.05		0.039	0.024	0.061	0.078	0.993	0584
				Interactions			
C1	F1	20.26g	20.31h	9.5f	9.55e	186f	185.03i
	F2	20.35f	20.38fg	9.7de	9.75d	187.8def	188.1fgh
	F3	21.05c	21.09c	9.75d	9.78d	188.5de	188.9ef
	F4	21.11bc	21.16b	10.01bc	10.09bc	193.5b	192.3c
C2	F1	20.3fg	20.35gh	9.61e	9.68de	186.9ef	187.1h
	F2	20.56e	20.65e	9.94c	9.96c	187.9de	188.2fg
	F3	21.08bc	20.11i	9.95c	9.99c	188.9cd	189.3e
	F4	21.13b	21.16b	10.05bc	10.08bc	195.8a	194.2b
C3	F1	20.32fg	20.42f	9.64de	9.68de	187.2def	187.8gh
	F2	20.95d	21.02d	10.11ab	10.18ab	188.8cde	189.4e
	F3	21.15b	21.20b	10.15ab	10.21ab	190.5c	190.9d
	F4	21.24a	21.29a	10.20a	10.24a	197.5a	196.2a
LSD 0.05		0..068	0.042	0.106	0.135	1.720	1.012

C1: Broad casting,, C2: Ridges C3: Raised bed , F1: 100% NPK (control), F2: 80% NPK+ EM, F3: 80% NPK+compost) and F4: 80% NPK+ mix (EM and compost).The means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P-value of ≤.0.05..

Table 12: Influence of different Cultivation Method, Fertilization and their interactions on OM, pH and EC post-harvest.

Treatments		OM% 2021 /2022	OM% 2022 /2023	pH 2021 /2022	pH 2021 /2022	EC 2022 /2023	EC 2021 /2022
Cultivation methods							
C1		1.49b	1.50b	8.07	8.08	1.279a	1.290a
C2		1.52a	1.53a	8.10	8.09	1.268b	1.280b
C3		1.53a	1.54a	8.02	8.05	1.256c	1.257c
LSD 0.05		0.0151	0.0086	ns	ns	0.0097	0.0096
Fertilization treatments							
F1		1.45d	1.46d	8.19	8.19	1.360a	1.352a
F2		1.48c	1.51c	8.12	8.11	1.266b	1.275b
F3		1.54b	1.54b	8.09	8.08	1.231c	1.248c
F4		1.59a	1.58a	8.05	8.05	1.214d	1.227d
LSD 0.05		0.0101	0.0074	ns	ns	0.0112	0.0091
Interactions							
C1	F1	1.432g	1.441h	8.19	8.19	1.363a	1.360a
	F2	1.467f	1.498f	8.17	8.17	1.290b	1.288c
	F3	1.492e	1.506ef	8.15	8.14	1.243cd	1.270d
	F4	1.552cd	1.540d	8.11	8.11	1.221ef	1.241ef
C2	F1	1.453f	1.466g	8.19	8.19	1.367a	1.360a
	F2	1.488e	1.515e	8.12	8.09	1.261c	1.285cd
	F3	1.546d	1.564c	8.08	8.07	1.227de	1.244ef
	F4	1.593b	1.587b	8.02	8.02	1.218ef	1.229f
C3	F1	1.462	1.476g	8.18	8.17	1.350a	1.335b
	F2	1.491e	1.519e	8.07	8.07	1.248c	1.252e
	F3	1.567c	1.559c	8.03	8.04	1.224de	1.231f
	F4	1.611a	1.606a	8.01	8.02	1.203f	1.211g
LSD 0.05		0.0175	0.0129	ns	ns	0.0194	0.0158

C1: Broad casting,, C2: Ridges C3: Raised bed , F1: 100% NPK (control), F2: 80% NPK+ EM, F3: 80% NPK+compost) and F4: 80% NPK+ mix (EM and compost).The means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P-value of ≤.0.05.

3- Discussion

The ability of the raised bed method to conserve water can be attributed to the fact that fewer water was irrigated since less water was supplied to the furrow because it was lower in rSaised beds than in other methods of cultivation **(Mollah *et al*., 2009**). In this concern, **(Swelam *et al*., 2015**) displayed that raised beds water losses via evapotranspiration, deep infiltration, surface runoff, plus leakage. These were in line with (**Rajab & Kasem, 2022)** who suggested that using raised beds can reduce the amount of water irrigation water, hence conserve water, This, in turn, exhibited the highest values of both WUE kg m^{-1} and grain yield. Generally, the efficiency of cultivation methods can be arranged as follows raised bed method then ridges method, conventional method gave the lowest results in both seasons. The effectively of raised bed method compared with other cultivating methods is due to its optimistic result on reducing consumptive and applied irrigated water (**Ismail *et al*., 2021**) found that this technique can save water by (21.81%) while wheat production. Moreover, the use of water-absorbent substances like compost, to increase the soil's ability to retain irrigation water may be an effective solution to meet the water requirements of the plant **(Nadeem *et al*., 2017)& Védère *et al*., 2023)** There are many studies indicating that compost reduces the use of irrigation water **(Amin & Badawy, 2017**) because it retains soil moisture for a long time, and also provides the soil with a large group of bacteria that have multiple important functions for plant growth and productivity **(Elsherpiny *et al*., 2023)**. On the other hand, bio stimulants like EM (Effective microorganisms) play an essential role in restoring a vigorous ecosystem in soil and water **(Badawy *et al*., 2019).** They described that, application of bio stimulants improved irrigation water use efficiency (IWUE) values for garlic. The obtained results in related with (Rashwan & El-Saied, 2022).

Growth and yield criteria of wheat that were produced from raised beds methods were higher than broadcasting method, this attributed to efficiency micro environment for wheat on beds wherever the cultivation at suitable and regular depth, proportionate seed dispersion, and an adequate irrigation water as compared to conventional method (broadcasting). Raised beds methods accelerate root growth due to water and nutrient use efficiency (Ozberk *et al*., 2009). While conventional cultivating method gave fewer yield due to fewer nutrients in the submerged region (Bhuyan *et al*., 2016). The greatest sunshine entree through canopy to lower leaves, which supplied extra potential for grain stuffing, by raised bed scattering, may also have contributed to the heavier grains acquired, whereas the lesser grains weigh generated under the broadcasting approach may have been the result of poor growth. (Dawelbeit & Babiker, 1997) and (Kiliç & *et al*., 2010) and enhance number of spikes besides number of grains per spike enriched grain yield in raised beds method (Mohiy & Salous, 2022). In addition,1000 grains (g) weigh was also greater in biological fertilizers with raised bed method possibly will be owing to the management and geometry of bed, fewer weeds density, and improved crop (Bhuyan *et al*., 2012). The obtained results are in consent by (Meleha *et al.*, 2020) (Singh *et al*., 2021) and (Mohiy & Salous, 2022). The lack of harmful weeds in the beds may be attributable to the dry upper surface of the beds, which prevented weed growth. Caused lowest weed dry matter accumulation, weed NPK depletion, and greatest grain and straw yields, crop NPK uptake, and soil NPK availability. (Verma *et al*., 2018).

Moreover, potential improvements in beds' agronomy enhanced soil structure as a result of decreased compaction caused by less water logging. Also, improving soil-chemical properties and decreasing soil salinity (EC) after wheat production (Aiad *et al*., 2021). Using a raised bed technique, fertilizers are closed to the ridges, improving crop nutrient availability and weed-control ability. Reduced infestation is the result of better fertilizer placement and earlier drying of the upper part of raised bed, which both increase fertilizer usage efficiency (Bhuyan *et al*., 2012). The root system is considerably deeper and longer allowing them to use nutrients in larger amounts of soil with low nutrients. Deeper roots stimulated absorption high nutrients subsequently higher assimilation which increased tillers and spikes production than conventional cultivating. Additionally, applying various fertilizers in raised bed promoted root growth, which can get moisture from deeper layers of soil. Furthermore, fertilizers promote the growth of a canopy above the soil, which blocks more solar radiation and, uses less water because the evaporation component of evapo-transpiration is reduced (Bhuyan *et al.*, 2016).

Adding of compost that is a rich of organic matter (Hussein *et al*., 2022). improves the physical characteristics of the soil, such as structure, porosity, bulk density, compression strength. Besides water holding capacity and water permeability, It improves the efficiency of plant development, agricultural production and quality (Ghazi *et al*., 2022). This enhancement as a result of altered pore geometry, especially in water-holding pores. (Abdou *et al*., 2023), consequently support in the water stress tolerance (Elsherpiny *et al*., 2023). The application of organic fertilizers like compost reduced soil pH (Yassin *et al*., 2023); In the meantime, the soil's cation exchange capacity. Subsequently, available nutrient contents of grains were significantly increased. (Abdou *et al*., 2023). Also, applying compost caused increases in available soil nutrient (NPK) (Omara and Farrag, 2022). The increase could be linked to the compost amendment's positive role as a vital source of multiple macro- and micronutrients required for plant growth by removing moisture and nutrients from the root zone therefore soil was provided with enough organic matter and nitrogen (Awwad *et al*., 2022) and (Hussein *et al*., 2022). Compost is increasingly used in conjunction with chemical fertilizers as part of a combined nutrient management strategy that increase agricultural productivity and nutrient use efficiency (Cozzolino *et al*., 2023). The acquired results matched with (Shehzad *et al*., 2023) on wheat and (Abdou *et al*., 2023) who proved that, addition compost might save amount of irrigation water and improve the production of black caraway plants without a significant reduction compared with wholly irrigated one. Moreover enhances soil properties plus improves root growth consequently lead to increasing the absorbtion of nutrients and water.

The health of the soil, which is a reflection of a complex set of biological, chemical, and physical interactions caused by microorganisms, is a key determinant of agricultural production (Joshi *et al*., 2019). For sustainable crop production, efficient microbial inoculations improve soil fertility (Elshony *et al*., 2019; Omara *et al*., 2022; Rashed and Hammad, 2023); and suppresses soil borne pathogens (Eid *et al.,* 2019; Mohamed, 2019; Abdelhafez *et al*., 2021). This biota can also fix atmospheric N , improves nutrient uptake by plants (Lalarukh *et a*l. 2022),accelerates the decomposition cycle of different organic resudies to set essential minerals free for proper plant growth (Tolba *et al.*, 2021; Farid *et al.*, 2022). Overall, these biota mentain the chemical and physical characteristics of soil. Our results matched with (Abu-Qaoud *et al*., 2021) who found that the application of EM significantly lowered electrical conductivity and had positive effects on crop quality and at the same time improved soil chemical and physical properties, which will increase availability of nutrients for wheat growth.

It's important to note that adding bio fertilizers in presence of compost increased in the microbial biomass in soil, which in turn increased their effectiveness in improving the growth of plants via production of growth promoting compounds like cytokinins, Indole Acetic Acid, Gibberillins (Saharan & Nehra, 2011). Moreover, this combination raised the nutritional status of wheat grain. Some bioinoculants can fix atmospheric N and increase the degradation rate of compost and therefore enrich soils with nutrients. In this concern, compost is regarded as a large store of nutrients, particularly P, K, and micronutrients (Fiorentino & Fagnano, 2011). Additionally, compost enhances the physical characteristics of soil, which enhances root development and increases nutrient uptake by plants These merits had positive consequences on improving the nutritional status of wheat plants and consequently increase yield component of wheat. These obtained results are concordant with (Abou-El-Hassan *et al*., 2019) and (Elbagory, 2023).

4- Conclusions

It might be suggested that using raised bed cultivation techniques, compost, and EM together are efficient ways for farmers to increase growth. and wheat productivity increasing the efficiency of use water by about 25% compared to conventional methods.

Conflicts of interest

There remained no possible conflicts of interest revealed by the authors.

Author contribution: The authors approve that they are free of any known financial conflicts of interest or close relations that might have observed to have effect on the research in this study.

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