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Economic evaluation of cereal crop production in Egyptian sandy soils

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Abstract: Two field experiments of Egyptian sandy soils were chosen. The main objectives of this investigation are to study and evaluate the effect of natural raw minerals, soil conditioners, their mixtures and their application rates in sandy soil subjected to different irrigation deficits on the economic yield of wheat and maize crops as well as on crop water productivity. Four types of soil conditioners (bentonite, compost, mixture of natural mineral raw materials and their mixtures 1:1:1) were mixed well to soil before cultivation. The application process was conducted through two recommended rates, the first rate represent the low (R1), while the second represent the high level (R2). Irrigation treatments were scheduled according to the moisture depletion regimes in three levels, irrigation at 30, 50 and 70 % depletion from soil available water. By summarizing these results in easy readable charts, adding soil conditioners improved crop water productivity and also increased the farm net return. The mixture from different conditioners (1:1:1) treatment realized the superiority for both experiments. The highly application rate (R2) was better than the lowest application rate (R1). Also, irrigation at 50 % depletion from available water achieved the best values of water productivity and economic evaluation in meaning of net return as well.

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1. Introduction:

Egypt is the largest wheat importer worldwide. According to the Food and Agriculture Organization of the United Nations **(FAO 2012)**, the area of cultivated wheat in Egypt is 1,336,234 hectares and the yield that comes out of it is 6.58 tons per hectare, resulting in a total wheat production of around 8,795,483 tons. According to the USDA the 2014 domestic wheat consumption in Egypt was 19,100,000 tons. With constant population growth and decreasing arable land in Egypt, the risk to demand levels is ever increasing. According to the United Nations (UN), the global population is expected to jump from slightly over 7bn to around 9.6bn by 2050, with most of that increase occurring in the developing world.1 As population and incomes increase in those regions, it is estimated that food production will have to grow by 70% in order to meet demand **(UN,2015).** Sandy soils widely exist in arid and semi-arid regions such as the east and west desert areas of Egypt. Increasing the productive lands is one of the major targets of the agricultural policy. The productivity of sandy soils is mostly limited by several agronomic obstacles. Their very low specific surface area caused its inert chemical and biological conditions. The fertility level of such soils is very poor and is controlled by their fine fractions, i.e. clay and organic matter contents. In this respect, **Abd El-Kader (1999)** showed that nutrients applied to raise the low fertility of sandy soils were subjected to loss by leaching. Due to low water retention of such soil, it needs frequent irrigations at short intervals. Nowadays, the term of « sustainable agriculture » is widely used in Egypt, which is keystone of the rational utilization of soils as one of our most important natural resources. It is the important aims of « sustainable agriculture » to protect and maintain of the multifunction of soils **(Varallyay, 2005).** For preservation and sustainability the productivity of soil we have to take special regard to sandy soils having unfavorable properties. Sandy soils characterized by less than 18 % clay and more than 68 % sand in the first 100 cm of the soil depth are the poor soils that occur in many parts of the world **(van Wambeke,1992).**

Tackling these problems can be achieved through applying organic amendments, natural raw minerals and soil conditioners. These materials improve the retentive capacities of these soils and allow plants to get their water requirements and phyto –available nutrients easily.

Cereal crops such as (wheat and maize) are very strategically important crops in Egypt because it's constituent and indispensable part of Egyptian food diet. Generally, there is a great gap between the consumption and production of such crops. On the other hand, it is worth noting that, the agriculture production in Egypt is mainly depending upon irrigated agriculture. The gap between supplies and demands of water is widening with increasing global population. We are suffering from this trouble, especially when we know that we are under water poverty limit. Because of the water limitation, one of the most important targets in the agriculture sector is how to save irrigation water and increase water use efficiencies. So, new techniques and practices are needed to achieve water save. Estimating irrigation water becomes important for project planning and irrigation management. Despite the progressive water shortage, the over irrigation practiced by the farmers usually using flood irrigation leads to low irrigation efficiency. So it is necessary to ascertain to what extent the water in the root zone can be depleted to produce high economic yield with using little water applied. Planning best irrigation regimes is very important for maintaining available irrigation water. The proper water management (irrigation scheduling) not only accurate determination of crop water requirements but also helps to know when and how much water should be applied to get high efficiency of each unit of water, **(Kheir ,2013)**. Regulated deficit irrigation is one of such practices. Many studies indicated that the deficit irrigation was a successful technique in crops irrigation, **Omran(2005) and Seif *et al*.(2005).** The agricultural sector faces the challenge to produce more food with less water by increasing crop water productivity results in either the same production from less water resources, or a higher production from the same water resources (**Kheir ,2013)**. Therefore, the main objectives of this investigation were to study and assess the effect of natural raw minerals and soil conditioner types, their mixtures (1:1:1) and application rates in sandy soils subjected to different soil moisture on the following parameters:

(i) Field water use efficiency (productivity) of wheat and maize crops under the studied conditions.
(ii) Evaluation the cereal crop production economically.

2. MATERIALS AND METHODS:

One field experiment represents arable sandy soil located at Abou-Omera Al-Sharkeya village , Baltim district, Kafr El-Sheikh Governorate 31° 34 40.6 N latitude and 31° 10 55.5 E longitude with an elevation of about 2 meters above sea level was chosen. Soil was cultivated with two cereal crops wheat and maize. Wheat crop was cultivated during the winter season period 2014/2015, meanwhile maize crop was cultivated during the summer season of 2015. The experimental plot area was 10m^2 (2x5 m).The experimental design was split-split plot arrangement with three replications. The main plots were devoted to three irrigation treatments as follows: after 30 % depletion from soil available water ; after 50 % depletion from soil available water and after 70% depletion from soil available water. Wheat and maize plants were exposed to deficit irrigation and started directly after life watering irrigation (El-Mohayaa irrigation) for achieving the selected available soil moisture depletion levels under consideration. The sub –plots were assigned to five types of soil conditioners and their mixtures 1:1:1(w/w). The conditioner treatments (w/w) were applied as follows: Control (without additions); Bentonite at application rates of 0.2 % and 0.3%. ; compost at application rates of 0.3 % and 0.5 %; Mixture of Natural Raw Minerals (MNRM) at application rates of 0.2 % and 0.3 %; and the mixtures of the three previous conditioners in 1:1:1 ratio at rates of 0.233% and 0.367%. The soil conditioner treatments were randomly distributed in the three main plots. The initial analysis of the experimental soil is shown in Tables 1and 2.

These conditioner types are mixed well with soil during its preparation for cultivating before sowing and incorporated into soil surface. Sub sub plots were occupied with two application rates as follows: R1 and R2 were (low) minimum and (high) maximum recommended application rates respectively. The chemical analysis of these materials listed in Table 3. Seeds of wheat plants (Triticum aestivum, Sakha 93 variety) were obtained from Crop Agronomy Research Department, Sakha Agriculture Research Station, Ministry of Agriculture and Land Reclamation. Grains of maize plants (Zea mays,L) three cross 321 variety were obtained from Maize Research Center, Agriculture Research Center, Ministry of Agriculture and Land Reclamation. Two field- experiments were carried out on cultivated area of Abou-Omera East village , Baltim district during the two successive growing winter and summer seasons period 2014/2015.

We also carried out the co-composting process during the summer growing season elongated five months from May 2013 to October 2013. Pyramidical piles (heaps) 2.5 × 2.5 ×1.5 m were built up under aerobic conditions. Different solid bio-wastes were used as substrates and augmented organically with farmyard manure (10 % w/w) as microbial organic activator as well as with urea, super phosphate and potassium sulfate as microbial chemical activators. The other certain additional materials were incorporated into for speeding up the conversion and improving the final product quality and as growth promoting substances, pH buffering agents and as bulking agents. The obtained chemical and physical characteristics of the used matured compost after co- composting process are listed in Table 4. This matured compost was used as soil conditioner.

Irrigation water supply:

Magnitude of irrigation applied water were calculated using the following soil moisture depletion equation as reported by (**Israelson and Hansen , 1962)** during wheat and maize growing season periods.

3. Results and discussions:

3.1. Crop water productivity as influenced by different treatments:

Data in Fig.1 showed that wheat water productivity values increased significantly as affected by application of natural soil conditioners. It was also found that second rate of application was better than first rate in increasing water productivity (WP). Under irrigation at 30% depletion from available water, the highest values of WP was recorded 1.81 kg m^{-3} with using mix of all under first rate of application followed by 1.47, 1.3 and 1.18 kg m^{-3} for MNRM, bentonite and compost respectively compared to control 1.03 kg m^{-3}. Whereas, under second rate of application, the highest value of WP 1.77 kg m^{-3} with adding mixture from all conditioners followed by MNRM, Bentonite and Compost respectively.

Data also indicated that, values of WP increased under irrigation at 50% depletion from available water and gave the highest values 1.53 kg m^{-3} as compared to irrigation at 30% and 70% depletion from available water. It was found that, the highest values of WP, 1.9 kg m^{-3} was recorded with adding mixture from all conditioners followed by 1.83, 1.61 and 1.45 for MNRM, bentonite and compost, respectively as compared to 1.13 kg m^{-3} with control under second rate of application. Such values decreased slightly with first rate of application, where the highest value of WP 1.59 kg m^{-3} with mixture from all conditioners followed by 1.55, 1.38 and 1.28 for MNRM, bentonite and compost, respectively. These results were in agreement with results obtained by **Michael (1978) and Naeem and Rainiaz (2005).** On the other hand, irrigation at 70% depletion from available water gave the lowest values of WP as compared to irrigation at 30 and 50%. This may be due to decreasing grain yield in this irrigation regime as compared to others.

Regarding maize crop water productivity as affected by different treatments, Data in fig. 2 shows that maize water productivity increased with applying conditioners especially with second rate of application as well as with increasing the rate of depletion from available water. Where, under 30 % depletion, maize water productivity increased to 0.75 , 0.745 , 0.73 and 0.91 kg m^{-3} for compost , mix of all , MNRM and bentonite respectively as compared with control 0.46 kg m^{-3}. While, under 50 and 70 % depletion this increasing in water productivity took the following order: mix of all > compost > MNRM > bentonite. Data also indicated that values of water productivity in case of second rate of application were better than those in first rate. This may be due to increasing water saving with second rate of application. With respect to irrigation depletion and its effect on maize water productivity. Data show that, under the same conditioner, increasing the level of depletion from available water increased maize water productivity. Where , mean value of water productivity under 70 % depletion was 1.15 kg m^{-3} which decreased to 0.73 kg m^{-3} under 30 % depletion passing by 0.95 kg m^{-3} under 50 % depletion from available water . These results were similar to those obtained by **Saleh and Ozawa (2006) and Karrow et al (2012).**

3.2. Economic evaluation of wheat as affected by adding some natural and conditioners and irrigation regime

Economic assessment requires some items through which the evaluation process can be conducted. The suggested items of the economic evaluation for each treatment (separately) in order to Trade – offs between them, economically are:

1 – Theoretical grain yield ; 2 – Total seasonal cost ; 3 – Total seasonal return 4 – Net return (NR) = (total return – total cost) ; 5 – Benefit Cost Ratio (BCR) = (total return / total cost) ; and 6 – Specific Cost (L.E/kg) = (total cost / theoretical grain yield).

In order not to overlook one of the components of income from the wheat crop (grain and straw) during the process of its economic evaluation. It has been converted the cash flow of the straw yield to what equivalent it in terms of weight of grains. Then added this assumed weight to the actual grain yield, to give what so – Called the theoretical grain yield. The latter is used in calculation some economic indicators that contribute to the economic evaluation. The following equation specialized to calculate theoretical grain yield:

Theoretical grain yield (kg acre^{-1}) = { straw weight (kg acre^{-1}) × price of one ton of straw (L.E) ⁒ price of grain L.E } + grain yield (kg) .

Data in Table 5 pointed out that there was an inverse relationship between the depletion level of the available soil moisture and the theoretical grain yield , while this relation was positive with conditioners and also with increasing the rate of application . It was obvious that, maximum value of theoretical grain yield 2648.37 kg acre^{-1} was achieved by irrigation at 50 % depletion from available water and decreased to 2236.38 kg acre^{-1} with 70 % depletion from available water passing by 2428.28 kg acre^{-1} under irrigation at 30 % depletion from available water. Vice versa was observed with conditioners , where , under the same level of irrigation , values of theoretical grain yield increased with increasing rate of conditioners and took the following descending order : mix of all > MNRM > bentonite > compost . From the data tabulated in Table 5 , it was clear that the mean values of the total seasonal return for various levels of soil moisture depletion were ranged in descending order from 50 % depletion from available water (6885.75 L.E acre^{-1}) to the treatment of 70 % (5815.74 L.E acre^{-1}) passing by the treatment of 30 % (6313.53 L.E acre^{-1}) . Concerning natural soil conditioners, data showed that within each irrigation treatment, increasing the rate of application resulting in increasing the total seasonal returns. Mix of all conditioners achieved the highest values of total seasonal return followed by MNRM , bentonite and compost respectively . This trend may be due to increasing grain and straw yield by using such conditioners.

Data in Table 5 and Fig. 3 revealed that the net seasonal, revenue showed the same trend as in the abovementioned indicator, (i.e. the seasonal total return) . This trend may be due to that the production cost for each system separately , seem to be semi – fixed , or that the differences between them are relatively very small compared to the corresponding value of the differences between the return for each system which are relatively larger . The highest value 1851.99 L.E acre^{-1} was obtained by adding mix of all conditioners with maximum rate under irrigation at 50 % depletion from available water. While, the lowest value of net return – 1951 L.E acre^{-1} was recorded by adding MNRM with highest rate under irrigation at 70 % depletion from available water . This may be attributed to increasing initial cost of MNRM (1200 L.E /acre) as compared to other conditioners. From the presented data in Table 5 and Fig. 4 it is clear that the same tendency of the abovementioned economic indicators appears obviously, that it prevalent with this indicator. The highest ratio 1.2 was obtained by irrigation at 50 % depletion from available water and decreased to 1.02 under irrigation at 70 % depletion from available water passing by 1.07 under 30 % depletion from available water. Data showed that, increasing the rate of conditioners increased the benefit cost ratio.

It is defined as the relation between the total seasonal cost (L.E acre^{-1}) and the theoretical grain yield (kg acre^{-1}) . It is clear from the data exhibited in Table 5 and Fig. 5 , that the specific cost of the theoretical grain yield for different treatments showed a reversal tendency to those of previous indicators , in which , the specific cost decreased as the available soil moisture content increased . While, adding conditioners increased such values specially MNRM1 under irrigation at 70 % depletion which gave the value of specific cost 2.93 L.E acre^{-1}.

3.3. Economic evaluation of maize as affected by adding some natural and conditioners and irrigation regime

Data in Table 6 pointed out that , the highest value of theoretical grain yield 3184.28 kg acre^{-1} was obtained by irrigation at 50 % depletion from available water and decreased to 2939.35 kg /acre under 70 % depletion from available water passing by 3038.75 kg acre^{-1} under 30 % depletion from available water as compared with control which was 2038.75 kg acre^{-1}. Respecting to natural conditioners and their effect on theoretical grain yield, data show that, under the same level of irrigation depletion, values of theoretical grain yield increased with adding soil conditioners. This increasing took the following descending order: compost > mix of all > MNRM > bentonite. Data also revealed that, second rate of application was better than first rate of application in increasing maize theoretical grain yield.

Data in Table 6 and Fig. 6 showed that compost gave the highest values of the net seasonal revenue followed by the first rate of mix of all. While, other conditioners were none economic. Where, under 30 % depletion from available water, the highest values of net return 841 and 362 L.E acre^{-1} were obtained by compost followed by first rate of mix of all. Under 50 % depletion from available water , the highest values of net return 679 L.E acre^{-1} was achieved by second rate of compost followed by 423 L.E acre^{-1} with first rate of mix of all. While under 70 % depletion from available water, first rate of compost gave the highest value of net return. Vice versa, the lowest value of net return - 1936 L.E acre^{-1} was recorded by adding MNRM with second rate under 30 % depletion. This may be attributed to increasing initial cost of MNRM (1200 L.E acre^{-1}) as compared with other conditioners. Fig.7 shows the highest ratio 0.97 was obtained by irrigation at 50 % depletion from available water. Data also indicated that compost gave the highest ratio followed by mix of all. Fig.8 indicates the lowest values of specific cost were obtained by adding compost and mix of all. Data also indicated that irrigation at 50 % depletion from available water gave the lowest value of specific cost

2.05 L.E $acre^{-1}$ as compared with 30 and 50 % depletion from available water.

Conclusion:

Under sandy soil conditions where high infiltration rate and low water holding capacity, nutrient and organic matter poverty and Structure less soil. Adding some natural soil conditioners like (compost, bentonite, MNRM and mixture from them) is very important for enhancing crop water productivity from such soils. The best conditioners used economically were mix of all conditioners and compost, where decreasing bulk density and hydraulic conductivity, increased ionic strength, soil available water, macro and micro nutrients, thus increasing the crop productivity and enhancing the crop economic return. Also, under the same conditioners, irrigation at 50 % depletion from available water is the best scheduling method achieves the highest value of crop water productivity economically.

Table 1. Initiative physico-chemical characteristics of the selected arable experimental site.

Soil Characters	Obtained values
Chemical analysis	
Soil reaction pH (1:2.5 soil-water suspension)	7.90
Electrical conductivity, EC dSm^{-1} (Soil past extract) at 25 C°	3.75
Saturation percentage(S.P)	40.0
Total soluble salts(T.S.S) $mg\ kg^{-1}$ soil	960(0.096%)
Calcium carbonate ($CaCO_3$)	0.60
Total soluble ions(1:5 Soil-water extractions)	
Soluble cations	
Ca^{+2} $meq\ L^{-1}$	1.00
Mg^{+2} $meq\ L^{-1}$	1.20
Na^{+} $meq\ L^{-1}$	3.70
K^{+} $meq\ L^{-1}$	0.10
Soluble anions	
$CO_3^{=}$ $meq\ L^{-1}$	0.00
HCO_3^{-} $meq\ L^{-1}$	1.50
CL^{-} $meq\ L^{-1}$	2.00
SO_4^{-2} $meq\ L^{-1}$	2.50
EC , dSm^{-1} (1:5 soil-water extraction)	0.602
Ionic strength (I.S)	4.45
Sodium adsorption ratio(SAR)	3.53
Soluble sodium percentage(SSP) %	61.7
Physical analysis	
Particle size distribution (g/100g soil)	
Coarse sand fraction %	50.0
Fine sand fraction %	5.50
Silt fraction	31.0
Clay fraction	13.5
Soil texture class	Loamy sand
Soil bulk density(Db) $Mg\ m^{-3}$	1.55
Soil particle density (Dp)) $Mg\ m^{-3}$	2.66
Total porosity(ρt) on volume basis %	41.73
Soil saturated hydraulic conductivity (S.H.C) $m\ day^{-1}$	2.65

Table 2. Soil moisture constants and its nutritional status of the selected experimental site before planting.

Soil variables		Obtained values
Soil moisture constants		
Soil field capacity(S.F.C)	%	18.0
Soil permanent wilting point(P.W.P)	%	9.00
Soil available water capacity(A.W.C)	%	9.00
Soil nutritional status		
Total organic-C	%	0.232
Organic matter(O.M)	%	0.400
Available macro-nutrients		
Available – N(K-sulphate extractable)	$mgkg^{-1}$ soil	21.5
Available – P($NaHCO_3$ extractable)	$mgkg^{-1}$ soil	8.90
Available – K(NH_4-acetate extractable)	$mgkg^{-1}$ soil	53.5
Available micronutrients		
Available – Fe(DTPA extractable)	$mgkg^{-1}$ soil	6.50
Available - Mn(DTPA extractable)	$mgkg^{-1}$ soil	5.00
Available-Zn(DTPA extractable)	$mgkg^{-1}$ soil	1.10
Available – Cu (DTPA extractable)	$mgkg^{-1}$ soil	0.66

Table 3. Chemical analysis of the used natural raw minerals and soil conditioners

Characteristics	Values	
	Bentonite	MNRM
Elemental oxides: %		
SiO_2	55.9	39.36
TiO_2	0.20	0.81
Al_2O_3	20.0	7.68
Fe_2O_3	0.70	4.05
MnO	0.001	0.67
MgO	0.65	3.20
CaO	2.70	15.07
Na_2O	1.76	1.95
K_2O	2.40	3.94
P_2O_5	0.80	7.33
SO_3	-	5.83
Loss on ignition	10.0	9.14
ECe dS m^{-1}(1:10 Bentonite-water extract(w/v)	1.82	
pH (1:2.5 bentonite-water suspension (w/v)	7.12	
Total soluble cations (*m*eq L^{-1}) (1:5 extracts)		
Ca^{+2}	0.79	
Mg^{+2}	0.27	
Na^{+}	1.95	
K^{+}	0.02	
Total soluble anions (*m*eq L^{-1}) (1:5 extracts)		
$CO_3^{=}$	-	
HCO_3^{-}	0.24	
Cl^{-}	1.59	
$SO_4^{=}$	1.06	
Cation exchange capacity, cmoles kg^{-1}	59.13	
Calcium carbonate %	14.27	
Particle size distribution %		
Clay fraction	85.75	
Silt fraction	10.54	
Sand fraction	3.71	

Table 4. Chemical properties of the used co-compost directly after composting process

Characteristics	**Values**
Dry weight (kg m^{-3})	650.0
Moisture content (%)	25.5
Odour and colour	Acceptable and dark
pH (1:10 compost-water suspension w/v)	7.16
EC (1:10 compost – water extraction w/v)	5.23
Total soluble salts(soil paste –water extraction 1:10)%	0.335
Saturation percentage % (g/100g	175.0
Total soluble salts (compost material)% (g/100g compost)	0.586
CEC (cmole kg^{-1})	64.34
Total organic – c %	25.5
Total organic matter %	43.96
C/N ratio	21.98
Total macro-nutrients %	
Total – nitrogen %	1.16
Total – phosphorus %	0.53
Total – potassium %	0.37
Available macro-nutrients (*mg* kg compost)	
Available – N (potassium sulfate)	100
Available – P (0.5 M $NaHCO_3$- pH 8.5)	50
Available – K (ammonium acetate pH 7)	85
Available micro-nutrients (*mg* kg compost)	
Available – Fe	450
Available – Mn	100
Available – Zn	35
Available – Cu	135
Total micro-nutrients (*mg* kg compost)	
Total –Fe	753
Total – Mn	361
Total – Zn	297
Total – Cu	168
Available heavy metals (*mg* kg compost)	
Available – cd	13.2
Available – Ni	62.7
Available – pb	120

Table 5. Economic criteria for the first wheat experiment

Water depletions	Soil conditioners	Theoretical grain Yield (kg acre^{-1}) **a**	Total Seasonal Return (L.E acre^{-1}) **b**	Total seasonal Cost , (L.E facre $^{-1}$) **C**	Net return (L.E acre^{-1}) **b-c**	Benefit Cost ratio ,BCR **b/c**	Specific Cost (L.E/Kg) **c/a**
30 %	Control	1771.53	4605.97	4029	576.9	1.14	2.27
	B1	2258.46	5871.99	5429	442.99	1.08	2.40
	B2	2553.84	6639.98	6099	540.98	1.08	2.38
	C1	1981.53	5151.97	5029	122.97	1.02	0.97
	C2	2316.15	6021.99	5645	376.99	1.06	2.43
	MNRM 1	2307.69	5999.99	6529	-529	0.91	2.82
	MNRM 2	2951.53	7673.97	7749	-75	0.99	2.62
	Mix of all 1	2644.61	6875.98	5754	1121.98	1.19	2.17
	Mix of all 2	3069.23	7979.99	6539	1440.99	1.22	2.13
	Mean	**2428.28**	**6313.53**	**5866.88**	**446.64**	**1.07**	**2.24**
50 %	Control	2094.61	5445.98	3954	1491.98	1.37	1.88
	B1	2451.53	6373.97	5154	1219.97	1.23	2.1
	B2	2771.53	7205.97	6024	1181.97	1.19	2.17
	C1	2352.30	6115.98	4954	1161.98	1.23	2.10
	C2	2449.23	6367.99	5349	1018.99	1.19	2.18
	MNRM 1	2665.38	6929.98	6454	475.98	1.07	2.42
	MNRM 2	3105.38	8073.98	7674	399.98	1.05	2.47
	Mix of all 1	2746.92	7141.99	5679	1462.99	1.25	2.06
	Mix of all 2	3198.46	8315.99	6464	**1851.99**	1.28	2.02
	Mean	**2648.37**	**6885.75**	**5745.11**	**1140.64**	**1.20**	**2.15**
70 %	Control	1893.07	4921.98	3859	1062.98	1.27	2.03
	B1	1910.76	4967.97	5259	-291	0.94	2.75
	B2	2367.69	6155.99	5929	1296.99	1.03	2.5
	C1	1899.23	4937.99	4859	-541	1.01	2.55
	C2	2150	5590.00	5479	111	1.02	2.54
	MNRM 1	2164.61	5627.98	6359	-731	0.88	2.93
	MNRM 2	2930.76	7619.97	7579	**-1951**	1	2.58
	Mix of all 1	2172.30	5647.98	5584	63	1.01	2.57
	Mix of all 2	2643.07	6871.80	6369	502.8	1.07	2.40
	Mean	**2236.83**	**5815.74**	**5697.33**	**-53**	**1.02**	**2.53**

Table 6. Economic criteria for the second experiment (maize growing season).

Depletion	Conditioners	Theoretical grain Yield (Kg/acre) **a**	Total Seasonal Return (L.E/acre) **b**	Total seasonal Cost (L.E/acre) **C**	Net return (L.E/acre) **b-c**	Benefit Cost ratio **b/c**	Specific Cost (L.E/acre) **c/a**
30 %	**Control**	**2038.75**	**4077.5**	**4664.0**	**-586.5**	**0.87**	**2.28**
	B1	2972.50	5945.0	6064.0	-119.0	0.98	2.04
	B2	3026.00	6052.0	6734.0	-682.0	0.89	2.22
	C1	**3252.50**	**6505.0**	**5664.0**	**841.0**	**1.14**	**1.74**
	C2	**3323.00**	**6646.0**	**6284.0**	**362.0**	**1.05**	**1.89**
	MNRM 1	3156.25	6312.5	7164.0	-951.5	0.88	2.26
	MNRM 2	3223.75	6447.5	8384.0	-1936	0.76	2.60
	Mix of all 1	3226.75	6453.5	6389.0	64.50	1.01	1.98
	Mix of all 2	3291.25	6582.5	7174.0	-591.5	0.91	2.17
	Mean	**3056.75**	**6113.5**	**6502.33**	**-399.9**	**0.94**	**2.13**
50 %	Control	2222.00	4444.0	4604.0	-160.0	0.96	2.07
	B1	3091.75	6183.5	6004.0	179.5	1.02	1.94
	B2	3187.50	6375.0	6674.0	-299.0	0.95	2.09
	C1	**3340.00**	**6680.0**	**6504.0**	**176.0**	**1.02**	**1.94**
	C2	**3451.50**	**6903.0**	**6224.0**	**679.0**	**1.10**	**1.80**
	MNRM 1	3223.75	6447.5	7104.0	-556.5	0.90	2.20
	MNRM 2	3331.25	6662.5	8324.0	-1561	0.80	2.49
	Mix of all 1	3376.00	6752.0	6329.0	423.0	1.06	1.87
	Mix of all 2	3434.75	6869.5	7114.0	**-** 244.5	0.96	2.07
	Mean	**3184.28**	**6368.5**	**6542.33**	**-151.5**	**0.97**	**2.05**
70 %	Control	2092.50	4185.0	4534.0	-349.0	0.92	2.16
	B1	2892.50	5785.0	5934.0	-149.0	0.97	2.05
	B2	2891.25	5782.5	6604.0	-921.5	0.87	2.28
	C1	**3098.00**	**6196.0**	**5534.0**	**662.0**	**1.11**	**1.78**
	C2	**3198.30**	**6396.6**	**6154.0**	**242.6**	**1.03**	**1.92**
	MNRM 1	3078.75	6157.5	7034.0	-976.5	0.87	2.28
	MNRM 2	3107.25	6214.5	8254.0	-2039	0.75	2.65
	Mix of all 1	**3156.25**	**6312.5**	**6259.0**	**53.5**	**1.00**	**1.98**
	Mix of all 2	**3213.75**	**6427.5**	**7044.0**	**-516.5**	**0.91**	**2.19**
	Mean	**2939.35**	**5878.7**	**6288.38**	**-434.6**	**0.94**	**2.13**

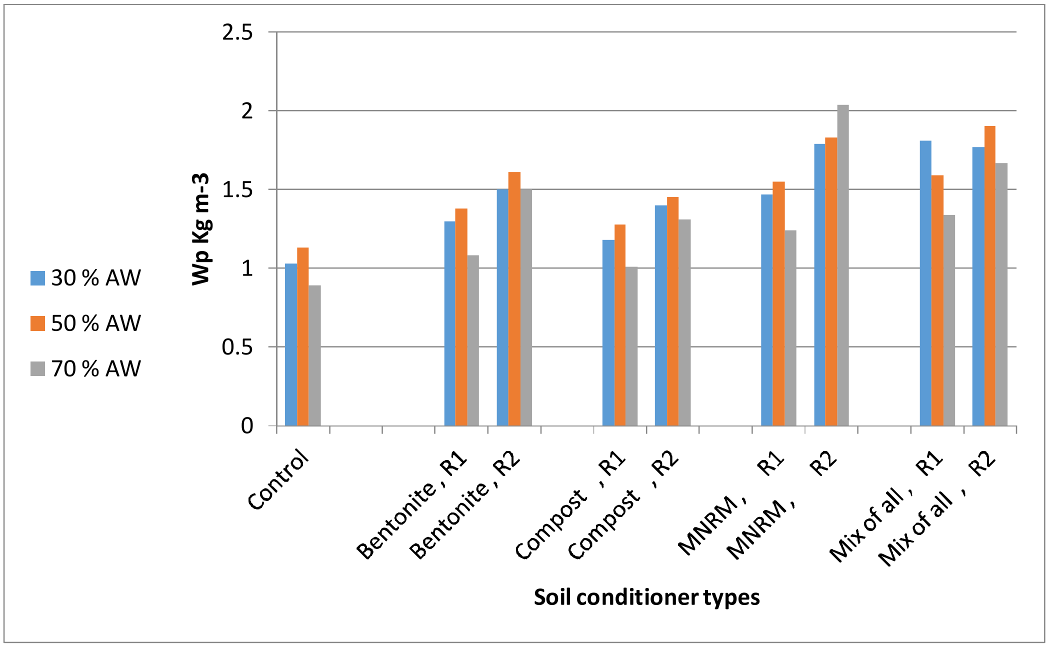

Fig. 1. Effect of natural soil conditioners on wheat Water productivity under different levels of water depletion.

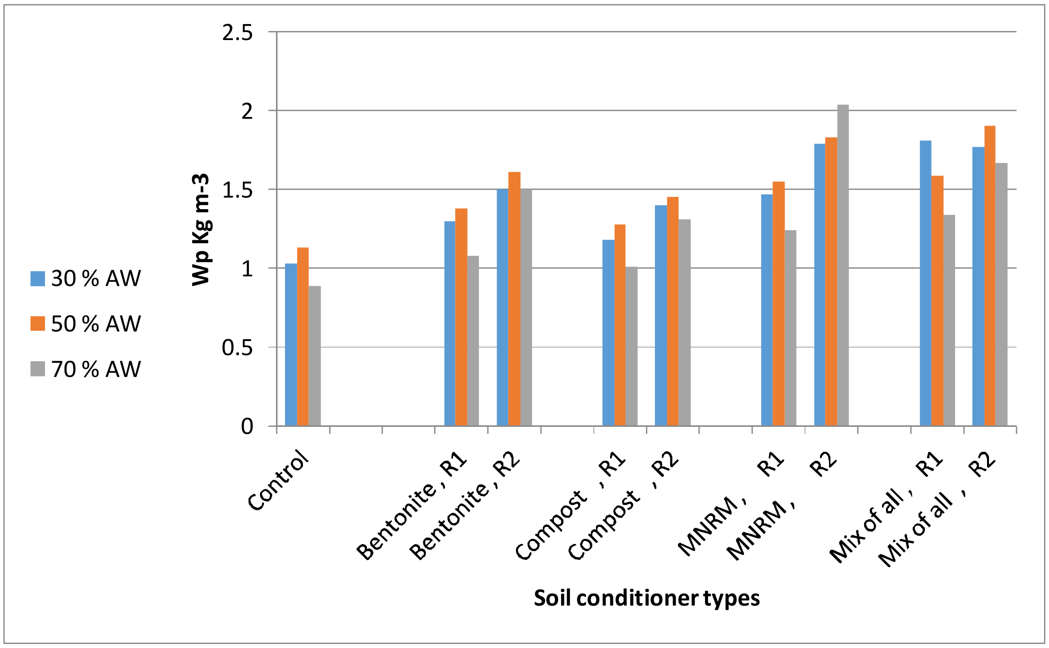

Fig.2. Effect of natural soil conditioners on maize water productivity under different levels of water depletion.

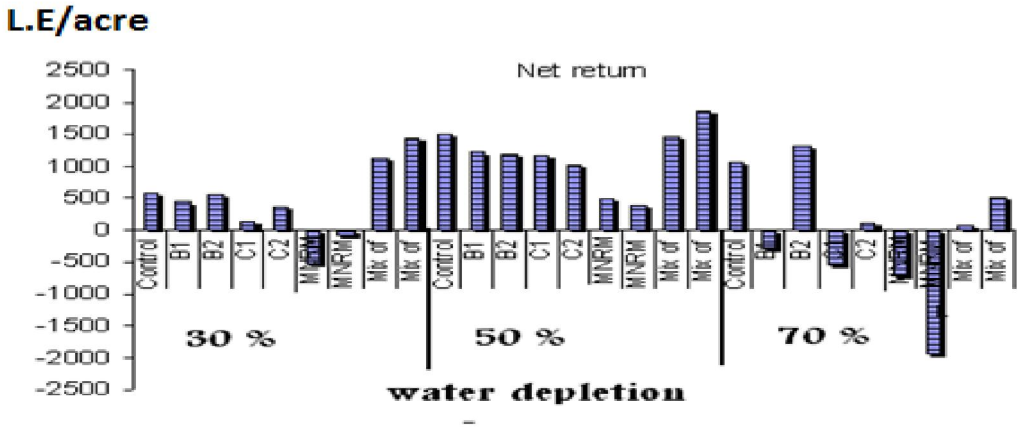

Fig.3. Net return of wheat yield as affected by the interaction between water depletion and conditioners.

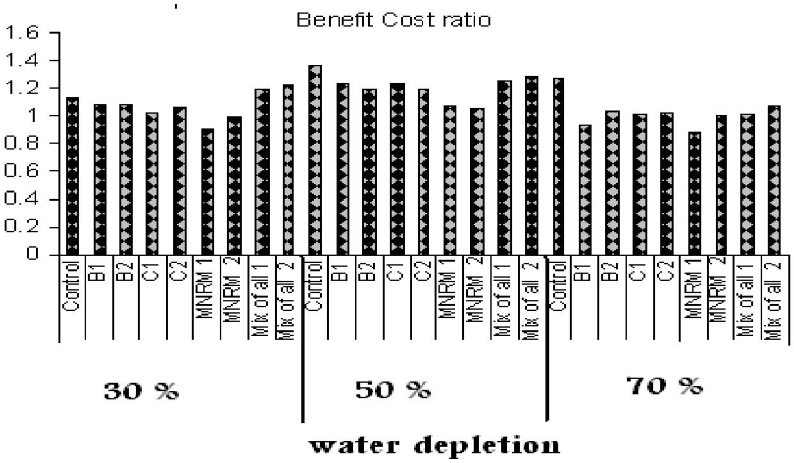

Fig.4. Benefit cost ratio of wheat yield as affected by the interaction between water depletion and conditioners.

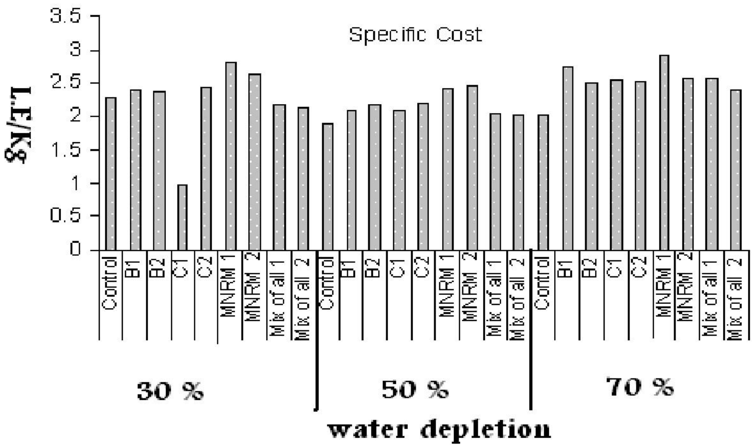

Fig.5. Specific cost of wheat yield as affected by the interaction between water depletion and conditioners.

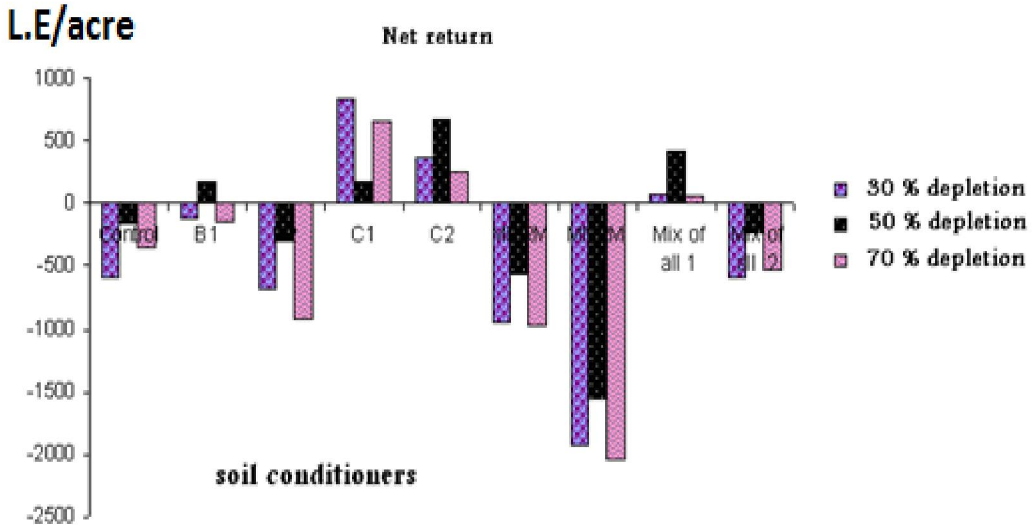

Fig.6.Net return of maize yield as affected by the interaction between water regime and conditioners.

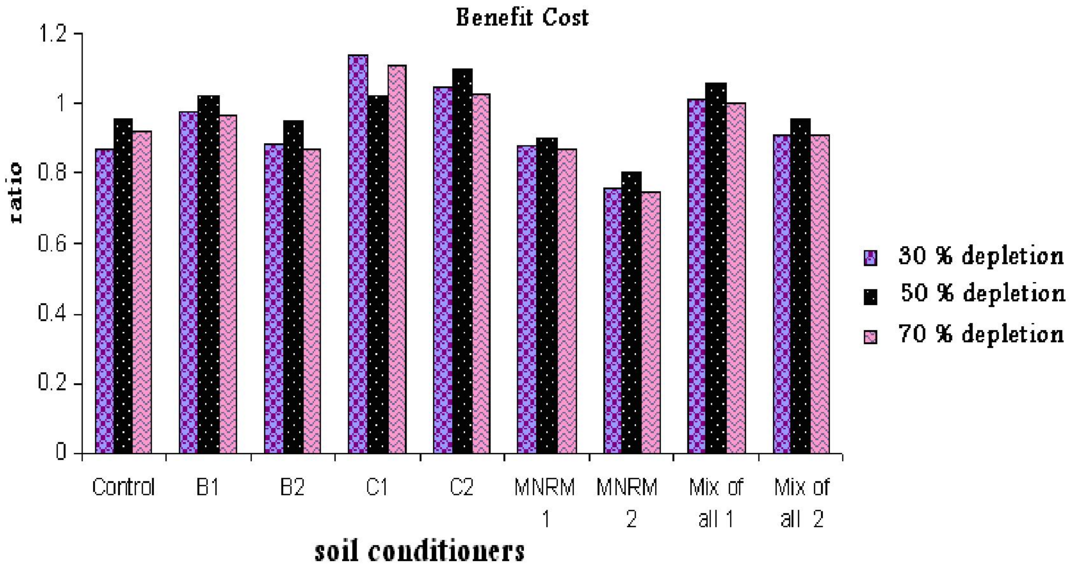

Fig.7. Benefit cost ratio of maize yield as affected by the interaction between water regime and conditioners

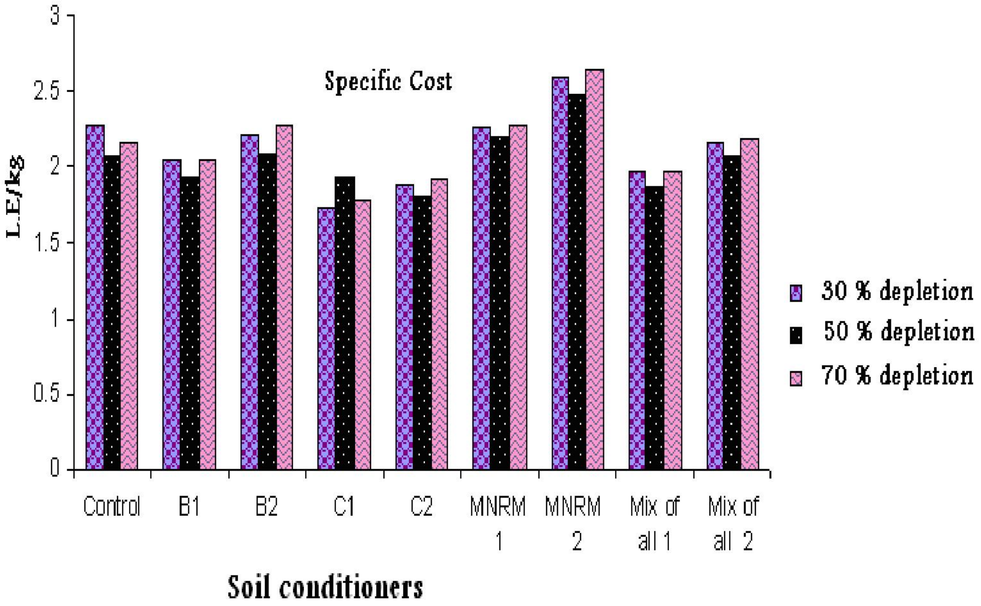

Fig.8. Specific cost of maize yield as affected by the interaction between water regime and conditioners.

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